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FUTURE
ISSUE 162

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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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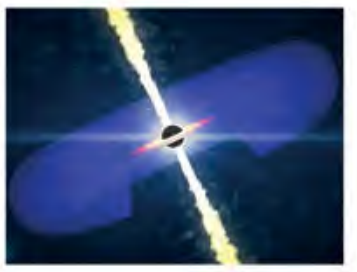
Issue 162

"The first tantalising hints that a breakthrough might be just around the corner came last year"

Inside the atom smasher
PAGE 26

HIGHLIGHTS



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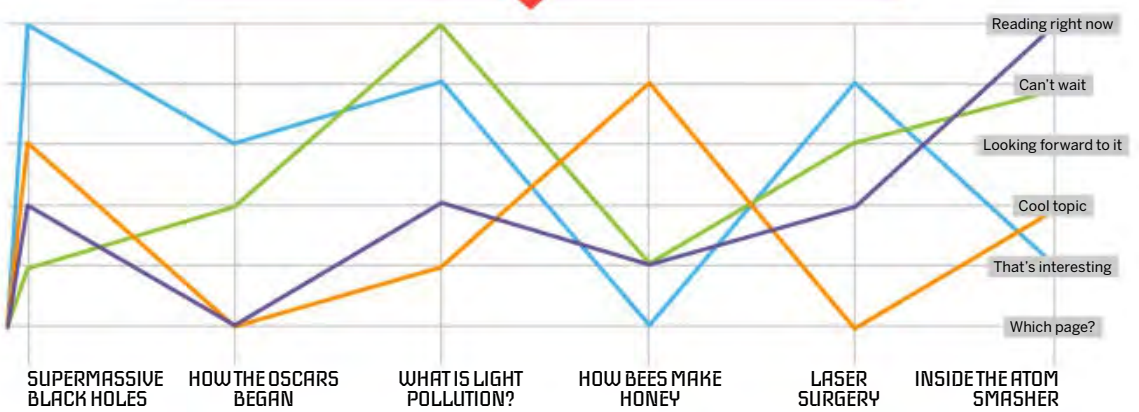
The strange, swirly and kaleidoscopic pattern you see above is the result of decades of research and experimentation that came to a cumulative head on 4 April 2012: it's the Higgs boson, or rather a data-generated visualisation that shows this fundamental particle being produced after smashing two particle beams together. It was a hugely important discovery, because this 'God particle' is believed to give things mass. The experiment that proved its existence could only be conducted in a massive machine on the cutting edge of science. What more could the particle accelerators found at CERN do for science? Read our main feature to find out.

Ben Biggs
EDITOR

WHAT WE'RE ANTICIPATING



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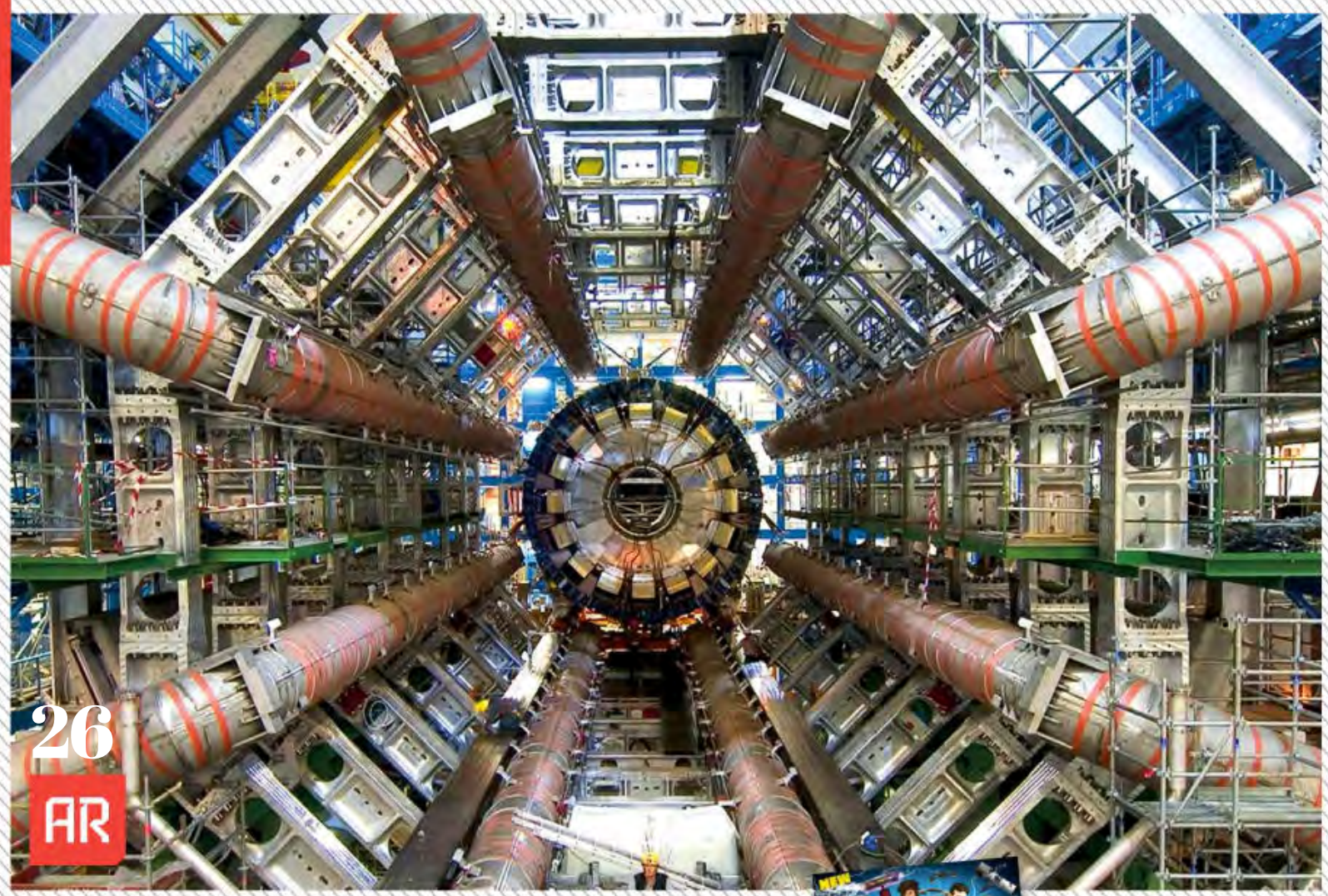
INSIDE

Issue 162



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REGULARS

MEET THIS ISSUE'S EXPERTS

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

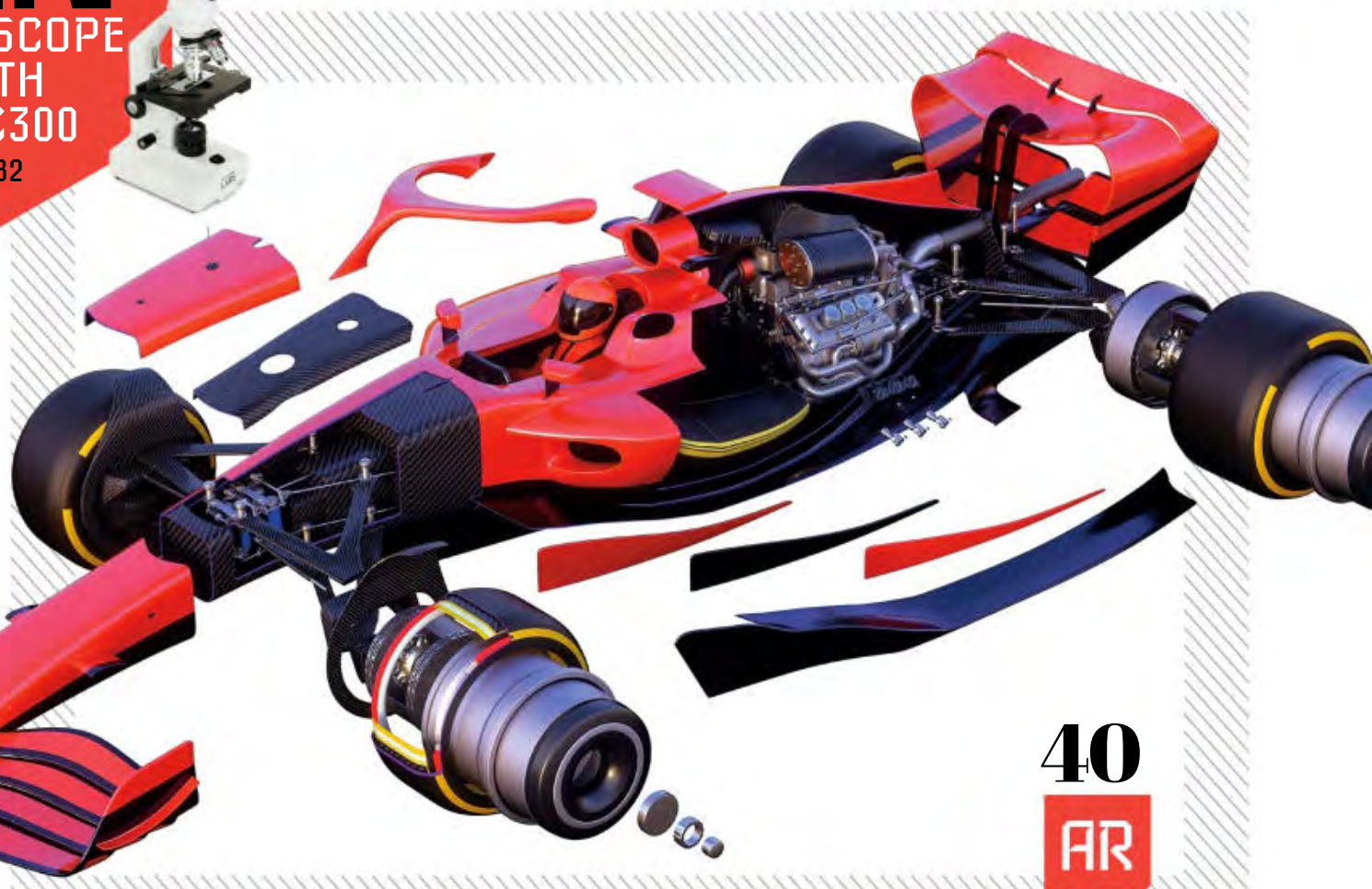
MIKE JENNINGS
Mike is a freelance technology journalist who is fascinated with gaming, futuristic technology and motorsport. He dreams of becoming a rally driver.

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

AR

WIN A MICROSCOPE WORTH OVER £300

PAGE 82



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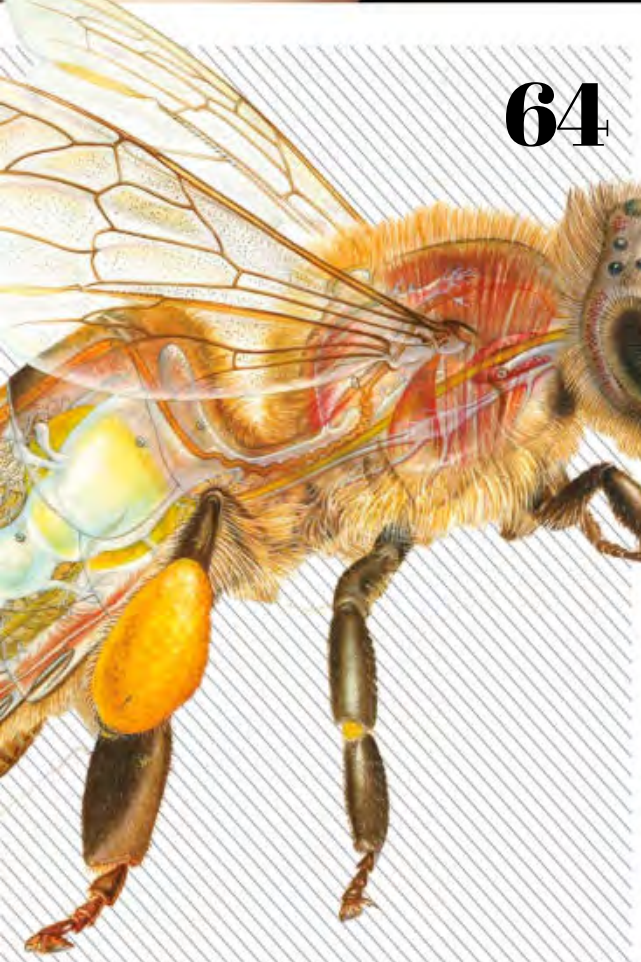

AR

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Head of a hydroid

Hydroids are invertebrates that either live alone or form colonies in freshwater environments. There are around 3,700 known species of hydroids around the world. During their lives, hydroids enter into three stages of life. This image shows the head of a hydroid (*Ectopleura larynx*) during its polyp stage with its tentacles unfurled, which house toxic cells to catch and kill plankton prey.

© Getty

Tranquil galaxy

NGC 976 exists around 150 million light years from the Milky Way. This image was captured by Hubble and makes it seem like it's a very tranquil galaxy, but it's actually home to some of the most violent known supernova explosions. Scientists can use the uniform energy of these explosions to estimate not only the distance of the supernovae but also the distance of the entire galaxy from Earth.

© ESA/Hubble & NASA, D. Jones, A. Riess et al

Forest stomper

The lowland streaked tenrec (*Hemicentetes semispinosus*) is a long-snouted insectivore that looks like a dipped-dyed cross between a shrew and a hedgehog. It's native to Madagascar and spends its time stomping on the ground of tropical rainforests to attract earthworms to the surface. The small mammals are covered in barbed black-and-yellow quills for defence against predators.

© Alamy

Changing waters

The dominant colour of water has changed in a third of the major rivers in the US over the last 35 years. This satellite image shows the hues of the nation's waterways as seen by the human eye. Natural changes to the colours of rivers are common due to changes in the presence of algae, fluctuations of sediments in the water and fluctuations of flow. The most extreme changes occur near human-made reservoirs.

© NASA Earth Observatory image by Joshua Stevens, using data courtesy of Gardner, J., et al

Argentinosaurus walking in the rocky desert

HISTORY

Long-necked dinosaurs could have had even longer necks

WORDS **LAURA GEGGEL**

Imagine a lumbering long-necked dinosaur, perhaps you've seen these herbivores animated in movies, munching on hard-to-reach leaves, or maybe you've visited a mounted skeleton in a museum. But get ready for a reality check: every sauropod neck you've ever seen is likely wrong, a new study finds.

Surprisingly few complete sauropod necks have been scientifically documented, and even specimens with relatively complete necks often have misshapen bones, distorted from tens of millions of years in the great outdoors. What's more, palaeontologists often can't agree where the neck stops and the backbone begins, and many don't factor in how long sauropod necks would be if tissues such as cartilage and fat were included in models. In short, "don't take too seriously the mounted skeletons that you see in museums," said Mike Taylor, a research associate in the School of Earth Sciences at the University of Bristol. If researchers had access to a complete sauropod neck and accurately accounted for its missing cartilage, which rarely fossilises, sauropod necks could easily be about one metre longer than we currently envision them to be, he said.

Sauropod necks have mesmerised Taylor for upwards of 20 years. "They're just fascinating on so many levels – mechanically, biologically, physiologically, ecologically," he said. "They're arguably the most extreme body parts evolved by anything that's ever lived." However, when he began to study them – for instance, to suggest that sexual selection was not the main driver for the sauropod's gratuitously long neck – Taylor realised that many sauropod neck fossils were woefully incomplete.

Dozens of sauropod specimens, even 'celebrity' sauropods such as Pittsburgh's Carnegie Museum of Natural History's diplodocus and apatosaurus, whose replica casts can be found around the world, and the large brachiosaur at the Natural History Museum in Berlin, have "imperfectly known necks," Taylor wrote in the new study. In specimens that were uncovered in the 19th and early 20th centuries, missing bones can be difficult to spot due to over-enthusiastic restorers.

Sauropods were big – the largest terrestrial animal, likely argentinosaurus, may have measured 35 metres long and weighed 70 tonnes, so it's not unexpected that complete fossilisation is rare. To fossilise, an animal has to be quickly covered with sediment before predators or the elements lay waste to it, and that's unlikely to happen to a huge beast. What's more, the neck vertebrae of sauropods were fragile and hollow, meaning they could be easily distorted, squashed or broken during the fossilisation process, Taylor said. Sometimes vertebrae are missing or jumbled, making it hard to decipher how long the neck was. "In mammals it's really easy to tell because there are seven cervical vertebrae in the neck and they don't have ribs attached," Taylor said. But in sauropods, some neck vertebrae attach to the ribs, making it hard to see where the neck ends and the trunk begins in some dinosaurs.

A lightning mapper on the GOES-16 satellite captured images of the megaflash over the southeastern US on 29 April 2020

PLANET EARTH

LIGHTNING BOLT BREAKS RECORD FOR LONGEST EVER RECORDED

WORDS **STEPHANIE PAPPAS**

Two storms in 2020 set two new records for lightning. One record was for longest single bolt, a record captured by a flash of lightning that stretched for about 477 miles from Texas to Mississippi during a storm on 29 April 2020. The second record was for longest duration bolt, flashing for an impressive 17.1 seconds during a storm on 18 June 2020 over Uruguay and northern Argentina.

The bolt that broke the record for length beat out the previous record holder, a 440-mile-long bolt that occurred during a storm in southern Brazil in 2018. The previous record holder for duration also occurred in northern Argentina, lasting 16.73 seconds in March 2019.

Lightning observation is changing as technology gets better. Previous records were detected by ground-based instruments known as lightning mapping arrays. But new satellite observations are allowing researchers a bird's-eye view of storms over huge distances. The two new bolts were recorded on instruments aboard the GOES-16 and GOES-17 satellites, which are operated by NASA and the National Oceanic and Atmospheric Administration (NOAA). Europe has a similar eye in the sky, the Meteosat Third Generation Lightning Imager, and China has the FY-4 Lightning Mapping Imager.

ANIMALS

Flatworm species named after pandemic

WORDS **PATRICK PESTER**

Scientists have discovered a hammerhead flatworm species that looks a bit like a miniature king cobra, or perhaps an itty-bitty snake with a moustache. Researchers found the tiny creatures hunting snails in France and Italy, and they've named the invaders after the COVID-19 pandemic. These new hammerhead flatworms are among two newly described species found in countries that researchers believe are not part of their native range, so they were very likely introduced there by humans.

Scientists dubbed the first soil-dwelling predator species *Humbertium covidum*, with *covidum* being a reference to COVID-19 as an "homage to the numerous casualties" of the pandemic and because much of the 55-page study was written during lockdowns. "Due to the pandemic, during the lockdowns most of us were home, with our laboratory closed. No field expeditions were possible," said Jean-Lou Justine, a professor at the Muséum National d'Histoire Naturelle in Paris."I convinced my colleagues to gather all the information we had about these flatworms, do the computer analyses and finally write this very long paper."

Typically found in warm parts of Asia, hammerhead flatworms are often accidentally transported around the world by humans in soil from the plant trade. These flatworms can reproduce asexually, so one hammerhead flatworm can give birth to offspring without a mate, making it easier for them to establish themselves as an invasive species, organisms that cause ecological or economic damage to an environment where they are not native.

Humbertium covidum were discovered in two gardens in Pyrénées-Atlantiques in southwest France and a garden in Veneto in northern Italy, although the species likely originated in Asia. Some reports indicate the species may also be in Russia, China and Japan.

Did you know?
There are over 20,000 known species of flatworm

The researchers discovered the second species, which they named *Diversibipalium mayottensis*, on Mayotte, a French island off the east coast of Africa in the Indian Ocean. This species could have been introduced to Mayotte from Madagascar.

The researchers studied the anatomy and morphology of the flatworms and carried out genetic analysis to formally describe the new species. *Diversibipalium mayottensis* have a unique green-blue iridescence, and the researchers determined the species belongs to a hammerhead sister group, distinct from all other hammerhead flatworms. This species could therefore be important to understanding the evolutionary history of hammerhead flatworms. Both of the new species measure about three centimetres long. That's small for hammerhead flatworms, which can grow to be more than 40 centimetres long, and may explain why the new species have previously been overlooked by researchers.

Humbertium covidum, one of the new hammerhead flatworm species

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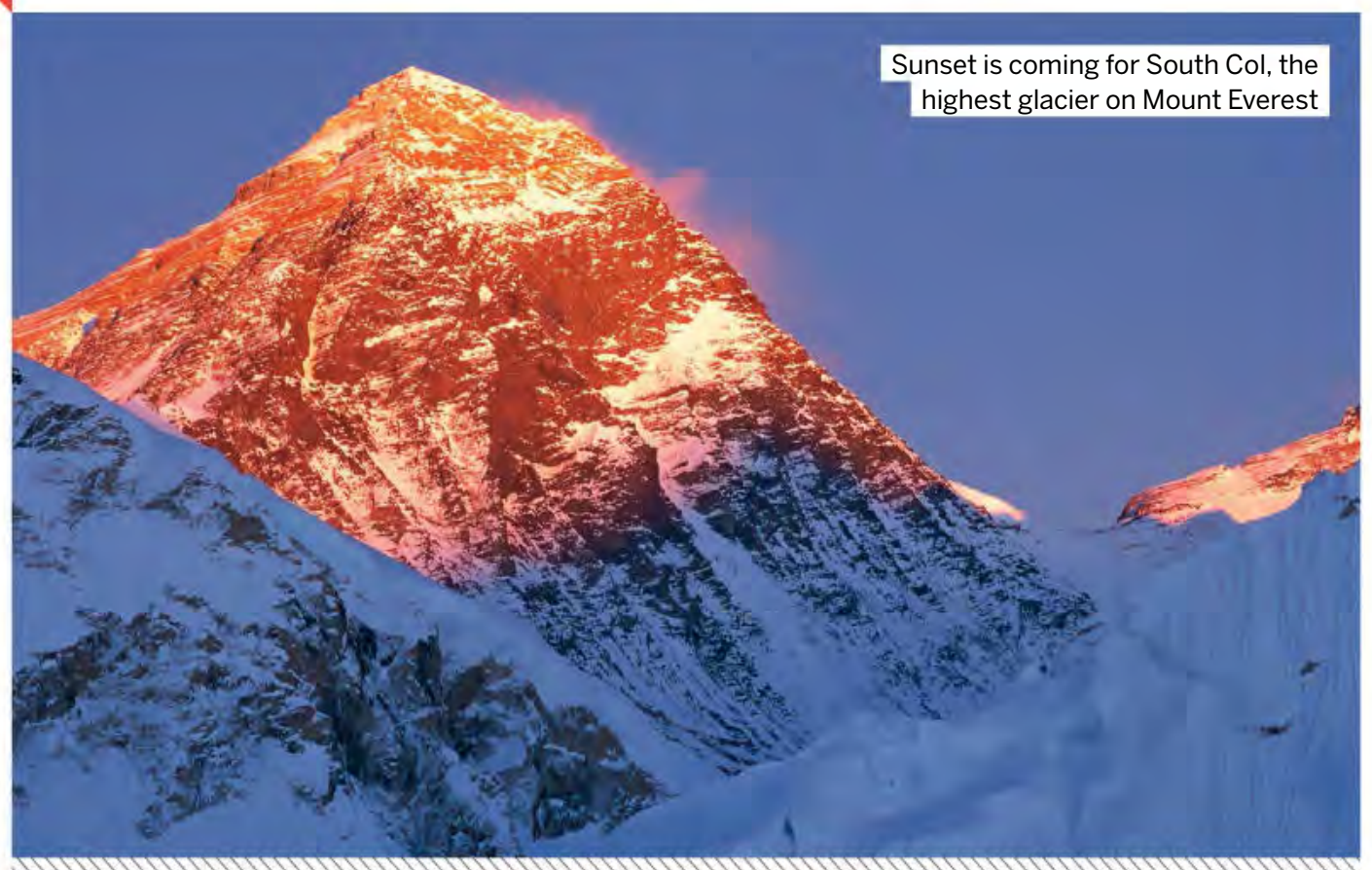


Sunset is coming for South Col, the highest glacier on Mount Everest

PLANET EARTH

Everest glacier has lost 2,000 years of ice since the 1990s

WORDS **BRANDON SPECKTOR**

Even the glaciers on Mount Everest aren't safe from climate change, new research suggests. In a record-setting study, a team of scientists scaled the world's highest peak to monitor the mountain's highest altitude glacier, the South Col glacier, standing nearly 8,000 metres above sea level, for signs of climate-related ice loss. After installing the two highest weather stations on Earth and collecting the world's highest ice core from the glacier, the team found that South Col is losing ice roughly 80 times faster than it took for the ice to accumulate on the glacier's surface.

The team's core analysis showed that ice that took 2,000 years to form on the glacier has completely melted away since the 1990s, and that the glacier is currently losing several decades worth of ice accumulation every year. "[This] answers one of the big questions posed by our [expedition] – whether the highest glaciers on the planet are impacted by human-source climate change," said Paul Mayewski, a glaciologist at the University of Maine and director of the University's Climate Change Institute. "The answer is a resounding yes, and very significantly since the late 1990s." The glacier's rapid decline could have serious impacts on the mountain and those who live near it. The melt may result in more avalanches on Everest, or expose more bedrock, making the terrain more treacherous for climbers.

On a recent expedition, ten researchers climbed to the base of South Col and installed two weather detection stations, one at 8,430 metres and the other at 7,945 metres above sea level. The team also drilled a ten-metre ice core from the glacier to reveal how the glacier ice's thickness has changed over time. With this data in hand, the team ran computer models to simulate the glacier's growth and retreat over thousands of years. The team concluded that South Col has lost more than 54 metres of ice thickness in the last 25 years. While the effects of wind and changes in humidity may have contributed to this ice loss, human-induced climate change is the overwhelming cause.

In fact, the team found that South Col may have begun thinning from climate change as early as the 1950s. However, by the 1990s, the melt rate accelerated significantly when the glacier's snowpack, outer layers of snow that accumulate over time, finally disappeared, exposing the glacier's raw ice to the Sun's radiation. Now missing its shield of white ice to reflect the Sun's rays, South Col will likely rapidly retreat. Ultimately, while South Col is just one glacier among many in the Himalayas, its position at the top of the world shows that no ice mass is safe from climate change.

HISTORY

430-YEAR-OLD NINJA WEAPONS IDENTIFIED

WORDS **OWEN JARUS**

Artefacts found in Japan may be ninja weapons, including several that look like forerunners to the throwing star. Archaeologists excavated the artefacts between 1960 and 2010 at several sites in Japan, including two castles, Iwatsuki and Hachiōji. The possible ninja artefacts date to the Siege of Odawara of 1590. During this siege, the Toyotomi and Tokugawa clans defeated the Hōjō clan, which had controlled a sizable portion of Japan, and captured both castles.

The siege took place during the Sengoku period, from 1467 to 1615, a time when Japan was divided between several warlords who battled for power. The artefacts include flat throwing stones that may have been predecessors of the shuriken throwing star and clay caltrops that may be an early form of the makibishi, a spiky weapon that could injure the feet of soldiers and horses. These artefacts were likely weapons of a "battle group which can move into action as ninjas," said Iwata Akihiro, an archaeologist and curator at the Saitama Prefectural Museum of History and Folklore.

These weapons were likely hastily constructed, but would have been effective. The flat throwing stones "were used to stop the movement of the enemy, who was going to attack at any moment, and while the enemy froze the soldier escaped," said Ahikiro. Meanwhile, the clay caltrops could "stop the movement of the enemy who invaded."

A hand-coloured illustration of mid-18th century Japan depicting a ninja

SPACE

The ISS will plunge into the sea in 2031

WORDS STEPHANIE PAPPAS

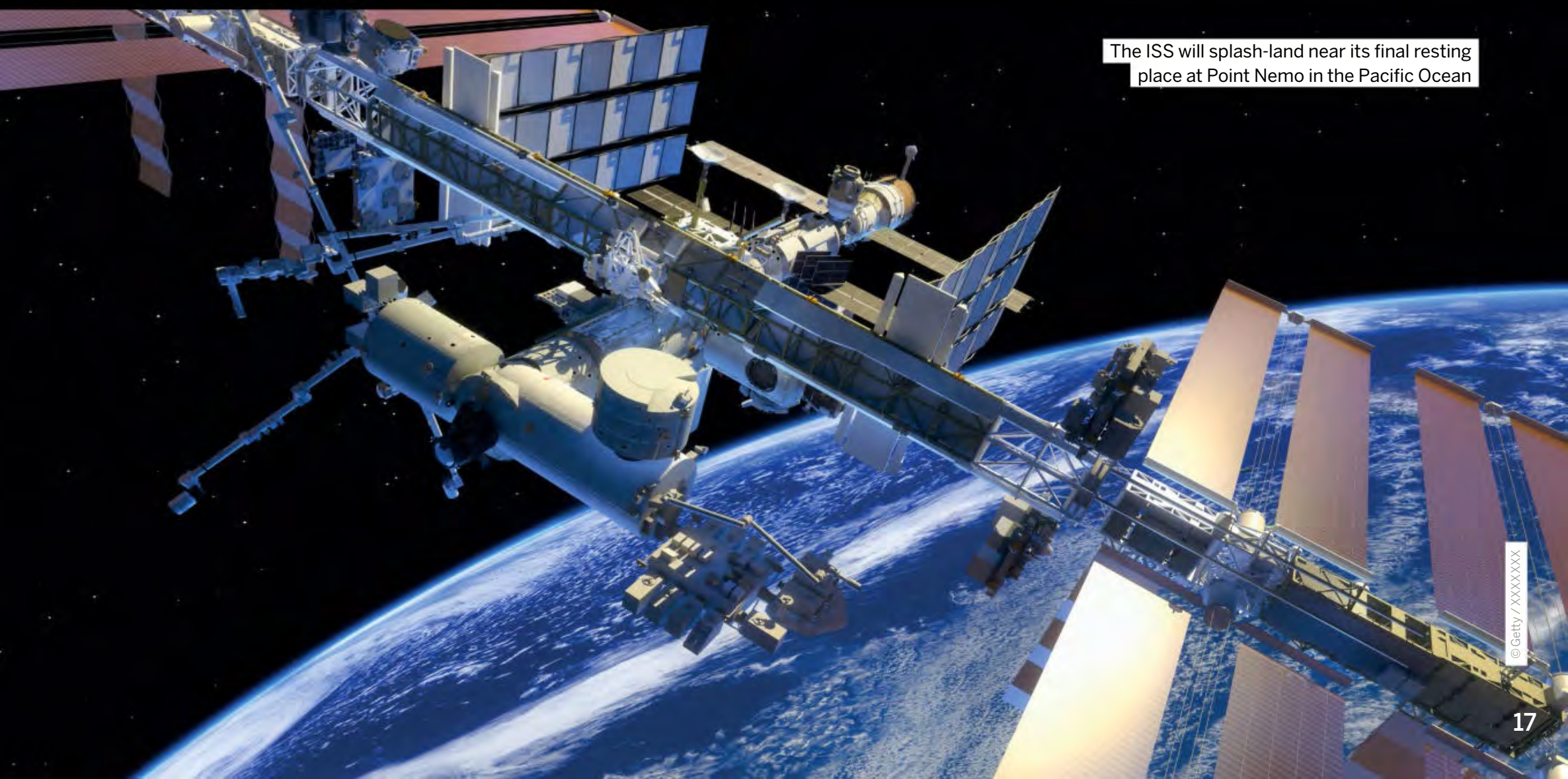
The orbiting laboratory, which launched in 1998, will splash-land 1,678 miles from land at Point Nemo, the final Pacific Ocean resting place for many dead satellites and space stations, such as Russia's Mir. The new expiration date for the ISS is due to a Biden administration commitment to extend support for the space station's operations through 2030, which NASA announced in late December. In January 2022 the space agency announced a new transition plan for low-Earth orbit science. In the lead-up to the decommissioning of the ISS, NASA has signed agreements with three private companies to launch commercial space stations for use by both private companies and government astronauts. These new commercial space stations will be launched by Blue Origin, Nanoracks LLC and Northrop Grumman Systems Corporation. They're expected to be operational by the late 2020s, before the ISS falls into the sea.

"The private sector is technically and financially capable of developing and operating commercial low-Earth orbit destinations, with NASA's assistance. We look forward to sharing our lessons learned and operations experience with the private sector to help them develop safe, reliable and cost-effective destinations in space," said Phil McAlister, director of commercial spaceflight at NASA Headquarters.

In the meantime, the ISS will remain busy with experiments undertaken both on behalf of NASA researchers and private contractors. "The International Space Station is entering its third and most productive decade as a groundbreaking scientific platform in microgravity," said Robyn Gatens, director of the International Space Station at NASA Headquarters. "This third decade is one of results, building on our successful global partnership to verify exploration and human research technologies to support deep-space exploration, continue to return medical and environmental benefits to humanity and lay the groundwork for a commercial future in low-Earth orbit." Among the long-term work being done on the space station are experiments meant to support NASA's plans to send humans back to the Moon and to Mars. NASA intends to send the first woman and first person of colour to the Moon this decade, though the timing has been pushed from 2024 to no earlier than 2025.

The ISS has been continuously occupied since 2000, but the football-field-length structure is showing its age. In 2021, small cracks were found in the space station's Zarya module, the second time since 2019 that fissures had been found aboard the orbiting lab. Though space stations have been deorbited before, the ISS is the largest human-made object ever to occupy low-Earth orbit. Deorbiting it may be a challenge.

In 1979, a disorganised and ultimately uncontrolled deorbit of NASA's Skylab space station sent pieces of debris scattering across Australia. The ISS is large enough that much of it will likely fail to burn up in the atmosphere, and its irregular-shaped solar arrays may make the station difficult to control as it spirals down to Earth.



The ISS will splash-land near its final resting place at Point Nemo in the Pacific Ocean

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GLOBAL EYE

SPACE

THREE GALAXIES TEAR EACH OTHER APART

WORDS **BRANDON SPECKTOR**

Corkscrewing through the cosmos, three distant galaxies collide in a stunning new image captured by Hubble. This cosmic crash is known as a triple galaxy merger, where three galaxies slowly draw each other nearer and tear each other apart with their competing gravitational forces.

Mergers like these are common throughout the universe, and all large galaxies, including our own Milky Way, owe their size to violent mergers like this one. As chaotic as they seem, mergers like these are more about creation than destruction. As gas from the three neighbouring galaxies collides and condenses, a vast sea of material from which new stars will emerge is assembled at the centre of the newly unified galaxy.

Meanwhile, existing stars will survive the crash mostly unscathed; while the gravitational tug-of-war among the three galaxies will warp the orbital paths of many existing stars, so much space exists between those stars that relatively few of them are likely to collide.

The merging galaxy cluster IC 2431 is located about 681 million light years from Earth in the constellation of Cancer. Astronomers detected the merger thanks to a citizen science project called Galaxy Zoo, which invited more than 100,000 volunteers to classify images of 900,000 galaxies captured by Hubble that were never thoroughly examined.

Three galaxies collide in this stunning new Hubble image

ANIMALS

Cat brains are shrinking, and it's humans' fault

WORDS **BRANDON SPECKTOR**

Thousands of years of human dependence has shrunk your cat's brain. Researchers compared cranial measurements – an indicator of brain size – of modern house cats with that of two of their closest wild ancestors, African (*Felis lybica*) and European wildcats (*Felis silvestris*). The team found that cranium size, and therefore brain size, in domesticated cats has shrunk significantly over the past 10,000 years or so compared with their wild ancestors.

This doesn't necessarily mean that your tabby is dumber than a wildcat. But according to one hypothesis, it shows that prioritising tameness in domesticated animals may have inadvertently changed the ways those animals' brains develop. These changes likely begin when an animal is still an embryo and just beginning to develop its neural crest cells, a special type of cell unique to vertebrates which plays a key role in the development of the nervous system, among other things. "Selection for tameness in the domestication of animals may have caused a downregulation in the migration and proliferation of neural crest cells, leading to decreased excitability and fear," the researchers wrote. "However, this downregulation may also cause correlated changes to morphology, stress response and brain size."

Did you know?
Cats were first domesticated around 7500 BCE

Researchers replicated several older studies from the 1960s and 1970s comparing the cranial size of domestic and wild cats. These supported the idea that domesticated cats have seen a significant reduction in brain size over the years, but some of these studies compared modern cats with just the European wildcat, which is no longer considered to be a direct ancestor. They compared house cats with the African wildcat, which genetic research has since confirmed to be the closest living ancestor. The team found that the old research still holds up, with house cats showing as much as a 25 per cent reduction in cranial size compared with wildcats.

The researchers also examined a number of hybrid wild/domesticated cat species, finding that these cranial measurements fit in a perfect middle ground between the wild and domestic species. All this goes to show that domestication has had a significant effect on the evolution of cats over the past several thousand years, a phenomenon seen in many other species of domesticated animals as well. Understanding this not only shines a light on some of the developmental changes that domestication incurs on wild animals, but also raises concerns about wild species that are threatened by hybridisation with domestic animals.

House cat skulls have gotten significantly smaller over the last 10,000 years, and so have their brains

HEALTH

Nine out of ten ticks carried fatal virus

WORDS CAMERON DUKE

A site in Pennsylvania recently recorded the highest ever concentration of ticks carrying a variant of potentially fatal Powassan virus called deer-tick virus (DTV). This rare virus has the potential to cause deadly infections with lasting neurological effects, and officials fear it and other serious tick-borne illnesses may become more common in the future. Powassan virus is transmitted to humans bitten by infected female black-legged ticks (*Ixodes scapularis*). Between 2008 and 2017, most of the cases were diagnosed in and around the Great Lakes region of North America.

The virus, which has two lineages, one of which is DTV, was first identified in 1952. While many cases of Powassan virus are asymptomatic, those that are symptomatic can be deadly. Initial symptoms include headaches, fever and vomiting, with the most severe cases involving neurological complications such as encephalitis (inflammation of the brain) and meningitis. Roughly one in ten neuroinvasive cases of Powassan virus are fatal, and about half of the survivors of these cases experience long-term neurological health impacts.

"The infection rate of ticks sampled from the Lawrence Township Recreational Park is extremely high; DTV transfers very quickly through the bite from an infected tick, and the health outcomes from deer-tick virus are more severe than other tick-borne illnesses typically seen in Pennsylvania," said Patrick McDonnell, secretary of the Pennsylvania Department of Environmental Protection.

Of the 25 ticks sampled from the park, 92 per cent tested positive for DTV. In comparison, the highest infection rate of DTV among ticks previously measured at a single US site was 25 per cent. While this is a rather small sample size, the nearly ubiquitous infection of these ticks has Pennsylvania officials concerned. The virus can be transmitted within 15 minutes of a tick bite, which is much faster than the time from bite to infection for many other tick-borne diseases, such as Lyme disease, in which a tick needs to be latched onto a person for more than 24 hours to transmit the disease. Because historically Powassan virus has been rare, there are no specific treatments, although a vaccine is in development.

This rare tick-borne disease has become more common in the US in recent years. Between 2016 and 2020, 134 cases of Powassan virus were reported in the US, compared with 44 cases between 2011 and 2015. In fact, annual cases of all tick-borne diseases reported to the CDC more than doubled between 2004 and 2019, rising from 22,527 in 2004 to more than 50,000 in 2019. This increase in infection rates is likely due to the expansion of the black-legged tick, the vector for both Powassan virus and Lyme disease. Researchers predicted that "the number of [Lyme disease] cases in the US will increase by over 20 per cent in the coming decades." Increased temperatures and humidity are likely to contribute to increased reproduction, survival and expansion of ticks. It's also been predicted that black-legged ticks will continue to expand farther northward across Minnesota, the Dakotas and Alaska by 2050.

Ixodes scapularis, also called the black-legged tick or deer tick, can infect people with the potentially fatal Powassan virus

©X-ray: NASA/CXC/SAO / Optical: DSS / IR: ESA/Hubble and NASA

People with Type 1 diabetes often use a blood sugar monitoring device to help control their sugar levels

HEALTH

‘Death receptor’ could help drive Type 1 diabetes

WORDS **NICOLETTA LANESE**

Insulin-producing cells in the pancreas carry a ‘death receptor’ that, when activated, causes the cells to self-destruct. This cellular self-destruct button may in turn contribute to the development of Type 1 diabetes, according to a new study in mice and human tissues. Type 1 diabetes is an autoimmune disorder where the immune system attacks the insulin-producing beta cells in the pancreas. A hallmark of Type 1 diabetes is the death of these beta cells, but exactly why those cells die isn’t entirely clear; scientists suspect that multiple mechanisms are at play.

The recent study identified the death receptor, called transmembrane protein 219 (TMEM219), which sits within the outer membrane of beta cells, as a key player in this process. A protein called insulin-like growth factor binding protein 3 (IGFBP-3) binds to the portion of the death receptor that juts off the cell surface, and by doing so it sets off a chain of events inside the cell. This chain of events spells certain doom for the beta cell: it triggers apoptosis, or cellular suicide.

In several laboratory studies with mice, the researchers tried different ways of preventing this chain of events from unfolding; the mice used in the study were genetically modified such that they’re prone to Type 1 diabetes. In one experiment, for example, the team deleted the death receptor altogether using genetic modification, and in another they blocked the receptor using a protein that had been modified for that purpose. The team found that when they temporarily blocked the death receptor in mice, a larger number of beta cells survived than did in untreated mice, and insulin production increased. This in turn delayed or prevented the onset of diabetes in the mice. When the team blocked the death receptor for an extended period of time, the animals’ beta cells increased in number.

The team also ran experiments with human beta cells. Applying IGFBP-3 to the tissues triggered rampant beta cell death, but by blocking the death receptors on the cells, the researchers could stop this damage from occurring and allow the cells to keep producing insulin. Supporting what they found in the laboratory, the team also found that people diagnosed with diabetes and those at high risk of diabetes both carried high levels of IGFBP-3 compared to those who did not have diabetes. This was also true of diabetic and prediabetic mice compared with healthy mice.

