BEAVER DAM CONSTRUCTION

REUSABLE ROCKET TOUCHDOWN

WHY CHILLIES ARE SPICY

HOW IT WORKS

INSIDE A MEDIEVAL CASTLE

When will we set foot on Mars?

WILL THE SUN EXPLODE?

What happens when black holes collide?

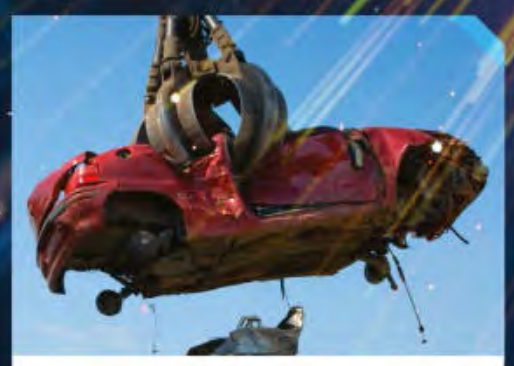
How do galaxies form?

Do space volcanoes exist?

30 AMAZING ANSWERS TO THE BIGGEST QUESTIONS IN THE UNIVERSE

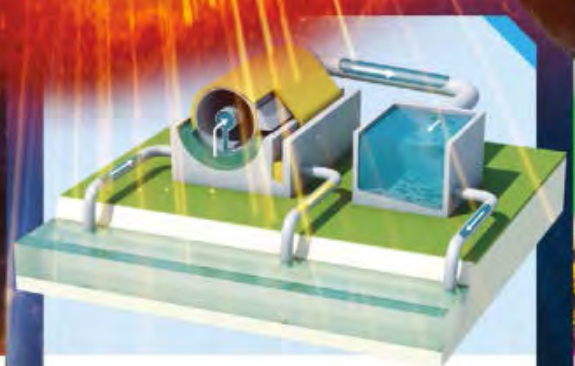
Why isn't Pluto a planet?

Win! ONE OF TEN BINOCULAR KITS



CAR CRUSHERS AND GIANT MAGNETS

HOW YOUR BODY USES STEROIDS



COOL CARBON CAPTURE TECH

MEET THE GARDEN POLLINATORS

FUTURE
ISSUE 165

Covid-safe Tech Camps

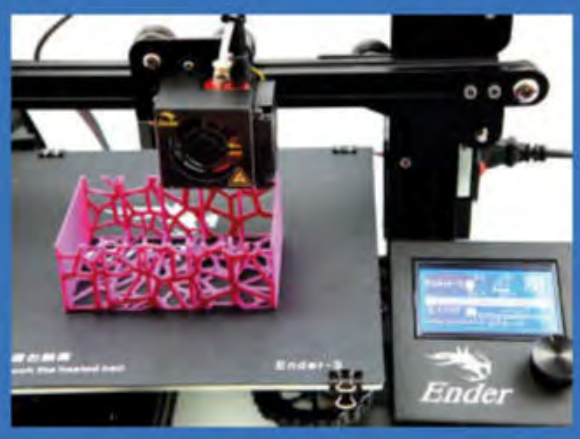
techcamp.org.uk

EASTER & SUMMER CAMP BOOKINGS NOW OPEN

Hard year for the KIDS?

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

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



Build your Own...

- 3D GAMES
- RACING DRONES
- LASER TAG SYSTEMS
- AI ASSISTANTS
- HIGH-SPEED CARS
- 3D PRINTERS

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

WELCOME

Issue 165

"This isn't the end for all stars. Some have enough mass to initiate further nuclear fusion"

HIGHLIGHTS

38 TOUCHDOWN
How reusable rockets make a perfect landing

46 CASTLE LIFE
Everyday medieval life in Caernarfon Castle

62 CAR CRUSHING
See inside a scrapyard and discover how vehicles are recycled

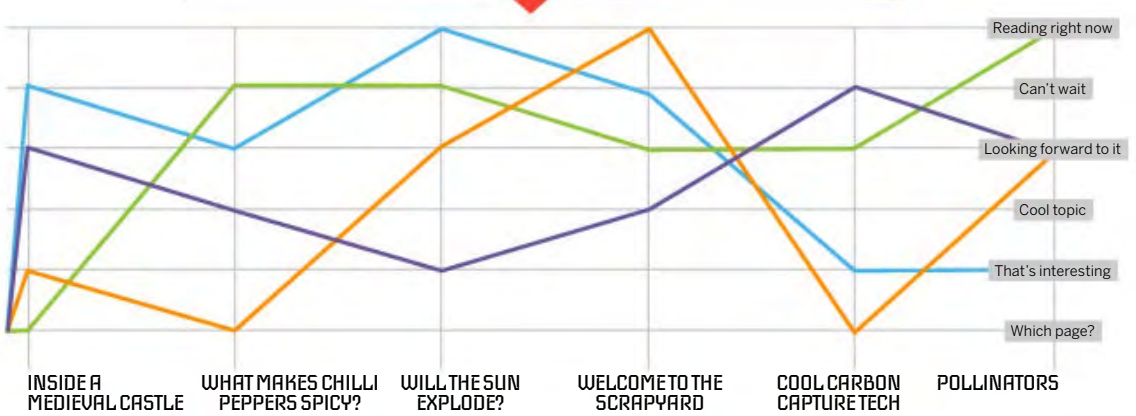
Will the Sun explode?
PAGE 26

SUBSCRIBE NOW
GO TO PAGE 24 FOR GREAT DEALS

The image above is an assembly of photographs taken by the Hubble Space Telescope in different wavelengths of light, after it snapped the same tiny patch of sky measuring a fraction of the angular diameter of the full Moon. It's called the eXtreme Deep Field, and in this sliver of sky we can see hundreds of galaxies that formed 600 million years after the Big Bang, now billions of light years from Earth. Thanks to *Star Trek*, space is often referred to as the 'final frontier', but it's really the first: however many new places and mysteries we've still to explore on Earth, there are many times that in the vastness of the universe. But we've solved some of those mysteries – read more on page 26. Enjoy!

Ben Biggs
EDITOR

WHAT WE'RE ANTICIPATING




NIKOLE
PRODUCTION EDITOR


SCOTT
SENIOR STAFF WRITER


AILSA
STAFF WRITER


DUNCAN
SENIOR ART EDITOR

FOR EXCLUSIVE HIW NEWS AND OFFERS, SIGN UP TO OUR MAILING LIST HOWITWORKSDAILY.COM/NEWSLETTER

© NASA

INSIDE

Issue 165

SPECIAL

26 Will the Sun explode?
What do astronauts eat? What if Earth stopped spinning? 30 amazing answers to space questions

SPACE

36 How to reuse a rocket
The latest space technology is making expensive disposable rockets a thing of the past

40 Can we create artificial gravity?
This space tech is based on well-known laws of physics and could change the future of space exploration

HISTORY

42 Inside a medieval castle AR
Take a look at life in a 13th-century Welsh castle and discover how castles evolved across Europe and beyond

48 What is a guillotine?
How this fearsome yet merciful execution device works

ENVIRONMENT

52 Pollinators
Discover the many species of birds, insects and mammals that keep our gardens blooming

58 How beavers construct dams
These clever critters are master architects, crucial to the health of the rivers they inhabit

TRANSPORT

60 Welcome to the scrapyard AR
Explore the breaking, crushing and melting machines that smash up cars

64 The fastest shoe in the world AR
Carbon-plate running shoes examined

TECHNOLOGY

66 Cool carbon capture technologies
The tools and techniques that could help undo global warming AR

72 What are NFTs?
These tokens are changing the way digital goods are traded

SCIENCE

74 Steroids: natural, medicinal and illegal
How these chemical messengers control everything from our mood to the way our body grows

78 What makes chilli peppers spicy?
Discover the compound that nature designed to put us off eating chillies

80 How is hair transplanted?
This surgical method allows healthy hairs to be moved around

AR ZONE

Bring the pages to life

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

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

SCAN HERE

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

REGULARS

06 Global eye
Science and tech news from around the world

22 Wish list
Gifts and gadgets for Father's Day

84 Brain dump
Your questions answered

90 Book reviews

92 Brain gym
Give your brain a workout with our puzzle pages

94 How to...
Grow bacteria at home on a petri dish

96 Letters
Have your say

98 Fast facts

MEET THIS ISSUE'S EXPERTS

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

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

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

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

JAMES HORTON
James works primarily in microbiology. He's an experienced science journalist, having written for a number of science magazines.

52

64

AR

36

Win!
ONE OF TEN BINOCULAR KITS
PAGE 82

42

AR

60

AR

58

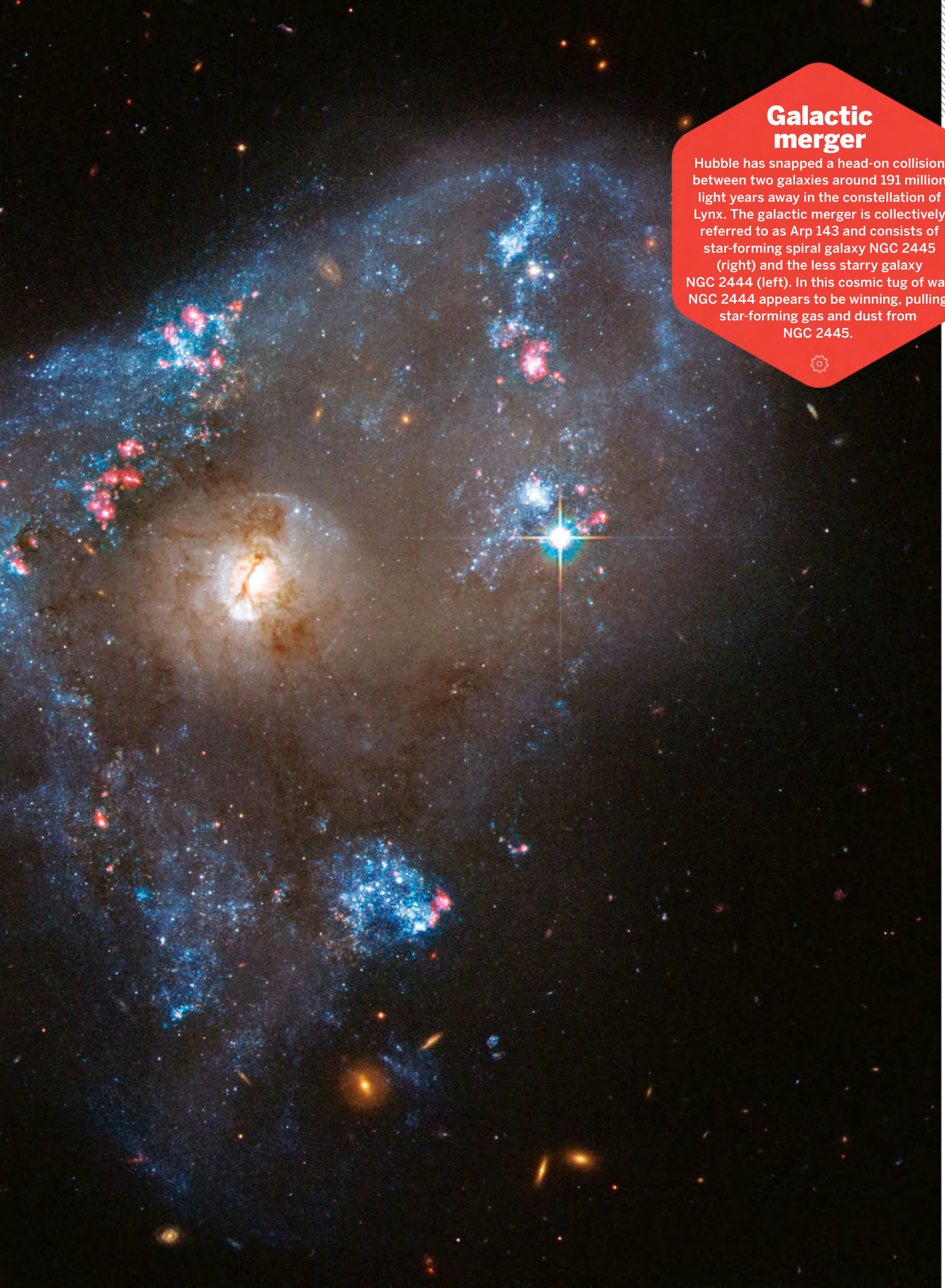
74

SUBSCRIBE NOW
GO TO PAGE 24 FOR GREAT DEALS

Mutually beneficial

This is a Clark's anemonefish (*Amphiprion clarkii*), often found between the bulbous tentacles of the bubble-tip anemone (*Entacmaea quadricolor*). Here they've found a home defended by stinging nematocyst cells. The fish brush against the stinging cells to acclimate, developing a mucus-like protective layer that coats their bodies. In return, the anemone is cleaned of parasites by the fish.

© Getty



Galactic merger

Hubble has snapped a head-on collision between two galaxies around 191 million light years away in the constellation of Lynx. The galactic merger is collectively referred to as Arp 143 and consists of star-forming spiral galaxy NGC 2445 (right) and the less starry galaxy NGC 2444 (left). In this cosmic tug of war, NGC 2444 appears to be winning, pulling star-forming gas and dust from NGC 2445.

© NASA, ESA, STScI, Julianne Dalcanton (Center for Computational Astrophysics / Flatiron Inst. and University of Washington/Joseph DePasquale (STScI)

Release the pollen

This shows the point at which a plant is ready to release its pollen and reproduce. The large green structures are the anthers of a flowering herbaceous plant called garden cosmos. A plant's anther is its male part, responsible for producing pollen. The spiky orange and pink grains are the plant's pollen. Once these grains are readily available on the surface of the anther, they're picked up by pollinators.

© Getty

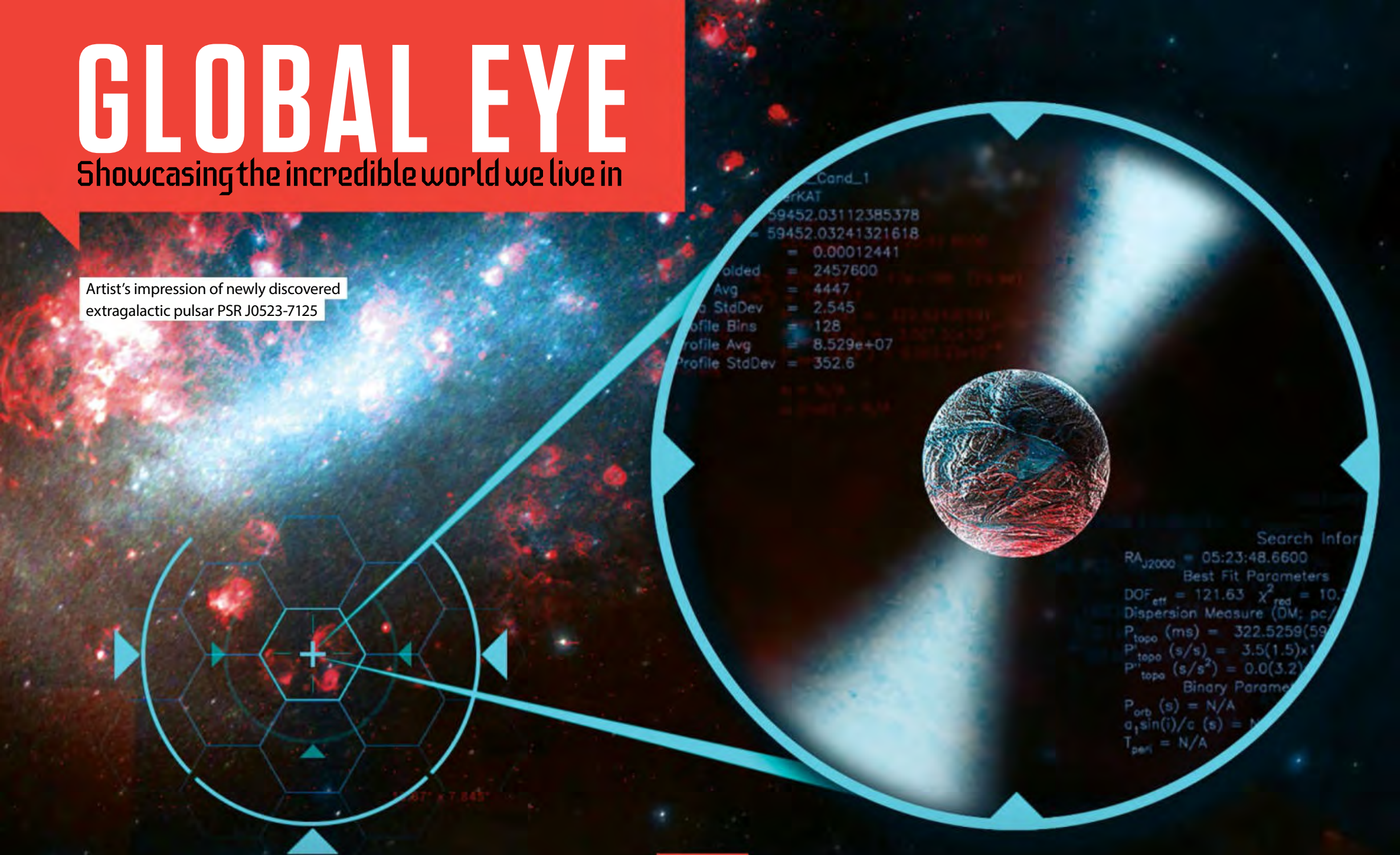
Watercolour lagoons

The waters surrounding the port town of Torrevieja, Spain, are home to different aquatic environments. Torrevieja Lagoon boasts a vibrant pink colour, a result of salt-loving algae like *Dunaliella salina*. The smaller, greenish lagoon on the right is known as La Mata. The water that fills La Mata is nowhere near as hypersaline – freshwater runoff from neighbouring mountains prevents salt from building up.

© NASA/JSC

GLOBAL EYE

Showcasing the incredible world we live in



Artist's impression of newly discovered extragalactic pulsar PSR J0523-7125

SPACE

Distant 'galaxy' revealed to be a massive pulsar

WORDS **BRANDON SPECKTOR**

A speck of light that scientists once wrote off as a distant galaxy may actually be the brightest pulsar ever detected outside the Milky Way. Named PSR J0523-7125 and located about 160,000 light years from Earth in the Large Magellanic Cloud – a satellite galaxy that orbits the Milky Way – the newly defined pulsar is twice as wide as any other pulsar in the region, and ten times brighter than any known pulsar beyond our galaxy. The object is so big and bright, in fact, that researchers originally interpreted it as a faraway galaxy. However, recent research suggests this is not the case. Using the Australian Square Kilometre Array Pathfinder (ASKAP) radio telescope in Western Australia, the study authors looked at space through a special pair of 'sunglasses' that block all wavelengths of light except for a specific type of emission associated with pulsars, the highly magnetised husks of stars. When PSR J0523-7125 showed up bright and clear in the results, the team realised they weren't looking at a galaxy at all, but at the pulsing corpse of a dead star.

Pulsars are highly magnetised, rapidly spinning remnants of exploded stars. As they rotate, streams of radio waves erupt from their poles, pulsing like lighthouse beams as those radio waves flash towards Earth. The radio waves emitted by pulsars are different from many other cosmic light sources, in that they can be circularly polarised – that is, the light's electric field can rotate in a circle as it propagates forward. This unique polarisation can provide scientists with a big clue in the tricky game of distinguishing pulsars from other distant light sources. In their new study, researchers used a computer program to filter out circularly polarised light sources from an ASKAP survey of pulsar candidates.

The team found that the presumed galaxy PSR J0523-7125 was emitting circularly polarised light, meaning it is almost certainly a pulsar. And because pulsars are incredibly small – typically packing a Sun's worth of mass into a ball no wider than a city – that means the object must be much closer, and much brighter, than scientists previously thought. Indeed, if this pulsar lurks in the nearby Large Magellanic Cloud, as the researchers suspect, then it is the single brightest pulsar ever found outside the Milky Way. That exceptional brightness explains why the object was misidentified as a galaxy after its initial detection, the researchers said. And by filtering out circularly polarised light from future star surveys, researchers may be able to unmask even more unusual pulsars that are hiding in plain sight. "We should expect to find more pulsars using this technique," said Tara Murphy, a radio astronomer at the University of Sydney in Australia. This is the first time we have been able to search for a pulsar's polarisation in a systematic and routine way."

The two merging galaxies in the VV689 system, nicknamed the 'angel wings'

SPACE

COSMIC ANGEL WINGS EMERGE FROM VIOLENT GALACTIC COLLISION

WORDS **SCOTT DUTFIELD**

An angel gets its wings as two distant galaxies collide in a stunning new image snapped by the Hubble Space Telescope. The galactic smashup took place in the VV689 system in Leo. The delicate wings formed as the two gravitationally bound objects collided and merged, deforming each other. While the two galaxies in the VV689 system are truly colliding, other images can be deceiving. "Unlike chance alignments of galaxies which only appear to overlap as seen from our vantage point on Earth, the two galaxies in VV689 are in the midst of a collision."

Many galaxy collisions are inevitable and were set in motion billions of years ago. By monitoring how galaxies move relative to each other, scientists can predict if and when galaxies will collide. The image of VV689 was discovered by the Galaxy Zoo citizen science project, in which hundreds of thousands of volunteers sift through a trove of data collected by different telescopes, including Hubble. After wading through images of galaxies, the public voted on a selection of noteworthy examples and submitted them for follow-up observations with Hubble's Advanced Camera for Surveys. Some of the examples included ring-shaped galaxies, galaxy spirals and a selection of galactic mergers, including VV689.

HISTORY

1,100-year-old 'altar of skulls' found in Mexico

WORDS **CALLUM MCKELVIE**

The grisly discovery of about 150 human skulls in a cave in Chiapas, Mexico, initially led local police to think they had come across a crime scene when they first inspected the site in 2012. Now, it's clear these victims didn't die recently: the skulls are pre-Hispanic and date from around 900 to 1200 CE and are most likely the victims of sacrificial rituals. Following the discovery, the bones were removed from the cave and taken to the state capital of Tuxtla Gutiérrez, where a joint operation between the police and the National Institute of Anthropology and History (INAH) began investigating the gruesome find.

The bones were discovered near the town of Frontera Comalapa in an area notorious for violence and immigrant trafficking. On top of that, it wasn't immediately clear that the human remains belonged to pre-Hispanic individuals, as piles of skulls from centuries-old Indigenous sites often have bashed-in skulls and are found in ceremonial plazas. But after analysing the remains, INAH researchers determined that the bones were over 1,000 years old. The remains are mostly of adult women, with the exception of skeletal remains of three infants. None of the skulls had teeth. The remains suggest that a tzompantli, or 'altar of skulls', once existed in the cave, said Javier Montes de Paz, a physical anthropologist at the INAH who helped determine the age of the bones. This is due to the fact that the remains are mostly skulls or fragments of skulls and that no complete skeleton was found.

Tzompantli were racks constructed out of wood on which Mesoamerican cultures would display the skulls of sacrificial victims. Mesoamerican scholar Juanita Garciagodoy wrote that "the detached heads of the sacrificial victims were pierced through the temples and slipped onto poles like beads on an abacus". Traces of aligned wooden sticks were reportedly found alongside the skulls, providing further evidence of a tzompantli, a record raised during the initial 2012 discovery noted.

This is not the first time a tzompantli may have been uncovered in Chiapas. In the 1980s, in Banquetas Cave, 124 skulls – all missing their teeth – were uncovered. Similarly, in 1993 during the discovery of the Devil's Tapesco Cave, five skulls were found that were thought to have been placed on a wooden tapesco, a kind of grid. Montes de Paz emphasised the need to continue archaeological research in the area.

Did you know?
Bone dissolves in around 20 years in fertile soil

A similar pile of skulls was excavated next to the Templo Mayor in Mexico City

© ESA/Hubble & NASA;W. Keel;J. Schmidt / ARC Center of Excellence for Gravitational Wave Discovery (OzGrav) / Getty

After a three-year shutdown, the LHC is once again smashing atoms together

SPACE

Large Hadron Collider breaks new record

WORDS SCOTT DUTFIELD

After a three-year hiatus, the world's most powerful particle accelerator is back in business and already breaking records. The Large Hadron Collider (LHC) – which is operated by the European Council for Nuclear Research (CERN) – is the world's largest particle accelerator and consists of a 17-mile ring of superconducting magnets buried between the border of France and Switzerland. The LHC uses these magnets to accelerate and smash together protons and ions to almost the speed of light, to help scientists understand particle physics, including the origin of mass, dark matter and antimatter. However, over the past three years, the LHC has been closed for maintenance and repairs.

"The machines and facilities underwent major upgrades during the second long shutdown of CERN's accelerator complex," said CERN's director for accelerators and technology, Mike Lamont. "The LHC itself has undergone an extensive consolidation program and will now operate at an even higher energy and, thanks to major improvements in the injector complex, it will deliver significantly more data to the upgraded LHC experiments." Now, beams of protons are once again circulating the LHC after it reopened on 22 April, and the LHC upgrades are already paying off.

After only three days of reopening, two beams of protons were accelerated to a record energy level of 6.8 trillion electronvolts per beam. The previous record occurred during the LHC's second run in 2015 when it reached energy levels of 6.5 TeV. This pilot run is the precursor to the third major run of the LHC, which is planned for this summer – called LHC Run 3. LHC scientists are gearing up to once again smash the new record by topping an energy output of 13.6 TeV. Along with colliding particles with greater energy, LHC scientists will collect data from more collisions than ever before. One of the experiments designed to study heavy-ion collisions – called A Large Ion Collider Experiment (ALICE) – can expect a 50 times increase in the number of ion collisions it can record thanks to the latest upgrade. LHC Run 3 is expected to last for three years until 2025, when it will once again have a prolonged shutdown between 2026 and 2030.

Did you know?
The LHC was built between 1998 and 2008

SPACE

CANADA MAKES MOON CRIMES ILLEGAL

WORDS BRANDON SPECKTOR

In April, Canadian Parliament proposed a measure that will make it illegal for Canadian astronauts to commit crimes on the Moon or while in orbit. The measure reads: "A Canadian crew member who, during a spaceflight, commits an act or omission outside Canada that if committed in Canada would constitute an indictable offense is deemed to have committed that act or omission in Canada." The bill adds that the same is true for crimes committed "on the surface of the Moon."

Canada recently joined NASA, the European Space Agency (ESA) and the Japan Aerospace Exploration Agency as members of the Lunar Gateway project – a mission to launch a small, international space station into orbit around the Moon, in order to support lunar surface operations such as the upcoming Artemis mission.

"The basic rule is that 'each partner shall retain jurisdiction and control over the elements it registers and over personnel in or on the Space Station who are its nationals," said the ESA. "This legal regime recognises the jurisdiction of the Partner State's courts and allows the application of national laws in such areas as criminal matters, liability issues and protection of intellectual property rights." In other words, a Russian who breaks a law in space is subject to Russia's law, an American to US law and so forth.

A new legal measure makes space crime illegal

HISTORY

Stonehenge was an ancient hunting hotspot

WORDS JONATHAN GORDON

Long before Neolithic people erected Stonehenge's majestic bluestones and sarsen stones, Mesolithic, or Middle Stone Age hunter-gatherers frequented the site, using it as a hunting ground. Later, farmers and monument builders moved into the region. Older research had suggested that before Stonehenge was built, the surrounding landscape included a closed-canopy forest. "There has been a long-running debate as to whether the monumental archaeology of Stonehenge was created in an uninhabited forested landscape or whether it was constructed in an already partly open area of pre-existing significance to late Mesolithic hunter-gatherers," the researchers wrote.

Now, new research shows that the area was historically an open woodland where large herbivores such as aurochs, an extinct cattle species, once grazed. Given the site's high use over time, it's likely that there was continuity between the Mesolithic hunter-gatherers and the Neolithic, or New Stone Age monument builders, the researchers said. In other words, it's not as if Stonehenge's builders suddenly 'discovered' the site for the first time; rather, it appears that people had known about this spot for centuries.

An early form of Stonehenge was built about 5,000 years ago, while the famous stone circle that still stands today was put together in the late Neolithic, around 2500 BCE Salisbury Plain, the plateau where Stonehenge sits, was considered a sacred area by ancient people and holds evidence of older structures dating back as far back as 10,500 years ago. The study centred around Blick Mead, an early hunter-gatherer spot on the edge of the Stonehenge World Heritage Site. Previous excavations of Blick Mead confirmed that Mesolithic people settled there prior to 8000 BCE, and the new research suggests humans continued to use this area into the Neolithic period.

To investigate Blick Mead, Samuel Hudson, a researcher at the University of Southampton, and colleagues dug a newly opened trench at the site and analysed ancient pollen, spores and DNA, as well as animal remains, found within the samples to learn more about how ancient people used the land during the late Mesolithic, between 5200 and 4700 BCE. Their analysis revealed the area used to have damp meadow conditions that sat next to an open grassland with a deciduous woodland close by. Wild animals would have grazed in those open fields, and hunter-gatherer communities that lived there 4,000 years prior to Stonehenge's construction would have hunted the grazers.

"The Stonehenge World Heritage Site is globally recognised for its rich Neolithic and Bronze Age monumental landscape, but little is known of its significance to Mesolithic populations," said the study's authors. But now it's clear that "hunter-gatherers had already chosen part of this landscape, an alluvial clearing, as a persistent place for hunting and occupation."

Stonehenge was a hunting hotspot for hunter-gatherers long before the monument existed

© Getty

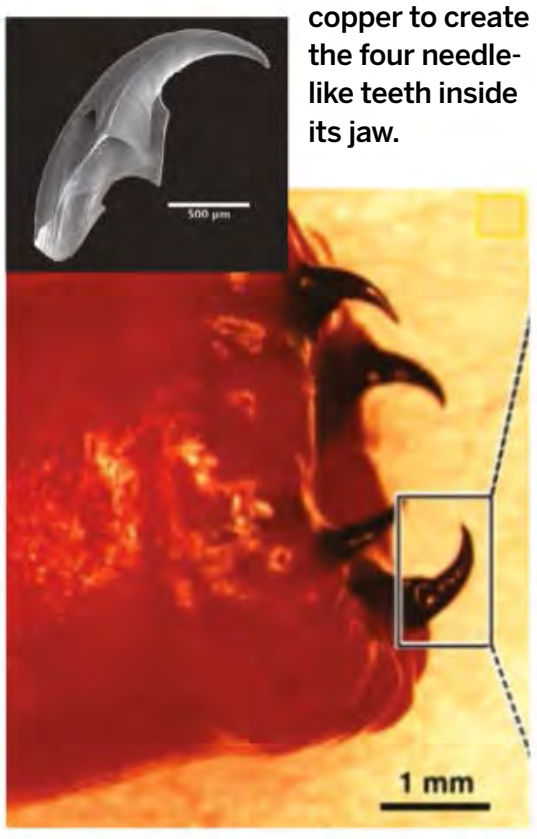
ANIMALS

VENOMOUS WORM GROWS DEADLY COPPER FANGS

WORDS **BEN TURNER**

A bloodworm species grows bizarre, deadly metal teeth with a single protein that transforms copper deposits located at the bottom of the seafloor into fearsome fangs. Bloodworms (*Glycera dibranchiata*) are segmented, bright-red marine worms that can grow to be 35 centimetres long and have two millimetre needle-like teeth made from a mixture of protein, melanin and copper, the highest concentration in any animal. As prolific hunters, upon contact with their prey the worm's jaw clamps shut and injects its victim with a deadly venom, paralysing the prey in preparation for being eaten alive.

To grow these copper-toothed jaws, which last through the worms' entire five-year life span, bloodworms harvest the metal from marine sediments on the seafloor. Then, through a chemical reaction, the worms fuse the copper to their jaws. The bloodworms begin this newly researched process by producing an amino acid called dihydroxyphenylalanine (DOPA) and using it to gather up seafloor copper into a thick, protein-rich liquid. Then, using the copper as a catalyst, the worm transforms DOPA into melanin, a polymer that can be combined with copper to create the four needle-like teeth inside its jaw.



Close-up image of a bloodworm fang

The man was infected with a type of roundworm called *Strongyloides stercoralis*

HEALTH

Man's rash caused by worms under his skin

WORDS **RACHEL RETTNER**

A rash that seemed to move across a man's entire body was due to worms crawling under his skin. The 64-year-old man, who lives in Spain, had been previously diagnosed with metastatic lung cancer and needed to be hospitalised because the cancer had spread to his spine and was pressing on his spinal cord. While in the hospital, doctors gave him a high dose of glucocorticoids, a class of steroids that fight inflammation and are sometimes used in cancer patients to help with side effects of chemotherapy and to aid in the treatment of certain cancers.

Four days after receiving the glucocorticoids, the man developed a rash in the form of red, wavy lines all over his body, along with mild diarrhoea. The man's stool tested positive for a type of roundworm called *Strongyloides stercoralis*. This roundworm is found worldwide, but is most common in the tropics, subtropics and in warm temperate regions. *S. stercoralis* larvae dwell in soil, so people usually become infected through contact with contaminated soil, but they can also become infected through contact with human waste or sewage. It's unclear how the man became infected, but he worked in sewage management. When the larvae come in contact with human skin, they can penetrate it and migrate through the body to the small intestine, where they burrow and lay their eggs. The eggs hatch inside the intestine. Most of the larvae are excreted in stool, but some can re-infect a host through a process known as autoinfection.

Most people infected with *S. stercoralis* don't develop symptoms, though some may develop non-specific symptoms such as abdominal pain, nausea, diarrhoea or constipation, as well as a rash where the worm entered the skin. But the infection can be life-threatening in people who take steroid medications, which suppress the immune system. The man's treatment with glucocorticoids predisposed him to this serious form of the infection, known as strongyloides hyperinfection syndrome. In this form, the worm's life cycle is accelerated, leading to a much higher number of worms in the body than in a regular case. The hyperinfection syndrome can also lead to the spread of the worms to lungs, liver, brain, heart and urinary tract; and can lead to death in up to 80 per cent of cases because the diagnosis often is delayed. Fortunately, the man received prompt treatment with the anti-parasitic drug ivermectin and his symptoms abated.

Did you know?
There are over 15,000 known species of roundworms

ANIMALS

Extinction threatens one in five reptile species

WORDS **DAVID CROOKES**

More than one-fifth of reptile species across the globe are threatened with extinction, with those living in forests found to be in far greater danger than those inhabiting arid areas. In the most comprehensive extinction-risk assessment ever carried out on reptiles, researchers discovered that as many as 21.1 per cent of all known species were at risk. Prior to this new research, there had been no formal attempt to determine how many reptiles were at risk of extinction. Instead, conservationists relied on the International Union for Conservation of Nature's (IUCN) Red List of Threatened Species, which provides the risk status of birds, mammals and amphibians.

By using the Red List's criteria, the study researchers discovered that 1,829 reptile species were vulnerable, endangered or critically endangered – a total of 21.1 per cent of the known species. They also found that 57.9 per cent of turtles and 50 per cent of crocodiles are threatened; overall, 40.7 per cent of amphibians, 25.4 per cent of mammals and 13.6 per cent of birds are considered threatened by the IUCN, according to the Red List.

The global study was carried out over 15 years with the help of 961 researchers representing 24 countries across six continents. Researchers assessed pre-existing surveys and datasets of turtles, crocodiles, lizards, snakes and tuatara in Africa, the Americas, Asia, Australia, the Caribbean, Europe and Oceania. Tuatara are endemic to New Zealand and are considered to be the last survivors of an order of reptiles that can be traced back to the Triassic period.

The authors said reptiles were being threatened globally by agriculture, logging, urban development and invasive species. This would explain why the researchers found that 30 per cent of reptiles living in forests were at risk of extinction, compared to 14 per cent of reptiles living in arid habitats. The researchers also found that threatened reptiles were concentrated in Southeast Asia, West Africa, northern Madagascar, the Northern Andes and the Caribbean – a finding that will enable conservationists to concentrate their efforts in places with the greatest need. The study also narrowed down the primary threats for different groups of reptiles. For instance, lizards that live on islands are threatened by predators that have been introduced there by people. By comparison, hunting and poaching are the main threats to turtles and crocodiles.

How climate change is threatening reptiles is not known for certain. However, research points to climate change as a looming threat because it reduces the window when temperatures are right for the cold-blooded animals to forage, and it can also alter the sex ratios of offspring in species where that is determined by temperature. "Reptiles are not often used to inspire conservation action, but they are fascinating creatures and serve indispensable roles in ecosystems across the planet," said Sean T. O'Brien, president and CEO of NatureServe.

Human settlements, the pet trade, traditional medicine, logging and agriculture are pushing some reptile species towards extinction

© Getty

PLANET EARTH

Underwater Antarctic volcano triggers 85,000 earthquakes

WORDS **TIA GHOSE**

A long-dormant underwater volcano near Antarctica has woken up, triggering a swarm of 85,000 earthquakes. The swarm, which began in August 2020 and subsided by November of that year, is the strongest earthquake activity ever recorded in the region. The quakes were likely caused by a 'finger' of hot magma poking into the crust, according to recent research. "There have been similar intrusions in other places on Earth, but this is the first time we have observed it there," said Simone Cesca, a seismologist at the GFZ German Research Centre for Geosciences in Potsdam. "Normally, these processes occur over geologic time scales" as opposed to over the course of a human life span.

The swarm occurred around the Orca Seamount, an inactive volcano that rises 900 metres from the seafloor in the Bransfield Strait, a narrow passage between the South Shetland Islands and the northwestern tip of Antarctica. In this region, the Phoenix tectonic plate is diving beneath the continental Antarctic plate, creating a network of fault zones, stretching some portions of the crust and opening rifts in other places. Scientists at the research stations on King George Island, one of the South Shetland Islands, were the first to feel the rumblings of small quakes. The team wanted to understand what was going on, but King George Island is remote, with just two seismic stations nearby.

Researchers used data from those seismic stations, as well as data from two ground stations for the global satellite navigation system, to measure ground displacement. They also looked at data from more far-flung seismic stations and from satellites circling Earth that use radar to measure shifting at ground level. The nearby stations are rather simple, but they were good for detecting the tiniest quakes. By piecing these data together, the team was able to create a picture of the underlying geology that triggered this massive earthquake swarm.

The two largest earthquakes in the series were a magnitude 5.9 quake in October 2020 and a magnitude 6.0 quake in November. After the November quake, seismic activity waned. The quakes seemed to move the ground on King George Island around 11 centimetres. Only four per cent of that displacement could be directly explained by the tremor; the scientists suspect the movement of magma into the crust largely accounts for the ground shift. "We think the magnitude 6.0 created some fractures and reduced the pressure of the magma dike," Cesca said. If there was an underwater eruption at the seamount, it likely happened at that time. But as of yet, there is no direct evidence for an eruption; to confirm that the massive shield volcano blew its top, scientists would have to send a mission to the strait to measure the bathymetry, or seafloor depth, and compare it to historical maps.

Scientists found the *Nannaria swiftae* millipede in Van Buren County, Tennessee

ANIMALS

Millipede species named after Taylor Swift

WORDS **AILSA HARVEY**

Scientists have described a previously unknown species of millipede in the Appalachian mountains – and named it after pop superstar Taylor Swift. Researchers discovered the millipede, along with 16 other newly described millipede species, as part of an extensive research project to sequence the DNA of species in the *Nannaria* genus, known as twisted-claw millipedes, so-named for the twisted and flattened claws on their front legs. Experts analysed 1,835 millipede specimens, most of which they collected under leaf litter, trees and rocks, in forest habitats across 17 US states.

Derek Hennen, lead study author and a researcher at Virginia Tech in Blacksburg, Virginia, is a fan of the American singer-songwriter Taylor Swift, and so he decided to name one of the millipede species *Nannaria swiftae*. "Her music helped me get through the highs and lows of graduate school, so naming a new millipede species after her is my way of saying thanks," said Hennen. The researchers discovered *N. swiftae*, known by the common name 'Swift twisted-claw millipede' in Van Buren County, Tennessee. *N. swiftae* play a vital role in their ecosystem by releasing nutrients into the soil of forest floors. As they eat decaying leaf litter, the millipedes break down the organic matter, aiding decomposition. Often these burrowing arthropods are completely buried in soil, making them challenging to find and capture.

Many of the species in the new study had previously been collected and preserved in museums and universities but had not yet been described scientifically. All of the newly described species measure between 18 and 38 millimetres long and have white legs and brown or black bodies spotted with red, white or orange. Features separating *N. swiftae* from the very similar species *N. austricola* and *N. scutellaria* include bumps on the modified legs.

Did you know?
Eumillipes persephone is a millipede with 1,300 legs

Hennen named another of these newfound millipede species after a person: *Nannaria marianae* was named after his wife, Marian. Not all of the newly described Appalachian millipedes were named after people; some names reference specific plants that grew near specimen collection sites. These include *N. liriodendra*, named after tulip trees (*Liriodendron tulipifera*), and *N. rhododendra* after rhododendrons. "Thanks to the plants, these millipedes have great habitat to live in," Hennen said in a tweet.

With the naming of *N. swiftae*, Swift joins a select group of musicians with animal namesakes, including Lady Gaga, whose namesake is a treehopper from Nicaragua named *Kaikaia gaga*; Elton John, a shrimp-like crustacean named *Leucothoe eltoni*, and Shakira, a parasitic wasp named *Aleiodes shakirae*.

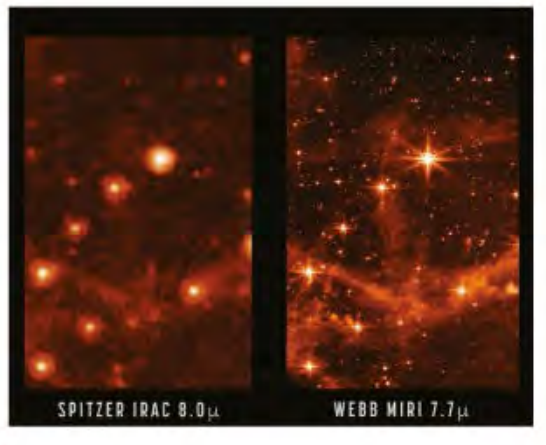
SPACE

JAMES WEBB TELESCOPE REACHES 'PERFECT' ALIGNMENT

WORDS **BRANDON SPECKTOR**

All four science instruments on NASA's James Webb Space Telescope (JWST) have achieved perfect alignment in advance of the telescope's debut this summer. "I'm delighted to report that the telescope alignment has been completed with performance even better than we had anticipated," Michael McElwain, a JWST project scientist, said. "There's no adjustment to the telescope optics that would make material improvements to our science performance."

To illustrate the telescope's readiness, NASA shared a teaser image taken by JWST's Mid-Infrared Instrument, or MIRI. The new image shows a side-by-side comparison of observations of a nearby galaxy taken by JWST, versus observations of the same galaxy taken previously by NASA's now-retired Spitzer Space Telescope. While the Spitzer image shows a blur of seven or so nearby stars located in the Large Magellanic Cloud, the JWST image of the same region captures the foreground stars in sharp detail, offset by wispy clouds of interstellar gas and hundreds of background stars and galaxies. With its instruments aligned, JWST awaits a final instrument calibration before it officially begins studying distant stars later this summer.



The Large Magellanic Cloud, as seen by NASA's Spitzer Space Telescope (left) and the new JWST (right)

© Getty / Newcastle University NASA;JPL-Caltech;ESA;CSA;STScI / Hennen D.A.;Means J.C.; Marek P.E

WISH LIST

FATHER'S DAY GIFT GUIDE

STARSENSE EXPLORER LT 114AZ

WWW.CELESTRON.COM £219 / $239.95

Celestron has reinvented the manual telescope with the StarSense Explorer – the first telescope that uses patented sky-recognition technology and your smartphone to analyse the night sky and calculate its position in real time. The StarSense Explorer is ideal for beginners thanks to the app's user-friendly interface and detailed tutorials, like having your own personal tour guide of the night sky. With StarSense Explorer, simply dock your phone, launch the app and explore the universe. Locating objects has never been easier, faster or more accurate. After you align your phone to the telescope's optics, StarSense Explorer generates a list of all the best celestial objects currently visible and can guide you to their locations. Even if you live in a light-polluted city, StarSense Explorer is advanced enough to pick out a whole range of celestial objects, including other planets, star clusters and nebulae. The entire telescope kit weighs around five kilograms, so it's perfectly portable and easy to bring anywhere to observe.

WORLD OF WARSHIPS

WWW.WORLDOFWARSHIPS.EU FREE

A free-to-play naval action MMO with a focus on epic sea battles from the first half of the 20th century. To celebrate Father's Day, *World of Warships* is giving you the chance to start your naval career with the following invite code: BOOM. By entering the code at **playships.eu** and creating an account, you'll receive digital gifts that will be delivered to your port. The invite code is only available for new players and must be used prior to account creation.

CLASSIC BATTLEFIELD TOURS

WWW.CLASSICBATTLEFIELDTOURS.COM FROM £1,250 (APPROX. $1,600)

Classic Battlefield Tours revisits some of the most interesting and defining moments in UK military history, including a cross-country tour to explore the English Civil War and a tour of Scotland's battlefields and stunning scenery. Standard tours are designed for groups of up to 15 people, unless otherwise stated. Tours are bespoke for groups, families or individuals and can be tailor made to discover a particular period and location of military history.

THE ALIEN ABDUCTION LAMP

WWW.ABDUCTIONLAMP.COM

£99 / $129

This is more than just a lamp – it's a work of art that adds an inimitable value to any space. If your dad's desk is looking a little drab and needs some new life, this lamp is full of it – but it's not life as we know it. Aboard the flying saucer lamp is an LED light source, glow-in-the-dark alien pilots, a scratch-resistant acrylic tractor beam, a USB connection and, most importantly, a cartoon bovine abductee. The Alien Abduction Lamp is the perfect gift for a sci-fi enthusiastic father.

MEMBERSHIP TO THE SOCIETY FOR POPULAR ASTRONOMY (SPA)

WWW.POPASTRO.COM

£25 PER YEAR (UK)

Membership would be a great gift for stargazers this Father's Day. Membership to SPA includes a bi-monthly copy of its unique magazine, *Popular Astronomy*, for astronomy and space news, observational guides and more. The SPA also offers meetings – both in-person and virtually – events and courses for budding astronomers. There are also SPA experts on hand for astronomy help and advice.

STARSENSE EXPLORER DX 102AZ

WWW.CELESTRON.COM

£379.99 / $429.93

The DX 102AZ works harmoniously with your smartphone to track and analyse overhead star patterns and calculate your exact position. With a large 102mm objective lens, this telescope has enough light-gathering ability to bring out impressive detail in celestial objects. You can expect sharp, bright views of Jupiter's four Galilean moons, its cloud bands and Great Red Spot, the rings of Saturn and much more. The telescope also includes a 90-degree erect image diagonal so you can use it during the day to view wildlife and landscapes. This telescope also comes with an ultra-stable alt-azimuth mount that provides a sturdy foundation for observing.

GREAT BRITISH HISTORY MAP

WWW.MARVELLOUSMAPS.COM

£14.99 (APPROX. £18.80)

Perfect for history buff dads. Multistoried Britain is a historical hotbed, heaving with clues from the past to inspire your future adventures. This history-centric map features over 1,500 visitable historical locations, journeys and stories. This cartographical blast from the past will inspire some intrepid time travel through bygone Britain.