“We think that in disease, IGFBP-3 production may be increased, so there’s a loss of beta cells,” said Dr Paolo Fiorina, a research associate and assistant professor at Harvard Medical School and Boston Children’s Hospital. The first human trials of such a treatment could begin by autumn 2022. “The common thought for Type 1 diabetes is that it’s autoimmune,” Fiorina said. “But immunotherapy doesn’t completely cure diabetes. We think that IGFBP-3 acts as a ‘betatoxin’ and disrupts the normal function of beta cells, and thus also contributes to the development of diabetes.”

HISTORY

‘Weirdest wonder’ of evolution had even weirder cousin

WORDS **BRANDON SPECKTOR**

With five eyes, a backwards-facing mouth and a long, claw-tipped trunk where its nose should be, *Opabinia regalis* is one of the strangest-looking celebrities of the Cambrian Period. This ancient sea-dweller is so unique that scientists have never discovered another species in the fossil record that appears to fit into its alien-faced family… until now.

Utaurora comosa is a small, spiky-tailed marine animal that lived a few million years after *O. regalis* in what is now North America. First described in 2008, *U. comosa* was originally classified as a relative of the fearsome Anomalocaris, a claw-faced apex predator that terrorised the Cambrian seas. But a new study suggests that *U. comosa* may have been much more than just another ancient predator.

Researchers reexamined the only known *U. comosa* fossil and compared it with more than 50 living and extinct animal specimens. The team concluded that *U. comosa* is almost certainly a relative of *O. regalis*, and not of Anomalocaris, making *U. comosa* only the second member of the family ever discovered and the first one found in more than 100 years.

From 541 to 485 million years ago, Earth’s seas bloomed with biodiversity for the first time. This era, sometimes called the Cambrian explosion, was when the relatives of all major animal groups alive today first appeared in the water. The Cambrian explosion also gave rise to the world’s first truly fearsome apex predators.

Those carnivorous killers are known as radiodonts, a reference to the circular-saw-shaped mouths on the undersides of their heads. Many of them, including the infamous Anomalocaris, also had grasping, claw-like appendages on the fronts of their heads, likely for snatching unsuspecting prey and delivering it to their hungry mouths.

The only known fossil of *U. comosa*, discovered in Utah’s Cambrian Wheeler Formation, had no such appendages on its head. Meanwhile, its two-and-a-half-centimetre-long body was segmented into 14 or 15 furrows, each tipped with a pointy flap, much like *O. regalis*. Despite these details, the *U. comosa* fossil was classified as a radiodont in 2008. However, researchers’ recent analysis showed that almost none of *U. comosa*’s traits fit in with the radiodont family and that the fossil creature was almost certainly related to *O. regalis*. “This means *O. regalis* was not the only opabiniid,” said palaeontologist Stephen Pates. “*O. regalis* was not as unique a species as we thought.”

Looks like *Opabinia regalis* wasn’t just a lonely freak of nature

A single star repeats in a hexagonal pattern in this image taken during Webb’s alignment, released on 18 February 2022

SPACE

JAMES WEBB TELESCOPE SNAPS STARRY HEXAGON

WORDS **ELIZABETH HOWELL**

The JWST finished the first major stage in its long process of aligning the observatory’s primary mirror. A single star was deliberately rendered 18 times into a hexagonal shape. Eventually, those 18 images will perfectly align into a single, sharp focus, but the interim result portrays a star repeated perfectly. “The image shows that the team has moved each of Webb’s 18 primary mirror segments to bring 18 unfocused copies of a single star into a planned hexagonal formation,” NASA officials wrote.

The images are steered into this particular pattern “so that they have the same relative locations as the physical mirrors,” said Matthew Lallo, systems scientist and telescopes branch manager at the Space Telescope Science Institute, which manages Webb. Next, the observatory will begin ‘segment alignment’, which will fix any larger positioning errors in the individual segments of the primary mirror and update the secondary mirror’s alignment. Once segment alignment is finished, the team will start the third phase, ‘image stacking’, that will ultimately bring the 18 images into one clear view.

Lallo said that the three-phase procedure will allow the team to experience “an intuitive and natural way of visualising changes” through the process. “We can now watch the primary mirror slowly form into its precise, intended shape.” Properly aligning the mirrors is a main goal of Webb’s commissioning, which is expected to conclude in the summer.

© Alamy / Getty / NASA/STScI/J. DePasquale

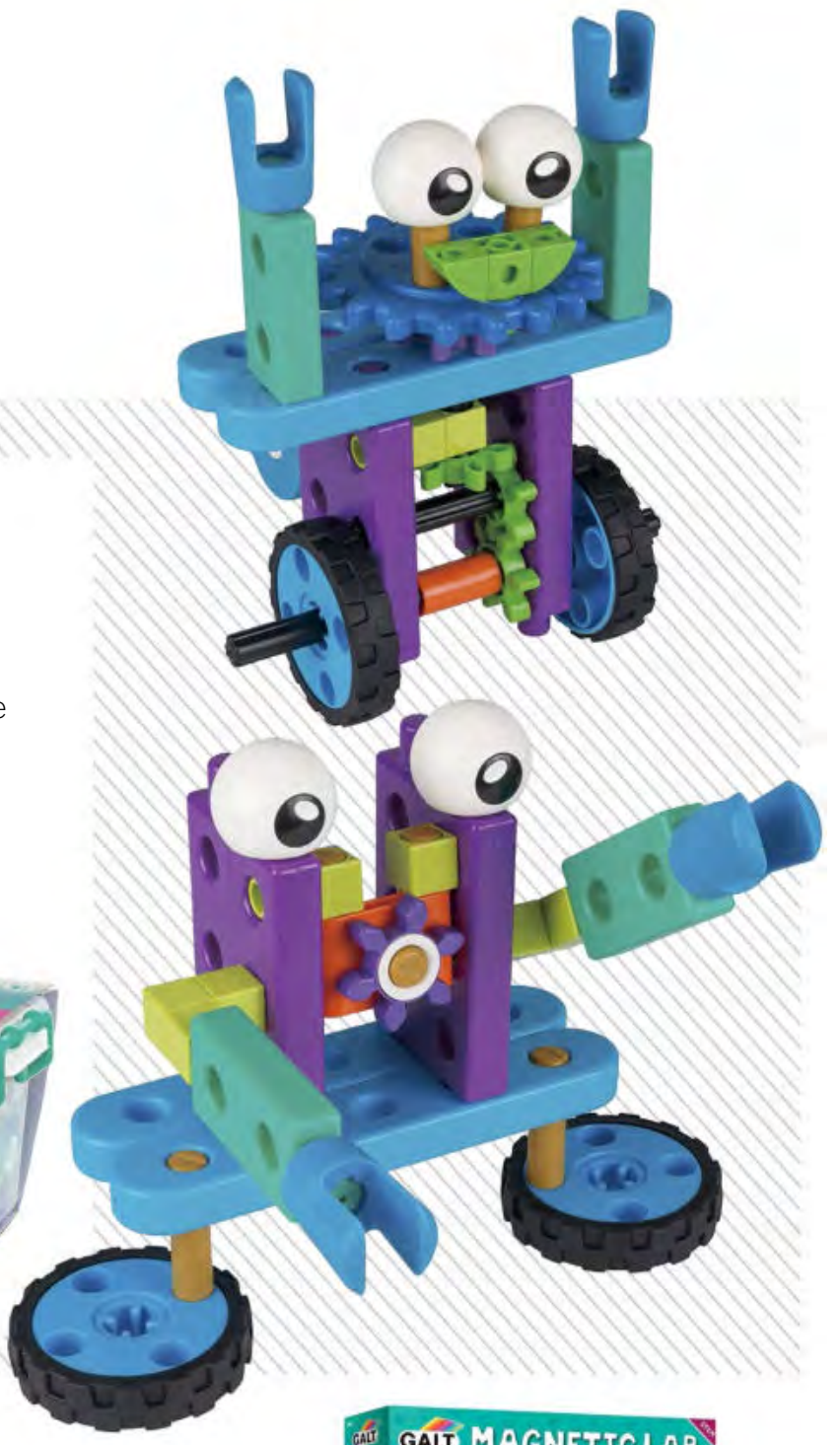
WISH LIST

The latest SCIENCE KITS

ROBOT ENGINEER

WWW.THAMESANDKOSMOS.CO.UK £38
STORE.THAMESANDKOSMOS.COM $49.95

Thames and Kosmos is well known for its fun and engaging science kits, and the Robot Engineer kit doesn't disappoint. One great feature of the Robot Engineer kit is the accompanying 32-page storybook. Users can follow the story of two inquisitive characters and build ten different robots that correspond to the robots in the story. The main characters Ty and Karlie go on fun adventures, building robots to perform tasks to help them solve problems along the way. Each robot has moving parts, wheels and gears to teach children how simple machines work. The kit includes 53 building block pieces made of plastic that are not motorised, making them suitable for users ages three and up. The combination of storytelling and robot design makes this kit an intuitive and engaging way to get children engaged in STEAM.



MAGNET MOVERS

WWW.LEARNINGRESOURCES.COM
£18 / $17.99

If you're looking for a child's first science kit, then Magnet Movers is a good place to start. This 39-piece set is one of the most basic science kits out there and is clearly intended for a very young user. The kit consists largely of vibrant pieces of plastic containing magnets for children to investigate and carry out ten magnetic experiments, such as creating a magnetic fishing pole.

Although it's simplistic in its design, it's an easy tool to get children thinking about physics concepts such as magnetism at a young age, while retaining an element of fun. This kit would be a great birthday gift or could be used as a fun at-home teaching tool.

MAGNETIC LAB

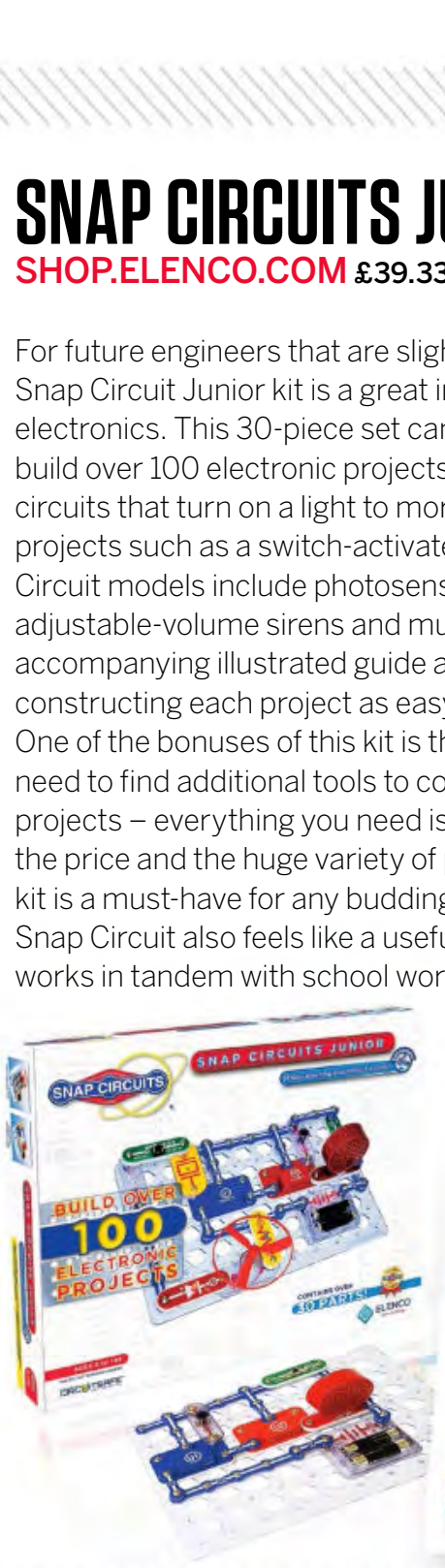
WWW.GALTTOYS.COM £14.99 / $23.95

For children aged six and over, this science kit is a great way to introduce them to the world of magnetism. The Magnetic Lab comes with a 24-page, full-colour laboratory guide book packed with fun experiments to introduce your budding scientists to STEAM learning. The experiments include driving a car without touching it, levitation tricks and how to recreate the sound of a rattlesnake. In the kit, you can expect a magnetic wand, racing car, four magnetic rings, a levitation stand, a capsule of iron filings, several magnets and much more. Each experiment is easy to follow and well-explained for its young audience. As a simple and straightforward science toy for your child, you can't go wrong with this science kit, especially considering the price. Although it doesn't include the typical chemical reactions or exploding volcanoes seen in other kits, Magnetic Lab is still a pretty cool kit for exploring the many possibilities of magnets.

SNAP CIRCUITS JUNIOR

SHOP.ELENCO.COM £39.33 / $44.99

For future engineers that are slightly older, the Snap Circuit Junior kit is a great introduction to electronics. This 30-piece set can be used to build over 100 electronic projects, from simple circuits that turn on a light to more complex projects such as a switch-activated siren. Circuit models include photosensors, lights, adjustable-volume sirens and much more. The accompanying illustrated guide also makes constructing each project as easy as possible. One of the bonuses of this kit is that there's no need to find additional tools to complete projects – everything you need is in the box. For the price and the huge variety of projects, this kit is a must-have for any budding engineer. The Snap Circuit also feels like a useful tool that works in tandem with school work.



SILLBIRD STEM 12-IN-1 EDUCATION SOLAR ROBOT

WWW.AMAZON.CO.UK £25.99
WWW.AMAZON.COM $34.99

This middle-of-the-road robot kit allows robotics enthusiasts over the age of eight to immerse themselves in engineering and develop new skills. As the name suggests, the build-it-yourself robot is made up of 190 pieces and can be transformed into 12 different orientations. One of the Sillbird solar robot kit's many advantages is that no batteries are needed to power your robotic creations. Inside the box is a solar-power panel that can store energy produced by the Sun and is used to drive the onboard motor. This kit is a great way to expand children's imagination when it comes to engineering and electronics, teaching them logical thinking and problem-solving skills.

STEAM POWERED KIDS MAGNET EXPLORATION

WWW.AMAZON.CO.UK / WWW.AMAZON.COM
£29.99 / $34.93

If you're looking for a more advanced STEAM kit that explores magnetism, then STEAM Powered Kids products like this kit are perfect for inquisitive minds. Kicking it up a level from simple magnetism, this science kit plays with the power of magnetic fields.

Using the same scientific principles as the maglev train, kids can create their very own magnetic transporter, a tabletop UFO and a compass yacht. There are over 20 experiments to enjoy and a guide to help children understand the science behind each activity. Among the 40-piece set there are also magnetic games to be played, such as super magnet car racing and fishing. Magnet Exploration will not only be a fun kit for kids over eight years old, but many parents will also likely want to give one or two of its experiments a try.

© Amazon

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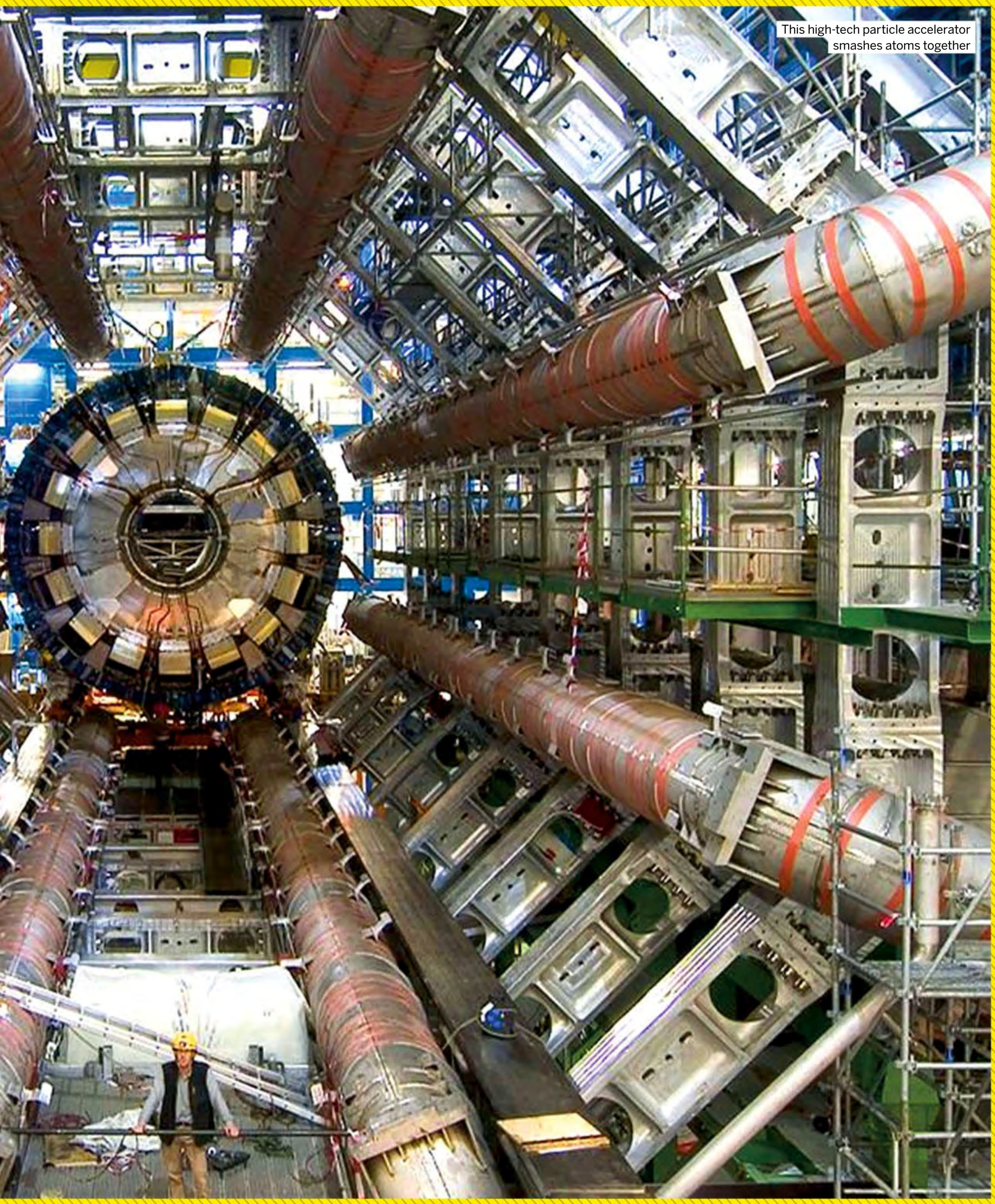
Inside the ATOM SMASHER

EXPLORE THE 16.6-MILE LENGTH OF THE WORLD'S BIGGEST PARTICLE ACCELERATOR AND DISCOVER THE INCREDIBLE NEW EXPERIMENTS CONDUCTED BY THE LHC

WORDS **ANDREW MAY**

DID YOU KNOW? CERN features prominently in Dan Brown's novel *Angels and Demons*, and the Tom Hanks movie based on it



This high-tech particle accelerator smashes atoms together

© Getty

If you see a news headline about exotic new subatomic particles, the chances are the discovery was made at CERN, the European Organization for Nuclear Research, located near Geneva in Switzerland. A recent example occurred in January 2022, when CERN scientists announced "evidence of X particles in the quark-gluon plasma produced in the Large Hadron Collider (LHC)". Hiding behind that technospeak is the eye-popping fact that CERN succeeded in recreating a situation that hasn't occurred naturally since a few microseconds after the Big Bang. That particular study drew on pre-existing data from the LHC, the world's biggest particle accelerator, which has been undergoing a major upgrade since 2018. When it restarts this spring after a three-year hiatus, we can expect a whole new spate of discoveries, so it's a good time to take a closer look at what makes the LHC – and the rest of CERN – so unique.

The LHC is a particle accelerator – a device that boosts subatomic particles to enormous energies in a controlled way so that scientists can study the resulting interactions. The 'large' that the L stands for is an understatement; the LHC is by far the biggest accelerator in the world right now, occupying a circular tunnel nearly 17 miles in circumference. The middle letter, H, stands for 'hadron', the generic name for composite particles such as protons that are made up of smaller particles called quarks. Finally, the C stands for 'collider' – the LHC accelerates two particle beams in opposite directions, and all the action takes place when the beams collide.

Like all physics experiments, the LHC's aim is to test theoretical predictions – in this case, the so-called Standard Model of particle physics – and see if there are any holes in them. As strange as it sounds, physicists are itching to find a few holes in the Standard Model because there are some things, such as dark matter and dark energy, that can't be explained until they do.

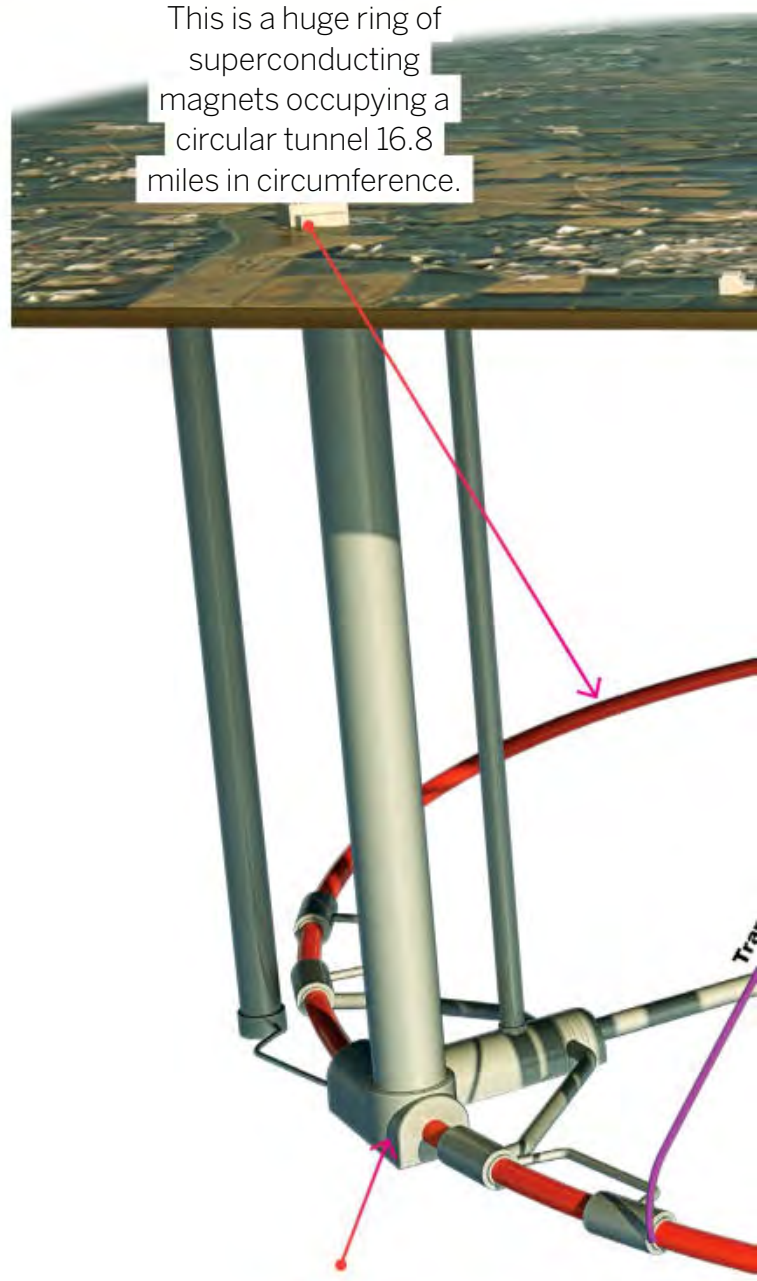
The LHC's biggest moment came in 2012 with the discovery of the Higgs boson. Although widely referred to as the 'God particle', it's not really as awesome in itself as that name might suggest. Its huge significance came from the fact that it was the last prediction of the Standard Model that hadn't yet been proven.

But the Higgs boson is far from being the LHC's only discovery. It's also found around 60 previously unknown hadrons, which are complex particles made up of various combinations of quarks. Even so, all those new particles still lie within the bounds of the Standard Model, which the LHC has struggled to move beyond, much to the disappointment of the numerous scientists who have spent their careers working on alternative theories. The first tantalising hints that a breakthrough might be just around the corner came last year, when analysis of LHC data revealed patterns of behaviour that indicated small but definite departures from the Standard Model.

The LHC opened for business in 2009, but CERN's history goes back much further than that. The organisation was established in 1954 following a recommendation by the European Council for Nuclear Research – or Conseil Européen pour la Recherche Nucléaire in French, from which it gets its name. Between its creation and the opening of the LHC, CERN was responsible for a series of groundbreaking discoveries, including weak neutral currents, light neutrinos and the W and Z bosons. As soon as the LHC is back up and running, we can expect discoveries to continue.

Left: The Standard Model of particle physics consists of 17 elementary particles

Below: CERN's first accelerator, the Synchrocyclotron, began operation in 1957

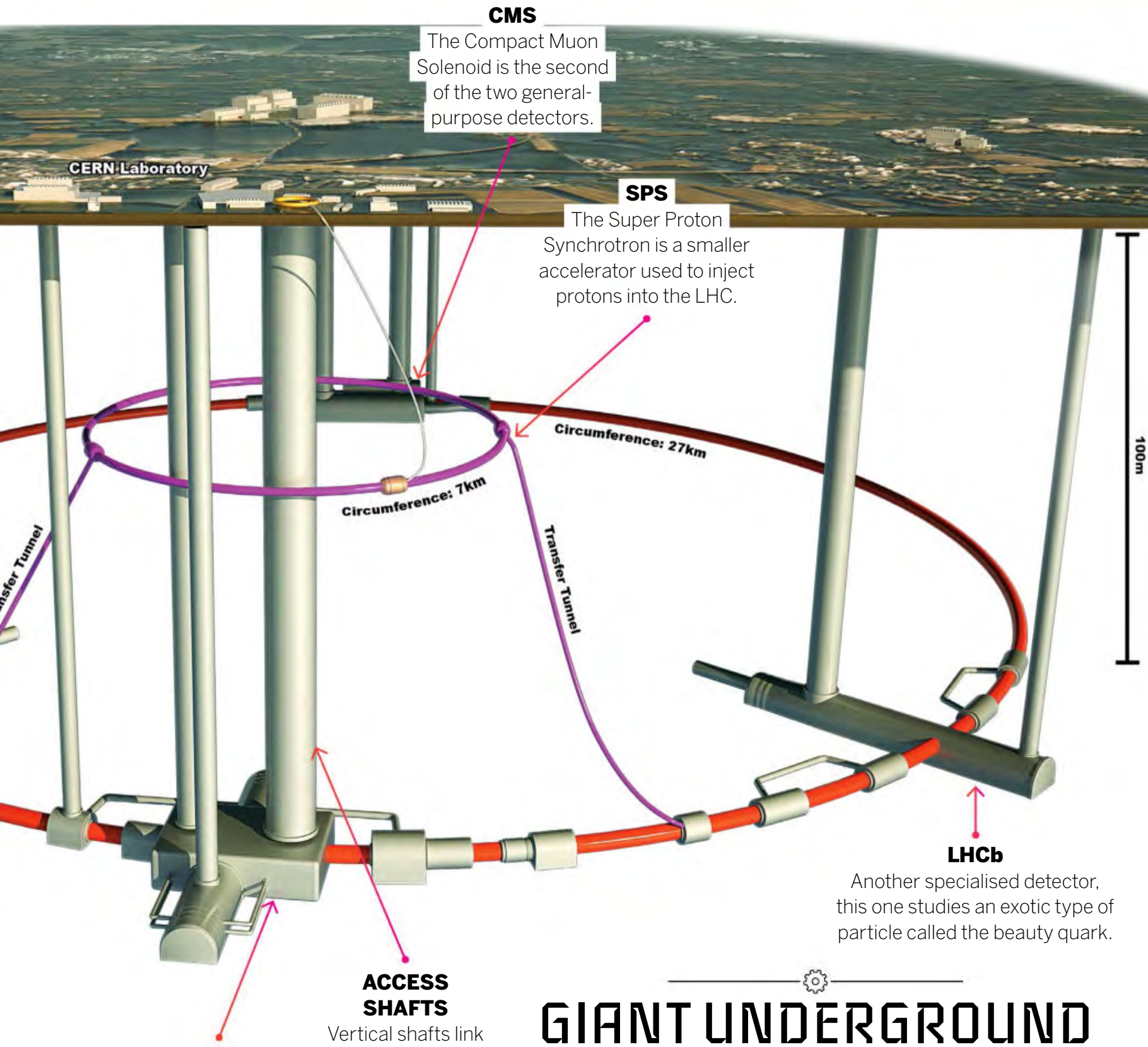


LHC
This is a huge ring of superconducting magnets occupying a circular tunnel 16.8 miles in circumference.

ALICE
This specialised detector looks at collisions between heavy ions, rather than single particles such as protons.

Did you know?
CERN has 23 member states, including the UK

DID YOU KNOW? The LHC will undergo another major upgrade from 2025 to 2027 to create the High-Luminosity LHC (HL-LHC)



CMS
The Compact Muon Solenoid is the second of the two general-purpose detectors.

SPS
The Super Proton Synchrotron is a smaller accelerator used to inject protons into the LHC.

LHCb
Another specialised detector, this one studies an exotic type of particle called the beauty quark.

ATLAS
This is one of the LHC's two principal general-purpose detectors.

ACCESS SHAFTS
Vertical shafts link the underground facilities to buildings on the surface 100 metres above.

GIANT UNDERGROUND LABORATORY

The Large Hadron Collider is located deep beneath the Franco-Swiss border near Geneva

IS CERN DANGEROUS?

People have speculated that experiments at CERN might pose a danger. Take the N in CERN, which stands for nuclear. This has nothing to do with the reactions that take place inside nuclear weapons, which involve swapping protons and neutrons inside nuclei. CERN's research is at a lower level, in the constituents of the protons and neutrons themselves. It's sometimes referred to as 'high-energy' physics, but the energies are only high when viewed on a subatomic scale. Particles inside the LHC typically only have the energy of a mosquito. People have also worried that the LHC might produce a 'mini black hole', but even in the unlikely case this happened, it would be unbelievably tiny and so unstable that it would vanish within a fraction of a second.


There's no danger that CERN would ever explode like a nuclear bomb

5 FACTS ABOUT CERN

1 A WORLD-BEATER
CERN is the largest scientific laboratory in the world, boasting record-breaking facilities. The Large Hadron Collider, for example, is seven times as powerful as any previous particle accelerator.

2 A LOT OF DATA
CERN's data centre accumulates over 30 million gigabytes of data every year. That's the same as 250 years of HD video – enough to fill over a million Blu-ray discs.

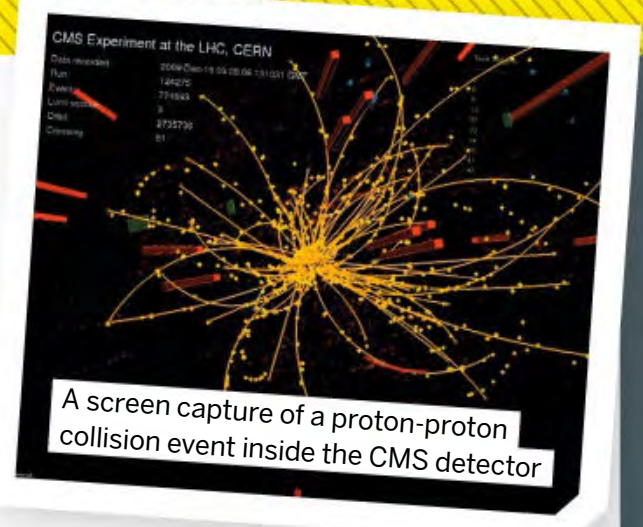
3 COLDER THAN SPACE
The LHC's superconducting magnets are cryogenically cooled to just 1.9 degrees above absolute zero, or 271.25 Celsius. That's even lower than the 2.7 degrees Kelvin of outer space.

4 ATOMS OF ANTIMATTER
Particle accelerators have always been able to create individual antiparticles, but CERN was first to combine these into atoms of antimatter in the form of antihydrogen.

5 CERN'S GREATEST INVENTION?
Despite its specialised research, CERN has made a major impact on ordinary life through its creation of the World Wide Web, originally as a way for scientists to share information.

© Alamy / CERN

HOW THE LHC WORKS



A screen capture of a proton-proton collision event inside the CMS detector

As huge as it is, the LHC can't function without the help of other machines around it. Before particles, which are usually protons but for some experiments are much heavier lead ions, are injected into it, they're passed through a chain of smaller accelerators that progressively boost their speed. Smaller is just a relative term; the last step in the injector chain, the Super Proton Synchrotron, is almost 4.3 miles in circumference. The end result is two beams travelling in opposite directions around the LHC at virtually the speed of light. The beams are kept on their circular trajectories by a strong magnetic field, which has the effect of bending the path of electrically charged particles. At four points around the LHC's vast ring, the opposing beams are brought together and made to collide, and that's where all the science happens.

Did you know?

LHC particles complete 11,000 circuits per second

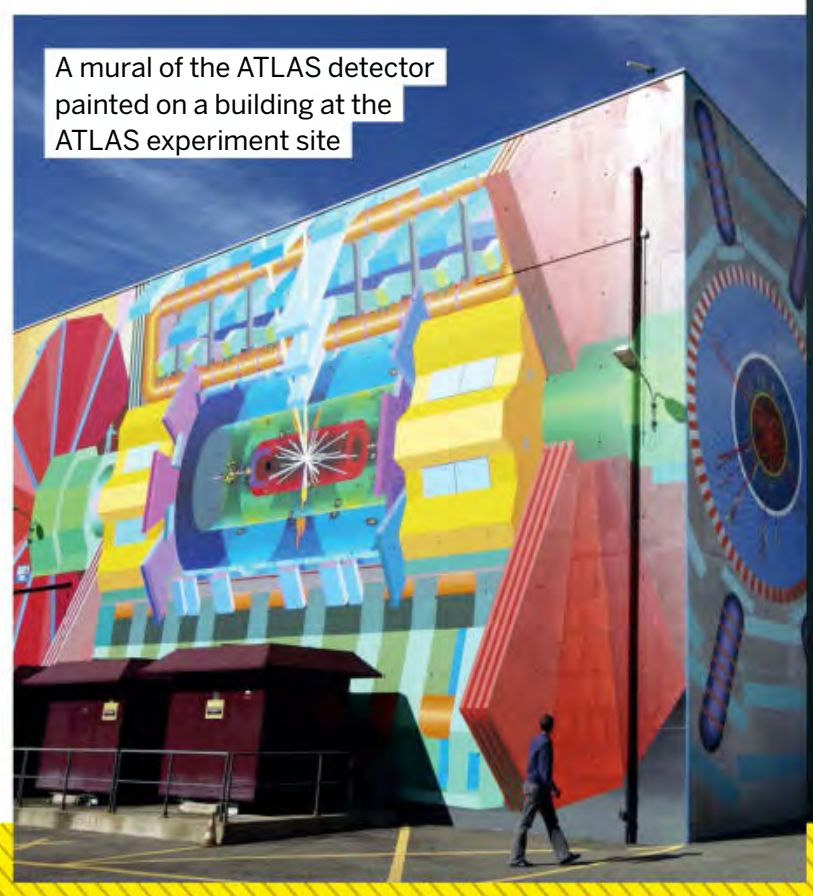
Particles are smashed together with such enormous energies that the collisions create a cascade of new particles – most of them extremely short-lived. The important thing for scientists is to work out what all these particles are, and that's not an easy task. The LHC has an array of sophisticated particle detectors for this purpose, each made up of layers of subdetectors designed to measure certain particle properties or to look for specific types of particles. For example, calorimeters measure a particle's energy, while the curving track of a particle in a magnetic field reveals information about its electric charge and momentum.

Two of the four collision points around the circumference of the LHC are occupied by large general-purpose detectors. These include the Compact Muon Solenoid (CMS), which can be thought of as a giant 3D camera, snapping images of particles up to 40 million times per second. The paths of the particles inside the detector are controlled by a gigantic electromagnet called a solenoid. Despite weighing 12,500 tonnes, it's actually quite compact, as the detector's name suggests. That middle word, muon, refers to an elusive particle similar to the electron but much more massive, which requires its own array of subdetectors wrapped around the solenoid. The LHC's other general-purpose detector, ATLAS (A Toroidal LHC ApparatuS), has an identical purpose to CMS, but differs in the design of its detection subsystems and magnets. It's also less compact than CMS, occupying a greater volume than any other particle detector ever built.

Many of the LHC's most important experiments, including the discovery of the Higgs boson, utilise the general-purpose detectors ATLAS and CMS. But it also has several other more specialised detectors that can be used in specific types of experiments.

The LHC forward (LHCf) detector, located close to the ATLAS interaction point, uses particles thrown forward in collisions as a means of simulating cosmic rays under laboratory conditions. Further along the beam trajectory is the ForwArd Search ExpeRiment (FASER), designed to look for light, weakly interacting particles that are likely to elude the larger detectors. A third experiment optimised for the forward direction is TOTal Elastic and diffractive cross-section Measurement (TOTEM), located near the CMS interaction point, which focuses on the physics of the high-energy protons themselves.

Away from ATLAS and CMS, the LHC has two other interaction points. One is occupied by A Large Ion Collider Experiment (ALICE), a specialised detector for heavy-ion physics. The final interaction point is home to two experiments on the very cutting edge of physics: LHCb, devoted to the physics of the exotic 'beauty quark', and MoEDAL – the Monopole and Exotics Detector at the LHC.


A mural of the ATLAS detector painted on a building at the ATLAS experiment site

THE MAIN DETECTORS

The LHC has two large general-purpose particle detectors, known as ATLAS and CMS

1 COMPACT MUON SOLENOID
Weighing around 14,000 tonnes, the CMS is 28 metres in length and 15 metres in diameter.

2 SUPERCONDUCTING COIL
Essentially a giant electromagnet, this generates a magnetic field 100,000 times as strong as Earth's.

3 COLLISION CHAMBER
The actual particle collisions occur here, in a vacuum chamber at the centre of the detector.

4 CALORIMETERS
Wrapped around the collision chamber, these absorb particles in order to measure their energy.

5 MUON CHAMBERS
Surrounding the collision chamber at a greater distance, these detect muons created by the collisions.

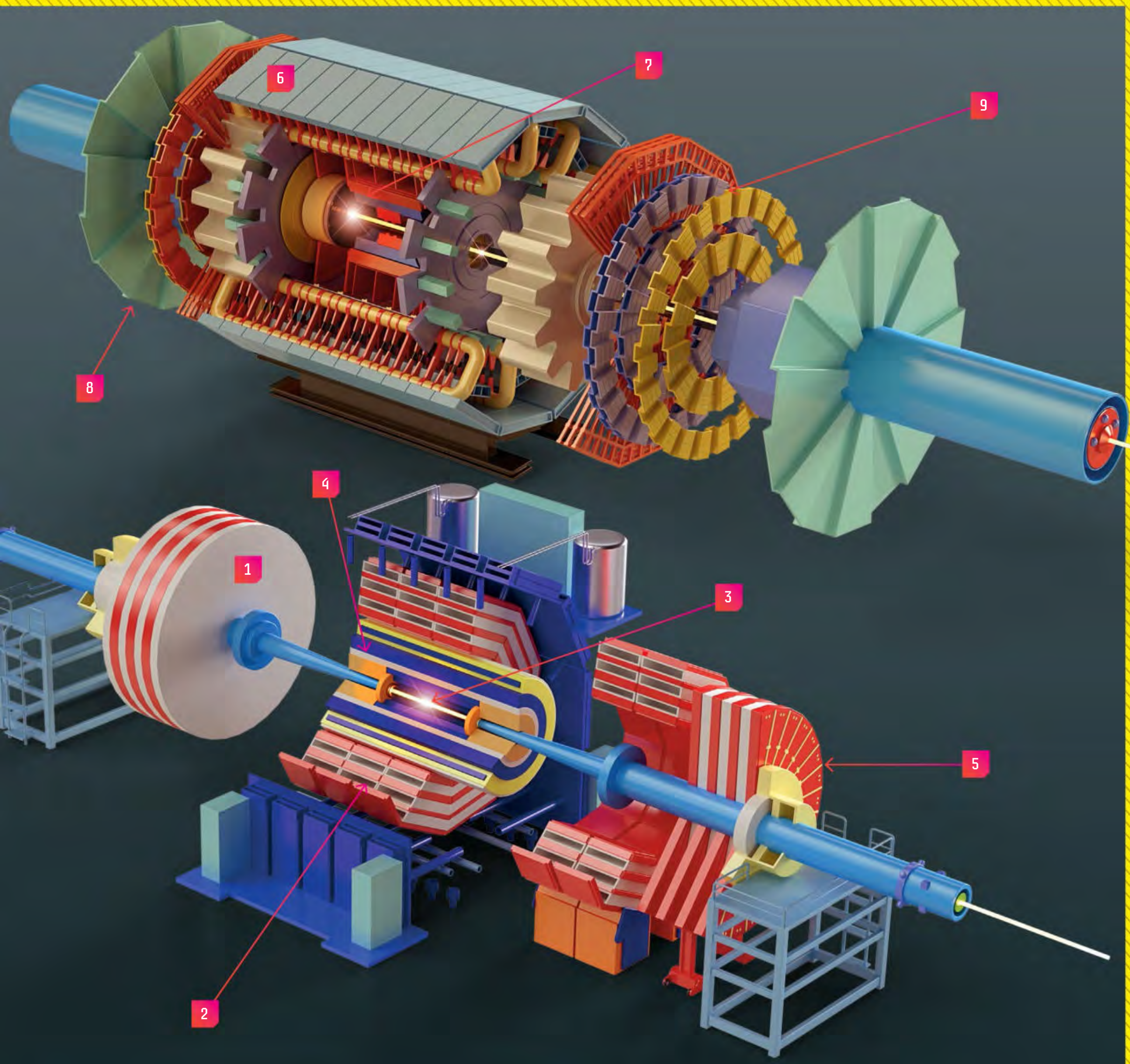
6 ATLAS
At 15 tonnes, this is lighter than the CMS, but it's physically larger: 44 metres long and 22 metres in diameter.