Save 10% with the exclusive code DADSHISTORY

BUILD YOUR OWN BINOCULARS

WWW.BUILDYOUROWNKITS.COM £19.99 (APPROX. $25)

A great gift and fun family project to enjoy this Father's Day, this binocular is constructed using robust sustainable cardboard without the need for extra glue or adhesives. Everything you need is provided in the kit – simply follow the instructions, press out the 67 precut parts, build and you're ready to explore.

AIRFIX SMALL STARTER SET SUPERMARINE SPITFIRE MKVC

WWW.AIRFIX.COM

£11.99 / $17.99

For military and model making fans alike, Airfix has transformed one of the most famous aircraft that's ever taken to the skies – the Supermarine Spitfire inter-war seaplane – into a new build-and-paint starter set. The set includes child-friendly paints, brushes and glues along with a new 'shadow-effect' mount stand.

QUICKBUILD FORD MUSTANG GT

WWW.AIRFIX.COM £14.99 / $19.99

The Ford Mustang GT is a great gift for car lovers and model enthusiasts. The pre-coloured pieces simply push together to build an impressive model which can then be decorated with the included self-adhesive stickers. Upon completing the construction of the model car, each of the building blocks blends seamlessly together, leaving no evidence of any building bricks.

© Celestron / Classic Battlefield Tours / Hornby / The Alien Abduction Lamp / Paper Engine / Squeaky Wheels Limited / Wargaming.net

TIME-LIMITED OFFER

SUBSCRIBE TODAY AND SAVE UP TO 58%

WHY SUBSCRIBE?

- **Brilliant value – save money on the cover price**
- **Free home delivery**
- **You'll never miss an issue**

SUBSCRIBE NOW

www.magazinesdirect.com/hiw/A45V

or call **0330 333 1113** and quote **A45V**

PRINT EDITION

SAVE 50%

Three issues for just £8.93

13 issues of **How It Works** in print over 12 months, with payments every three months

PRINT + DIGITAL EDITION

SAVE 58%

Three issues for just £12.68

13 issues of **How It Works** in print and digital over 12 months, with payments every three months

DIGITAL EDITION

SAVE 50%

Three issues for just £6.48

13 issues of **How It Works** in digital over 12 months, with payments every three months

*Terms and conditions: Offer closes 31 July 2022. Offer open to new UK subscribers only. Pricing is guaranteed for the first 12 months and we will notify you in advance of any price changes. Please allow up to six weeks for delivery of your first subscription issue, or up to eight weeks overseas. The full subscription rate is for 12 months (13 issues) and includes postage and packaging. If the magazine ordered changes frequency per annum, we will honour the number of issues paid for, not the term of the subscription. For full terms and conditions, visit **www.magazinesdirect.com/terms**. For enquiries please call +44 (0) 330 333 1113. Lines are open Monday to Friday 9am to 5pm UK time or email **help@magazinesdirect.com**. Calls to 0330 numbers will be charged at no more than a national landline call and may be included in your phone provider's call bundle.

SPECIAL

30 AMAZING ANSWERS TO THE BIGGEST QUESTIONS IN THE UNIVERSE

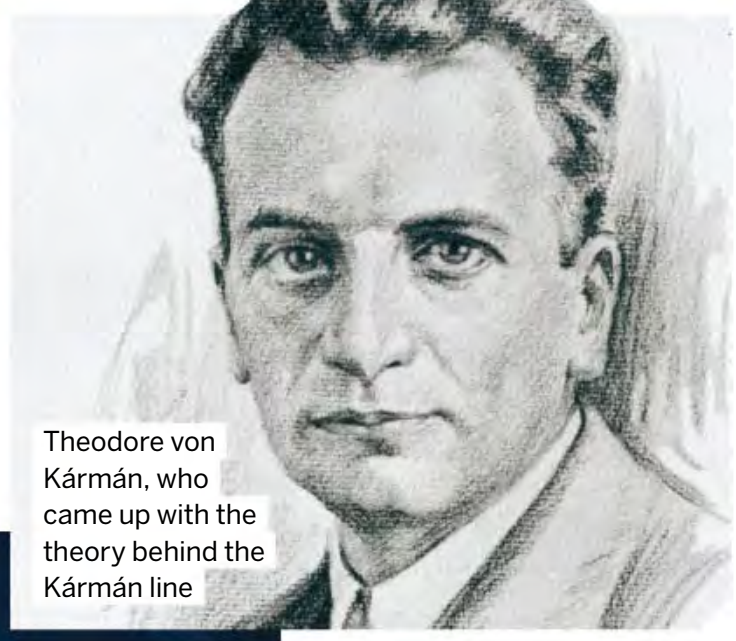
WORDS ANDREW MAY, MARK SMITH & ROBERT LEA

DID YOU KNOW? Air density at sea level is over a million times greater than at the Kármán line

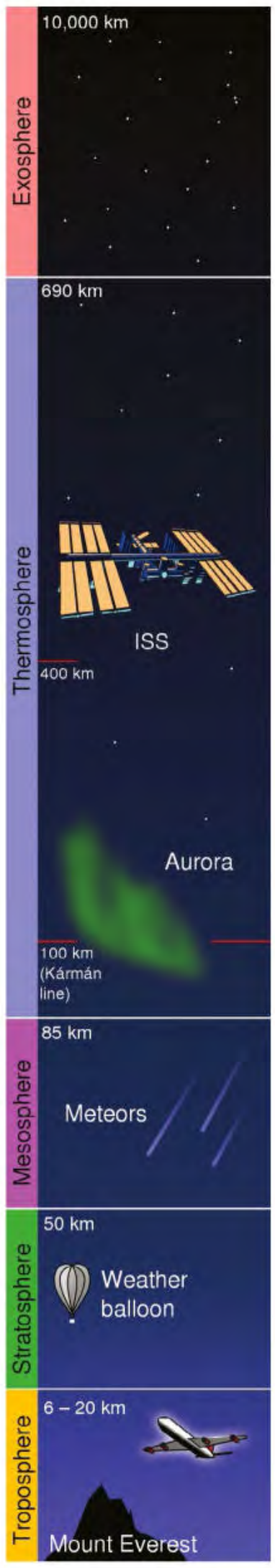
WHERE DOES SPACE START?

1 There's an easy answer to this question: space starts at the top of Earth's atmosphere. The hard part is saying just where that 'top' is. The fact that the atmosphere doesn't end abruptly, but just gets thinner and thinner, means there's no hard and fast upper bound you can put on it. To some extent, it's simply a question of coming up with an easily memorable number that's in the right ballpark. To NASA and the US military, for example, space starts at an altitude of 50 miles. To the international community, on the other hand, it starts at 100 kilometres, which at 62 miles is a little higher. In the middle of the 20th century, a Hungarian-American aerospace engineer named Theodore von Kármán asked a simple question: At what altitude does the speed needed to keep an aircraft aloft through aerodynamic lift become so high that it exceeds orbital velocity? He did the necessary calculations, then rounded the answer to that memorable figure of 100 kilometres, or 62 miles. This altitude is now known as the 'Kármán line' in his honour.

Earth's atmosphere appears very thin in this view from the International Space Station



Theodore von Kármán, who came up with the theory behind the Kármán line



EXOSPHERE
The outermost layer of the atmosphere, the exosphere reaches as far as 6,200 miles from Earth's surface.

THERMOSPHERE
Extending from about 53 miles up to 375 miles, this layer includes the Kármán line and many satellite orbits.

MESOSPHERE
This atmospheric layer, up to 53 miles altitude, is still dense enough to cause falling meteors to burn up.

STRATOSPHERE
This intermediate layer, up to 31 miles altitude, accounts for around a fifth of the atmosphere's gas content.

TROPOSPHERE
Extending up to around 12 miles altitude, this is where most aircraft fly – and where most weather happens.

LAYERS OF THE ATMOSPHERE

Earth's atmosphere, though it gets very thin, extends a surprisingly long way

WHAT IF EARTH STOPPED SPINNING?

2 **Earth has so much rotational energy – over 200 quintillion gigajoules – that it will take billions of years to lose it all. If it slowed to the point where it was tidally locked to the Sun, one side would be in perpetual daylight and the other side in perpetual night.**

Earth has so much rotational momentum it would be hard to stop it spinning

WHERE ARE THE WORLD'S SPACEPORTS?

3 **Spaceports are dotted all over the world in locations where you're most likely to find functioning private or state-run space programs. Since they were first developed, 28 spaceports have been used to launch satellites into orbit, with 22 active today.**

The Kennedy Space Center at Cape Canaveral in Florida, is probably the world's best known spaceport, The privately operated Rocket Lab Launch Complex One in New Zealand serves as a commercial launch site. The European Space Agency's Guiana Space Centre in French Guiana, The Jiu Quan Satellite Launch Center, China, and the Baikonur Cosmodrome in Kazakhstan are among the other best known ones.

Space Shuttle Atlantis (foreground) sits on Launch Pad A and Endeavour on Launch Pad B at the Kennedy Space Centre in Florida

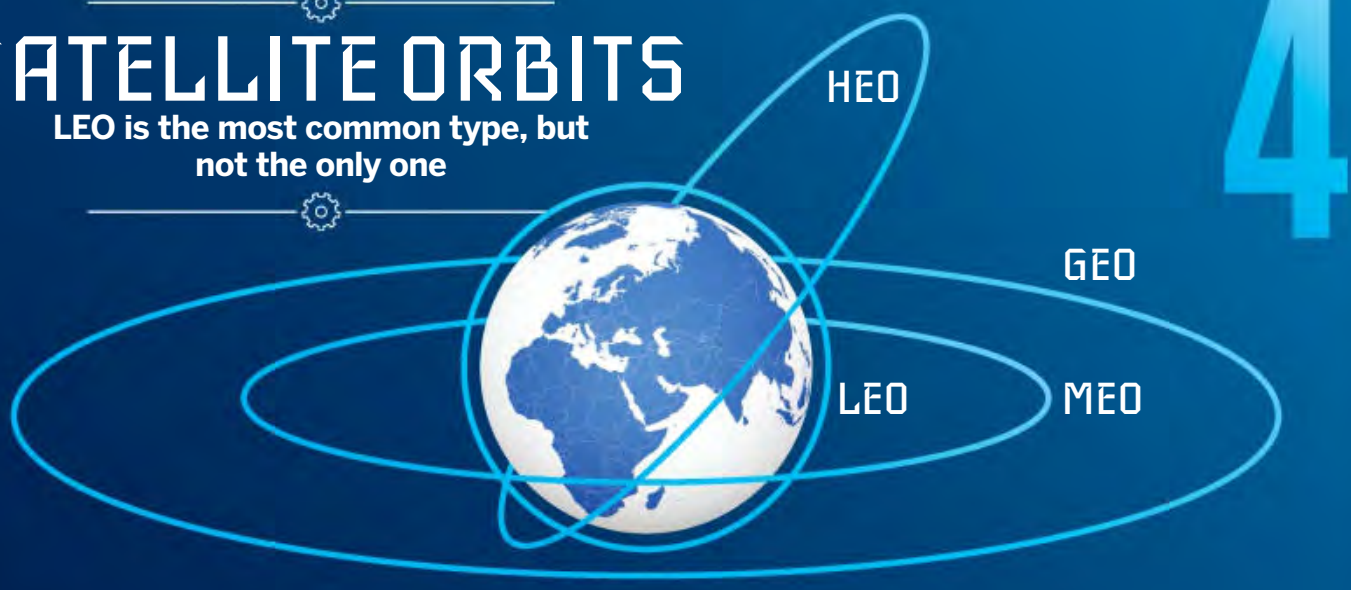
© Getty / NASA / NOAA

WHAT IS LOW-EARTH ORBIT?

In very simple terms, a low-Earth orbit (LEO) is exactly what it says: an orbit around Earth at an altitude that lies towards the lower end of the range of possible sustainable orbits. The majority of satellites are to be found in LEO, as is the International Space Station. In order to remain in such an orbit, a satellite has to travel at around 17,500 miles per hour, at which speed it takes around 90 minutes to complete an orbit of the planet.

SATELLITE ORBITS

LEO is the most common type, but not the only one



LEO
62 TO 930 MILES
Most satellites – and the International Space Station – are found in low-Earth orbit.

MEO
3,100 TO 6,200 MILES
Medium-Earth orbit is useful for certain applications, such as navigation satellites.

GEO
22,370 MILES
Geostationary satellites rotate at the same speed as Earth, so they appear to 'hover' over a fixed location.

HEO
LEO TO GEO
While LEO, MEO and GEO are near-circular, highly elliptical orbits alternate between low and high altitudes.

4

WHAT WOULD HAPPEN IF ALIENS MADE CONTACT?

7 This is more likely to happen in the form of a message, such as a radio signal, than a visit. The scientists searching for such signals follow protocols to sift out hoaxes and natural sources, but if a message is proved genuine it would be made public.

Radio telescopes scour the skies in search of messages from extraterrestrial civilisations

DOES THE SUN ROTATE?

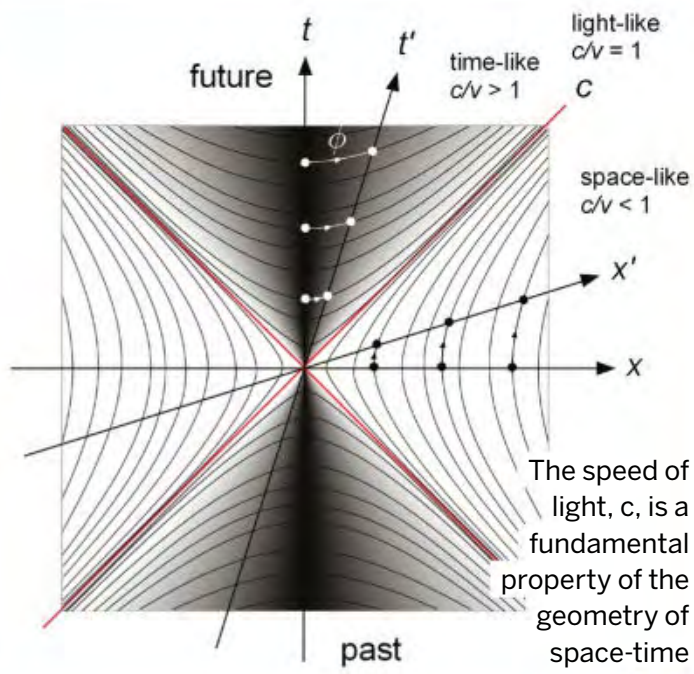
8 **Yes. We've known since the 17th century that the Sun rotates. Like the majority of the Solar System's planets, this rotation is counter-clockwise, but as well as being significantly slower than that of Earth, the Sun's rotation is much more complex than the rotation that gives rise to our day. While Earth and the other inner planets are composed of solid rock, the Sun is an ultrahot ball of dense ionised gas – mainly hydrogen and helium – called plasma. That means the way it rotates is different to the way our planet, Mars, Venus, and Mercury do. The Sun experiences something called differential rotation. This means its rotation proceeds at different rates depending on where you look at the star.**

The Sun does rotate – but not at a uniform speed

HOW DO ISS ASTRONAUTS GO TO THE TOILET?

5 Pretty much like anyone on Earth, except that waste is directed where it needs to go with the aid of air currents rather than gravity. Having said that, space toilets aren't cheap – the latest one on the ISS cost $23 million (£18.5 million) to develop.

A space toilet is a bit like an ordinary toilet, but more complex and much more expensive



The speed of light, c, is a fundamental property of the geometry of space-time

IF LIGHT SPEED IS IMPOSSIBLE, HOW DOES LIGHT ACHIEVE IT?

6

The speed c, which we call light speed, is a basic parameter affecting the geometry of space and time. One of its consequences is that objects possessing mass can never reach that speed, but another is that massless particles – such as photons of light – must always travel at c.

DID YOU KNOW? The very first satellite, Sputnik 1, was launched into an elliptical low-Earth orbit on 4 October 1957

WHAT DO ASTRONAUTS EAT?

Staying on the International Space Station takes a huge toll on astronauts' bodies. The very low gravity – known as microgravity – leads to drops in bone density of up to 20 per cent on a six-month mission, as well as loss of muscle mass. If they don't eat and exercise properly, it can be difficult to move on return and can even lead to them easily breaking bones.

Providing their bodes with vitamins and calcium is vital and lots of planning goes into it. In fact, on the ISS, each food package has a barcode that astronauts have to scan so mission control can keep track of what they're eating.

Also, because gravity has an effect on how fluids behave in our bodies, it can have an impact on how astronauts taste and smell, so space food usually tastes very strong. Expect spicy flavours like peppers and chilli if you ever get invited for dinner on the ISS.

Did you know?

Astronauts dispose of their food waste in a special trash compactor

The first man to eat in space was the first man in space himself – Soviet cosmonaut Yuri Gagarin in 1961. While aboard Vostok 1, he chowed down on beef and liver paste, squeezing it into his mouth from an aluminium tube the way we'd squeeze toothpaste.

Things have changed a lot since then, with the meals astronauts eat now looking and smelling a lot like what we would enjoy here. They even have cutlery, chairs and tables. They have fresh fruit and vegetables, kept in the ISS' fridge. Then there's meat and dairy, which get a dose of ionising radiation before being packaged to give them a longer shelf life and kill bacteria.

Low-moisture foods also stop the spread of bacteria, with things such as nuts, biscuits and chocolate being prepackaged as snacks. Salt and pepper is available in liquid form, because the particles could clog up the ventilation system.

There are also meals that have had water taken out of them and re-applied on the ISS to make them edible, much like some of the freeze-dried noodle and pasta snacks you might have in your own lunchbox.

From vegetables and fruit to delicious desserts, there are over 100 items on the space station's menu to help the crew get the up to 3,300 calories which they need each day to perform their duties. They have three regular mealtimes every day, with snacks provided for when they get an attack of the space munchies.

Astronauts try and sit down at the table for a proper meal to make things feel as normal as possible

TASTY SELECTION OF ASTRONAUT FOOD

The ISS crew can tuck into all their favourites just like they would down on Earth

1 MEAT FEAST
Meat can be freeze dried so it lasts longer. The vitamins and iron are really important for keeping astronauts strong.

2 CUTLERY, COME BACK
Magnets keep the cutlery from floating away in microgravity. How frustrating would that be if you were hungry?

3 SWEET TREATS
Just because you're in space doesn't mean you have to leave your favourite candy behind.

4 SNACK ATTACK
Biscuits and other snacks are perfect for dealing with a rumbling tummy. They've got very little moisture so they last for ages.

5 SPACE POPEYE
Even in space there's no escape from your five a day; vacuum packing helps preserve the vitamins and minerals in food like spinach.

© NASA / Getty / Encyclopaedia Britannica / Wiki: Maschen

MOON LANDING DESTINATIONS

Astronauts have walked on several different areas of the Moon, collecting samples and exploring the surface

APOLLO 12
24 NOVEMBER 1969
The second mission landed in the Ocean of Storms, 535 feet from the Surveyor 3 probe, which had landed there two years earlier.

APOLLO 14
9 FEBRUARY 1971
Commander Alan Shepard and Lunar Module Pilot Edgar Mitchell landed near Cone Crater in the Fra Mauro region.

APOLLO 15
7 AUGUST 1971
The first of the Apollo 'J' missions landed in the Imbrium Basin, one of the largest craters in the Solar System.

APOLLO 17
19 DECEMBER 1972
The final Apollo Moon landing took place in the Taurus-Littrow Valley on the eastern rim of the Mare Serenitatis region.

APOLLO 11
20 JULY 1969
The ground-breaking first mission to the Moon landed in the Sea of Tranquillity.

APOLLO 16
27 APRIL 1972
Landing in the Descartes Highlands region, scientists thought the area would be volcanic, but samples taken found that to be incorrect.

10 WHO HAS WALKED ON THE MOON?

The first footprint left by Neil Armstrong will be there for a million years

As exclusive achievements go, walking on a world other than Earth is a pretty amazing one. People have gone into space before and since, but only a small and select group of people have actually touched down on what is essentially an alien world, albeit a small one.

Earth's only natural satellite is almost 236,400 miles away, a mere stone's throw in galactic terms. And it was in 1969 that the ground-breaking first walk on the Moon took place, with Neil Armstrong the first to make a footprint and utter the words, "One small step for man, one giant leap for mankind."

Closely followed by Edwin 'Buzz' Aldrin, the duo were the first of 12 people who have walked on the Moon in what were termed the Apollo missions. There are 24 people in all who have made the journey – all Americans – with the other 12 of remaining on various spacecraft. All the Apollo missions took place between 1968 and 1972.

One of the most striking things about walking on the Moon is the low gravity. The Moon's gravity is about a sixth of Earth's, meaning you'd weight only about 16 per cent of what you do here. You'd also be struck by the sharp colours due to the very thin atmosphere.

Nasa is planning the Artemis missions, which will see the first woman and first person of colour touch down there. It will partner with commercial and international organisations to establish a permanent base on the Moon, which it will use as a springboard for an eventual mission to Mars. NASA's initial goal was to reach the Moon again by 2024, but the date has been pushed back to no sooner than 2025.

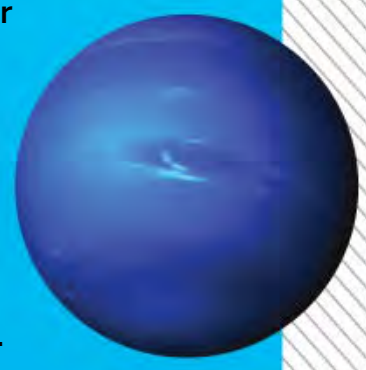
WHEN WILL HUMANS SET FOOT ON MARS?

11 The most optimistic estimates come from SpaceX founder Elon Musk, who at one time set his sights on a crewed landing in 2024. But the technological challenges are proving harder than he thought, and his best case date is now 2029.

These astronauts are practising for an eventual mission to Mars

DO NEPTUNE AND URANUS ALSO HAVE SPOTS?

12 Jupiter's Great Red Spot is a gigantic, hurricane-like storm that has been raging in its upper atmosphere for at least two centuries. Similar storms, though generally shorter lived and less spectacular, have been observed on other planets including both Neptune and Uranus.



WHY ARE THE PLANETS DIFFERENT COLOURS?

13 The colour depends on two things – first, whether we're seeing the planet's surface or atmosphere, and second, what that's composed of chemically. Earth is a blue planet because of the water in its oceans, while Neptune and Uranus are blue due to the methane in their atmospheres.

DID YOU KNOW? Saturn has 53 confirmed moons

Hale-Bobb was one of the most impressive comets of the 20th century

WHAT'S THE DIFFERENCE BETWEEN COMETS, ASTEROIDS AND METEORS?

14 We've all probably heard of comets, meteors and asteroids. We think of them as chunks of space rock or ice that traverse our Solar System and occasionally hit Earth and other planets, but how do they differ from each other and what can we learn from them?

Asteroids are lumps of rock left over from the formation of the Solar System 4.6 billion years ago. They orbit the Sun with many of them residing in a part of the Solar System called the asteroid belt, a torus-shaped field of floating interstellar rocks between Mars and Jupiter. They range in size from Vesta – the largest at about 329 miles in diameter – to ones that are less than ten metres across.

Sometimes one asteroid can hit another, with a small piece breaking off and becoming something called a meteoroid. When such a meteoroid hits Earth's atmosphere it begins to burn up, creating a fire trail through the sky which is visible with the naked eye – a meteor. But sometimes they aren't completely vaporised in the atmosphere and hit Earth, when this happens they're called meteorites.