7 INNER DETECTOR
This takes the form of a cylinder 2.4 metres in diameter, wrapped around the central collision chamber.

8 MUON SPECTROMETERS
Like the CMS, ATLAS has several detectors designed to study muons produced in particle collisions.

9 TOROIDAL MAGNETS
These create the strong magnetic field needed to produce curved particle tracks.

DID YOU KNOW? Calling the Higgs boson 'the God particle' is a euphemism; it was originally 'the goddamn particle'



THE HIGGS BOSON

When physicists come up with new theories, they always try to make sure they can be tested experimentally. That happened in the early 1960s, when Peter Higgs and others developed a theory to explain why certain force-carrier particles have non-zero mass. The theory predicted the existence of a previously unsuspected particle, dubbed the Higgs boson. The next step was to find the Higgs boson, thus validating the theory. As simple as that sounds, it led to a decades-long hunt around the world. The end finally came in 2012, when data from a combination of ATLAS and CMS measurements proved beyond doubt that the Higgs boson had been discovered.

Schematic illustration of two Higgs bosons being created in a collision between two protons

AR zone

SCAN HERE

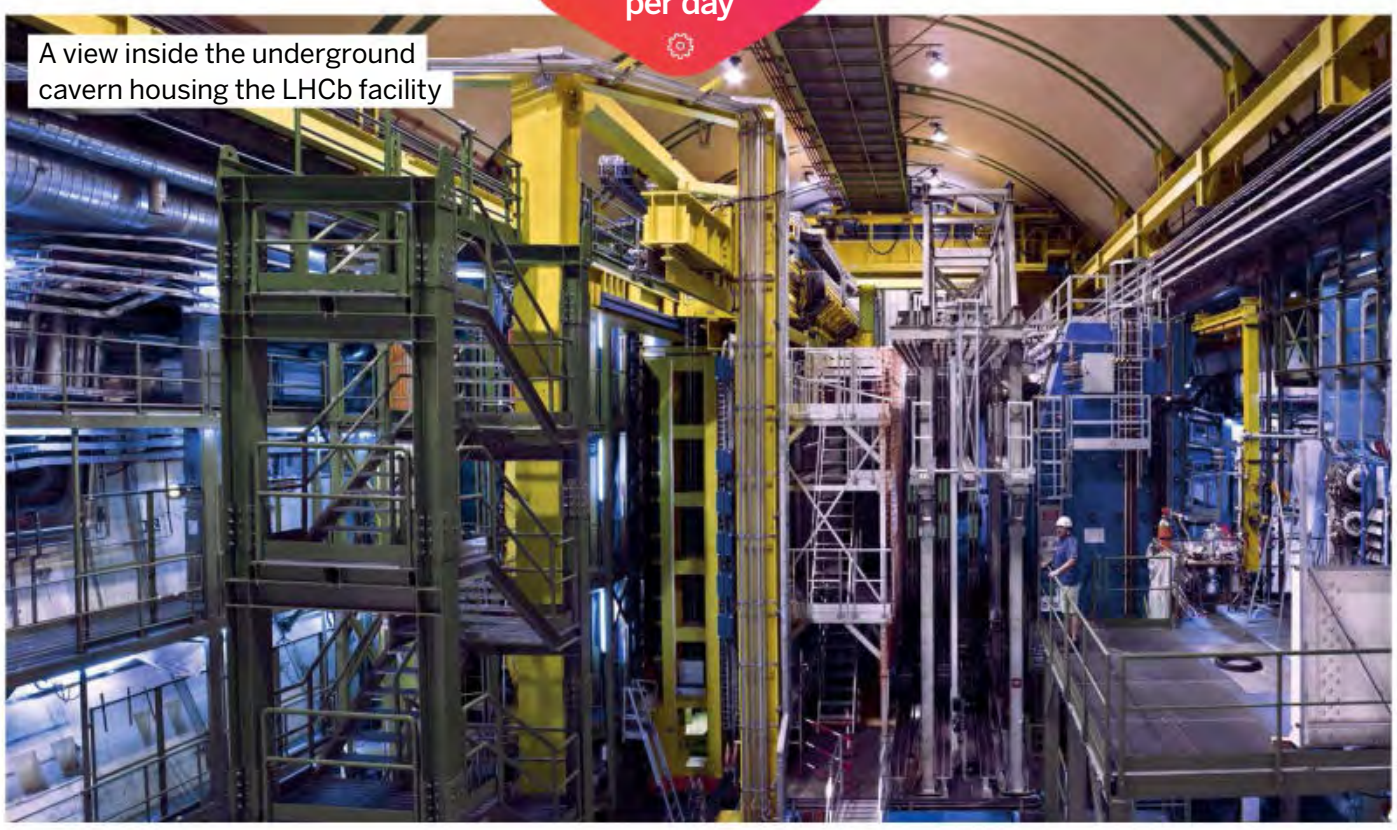
© Getty / CERN / Illustration by Nicholas Forder

CERN'S MANY EXPERIMENTS

One of the key mysteries of the universe is the striking asymmetry between matter and antimatter – why it contains so much more of the former than the latter. According to the Big Bang theory, the universe must have started out with equal amounts of both. Yet very early on, probably within the first second, virtually all the antimatter had disappeared, and only the normal matter we see today was left. This asymmetry has been given the technical name 'CP violation', and studying it is one of the main aims of the Large Hadron Collider's LHCb experiment. All hadrons are made up of quarks, but LHCb is designed to detect particles that include a particularly rare type of quark known as 'beauty'. Studying CP violation in beauty-containing particles is one of the most promising ways to shed light on the emergence of matter-antimatter asymmetry in the early universe.

Did you know?

CERN can make 0.1 picograms of antimatter per day



A view inside the underground cavern housing the LHCb facility

One of the project scientists inside the CLOUD experiment chamber

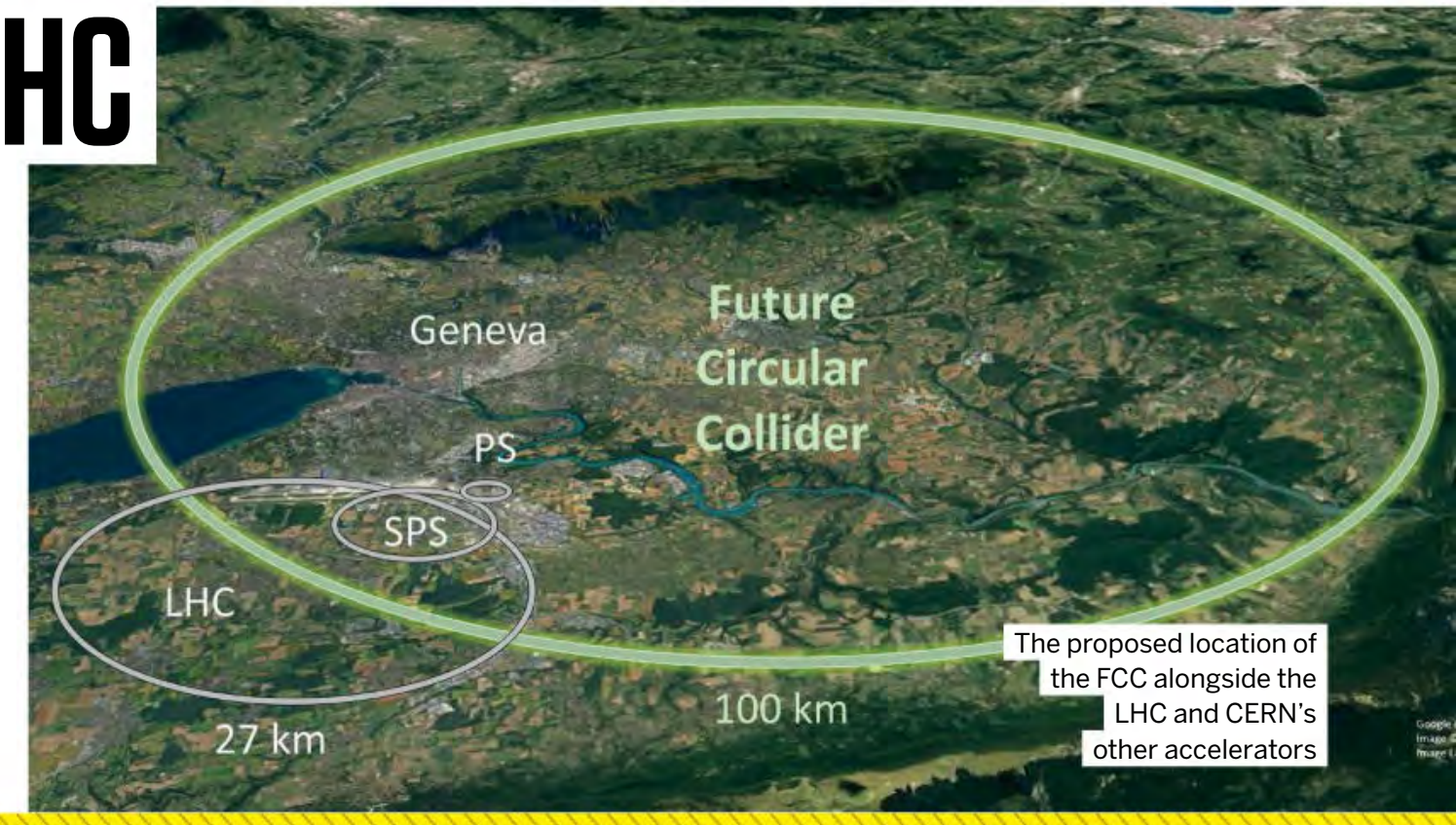
CLIMATE SCIENCE

Away from the LHC, there are other facilities at CERN that are doing equally important research. Linking particle physics to climate science may not be an obvious step, yet that's what one experiment is doing at CERN's Proton Synchrotron.

This is a smaller and less sophisticated accelerator than the LHC, but it's still capable of doing useful work. The climate experiment is called CLOUD, which gives a strong hint of what it's about, although the name actually stands for Cosmics Leaving Outdoor Droplets. Earth is under constant bombardment by cosmic rays, and it's been theorised that these play a role in cloud formation by seeding tiny water droplets. It isn't an easy process to study in the real atmosphere with real cosmic rays, so CERN is creating its own cosmic rays with the accelerator. These are then fired into an artificial atmosphere, where their effects can be studied much more closely.

BEYOND THE LHC

Over 12 years after it entered service, the LHC is still the world's biggest and most powerful particle accelerator. But it won't hold that record forever. Several countries have plans to go a step further, including China's Circular Electron Positron Collider and the International Linear Collider in Japan. Europe's own proposal is the Future Circular Collider (FCC), to be built near the LHC at CERN but dwarfing it in size. Though not yet financially approved – the estimated cost is £20 billion ($27 billion) – the design is well advanced. The FCC would be 62 miles in circumference and sit alongside the LHC, which it would use as a particle injector, ultimately achieving energies seven times greater than its predecessor.



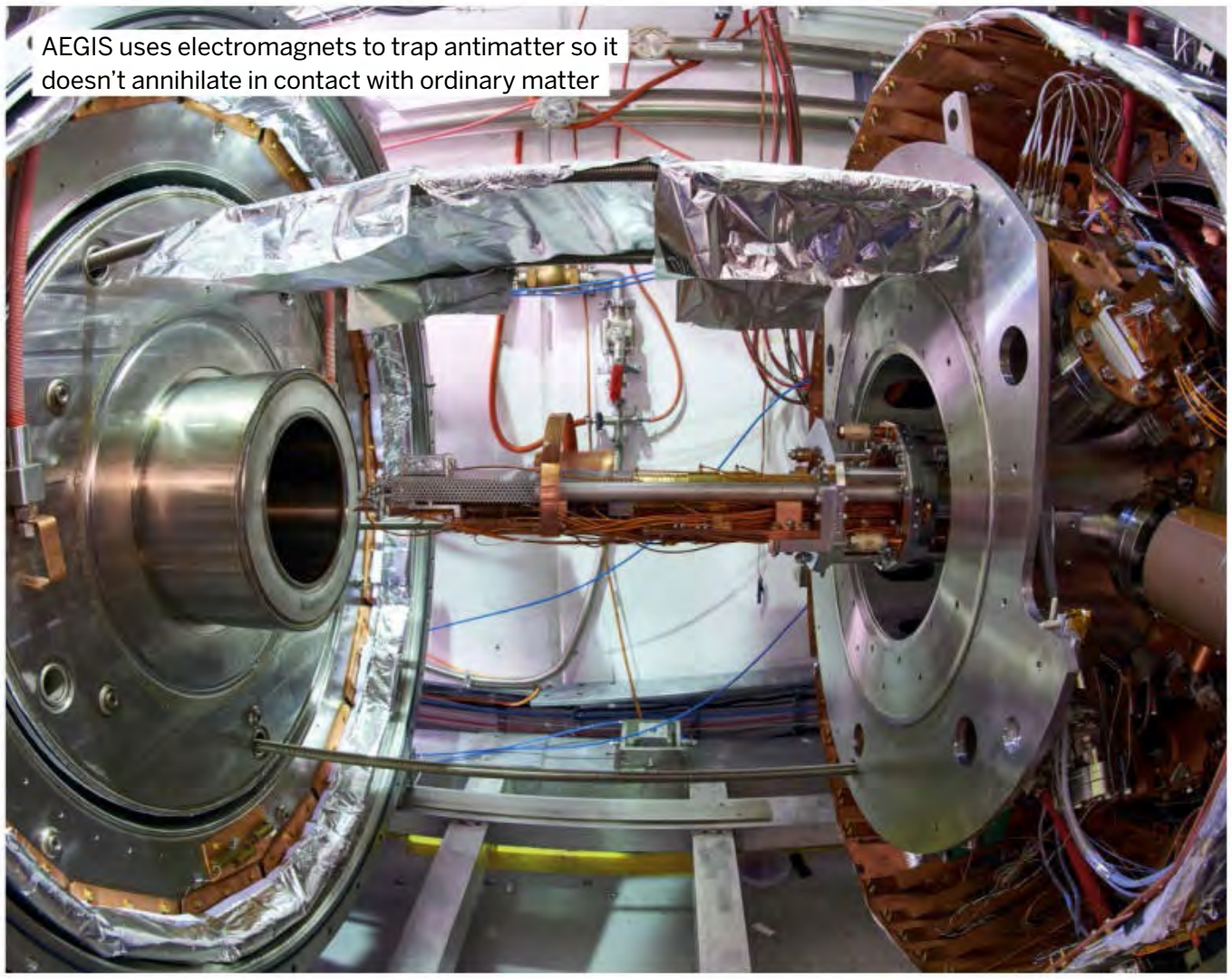
The proposed location of the FCC alongside the LHC and CERN's other accelerators

DID YOU KNOW? The LHC tunnel was once home to CERN's Large Electron-Positron Collider

MAKING ANTIMATTER

Antimatter often pops into existence inside CERN's high-energy accelerators as one half of a particle-antiparticle pair. But in the usual course of events, the antiparticles don't last long before they're annihilated in collisions with ordinary particles. If you want to create antimatter that stays around long enough for detailed study, you need more than just an accelerator. This is where CERN's unique 'antimatter factory' comes in.

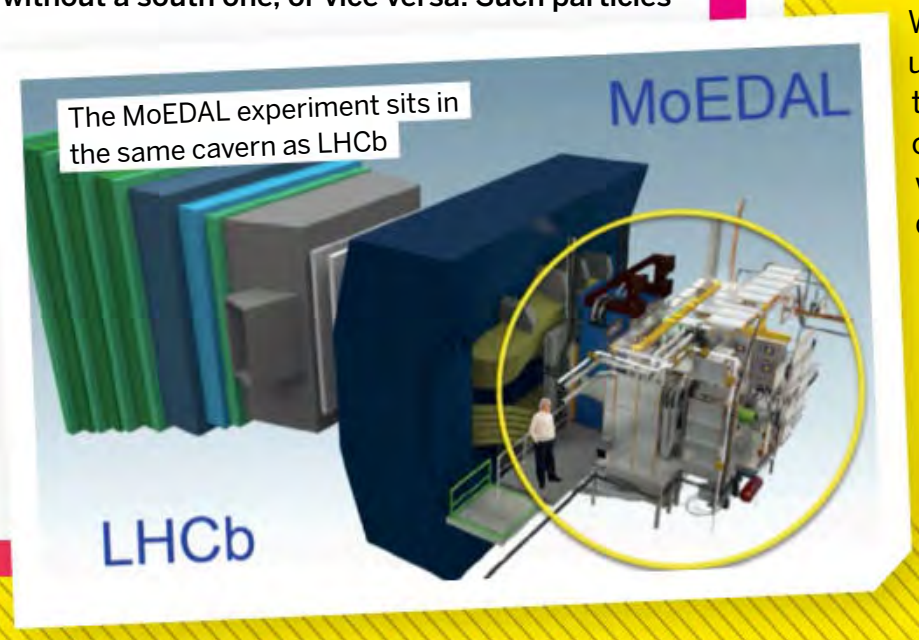
It takes antiparticles created in the Proton Synchrotron and slows them down to manageable speeds in what is effectively the exact opposite of a particle accelerator: the Antiproton Decelerator. The resulting 'antiatoms' can then be studied by a range of instruments, such as AEGIS (Antihydrogen Experiment: Gravity, Interferometry and Spectroscopy). One question that AEGIS should be able to answer soon is the fascinating one of whether antimatter falls downwards in a gravitational field, like ordinary matter, or upwards in the opposite direction.



AEGIS uses electromagnets to trap antimatter so it doesn't annihilate in contact with ordinary matter

HUNTING EXOTIC PARTICLES

Sharing the same cavern as LHCb is a smaller instrument called MoEDAL, which stands for Monopole and Exotics Detector at the LHC. While most CERN experiments are designed to study known particles, this one is aimed at discovering unknown ones that lie outside the Standard Model. A monopole, for example, would be a magnetised particle consisting only of a north pole without a south one, or vice versa. Such particles have long been hypothesised, but never observed. The purpose of MoEDAL is to look out for any monopoles that might be created in collisions inside the LHC. It could also potentially detect certain 'stable massive particles' that are predicted by theories beyond the Standard Model. If it's successful in finding any of these particles, MoEDAL could help resolve fundamental questions such as the existence of other dimensions or the nature of dark matter.



The MoEDAL experiment sits in the same cavern as LHCb

Dr Clara Nellist standing next to the ATLAS detector at CERN

WORKING WITH THE LHC

We speak to CERN scientist Clara Nellist about her work with the LHC's ATLAS detector

How did you come to be involved with the ATLAS experiment?

I started on ATLAS for my PhD research. I was developing new pixel sensors to improve the measurement of particles as they pass through our detector. It's really important to make them resistant to radiation damage, which is a big concern when you put the sensors close to the particle collisions. Since then, I've had the opportunity to work on a number of different projects, such as understanding how the Higgs boson and the top quark interact with each other. Now I'm applying machine learning algorithms to our data to look for hints of dark matter. One of the biggest mysteries in physics right now is, what is 85 per cent of the matter in our universe? We call it dark matter, but we don't actually know much about it!

What's it like working with such a unique and powerful machine?

It's really amazing to be able to work on this incredibly complicated machine with people from all over the world. No one person can run it all, so each team becomes an expert on their specific part. When we all work together, we can make discoveries about the smallest building blocks of our universe.

Are there any exciting new developments you're particularly looking forward to?

We're starting the Large Hadron Collider up again this year, so I'm really excited to see what we might find with it. Part of our work is to understand the particles we already know about in as much detail as possible to check that our theories match what we measure. But we're also looking for brand-new particles that we've never seen before. If we find something new, it could be a candidate for dark matter, or it could be something completely unexpected.

© CERN / Clara Nellist

SMASHING ATOMS BY NUMBERS

1 BILLION

The approximate number of collisions per second in the LHC

1968

The year CERN built the first computerised particle detector

THE CMS MAGNET CONTAINS MORE IRON THAN THE EIFFEL TOWER

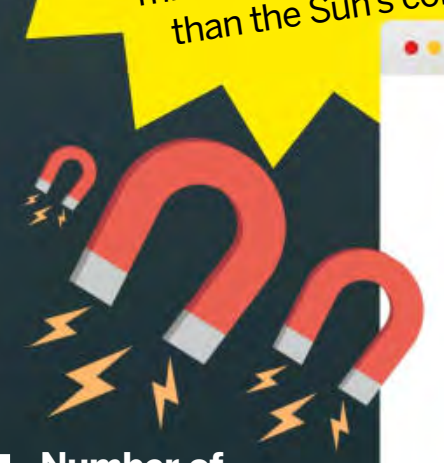
750 GIGAWATT HOURS

The annual power consumption of the LHC is thousands of times that of the average home

4 TRILLION CELSIUS

The quark-gluon plasma created in the LHC is millions of times hotter than the Sun's core

THE LHC IS THE MOST COMPLEX MACHINE EVER BUILT



1989

The year CERN created the world's first web page

9,593

Number of magnets around the circumference of the LHC

4,332,000,000 Swiss Francs

The total construction cost was nearly £3.5 billion ($4.7 billion)

DID YOU KNOW? Prior to the LHC, the world's most powerful accelerator was the Tevatron at Fermilab, near Chicago

7

There will be many times more collisions after the HL-LHC upgrade

3

Number of quarks in a proton

Around 2,500

Number of permanent staff members at CERN

2,000+

LHC research has generated thousands of scientific papers

95%

Most of the known universe isn't explained by the Standard Model

2025

The LHC's next major shutdown won't begin for a few years

125

Mass of the Higgs boson relative to the proton

5

CERN physicists have earned themselves several Nobel Prizes

THE ATLAS DETECTOR IS THE SIZE OF A SIX-STOREY BUILDING

THE VACUUM INSIDE THE LHC IS COMPARABLE TO INTERSTELLAR SPACE

© Getty

HOW THE OSCARS BEGAN

2022 marks the 94th Academy Awards: we explore the history, glories and controversies of the biggest film awards ceremony in the world

WORDS NIKOLE ROBINSON

DID YOU KNOW? The Oscar trophy is officially named the Academy Award of Merit

Every year, film fanatics all over the world prepare for the most prestigious movie awards ceremony, eagerly awaiting the nominations and eventual reveal of the winners in an extravagant celebration, broadcast in over 200 countries. But the Academy Awards wasn't always the celebrity spectacle it is today. In fact, it had rather humble beginnings.

The Academy of Motion Picture Arts and Sciences was founded in 1927 after talks led by MGM studio head Louis B. Mayer highlighted the need for an organisation to oversee and unite Hollywood. With this, technology could be standardised between studios and disputes could be solved impartially. A banquet was held to discuss the formation of this organisation, and its 36 attendees became the Academy's inaugural members, with actor Douglas Fairbanks becoming its first president. Originally divided into five branches – actors, directors, producers, technicians and writers – there are now 17 branches within the Academy.

One of the Academy's first committees suggested that annual awards be given out in 12 categories, with these to be "considered the highest distinction attainable in the motion picture profession". In 1928, Mayer set MGM art director and Academy founder Cedric Gibbons to work on designing a statue as impressive as the honours being given. Gibbons drew up a golden crusader holding a sword, perched atop a reel of film – the reel has five spokes to signify the five original branches of the Academy. Very little has changed since the statuette's original design, with the Oscar becoming perhaps the most iconic and recognisable award in the world.

"The Academy Awards wasn't always the celebrity spectacle it is today"

The event came to fruition the following year, with the first Academy Awards set for 16 May 1929 to honour films released in 1927 and 1928. With sound only just revolutionising the motion picture industry, it was deemed unfair that silent films would have to compete against them, and so 'talkies' were excluded. The ceremony didn't have any of the pomp and splendour of today, being a simple affair that

1936

Dudley Nichols became the first to decline an award, winning Best Screenwriter for *The Informer*. The Writer's Guild was on strike at the time of his refusal, and this was his way of showing solidarity.

1939

Hattie McDaniel became the first African-American winner, receiving the Oscar for Best Supporting Actress for her role in *Gone With the Wind*.

1942

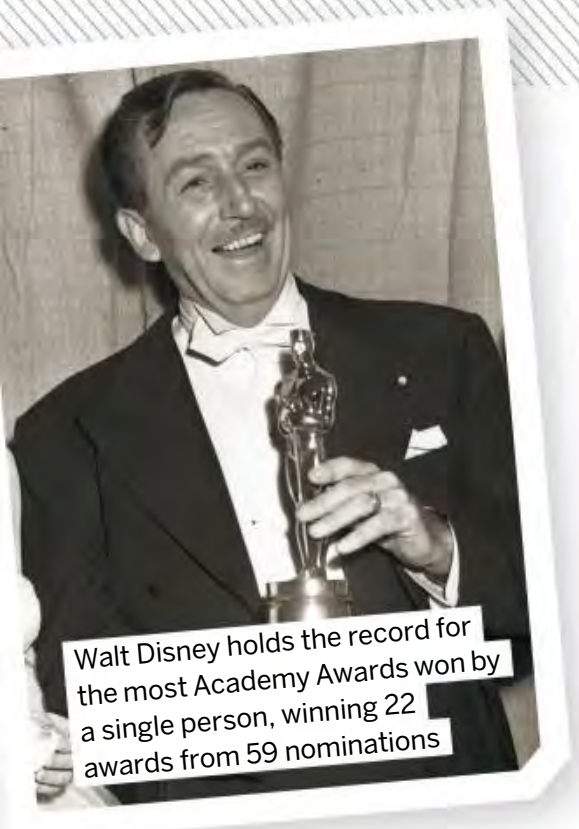
Often viewed by critics as the greatest film ever made, *Citizen Kane* controversially missed out on Best Picture, with the award going to *How Green Was My Valley*.

1958

Donald Duck cohosted the Oscars alongside Bob Hope, Jack Lemmon, David Niven, Rosalind Russell and James Stewart by way of an animated film. Unfortunately, he didn't go down as a very popular host.

1969

Barbara Streisand and Katharine Heburn tied for Best Actress for their roles in *Funny Girl* and *The Lion in Winter* respectively. Hepburn wasn't in attendance, so Streisand didn't have to share the stage.



Walt Disney holds the record for the most Academy Awards won by a single person, winning 22 awards from 59 nominations

WHAT'S IN A NAME?

From 1939, the name 'Oscar' was officially adopted for the golden idols handed to winners, but there are different tales for where this originated: the most popular account says the Academy's first librarian, Margaret Herrick, remarked that the bronze-and-gold statutes looked just like her uncle Oscar, and the name later stuck. But Hollywood gossip columnist Sidney Skolsky also has a claim to the name. In his 16 March 1934 column detailing Katherine Hepburn's first win, he used the name Oscar for the award in reference to jokes made by vaudeville comedians. This is the first record of the name being used in print.

Award statuettes held securely backstage at the 92nd Academy Awards

© Getty / Wiki: UCLA: ; Celest.ru ; Alexander Kahle

only lasted 15 minutes and had 270 attendees. The winners had actually been announced three months earlier, so there wasn't much suspense surrounding the event or press involvement – in fact, the first Oscars wasn't even broadcast!

Public interest had grown by the following year, and the 2nd Academy Awards was broadcast over the radio. Academy membership also increased after the event generated interest within the industry, with only members able to nominate and vote for their colleagues – a way for them to honour their peers and for voting to be specialised. Today, new applicants must be sponsored by existing members, and membership remains exclusive to those within the 17 branches of the film industry. Each branch nominates within its own categories, but final votes are counted from all members.

In early ceremonies, all a nominee's work from that year was considered for an award, though this later changed to individual performances. In all categories but Best Picture, members vote for their top choice. However, Best Picture is voted for preferentially so that the result better reflects all voters. This can mean that if enough members share the same second choice, that film can end up winning the Oscar instead of a less popular first choice.

With growing interest came more aplomb, with celebrity hosts chosen to make the evening more entertaining rather than just being a presentation of awards. Bob Hope first hosted in 1940, and has since led the event 19 times over 50 years. There have also been musical numbers and animated features created just for the show, and music from nominated films is performed live for attendees. The Red Carpet, where celebrities dress in outrageous outfits and pose for the press, has become synonymous with the Oscars, but this wasn't rolled out of the event entrance until 1961.

Since the awards began being televised the ceremony has become even more extravagant, with entire crews working behind the scenes to make the Oscars an unforgettable night each year. The televised broadcasts have even picked up a total of seven Emmy awards, and have been in the running for many more.

Did you know?

Avatar is the most expensive film to pick up an Oscar... or three

1974

Susan Sarandon and Tim Robbins were banned from future events for using the ceremony to speak out against the treatment of Haitian refugees. Richard Gere was also banned for protesting against the Chinese government.

1993

34-year-old art dealer Robert Opel ran across the stage stark naked, flashing a peace sign behind cohost David Niven. However, it's debated whether this was a publicity stunt.

2006

Björk revealed her infamous Marjan Pejoski swan dress on the red carpet of the 73rd Academy Awards, with the Icelandic star also pretending to lay eggs. It's become one of the most iconic Oscars outfits.

2010

Kathryn Bigelow became the first woman to win Best Director for *The Hurt Locker*. This highlighted the problem of sexism in Hollywood, as it took until the 82nd ceremony for a woman to receive this award.

2017

La La Land was mistakenly announced as Best Picture when the envelope contained a duplicate of Emma Stone's Best Actress win for her leading role in the film. *Moonlight* was the intended recipient of the Oscar.

CELEBRATING TECHNOLOGY

When the Oscars began, film was just coming out of the silent era and visual effects were done by way of movie magic. Special effects, filmmaking techniques and hardware have come a long way since the early days of cinema, so it seems fitting that these developments have their own set of awards. Starting with the 4th Academy Awards in 1931, the Academy has hosted the Scientific and Technical Awards alongside the main event, honouring the most significant improvements in film production and the motion picture industry and the science and technology that makes these possible. The first winners received awards for noise-reducing recording equipment and super-sensitive panchromatic film; more recent developments that have been recognised are IMAX's wide-angle viewing experience, motion capture, advanced 3D modelling techniques and telescopic crane cameras. With filmmaking relying more and more on technology in the modern era, these awards ensure breakthroughs which further the industry don't go unnoticed.

A fluid-effects system won a 2007 Technical Achievement Award

DID YOU KNOW? Due to metal shortages in World War II, the awards were made from painted plaster instead

3,140

Over 3,000 Oscar trophies have been awarded so far

1930

The 2nd and 3rd Academy Awards were both held in the same year

EACH 34.3-CENTIMETRE AWARD COSTS ABOUT $400 (£300) TO MAKE, BUT MUST BE SOLD BACK TO THE ACADEMY FOR $1 (£0.74)

ONE

To date, Halle Berry is the only African American to win Best Actress

24

Oscar statuettes are made of bronze, coated in 24-carat gold

IN 1940 *THE LA TIMES* PUBLISHED THE WINNERS PRIOR TO THE EVENT, BEGINNING THE TRADITION OF SEALED ENVELOPES

1953

The first year the ceremony was televised

SIX

There have been six ties for an Oscar; the first was for Best Actor in 1932

55

A shipment of unmarked Oscars was stolen in 2000. 52 of them were found in a dumpster by scavenger Willie Fulgear

14

The most nominations for a single film. *All About Eve*, *Titanic* and *La La Land* share this honour

5 BIGGEST AWARD WINNERS

1 THE LORD OF THE RINGS: THE RETURN OF THE KING (2003)
The third and final instalment of the fantasy epic made a sweep of the 76th Academy Awards, winning all 11 categories it was nominated for and running rings around the other nominees.

2 TITANIC (1997)
Sinking the competition, James Cameron's disaster-romance picked up 11 out of 14 awards, also becoming the highest grossing film of all time until *Avatar*.

3 BEN-HUR (1959)
With a budget and production of biblical proportions – and a runtime of over three hours – *Ben-Hur* took home 11 out of 12 trophies, though it's not the longest film to win an Oscar.

4 WEST SIDE STORY (1961)
Recently remade for the 21st century, the original 1961 musical received 10 of the 11 awards it was nominated for, only missing out on the award for Best Adapted Screenplay.

5 THE ENGLISH PATIENT (1996)
With 12 nominations at the 69th Academy Awards, this British war film won in nine categories. It also became the first digitally edited film to win the award for Best Editing.

© Alamy / Getty

FORMULA 1 EVERYTHING YOU NEED TO KNOW

Discover the race cars, technology, drivers and crews behind the world's biggest and most popular motorsport

WORDS **MIKE JENNINGS**

DID YOU KNOW? The halo, which protects drivers' heads, can withstand 12,000 kilograms of pressure


The first corner is often the busiest in F1, with 20 cars in close proximity

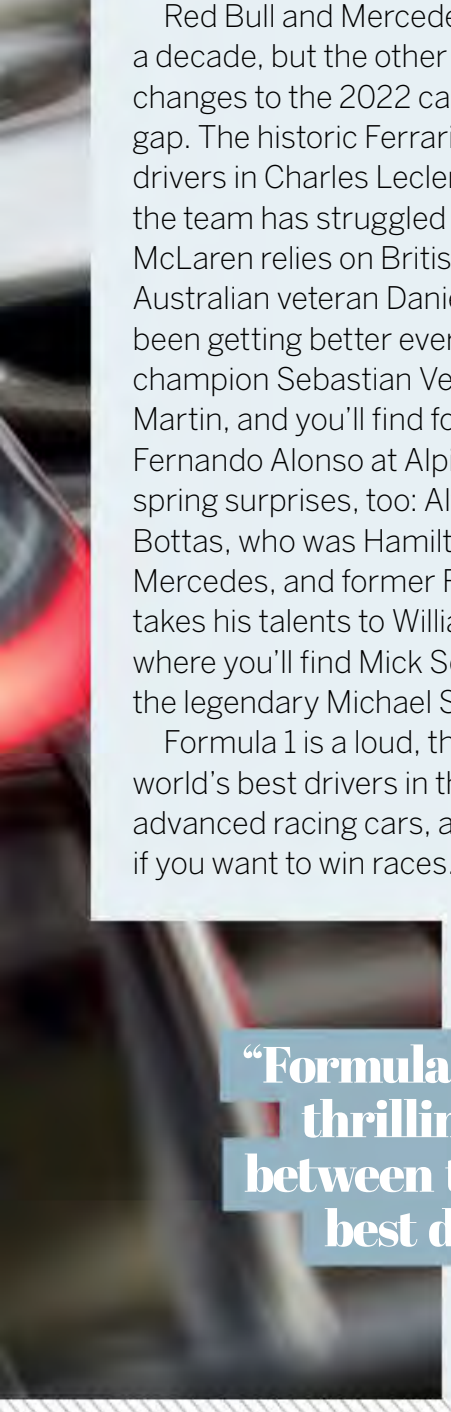

Cars are built from deformable parts, while drivers sit in a super-strong safety cell

Formula 1 is the fastest, most popular and most lucrative motorsport on the planet. Its status means it attracts the best drivers, the biggest car manufacturers, huge media attention and global audiences in the hundreds of millions. It's a big deal. Races take place on five continents, the season stretches across most of the year and F1 has never been so popular on social media. The sport has just experienced one of its best ever seasons, too: the 2021 campaign was a fierce and sometimes bad-tempered battle between Lewis Hamilton's Mercedes team and Red Bull Racing's Max Verstappen.

It's a big, bold, high-tech circus, but it can be complicated if you're not sure how F1 works. The first race of 2022 took place in Bahrain, and this season will be the longest ever, with 23 races, so there's never been a better time to dive into the cockpit. Ten teams – each with two drivers – will contest the 2022 campaign. Red Bull's world champion, Max Verstappen, will drive alongside Sergio Perez. Mercedes will field seven-time world champion Lewis Hamilton alongside young driver George Russell, who joined the big leagues after impressing with the weaker Williams team.

Red Bull and Mercedes have dominated F1 for a decade, but the other teams hope that big changes to the 2022 cars will help them close the gap. The historic Ferrari team has excellent drivers in Charles Leclerc and Carlos Sainz, but the team has struggled with a weaker car. McLaren relies on British driver Lando Norris and Australian veteran Daniel Ricciardo, and they've been getting better every year. Four-time world champion Sebastian Vettel drives for Aston Martin, and you'll find former world champion Fernando Alonso at Alpine. Smaller teams can spring surprises, too: Alfa Romeo will field Valtteri Bottas, who was Hamilton's teammate at Mercedes, and former Red Bull driver Alex Albon takes his talents to Williams. Then there's Haas, where you'll find Mick Schumacher – the son of the legendary Michael Schumacher.

Formula 1 is a loud, thrilling battle between the world's best drivers in the world's most advanced racing cars, and you need good drivers if you want to win races. It's not just about the driver, though. Theywrangle incredible vehicles, the fastest open-wheel, single-seater racing cars around, and their aerodynamic design means they travel faster than some planes on takeoff. F1 cars produce 5G of downforce, so they can take corners at sensational speeds, and they race at more than 200 miles per hour. Teams spend millions of pounds developing their cars. And while every F1 team must adhere to strict regulations to ensure fair racing, teams with the biggest budgets and best engineers tend to develop better components and produce faster, more reliable cars.


"Formula 1 is a loud, thrilling battle between the world's best drivers"

Success in F1 is about strategy, too. Teams use different tyres during races: softer tyres provide more grip but deteriorate quickly, while harder tyres have less grip but last longer. No tyres last for a full race, though, so teams must decide when to pit their cars to fit a new set. A pit stop costs time, but can allow teams to gain strategic advantages. They've also got to consider the weather, because rain dramatically alters a race – it changes which tyres work well, allows some drivers to thrive and means that others will struggle.

Races take place on Sundays and usually last about two hours; here you'll get to see the world's best drivers locked in intense on-track battles. But Formula 1 is not just about those Sunday races. It's a travelling festival of motorsport, and you can watch days of on-track action in the lead-up to the main Sunday event. Qualifying, which takes place on Saturdays, determines the starting order for the Sunday race. F1 uses two different qualifying formats: most Saturdays have an hour-long session where drivers push their cars to the limit, because faster lap times mean a better starting spot on the Sunday. In 2022, six circuits will host an alternative format called Sprint Qualifying, where a short race on the Saturday decides starting positions on Sunday. F1 weekends also feature practice sessions, with three on Friday and a final practice run on Saturday mornings. These are important: they give drivers and teams the chance to test different car set-ups, learn the circuit and devise strategies. The top-ten drivers in each F1 race get points – the winner gets 25, the second-place driver gets 18 and amounts decline further. The driver with the fastest lap during the race gets an extra point. Those points decide each year's champion.

WHY IS IT CALLED FORMULA 1?

European racing used to be organised by the Association Internationale des Automobile Clubs Reconnus (AIACR). World War II stopped that, and a new organisation called the Fédération Internationale de l'Automobile (FIA) was created to rebuild racing after the hostilities. By 1946 the FIA was planning a world championship, and by 1950 Formula 1 was ready to start. The term 'Formula' represents a set of standards that every participating car must meet before it's allowed to race, and it was called Formula 1 because it's the top tier of racing. That's still in place today, where cars all adhere to the same design basics, and this naming convention is also used for other types of racing, like Formula 2, Formula 3 and Formula Renault.

The first F1 races were frantic affairs, with big crowds and little regard for safety

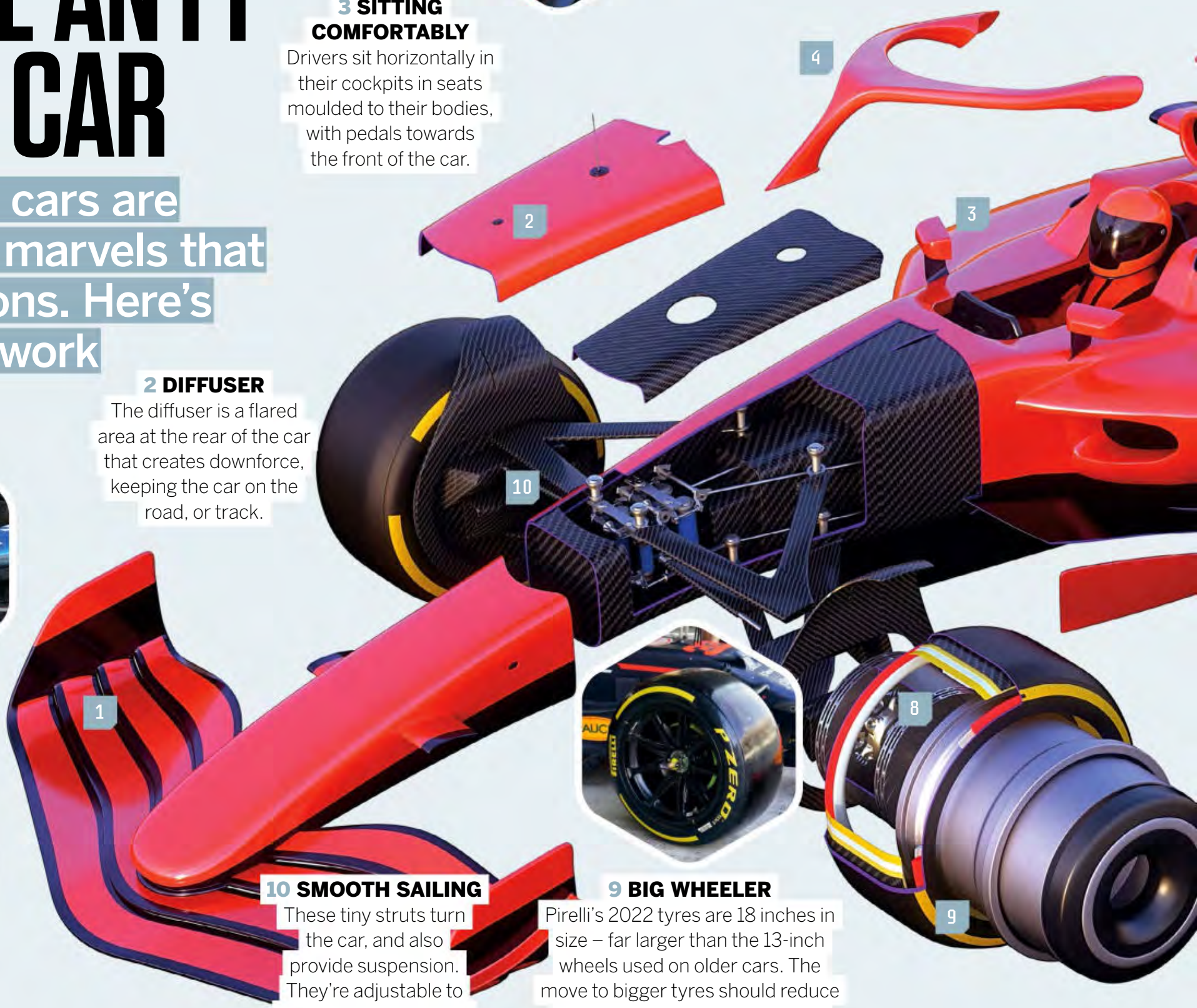
© Alamy / Getty

INSIDE AN F1 RACE CAR

Formula 1 cars are high-tech marvels that cost millions. Here's how they work

4 SAFETY FIRST
Safety is crucial in F1, and a tubular titanium structure called a halo protects drivers from large objects and debris during races. The halo was introduced in 2018 and has proven a successful and life-saving addition to open-wheel racing.