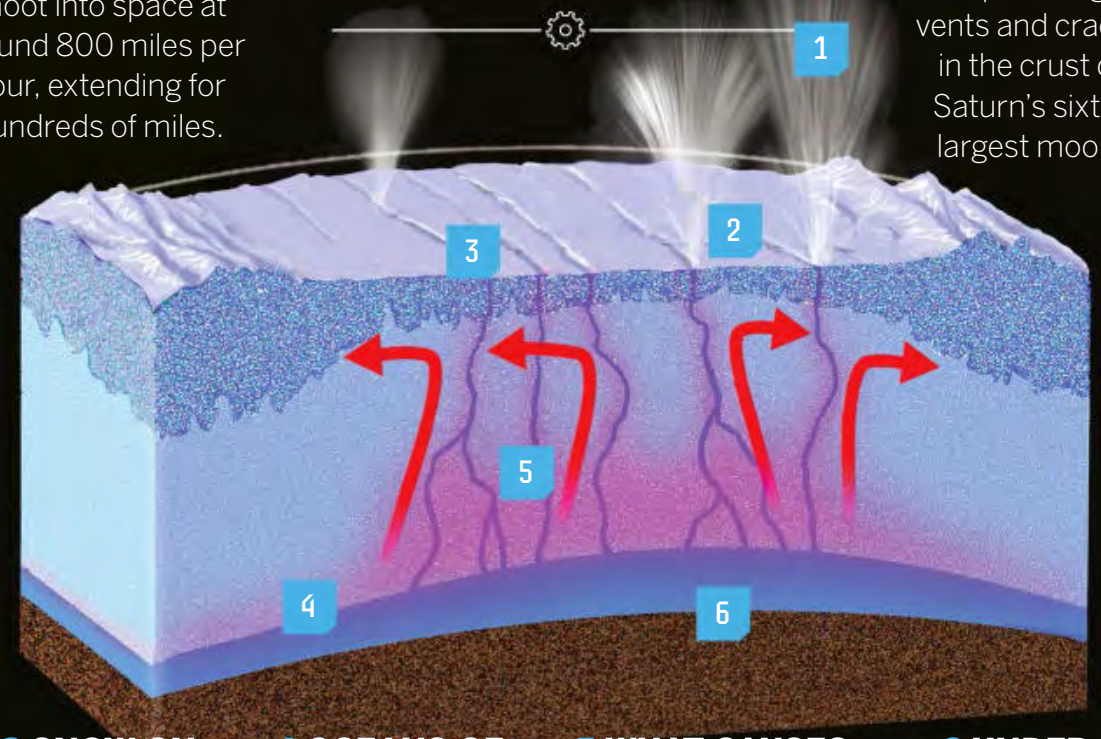
Comets are made of a mix of ice, rock and gas. They're also leftovers from the formation of the Solar System and orbit the Sun. But because of the way they're made, as they get closer their ice and dust begin to melt which gives it a beautiful 'tail'. These tails can stretch for millions of miles and are sometimes visible from Earth.

ARE THERE ANY VOLCANOES IN SPACE?

15 Yes. Within our Solar System, the Moon and Mars are rich with evidence of volcanoes and fiery volcanic activity, while other bodies possess volcanoes that spew ice from their frozen vistas. Now volcanically inert, the surface of the Moon once hosted spectacular eruptions that created large lava flows. Aside from Earth, Mars is host to even more volcanic features than our planet. Primary among these is Olympus Mons, the largest volcano in the Solar System at over twice the height of Mount Everest. Venus has lava flows that cover up to 90 per cent of its surface, with up to 1,600 major volcanoes and as many as a million smaller ones. But currently, the most volcanic body in the Solar System is Io, one of Jupiter's moons, caused by the huge gravitational influence of the gas giant deforming the tiny moon.

ICE VOLCANOES

Not all volcanoes spew hot lava: ice volcanoes have been discovered on moons like Enceladus



1 ICE GEYSERS OF ENCELADUS
Plumes containing water and simple organic chemicals shoot into space at around 800 miles per hour, extending for hundreds of miles.

2 CRACKS IN ENCELADUS' SURFACE
These plumes erupt through vents and cracks in the crust of Saturn's sixth-largest moon.

3 SNOW ON ENCELADUS
Some of the ejected material freezes and falls back as snow, coating Enceladus and making it the most reflective body in the Solar System.

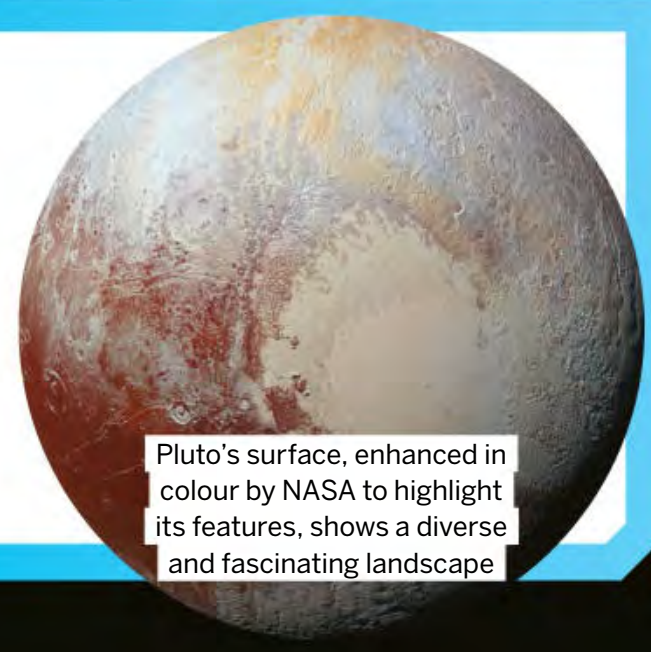
4 OCEANS OF ENCELADUS
The source of the ice geysers is the global liquid water ocean that lies beneath Enceladus' icy crust.

5 WHAT CAUSES THESE VOLCANOES?
The gravitational pull of Saturn could be causing tidal forces that squeeze and stretch Enceladus, heating material and causing it to explosively escape.

6 UNDER THE OCEAN
Beneath the ocean of Enceladus lies the moon's rocky core.

WHY ISN'T PLUTO A PLANET?

16 Pluto was until recently considered one of our primary planets. That all changed, however, following the 2005 discovery of another world in the Kuiper Belt. The outer edges of the Solar System were now shown to host multiple tiny worlds, so should they all be counted as planets? If not, then why was Pluto considered one? The following year, the International Astronomical Union asked participants to vote on Resolution 5A: Definition of 'planet'. It produced the following trio of rules for attaining full planetary status: a planet must be in a stable orbit around its star, have enough mass for its gravity to force it into a spheroidal shape, and have cleared the debris field in its orbit. Pluto only passes the first two tests, so has been redesignated as a dwarf planet.



Pluto's surface, enhanced in colour by NASA to highlight its features, shows a diverse and fascinating landscape

© Getty / NASA / Alamy

WILL THE SUN EXPLODE?

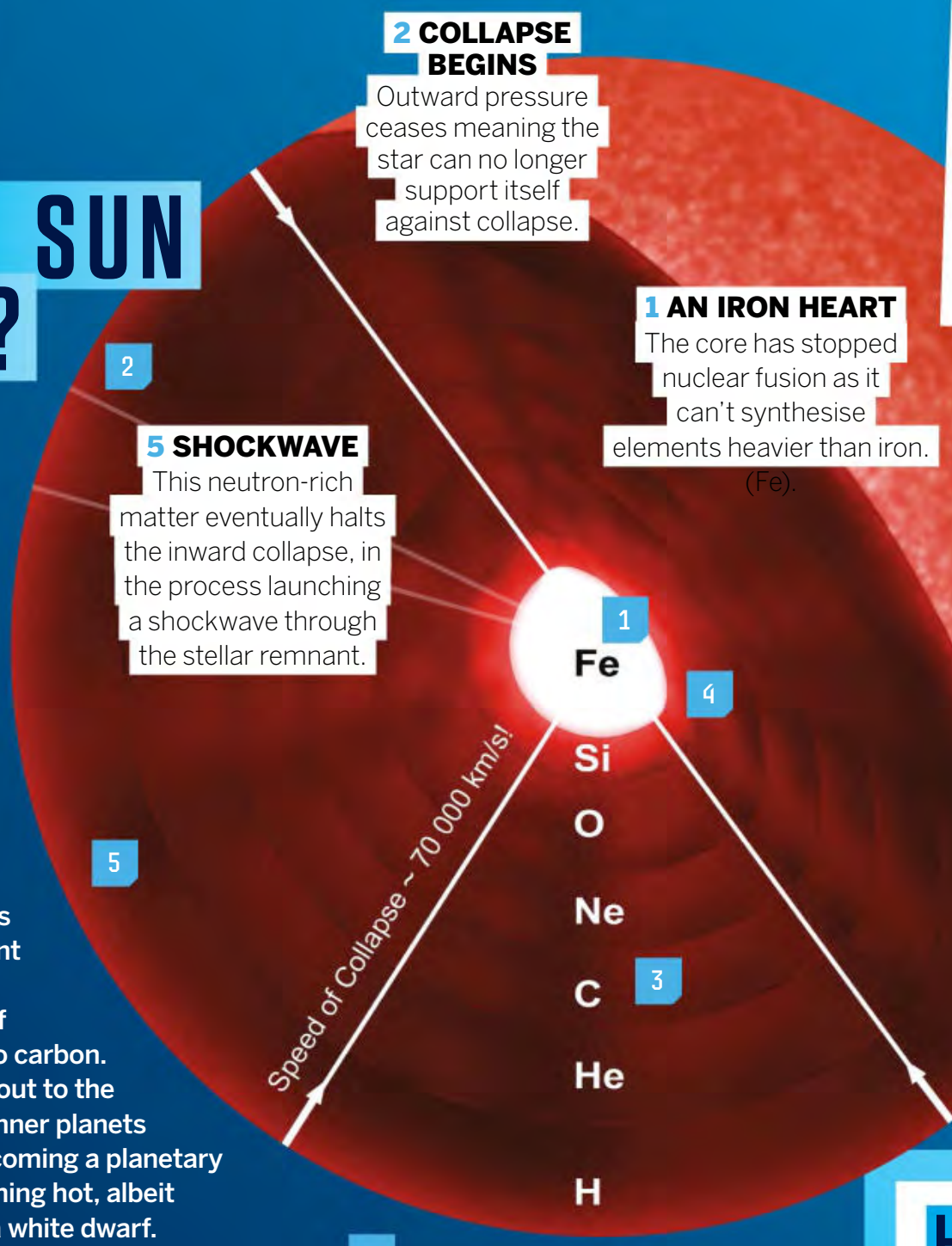
17 Not precisely: in around 4.5 billion years the Sun will run out of hydrogen in its core, meaning it can no longer sustain nuclear fusion. This will signal the end of the outward pressure that stops its core from collapsing under gravity.

As the core collapses, the outer layers of the Sun will puff out in a series of outbursts beginning a short-lived red giant phase for our star. In the core, helium created by the fusion of hydrogen will begin to fuse into carbon.

The outer layers will spread out to the orbit of Mars, consuming the inner planets including Earth, eventually becoming a planetary nebula that surrounds a scorching hot, albeit cooling stellar core known as a white dwarf.

This is how our Sun and other low to medium-mass stars will remain for trillions of years, so in short: no, our Sun won't explode.

This isn't the end for all stars, however. Some have enough mass to push past this white-dwarf phase and initiate further nuclear fusion – a supernova – and transform into an exotic stellar remnant. The dividing line between these fates is the Chandrasekhar limit – the value of which for a white dwarf is generally considered to be 1.4 times the mass of the Sun, which was first predicted by Subrahmanyan Chandrasekhar in 1931.




Subrahmanyan Chandrasekhar relaxes at Yerkes Observatory, University of Chicago, in 1939

CORE COLLAPSE

A white dwarf with a mass exceeding 1.4 solar masses can't protect itself against gravitational collapse

Did you know?

A teaspoon of neutron star weighs around 4 billion tonnes

HOW DO NEUTRON STARS FORM?

18 When stars run out of nuclear fuel, they collapse down to very dense objects. For stars that are a few times more massive than our own Sun, the collapse doesn't stop until all the atoms have been compressed down into neutrons – the result is a neutron star.


There's a rapidly spinning neutron star at the centre of the Crab Nebula

HOW HOT IS THE SUN?

19 The Sun's atmosphere is made of several layers, including, the corona and the chromosphere. The outer layer, the corona, extends out for thousands of miles above the surface and is in excess of 1,000,000 degrees Celsius. The chromosphere extends out for about 1,200 miles above the surface of the Sun and has a temperature that ranges from 4,000 to 6,000 degrees Celsius. At the interior of the Sun, the convective zone has a temperature of 2,000,000 Kelvin, which is about 2,000,000 degrees Celsius, while the core is the hottest region of the Sun, with temperatures here estimated to be as high as 16,000,000 Kelvin, or 16,000,000 degrees Celsius. The core has an incredible density too – around ten times that of gold.

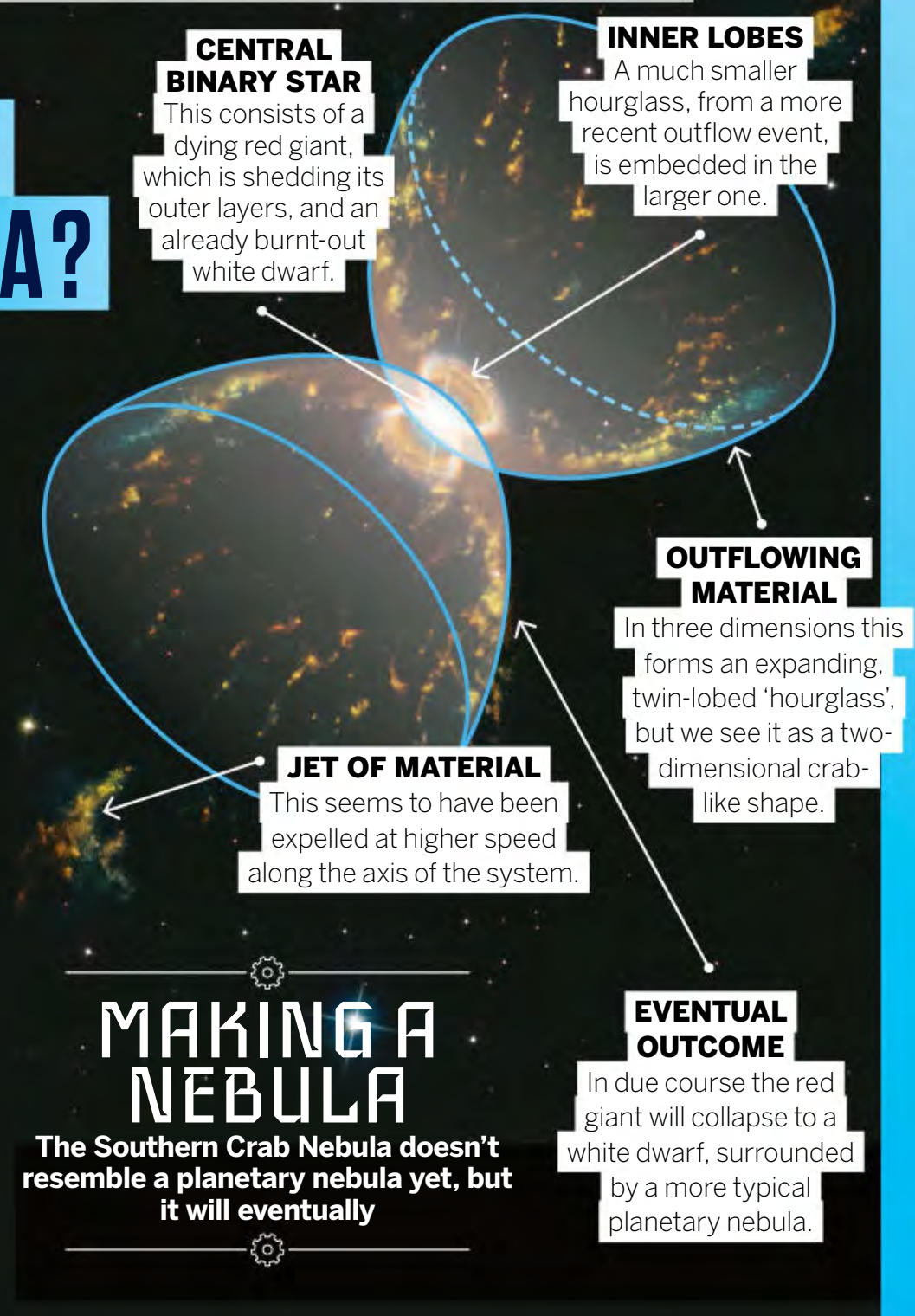
DID YOU KNOW? In *Star Wars*, parsec is used as a unit of time rather than distance

WHAT IS A NEBULA?

20 Nebula is a Latin word meaning 'cloud'; its plural form is nebulae, and it stands for clouds of gas and dust located inside our galaxy.

There are several different types of nebulae. Most nebulae consist primarily of gas that is able to glow with its own light, creating the colourful displays we're familiar with. But other nebulae are much dustier in their composition, and block the light from more distant objects beyond it.

Nebulae play a key role in the life cycle of stars, both at their birth and death. Stars are born in dense clumps of gas, dust, and other material inside diffuse emission nebulae, also frequently referred to as stellar nurseries. At the other end of a star's life, we encounter another, rather different, type of emission nebula. Stars like the Sun end their lives as highly compact white dwarfs, but as they shrink down into this phase they release clouds of gas which form a so-called 'planetary nebula'. Not all stars end their days in the relative serenity of a planetary nebula. A star that's much more massive than the Sun will eventually explode as a supernova, and the debris flung out from that explosion forms yet another kind of nebula called a supernova remnant.



MAKING A NEBULA

The Southern Crab Nebula doesn't resemble a planetary nebula yet, but it will eventually

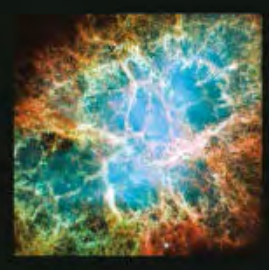
NEBULA CLASSIFICATION

Nebulae can be sorted into a range of different categories

EMISSION NEBULA
Example: The Orion Nebula
A diffuse nebula with ongoing star formation, the gas here is hot enough to glow with its own light.

REFLECTION NEBULA
Example: NGC 1999
A reflection nebula doesn't emit its own light,but scatters light from embedded stars.

PLANETARY NEBULA
Example: Helix Nebula
This is composed of expanding gas that was blown off by a star as it collapsed to a white dwarf.



SUPERNOVA REMNANT
Example: Crab Nebula
Exactly as the name says, this is all that remains of a star that has exploded as a supernova.

DARK NEBULA
Example: NGC 281
A giant cloud of dust that blocks light from anything beyond it, looking like a hole in the sky.

WHAT IS A PARSEC?

21 **A parsec is a unit of distance that's often used by astronomers as an alternative to the light year, just as kilometres can be used as an alternative to miles. One parsec is approximately 3.26 light years, or almost 19 trillion miles. To that extent, it's easy enough to answer the question. But understanding just how a parsec is defined, and why it's used, is a little harder.**

Our nearest stellar neighbour, Proxima Centauri, is 1.3 parsecs away

HOW COLD CAN SPACE GET?

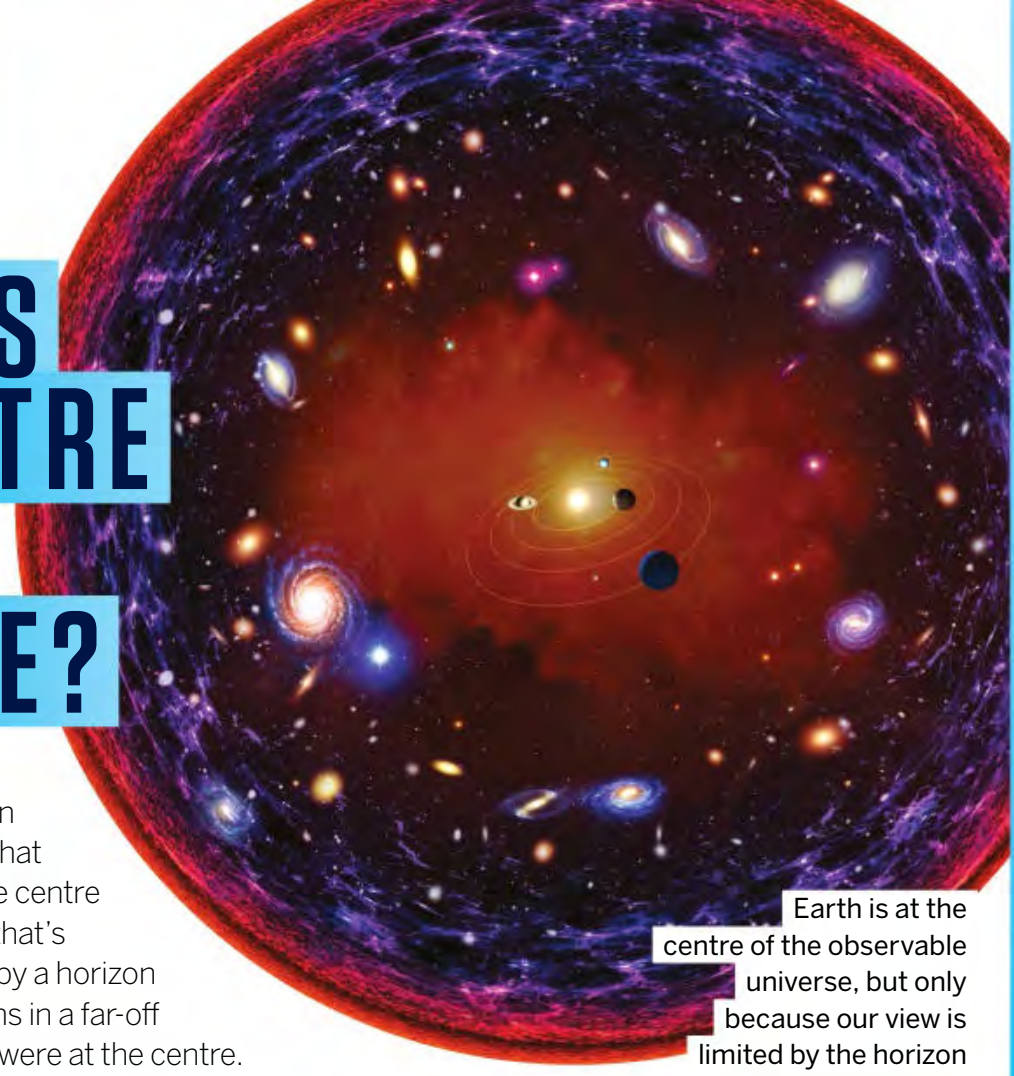
22 **A young planetary nebula located 5,000 light years from Earth in the constellation of Centaurus, the Boomerang Nebula is the coldest object we have found in the universe thus far. The nebula – whose name comes from its curved asymmetric shape – has a temperature of -272 degrees Celsius, just one degree warmer than absolute zero. Its incredibly cold temperature could be the result of the fact that the nebula is expanding rapidly. The Boomerang Nebula's shape appears to have been caused by ultracold gas being blown away from a dying star at its heart by powerful 311,000 mile per hour winds.**

The Boomerang Nebula imaged in 1998 by the Wide Field Planetary Camera 2

© NASA/ ESA R. Sahai and J. Trauger (Jet Propulsion Laboratory) and the WFPC2 Science Team / NASA;ESA / Getty

WHERE IS THE CENTRE OF THE UNIVERSE?