3 SITTING COMFORTABLY
Drivers sit horizontally in their cockpits in seats moulded to their bodies, with pedals towards the front of the car.



2 DIFFUSER
The diffuser is a flared area at the rear of the car that creates downforce, keeping the car on the road, or track.

1 NOSE AHEAD
The front wing and nose sections have been completely redesigned for 2022. The revised aerodynamics should keep air closer to the sides of the car so other vehicles won't be disturbed by turbulence, meaning drivers can race with more confidence.

10 SMOOTH SAILING
These tiny struts turn the car, and also provide suspension. They're adjustable to reflect the demands of different circuits.

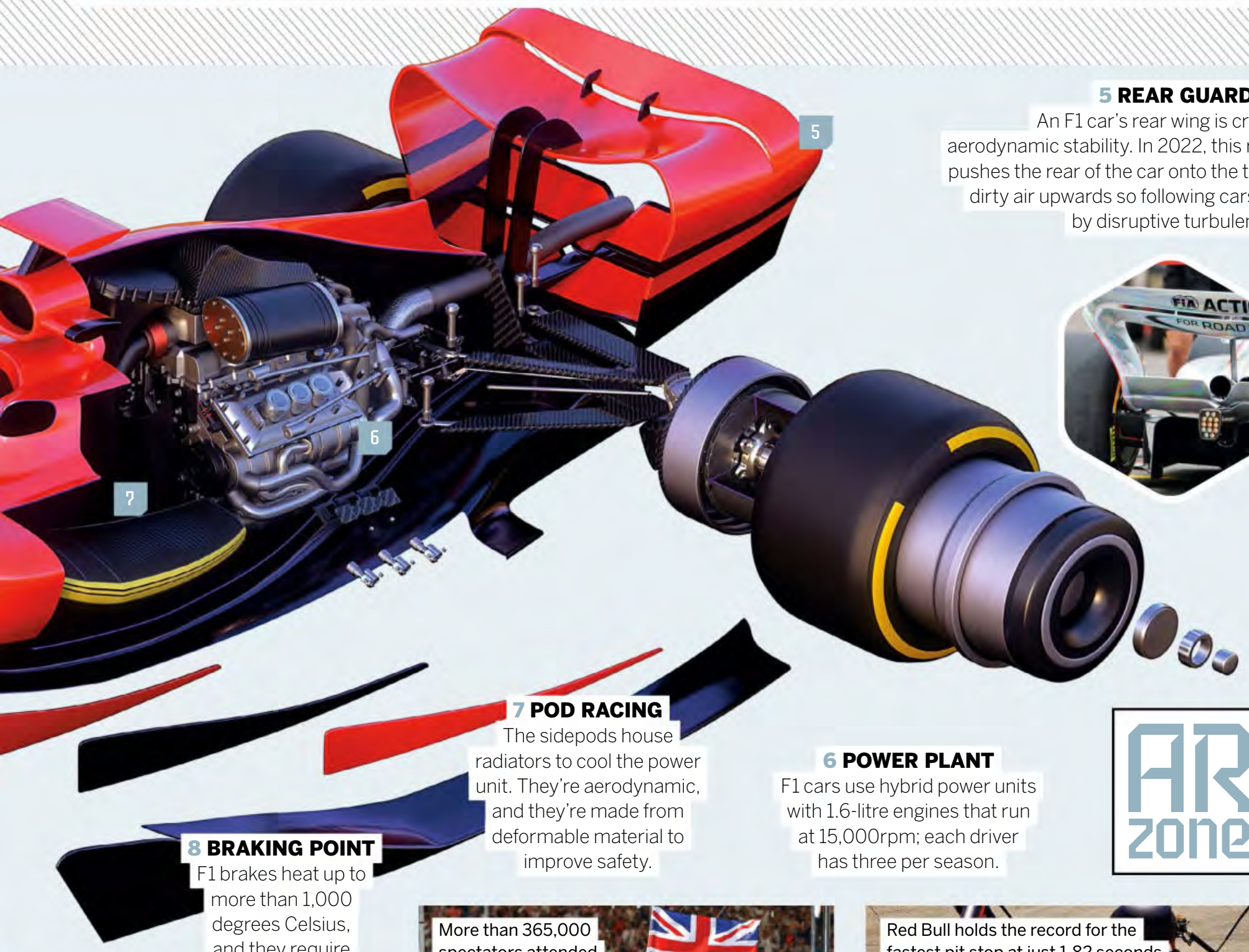
9 BIG WHEELER
Pirelli's 2022 tyres are 18 inches in size – far larger than the 13-inch wheels used on older cars. The move to bigger tyres should reduce overheating, improving grip and leading to more aggressive racing.

2022'S BIGGEST CAR UPGRADES

Formula 1's 2022 cars have undergone radical changes when compared to last year's models. The big upgrades concern aerodynamics – the way that the cars behave as they move through the air – and they should promote closer racing. The front sections of this year's cars look very different, for starters; their curvier construction helps keep air flowing narrowly down the sides of each car so other racers aren't disturbed by unpredictable currents. The rear wing has been redesigned, too. It's taller and sends air straight upwards so racers don't get jostled as they follow another driver. This year's cars also have larger tyres than before, which reduces overheating and improves grip – another move to ensure better racing. Elsewhere, 2022's cars now use a fuel that's made from ten per cent biofuel, which reduces F1's reliance on fossil fuels. The power unit underneath all of this is unchanged, though, which means that F1 remains a hybrid motorsport.

Haas is F1's only American team, and it was the first squad to launch its 2022 car

DID YOU KNOW? Hamilton has the most race victories, with 103 since his debut for McLaren at the 2007 Australian Grand Prix



5 REAR GUARD

An F1 car's rear wing is crucial for aerodynamic stability. In 2022, this redesigned feature pushes the rear of the car onto the track while sending dirty air upwards so following cars aren't affected by disruptive turbulence.

7 POD RACING

The sidepods house radiators to cool the power unit. They're aerodynamic, and they're made from deformable material to improve safety.

6 POWER PLANT

F1 cars use hybrid power units with 1.6-litre engines that run at 15,000rpm; each driver has three per season.

8 BRAKING POINT

F1 brakes heat up to more than 1,000 degrees Celsius, and they require huge force and finesse from drivers to work effectively.

AR zone SCAN HERE


More than 365,000 spectators attended the 2021 British Grand Prix – a record-breaking crowd


Red Bull holds the record for the fastest pit stop at just 1.82 seconds

Did you know?

7,500 simulations were used to design the 2022 car

MERCEDES W12: TITLE WINNER

F1 SEASON INTRODUCED: 2021

BRAKE HORSEPOWER: 1,050

WEIGHT: 752 kilograms

FERRARI F2002: ICONIC DESIGN

F1 SEASON INTRODUCED: 2002

BRAKE HORSEPOWER: 835

WEIGHT: 600 kilograms

WILLIAMS FW18: BRITISH BATTLER

F1 SEASON INTRODUCED: 1996

BRAKE HORSEPOWER: 700

WEIGHT: 595 kilograms

LOTUS 78: AERODYNAMIC INNOVATION

F1 SEASON INTRODUCED: 1977

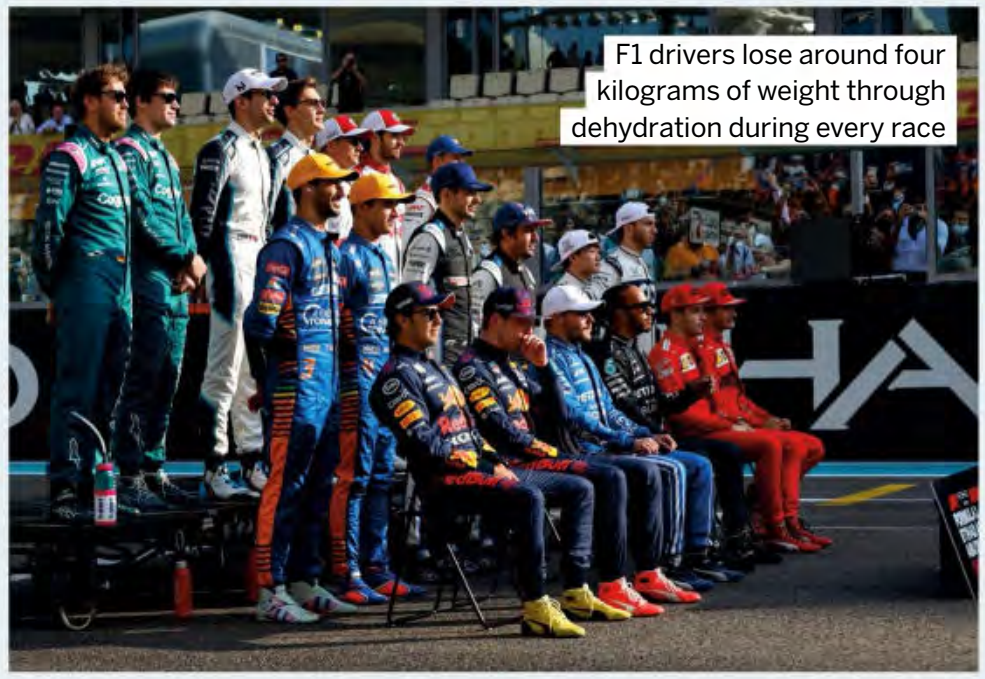
BRAKE HORSEPOWER: 480

WEIGHT: 588 kilograms

© Alamy / Getty / Haas F1 / Illustration by Nicholas Forder

The Hungaroring is one of F1's most picturesque tracks – and one of the trickiest

CIRCUIT BREAKERS



F1 drivers lose around four kilograms of weight through dehydration during every race

Racing circuits are loops of road that are built to challenge drivers, promote overtaking and deliver exciting racing. The best tracks allow F1 cars to reach their top speeds, and top circuits combine fast corners for brave, high-speed overtakes and slower corners for dramatic battling. Most F1 races take place at purpose-built circuits that are used for lots of different kinds of motor racing – indeed, if you attend an F1 race you'll see other cars racing during breaks between F1 sessions.

In 2022, seven races will take place on street circuits – tracks built in existing cities. The most famous is the Monaco Grand Prix route, which has been used since 1929, and in 2022 there's a new circuit in Florida that will race around the Miami Dolphins' NFL stadium.

F1 circuits range from between 2.075 and 4.352 miles in length, and most F1 races need to run for at least 190 miles, so races typically last between 44 and 78 laps. Most circuits run clockwise, and they all have long start-finish straights where races begin and end. Every circuit has a pit area where cars can leave the track to get new tyres and components, and grandstands for fans surround each circuit.

Circuits have changed dramatically over the years. They're far safer now – they're surrounded by padded barriers to absorb car impacts, and corners have large gravel areas to slow cars down if they leave the track. Many circuits have undergone layout changes to alter average speeds and promote better racing, including some of F1's most famous venues.

Did you know?

Formula 1 cars contain about 80,000 components

Take Silverstone, for instance – the circuit that's hosted the British GP more than any other. It was originally an airfield, and racers used the old runways before that was deemed unsafe. Over the years it's had chicanes added and corners altered, and in 2010 new corners were added and a new start-finish straight was built. Hockenheim in Germany was famous for long straights that plunged through a forest, but in 2002 the straights were abandoned in favour of a new layout with loads of tight corners. Belgium's Spa-Francorchamps circuit was originally nine miles long, but its current design is just over four miles. For the 2022 season its most famous corners, Eau Rouge and Raidillon, are being redesigned after several high-profile accidents. F1 circuits don't stay still for long – a bit like the cars that race on them.

5 FACTS F1'S REAL-WORLD IMPACT

1 HARNESSING HYBRIDS
The incredible efficiency of F1's hybrid power units has made hybrid road cars more efficient, and Mercedes uses some of its hybrid tech in its road cars.

2 ENERGY-SAVING BRAKES
F1's Kinetic Energy Recovery System (KERS) charges cars' batteries by reclaiming energy during braking. It's been around since 2009, and similar systems are now found in hybrid cars and buses.

3 SUSPENSION SPREADING
Active suspension first arrived in F1 in 1992, allowing suspension height to change depending on the road conditions. Since then, it's become a standard feature on many road cars.

4 PADDLE SHIFTING
Ferrari was the first team to use paddle shifters to enable super-fast manual gear changes. Now they're standard in F1 and found on all kinds of everyday cars.

5 CARBON FOOTPRINT
Carbon fibre is sturdy and lightweight, and it was pioneered by McLaren in the 1980s. Now it's used on virtually every sports car thanks to its robust, weight-saving design.

DID YOU KNOW? F1's tech-filled steering wheels are packed with features, screens and dials, and cost more than £50,000 ($68,000)

STAYING ON TRACK

A spectator's guide to the technology of an F1 race track

BREAKING THE LIMITS

The speed trap on the circuit's longest straight highlights which cars are faster than others.

GRID GAMES

The start-finish line is where races begin and end, so this is where you'll see someone waving a chequered flag.

TAKE THE INITIATIVE

Drivers can deploy the Drag Reduction System (DRS) along the circuit's straights if they're less than one second behind the car in front. DRS activation lowers a flap on the car's rear wing, which reduces drag and increases top speeds, giving the driver behind an opportunity to overtake.

DRAG RACING

If a car is close behind a rival at a particular point, drivers can use the DRS.

STRAIGHT TO THE POINT

Most circuits start with a straight followed by a slower corner, encouraging cars to overtake by ducking inside rival racers.

STOP AND GO

The pit lane runs parallel to the start-finish straight. Each driver has their own garage where new tyres are fitted and broken parts are replaced. The teams have their facilities around this part of the circuit, too, and this is where you'll find journalists, TV crews and officials.

SPLIT DECISIONS

Circuits are divided into three sections, called splits, and lap times are calculated by adding together the time taken to travel through each of these sectors. Individual split times are useful – they allow teams to see if their cars are faster or slower in certain areas of the track.

PERFECT TECHNIQUE

Technical sections with lots of corners in quick succession allow the best drivers to gain time on other cars.

Ferrari has won more constructors' titles and races than any other manufacturer

© XXXX

Changing gears on mountain bikes allows riders to travel across varied terrain

HOW PUSH BIKE GEARS WORK

Understanding this mechanism can improve your control over your bicycle

WORDS **AILSA HARVEY**

When riding a bike, a high gear is optimal for sustaining high speeds and descending, while a low gear provides a comfortable pedalling speed for climbing hills. However, no single gear is optimal for tackling all terrain – this is why bikes have a gear system.

As the pedals on a bike turn, they rotate a chainring, causing the bike's chain to circulate between the pedals and the rear wheel. At the centre of the rear wheel, the chain attaches to one of a series of cogs. When the gear is changed, the chain jumps between them. The mechanism responsible for causing these movements is called a derailleur.

When set at a low gear, the chain attaches to the largest cog on the cassette, closest to the bike's frame. In this gear, one full rotation of the pedals equals fewer turns of the rear wheel than when in harder, or higher, gears. Pedalling requires less force in low gears and feels more comfortable when cycling uphill. As you move up through the gears, the wheel rotates more with a single rotation of the pedals. Each rotation per pedal gives the gear ratio.

Most modern road bikes will have a derailleur at both the front and back of the bike, multiplying the number of gears available to the rider. A bike with only one chainring at the front and a cassette at the back with 11 cogs gives the cyclist a total of 11 gears. However, bikes with two front chainrings, with two cogs, provide 22 gears. When riding a bike with two chainrings or more, the chain is moved across to the larger chainring to reach higher gears, and so the highest gear is when the chain is on the largest chainring at the front, but the smallest cog at the back.

Did you know?

Mechanical and electronic shifting can be used to change gears

HANDLEBAR SHIFTERS

To control the gears at the front of the bike, a cyclist uses their left handlebar, while the right controls the gears on the cassette at the back. Not all bikes have two chainrings, but all have gears at the back. The handlebar controls are called shifters, as they are used to shift the chain onto different cogs.

When changing gears, it's important to pedal at the same time, as this allows for a smooth transition across cogs. Many bikes display a number on the handlebars to show what gear the bike is in. How gears are changed depends on the bike. Usually part of the handlebar needs to be twisted towards or away from the rider to move the gear number up or down. In other bikes, a small lever is pushed up and down with the thumb. Higher numbers indicate higher gears.

When using shifters on road bikes, the protruding levers are pushed inwards, towards the centre of the handlebars, to click down a gear. A smaller button is pushed inwards to move into a higher gear. The shifters are the same levers used to bring the bike to a stop. When pulled towards the cyclist, as opposed to inwards, the brakes are applied.

To change gears, a cyclist reaches for the lever in front of the handlebars

DID YOU KNOW? The first geared bike was invented by James Starley in 1871, called the Ariel

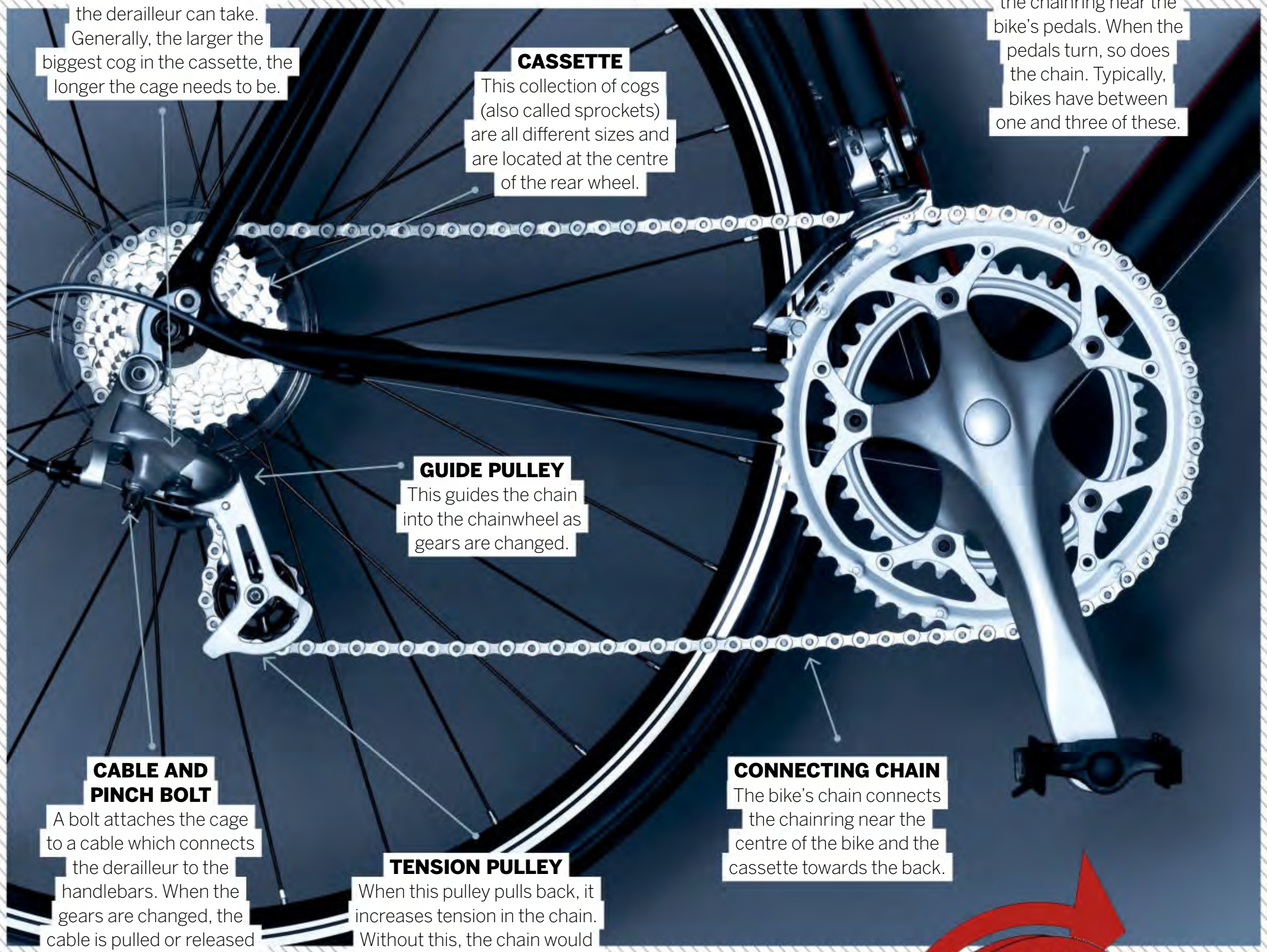
GEARS IN MOTION

How a derailleur works

CAGE
Connecting two pulleys, the length of a bike's cage determines how much slack the derailleur can take. Generally, the larger the biggest cog in the cassette, the longer the cage needs to be.

CASSETTE
This collection of cogs (also called sprockets) are all different sizes and are located at the centre of the rear wheel.

CHAINRING
The chain slots onto the chainring near the bike's pedals. When the pedals turn, so does the chain. Typically, bikes have between one and three of these.



GUIDE PULLEY
This guides the chain into the chainwheel as gears are changed.

CABLE AND PINCH BOLT
A bolt attaches the cage to a cable which connects the derailleur to the handlebars. When the gears are changed, the cable is pulled or released and the cage is moved inwards or outwards.

TENSION PULLEY
When this pulley pulls back, it increases tension in the chain. Without this, the chain would hang loose when in lower gears and slip off the chainwheel.

CONNECTING CHAIN
The bike's chain connects the chainring near the centre of the bike and the cassette towards the back.

GEAR HUBS

A gear hub is considered by some cyclists to be the future of bike gears, as it keeps the number of gear ratios high without the bike requiring two derailleurs. The gears are contained within the device's shell as opposed to the cogs on traditional bikes, which are exposed to the elements. To turn the rear wheel faster than the chain, small gears rotate inside a gear ring, which is connected to the bike's external cog. The central sun gear (yellow) is fixed and doesn't move. Rotating around this are planet gears (blue) with teeth that interlink with the large ring gear (red). As the cyclist pedals, the planetary gears move against the ring gear, spinning it faster than the pedals' rotation to turn the rear wheel. A series of these gear structures can be found inside a gear hub. Depending on the selected gear ratio, a different one connects to the external cog. Planet gears with less teeth push the wheel around further for each pedal.

A series of ring, planet and sun gears can be found in internal gear hubs

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LASER SURGERY

How does this knife-like light cut, alter and repair our bodies?

WORDS AILSA HARVEY

DID YOU KNOW? The first laser surgery on a patient's eyes was carried out in 1987

A laser – which stands for light amplification by stimulated emission of radiation – is a source of light that can be used for a variety of applications in surgery. Laser light differs from from that which you encounter in everyday life. Naturally occurring light from the Sun, or artificial light from a light bulb, emits a range of wavelengths of light, travelling in many different directions. Laser light, however, is polarised, focusing a beam onto one precise location.

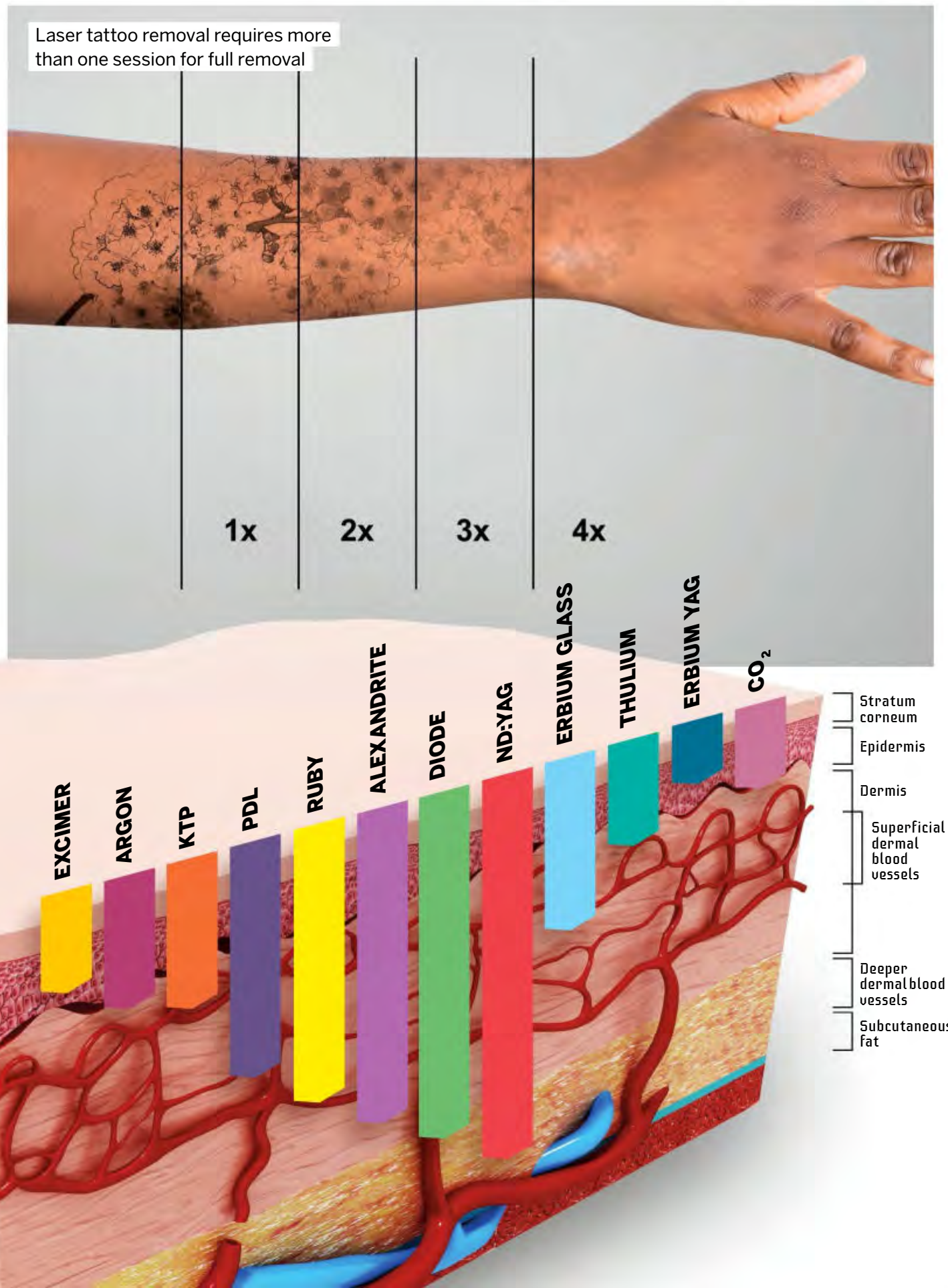
In medicine, the laser wavelength is selected based on the aim of surgery. Some lasers, such as erbium lasers, are ideal for cutting body tissue, but aren't as useful for sealing torn tissue. This method, called coagulation, uses heat produced by the laser to either destroy the cells or attach two pieces of tissue together.

Did you know?

The first working laser was used in 1960

As different wavelengths of light come into contact with different types of tissues and skin, they respond in different ways. Light can be reflected, scattered or absorbed by the body's cells, while other times lasers pass right through the skin. Chromophores, which are molecules in the body that absorb particular wavelengths, cause them to present a specific colour. These molecules absorb more of the light during laser surgery. Examples of chromophores in the human body are haemoglobin and melanin. Absorption in these areas can cause physical, chemical and temperature changes.

Using lasers instead of surgical instruments has many benefits. For example, lasers can reduce the risk of damage to surrounding tissues. After laser surgery, stitches are less likely to be needed, bleeding is reduced and the healing time for some operations is much shorter.



WAVELENGTH DEPTH

Chemicals in lasers produce wavelengths that penetrate different levels of the skin

308NM - EXCIMER

This type of laser is commonly used in laser eye surgery to treat nearsightedness, also known as myopia, as it just needs to reach the front of the eye.

488 TO 514NM - ARGON

This laser contains argon gas and produces a blue-green beam.

532NM - KTP

KTP lasers contain potassium titanyl phosphate (KTP) crystals.

585 TO 600NM - PULSED DYE

Pulsed dye lasers (PDL) use yellow light in a concentrated beam.

694NM - RUBY

Synthetic ruby crystal is used to amplify the light's power.

755NM - ALEXANDRITE

This laser penetrates the skin as deep as hair follicles and is absorbed by melanin.

800NM - DIODE

Made of gallium, aluminium and arsenic, a diode laser produces light in the visible to infrared range.

1,064NM - ND:YAG

This infrared laser contains the crystal yttrium aluminium garnet (YAG) and the metal neodymium.

1,540NM - ERBIUM GLASS

Erbium glass lasers are mostly absorbed by water molecules in the skin.

1,927NM - THULIUM

Thulium lasers emit a continuous beam that effectively vaporises tissue, such as large glands.

2,940NM - ERBIUM YAG

This is similar to Nd:YAG, but contains the metal erbium instead of neodymium.

10,600NM - CO_2

This was one of the first gas lasers to be made. When cutting, its precision is down to a fraction of a millimetre.

© Getty / Alamy

DIODE

RETINA TEAR

The retina at the back of the eye is a light-sensitive tissue that receives the light that enters the eye. When that light hits the retina, the tissue creates neural signals that are sent to the brain. Without this process, we wouldn't be able to see or make sense of the visual information entering our eyes.

As people age, the jelly-like substance surrounding the retina can shrink, pulling on the retina and causing it to tear and bleed. Lasers can help prevent this damage, by creating small burns around the tear. The scarred tissue that is left after the operation is tougher and serves as protection to stop the tissue tearing further.

Did you know?

Lasers briefly heat tattoo pigments to thousands of degrees

Diode lasers are directed to the back of the eye to treat the retina

EXCIMER

LASER EYE SURGERY

LASIK eye surgery involves reshaping the cornea

UV LASER
The excimer laser is an ultraviolet laser that vaporises the cornea tissue to reshape it.

CREATING A FLAP
A surgeon cuts a flap in the cornea.

TARGETING
To control the laser's position, a target is projected onto the correct area.

CORNEA
This is the transparent surface that's responsible for refracting light into the eye.

AFTER SURGERY
When the cornea is repositioned, light is reflected to a precise point at the back of the eye – the retina – reducing blurry vision.

DID YOU KNOW? Around 15,000 people undergo laser eye surgery every year in the UK alone

PDL

BIRTHMARKS AND SCARRING

Pulsed dye lasers are used in laser surgeries that target the blood vessels in the skin. This makes them ideal for patients wishing to reduce the appearance of birthmarks or scars. Treatment with PDL takes a few minutes, but usually requires about three separate treatments. The concentrated beam of light is released in bursts and aimed at dilated or excess blood vessels. The light is converted into heat, which destroys some of the blood vessels and leaves the surrounding skin unaffected.

PDL treatment has been used to reduce the redness that arises in port wine birthmarks. This colouration of the skin is caused by the abnormal swelling of blood vessels. Because they are bigger, the excess blood reddens the skin. Another use of this type of laser treatment is to reduce hypertrophic scars. This is when excess collagen is produced at the site of a wound, making a scar appear thicker, wider and often raised. As well as reducing the redness of the scar, PDL treatment can improve the tissue's flexibility.

A woman with a port wine birthmark before and after laser treatment

RUBY ALEXANDRITE

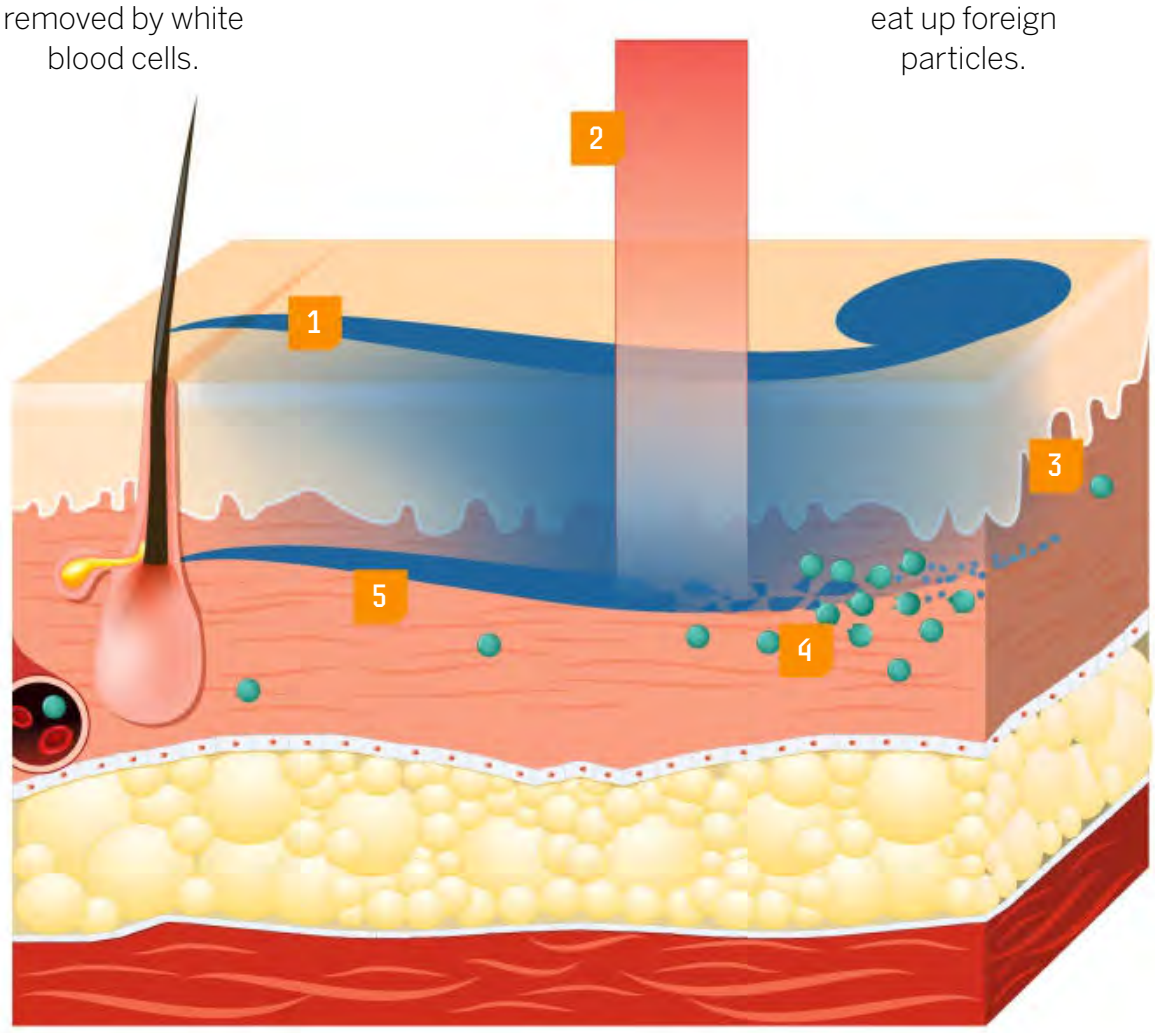
HOW DOES TATTOO REMOVAL WORK?

Lasers break up pigments of tattoo ink in the skin

1 PIGMENT PARTICLES
In tattoos, the majority of ink pigment particles are too large to be removed by white blood cells.

2 LASER
When a laser is focused on the ink particles, the heat produced breaks them apart.

3 PHAGOCYTES
Phagocytes are a type of white blood cell that eat up foreign particles.



4 IMPORTANCE OF COLOUR
Lasers are selected based on the ink pigment colour. Black pigment absorbs all laser wavelengths, so is easier to target.

5 TREATED INK
When the tattoo is treated with lasers, the ink is broken down into manageable pieces to be removed by phagocytes.

Lasers can be used to remove unwanted hair

© Getty / Alamy / Science Photo Library

AR zone
SCAN HERE

ND:YAG

REACHING THE SPINE

Surgical tools and technology allow lasers to reach deep in the spine to reduce pressure on spinal nerves

HERNIATED DISC
Inside the intervertebral disc is soft tissue called the nucleus. When the harder exterior is ruptured, the nucleus can push out of the disc.

COMPRESSED NERVE
The nucleus puts pressure on the spinal nerves as it becomes displaced. This can cause significant pain.

ENDOSCOPE
The laser can reach deep into the body to treat the spine through a device called an endoscope. The metal cylinder contains the laser, so only the targeted tissue is in contact with it.

LASER
Energy from the laser breaks down nucleus tissue to relieve pressure on the nerve.

INTERVERTEBRAL DISC
Between the vertebrae of the spine are soft, shock-absorbing discs.

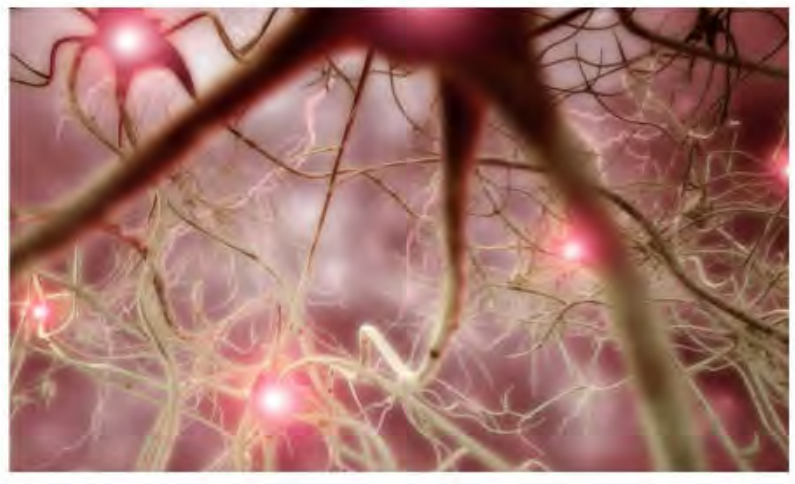
LIGHT AND CAMERA
A light and camera can be used at the end of the endoscope so that surgeons can see the affected area clearly without cutting open the body.

DIODE

TREATING NERVES

Much of the pain and numbness that results from nerve damage is caused by peripheral nerves – those that are not in the brain or spinal cord. This type of nerve damage is called neuropathy. One of the most common forms of treatment for this is laser therapy. In neuropathy laser treatment, lasers are used to increase blood circulation to the damaged areas. As the blood transports nutrients and oxygen to the area, the nerves have a better chance at repairing themselves and the pain experienced is lessened.

When the laser penetrates the skin, energy is released into the surrounding tissue. The laser's light energy is transferred into cellular energy and used for improved blood circulation. Skeletal muscles play a crucial role in the circulation of blood. Assisting the heart, these muscles contract around blood vessels to further pump blood. The muscle cells absorb energy from infrared lasers, making them more active and efficient.



Peripheral nerves relay information between your brain and the rest of your body

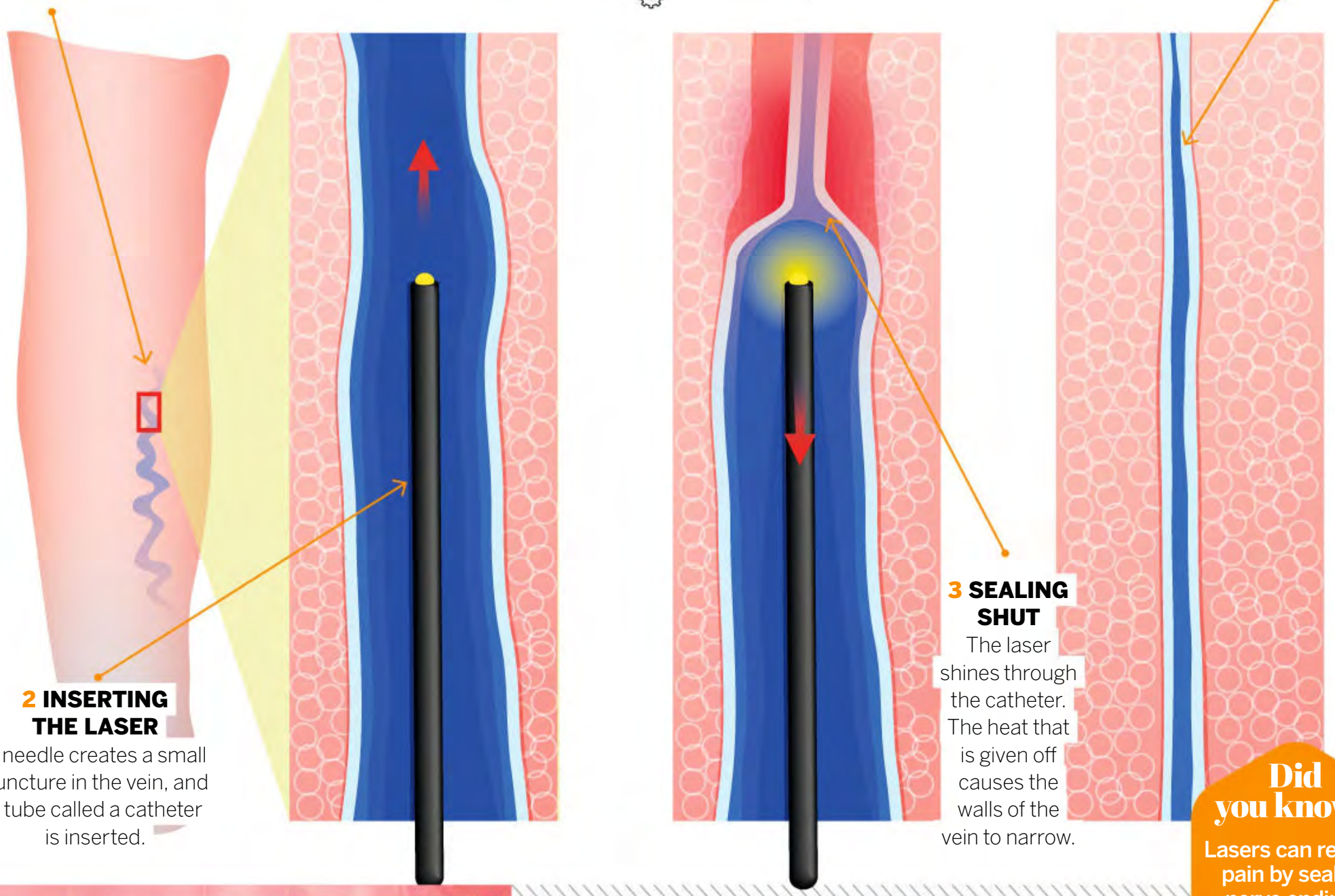
DID YOU KNOW? A wavelength is the distance between the crests of two electromagnetic waves

DIODE

ENDOVENOUS LASER TREATMENT: SEALING BLOOD VESSELS

How can lasers close enlarged veins?