23 Telescopes can see the same distance in all directions, so in that sense Earth is at the centre of the observable universe. But that's only because we're surrounded by a horizon beyond which we can't see. Aliens in a far-off galaxy would likewise think they were at the centre.



Earth is at the centre of the observable universe, but only because our view is limited by the horizon

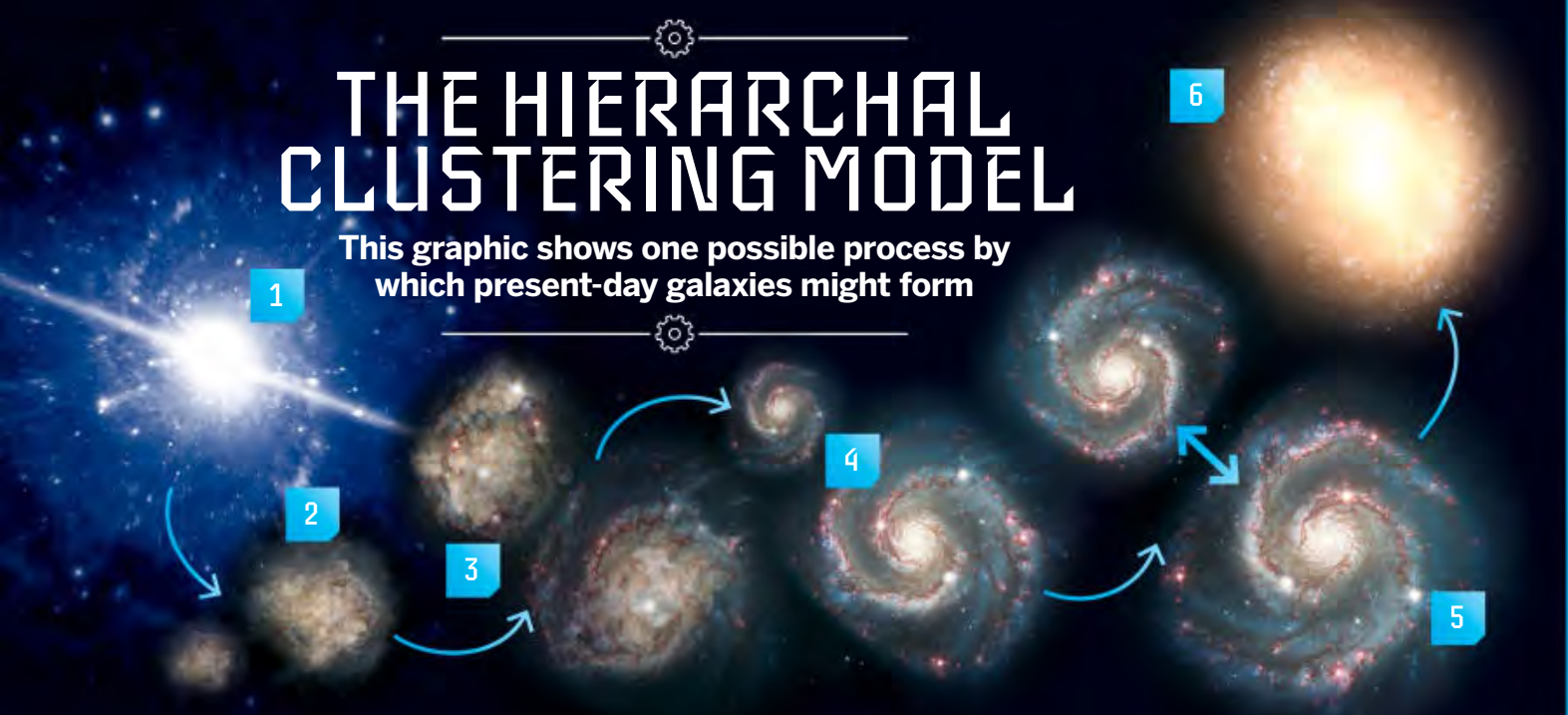
HOW ARE GALAXIES FORMED?

24 As the universe expanded in size following the Big Bang, all the matter in it was spread out more and more thinly. At the same time there was a competing effect – the force of gravity – that was pulling this diffuse matter into denser clumps. The gravity of some of the clumps was strong enough to pull in more matter and allow them to grow. As the mass of the clumps increased so did their gravitational pull, causing them to collapse down to a smaller size and higher density, forming the first protogalaxies.

That much is pretty much agreed by all astronomers. What is less certain is how those first protogalaxies relate to the mature galaxies we see today. Essentially, there are two competing theories: the older top-down theory, and the more recent hierarchal clustering model, which introduces dark matter and galactic mergers.

THE HIERARCHAL CLUSTERING MODEL

This graphic shows one possible process by which present-day galaxies might form



1 THE BIG BANG
The universe starts to expand, with matter initially spread fairly uniformly through it.

2 CLUMPS OF DARK MATTER
Fluctuations in the distribution of dark matter cause clumps to form, held together by gravity.

3 ACCRETION OF GAS
Through the action of gravity, the dark matter pulls in surrounding gas, which then starts to form stars.

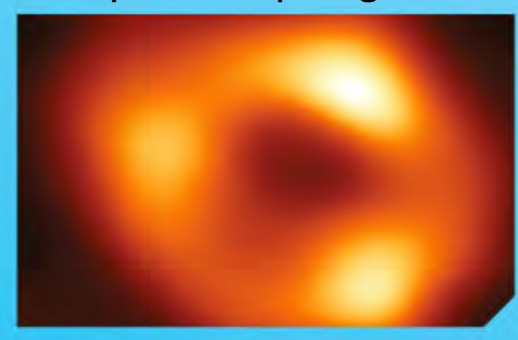
4 SMALL GALAXIES FORM
The gas falls into a flat disc where further stars form, resulting in the first, relatively small galaxies.

5 GALAXY MERGERS
Over time, neighbouring galaxies bump into each other and merge, creating ever larger galaxies.

6 GIANT ELLIPTICAL GALAXY
The most likely end product of multiple mergers is a giant elliptical galaxy.

WHAT'S AT THE CENTRE OF THE MILKY WAY?

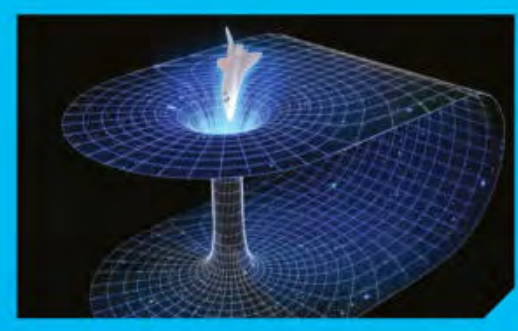
25 A bright and compact region of space known as Sagittarius A*, with a supermassive black hole over 4 million times the mass of our Sun. Supermassive black holes likely reside at the heart of more spiral and elliptical galaxies.



Our black hole was recently imaged

DO WORMHOLES REALLY EXIST?

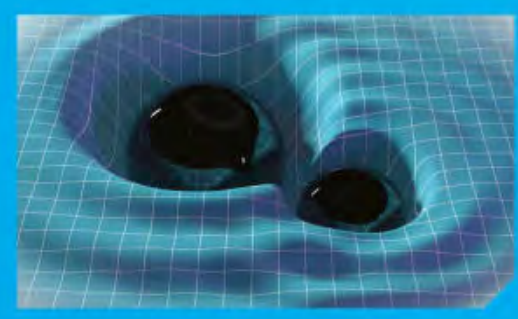
26 Wormholes first appeared as a prediction of Einstein's general relativity. So they can exist in theory, but may or may not exist in reality. Astronomers are still trying to work out how to detect them if they do.



A wormhole is a hypothetical 'shortcut' from one point in space-time to another

WHAT HAPPENS IF TWO BLACK HOLES COLLIDE?

27 The main effect of the collision – at least in terms of what we can observe – is a ripple-like disturbance in the fabric of space-time in the form of gravitational waves.



Schematic illustration of gravitational waves forming as two black holes collide

DID YOU KNOW? Galaxy GN-z11, close to the edge of the observable universe, is moving away from us at almost 186,400 miles per second

The Andromeda Galaxy, which is gravitationally bound to the Milky Way, is actually approaching and is thus blueshifted

WHY ARE MOST GALAXIES MOVING AWAY FROM US?

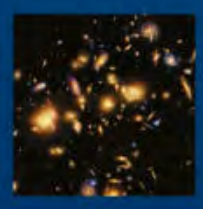
30 The simple answer to this question is that the whole universe is expanding. Pick any two galaxies at random, and chances are they're moving away from each other.

Edwin Hubble measured the distance to the Andromeda galaxy in 1924 by observing a certain type of pulsating star called a Cepheid variable, which exhibits a close relationship between intrinsic luminosity and pulsation frequency. So knowing the frequency tells you the luminosity, and comparing this with the observed brightness tells you the distance. When Hubble did this for Cepheids in the Andromeda galaxy, it became clear that it must lie outside the Milky Way.

As well as measuring the distances to other galaxies, Hubble also studied their 'redshift'. This is a property of the light spectra emitted by astronomical objects that arises from a phenomenon called the Doppler shift. Think of a vehicle whizzing past you. As it's approaching the sound is higher pitched, then as it recedes into the distance it's lower pitched. What happens is that sound waves are bunched up when they're moving towards you, and stretched out when they're moving away. It's the same with light waves, except we perceive the difference as a change in colour instead of pitch: if the source is moving away from us, we see it shifted towards the red end of the spectrum – hence the term 'redshift'. Hubble's great discovery in 1929 was that a galaxy's redshift is proportional to its distance – a result now known as 'Hubble's law'. It gave astronomers a new way of measuring the distance to galaxies that were too far away for the Cepheid method, simply by measuring their redshift.

REDSHIFT VERSUS DISTANCE

The farther away a galaxy cluster is, the faster it is moving away from us



VIRGO CLUSTER
Distance: **78 million light years**
Velocity: **745 miles per second**
This forms the heart of the Virgo Supercluster, to which our Local Group belongs.

URSA MAJOR CLUSTER
Distance: **1,000 million light years**
Velocity: **9,320 miles per second**
A more distant galaxy cluster in the constellation of Ursa Major, the Great Bear.

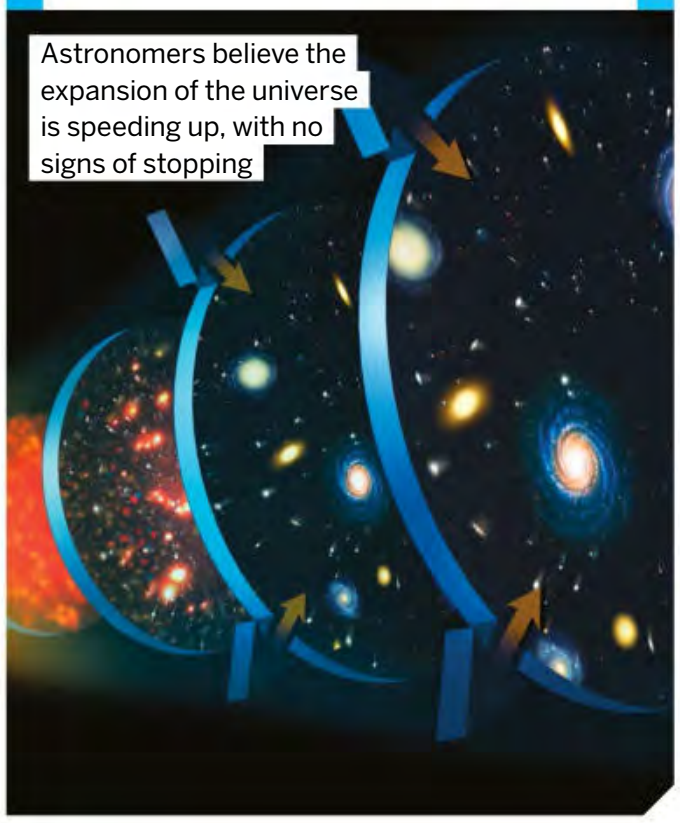
CORONA BOREALIS CLUSTER
Distance: **1,400 million light years**
Velocity: **13,670 miles per second**
This highly concentrated cluster contains over 400 galaxies.

BOÖTES CLUSTER
Distance: **2,500 million light years**
Velocity: **24,233 miles per second**
A very distant galaxy cluster in the constellation of Boötes, the Herdsman.

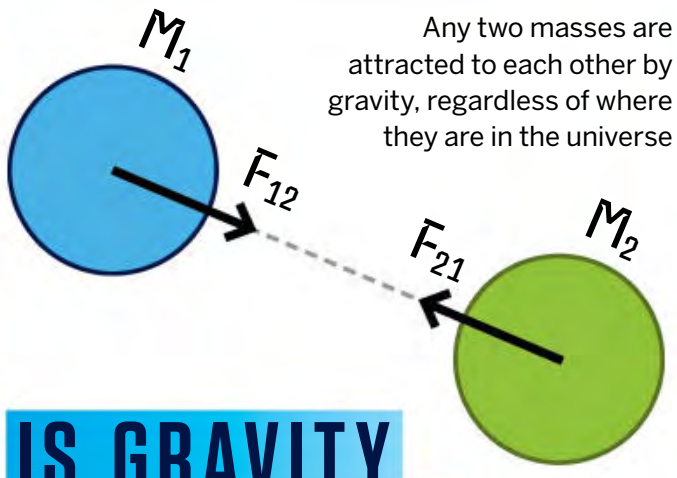
HYDRA CLUSTER
Distance: **3,960 million light years**
Velocity: **37,903 miles per second**
Another high-redshift cluster, this one is located in the constellation of Hydra.

WILL THE UNIVERSE STOP EXPANDING?

28 At one time this was considered a definite possibility, if the universe contained enough matter that its gravity would eventually slow the expansion to a halt. But with the discovery that 'dark energy' is accelerating the expansion, it looks as though the universe will continue expanding forever.



Astronomers believe the expansion of the universe is speeding up, with no signs of stopping



Any two masses are attracted to each other by gravity, regardless of where they are in the universe

IS GRAVITY EVERYWHERE IN SPACE?

29 Gravity is everywhere, but it's not always perceptible. Gravitational fields, produced by massive objects, pervade the universe. But we're not always aware of gravity – only when there's another force, such as the upward resistance of a planet's surface, opposing it. So astronauts in space feel they're in zero gravity.

© Alamy / Getty / NASA;ESA / Havard / Wiki: Pablo Carlos Budassi

HOW TO REUSE A ROCKET

A new generation of spaceflight is making single-use rockets a thing of the past

WORDS **SCOTT DUTFIELD**

It's been almost 100 years since the very first liquid-fuelled rocket was launched by Dr Robert H. Goddard in 1926. Goddard's three-metre-tall rocket was filled with petrol and liquid oxygen and was fired 12 metres into the air. Although the payload of Goddard's novel rocket was only around 4.5 kilograms, his method is still used today to send spacecraft and satellites beyond Earth's atmosphere on rockets with payloads of millions of kilograms.

But what happens to the rocket once it's done its job of delivering cargo beyond Earth's gravitational grip has changed in recent years. Once a rocket has launched, its return to the surface is typically a nosedive into the ocean. The primary stage of a rocket, which houses engines that generate the initial thrust, breaks away from the rocket's second stage and plunges into the ocean. Rockets that function this way are single-use, with a new rocket required for each launch. However, over the past decade, rocket manufacturers have successfully demonstrated that rockets can fly themselves safely back to Earth's surface and land, ready for reuse.

The first rocket to break through the barrier of Earth's atmosphere, successfully return to the surface and land vertically was created by Blue Origin – an aerospace manufacturer owned by Amazon founder Jeff Bezos. In 2015, the New Shepard booster completed its launch mission 62 miles above the surface and returned to Earth, settling into the same vertical position as when it launched, known as vertical takeoff and landing (VTOL). During a rocket's VTOL, its onboard engines complete a series of ignitions, which are carried out autonomously. New Shepard's Blue Engines (BE-3) continuously propel the rocket into space. Upon its return to the surface, intermittent ignition guides it vertically to the

Falcon 9 launch from Florida

The reusable Falcon 9 rocket during landing

DID YOU KNOW? The Falcon 9 can generate more than 1.7 million pounds of thrust at sea level

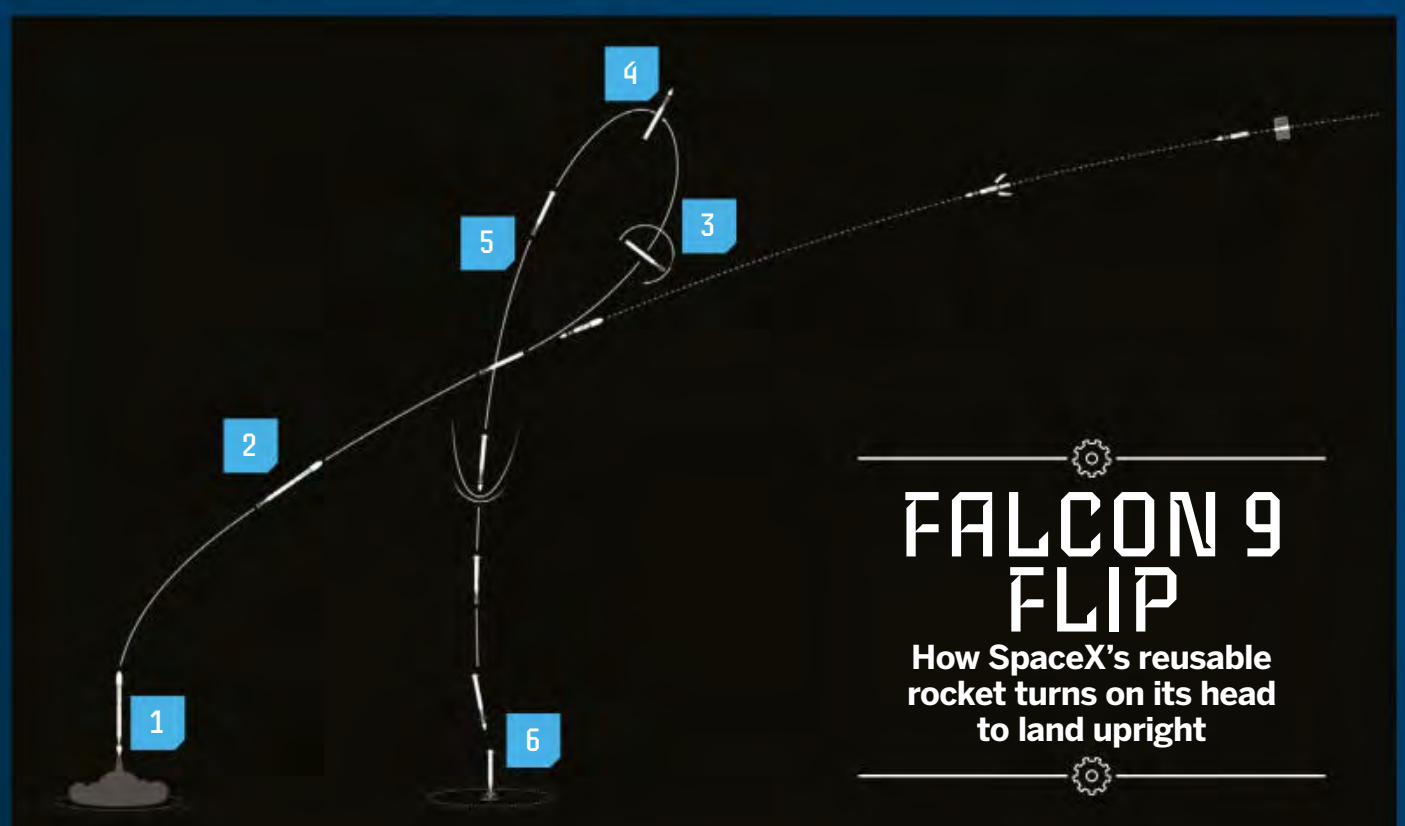
launchpad. Additional drag fins on the outside of the rocket also help to slow down the rate of its descent, bringing its falling speed to around 387 miles per hour. When the rocket is about 30 metres above the ground, re-igniting the engines brings its landing speed to 4.4 miles per hour for a gentle landing. Since the first successful launch, four different New Shepard rockets have made 15 suborbital test flights.

Along with Blue Origin's creation, tech giant Elon Musk and his aerospace company SpaceX have created the next generation of reusable rockets, the Falcon 9. The rocket is divided into two stages. The first consists of nine engines, called Merlin engines. These use liquid oxygen and kerosene propellant. Within the first stage are four landing legs made of carbon fibre and aluminium honeycomb. The second stage includes another Merlin engine for travel through the vacuum of space, along with room for the rocket's payload, typically satellites. Once the second stage has been successfully delivered into space, the first stage detaches and falls back to Earth's surface. The rocket performs a midair rotation so that the nine Merlin engines are facing the same direction as during launch. When a Falcon 9 is approaching its landing target, it will autonomously reignite some of its engines, extend its landing legs and gently guide itself onto the landing pad. So far, SpaceX has launched more than 150 Falcon 9 rockets, made more than 110 landings and reflown more than 90 rockets.

Did you know?

New Shepard reached five miles per hour for landing

Testing of a SpaceX Merlin engine



FALCON 9 FLIP

How SpaceX's reusable rocket turns on its head to land upright

1 LAUNCH
During launch, the engine burns for 162 seconds, propelling the rocket into space.

2 ASCENT
158 seconds into the rocket's ascent, the engines are cut off. At this point the rocket is travelling ten times the speed of sound.

3 FLIP
Cold gas thrusters at the head of the first stage turn the rocket around.

4 BOOSTBACK BURN
The Merlin engines once again ignite to propel the rocket back towards the surface.

5 GRID FINS
Hypersonic grid fins placed in the middle of the first stage work like rudders to help orient the rocket upon re-entry.

6 LANDING
The landing legs are deployed and the Merlin engines fire a final time to autonomously guide the rocket to the landing pad.

ELON'S STARSHIP

Sending rockets into space and having them land safely back on Earth is one thing, but what about landing on other worlds? Another of SpaceX's creations is the Starship, currently in its 15th iteration, which combines a Starship spacecraft and a Super Heavy rocket. Like the Falcon 9, the Super Heavy is a reusable rocket, designed to deliver cargo or human crews through Earth's atmosphere and on to Mars.

The rocket has been designed to carry more than 100 tonnes into Earth orbit. Both the Starship spacecraft and the Super Heavy rocket have been designed to be able to self park on other worlds. In a mission to the Moon or Mars, the first stage of the Super Heavy rocket propels its cargo into Earth orbit and beyond – burning liquid methane and liquid oxygen as fuel. Once the Starship spacecraft – the second stage – is separated, the Super Heavy rocket will propel itself back to the launchpad while the Starship journeys onto Mars.

Much like the smaller Falcon 9, the launch vehicle can autonomously land at a new location. On 5 May 2021, the Starship SN15 completed its fifth high-altitude test flight – reaching around 6.2 miles. The Super Heavy rocket is due to complete its first Earth orbital test flight some time in 2022.

The tenth version of SpaceX's Starship in flight

©Getty / SpaceX

PERFECT LANDING

How the SN15 Starship test flight landed safely back on the ground

3 BELLYFLOP
At 6.2 miles above Earth's surface, reaction control system (RCS) thrusters adjusted SN15 into a horizontal orientation.

4 FUEL SHIFT
Liquid oxygen was funnelled into the head of SN15 to maintain a horizontal free fall. Its weight acted like the ballast on a sea vessel.

2 SLOWING ASCENT
Around two minutes into the test flight, the first raptor engine was shut off, then a second after three minutes and the third at four minutes.