1 VARICOSE VEINS
These veins are enlarged and twisted due to increased blood pressure. They can be uncomfortable and increase the chance of blood clots.



2 INSERTING THE LASER
A needle creates a small puncture in the vein, and a tube called a catheter is inserted.

3 SEALING SHUT
The laser shines through the catheter. The heat that is given off causes the walls of the vein to narrow.

4 WITHDRAWING LASER
As the laser is pulled back through the vein, the walls narrow until the vein is no longer enlarged.

Did you know?
Lasers can reduce pain by sealing nerve endings

This illustration shows the application of lasers to shrink a tumour of the oesophagus

ND:YAG CO_2 ARGON

HOW ARE LASERS USED TO TREAT CANCER?

Laser treatment and surgery can be used either to destroy cancer cells or activate cancer drugs. CO_2 and Nd:YAG lasers are the wavelengths typically chosen to shrink tumours and are often used in endoscopes, tube-like instruments with a camera on the end that can probe deep into the body. This treatment includes laser surgery to remove polyps in the intestines that may grow and become cancerous and cancer in the skin.

Another form of laser treatment applied to cancer is laser-induced interstitial thermotherapy (LITT). Often used for tumours located in the liver and brain, LITT uses heat to damage cancer cells or remove the oxygen and nutrients they need to survive. Alternatively, argon lasers are used to treat cancer patients who are using light-sensitive drugs, called photosensitising agents, to destroy abnormal cells. Argon lasers are targeted at the drug once it has entered cancer cells. This activates it, only beginning damage when in the abnormal cells so that it doesn't impact any healthy cells it may enter beforehand.

© Alamy / Getty / Illustration by Adrian Mann

The bacteria *Ideonella sakaiensis* can break down a water bottle

MEET THE PLASTIC-EATING BACTERIA

Tiny organisms could have a massive impact on our environmental plastic problem

WORDS **SCOTT DUTFIELD**

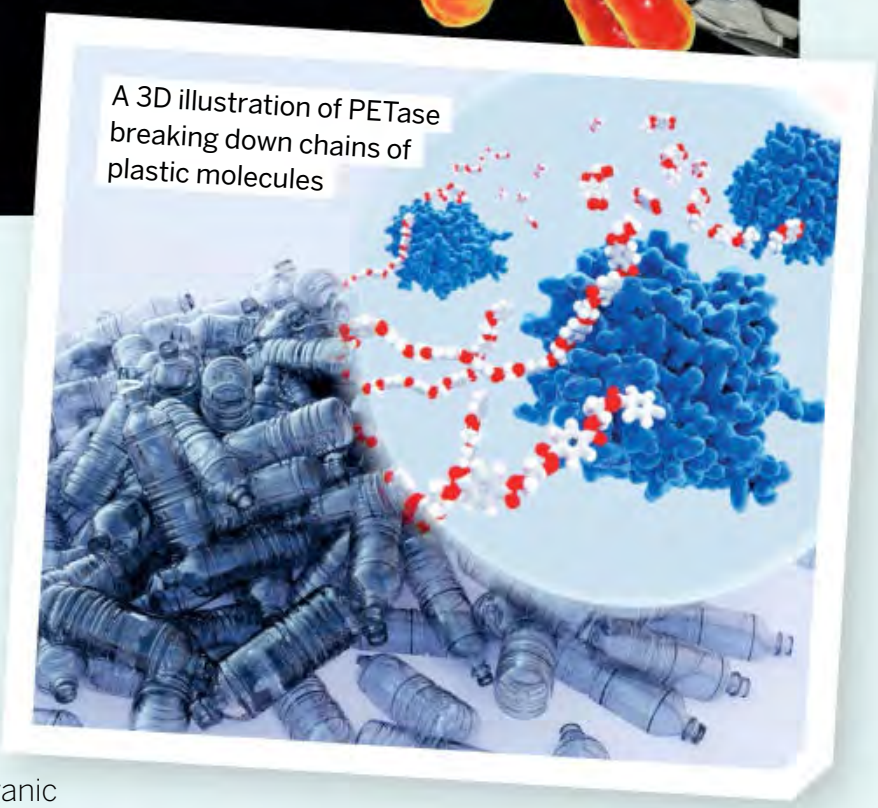
At least 14 million tonnes of plastic is offloaded into our oceans every year. This pollution has a severe impact on marine ecosystems and can affect human health. Once plastic enters the ocean it can suffocate and entangle animals. Microplastics are also ingested by many marine species that are both preyed upon by other species and that we catch for food. Once ingested, microplastics can leach the toxic contaminants that have collected on their surfaces into the bodies of the organisms that consume it. Those toxins can accumulate and transfer up the food chain from marine life into humans whenever we eat something that has been taken from the sea. On land, the majority of plastic ends up either building up in landfills or being burnt in incinerators, which releases toxic fumes. Just 16 per cent of all plastic produced is recycled to make new plastic.

Did you know?

380 million tonnes of plastic waste is produced each year

However, in 2016 Japanese scientists made a remarkable discovery that could help tackle the world's plastic problem. Having collected plastic bottles outside a recycling facility, scientists discovered that a species of bacteria was 'eating' its way through the bottles. Normally, bacteria spend their time absorbing dead organic matter, but *Ideonella sakaiensis* has developed a taste for a certain type of plastic called polyethylene terephthalate (PET).

After analysing the bacteria, the scientists found that it produced digestive enzymes called hydrolysing PET, or PETase. When these enzymes interact with PET plastic, they break down the long molecular chains into shorter chains (monomers) called terephthalic acid and ethylene glycol. These monomers are then broken down further to release energy for growth of the bacteria.



A 3D illustration of PETase breaking down chains of plastic molecules

Following the discovery, many genetic scientists have experimented with *Ideonella sakaiensis* to improve its efficiency. One such research venture has been to genetically engineer bacteria that are more efficient at enzyme production, such as *E. coli*, and turn them into PETase factories. Although the discovery offers hope in the fight against mounting plastic, scientists caution that we are still years away from widespread commercial use. Also, PETase only decomposes PET plastic; there are six other plastic types that we are still unable to degrade using enzymes.

DID YOU KNOW? 80 per cent of all marine debris found on ocean surface water is plastic

BREAKING DOWN PLASTIC

How genetically engineered *E. coli* can work as a PETase factory

1 *IDEONELLA SAKAIENSIS*
Discovered in Sakai, Japan, in 2016, this bacteria naturally produces enzymes called PETase, which are able to break down plastic.

2 GENETIC EXTRACTION
The portion of genetic information that causes *Ideonella sakaiensis* to make PETase is extracted.

3 DNA CARRIERS
The PETase-coding genetic information is then inserted into a plasmid backbone, a circular sequence of genetic information used in genetic engineering.

4 ENGINEERED *E. COLI*
The plasmid backbone is then inserted into *E. coli* bacteria using either heat or electricity.

5 FARMING
E. coli begin to secrete PETase, which can be collected and purified.

“Scientists have experimented with *Ideonella sakaiensis* to improve its efficiency”

TURNING PLASTIC INTO VANILLA

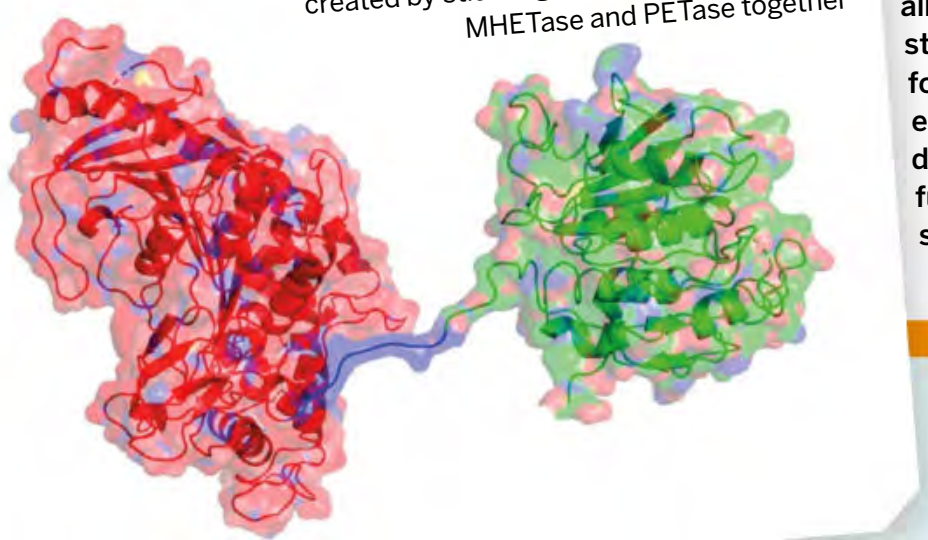
Researchers at the University of Edinburgh have been using *E. coli* bacteria to convert plastic into vanillin, the primary component of vanilla extract. Considering that the global demand for vanillin exceeded 37,000 tonnes in 2018 and that 85 per cent is made from chemicals taken from fossil fuels, using plastic could be an eco-friendly alternative.

After degrading PET plastic into its basic monomers, researchers took the process one step further and converted one of those monomers, terephthalic acid, into vanillin through a series of chemical reactions. The resulting vanillin is believed to be fit for human consumption, though further investigation is needed.

Vanillin, the chemical flavour of vanilla, can be created from degraded plastic

SUPER PETASE

Researchers at the University of Portsmouth have re-engineered PETase to create an enzyme ‘cocktail’ that they say can digest plastic up to six times faster than normal. The scientists combined PETase with another plastic-eating enzyme called MHETase to form one super enzyme. The combined PETase-MHETase enzyme was created with a synchrotron, a type of particle accelerator that uses X-rays 10 billion times brighter than the Sun. It allowed researchers to see the individual atoms of each enzyme and draw their molecular blueprints, which ultimately allowed researchers to stitch their DNA together to form a super enzyme. This enzyme can also break down polyethylene furanoate (PEF), a sugar-based bioplastic.



A scientific illustration of the ‘super enzyme’, created by stitching plastic-eating enzymes MHETase and PETase together

© Getty / Shutterstock / Rosie Graham

THE POWER OF ANAESTHESIA

How doctors use precise amounts of drugs to render patients insensitive to pain

WORDS **AILSA HARVEY**

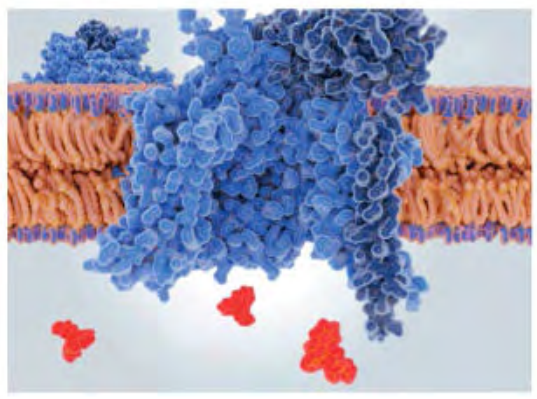
Would you let someone cut through your leg if you could feel everything? Before the earliest forms of anaesthetics were used in the 1840s, going through a surgical procedure would have been an ordeal. Today surgeons can cut into a person's gut and remove some of their insides without the patient feeling a thing.

The medicines that make this possible are called anaesthetics. They work by blocking nerve impulses between the surgical site and the central nervous system. The active ingredients in these medications are blocking agents that attach to sodium channels, preventing sodium ions from binding and sending signals across nerves. The location of this effect and length of time that the anaesthetics remain in the body depend on the type of surgery taking place.

Anaesthesia can be accompanied by a state of complete consciousness, unconsciousness or somewhere in between. The latter is established through sedation, which makes a patient extremely sleepy and less receptive to pain, but keeps them conscious. This method is reserved for minor procedures to keep a patient relaxed. The development of new anaesthesia techniques has transformed surgeons' capabilities. For example, control over which areas are targeted means that brain surgeries can take place while patients are awake. They feel no pain but remain conscious so that surgeons can study any impact to brain activity as they cut tissue.

HOW DO WE FEEL PAIN?

Every time your skin is touched, chemicals are sent around your body to alert you and cause you to feel the appropriate sensation. You might consider pain to be a negative sensation, but this response helps to ward us away from danger and prevent further damage. First, specialised receptor cells that are widespread in the skin detect either pain, temperature, pressure or friction. Pain receptors are called nociceptors. These are activated when there's damage to a cell, whether that's through cuts or burns. The receptors respond by sending a signal, through neurons, to the brain and spinal cord, making you aware of the pain so that you can move your body to safety. During surgery, cells need to be damaged without causing this chain reaction.

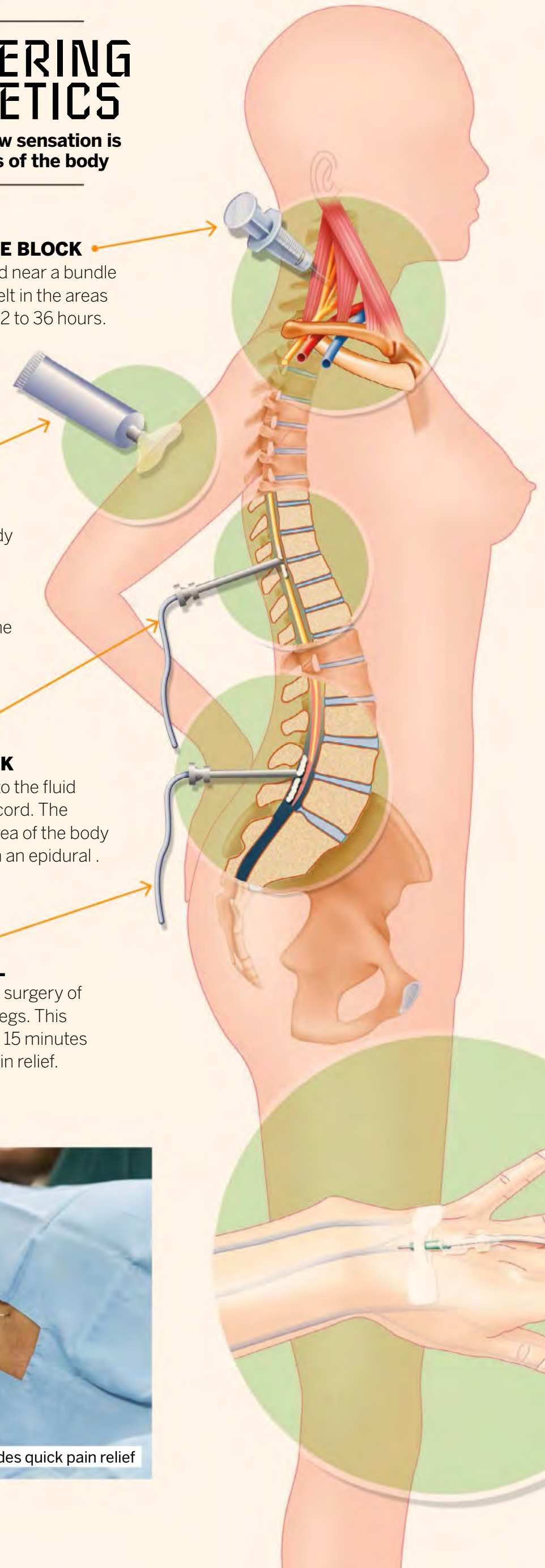


Blocking agents (red) position themselves in ion channels (blue) to stop production of electrical impulses in nerves

DID YOU KNOW? ‘Anaesthesia awareness’ is when a patient wakes up during surgery, but brain activity is monitored to prevent this

ADMINISTERING ANAESTHETICS

From general to local, how sensation is halted in different areas of the body



PERIPHERAL NERVE BLOCK

When anaesthetic is injected near a bundle of nerves, sensation isn’t felt in the areas these nerves travel to for 12 to 36 hours.

LOCAL ANAESTHETIC

Only specific areas of the body are numbed when local anaesthetics are applied. Injections, creams, gels or sprays can be applied, and the patient remains conscious.

SPINAL BLOCK

Drugs can be injected into the fluid surrounding the spinal cord. The anaesthetic numbs a large area of the body and is more immediate than an epidural .

EPIDURAL

Epidurals are used for surgery of the lower belly and legs. This method can take up to 15 minutes to achieve good pain relief.

An epidural nerve block provides quick pain relief

TOTAL LOSS OF SENSATION

The first stage of general anaesthesia is the induction stage. Patients will see an anaesthetist in the holding area of the hospital. As medication is given to the patient, they begin to feel drowsy, but are not yet unconscious. They may be able to have a chat after the medication has entered the body, but speech and breathing is likely to be slow. Eventually, the patient loses consciousness at the end of the induction stage. In the second stage of anaesthesia, patients display uncontrolled movement. This can be the most dangerous stage, as unpredictable events such as vomiting can occur. The shorter this stage is the better. When these movements stop, stage three begins. This stage is the state of consciousness needed for surgery to take place. The muscles are fully relaxed and the eyes are still. A patient is kept in this state until the end of the surgery.

Anaesthetists monitor patients’ vital functions to make sure they stay under the effects of an anaesthetic

GENERAL ANAESTHETIC

This method removes feeling from the entire body and causes the patient to become unconscious. The medication can be provided through a drip into a vein or inhaled through a gas mask.

Did you know?

Smokers may need more anaesthetic than non-smokers

© Getty / Alamy

WHAT IS LIGHT POLLUTION?

How artificial light is keeping the true night sky in the dark

WORDS **SCOTT DUTFIELD**

DID YOU KNOW? Around 80 per cent of Americans can't see the Milky Way

THE BRIGHTEST CITIES ON EARTH

The global urban average is around 18.9 radiance units, which is a little brighter than West Yorkshire

Cities by radiance

1 MOSCOW, RUSSIA 152.27
2 SAINT PETERSBURG, RUSSIA 152.24
3 MECCA, SAUDI ARABIA 139.41
4 CHELYABINSK, RUSSIA 136.43
5 KUWAIT CITY, KUWAIT 131.39
6 RIYADH, SAUDI ARABIA 127.29
7 CALGARY, CANADA 124.32
8 EDMONTON, CANADA 123.71
9 KAZAN, RUSSIA 115.46
10 HELSINKI, FINLAND 111.54

Pollution comes in many forms, such as plastic waste, greenhouse gases and sewage. However, there's one type of pollution that often gets overlooked, and it can have serious implications for our environment and even our health.

Light pollution, or photopollution, is the presence of excess artificial light and is a result of urbanisation and industrialisation. Street lighting, domestic and commercial lights, vehicles and security lights all contribute to the creation of a dome-like shield of light pollution called skyglow. Along with skyglow, light pollution consists of glare, light trespass and clutter. Glare relates to light that can cause direct visual discomfort, whereas light trespass is light that escapes from sources such as bedroom windows. Clutter is the excessive grouping of lights.

Light pollution can also be amplified by air pollution, such as smoke and dust. This is because these types of pollution can scatter light in all different directions, brightening the sky even further. One of the immediate effects light pollution has on our environment is to obscure our view of the true night sky. Without the presence of artificial light, the night sky is awash with celestial bodies, far-away galaxies and constellations. However, if you're looking up from the belly of a big city, you'd be unable to see many of these night sky objects. Around 99 per cent of people living in Europe and America live under skies that are almost ten per cent brighter than they would naturally be. This also means that a large portion of the population doesn't use the full potential of their eyes. The retina of the human eye can naturally adjust its light-sensing cells to acclimate to very low-light conditions to allow some sort of night vision. But because of light pollution, 37 per cent of people living in America don't use their night vision at all.

Did you know?

London has 2.8 million street lights

To monitor and characterise light pollution, American astronomer John E. Bortle created the Bortle dark-sky scale, which measures the brightness of the night sky at different locations. This scale measures our ability to observe celestial objects, such as planets and stars, under the interference of skyglow. Other than depriving us of a starry sky, there are many more implications to excess use of artificial light, such as throwing the human body's natural cycle out of whack.

Brown long-eared bats are one of the many species in the UK affected by light pollution

Circadian rhythms are a group of physiological and neurological changes that occur in the body over a 24-hour period. Collectively, they're also known as our body clock and are related to our sleep-wake cycle.

Once the Sun has gone down and we are exposed to low light, our bodies naturally release a hormone called melatonin. Melatonin is released from the pineal gland in the brain and

© Getty / NASA Earth Observatory/Joshua Stevens/ Miguel Román/NASA's Goddard Space Flight Center

The Milky Way above Telluride, Colorado, on a clear night

Did you know?

Newcastle leaves the most lights on in the UK

helps to increase tiredness and regulate sleep cycles, with peak production occurring in the early hours of the morning. However, light pollution has been found to curb melatonin production in humans, even at low levels. This can result in disturbed sleep and impacts our immune system and responses to stress. It has also been suggested that melatonin disruption by way of light pollution is connected to the increased risk of hormone-related cancers, such as breast or prostate cancer.

Circadian rhythm doesn't only affect humans, but most other living things. In studies of the European perch, researchers found that even the lowest light intensities disrupted melatonin production within this fish. While researching the reproductive cycle of wallabies, researchers have also found that births were weeks earlier among wallabies living near light polluted areas, such as naval bases, than those living in more rural areas. The same study found that the use of outdoor light-emitting diodes (LEDs), which emit wavelengths in the blue spectrum of light, suppresses melatonin five times more than traditional outdoor lighting.

Along with causing health issues, light pollution can interfere with the behaviour of wildlife. Nocturnal predators such as bats are among the most affected by light pollution. These flying mammals are well adapted to hunting at night and actively avoid illuminated areas. Unfortunately, their insect prey is attracted to light sources, leading to barren hunting grounds for bats. Also, when sources of artificial light are placed outside a bat's roost, it can prevent them from ever leaving home and lead to them starving to death.

For newborn turtles, the presence of artificial lighting can make the difference between life and death. As turtle hatchlings emerge along sandy beaches, their natural instinct is to scurry to the ocean bathed in moonlight. However, street and commercial lights along the coast can confuse the hatchlings and cause them to move inland, where they are often eaten or killed by traffic.

9/8

INNER CITY/ CITY SKY

The sky is brightly lit, and many or all of the constellations are not visible. Some celestial objects, such as the Moon, other planets and the brightest stars in the sky, can be seen.

7

CITY/SUBURBAN TRANSITION

A greyish hue covers the sky, with many celestial objects obscured from view. The Milky Way's spiral arms and the bright Andromeda Galaxy are invisible.

6

BRIGHT SUBURBAN SKY

In clear conditions the Milky Way may be seen at the zenith, directly above, but our neighbouring galaxy Andromeda remains mostly hidden without the aid of binoculars.

5

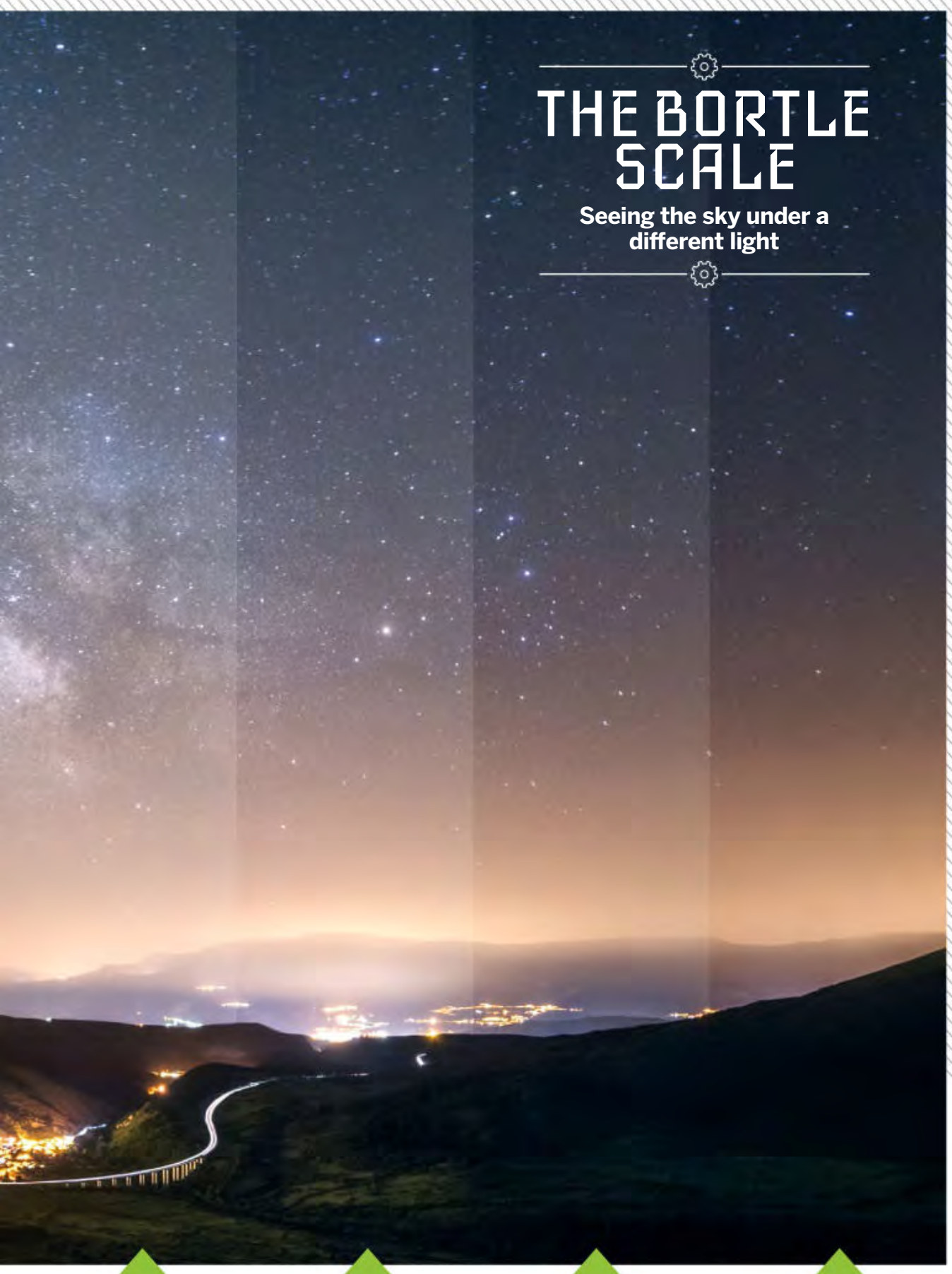
SUBURBAN SKY

Celestial objects are brighter, but there are still weak views of the Milky Way. Clouds are also brighter than the sky.

DID YOU KNOW? 4.7 million people in the UK admit to leaving the light on when they go to bed

THE BORTLE SCALE

Seeing the sky under a different light



4
SUBURBAN/ RURAL TRANSITION
Domes of light pollution can be seen near the horizon, as well as slight views of the Milky Way.

3
RURAL SKY
Some light pollution is seen on the horizon, but the Milky Way is more visible. Other galaxies can be distinguished by the naked eye.

2
DARK-SKY SITE
Clouds appear as black silhouettes in the sky. Bright galaxies and globular clusters can be seen with the naked eye.

1
EXCELLENT DARK-SKY SITE
The Milky Way and constellations are clearly visible. You can also see the faint glow from Earth's atmosphere, called airglow.

5 WAYS TO REDUCE LIGHT POLLUTION

1 TURN LIGHTS OFF
One surefire way to reduce light pollution is to minimise the artificial light we use. Consider when a light is a necessity and when it isn't, such as decorative garden lighting.

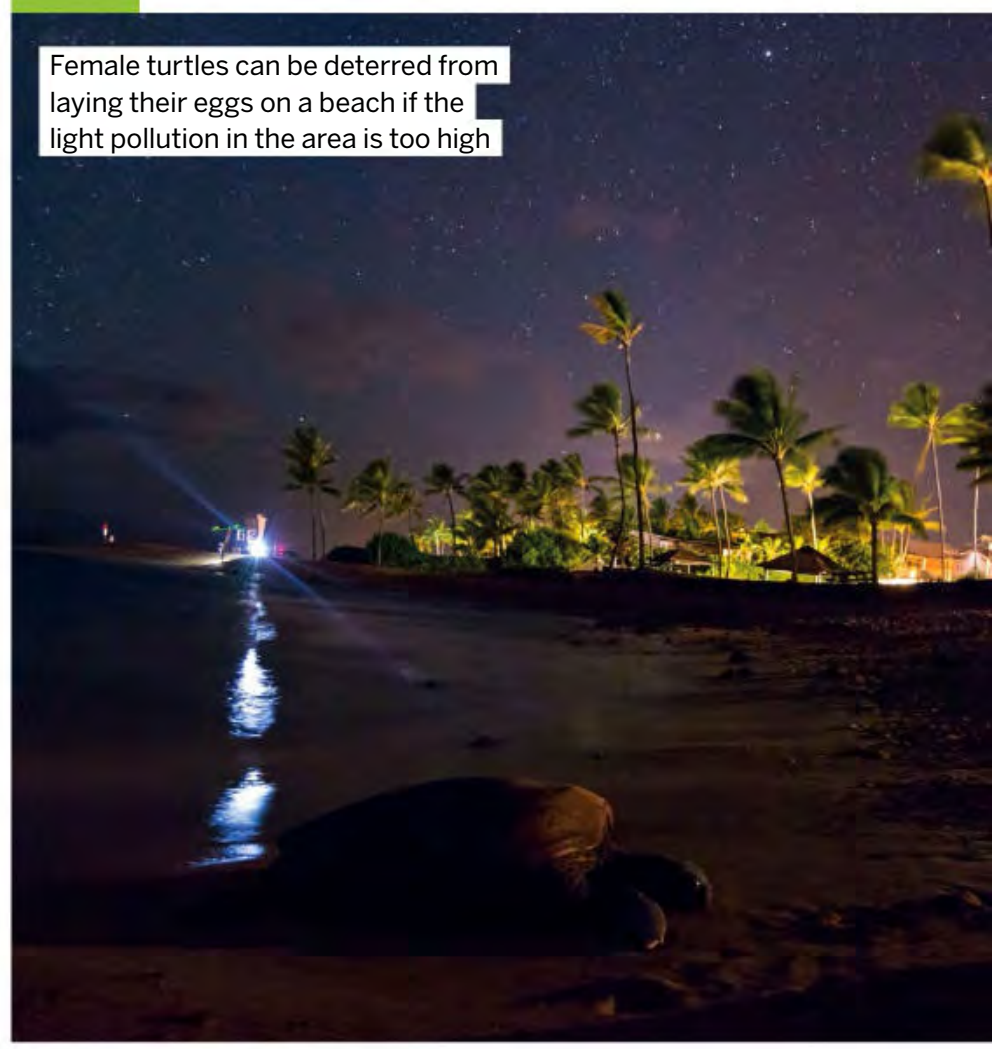
2 USE WARM LIGHT
Warm white and orange-coloured bulbs are less polluting than cold blue lights. This can assist with both your circadian rhythm and that of local wildlife.

3 CHANGE DIRECTION
Don't use upward-emitting lights near reflective surfaces, such as ponds or pebble paths. Instead use covered and downward-facing bulbs.

4 CHOOSE THE RIGHT LOCATION
Check that your outdoor lighting isn't near a bat roost or isn't lighting up feeding sites, such as trees, for nocturnal predators.

5 GO AUTOMATIC
Use an automatic lighting system to ensure your lights switch off at a certain time of night. Motion sensors are also a great tool to minimise excess light use.

© Getty / Shutterstock



Female turtles can be deterred from laying their eggs on a beach if the light pollution in the area is too high

HOW BEES MAKE HONEY

This process turns nectar into a sticky, sweet substance

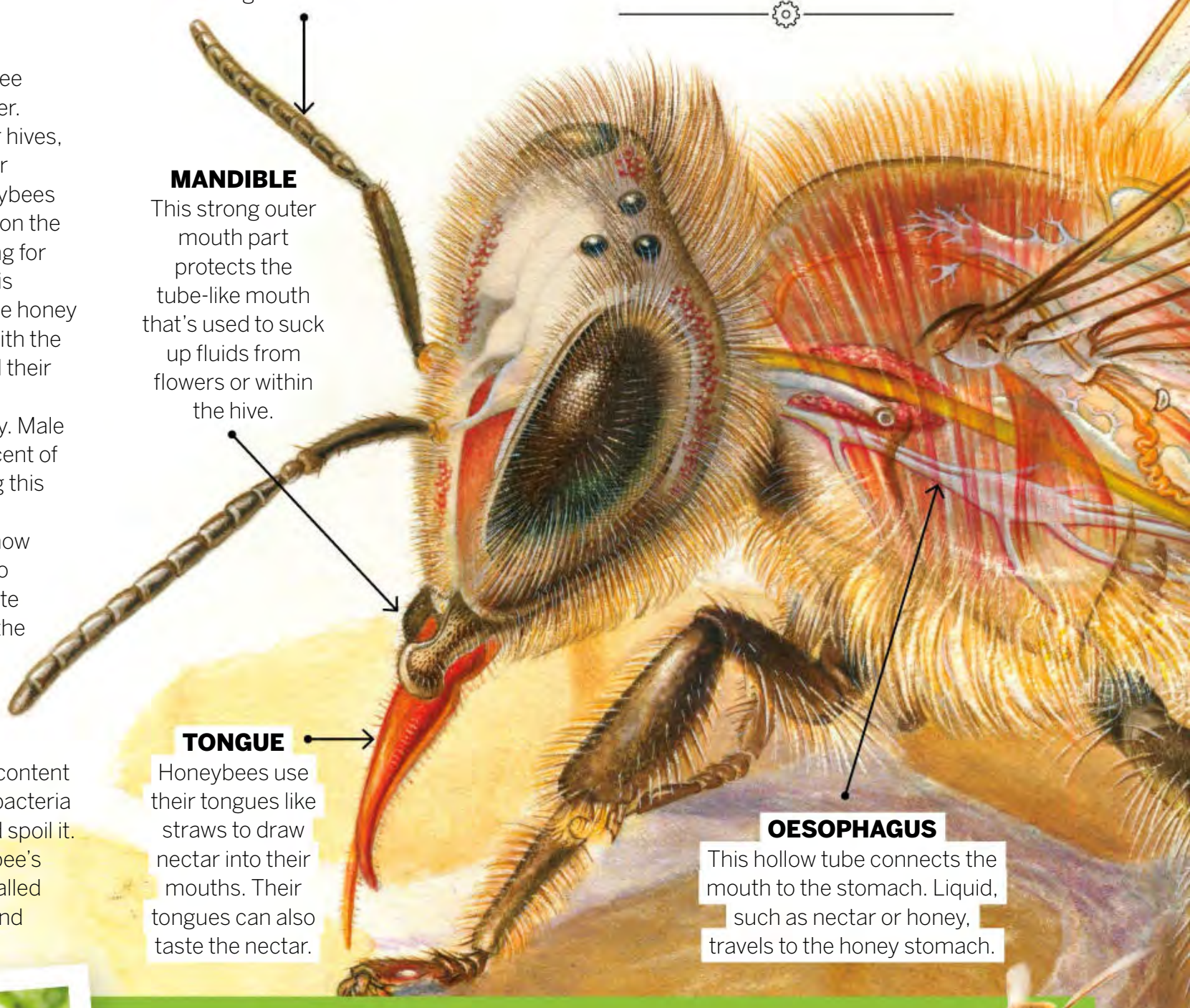
WORDS **AILSA HARVEY**

Unlike many other bees, honeybee species don't hibernate in winter. Instead they stay active in their hives, but what's their secret to winter survival? During the coldest months, honeybees cluster together to keep warm and survive on the sweet substance that they've been hoarding for weeks in advance. That special substance is honey. All the bees in a hive benefit from the honey haul, but the job of honey production lies with the female worker bees. These forager bees fill their stomachs with nectar from flowers before returning to the hive to convert it into honey. Male honeybees, which make up about ten per cent of the hive population, spend their lives eating this honey before leaving the hive to mate.

There are many factors that determine how much honey a single bee colony will need to produce for winter. It depends on the climate where the bees live, how much ventilation the hive has, and the number and type of bees in the hive. Honeybees will continue to make honey until every cell in their hive is full, and once produced, honey is very long-lasting. Honeybees reduce the water content in honey, which greatly limits the ability of bacteria and other microorganisms to grow in it and spoil it. Before nectar becomes honey, it enters a bee's stomach. An enzyme in bees' stomachs, called glucose oxidase, breaks down the nectar and helps produce the honey.

NECTAR COLLECTORS

A honeybee's anatomy is adapted to collect and transfer the sweet substance



ANTENNA
Used to detect airborne scents, bees navigate towards sugary nectar using their antennae.

MANDIBLE
This strong outer mouth part protects the tube-like mouth that's used to suck up fluids from flowers or within the hive.

TONGUE
Honeybees use their tongues like straws to draw nectar into their mouths. Their tongues can also taste the nectar.

OESOPHAGUS
This hollow tube connects the mouth to the stomach. Liquid, such as nectar or honey, travels to the honey stomach.

Beekeepers often harvest honey three times in one season

SHOULD WE HARVEST HONEY?

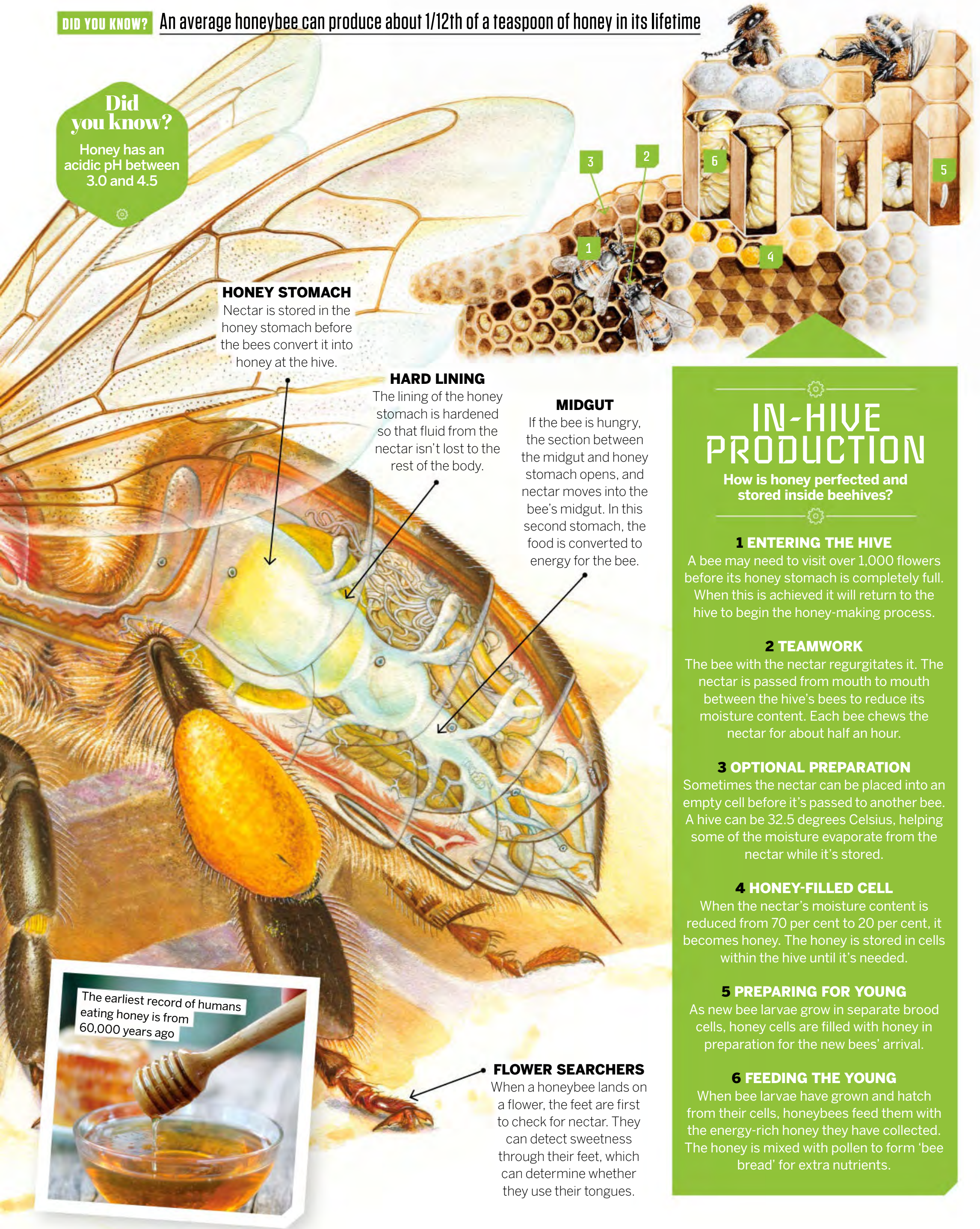
Beekeepers harvest and sell the honey made by bees in artificial hives. Bees can produce more honey than they need to sustain their colony over the winter period, so many beekeepers believe that using the excess for human benefit causes little harm to the bees' welfare. Others claim that the bees are overworked as they have to make up extra volumes of honey to replace what's taken.