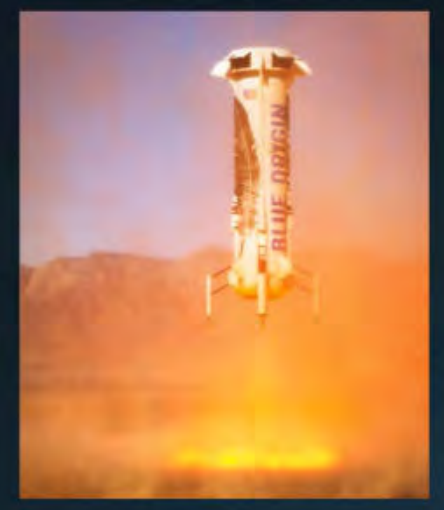
5 SKY DIVE
For more than one-and-a-half minutes, SN15 was in free fall. The engines re-ignited to shift its orientation vertically 90 degrees.

SUPER HEAVY ROCKET

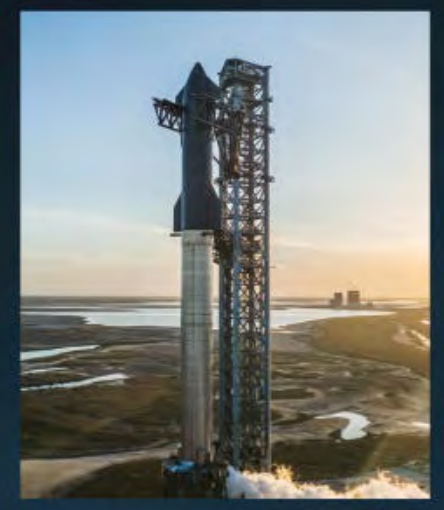
ACTUATED FORWARD FLAPS

Liquid methane and liquid oxygen tanks: 1,200 tonnes of propellent

Starship: 50 metres tall



Blue Origin's reusable New Shepard rocket during landing



Construction of the SpaceX Starship and Super Heavy

Did you know?

Minus propellent, Starship weighs 85 tonnes

Total height: 72 metres tall

ACTUATED FLAPS
During landing, actuated flaps act like rudders to control the direction of descent, including rotation.

1 LIFTOFF
On 5 May 2022, the three raptor engines aboard SN15 ignited at 22:24 (UTC).

6 BALANCING ACT
Two of the three raptor engines pivoted, adjusting their thrust output to stabilise the vertical orientation of SN15 in a process called gimballing.

7 LANDING
Six folded landing legs were deployed and the SN15 engines gently reduced their output to land the spacecraft after a total of six minutes.

DID YOU KNOW?
Starship can theoretically enter Mars' atmosphere at around 4.6 miles per second

© Illustration by Tony Bela (tonybela.com) / Alamy / SpaceX

CAN WE CREATE ARTIFICIAL GRAVITY?

Discover the technology that could provide more natural spacecraft environments for future space exploration missions and space tourism

WORDS **ROBERT LEA**

Depictions of space travel in science-fiction are replete with scenes set on craft travelling through space with the occupants enjoying the comforts of simulated Earth-like gravity. This concept isn't just limited to TV shows like *Star Trek*, however. Real-world researchers are working on methods to create artificial gravity in space. Not only would this simplify the next era of space exploration, making tasks more straightforward, but it is crucial for potential space tourism – and the need for artificial gravity goes beyond convenience.

The effects of microgravity in space can actually be harmful to humans, so as we look at longer crewed missions, including journeying to Mars, artificial gravity could be essential to our astronauts' health. In his 1905 theory of special relativity, Albert Einstein said that gravity and acceleration are actually indistinguishable. That means that in a rocket travelling at 9.81 metres per second squared – the downward acceleration of gravity here on Earth – an astronaut would feel their body anchored to the floor just like it is on their home planet. The problem is you can't always be accelerating at this rate during a real space journey or stay, especially if you're onboard an orbiting space station. Fortunately, there is more than one form of acceleration – and by using centrifugal force we can generate something equivalent to gravity on Earth.

One possible way of creating artificial gravity in space is by utilising a technology called an O'Neill cylinder. Named after the physicist who proposed them, Gerard O'Neill, this consists of a pair of massive cylinders that rotate in opposite directions, allowing them to be permanently directed toward the Sun, replicating gravity. Jeff Bezos, the owner of space-exploration company Blue Origin, has proposed O'Neill cylinders as the basis of floating space colonies allowing vast numbers of humans to live in orbit.

Aside from being a long way from any kind of practical application, at over 32 kilometres long and 6.5 kilometres in diameter – designed to house several million people – O'Neill cylinders are way too big for most applications smaller than colonies in space. Researchers at the University of Boulder Colorado have devised a smaller-scale alternative – isolated rotating systems that could fit inside the rooms of more readily viable spacecraft. While this wouldn't provide artificial gravity for the whole craft or station, it would allow space travellers to retreat to a specific area and spend some time experiencing a gravitational field more like that of Earth.

Did you know?

Nautilus X was a centrifuge craft that didn't clear its design stage

The system also uses centrifugal acceleration replicating a gravitational field of 1g – the same as that on Earth – with astronauts lying down on a short-radius centrifuge for a quick spin. Spinning astronauts might not be the ideal solution, however, as anyone who has ridden the teacups one too many times can tell you, this comes with its own adverse health effects.

Aside from vehicles with one rotating room, other ideas for providing artificial gravity have included long spinning stick-like vehicles 100 metres across with a nuclear reactor on one end and a crew compartment on the other for journeys to Mars, but these have had engineering issues preventing their application so far. The first artificial gravity device in space could be the prototype gravity ring of the proposed Voyager Space Station.

LET THERE BE LIGHT
An overhead mirror angled at 45 degrees provides light from the Sun to the inhabitants of the torus.

THE OUTER RING
Within the one-mile-diameter habitation ring is room for between 10,000 and 140,000 permanent residents.

Testing out a centrifuge that could allow astronauts to briefly retreat to Earth-like gravity

Massive space colonies with Earth-like gravity remain in the realm of science fiction

DID YOU KNOW? Rejected ideas for artificial gravity have included magnets in astronauts' boots

THE STANFORD TORUS

Researchers from NASA and Stanford University proposed a centrifugal artificial-gravity space station

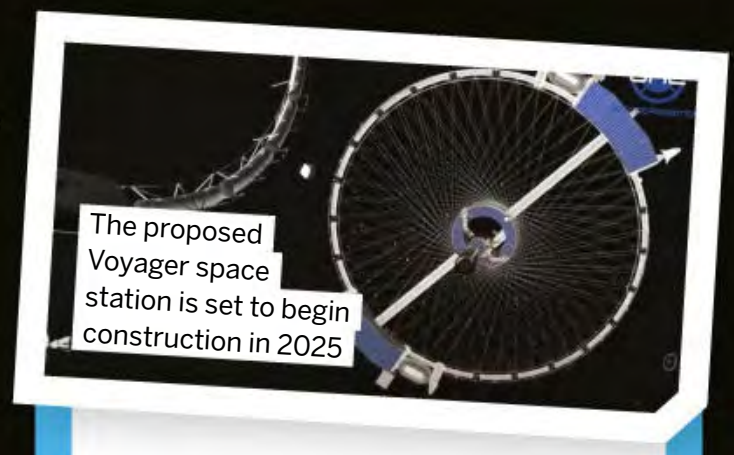
CONNECTING TO THE HUB
Spokes connect the spinning outer region to the stationary central hub, providing access for inhabitants.

THE CENTRAL HUB
The central region, or hub, experiences the lowest gravity of the structure, making it the ideal place for craft to dock.

GRAVITY WITH A SPIN
The outer ring rotates once a minute, providing between 0.9 and 1g of artificial gravity.

HEAT RELEASE
A giant 87,420 square metre non-rotating radiator releases waste heat created during energy consumption.

THE SOLAR FURNACE
The station's solar furnace, with attached solar-power cells, transforms solar energy into electricity powering the torus.


The proposed Voyager space station is set to begin construction in 2025

THE VOYAGER SPACE STATION

The Voyager Space Station is a planned rotating-wheel space station set to begin construction in 2025. Pioneered by the Orbital Assembly Corporation (OAC), Voyager will differ from the International Space Station in two key ways: it will be open to the public and it will have artificial gravity. Placed in a low-Earth orbit, the space hotel will rotate rapidly enough to generate artificial gravity for its 400 occupants. If the station is completed as currently planned it will become the largest human-made structure ever placed into orbit.

The first steps of the project will include the creation of a prototype gravitational ring to improve that artificial gravity in space is viable. The 60-metre-diameter ring will generate gravity equivalent to roughly 40 per cent that of Earth's, or about the same as the gravity of Mars.

HEALTH EFFECTS OF MICROGRAVITY

Establishing artificial gravity could be key to protecting the health of astronauts on long-term space missions. For five decades NASA's Human Research Program (HRP) has studied the effects of microgravity on the human body. They've found that deprived of the gravity of Earth, weight-bearing bones lose on average 1 to 1.5 per cent of mineral density during every month of spaceflight. Muscle mass is lost more rapidly in microgravity than it is on Earth. In addition, during spaceflight fluids in the human body can shift upwards putting pressure on the eyes that potentially lead to vision issues.


NASA astronaut Karen Nyberg uses a device to check eye health potentially impacted by microgravity

© NASA / Alamy / University of Colorado at Boulder / Orbital Assembly

INSIDE A MEDIEVAL CASTLE

Discover the different types of castles that developed across the Middle Ages and how they were used

WORDS **JO ELPHICK**

When you think of the medieval period you likely imagine knights on horseback, jousting contests and, most important of all, a magnificent stone castle. But it wasn't just ruling monarchs who owned castles, and although these imposing buildings seem very British, they actually first appeared across Central Europe.

In order to understand why castles became so popular in medieval Europe, it's necessary to look at life in the Early Middle Ages. From 800 to 888 CE the Carolingian Empire controlled the majority of Western and Central Europe, just as the Roman Empire had before them. However, when the Carolingian way of life broke down, so too did the central government. Gradually, the nobles began fighting over individual pockets of land. Each lord wanted to regain power and control over his own area, and it wasn't long before violence broke out across the land.

As if this infighting wasn't bad enough, foreign warriors sensed the vulnerability of Europe after the fall of the Carolingian Empire and decided to attack. Vikings made their way to European shores and began pillaging the local villages while the Magyars of historic Hungary began looting raids all across central Europe.

Local lords took it upon themselves to set up their own individual governments, judicial systems and farming, but the continuous warring meant that they needed a way of protecting their personal estates. It was during this period of hostility that the first European castles were born. By using geographical features of the land such as cliffs, mountains and rivers, buildings could be partially defended – Bran Castle in Transylvania is a prime example of a perfect castle location. However, more was needed if the seats of power were to remain safe.

Ditches were dug, with the soil then used to create a steep hill or 'motte'. Fortified keeps were built on top with a wooden fence erected around

DID YOU KNOW? Windsor Castle is the largest occupied castle in the entire world

the perimeter. The lord and his family could live within the safety of the keep, protecting their personal wealth and ensuring that their government could survive attacks from neighbouring nobility who wanted to increase their own land and power.

William the Conqueror brought the castle to England in 1066. Having won the Battle of Hastings, he proceeded to build motte-and-bailey castles across the UK. Fortresses like Dunluce Castle, precariously perched on the rocky cliffs of Northern Ireland's coastline, took advantage of any natural land formations. It was protected on one side by the sea while the villagers settled outside the castle gate. If there was no geographical advantage, an artificial hill was created, such as the motte built in the centre of Windsor Castle, known as the Middle Ward.

The castle soon became a reward offered by the monarch to the nobles in return for their support. With the ever-present threat of a civil war, the king required reliable allies across the country who could quell unrest as it broke out among the people. These later 'gifted' castles were far more luxurious, offering the nobility a beautiful home as well as a secure place to hold administrative meetings.

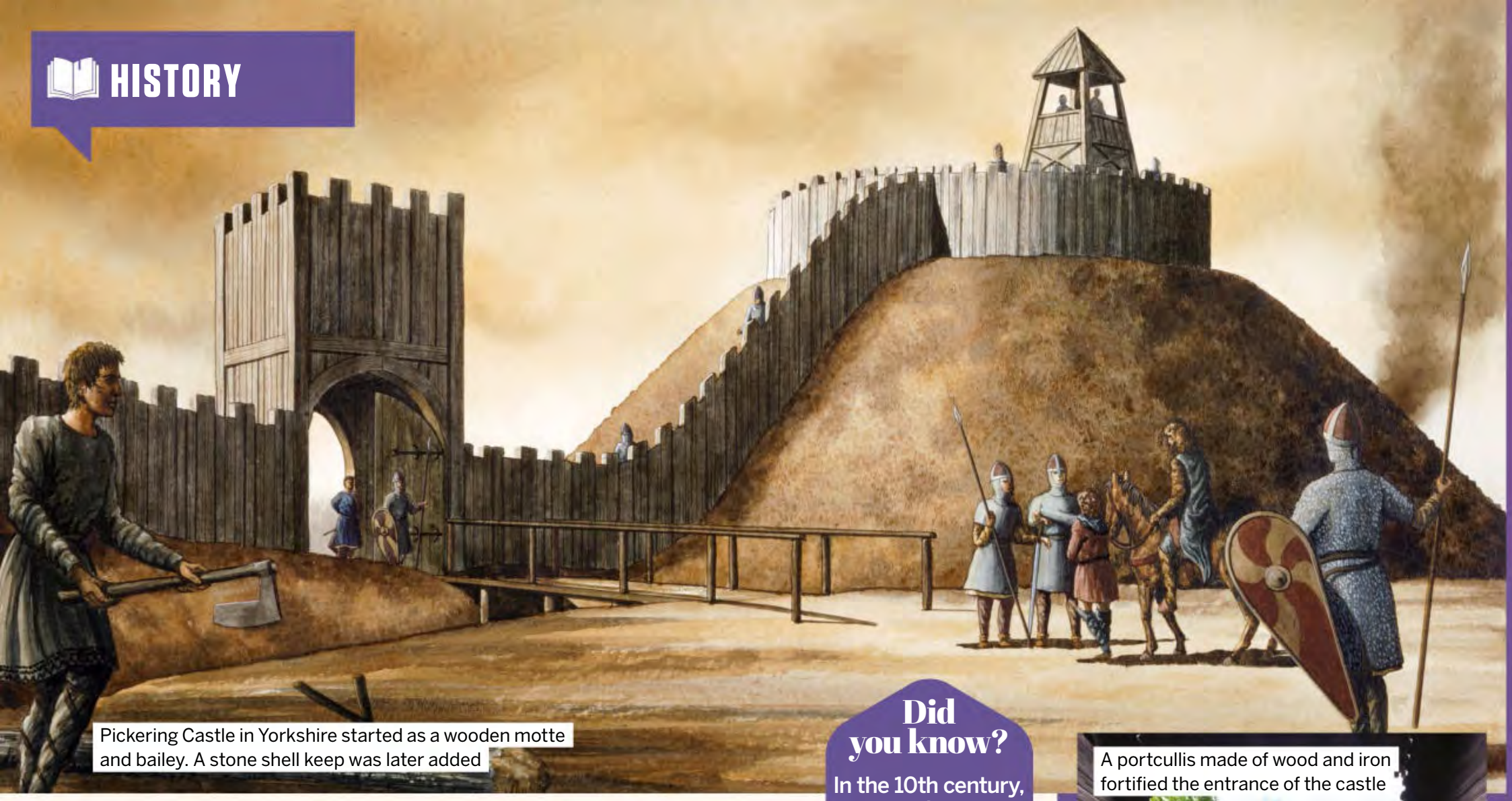
As time progressed and weaponry improved, castles needed to change their basic design and the materials used. Originally, windows were closed with wooden shutters, but these were later replaced with stone slits known as 'arrow loops' that made it very difficult for enemies to shoot their arrows through. Stone walls became thicker and higher, with crenulations that allowed guards to both fire their bows and arrows and to shield themselves from attack. However, with the arrival of the cannon even the fortified concentric castles crumbled, and the call for these draughty stone buildings dwindled away.

The Walls of Ávila in Spain depict the crenulations of a medieval castle

A MAN'S HOME IS HIS CASTLE

The broad definition of a castle is a large structure built to ward off attackers and keep the occupants and their belongings safe. It generally has extremely thick walls that can't be breached and battlements with accompanying towers where soldiers or guards can be placed to keep watch over the surrounding land. In order for it to be a castle and not just a fort, it also needed to be home to royalty or a wealthy lord. Ultimately, if the building acted as a fortress and a manor house, historians will consider it to be a castle.

© Getty



Pickering Castle in Yorkshire started as a wooden motte and bailey. A stone shell keep was later added

EVOLUTION OF THE EARLY STRONGHOLDS

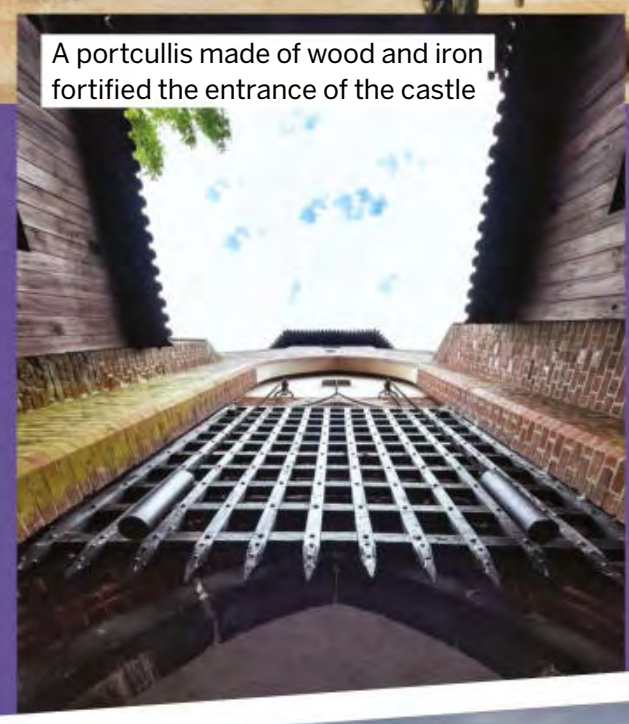
Early medieval strongholds, introduced during the Norman invasion of 1066, were known as motte-and-bailey castles. The 'motte' consisted of a large mound of earth with a tower placed on top. This was built from timber sourced from nearby forests. A fortified enclosure, or 'bailey', was surrounded by a wooden fence at the base. Many were built as the Normans settled in England, but it wasn't long before the warring Anglo-Saxons discovered a major flaw in the design. Wooden towers could easily be burnt down, and even if they were left untouched the wet weather soon began eating away at the vulnerable timbers.

Eventually, the wooden timbers were replaced with stone, thereby avoiding the obvious disadvantages of the wooden tower. The square Norman keep towers were a distinct improvement on their predecessors since they had far thicker walls, but there were still issues with the design. The corners had defensive blind spots, and although they were no longer threatened by an attack by fire, they were still easy to undermine.

By 1270, medieval castles had evolved into the concentric designs we think of today when imagining a castle, with multiple curtain walls and many fine gatehouses.

Did you know?

In the 10th century, a castle cost about £100 ($123) to build



A portcullis made of wood and iron fortified the entrance of the castle

Dunluce Castle is used as Pyke Castle of House Greyjoy in *Game of Thrones*

> **"The 'motte' consisted of a large mound of earth with a tower placed on top"**

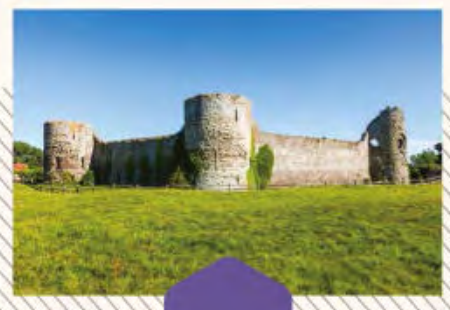
BUILDING UP

Early 900

Western and Central European nobles created fortified residences to protect their wealth and administrative functions from the Moors and Vikings.

1066

With a Norman victory at the Battle of Hastings, William the Conqueror introduced the concept of castles to England.



1067

Cheaply built motte-and-bailey castles were built close to William the Conqueror's landing site along England's south coastline.

1072

William the Conqueror consolidated his power and motte-and-bailey castles spread across the British Isles.

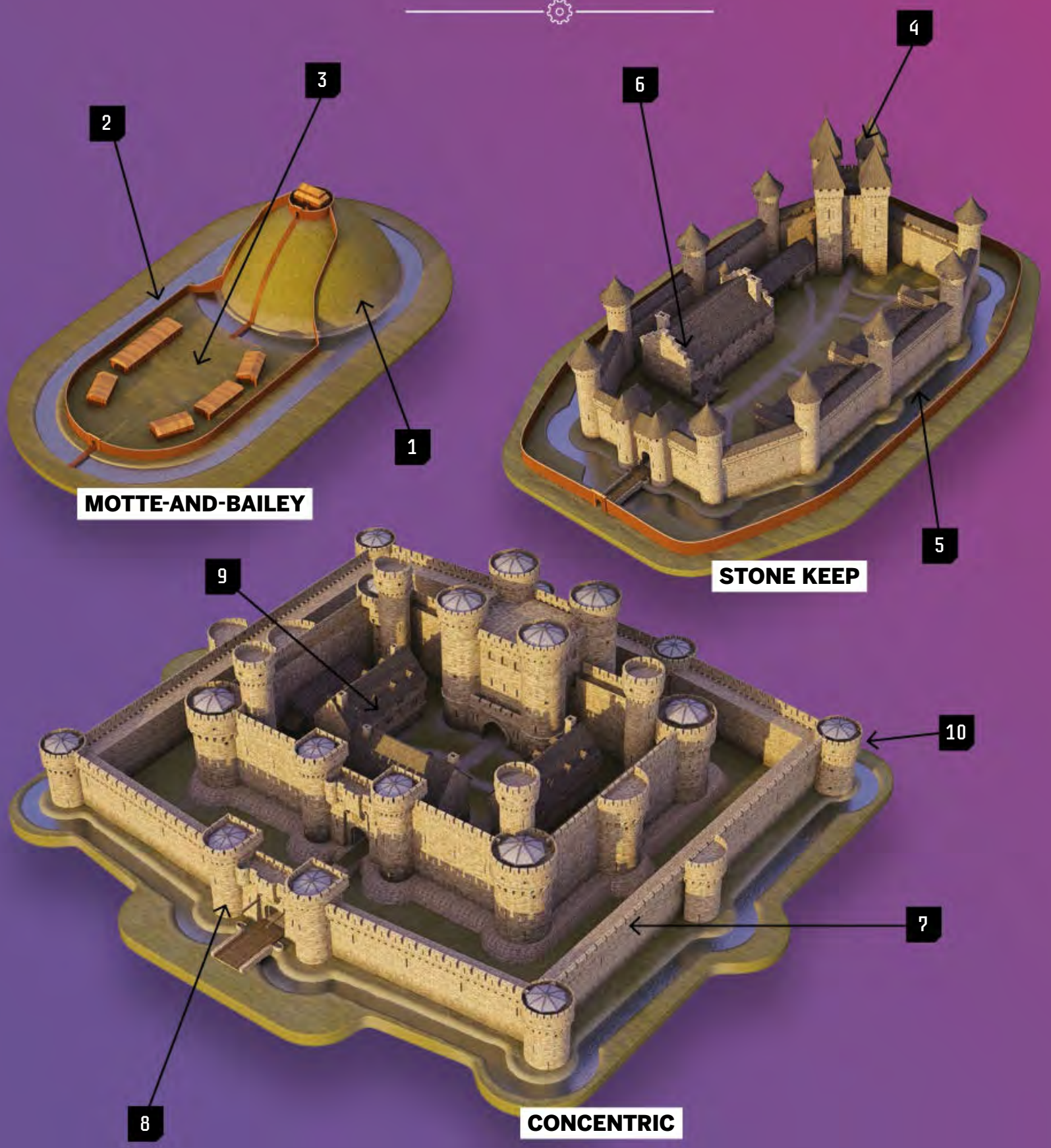
1078

The original White Tower of the Tower of London was built by William the Conqueror using Kentish ragstone and mudstone.