As bees search for nectar, hairs on their bodies brush flowers and pick up pollen. When flying from flower to flower, the bees transfer the pollen and help flower species to reproduce. This is why it's beneficial to protect bee populations. Harvesting honeybee produce increases the number of bees in an area, but because these domesticated bees compete with other native bee species, flower resources become limited and can eventually cause other bee species to die out. Different bee species target specific flowers, and so a balance of honeybees and other bee species is essential in the long-term survival of plant and insect species.

DID YOU KNOW? An average honeybee can produce about 1/12th of a teaspoon of honey in its lifetime

Did you know?

Honey has an acidic pH between 3.0 and 4.5



HONEY STOMACH
Nectar is stored in the honey stomach before the bees convert it into honey at the hive.

HARD LINING
The lining of the honey stomach is hardened so that fluid from the nectar isn't lost to the rest of the body.

MIDGUT
If the bee is hungry, the section between the midgut and honey stomach opens, and nectar moves into the bee's midgut. In this second stomach, the food is converted to energy for the bee.

FLOWER SEARCHERS
When a honeybee lands on a flower, the feet are first to check for nectar. They can detect sweetness through their feet, which can determine whether they use their tongues.

IN-HIVE PRODUCTION

How is honey perfected and stored inside beehives?

1 ENTERING THE HIVE
A bee may need to visit over 1,000 flowers before its honey stomach is completely full. When this is achieved it will return to the hive to begin the honey-making process.

2 TEAMWORK
The bee with the nectar regurgitates it. The nectar is passed from mouth to mouth between the hive's bees to reduce its moisture content. Each bee chews the nectar for about half an hour.

3 OPTIONAL PREPARATION
Sometimes the nectar can be placed into an empty cell before it's passed to another bee. A hive can be 32.5 degrees Celsius, helping some of the moisture evaporate from the nectar while it's stored.

4 HONEY-FILLED CELL
When the nectar's moisture content is reduced from 70 per cent to 20 per cent, it becomes honey. The honey is stored in cells within the hive until it's needed.

5 PREPARING FOR YOUNG
As new bee larvae grow in separate brood cells, honey cells are filled with honey in preparation for the new bees' arrival.

6 FEEDING THE YOUNG
When bee larvae have grown and hatch from their cells, honeybees feed them with the energy-rich honey they have collected. The honey is mixed with pollen to form 'bee bread' for extra nutrients.

© Getty

BUILDING DEMOLITION EXPLAINED

How houses, high-rises and other tall structures are collapsed into rubble

WORDS AILSA HARVEY

When a new building is being designed and constructed, careful calculations and weeks of labour go into producing strong homes, offices and recreational spaces. The materials used are often chosen to brace against the weather and remain in place for many decades. However, some buildings are purposefully removed before they can stand the test of time.

There are many reasons why a building may need to be demolished. Older buildings are often targeted for demolition because they require too much maintenance. To increase their value, other properties can be partially demolished and rebuilt with extensions. Other times a building is deemed to be unsafe: the foundations may be faulty, or the building may have been built with dangerous materials such as mercury, lead or asbestos – a naturally occurring mineral sometimes used in insulation that can damage the lungs when inhaled.

Properties are constantly being rebuilt and removed to make way for new layouts, better builds and modern architecture. But some old buildings are preserved as an important part of history. Private organisations and local governments can decide against a building's demolition if it can be proven to hold historical significance. When permission for demolition is granted, modern technology can see skyscrapers fall from the skyline in a matter of seconds, transforming the landscape and allowing new buildings to be constructed in place of the old ones.

"The foundations may be faulty, or the building may be built with dangerous materials"

DID YOU KNOW? Around 50,000 buildings are demolished in the UK each year

5 WAYS TO DEMOLISH

1 SELECTIVE
Only specific features of the building are removed. This could be an older, unwanted section of a building, or a dangerous or damaged part that's uneconomical to fix.

2 TOTAL
Total demolitions involve the removal of entire structures. The land may be used for another purpose and allows for a city's layout to be restructured.

3 INTERIOR
The walls and ceilings are taken out as part of the demolition process. This might be to create a larger interior space or to clear it for a new layout.

4 DISMANTLING
Carefully deconstructing a building section by section means that materials can be reused instead of creating a pile of waste rubble.

5 EXPLOSIVE
Targeting the structural parts of the building, explosives can bring down entire high-rise buildings quickly and efficiently.

Did you know?

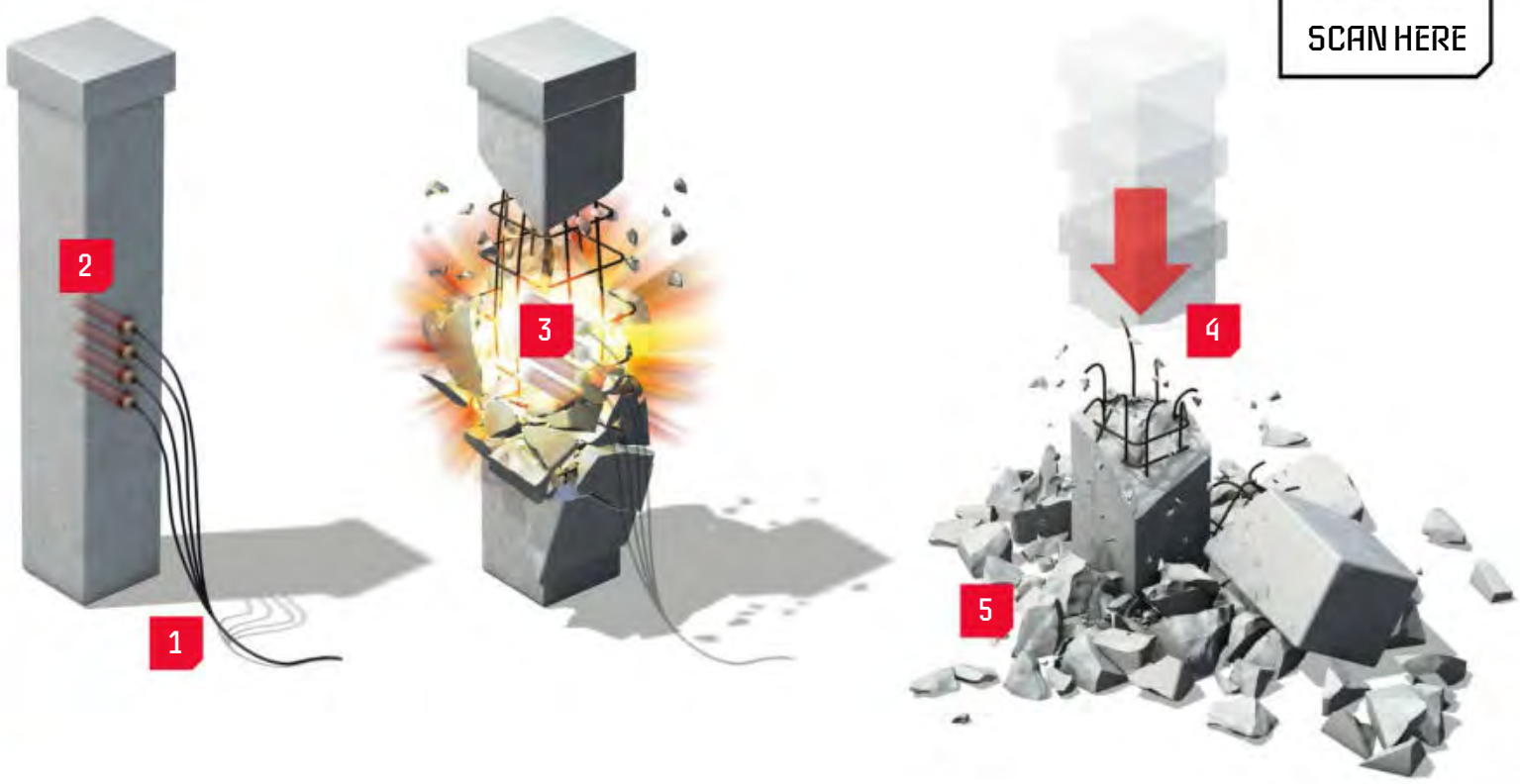
Wrecking balls were first used in the 1930s

IMPRESSIVE IMPLOSIONS

How explosives are used to send buildings crashing to the ground

AR zone

SCAN HERE



1 METHOD OF DESTRUCTION
Dynamite is usually used for concrete buildings, while cyclonite may be chosen to blow up steel.

2 DRILLING HOLES
Evenly spaced holes are drilled along the building's columns. This is where the explosives are positioned.

3 THE BIG BANG
An electric current is created to trigger the explosives. As this happens, each explosive breaks apart surrounding material at the same time.

4 INWARD COLLAPSE
Because the building is broken apart at different heights, but at the same time, everything falls to the ground in unison and in a straight line.

5 RUBBLE REMNANTS
The building falls into its own footprint, but the rubble will not be completely contained.

Only experts are allowed on site during a building's demolition process

PRIOR PREPARATION

Before bringing a building to the ground, the structure and the surrounding area need to be analysed. Demolition can be a dangerous process when the necessary steps aren't followed. First, a building is surveyed. Experts make a note of the materials that were used in the construction of all areas, the method used to build and the location of any nearby buildings and communities. Any hazardous materials, such as flammable or in more unusual cases, radioactive materials, are removed before demolition to make the process as safe as possible. Next, the demolition plan is finalised. This includes the method that will be used based on the building materials and size, as well as the logistics of clearing the rubble. A large area will need to be sectioned off if explosives are being used and prior warning given to nearby residents.

© Alamy / Getty / Illustration by Adrian Mann

HEAVY EQUIPMENT

These tools and machines are used to take buildings apart

Did you know?

Modern buildings are designed to last for at least 60 years

PULVERISER

Pulverisers are used to crush and break concrete. These can be used to break already-demolished material into manageable pieces, so it can be sorted and removed from the demolition zone.

SHEAR JAWS

These sharp cutters can cut through the metal in a building. They're used to reduce the size of beams and pipes.

HAMMER

The hammer's repeated impulses break apart tough materials such as concrete.

WRECKING BALL

The wrecking ball is usually attached to a crawler crane. After positioning it in the right place, the operator releases the ball, causing it to smash through buildings.

EXCAVATOR

This vehicle can be used to scoop up rubble and take it away.

SCAN HERE

AR zone

SCAN HERE

DID YOU KNOW? The explosive cyclotrimethylenetrinitramine expands at 8,230 metres per second

TALLEST FALL

In November 2020, the 165-metre Mina Plaza in Abu Dhabi came hurtling to the ground. As it did, it became the tallest building to be demolished using explosives. Mina Plaza was made up of four towers, each rising 144 storeys. The process of imploding this building only took eight seconds, carried out in 0.25-second intervals. To ensure safety during the demolition, the area within a 1,100-metre radius was sectioned off. This exclusion zone limited danger from flying debris. The space previously occupied by the tower blocks will be used to create a large commercial tourist area.

Tall buildings can be effectively demolished with explosives

NEW TECHNIQUES

Taking buildings out of the skyline can be useful for redevelopment and removing unsafe structures. But in its early days, demolition was primarily a military tactic. As early as 1069, settlements could be destroyed by firing heavy objects into their walls.

In the 1960s and 1970s, demolition was increasingly used as a beneficial service to communities. In the 1960s the use of wrecking balls reached its peak. This involves swinging a giant steel ball on a chain into the sides of buildings. These are less commonly used now, as control over the swinging ball is limited. The earliest attempt to demolish a building by explosion was in 1773, and is the most common method today.

These flats in North London were dismantled with a wrecking ball

© Getty / Illustration by Adrian Mann

Testing barrels for radioactive material

Uranium ore is a source of ionising radiation

HOW A GEIGER COUNTER WORKS

These handy devices measure radiation levels, producing an iconic clicking sound

WORDS **SCOTT DUTFIELD**

A Geiger counter, also known as the Geiger–Müller tube or G-M tube, is an inexpensive and useful instrument used to quickly detect and measure radiation. There are two types of radiation: non-ionising and ionising. Forms of non-ionising radiation, such as microwaves, have enough energy to shake atoms around, but not enough to knock electrons off them and change their composition. Ionising radiation, on the other hand, can strip atoms of their electrons in a process called ionisation. As a result, an ion pair is formed – a positively charged atom and a negatively charged electron. A Geiger counter exploits the natural process of ionisation to detect and measure radiation.

A Geiger counter houses a stable gas within its chamber. When exposed to radioactive particles, this gas ionises and creates an ion pair. This generates an electrical current that the counter typically records over a period of 60 seconds. When ionisation occurs and this current is produced, the device's speaker clicks and crackles every time an ion pair is formed, and a reading is given, often in millisieverts (mSv). There are several different types of radioactive particles that cause ionisation, known as either alpha, beta or gamma radiation. However, Geiger counters can not differentiate between the different types of radiation.

Exposure to ionising radiation can be damaging to human health. When this kind of radiation comes into contact with the atoms that make up our living cells, and in particular molecules of DNA, its energetic nature can disrupt, damage or alter them. Short exposures to some forms of radiation, such as X-rays for medical examinations, don't cause immediate health risks. However, prolonged exposure can lead to mutations in DNA and produce cancers. Geiger counters are an invaluable tool when evaluating a potential source of radioactivity.

Did you know?

The most radioactive element is radium

A Geiger–Müller counter used in detecting radioactivity and radiation

TYPES OF IONISING RADIATION

ALPHA RADIATION
These are charged particles that contain two protons and two neutrons, similar to he nucleus of a helium atom. They are heavy and slow moving, and can be blocked by a piece of paper or a thin layer of skin, making them significantly less hazardous than other types of radiation.

BETA RADIATION
These particles are similar to electrons, sometimes the counterparts of positrons. They are relatively light particles, around one-thousandth the mass of a proton. Natural sources of beta radiation are radioactively decaying elements such as uranium or actinium.

GAMMA RADIATION
Gamma radiation, also referred to as a gamma ray, is a form of electromagnetic radiation similar to X-rays. This radiation emits the highest energy photons – particles of electromagnetic radiation – in the electromagnetic spectrum. Gamma rays are highly penetrating and can easily pass through the body to cause damage.

DID YOU KNOW? More than 250,000 million tonnes of radioactive waste currently sits in storage globally

COUNTING IONISATION

How the Geiger-Müller tube uses simple science to detect dangerous radiation

1 WINDOW
Radiation particles enter the counter via a window which is thin enough for them to pass through. This is typically made of a mineral called mica.

2 RADIATION
Ionising radiation enters the tube and interacts with the gas within; this causes the electrons to break away from the gas atoms.

4 COUNTER
The counter, or reader, measures the amount of times a current is produced during ionisation to indicate the amount of radiation present.

GAS
An inert gas, such as helium or argon, fills the centre of the tube. This gas does not conduct electricity between the rod and the wall of the tube.

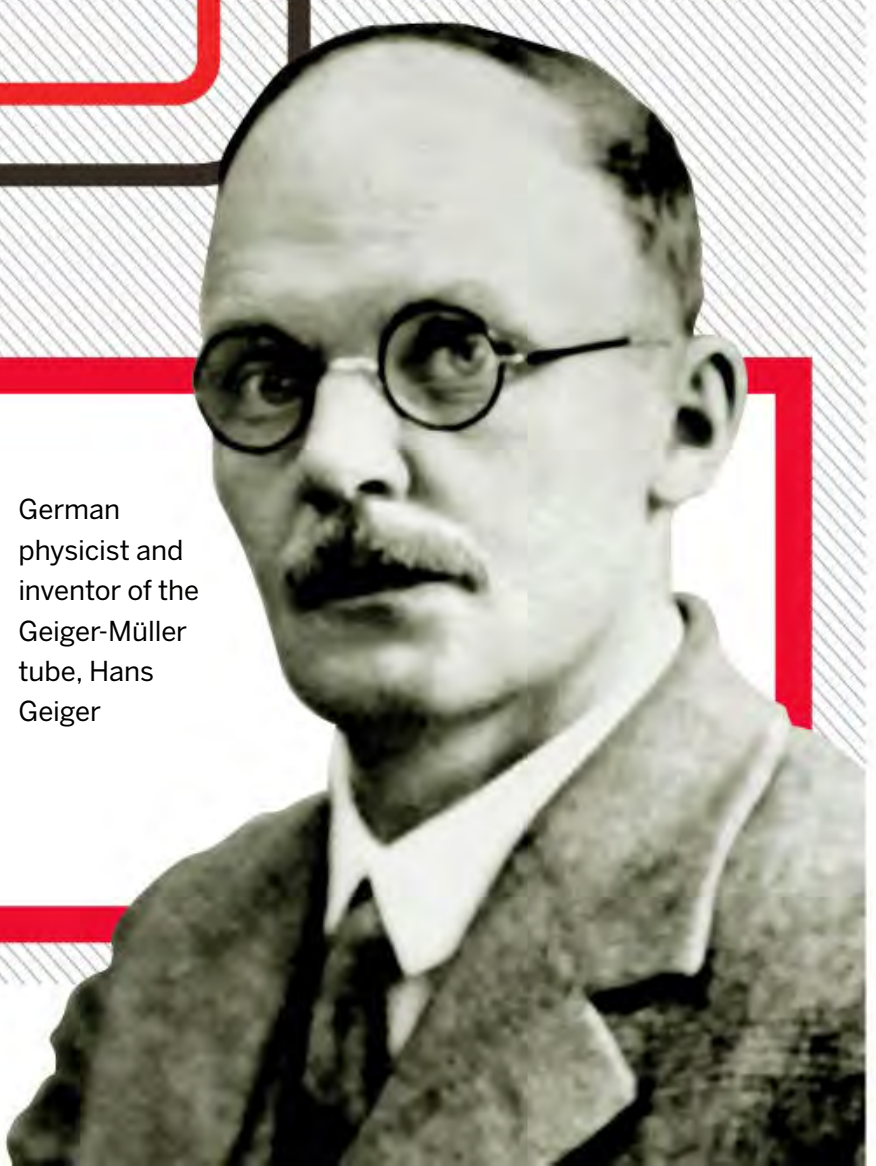
3 CURRENT
Once enough ionisation has occurred an electrical current is created between the positive rod and the walls of the tube.

ROD
The positively charged rod in the tube attracts free-flying electrons known as ions.

CREATING THE COUNTER

The Geiger counter was first conceptualised and designed by German physicist Hans Wilhelm Geiger and British physicist Ernest Rutherford in 1908, though their initial counter could only detect alpha particles. The pair used their counter to study alpha particles, and soon published the findings of several groundbreaking experiments such as the gold foil experiment, which ultimately revealed the nuclei of atoms to the world.

Between 1925 and 1928, Geiger and his PhD student Walther Müller improved the sensitivity of the counter to detect all types of ionising radiation. The design of the Geiger-Müller tube remains relatively unchanged in Geiger counters used today.



German physicist and inventor of the Geiger-Müller tube, Hans Geiger

© Alamy / Getty

WHAT IS A FIREWALL?

Discover how your computer filters out threats while allowing you access to everything you want to look at online

WORDS **JACK PARSONS**

You can use a separate computer or buy a dedicated device to use as a physical firewall

The internet connects you to the world. You can use it to communicate with 4.9 billion people worldwide, accessing more knowledge than at any other time in history. The downside is that everybody also has access to you. This includes hackers and viruses that want to steal your data, take control of your computer or even destroy it. To stop this from happening, a firewall controls the data flowing between your computer and the internet. Think of this as a border guard checking your passport when you go on holiday. A firewall inspects data to make sure it has the right permissions. If it does, it can pass through. If it doesn't, it's instantly blocked.

A firewall works at your computer's ports. When we're talking about computer networking, a port isn't the same as a jack or socket. It's a virtual entry point where your computer exchanges information with other networks.

Every computer has lots of ports, each of which handles different kinds of data. For instance, emails often go to port 25, while web pages go to port 80 – even though they both come through the same internet connection.

When a firewall checks if data can enter your network, it'll read a message that comes with it called 'metadata'. This will list a string of numbers indicating where the data has come from, known as 'the source address'; where it's going, the 'destination address', or your PC, and over which port. Whether the data has permission will all depend on a set of rules known as a protocol, which a computer's owner or an IT manager can adjust any way they want. As well as restricting what types of files you can download onto your computer, these rules can be set to prevent you – or any other particular user – from uploading certain files to the internet.

Did you know?

The first commercial firewall was DEC SEAL

Your firewall is likely installed as a program on your computer. But there are also hardware firewalls that plug in between your computer and internet router. However, hardware firewalls still rely on software to monitor ports, so the only real difference between firewall software and firewall hardware is that one filters data on individual computers, while the other does it for whole computer networks. If you're extra concerned about your cybersecurity, you can use both software and hardware firewalls.

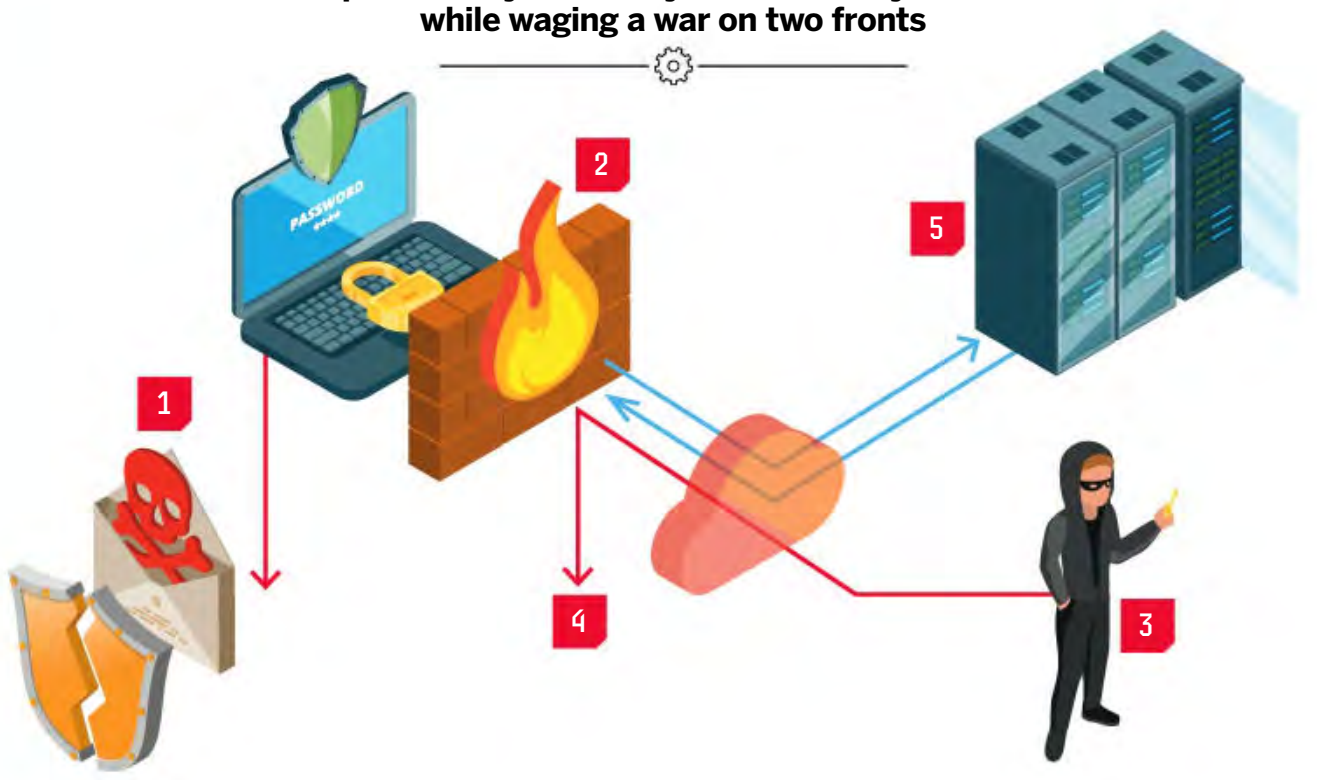
PACKET CHECKING

A video file isn't sent from YouTube to your computer as a single file. It's broken down into smaller pieces called 'data packets', which reassemble once you receive them. Packet-filtering firewalls check each data packet to make sure it has permission to pass through your network. Threats have become a lot more sophisticated, so new types of firewalls have emerged. Stateful packet inspection firewalls don't just assess each packet, also making sure they all come from the same network connection.

The rise of apps for smartphones has forced firewalls to get smarter too

HOW A PERSONAL FIREWALL KEEPS YOU SAFE

This simple security tool lets you view what you want online while waging a war on two fronts



1 THE THREAT WITHIN
A program you installed on your computer tries to send your precious files to a hacker.

2 STOPPED AT THE WALL
This program isn't authorised to access the internet, so the firewall instantly blocks it.

3 EXTERNAL HACKING ATTEMPT
A hacker tries to transfer a file to your computer, which contains a virus.

4 ACCESS DENIED
From reading the metadata, the firewall can tell the file wasn't requested by your computer and rejects it.

5 PERMISSION GRANTED
Your web browser is authorised to request web pages, so the firewall allows it to access the internet.

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SUPERMASSIVE BLACK HOLES

A look at the mysterious giants that lurk at the hearts of most galaxies

WORDS **ANDREW MAY**

Theoretically, if you compress a sufficient amount of matter into a small enough space, it will create such a powerful gravitational field that nothing – not even light – can escape from it. That's the basic idea behind black holes, and it's so bizarre that for many years scientists thought they couldn't possibly exist in reality. Yet today we know the universe is filled with them – perhaps as many as one for every ten visible stars. A few of those black holes are truly enormous, with masses millions of times greater than the Sun. They're known as supermassive black holes.

Black holes are among the most mysterious and awesome objects in the universe. From a naive point of view, however, anything that isn't a black hole might appear to be the real mystery. If gravity is a force that inexorably pulls objects together, why doesn't any random clump of matter ultimately collapse down to a black hole? The answer is that there are other non-gravitational forces that act in the opposite direction, halting the collapse before it can go all the way. For example, stars are held up by thermal pressure. When that eventually becomes too weak to resist the force of gravity, other forces may come into play to prevent total

DID YOU KNOW? Stars close to the Milky Way's central black hole are whizzing around it at eight per cent the speed of light

MASSIVE

collapse, resulting in a white dwarf or neutron star forming. But if there's so much matter present that even those forces break down, then gravity finally wins and a black hole is formed. This is the ultimate fate of the most massive stars that started life considerably bigger than the Sun, but it can also happen on an even vaster scale, involving masses millions of times greater than any star. These are the supermassive black holes believed to lurk at the hearts of most galaxies .

It's impossible to observe a black hole directly because, as their name suggests, they don't emit any light or other radiation. But they can be detected via their gravitational effect on visible stars in their neighbourhood, which orbit around the black hole much faster than they would around a normal object of similar size. By measuring the speed of stars close to the black hole, astronomers can estimate its mass. That's how they know the black hole at the centre of our own galaxy has a mass around 4 million times that of the Sun. As big as that sounds, it's really quite tiny compared to the largest supermassive black holes that have been measured, some of which approach 100 billion solar masses.

Contrary to their fearsome reputation as gobblers of anything that ventures too close to them, the black holes at the centres of most galaxies lead fairly quiet lives, only giving away their existence through subtle effects on nearby stars. In an active galaxy, however, a supermassive black hole really does live up to its voracious reputation. Surrounded by a swirling 'accretion disc' of rapidly rotating gas and dust, matter is constantly spiralling down into the black hole and being consumed. In the process, the black hole releases enormous amounts of energy, sometimes outshining the rest of the galaxy. It was in one such active galaxy's accretion disc that the Event Horizon Telescope (EHT) succeeded in capturing a direct image of a black hole in 2019. The ominous shadow of Messier 87's 6.5-billion-solar-mass black hole is clearly visible, quite literally as a 'black hole', at the centre.

Active galaxies like NGC 4194 get their energy from a central supermassive black hole

© NASA

HOW THEY FORM

The iconic EHT image of the black hole at the centre of Messier 87

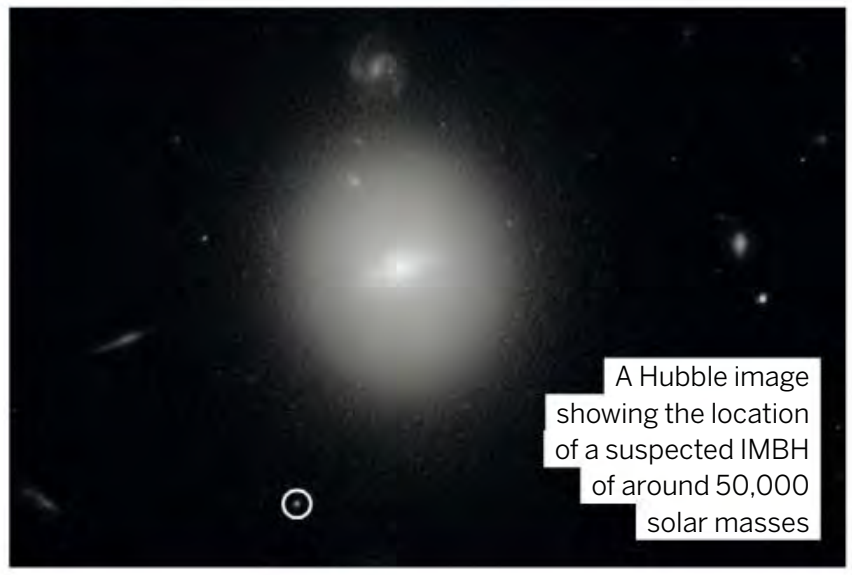
Did you know?

SLABs are theorised 'stupendously large black holes'

There are several theories as to where supermassive black holes come from

Films often portray black holes as giant cosmic vacuum cleaners, relentlessly sucking in material until there's nothing left. If that was how real black holes worked, there would be no mystery as to where the supermassive kind came from: once an 'ordinary' black hole had formed from stellar collapse, it would simply grow and grow until it reached enormous size. But real black holes don't suck matter in like this; they merely attract it with the same law of gravity as a normal object of the same mass. Their exceptional nature comes from the fact that they're super-condensed and the force of gravity increases as distance decreases, so it's possible for an orbiting object to stray into a region where gravity becomes incredibly strong. At larger distances, however, a black hole's gravity is perfectly normal. But if a black hole is incapable of sucking in distant matter, how does it ever grow to supermassive size? At present, no one knows the answer to this, although there are several promising theories.

Although they may not be the rapacious predators portrayed in science-fiction, we know that some black holes do absorb new material, and that's what's going on in the accretion discs of active galaxies. Occasionally pairs of black holes crash into each other and merge to produce a single, larger black hole, and we know that from evidence of gravitational waves, which have been observed on a regular basis since they were first discovered in 2015. But accretion and mergers, while undoubtedly part of the solution, aren't enough in themselves to explain the observational evidence for supermassive black holes. That's because we know the first active galaxies, which must have been powered by central black holes, were formed very early in the



A Hubble image showing the location of a suspected IMBH of around 50,000 solar masses

SUPERDENSE OBJECTS IN SPACE

There's a whole spectrum of compact astronomical objects, culminating in supermassive black holes

WHITE DWARFS
SOLAR MASSES: UP TO ONE

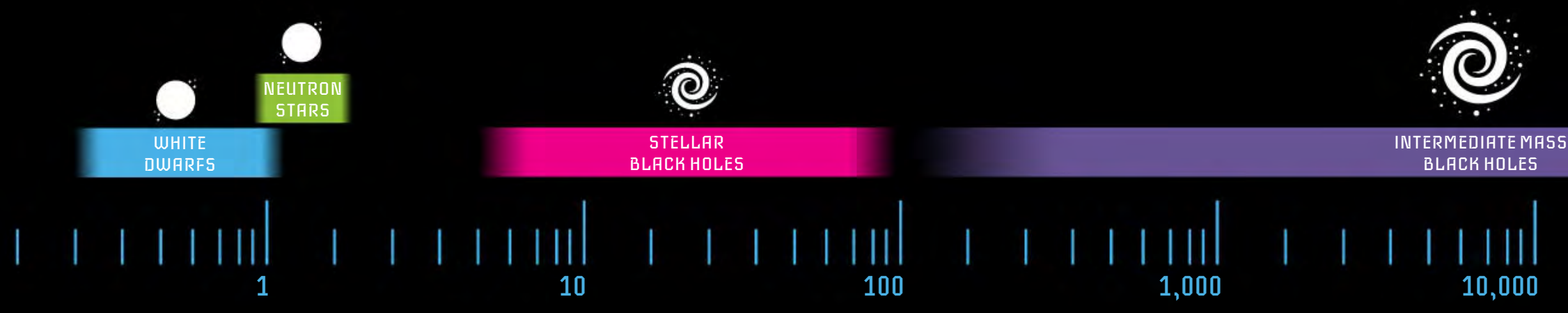
The end result of stellar evolution for low-mass stars like the Sun, these consist of a dense plasma of atomic nuclei and electrons.

NEUTRON STARS
SOLAR MASSES: AROUND 1.4

Formed from stars between 10 and 25 solar masses, these are composed almost solely of neutrons – particles that are normally just one component of an atomic nucleus.

STELLAR BLACK HOLES
SOLAR MASSES: 5 TO 50

Stars that are too heavy to stop at the neutron stage collapse all the way to a black hole, with all their mass concentrated into a single point.



DID YOU KNOW? If supermassive black holes lie at the hearts of most large galaxies, there are 100 billion of them

HOW BLACK HOLES GROW

The earliest black holes to form in the universe will be much bigger today

1 GIANT STAR
The first generation of very massive stars, hundreds of times as massive as the Sun, would have burnt through their nuclear fuel very quickly.

2 SEED BLACK HOLE
The star collapsed down to a black hole of tens of solar masses, which then acted as a seed for the creation of a much larger black hole.

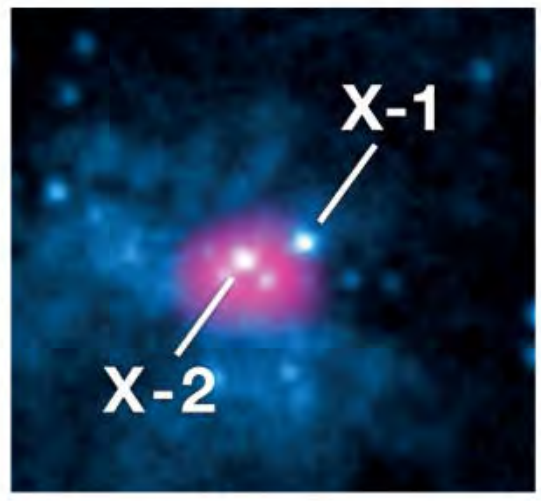
3 ACCRETION
Over billions of years, gas and dust spiralling into the black hole increased its mass, but this isn't enough to explain supermassive black holes.

life of the universe. For example, a supermassive black hole of a billion solar masses is believed to have existed in one galaxy more than 12 billion years ago, around 90 per cent of the way back in time to the Big Bang.

It's possible the stellar life cycle, which is so crucial to the standard model of black hole formation, had nothing to do with the creation of the oldest supermassive black holes. Instead they may have formed almost immediately from the gravitational collapse of an enormous cloud of gas, one that already contained as much matter as millions of stars. According to this theory, a 'direct-collapse black hole' would have taken around 150 million years to form – the blink of an eye in cosmic terms. Another hypothesis invokes the idea of primordial black holes, theorised to have been created in the Big Bang itself. These are sometimes proposed as a possible explanation for dark matter and are generally assumed to have been quite small in size. However, they might have served as the basic seeds from which present-day supermassive black holes grew.

INTERMEDIATE MASS BLACK HOLES

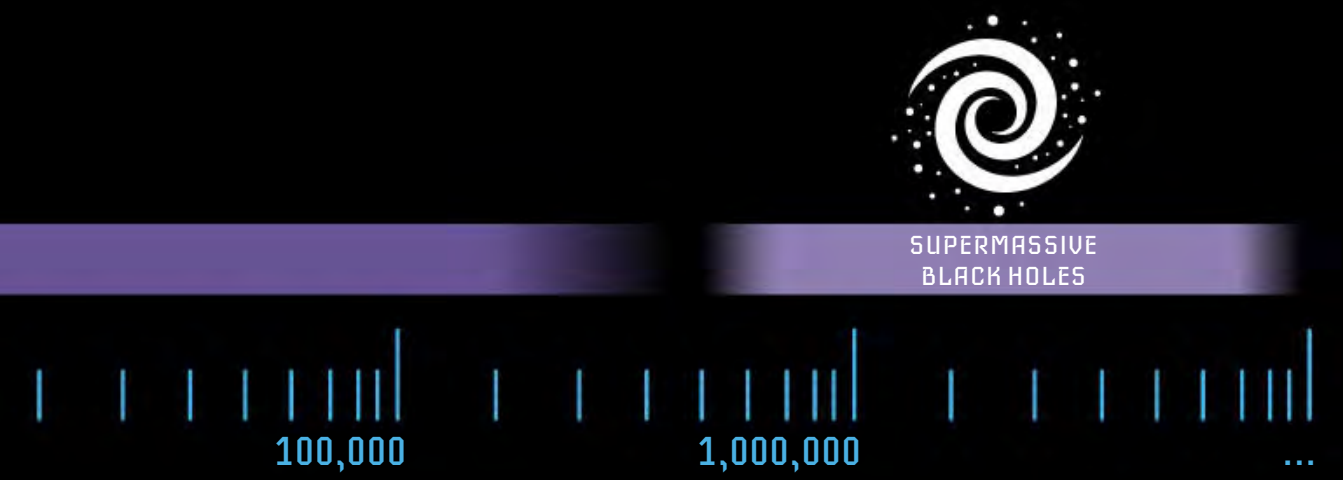
There's good observational evidence for two types of black hole: those that formed from collapsing stars, which can be several tens of solar masses, and the supermassive kind, which are millions or billions of solar masses. This leaves a gap, from a hundred solar masses up to several hundred thousand, where the evidence is much scarcer. Dubbed intermediate mass black holes (IMBHs), these could be produced by any of the mechanisms proposed to explain supermassive black holes, whether by mergers, accretion, collapsing gas clouds or primordial black holes. It's possible that IMBHs could be found at the centres of very small galaxies, and there's some evidence this is the case. It's also possible that IMBHs exist in larger galaxies, but away from the centre. A bright source of X-rays in Messier 82 may be associated with an IMBH of around 400 solar masses.



A bright X-ray source in galaxy Messier 82, labelled X-1, may be an IMBH

INTERMEDIATE MASS BLACK HOLES
SOLAR MASSES: 100 TO 100,000
The most elusive kind of black hole, these are nevertheless believed to exist, for example in the centres of very small galaxies.

SUPERMASSIVE BLACK HOLES
SOLAR MASSES: OVER 1,000,000
These monster black holes are known to lurk in the centres of most large galaxies, and there's no theoretical limit to how large they can grow.



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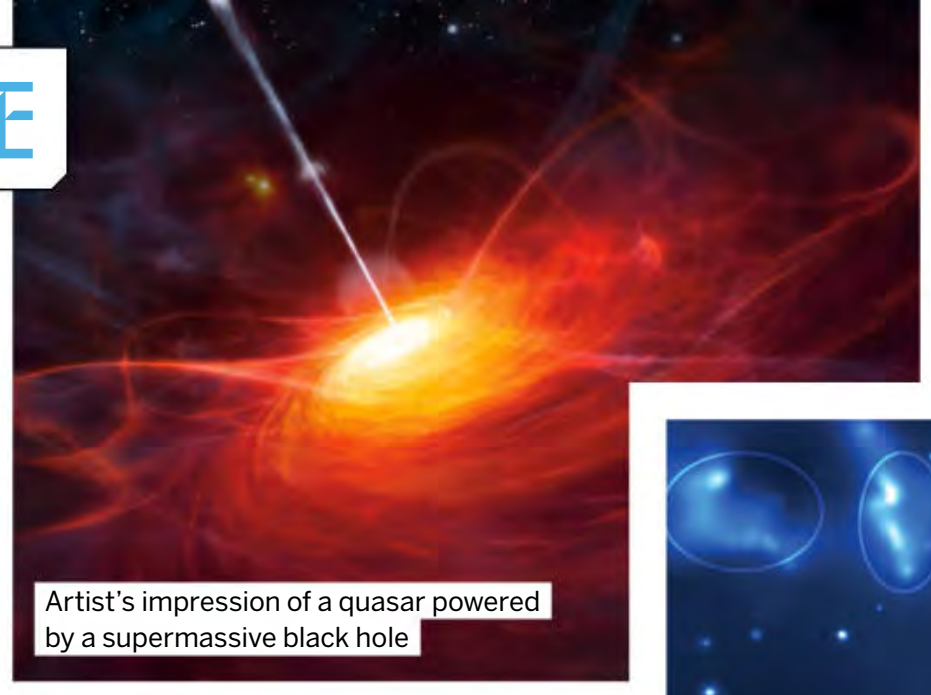
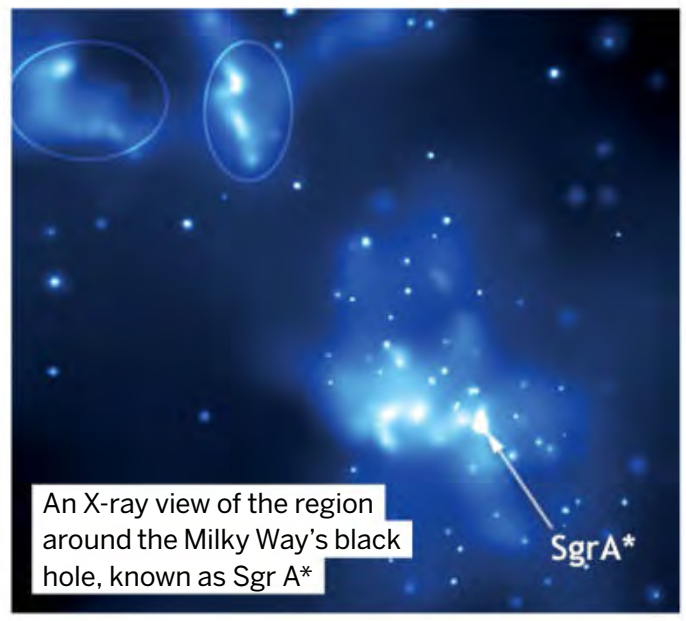
MAKING AN ACTIVE GALAXY

How the infalling of material powers black holes


Artist's impression of a quasar powered by a supermassive black hole



An X-ray view of the region around the Milky Way's black hole, known as Sgr A*

In normal galaxies, most of the light we see comes from the billions of stars they contain, but active galaxies are different. They radiate huge amounts of excess energy across the whole of the electromagnetic spectrum, all appearing to emanate from the very central region, or nucleus, of the galaxy. Perhaps unsurprisingly, the underlying power source for these 'active galactic nuclei' is believed to be the central black hole. Yet most ordinary galaxies also likely possess supermassive black holes, without displaying any unusual activity. So what makes an active galaxy so active?

The answer is that active galaxies involve matter constantly falling into the black hole, emitting large amounts of energy in the process. Technically known as accretion, this doesn't happen in the way you might imagine, with the matter falling straight down into the black hole. That's because the material has rotational motion that – at least temporarily – counteracts the pull of gravity, just as an orbiting satellite is prevented from falling to Earth. Instead the material forms a rapidly spinning 'accretion disc' around the black hole. But it does fall in eventually, because friction within the disc gradually slows the rate of spin, causing the material to spiral inexorably inwards.

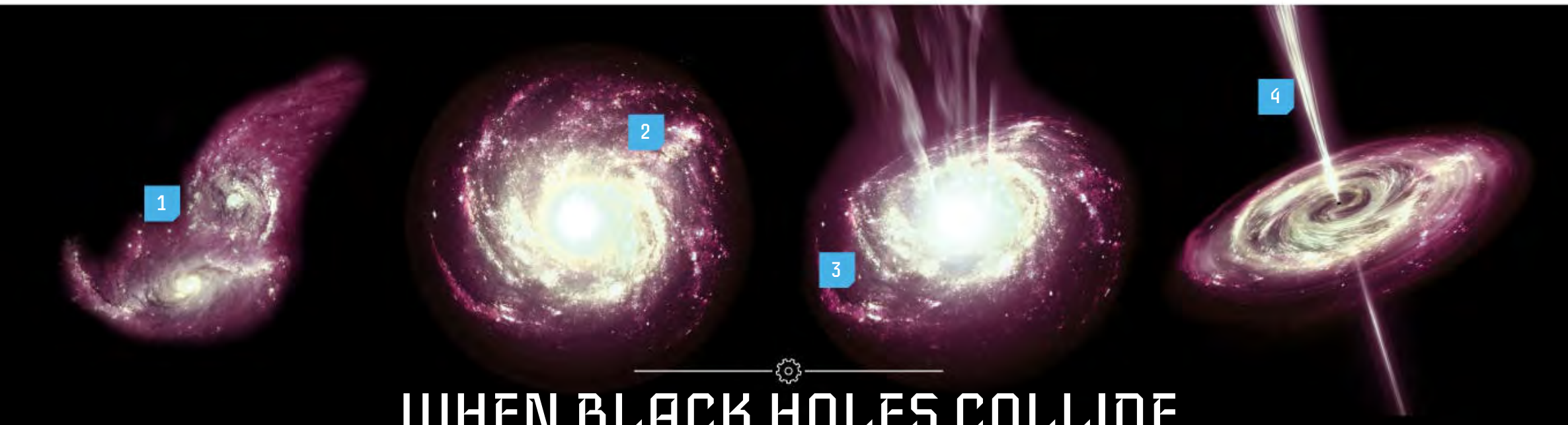
In some active galaxies, the accretion process blasts out two narrow jets of high-energy particles in opposite directions. These jets, travelling at almost the speed of light, can sometimes extend for hundreds of thousands of light years. But what we actually see from Earth depends on how we're viewing the galaxy relative to the direction of the jet – and if it has a jet at all. Another complicating factor is the presence of a dusty, doughnut-shaped region called a torus around the accretion disc. This may obscure our view of the active galactic nucleus if we view it from certain angles.

There's quite a zoo of active galaxies: some of them differing intrinsically, others only because we view them from different directions. The brightest of all are quasars, thought to have been particularly common in the early universe when there was more gas available for accretion. Another bright type is a blazar, which is what we see when we view an active galaxy's jet head-on. At the more 'normal' end of the active galaxy spectrum are Seyfert galaxies, which are active spiral galaxies, and radio galaxies, which are active ellipticals.

But is it possible for a non-active galaxy to become an active one? The main requirement is for a sufficient amount of fresh material to be accreted onto the black hole. That's something that's unlikely to happen in the normal course of events, with one important exception. That's the case where two galaxies crash into each other and coalesce into a single, larger galaxy. Things can get pretty chaotic in such situations, and it's possible new material may find its way to the vicinity of the central black hole, or more likely two black holes before they eventually merge and create a brand-new active galaxy.

Did you know?

Quasar stands for quasi-stellar radio source



WHEN BLACK HOLES COLLIDE

Galaxy collisions aren't uncommon. When they occur, the central black holes eventually merge too

1 MERGING GALAXIES
Two galaxies crash into each other, initially producing a confused mess of material, but then settling down to become a single, merged galaxy.

2 TWO BLACK HOLES
The supermassive black holes that started at the centres of the original galaxies gradually spiral towards each other, eventually coalescing into a single black hole.

3 HIGH-ENERGY JET
The combined black hole may cause the core of the merged galaxy to eject streams of hot gas containing particles travelling close to the speed of light.

4 VISIBLE CONSEQUENCES
The newly merged supermassive black hole gives its presence away through the release of gravitational waves and high-energy electromagnetic radiation.

DID YOU KNOW? Accretion of matter onto a black hole is the most efficient energy-production mechanism in the universe

ACTIVE GALACTIC NUCLEI

In an active galaxy, all the action takes place near the central black hole

AR zone

SCAN HERE

JETS
High-energy jets shoot out in opposite directions, perpendicular to the accretion disc. They can be very bright if seen head-on.

SUPERMASSIVE BLACK HOLE
All the energy ultimately comes from the black hole's incredibly strong gravitational field.

DUSTY TORUS
The accretion disc is surrounded by a larger, doughnut-shaped region of dust-like material, which obscures the view from some angles.

ACCRETION DISC
Material orbiting the black hole at close range releases huge amounts of energy as it gradually spirals in.

VIEWING DIRECTION
How much activity an observer actually sees depends on their viewing angle relative to the disc, torus and jets.

"The accretion process blasts out two narrow jets"

SUPERMASSIVE EXAMPLES

LEO I DWARF GALAXY
Although this tiny galaxy is only about 20 million solar masses in total, its central black hole is proportionately huge at around 3 million solar masses.

CENTAURUS A
This huge elliptical galaxy – a cosmic neighbour at just 13 million light years away – is a powerful radio emitter thanks to the 55-million-solar-mass black hole at its centre.

NGC 7727
The product of two merging galaxies, NGC 7727 still retains two supermassive black holes – of 154 and 6.3 million solar masses – just 1,600 light years apart near its centre.

ABELL 2261
This cluster of galaxies is estimated to have a black hole of up to 100 billion solar masses near its centre. Frustratingly, its exact location continues to elude detection.

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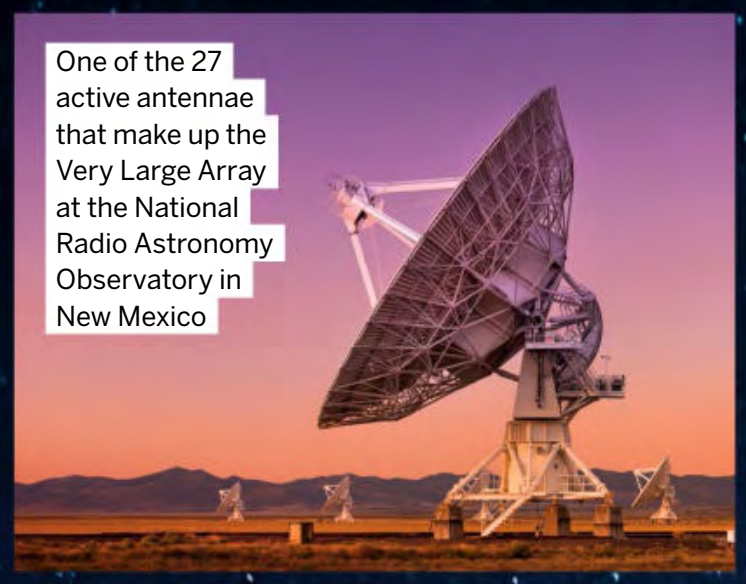
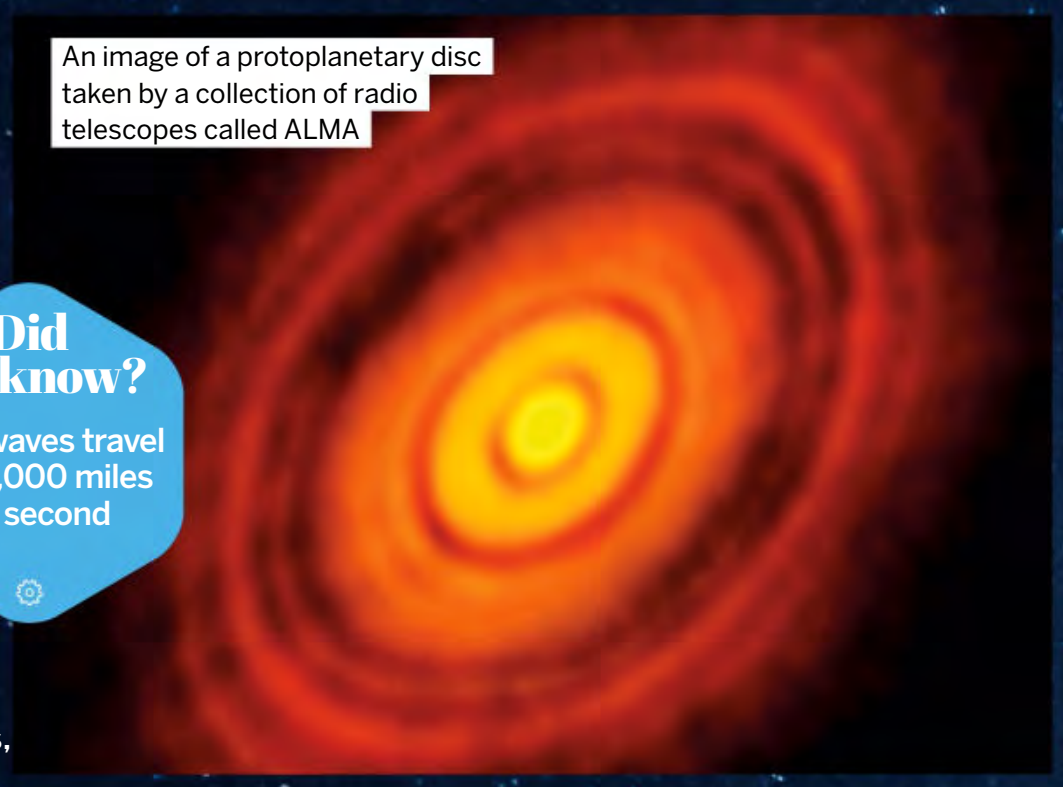
VIEWING DEEP SPACE FROM EARTH

How radio telescopes piece together photos of deep space from all around the world

WORDS **SCOTT DUTFIELD**



One of the 27 active antennae that make up the Very Large Array at the National Radio Astronomy Observatory in New Mexico



An image of a protoplanetary disc taken by a collection of radio telescopes called ALMA

Did you know?

Radio waves travel at 186,000 miles per second

The electromagnetic spectrum is made up of different wavelengths of light. Each wavelength is made up of tiny particles called photons, which have different levels of energy. At the higher energy end of the spectrum are X-rays and gamma rays, while wavelengths with the lowest energy are infrared and radio waves.

Scientists have found that the oldest and coldest celestial bodies and places in the universe emit low-energy radio waves, and by observing these radio waves using giant telescopes dotted around the world, they can study the composition, structure and motion of these cold spots.

One of the biggest benefits of radio astronomy is being able to look through stellar nurseries, called nebulae. A nebula is a large cloud of cosmic dust and gas out of which stars form. Stars, by their very nature, emit enormous amounts of visible light. However, a nebula's dust and gas block visible light travelling through it. Stars also release radio waves, which can travel through a nebula's haze and can be picked up by massive radio telescopes on Earth.

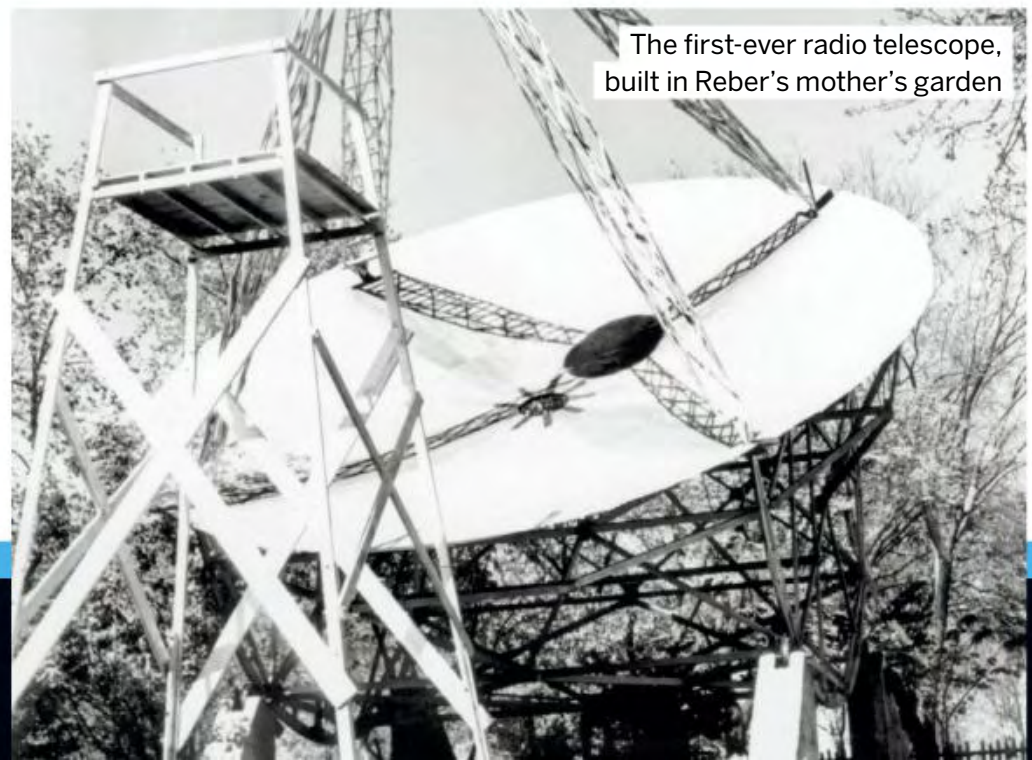
Radio telescopes work in a similar way to optical telescopes you might have at home, but instead of collecting visible wavelengths of light, they gather weak radio waves and bring them into focus.

One of the most distinguishing features of a radio telescope is its large parabolic dish, a symmetrical open curve also known as the primary reflector. The shape of the telescope is useful in making incoming radio waves bounce off the primary antenna into a single focal point at the secondary reflector in the middle of the dish. At the secondary reflector, the radio waves are again bounced back towards the centre of the dish, where they're funnelled through cone-shaped structures and end up at the telescope's receivers. The receiver then converts the radio waves into an electrical current, which can be translated into an image or data that reveals space secrets.

For example, the first binary pulsar was discovered using a radio telescope in 1974. Binary pulsars, two highly magnetised neutron stars orbiting one another, are one of the few objects that allow scientists to test out Einstein's theory of general relativity.

A NOVEL IDEA

The first reports of extraterrestrial radio emissions came in 1931 from Karl Jansky, an engineer at Bell Telephone Laboratories. With just a turntable and antenna pointed at the sky, he discovered radio waves coming from the centre of the Milky Way. The first radio telescope was created by a 26-year-old engineer, Grote Reber from Wheaton, Illinois, six years after Jansky's discovery. Reber used spare parts from his Ford Model T truck, wooden rafters and sheet metal to construct a telescope almost nine metres wide. With it, Reber was the first to find evidence of galactic radiation, and the data he collected produced the first radio maps of the sky.



The first-ever radio telescope, built in Reber's mother's garden

DID YOU KNOW? The Five-hundred-meter Aperture Spherical Telescope (FAST) in China is the largest radio telescope on Earth

LOOKING FOR RADIO WAVES

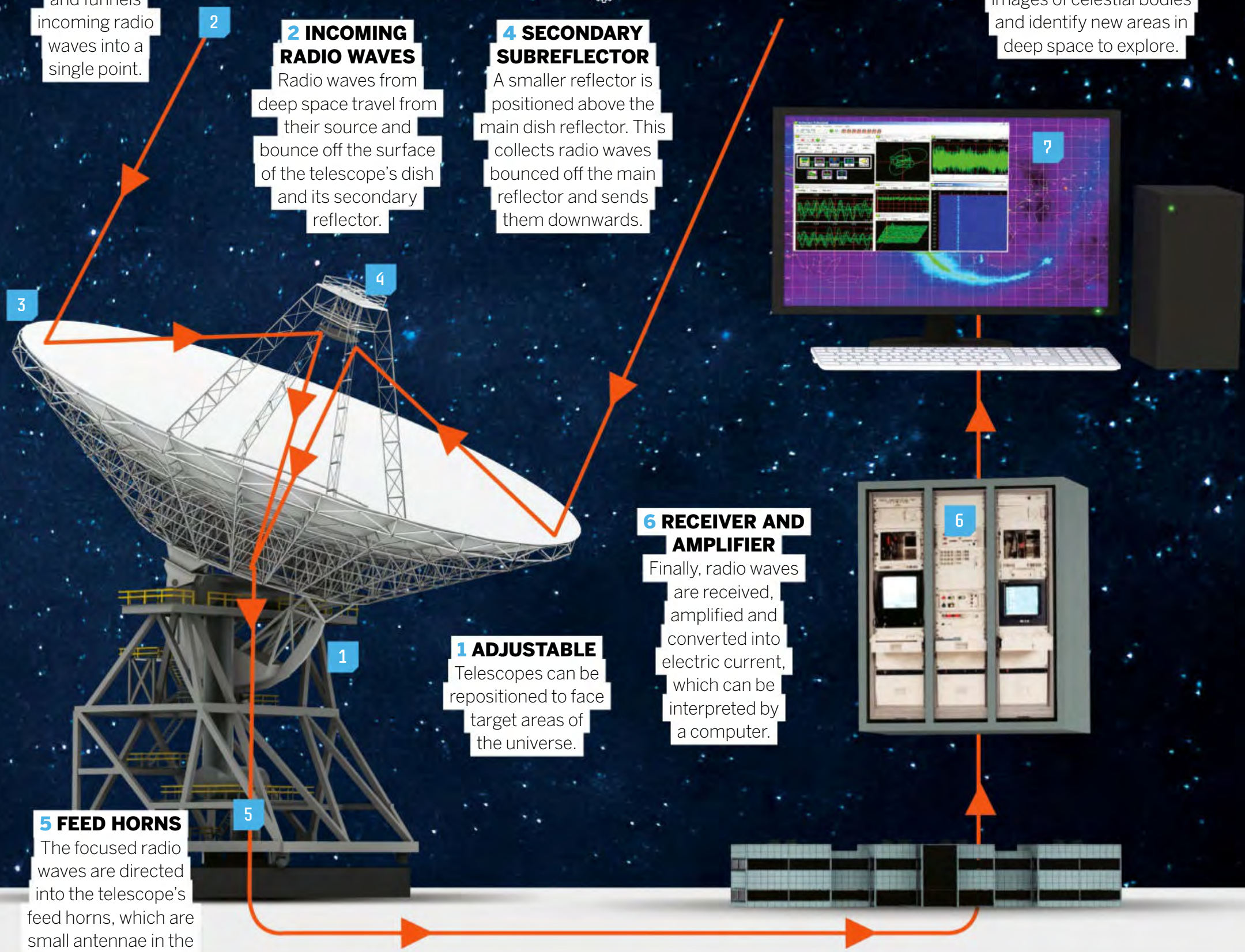
How these telescopes capture and process signals from space

3 PARABOLIC REFLECTOR
The parabolic antenna focuses and funnels incoming radio waves into a single point.

2 INCOMING RADIO WAVES
Radio waves from deep space travel from their source and bounce off the surface of the telescope's dish and its secondary reflector.

4 SECONDARY SUBREFLECTOR
A smaller reflector is positioned above the main dish reflector. This collects radio waves bounced off the main reflector and sends them downwards.

7 ANALYSIS
Scientists use the data from radio telescopes to construct images of celestial bodies and identify new areas in deep space to explore.



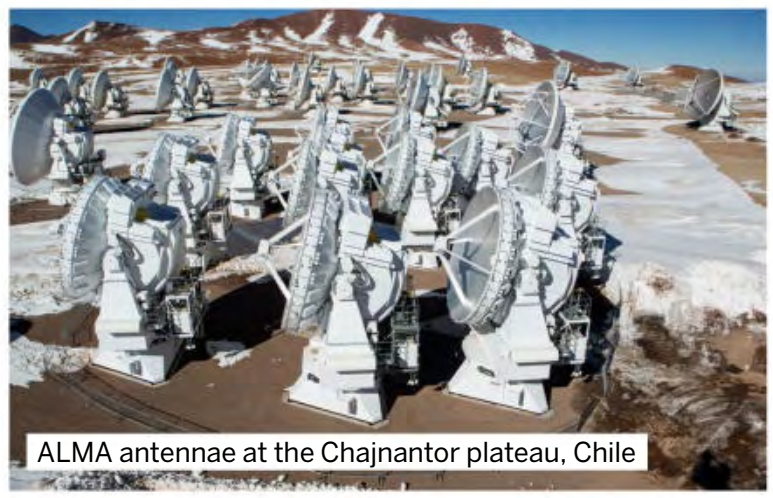
6 RECEIVER AND AMPLIFIER
Finally, radio waves are received, amplified and converted into electric current, which can be interpreted by a computer.

1 ADJUSTABLE
Telescopes can be repositioned to face target areas of the universe.

5 FEED HORNS
The focused radio waves are directed into the telescope's feed horns, which are small antennae in the centre of the dish.

TELESCOPE ARRAYS

Although a single large radio telescope, such as the now-defunct Arecibo Observatory in Puerto Rico, can see deep into space, when an array of antennae come together they can become one giant telescope. One example can be found in Chile, called the Atacama Large Millimeter/submillimeter Array (ALMA). ALMA consists of 66 antennae that are synchronised to collect and record radio waves from space. The precision at which each antenna needs to be in sync is down to a millionth of a millionth of a second. For a single radio telescope to capture as many radio waves as ALMA, it would have to be around ten miles wide. The data collected from ALMA is used to study stars and galaxies that emerged billions of years ago and learn how they formed. It can also help scientists explore the chemistry of the cosmic clouds they were born from.


ALMA antennae at the Chajnantor plateau, Chile

© Getty / ALMA (ESO/NAOJ/NRAO) / NRAO/AUI/NSF

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A: HYDROGEN B: NITROGEN C: GLUCOSE

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OFFER EXPIRES **31 MAY 2022**

BRAINDUMP

Amazing answers to your curious questions

Did you know?
Aomori City in Japan has the highest average snowfall

Why is snow white?

Katy Kruick

To answer this question there are two things which need to be considered – colour theory and refraction. Refraction is the change in direction of light as it goes from one material to another. It's due to a slight change in the speed of the light, and it explains why straws look bent in water. When light enters snow, it refracts. This is because snow is made from lots of ice crystals tightly packed together, the important fact here being that these crystals are translucent – light can pass through, but not in a direct path; it changes direction.

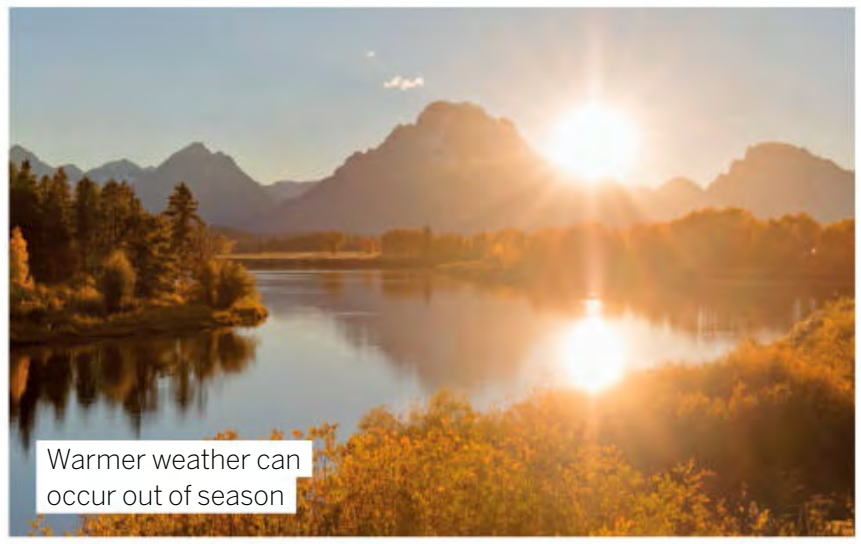
Additive colour mixing tells us that if we combine all of the frequencies of colours we get white light. When light falls on snow it is composed of a mixture of different frequencies which all refract slightly differently as they enter the ice crystals. Eventually, due to refraction, the light leaves the surface of the snow in all directions and hits our eyes. This light is composed of a mixture of frequencies, which our eyes detect as white light.

WHAT IS AN INDIAN SUMMER?

Nigel Peterson

The definition of an Indian summer is a period of mild sunny weather that is out of season. The term is commonly used to describe a sunny spell which can occur after the first frost. The first recorded usage of the term was in 1778, by a Frenchman who lived in America called John de Crèvecœur who mentioned it in a letter. The term had spread to Britain by the 19th century.

Indian summers are caused by stalled high pressure; this high pressure pushes air towards areas of low pressure, which makes wind. Due to the rotation of the Earth, these winds rotate counterclockwise about the Northern Hemisphere and can sometimes curve south, picking up warmer air and bringing it further north, and making it unseasonably warm.



Warmer weather can occur out of season

HOW DOES A GALILEO THERMOMETER WORK?

Sarah Cook

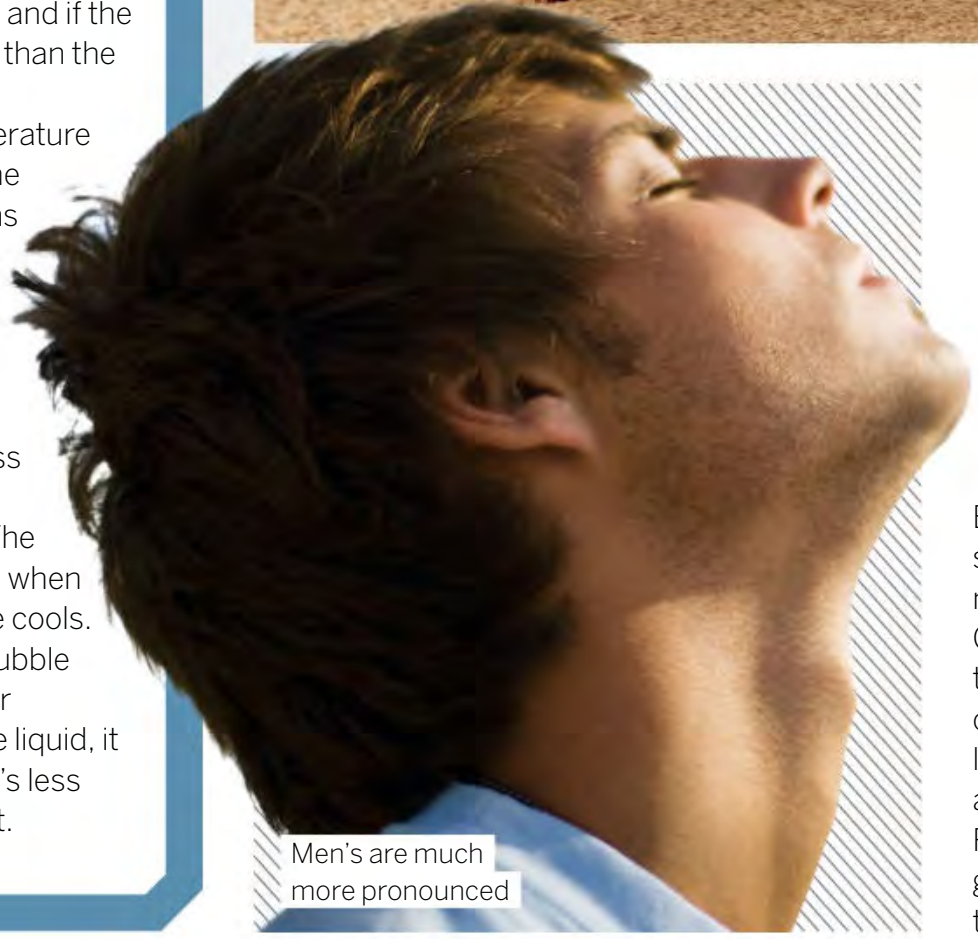
The Galileo thermometer consists of a vertical glass tube, typically filled with water, and sealed glass bubbles containing coloured water or alcohol. Each bubble is also attached to a specific mass and labelled with the temperature it represents to calibrate its density. The temperature can be read by interpreting the distribution of these bubbles. The principle of buoyancy states that if an object is less dense than a liquid, it floats, and if the object is denser than the liquid, it sinks. When the temperature of the liquid in the glass tube begins to warm up, it expands – hence lowering the density of the liquid, as its mass now occupies a larger volume. The opposite occurs when the temperature cools. Therefore, if a bubble becomes denser compared to the liquid, it will sink; and if it's less dense it will float.

Fleas are common pests in households with pets

How can fleas jump so high compared to their size?

Richard Collins

If you have ever watched a flea jump, you may be startled to see that they can jump astonishingly high, and far, compared to their size. This is down to a combination of strong leg muscles and pads of a rubber-like protein called resilin, located above the hind legs of the flea. When the flea prepares to jump, it crouches, squeezing the resilin. This resilin is able to store energy and release it suddenly in one go, a little bit like a spring. This launches the flea as if from a catapult, allowing the flea to jump up to around 35 centimetres in length and 20 centimetres in height.



Men's are much more pronounced

Do women have an Adam's apple?

Raj Turner

Everyone has an Adam's apple, but men's are usually easier to see. It's a bump on the neck that moves when you swallow, named after the biblical Adam. Supposedly, it's a chunk of the Garden of Eden's forbidden fruit stuck in his descendants' throats, but it's actually a bump on the biggest piece of cartilage – thyroid cartilage – surrounding the voice box, or larynx. The thyroid cartilage is shield-shaped; the Adam's apple is the bit at the front. But why do men's stick out more? Partly because they have bonier necks, but also their larynxes grow differently during puberty to accommodate their longer, thicker vocal cords, which give them deeper voices.

© Getty

Carbon monoxide is produced when carbon-based fuels like wood and oil burn

Did you know?
The gas is one part carbon and one part oxygen

Why is carbon monoxide poisonous?

Paul Lawrence

Carbon monoxide (CO) is a poisonous, colourless, odourless and tasteless gas, formed when there is not enough oxygen present when carbon-based fuels such as wood and oil burn, like in incomplete combustion. Exposure to carbon monoxide can cause symptoms that include headaches, nausea and even death.

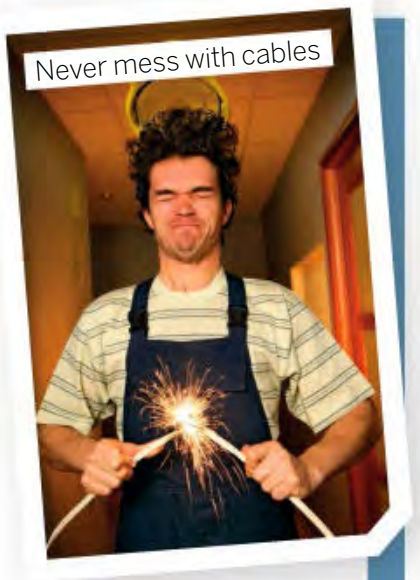
Carbon-monoxide poisoning is mainly caused by your body's cells being deprived of oxygen, which is used to release energy from your food via aerobic respiration. Oxygen is usually carried through the circulatory system by haemoglobin found within red blood cells, with each haemoglobin protein being able to carry up to four oxygen molecules at a time. However, carbon monoxide reduces the amount of oxygen being delivered to cells in two ways. Firstly, the affinity (strength and likelihood of binding) of haemoglobin to carbon monoxide is over 200 times greater compared to that with oxygen. This means carbon monoxide is more successful while competing for the same binding site as oxygen on haemoglobin, therefore reducing the amount of oxygen that's carried. Secondly, if a carbon monoxide molecule binds with haemoglobin, subsequent oxygen molecules are bound more tightly, preventing the oxygen from being released.

WHAT ARE AMPS, WATTS, VOLTS AND OHMS?

John Wu

Amps, watts, volts and ohms are all units of measurement, in a similar way that the metre is a unit for distance. The ampere (amp) is the unit of electric current. The symbol for amps is A. Current is a measurement of how much charge is moving through a particular point in a unit of time. One amp is the current generated when 6.242 x 10^{18} electrons pass a particular point per second. That's 6,242 followed by 18 zeros – a lot of electrons!

Watts are a measurement of electrical power. The symbol for the watt is W, and one watt equals one joule per second – joule is the unit of energy. A 60W light bulb converts 60 joules of electrical energy to heat and light every second. Volts are the unit of measurement for voltage. Voltage is a measurement of electrical potential energy per unit charge, and one volt is equivalent to one joule per coulomb. Coulomb is the unit of charge. When current flows through something, it'll experience resistance. This is measured in ohms. Some materials, like wood, have a high resistance, which means little current can flow through. Other materials like copper have a low resistance and conduct electricity well.



Never mess with cables

WHY DO OUR EARS 'POP' ON PLANES?

James O'Toole

The eardrum is a thin membrane that helps transmit sound. Air pressure is exerted on both sides of the eardrum, with the surrounding atmospheric pressure pushing it inwards, while air being delivered via a tube between the back of your nose and the eardrum pushes it outwards. This narrow tube is called the Eustachian tube; when you swallow, the tube opens, and a small bubble of air is able to move, causing a 'pop'.

Rapid altitude changes in planes make the 'pop' much more noticeable due to bigger differences in pressure. Air pressure decreases as a plane ascends, hence air must exit the Eustachian tubes to equalise these pressures, again causing a 'pop'. Conversely, as a plane descends, the air pressure starts to increase, therefore the Eustachian tubes must open to allow through more air in order to equalise the pressure again, causing another 'pop'. So there's no need to worry: although popping ears are uncomfortable, they're part of a completely natural process.

How do footballers bend the ball?

Tom Hudson

In the multi-billion-dollar industry that is football today, managers are striving to have the perfect foot on a striker. Cristiano Ronaldo most likely spent all his spare time perfecting it, and many aspiring strikers probably still do.

Bending the ball in the air is down to physics and a little thing called the 'sweet spot'. Attacking the sweet spot is what gets the ball off the ground, ideally making it spin like crazy. But when the ball starts to fly, it's all down to the airflow around it and its speed. When gliding through the air, it spins either left or right depending on the striker's footwork. The drag airflow slows the ball down. As the ball loses speed the airflow changes its behaviour, and the intensity of the spin increases. This ever-slowing ball dips ferociously in a well-placed arc, hopefully finding the back of the net.

Ronaldo is considered one of the best footballers of all time

WHY DO I NEED AN ELECTRICAL ADAPTOR WHEN I TRAVEL?

Gemma Aston

If you travel to a different country, one of the first things you might look for in your hotel room is a plug socket, only there's a good chance it will look different – maybe bigger, smaller or have a different number of holes. This is because back when electricity grids were first being introduced, many countries decided to develop plugs and sockets of their own rather than adopting a world standard. As well as the shapes and sizes of the plug sockets changing depending on the country, the voltage and frequency of the AC current varies too. Europe and most other countries in the world use a voltage which is twice that in the US. Plug an appliance from the US into a power supply in Europe without an adaptor and you will probably see a spectacular yet highly dangerous firework display, as the voltage will be too high. It's worthwhile to check the power outlets of the country you are visiting before you travel, then you can make sure you take the correct adaptor.

© Getty

Dry ice is used in smoke machines

How does dry ice work?

Sarah Smee

Dry ice is the name given to solid carbon dioxide (CO_2), and it looks a bit like water ice, except dry ice is much colder. This is because CO_2 sublimes (turns straight from a solid to a gas) at around -78 degrees Celsius, so you wouldn't want to be holding this stuff as a solid for the risk of experiencing quite a bad 'cold burn'.

When you see the smoky effect given off when dry ice sublimes, you are not seeing the CO_2 gas, because CO_2 gas is invisible. What you're seeing is water vapour in the air which has condensed as it comes into the vicinity of the cold CO_2 gas, a little bit like the water vapour we breathe out on a cold day, which condenses to form a visible cloud.

WHAT IS DEEP VEIN THROMBOSIS?

Margaret Harris

Veins are blood vessels that carry blood back to the heart. Deep veins are those found deep inside the body, as opposed to veins closer to the surface, called superficial veins. If a blood clot (thrombosis) forms in one of your deep veins, normally in your leg, this condition is called deep vein thrombosis (DVT). Clots can cause swelling and pain and may lead to complications such as a pulmonary embolism – the initial blood clot gets transported and deposited in the arteries supplying the lungs, causing a blockage. Immobility for long periods, such as plane journeys, decreases the blood flow rate through your deep veins, as the muscles surrounding these blood vessels are not contracting; this promotes the formation of blood clots.

Flying often can increase your chance of developing DVT

WHY DOES SMOKE COME FROM A FIRE?

Tom Wilson

When you can see smoke coming from a fire, what you are actually seeing are volatile hydrocarbons. Hydrocarbons are compounds existing of hydrogen and carbon. When hydrocarbons become volatile they become a gas from a solid or liquid state. Combustion of hydrocarbons is a process in which the hydrocarbons react with oxygen to produce water, carbon dioxide and energy. Hydrocarbon + oxygen = water + carbon dioxide + energy, or $CH_4 + 2O_2 = 2H_2O + CO_2$ + energy.

When this combustion is incomplete there is not enough oxygen present and the carbon dioxide cannot form, leading to production of carbon monoxide or carbon. Hydrocarbon + oxygen = carbon monoxide or carbon + water.

Smoke is seen when the carbon is present in the combustion, as this will show a visible gas. When there is complete combustion you cannot see any smoke because water and carbon dioxide produce colourless gases.

HOW COLD WOULD THE SEA HAVE TO BE TO FREEZE?

Alex Wood

Pure water (H_2O) contains no impurities and freezes at zero degrees Celsius. However, on average seawater contains 3.5 per cent of dissolved salts, which lowers the freezing point; this phenomenon is called freezing point depression. Freezing point depression is a colligative property of matter, which means it depends on the number of molecules present, not on the specific type of molecule or their mass – the dissolved substance doesn't have to be salt, but any soluble substance; it's the amount of dissolved molecules that's important. In terms of seawater, the average freezing point is about -2 degrees Celsius. However, it does vary around the world due to differing amounts of chemicals, like salts, dissolved in it.

Sea ice forms in colder parts of the world

Did you know?

Ice covers about ten per cent of Earth's surface

WHAT IS A STINK PLANT AND WHY DOES IT STINK?

Steve Champion

The titan arum, or stink plant, is an odd plant however you look at it. Known as the 'corpse flower' in Indonesia, it's a colossal organism, the central column, or 'spadix', growing up to three metres tall. The plant's corm – the underground root system where it stores its food – is the largest in the world. Once the flowers around it are ready for pollination, the spadix begins to generate the disgusting smell to attract sweat bees, beetles and other carcass-eating insects. Thinking they've found a meal, or somewhere to lay their eggs, the insects arrive and crawl over the flower. While they go away hungry, they also ensure pollination occurs. To make certain of this, the spadix's tip heats to near-human body temperature, while the red colouration and texture of the lower section completes the illusion.

A titan arum

Contrails stay in the sky long after the plane has passed

Why do those long, white clouds form behind jets?

Craig Wilson

These long, white clouds are called condensation trails, or contrails. Jet fuel is made of carbon and hydrogen, which burns in the presence of oxygen. In this reaction, some of the carbon joins with the oxygen to make carbon dioxide (CO_2) and some of the hydrogen joins with oxygen to make water (H_2O). The water which comes out of the engine is invisible water vapour, but as soon as it is exposed to the colder temperatures of the upper atmosphere it condenses into little drops of liquid water, which become suspended in the air and is what we see as contrails. This is a similar effect to what you notice on a cold day when you breathe out; the water vapour in your breath condenses as it meets the cold air, and you can see your breath.