DID YOU KNOW? The oldest standing castle in Europe is Château de Doué-la-Fontaine in France, which was built in 950 CE

CASTLE CHARACTERISTICS

Medieval castles came in three main flavours, each one a natural evolution in defence



1 MOTTE
The earthen mound could be up to 30 metres high. Steep sides called the 'scarp' made it difficult for intruders to climb up.

2 WOODEN PALISADE
This surrounded the bailey to keep the enemy out and was used in conjunction with a ditch that ran around its edge.

3 BAILEY
This courtyard contained domestic buildings such as the kitchens and stables and areas where the livestock could graze.

4 STONE KEEP
Stronger than a wooden tower, the stone keep was the improved living quarters of the lord and the last line of defence.

5 MOAT
A wide, deep ditch was dug around the castle and filled with nearby water to prevent intruders from reaching the walls.

6 GREAT HALL
Here the lord of the castle could hold banquets, reinforcing his status in the area.

7 CURTAIN WALLS
The double layer of protective walls had to be thick enough to withstand bombardment and too high for attackers to climb over.

8 THE GATEHOUSES
These entry points were protected by a metal grill, or 'portcullis'. Boiling oil was poured onto the enemy through 'murder holes' made in the ceiling.

9 DOMESTIC BUILDINGS
The kitchens, stables, a brewery and the water well were kept safe within the inner bailey.

10 TOWERS
Circular towers were strategically placed around the curtain walls to give archers a 360-degree view.

1087
William died, instigating battles between the new king and Norman nobility. Wooden palisades were replaced with stone walls called shell keeps.

1100
Motte-and-bailey castles were gradually replaced by more robust stone keeps.

1199
Nobles had to acquire a 'licence to crenellate' from the king in order to fortify their homes into keeps.

Circa 1250
Curtain walls and towers were added to stone keeps, creating the first concentric castles.

Circa 1450
The arrival of improved military weapons such as the cannon meant that castles were no longer as popular, so they went into decline

© Getty / Illustration by Nicholas Forder

IMPOSING CAERNARFON CASTLE

Designed to quash the warring Welsh princes, King Edward I's master mason built this magnificent castle on the site of a former Roman fort and a primitive motte-and-bailey

QUEEN'S GATE
This smaller gate was used by merchant seamen to unload their cargo and bring it into the castle.

CHAMBERLAIN'S TOWER
The four main towers, designed with multisided walls, contained sumptuous living accommodation over three floors.

DECORATIVE CURTAIN WALLS
The beautiful colour-coded stones, placed in bands around the walls in a lavish design, reinforced King Edward's

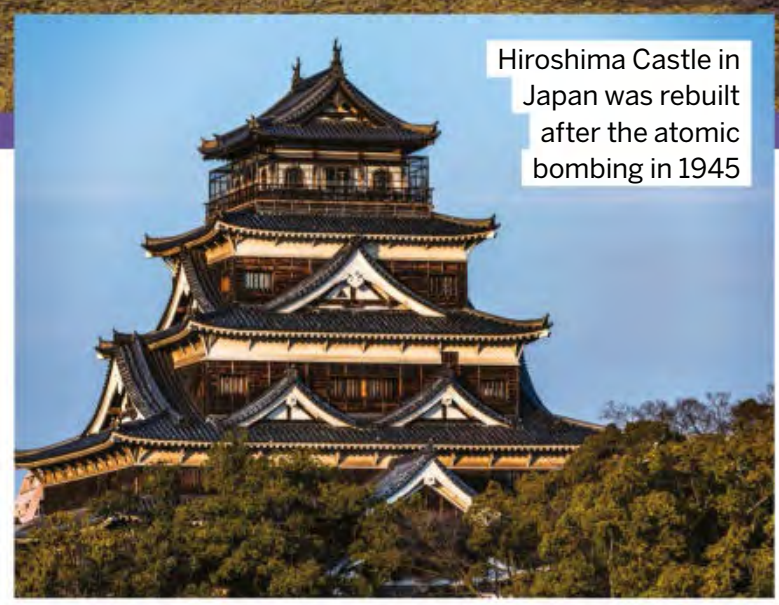
KING'S GATE
The enormous King's Gate, with its portcullis and terrifying murder holes, secured Caernarfon's reputation as one of the greatest buildings of the Middle Ages.

KITCHENS
Food was shipped in from overseas and brought to the busy kitchens via the river and newly erected quay.

"Foreign warriors sensed the vulnerability of Europe"

CASTLES BEYOND EUROPE

Just as European castles were designed to act as both a fortress and a luxurious home, so too were the remarkable strongholds built further afield. Each country relied upon the natural contours of the area, such as a hill or a cliff, for security and utilised local resources to build their structure. Japanese castles were predominantly built of wood and stone and were created not only to safeguard, but also to show off the wealth of the feudal lords. The Citadel of Aleppo in Syria was made of limestone and was similarly designed to protect and impress. The medieval castle Fasil Ghebbi in Ethiopia included 12 gated towers to protect the royal family. It was the first two-storey building in the country.



Hiroshima Castle in Japan was rebuilt after the atomic bombing in 1945

DID YOU KNOW? The magical castle in Disney's *Sleeping Beauty* is based on a real castle in Germany called Neuschwanstein

GREAT HALL
There were two halls situated inside the Inner Bailey. The Great Hall was used by the king when hosting banquets.

QUEEN'S TOWER
In 1284, Queen Eleanor gave birth to the future King Edward II in the plush rooms situated inside the Queen's Tower.

AR zone
SCAN HERE

EAGLE TOWER
This ten-sided tower measured over ten metres across and was adorned with stone eagles, reflecting the site of the Roman fort.

Did you know?
Castle comes from a Latin word meaning 'fortress'

DITCH
A deep ditch filled with water separated the castle from the town, acting as a protective moat.

TOWN WALLS (NOT SEEN)
At 734 metres long, the town walls cost £3,500 ($4,300) to build at the time.

WATER GATE
During the Welsh Revolt of 1294, the dissenting locals breached a number of the fortified gates.

IDEAL LOCATION
Caernarfon Castle, built at the mouth of the River Seiont, allowed ships to bring supplies and timber right to the door.

BIG AND WELL BUILT

HIMEJI CASTLE
Location: **Japan**
Year built: **1333**
Castle type: **Azuchi-Momoyama**
Size: **41,468 square metres**

NORWICH CASTLE
Location: **England**
Year built: **1067**
Castle type: **Stone keep**
Size: **93,077 square metres**

CAERPHILLY CASTLE
Location: **Wales**
Year built: **1268**
Castle type: **Concentric castle**
Size: **121,405 square metres**

MALBORK CASTLE
Location: **Poland**
Year built: **1274**
Castle type: **Concentric castle**
Size: **143,591 square metres**

© Getty / Illustration by Nicholas Forder

WHAT IS A GUILLOTINE?

Incredibly, this execution device was designed by someone who was against the death penalty

Did you know?

The entire guillotine weighed 580 kilograms

WORDS **AILSA HARVEY**

For almost two centuries, the guillotine was used as an execution device in capital crimes – crimes that required punishment with the most severe of sentences. It was first used in the 1700s, during a time where executions were commonly held as public events. As an alternative to the brutal killing methods of the time – which included the guilty party being attached to animals and pulled apart – the guillotine was invented by a French surgeon and physiologist, Antoine Louis, with the aim of executing the sentence quickly with as little pain and suffering as possible.

The vertical wooden structure held a sharp blade, attached to a rope between two tall posts. Below the blade, the person being executed would be placed face-down with their head secured to prevent movement. As it fell onto the neck, the blade was designed to make a single, clean cut. During the French Revolution, the guillotine was used to execute thousands of people, including King Louis XVI. Executioners continued to use the guillotine until September 1981, when capital punishment was abolished in France.

Joseph-Ignace Guillotin wasn't happy to learn that the guillotine was named after him

WHO WAS DR GUILLOTIN?

The guillotine wasn't named after someone who wanted murderers to pay the ultimate price. In fact, Doctor Joseph-Ignace Guillotin opposed the death penalty. Guillotin was born in Saintes, France, in 1738, and from 1789 he became a Paris deputy to the French National Assembly. This meant he held some power in lawmaking. In his first year as part of the assembly, Guillotin helped pass a law stating that all executions be made by means of machine. While the death penalty remained in force, Guillotin refocused his goal to make execution as pain-free as possible. The machine he suggested was a quick and simple alternative to burning people alive or hanging. Although he didn't invent the device itself, because Guillotin advocated for these changes the machine was named after him.

DID YOU KNOW? The first life claimed by the guillotine was in 1792

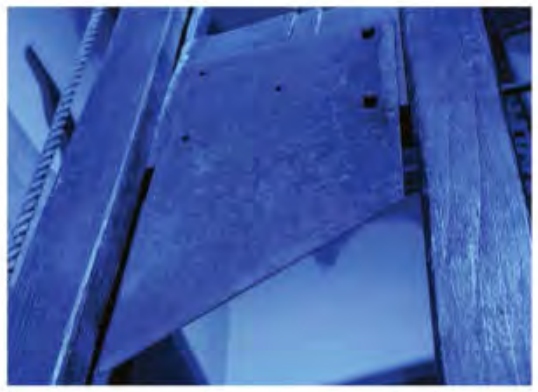
OFF WITH YOUR HEAD

A guillotine made a clean, quick chop

CONSCIOUSNESS EXPERIMENT

Removing someone's head almost instantly kills them. But when the guillotine was first used, scientists didn't know for sure if consciousness was lost immediately. In 1879, an experiment was carried out to find out if people remained conscious after losing their head to the guillotine. A 23-year-old murderer named Theotime Prunier agreed to take part in the experiment during his execution on 13 November 1879.

Five minutes after Prunier was executed, doctors examined his separated head. They noted its pale appearance, still and sunken eyeballs, no blood in the face and an expression frozen in shock. As part of the test for consciousness, doctors continuously shouted Prunier's name loudly, pinched his cheek and inserted an ammonia-covered brush into his nostril. A lit candle was then held next to the eyes and silver nitrate placed on the eyeball. No movement was recorded throughout the entire experiment, so consciousness in a severed head couldn't be proven. This was used as an argument to continue using the guillotine as the most humane execution technique.



The heavy blades meant people were quickly beheaded

BLADE POSITIONING
The rope ran through a wheel placed below the frame. An executioner controlled the height of the blade by turning this wheel to release or raise the rope.

WEIGHTY FALL
Called a mouton, this block held the blade in place while adding weight to make the blade fall faster. Combined, the blade and mouton weighed 40 kilograms.

DÉCLIC
This was the lever that triggered the execution. When the executioner pulled it, the blade was released from the top.

CUTTING BLADE
The steel blade sliced through the necks of those being executed.

LUNETTE
This head restraint opened up so that the neck and head could be placed into position. The top half was lowered over the neck so that the head couldn't be moved.

© Alamy

Future Genous

THE BRAND NEW

★ EDUTAINMENT ★ BOOKS FOR KIDS!

For ages 7+

OUT NOW!

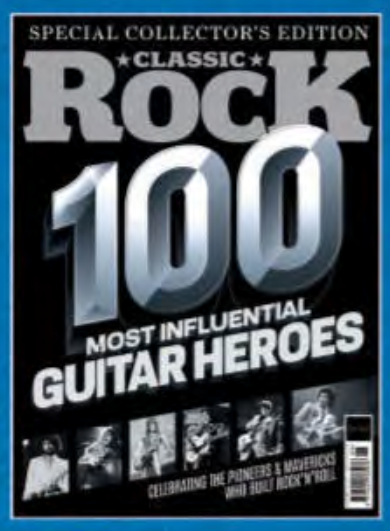
on SALE now

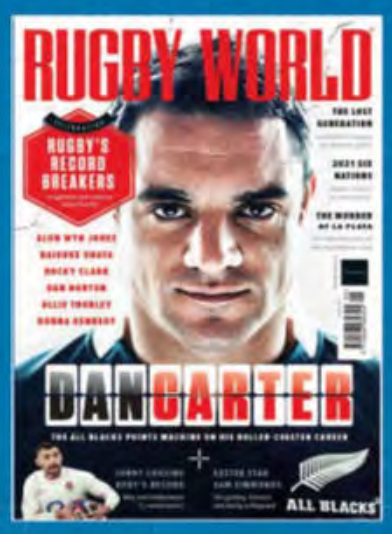
★ Solar System ★ Cool Chemistry
★ Human Body ★ Animal Kingdom
★ Ancient Egyptians ★ Computers & Learn to Code
★ Weather ★ Ancient Greece ★ Dinosaurs

WATCH VIDEOS WITH OUR INCREDIBLE INTERACTIVE EXPERIENCE

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

✚ Puzzles ✚ Activities ✚ Experiments ✚ Facts ✚ More!





FATHER'S DAY SUBSCRIPTION OFFER

EXTRA 10% OFF

- Make his day with the gift that keeps on giving
- He'll never miss an issue of his favourite magazine
- Free delivery included

SEE THE FULL SUBSCRIPTION RANGE AT

www.magazinesdirect.com/DAD

Or phone 0330 333 1113 and quote code **FD22**

Terms and Conditions: Offer closes 30th June 2022. Offer open to new subscribers only. Direct Debit offer is available to UK subscribers only. After your trial issues, your subscription will continue at the price shown at the point of purchase. Saving is based on full subscription rate. We will notify you in advance of any price changes. Please allow up to six weeks for delivery of your first subscription issue (up to eight weeks overseas). If the magazine ordered changes frequency per annum, we will honour the number of issues paid for, not the term of the subscription. Payment is non-refundable after the 14 day cancellation period unless exceptional circumstances apply. Selected magazines are available on this introductory offer and exclusions apply. For full terms and conditions, visit www.magazinesdirect.com/terms. For enquiries please call: +44 (0) 330 333 1113. Lines are open Monday-Friday 9am-5pm UK Time (excluding Bank Holidays) or e-mail: help@magazinesdirect.com. Calls to 0330 numbers will be charged at no more than a national landline call, and may be included in your phone provider's call bundle.

POLLINA

Meet the many species that keep gardens across the globe blooming

WORDS **SCOTT DUTFIELD**

DID YOU KNOW? Fossil records show that beetles started pollinating flowers around 200 million years ago

POLLINATORS

Pollination is one of the cornerstones of life on Earth. As part of the wider global ecosystem, plants are the beginning of almost every food chain, are habitat builders and atmospheric oxygen producers. Without plants, the world would surely fall barren and unable to sustain life. That's why the creatures that spend their time keeping the planet's plant population alive are invaluable. Although not all plants require the helping hand of a pollinator, between 75 and 95 per cent of all flowering plants on Earth rely on pollinators to reproduce. There are two main types of pollination among flowering plants: self-pollination and cross-pollination. As the name suggests, self-pollination is all contained within the individual plant, whereas cross-pollination requires a helping hand from external factors, such as the wind, rain and other living creatures, or pollinators.

In the process of cross-pollination, a pollinator – for example, a bee – will land on a flower to drink sweet nectar produced by plant glands called nectaries. Bees will also eat a portion of the pollen within the flower as a source of protein. While feasting on this food source, loose grains of pollen produced by the plant's male reproductive organ, called the stamen, are picked up accidentally by the bee as it brushes against the head of the stamen, called the anther.

Some bees, such as the bumblebee, 'buzz pollinate', whereby the vibrations of their wings shake pollen free from the anther and blow it into the air. Once the bee is done with its meal, it will journey to another plant for more nectar. On arrival, the hitchhiking pollen grains fall onto the female reproductive organs of this plant – called the stigma – and cellular reproduction gets underway.

A beehive of around 20,000 members can pollinate around 20 million flowers per day.

Bees are just one of the countless species of pollinators on Earth. There are more than 200,000 different species of pollinating animals around the world, 1,000 of which are vertebrate species such as birds and mammals.

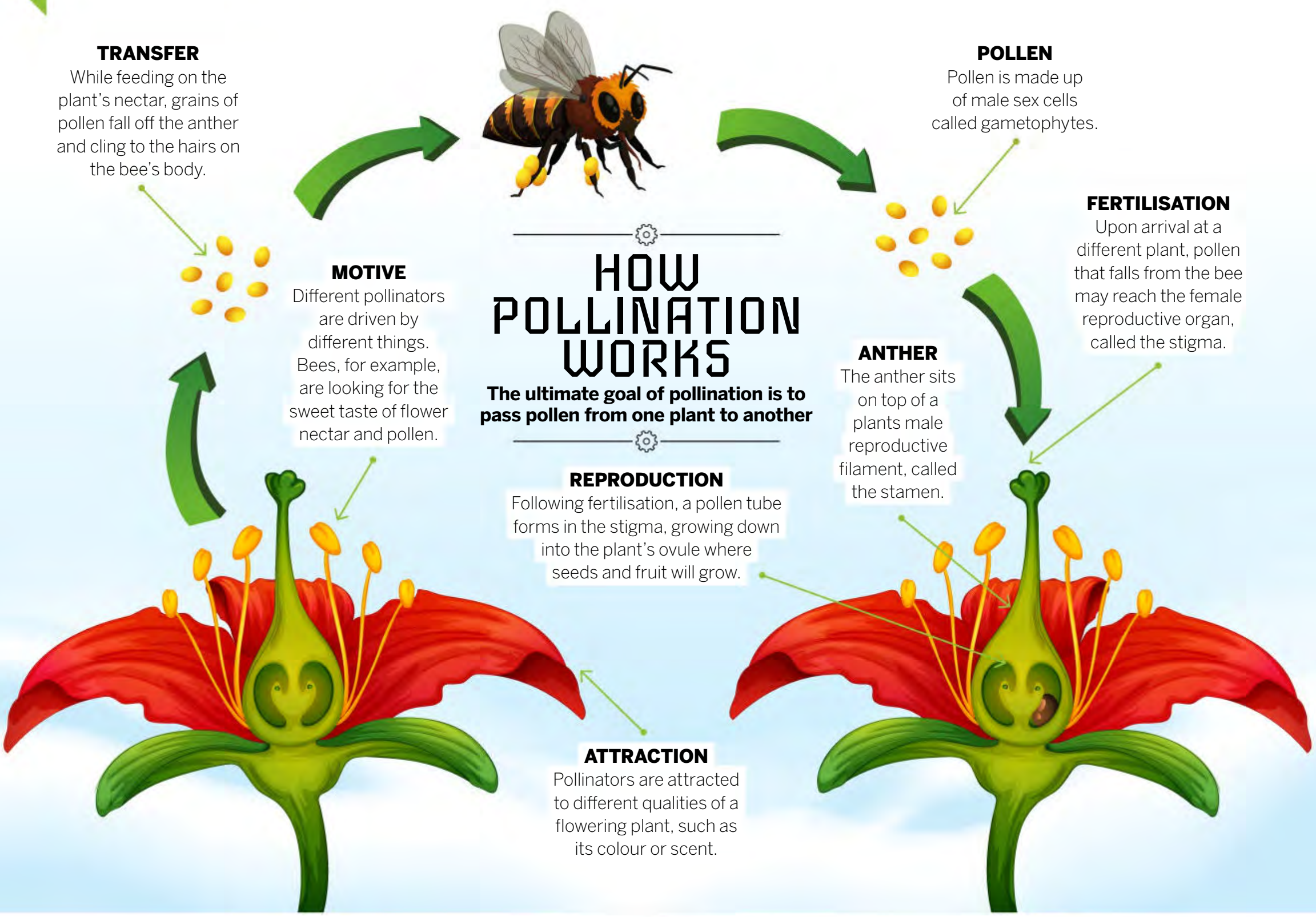
Did you know?

Honeybees can carry around 35 per cent of their weight in pollen

© Getty

HOW POLLINATION WORKS

The ultimate goal of pollination is to pass pollen from one plant to another



TRANSFER
While feeding on the plant's nectar, grains of pollen fall off the anther and cling to the hairs on the bee's body.

MOTIVE
Different pollinators are driven by different things. Bees, for example, are looking for the sweet taste of flower nectar and pollen.

ATTRACTION
Pollinators are attracted to different qualities of a flowering plant, such as its colour or scent.

REPRODUCTION
Following fertilisation, a pollen tube forms in the stigma, growing down into the plant's ovule where seeds and fruit will grow.

POLLEN
Pollen is made up of male sex cells called gametophytes.

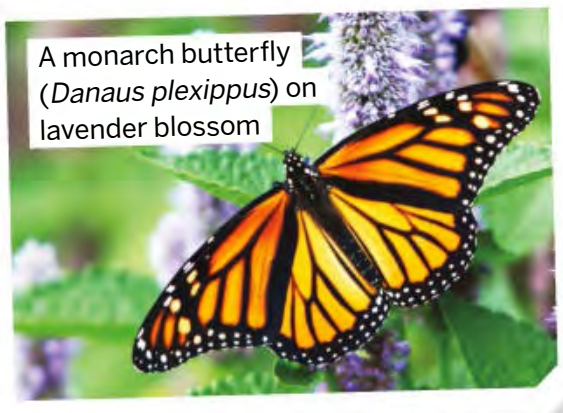
ANTHER
The anther sits on top of a plants male reproductive filament, called the stamen.

FERTILISATION
Upon arrival at a different plant, pollen that falls from the bee may reach the female reproductive organ, called the stigma.

INSECT POLLINATORS

Bees are the most prolific pollinators on Earth. Scientists have found that around two per cent of the world's wild bee population is responsible for around 80 per cent of global pollination. As a big part of their diet, pollen is a high priority. Bees have evolved structures on their legs called corbiculae, or pollen baskets, to ferry pollen between plants before heading back to the hive. A typical colony of honeybees (*Apis mellifera*) – around 20,000 strong – will collect around 57 kilograms of pollen per year.

But bees are by no means the only insects that facilitate plant reproduction. There are hundreds of thousands of insect species that pollinate plants. Butterflies are expert pollinators, especially for flat flowering plants. Driven by a desire to drink nectar, they serve as a butterfly's source of water, carbohydrates and amino acids.



A monarch butterfly (*Danaus plexippus*) on lavender blossom

An ornate day gecko feeding on nectar from bois boeuf (*Gastonia mauritiana*) blossoms

REPTILE HELPERS

Lizards aren't the first creatures that come to mind when thinking about pollination. In fact, there are only a few species that even visit flowers, including the nectar-hungry Noronha skink (*Euprepis atlanticus*), which seeks out flowers of the Mulungu tree (*Erythrina velutina*) in Brazil. These flowers bloom during Brazil's dry season, and these skinks take advantage of the water content of the flowers' nectar. Without fur and hairs for pollen to cling to, it gets stuck between the lizard's scales – predominantly on its belly and chin. Similarly, on the Indian Ocean island nation of Mauritius, the ornate day gecko (*Phelsuma ornata*) can be seen with grains of pollen covering its scaly face after a day foraging for nectar.

DID YOU KNOW? Windborne pine pollen can travel up to 1,800 miles before landing

A Mexican violetear (*Colibri thalassinus*) feeding on flowers

BRING IN THE BIRDS

Bird pollination – also known as ornithophily – occurs among 2,000 or so avian species across the world. Along with feeding on nectar, some birds come face to face with a flower to eat all the tiny invertebrates that live within it, such as spiders and beetles. Pollinating birds typically belong to five groups: New World blackbirds, honeycreepers, sunbirds, honeyeaters and hummingbirds.