© Getty

THE LIBRARY

The latest book releases for curious minds

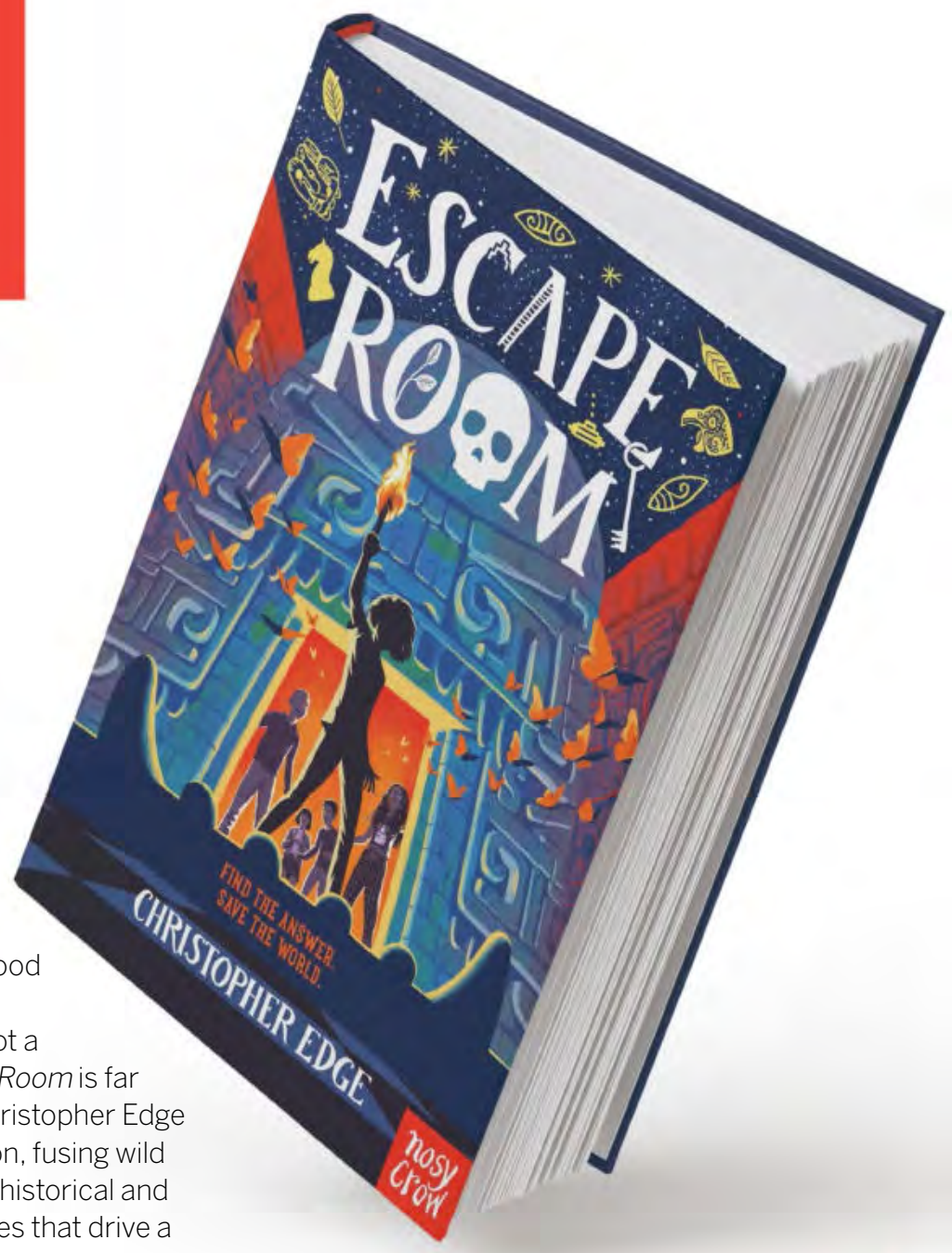
ESCAPE ROOM

WHAT HAVE YOU DONE TO SAVE THE WORLD TODAY?

AUTHOR **CHRISTOPHER EDGE**
PUBLISHER **NOSY CROW**
PRICE **£7.99 / $11.99**
RELEASE **OUT NOW**

Ami Oswald is a clever, if otherwise average-seeming Generation Z girl hanging out with a few newfound friends in an escape room. Their host tells them they need to solve the puzzles to save the world, and they're all too keen to get stuck in – this escape room is particularly convincing in its detail, after all. After cracking the first puzzle and advancing past a chess-playing automaton, the escape room opens up into a Tardis-like series of chambers containing devious problems that demand solutions from the five young players before they can move onto the next one. Each new puzzle is increasingly realistic and threatening, so that by the time they've passed a huge library improbably contained in the bowels of the building, the team are having their doubts, to say the least, about whether they're playing a game or whether their fate and the fate of the world really is in their hands.

The use of an escape room as a plot device is a trendy concept – a nifty one, if we're going to be generous. And the story arc is very familiar, too, bringing to mind Marshall Cavendish's *The Ancestral Trail*... people of a certain age may well have fond childhood memories of that popular magazine series. That's not a criticism, though. *Escape Room* is far from derivative: author Christopher Edge has an enviable imagination, fusing wild science fiction with literal, historical and scientific objects and places that drive a compelling narrative. The automaton is Edgar Allan Poe's Chess Player of Maelzel, for example, which one of Ami's companions, Min, eagerly points out. And as they reel from one perilous puzzle to the next, each of the players brings a key snippet of knowledge to the situation. These 12 year olds are precocious and incredibly advanced, suspiciously so, but that doesn't take any of the potency out of the twist, which neatly ties *Escape Room* up and leaves us feeling quite satisfied. No spoilers here, obviously.



Author Edge has an enviable imagination

It's a well-told and clever story that will fire the imagination of anyone who reads it. It made us pause to Google many of the curious real-world objects it refers to, so who knows what *Escape Room* could inspire in its younger target audience?

HURRICANE LIZARDS AND PLASTIC SQUID

HOW THE NATURAL WORLD IS ADAPTING TO CLIMATE CHANGE

AUTHOR **THOR HANSON**
PUBLISHER **ICON BOOKS / BASIC BOOKS**
PRICE **£20 / $28**
RELEASE **OUT NOW**

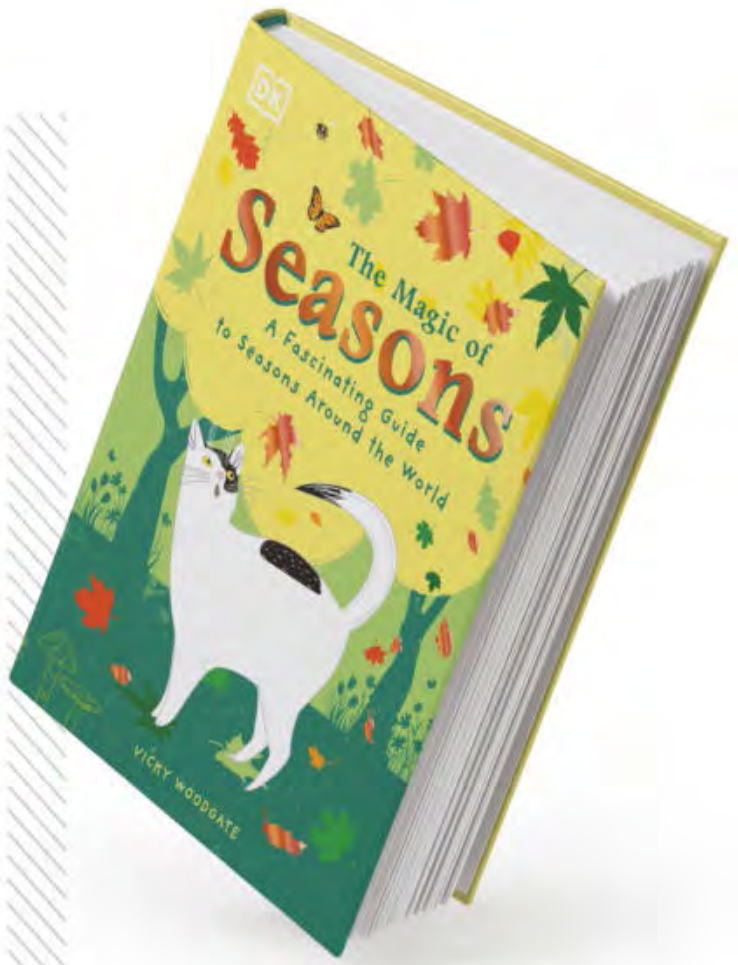
As the effects of climate change become ever more apparent, we're often left wondering what the world will look like in the future. In this book, author and conservation biologist Thor Hanson begins to paint that picture. Hanson explores the resilience of nature in the face of human adversity, as well as its inability to adapt under the environmental weight of climate change. He presents an insightful perspective on how the climate has shifted over time and how different climatic zones may form in response to temperature rises and poleward-moving wildlife. This isn't a doomsday look at the future of Earth, but encourages the reader to think critically about the impact we have on the planet, offering valuable lessons for humankind to learn. This is an excellent read for nature-lovers, environmentalists or anyone looking to better understand the world we live in.

BLAST OFF!

HOW MARY SHERMAN MORGAN FUELLED AMERICA INTO SPACE

AUTHOR **SUZANNE SLADE**
ILLUSTRATOR **SALLY W. COMPORT**
PUBLISHER **ASTRA PUBLISHING HOUSE**
PRICE **£14.03 / $18.99**
RELEASE **12 APRIL**

From sitting on a farm in North Dakota to sitting at the forefront of rocket science, discover the incredible and revolutionary work of Mary Sherman Morgan. Rocket launches seem like a weekly occurrence these days, but at the start of the Space Race the concept of launching an object beyond Earth's grasp was nothing more than an idea – mainly because scientists couldn't work out how to get a rocket off the ground without it exploding. That was until Mary gave it a go. This biographical book tells the wonderful story of how Morgan created rocket fuel that powered the first successful launch to deliver a satellite into space. Although the content is factual, it's filled with the same tropes of any good piece of fiction: ambition, success, failure and ultimately triumph. It's an excellent read for any budding scientist, especially any young girls who want to pursue a career in STEAM.



THE MAGIC OF SEASONS

A CHILDREN'S GUIDE TO GLOBAL SEASONS

AUTHOR **VICKY WOODGATE**
PUBLISHER **DORLING KINDERSLEY**
PRICE **£9.99 / $17.99**
RELEASE **OUT NOW**

We may experience the seasons as the warm, cold, sunny and stormy weather we witness in patterns throughout the year, but there is much more to know about the science of the seasons and the variety of ecosystems that they create across our planet, such as what causes different seasons, how they vary around the world and how climate change is transforming them.

The Magic of Seasons includes a perfect balance of in-depth knowledge and readability. It answers almost any question readers may have about the seasons, from the history of the Moon and its role in creating them to seasonal celebrations and the future of the climate. While dealing with complex physics, cultural traditions and scientific processes, the reader is informed through diagrams, timelines and captivating design and illustrations.

For children between the ages of seven and nine who are curious about the world and their environment, this book has the ability to widen their knowledge and engage their minds through quizzes, activities, quirky facts and more.

HOW SCIENCE SAVED THE EIFFEL TOWER

THE HISTORY OF PARIS' FAMOUS LANDMARK

AUTHOR **EMMA BLAND SMITH**
ILLUSTRATOR **LISA VISIRIN**
PUBLISHER **CAPSTONE PRESS**
PRICE **$17.99 (APPROX. £13.40)**
RELEASE **1 AUGUST**

You've almost certainly heard of the Eiffel Tower and can probably visualise its distinctive shape. But do you know its story, that this tall icon was once deemed useless and its place in France's capital city was put at risk? This book tells the story of engineer Gustave Eiffel's idea to keep his masterpiece in existence. He devised a plan to convert the structure into a one-of-a-kind science laboratory.

Throughout the book, illustrations transport the reader to the Parisian streets of the late-1800s, with many intricate details to marvel at, while the story itself tells of the combined levels of genius and determination that Eiffel displayed. As the author narrates the plans to save the tower, the high importance of science in history becomes apparent.

By the end of *How Science Saved the Eiffel Tower*, you will view the landmark in a new light, and might even learn some French along the way. Well-written and presented to hold the attention of children, this book teaches young readers how the Eiffel Tower both added to Paris' unique skyline and eventually became a vital tool for the French military, aviation industry and weather bureau.

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

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

MEDIUM

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

HARD

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

Word search

Find the following words

BOSON
PLASMA
OSCARS
FORMULA
LIGHT
LASER
SUPERMASSIVE
BEES
PLASTIC
DEMOLISH
RADIO
GEIGER

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

What is it?

Hint: Its colour is its name

A

Spot the difference

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

QUICKFIRE QUESTIONS

Q1 How much does a teaspoon full of neutron star weigh?
- Four kilograms
- 4,000 tonnes
- Four grams
- 4 billion tonnes

Q2 Which insect can live for a week after losing its head?
- Wasp
- Cockroach
- Housefly
- Ladybird

Q3 How far does an average person walk in their lifetime?
- 1,100 miles
- 260,000 miles
- 110,000 miles
- 1 million miles

Q4 Which animal has three hearts and nine brains?
- Grasshopper
- Scorpion
- Earthworm
- Octopus

Q5 How many colours are in a rainbow?
- Six
- Seven
- Eight
- Nine

Q6 Which gas do plants use in the process of photosynthesis?
- Carbon dioxide
- Carbon monoxide
- Hydrogen sulphide
- Nitrogen

Answers

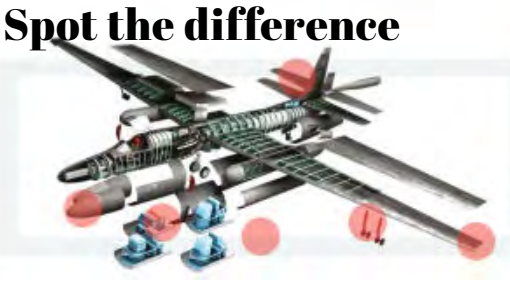
Find the solutions to last issue's puzzle pages

Q1 -40°
Q2 RED
Q3 MANATEE
Q4 VENUS
Q5 ROLLS-ROYCE
Q6 BICYCLE

What is it?

LAVA

Spot the difference



© Getty

HOW TO...

Practical projects to try at home

KIT LIST

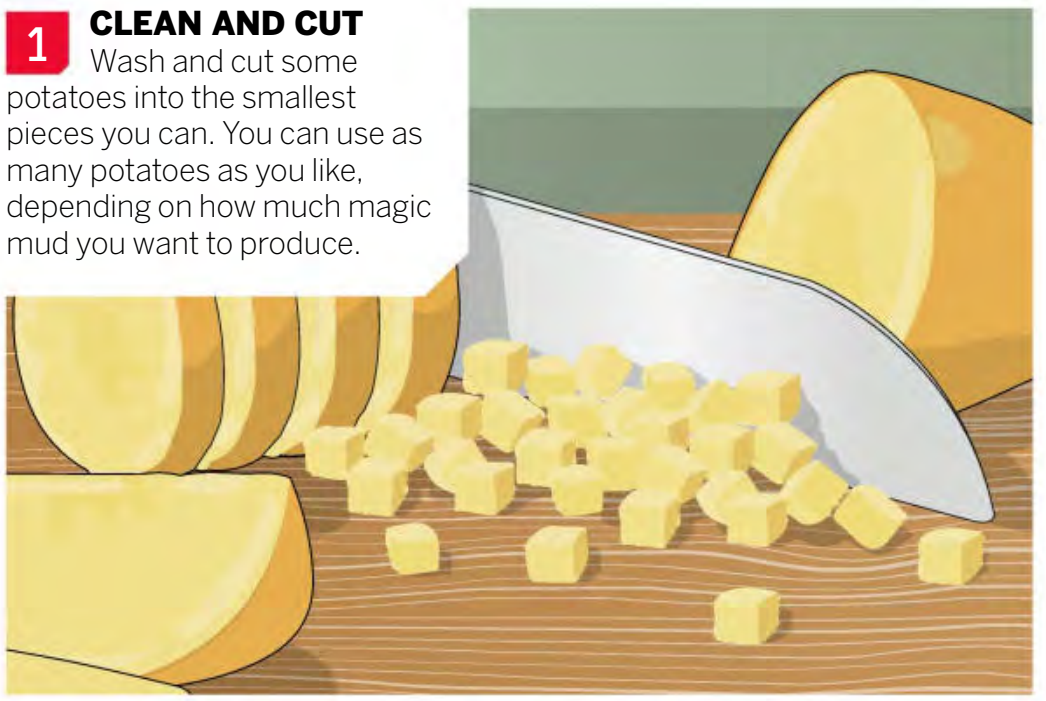
- Potatoes
- Two large bowls
- Hot water
- Strainer
- Jam jar with lid
- Spoon

Extra items for second experiment:

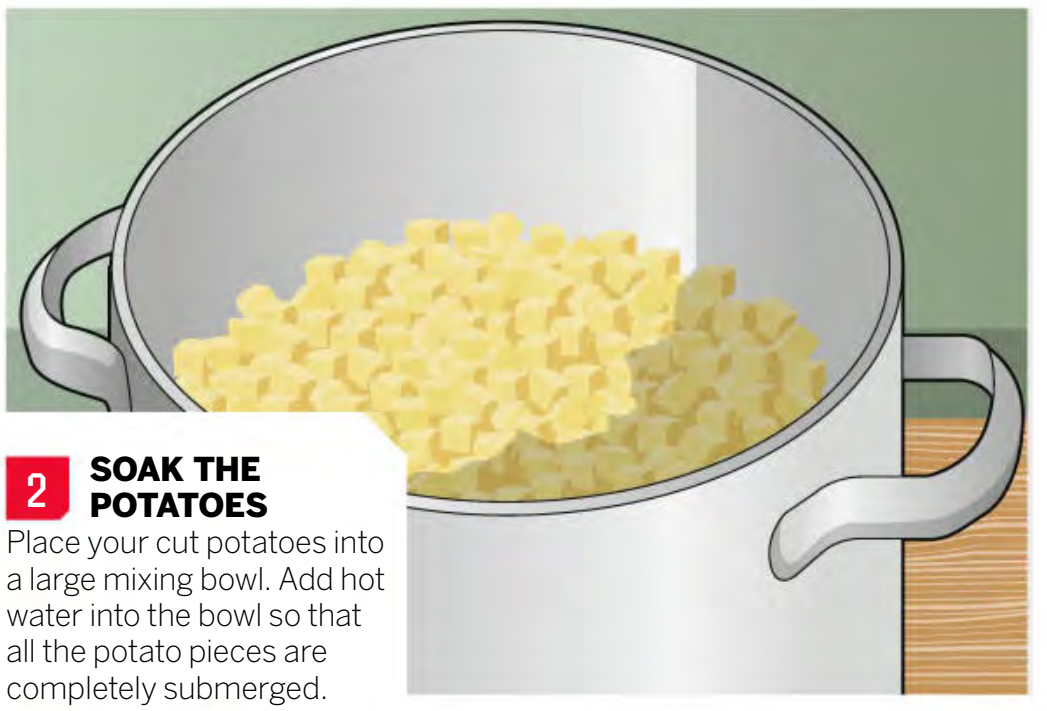
- Blacklight (UV-A light)
- Tonic water

MAKE MAGIC SPUD MUD

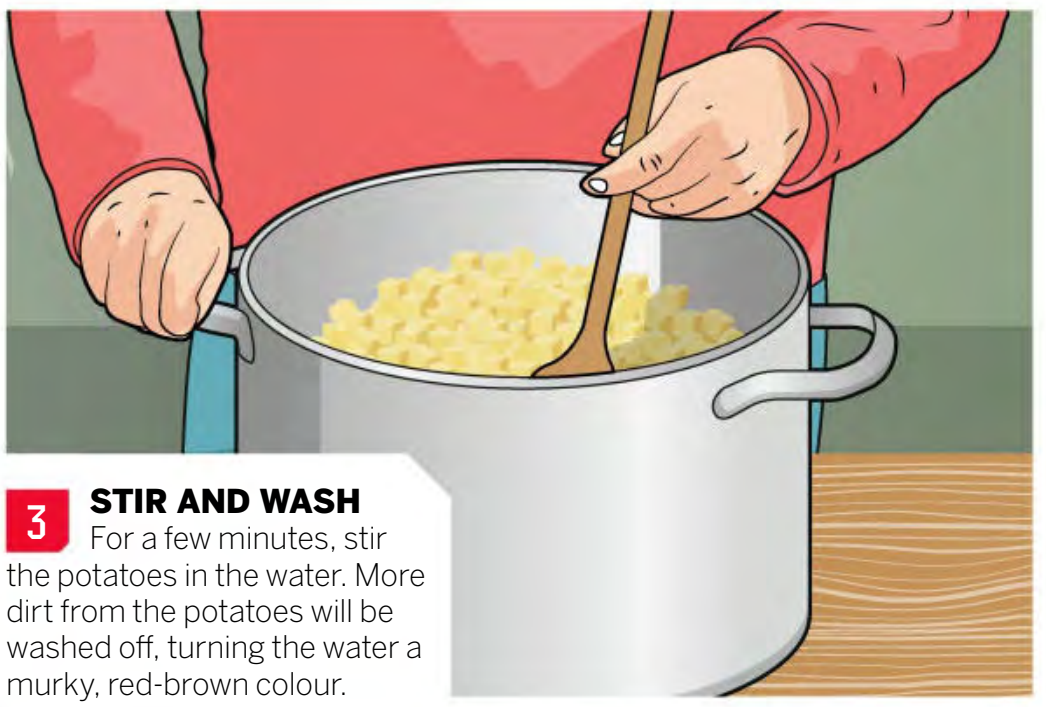
Explore the mesmerising properties of this unique, gooey substance using the humble potato



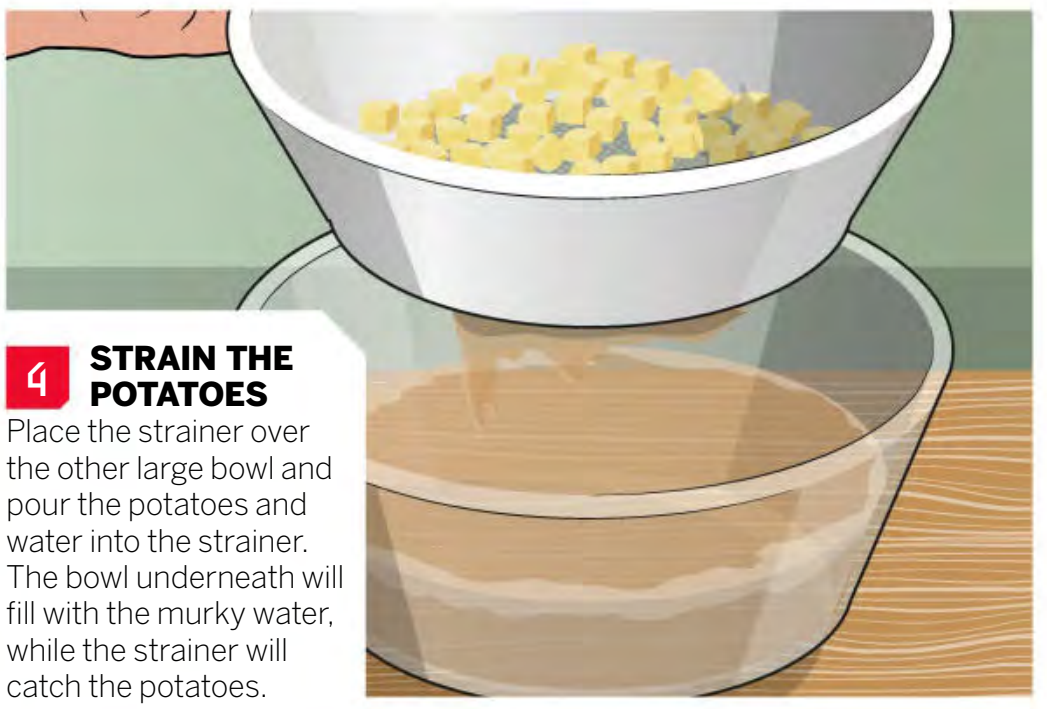
1 CLEAN AND CUT
Wash and cut some potatoes into the smallest pieces you can. You can use as many potatoes as you like, depending on how much magic mud you want to produce.



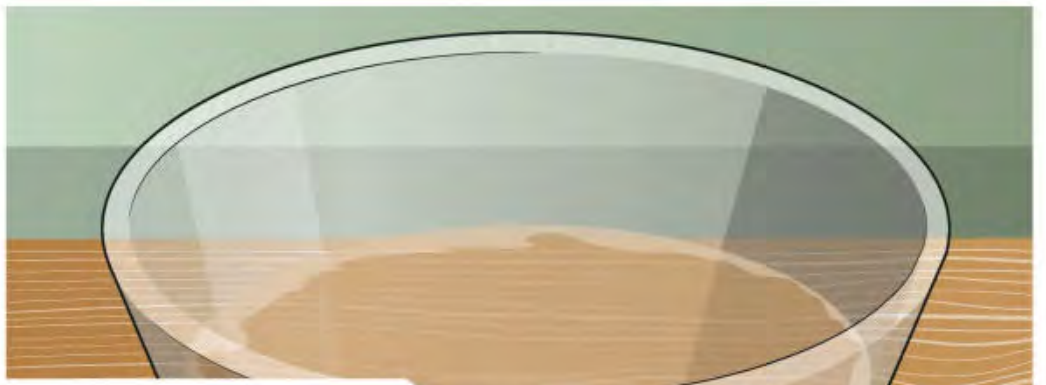
2 SOAK THE POTATOES
Place your cut potatoes into a large mixing bowl. Add hot water into the bowl so that all the potato pieces are completely submerged.



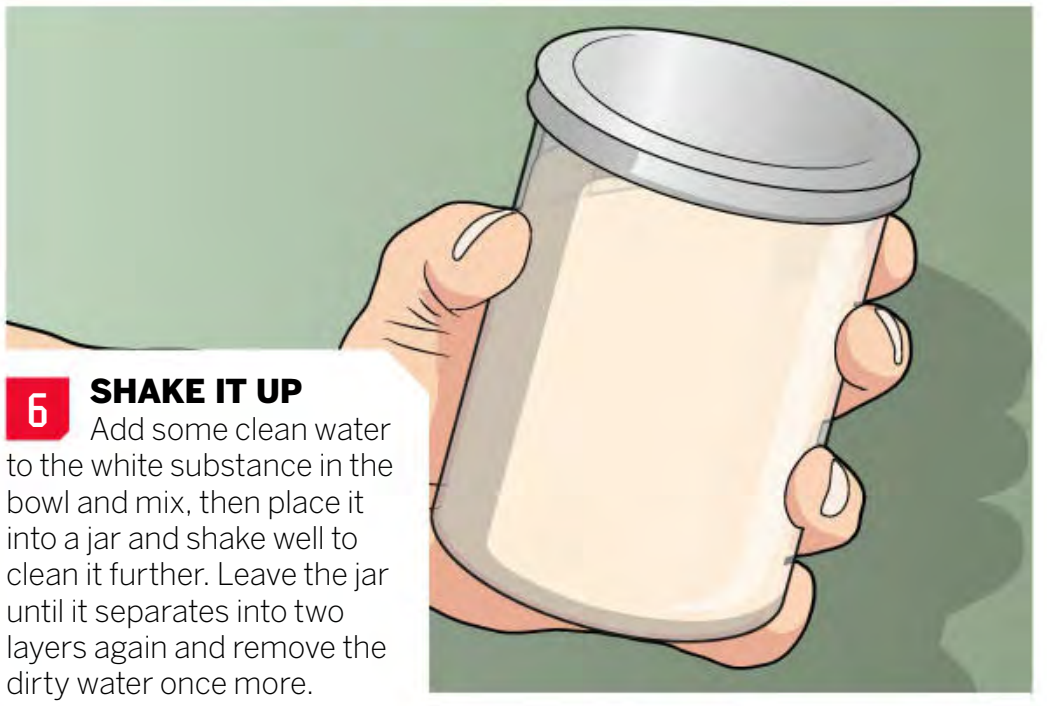
3 STIR AND WASH
For a few minutes, stir the potatoes in the water. More dirt from the potatoes will be washed off, turning the water a murky, red-brown colour.



4 STRAIN THE POTATOES
Place the strainer over the other large bowl and pour the potatoes and water into the strainer. The bowl underneath will fill with the murky water, while the strainer will catch the potatoes.



5 WATCH THE WATER
Leave the murky water in the bowl for about ten minutes. You should see the liquid begin to separate into two layers. Pour the dark water away so that you're left with the white bottom layer.



6 SHAKE IT UP
Add some clean water to the white substance in the bowl and mix, then place it into a jar and shake well to clean it further. Leave the jar until it separates into two layers again and remove the dirty water once more.

NEXT ISSUE
MAKE AND EXCAVATE YOUR OWN SPONGE FOSSIL

DON'T DO IT ALONE!

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

7 EXPLORE THE SUBSTANCE

Scoop the white gooey substance out of the jar and place it in another container. Using a spoon – or your hands if you don't mind the mess! – explore the consistency. See how the substance behaves when you move it around and when it falls from your hands.

8 EXPERIMENT TWO

Leave the substance alone for about two days and it will become a crumbly, dry powder. Add a few spoonfuls of the powder into a bowl with small amounts of tonic water until it becomes harder to stir.

9 FLUORESCENT GOO

Under a blacklight, the goo will glow. The substance should behave the same as before, but has gained a magical fluorescence.

SUMMARY

As you play around with this interesting goo, you'll notice that it behaves differently when it's at rest. If you throw it between your hands it will feel just like pizza dough, but when you hold it still it will become slimy and fall through your fingers. This mud is mostly made up of potato starch. Starch is a carbohydrate containing very small particles. The potato mud in this experiment is made up of starch and water. As the particles are so small, they are largely influenced by electric charges between them, causing them to repel each other and act like a liquid. When you move the substance slowly, these separate particles slide past each other and flow like a thick liquid. Fast movements, however, overcome the forces of repulsion. The particles touch each other and move together like a solid.

If you have an ultraviolet light and carry out the second half of the experiment, you may wonder how just tonic water and potatoes can glow. The crucial ingredient is quinine in the tonic water, a naturally occurring chemical compound that absorbs the ultraviolet light from the blacklight and re-emits it as visible light, creating fluorescence. Can't get hold of a blacklight? You can also use food colouring to customise your spud mud!

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.

DISCLAIMER

Neither Future Publishing nor its employees can accept any liability for any adverse effects experienced during the course of carrying out these projects or at any time after. Always take care when handling potentially hazardous equipment or when working with electronics, and follow the manufacturer's instructions.

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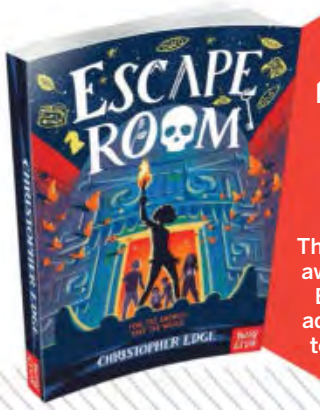
INBOX

Speak your mind



WIN!

AN AMAZING PRIZE FOR LETTER OF THE MONTH

ESCAPE ROOM

The latest mind-blowing novel from award-winning author Christopher Edge, *Escape Room* is a thrilling adventure that challenges readers to think about what they've done to save the world today

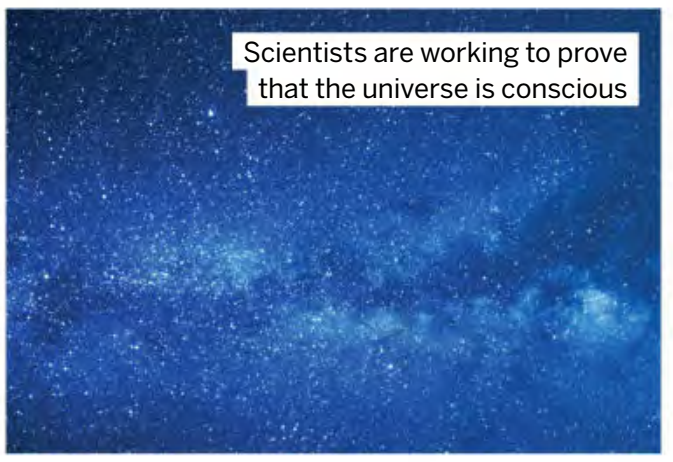
PHYSICAL AND NON-PHYSICAL

Dear **HIW**,
Are there any developments in science that suggest that not only is matter a form of energy, but that matter and mind may be part of a continuum that links the physical world with the non-physical dimension of consciousness?
Robert Marshall

Science can't thoroughly explain consciousness. While we've learned a lot about physical brain activity and its impact on behaviour and consciousness, some suspect we'll never truly know exactly how consciousness emerges. In much of the 20th century, the non-physical dimension of consciousness wasn't regarded as 'serious science', so developments in our understanding of consciousness are in relatively early stages. Being non-physical, it's vastly different from other scientific fields. Evidence of its existence comes not from experiments, but direct awareness of personal feelings.

But researchers are determined to find answers. Physicists Johannes Kleiner and Sean Tull are currently working to precisely define consciousness and see whether they can prove the universe is conscious. They believe consciousness exists in even the tiniest pieces of matter throughout the universe and are attempting to prove this with their mathematical model based on Integrated Information Theory (IIT). This is a relatively new theory, only emerging in the last few years, and while we have no concrete answers as to how physical and non-physical dimensions are connected, new theories are being developed all the time to seek the answers.

LETTER of the MONTH


Scientists are working to prove that the universe is conscious

The **Amazing Technology** bookazine includes information about interstellar travel, virtual-reality technology and the evolution of robots

HOW IT WORKS BOOKAZINES

Dear **HIW**,
Thank you **@HowItWorksmag** for this perfect gifted bookazine. I couldn't have chosen better myself #STEM #STEAM #MakerEd
Donna Rawling

We're glad to hear you enjoyed the Amazing Technology bookazine you won as part of a giveaway to subscribers. We hope you have learned more about how some of the most incredible pieces of technology are transforming the world around us. How It Works bookazines cover a wide range of both niche and broad topics. You can browse more of the latest bookazines in stores or by clicking the 'Guides & Specials' tab at magazinesdirect.com.

CASHEW APPLES

Dear **HIW**,
Recently, someone told me that cashew nuts come from apples. Is this true?
Gary Leonard

Thanks for your question, Gary. It may seem surprising, as some nuts grow beneath the ground, but it's true that cashew nuts grow on trees from fruit. The fruit is called a cashew apple, or cashew fruit. These fruits are native to Brazil, but now also grow in Africa, India and Vietnam.

When harvesting cashews, the entire fruit is picked before the nut is removed. The nuts are dried by hand and baked to make it easier to remove the outer shells. Cashew nuts are then washed and eaten, and can be transported around the world. The cashew apple itself is edible too, but perishes easily.


The cashew nuts can be seen at the bottom of these fruits

NEXT ISSUE

ISSUE 163

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COMMENTS OR QUESTIONS

Readers can email their comments to **howitworks@futurenet.com**

Dear **HIW**,
In the Inbox section of your magazine, you ask readers for their questions and comments. However, you only show questions and answers. This may be confusing to some readers, who may like to comment on previous articles, but feel it would be inappropriate.
Robert

Hi Robert. Thanks for raising this. We welcome both questions and comments about the magazine, science and technology or current topics. In some issues there may not be many – or any – comments, or vice versa. This is because there's usually a high volume of questions being sent in for this section, and we can't print everything. That said, we love to receive feedback and questions, along with any images, from our readers. We try to respond to as many as possible!

The creature this LEGO creation is based on walked the Earth over 65 million years ago

LEGO REX

@HowItWorksmag,
In issue 161, Fast Facts says that 2.5 billion *T. rexes* have walked the Earth. Is this fine specimen included in that number?
Chloe (@loopylouspurs)

Around 2.5 billion *T. rexes* roamed planet Earth during their 2.4-million-year existence, but it seems from your photograph that some are being brought back into existence in brick form! This looks brilliant, and we can only imagine how satisfying it must have been to put this large LEGO model together.

WE ASKED YOU

This month on social media, we asked you: If you could take a trip into space, what would you want to see?

@PRATIKSHYA.TRIPATHY
I want to see a black hole because I am always curious about how time gets slow near it

@MATTHEW JARVIS
I'd want to see either Jupiter or Saturn from the surface of one of the moons; either from Mimas around Saturn, or Europa around Jupiter

@KEV TRUEMAN
Jupiter and its moons

@AHMED BARRASALI
A non-stop journey to the end of the universe

@MAIA_H3
Saturn's rings

@SCIMAXFACTS
I would want to visit GN-z11 due to it being the most distant galaxy in the universe

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HOW IT WORKS

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FAST FACTS

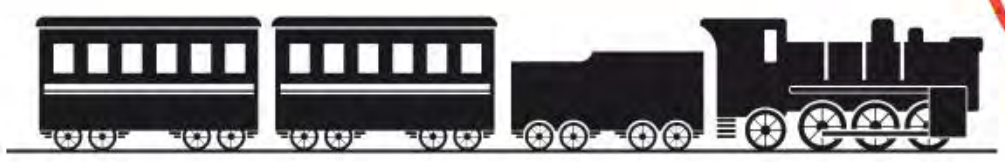
Amazing trivia that will blow your mind

J

The only letter that doesn't feature in the periodic table of elements

2.3 BILLION YEARS

Earth's oceans will boil away in the future



600 BCE

The ancient Greeks invented a predecessor to the railway

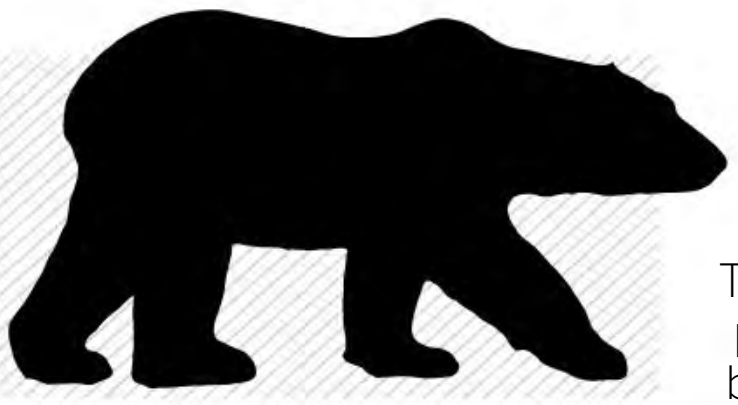
300

Human babies have nearly 1.5 times the number of bones than adults

It's possible for water to freeze and boil at the same time

3.8 BILLION

Over half the world uses the internet every day



1886

The first automobile was patented over 20 years before the Ford Model T

THE FIRST COMPUTER BUG WAS LITERALLY A MOTH TRAPPED IN A COMPUTER

POLAR BEARS ARE SO WELL INSULATED, INFRARED CAMERAS DON'T WORK ON THEM

50%

Half of the world's oxygen is produced in the sea

SIX MINUTES

Brain cells take very little time to react to alcohol

© Getty

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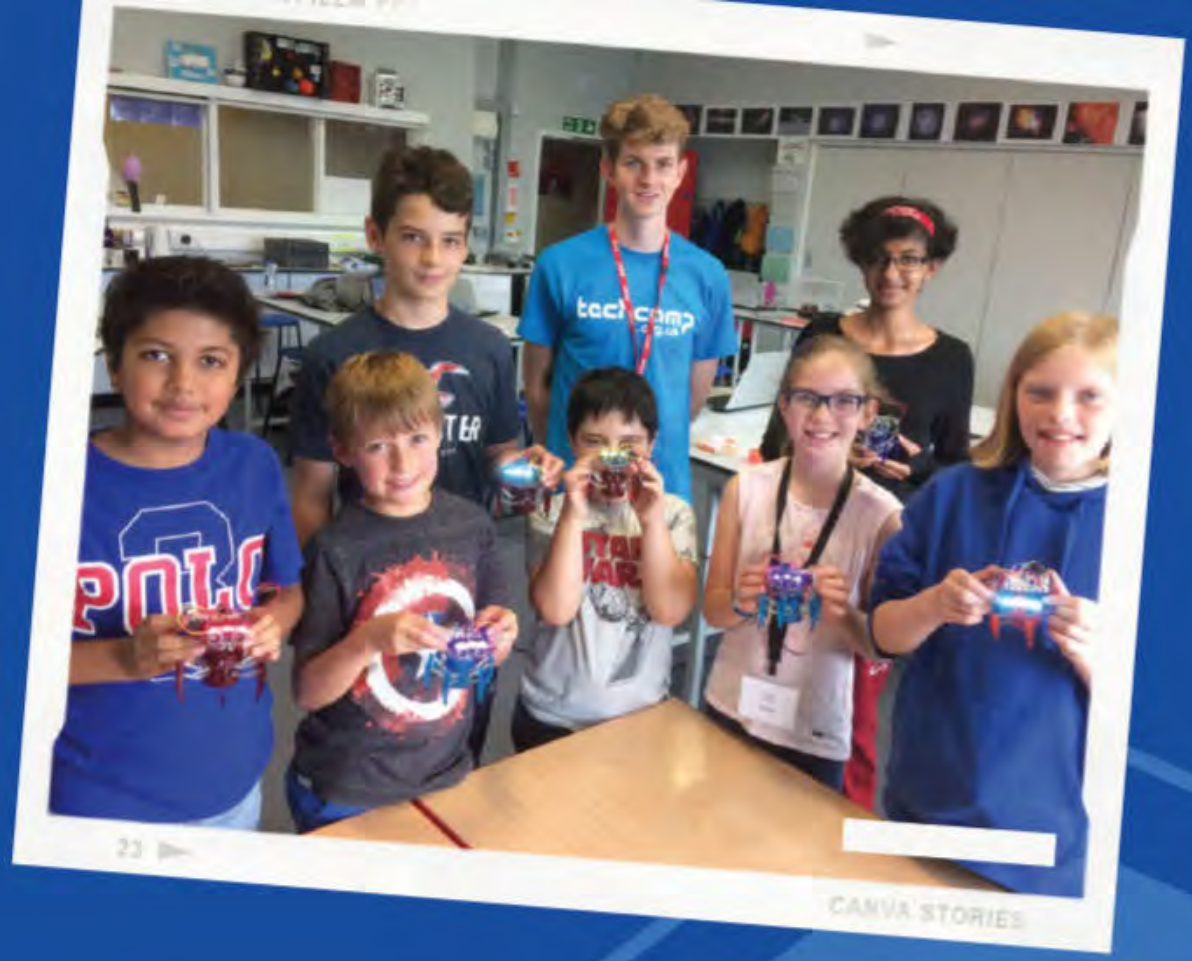

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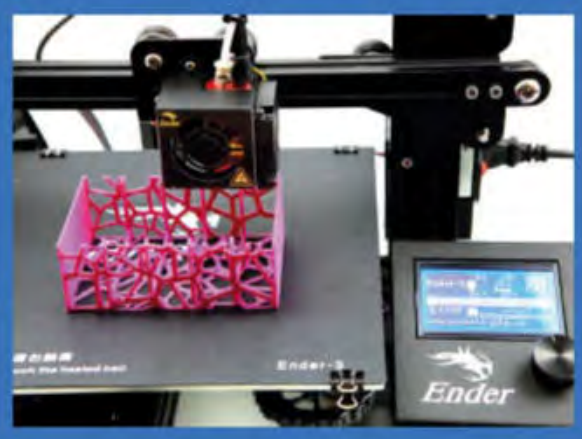

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