Hummingbirds are the most recognisable among bird pollinators. There are more than 350 species of hummingbirds on Earth, all of which can be found in the Western Hemisphere. These small birds – which weigh around four grams on average – are hungry creatures. With a preference for bright tubular flowers, hummingbirds hover adjacent to the flower – beating their wings over 80 times per second – and use their long tongues to lap up the nectar within.

Due to the furious flapping of their wings, hummingbirds feed regularly – between five and eight times per hour on average. A hummingbird's appetite means a lot of trips between flowers, and therefore lots of pollen captured on the ends of their beaks and passed between plants. The rapid movement of their wings causes a wind storm inside the tubular flowers, throwing pollen out into the air and hopefully onto other flowers.

Did you know?

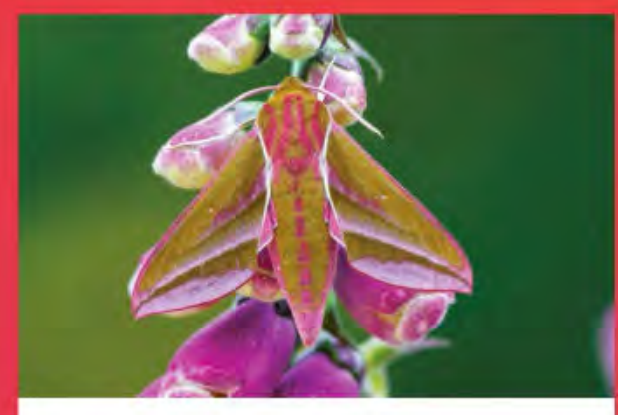
A single corn plant produces 2 to 5 million pollen grains

BEYOND BEES

These other insects are vital to plant pollination

HOVERFLIES

While furiously flapping their wings, hoverflies drink from plant nectar as pollen collects on their hairy bodies. They aren't as well adapted to collect pollen as bees, but studies have shown hoverflies might be more efficient at pollination. While studying open flowers, scientists have found that plants pollinated by hoverflies produced more seeds than those pollinated by bees.



MOTHS

As nocturnal feeders, moths extend a tongue-like structure called a proboscis to lap up nectar from deep tubular plants like honeysuckle. The furry thorax of a moth is where the majority of pollen is collected while they feed. Research has shown that moths that settle on a flower's surface rather than hovering pollinate a more diverse collection of plants compared to some bees and hoverflies.

BEETLES

Unlike the majority of pollinating creatures, beetles aren't just interested in the nectar of flowering plants. Instead they munch on other parts of the plant, often defecating in the flower as they pass through, called 'mess and soil' pollinators. Along the way, beetles will accidentally collect pollen as they go. Some species, such as the common red soldier beetle, use flower heads as a mating site.

WASPS

Wasps do indeed serve a positive function in the garden. Echoing the same pollination behaviour as bees, wasps buzz from flower to flower drinking nectar and dropping off pollen. Fig wasps are responsible for pollinating 900 species of fig trees. Female fig wasps lay their eggs in male figs. The resulting offspring emerge from the fruit carrying pollen, which they deliver to another fig tree.

© Getty / Alamy

FURRY POLLINATORS

Many mammals also make plant pollination possible

LEMURS

In Madagascar, traveller's palm trees (*Ravenala madagascariensis*) are mainly pollinated by the world's largest pollinator, the black-and-white ruffed lemur (*Varecia variegata*). Thanks to their nimble and dexterous hands, these lemurs are able to prise open the tough bract (protective layer) of the tree's flower. While burrowing into the opened flowers to lap up sugary nectar, the face and snout of the lemurs get covered in pollen. After visiting several trees, the successfully pollinated plants will then produce nutritious fruit, which the lemurs will also eat.

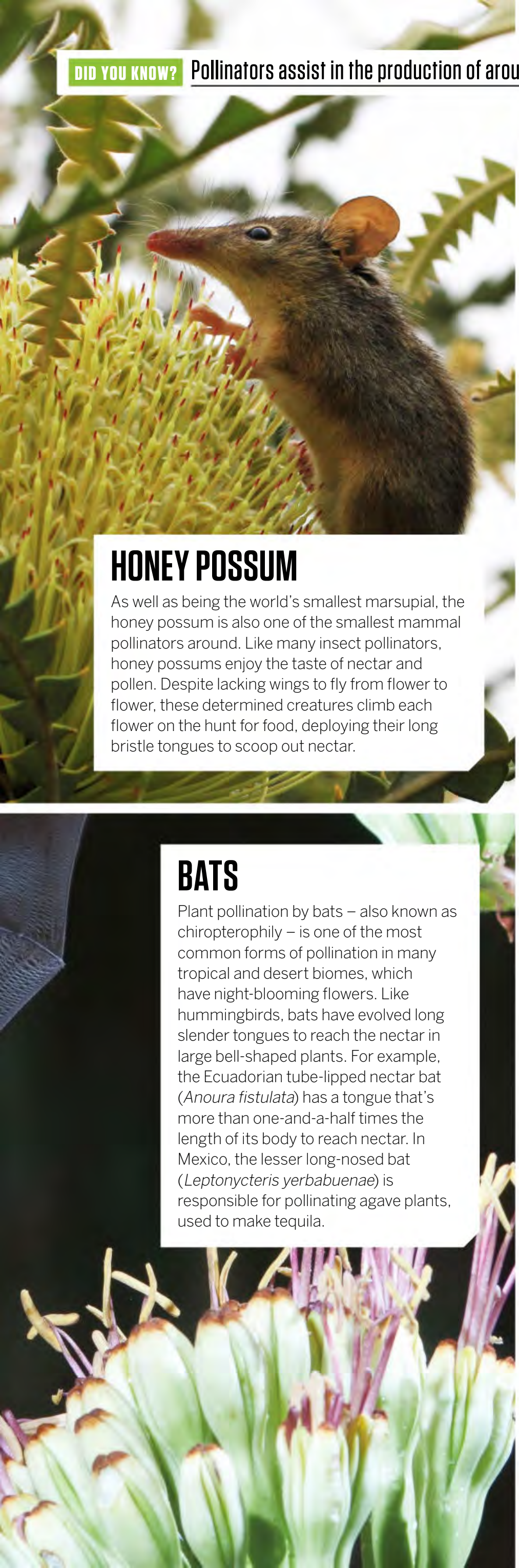
SLOW LORIS

A slow loris is a small mammal weighing around 1.2 kilograms that can be found on the Indonesian island of Java. These nocturnal tree climbers spend their time moving through the thick vegetation of Java's tropical rainforest on the hunt for fruit and tree sap, as well as insects, lizards and even other small mammals. On its nightly travels, a slow loris passively pollinates coffee plants and eats any harmful insect larvae that damage the crop plants.

Did you know?

Unlike bees, butterflies can see the colour red

DID YOU KNOW? Pollinators assist in the production of around 30 per cent of the human diet



HONEY POSSUM

As well as being the world's smallest marsupial, the honey possum is also one of the smallest mammal pollinators around. Like many insect pollinators, honey possums enjoy the taste of nectar and pollen. Despite lacking wings to fly from flower to flower, these determined creatures climb each flower on the hunt for food, deploying their long bristle tongues to scoop out nectar.

BATS

Plant pollination by bats – also known as chiropterophily – is one of the most common forms of pollination in many tropical and desert biomes, which have night-blooming flowers. Like hummingbirds, bats have evolved long slender tongues to reach the nectar in large bell-shaped plants. For example, the Ecuadorian tube-lipped nectar bat (*Anoura fistulata*) has a tongue that's more than one-and-a-half times the length of its body to reach nectar. In Mexico, the lesser long-nosed bat (*Leptonycteris yerbabuenae*) is responsible for pollinating agave plants, used to make tequila.

A prototype of a robo-buzzer pollinator, capable of shaking plant stamens for pollen release

HUMAN POLLINATORS

Humans have historically lent a helping hand in plant reproduction, particularly through agriculture. Since ancient times, humans have developed methods of hand pollination for increasing the yield of crops. Around 3,500 BCE in Lower Mesopotamia, the date palm was fertilised by human hands to optimise its fruit production and produce greater yields. Initially this was achieved by simply rubbing the pollen off the male parts of the tree and transferring them to its female counterparts. However, over time human pollination has evolved mechanically. The predominant form of artificial pollination comes from giant mechanical shakers that forcibly loosen pollen from flowering crops, releasing it into the wind for pollination or harvesting it for hand pollination. Water spray containing pollen is also used to deliver harvested pollen.

In recent years, one mechanical pollination method has employed drone technology to mimic the pollen-spreading ability of pollinators. For example, the Dropcopter – an agricultural drone – can fly up to three metres into the air and spray harvested pollen over crop plants for fertilisation. Scientists are also developing and building microrobots that simulate bee pollination. Taking buzz pollination as their inspiration, engineers from both the UK and US are developing tiny bee-like robots to mechanically shake individual flowers to release their pollen. These 'robo-buzzer' robots would release a high-frequency sound to vibrate and ultimately release a plant's pollen from its stamen. Prototypes of the robo-buzzer are the same size as a fingernail and weigh a quarter of a honeybee.

> "Humans have developed methods of hand pollination for increasing yields"

Mechanical pollination may one day become the predominant way crops are fertilised in the future. As the effects of climate change and global warming become more apparent, populations of natural pollinators such as bees and butterflies appear to be heavily hit by a changing world. In European countries alone, at least 37 per cent of the total bee population and 31 per cent of the butterfly population are in decline.

© Alamy / Getty / Mario Vallejo-Marin

Dams are made of sticks, branches, mud, stones and vegetation

The teeth marks displayed on this tree show how a beaver can cut down thick trunks

Did you know?

Beavers eat leaves, roots and bark from trees

HOW BEAVERS CONSTRUCT DAMS

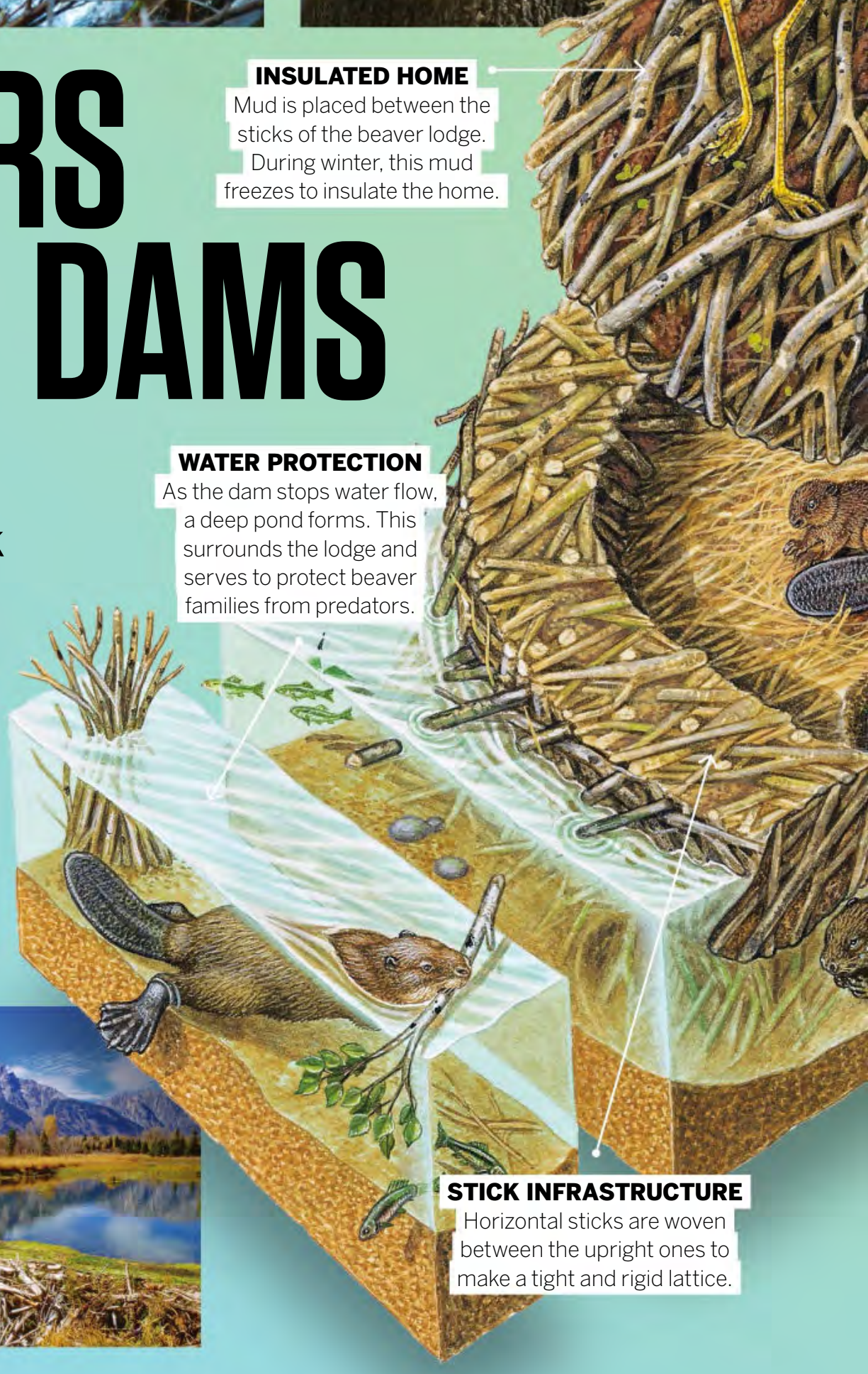
A look inside the homes of beavers to see their masterful builds at work

WORDS **AILSA HARVEY**

Animals often have to make the most of an environment in order to survive, but not many alter their surroundings to do so as much as the beaver. Beavers, which have evolved to live in aquatic environments, have webbed feet and flat tails to help them navigate rivers and long, waterproof fur to keep them warm and dry. Their anatomy alone is enough for these large rodents to flourish in freshwater environments. But beavers don't rely purely on these bodily adaptations. Beavers have learned how to edit the landscape to best suit them by building beaver dams.

To block the flow of rivers and create a perfectly still body of water to build their homes in, beavers build dams in shallow, low-lying waters. The materials used to build these structures depend on the riverside resources available. This includes logs, mud and sometimes rocks. The surrounding tree populations are reduced during the building process, but as the dam produces flooding, the water extends towards new trees. The beavers can then use these for further building or for food.

This beaver dam was built in the Teton Range



INSULATED HOME
Mud is placed between the sticks of the beaver lodge. During winter, this mud freezes to insulate the home.

WATER PROTECTION
As the dam stops water flow, a deep pond forms. This surrounds the lodge and serves to protect beaver families from predators.

STICK INFRASTRUCTURE
Horizontal sticks are woven between the upright ones to make a tight and rigid lattice.

DID YOU KNOW? Beavers can build dams up to two metres in height

LODGE
Beavers build a large living chamber behind the dam. Beavers remain here for much of winter.

TEAMWORK
All members of a beaver family work together to collect materials and build dams.

BEAVER DAM
A dam stretches across the entire width of the river and above the water's surface to stop the flow of water.

MUD PLASTER
To seal loose parts of the dam, beavers place wet mud into any gaps.

STABILISERS
Sticks that branch into V shapes are used to fix other horizontal sticks into place.

ROCK SUPPORT
If available, heavier stones and rocks are used to prevent the dam from being washed away.

UNDERWATER ENTRANCE
Beavers swim into the lodge using hidden underwater entrances. This prevents access to predators.

HOW DAMS AFFECT THE ENVIRONMENT

Beaver dams play an important role in keeping the local environment and wildlife healthy. Although the goal is to create a habitat for themselves, the wetlands that dams produce are utilised by other species. Fish, waterfowl and amphibians take advantage of these still waters to build their own homes. By flooding land with their dams and removing some of the surrounding trees, other plant life has space to grow in their place. In certain areas, beaver activity can increase biodiversity by 50 per cent.


Increased vegetation growth around beaver dams can attract wildlife

OPEN HOUSE

How do beaver dams keep these animals protected?

BUILDERS' BODIES

Beavers' strong teeth never stop growing. Used to cut branches and gnaw them into shape, the wearing of these tools won't impact future builds. The tough teeth are covered in strong, high-iron enamel and curve backwards slightly to help cut through wood more effectively. Coupled with powerful lower jaw muscles, their teeth are ideal for manipulating riverside materials. They also have paw-like hands with high dexterity. They can hold and move objects into precise positions using their hands. To carry building materials long distances through the water, beavers will hold sticks in their mouths. Behind their teeth are a pair of inner lips. These close while the mouth remains open for transportation, preventing them from swallowing water as they swim.


Beavers' teeth are orange because they contain so much iron

© Alamy / Getty

WELCOME TO THE SCRAPYARD

How specialised scrapping machines break, crush and melt old vehicles, returning them to raw materials

WORDS **AILSA HARVEY**

DID YOU KNOW? When recycling metal, 74 per cent less energy is used than during the production of new steel

Much of the framework of cars and other vehicles is metal – mostly steel, aluminium and even some copper. This metal is mined as raw materials from Earth and shaped into a great variety of things, but what happens to these materials when they become worn and unusable?

Instead of burying old vehicles underground at landfill sites and sourcing new metal, scrapyards collect and recycle used metal. By doing so, around 80 per cent of the energy used to make more metal from raw materials can be saved. Scrapyards will also pay you for your old metal items – particularly old vehicles.

Organising metal waste might not look like a sophisticated operation. However, complex machinery and high-tech processing is required to transform worn and broken objects into materials that pass the necessary quality tests for use in new projects. Instead of organising metal by hand, which was the only option in early scrapyards, today's scrapyard workers can be assisted by automatic laser and X-ray processing. This process allows workers to quickly identify metals with high-energy lasers directed at a piece of metal, giving its atoms more energy to move. As they move, the atoms are analysed to reveal a metal's makeup, quickly detecting lighter alloys such as steel. The environmental benefit of having an efficient scrapyard system means that greater efforts to develop scrapyard technology have been made in recent years.

Did you know?

The owner of a scrapped car is sent a 'certificate of destruction'

"Scrapyards will also pay you for your old metal items– particularly old vehicles"

A large magnet lifts ferrous metals at a scrapyard

CAR-CRUSHING TECHNIQUES

How an old or crashed car is compacted

Scan the code to watch old cars being flattened by car-crushing machines

FLATTENING

The first step of scrapping a car involves removing any useful working parts, tyres to recycle and any part containing potentially hazardous materials, such as vehicle batteries that contain strong acids. This is called the vehicle depollution process. Once this is completed, the vehicle is placed into a large pressing machine to crush it flat.

First, a crane places the car onto the hydraulic machine. This consists of one or two large panels which move closer together to crumple the metal and flatten the car's frame between them. Glass is often removed from the windows beforehand.

Scan the code to watch a flattened car emerge as a cube

CAR TO CUBE

Machines called balers press a crushed car into a tightly packed cube. Before being placed into the machine, excavators may drop the cars from a height or break the roof. This helps prolong the life of crushing machines by making the car weaker. Balers usually have an opening which can be closed to fully contain the car. As the car is rotated and crushed, a neat cube is produced inside.

© Getty

AR ZONE

ON-SITE PROCESS

From donation to delivery, these are stages involved in metal recycling

MELTING

Metal can be melted and reshaped. At scrapyards, metals are separated and taken into a large furnace, with temperatures tailored towards their melting points. Although the furnaces use a lot of energy during this process, recycling metal this way uses less than producing it from raw materials. Eventually, the molten metal is transported on a conveyor belt into a cooling chamber to solidify in uniform bars.

SORTING

Crane grabbers attached to mobile vehicles are used to transport and sort large volumes of metal. This includes transporting metals at different stages into organised piles. These vehicles are essential for easily moving large metal items such as cars. Excavation grabbers are used to transport metal in bulk across sites, while fixed grabbers can only operate within a radius of a few metres.

COLLECTING

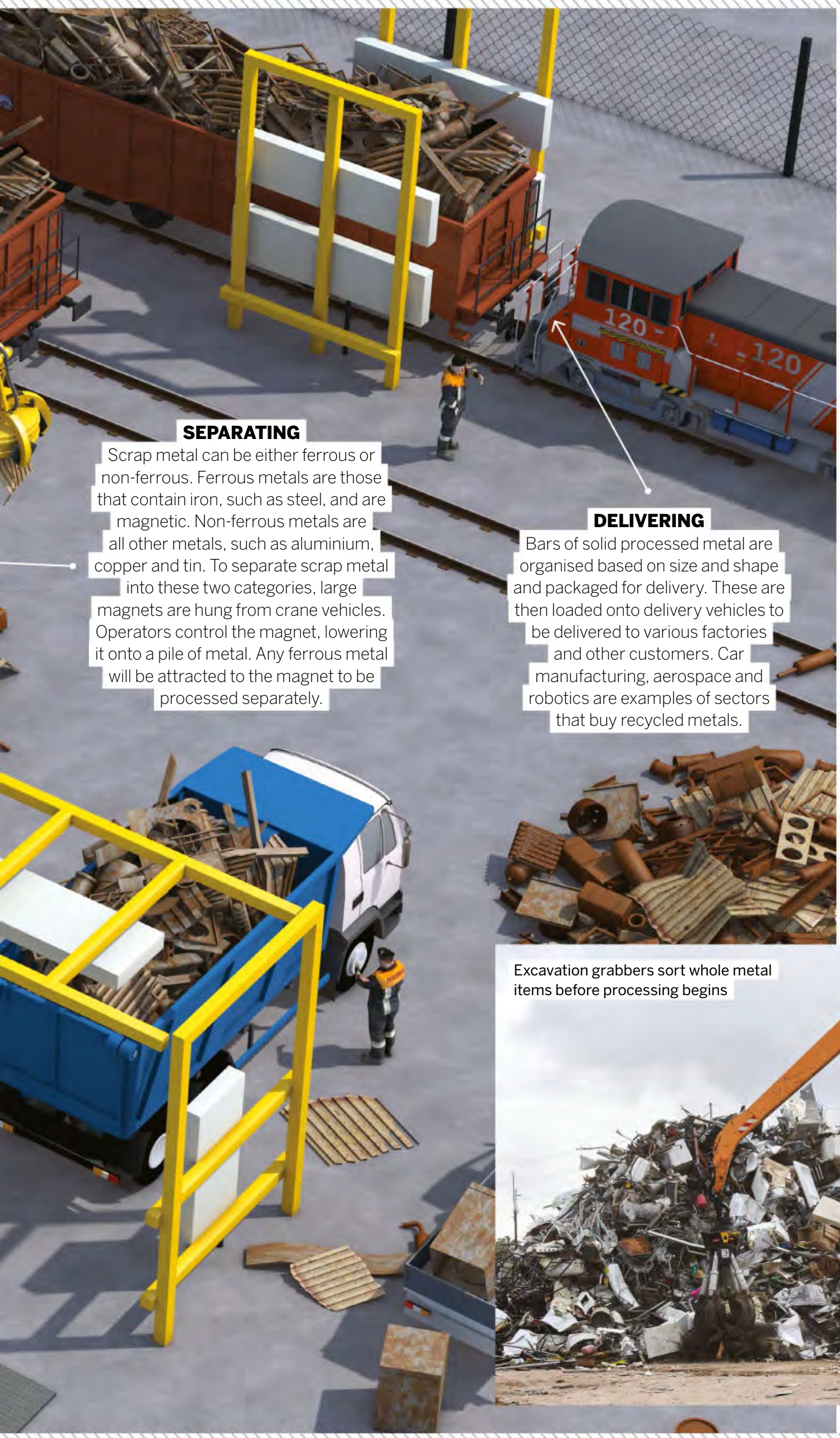
Scrapyards will process items that have a significantly high percentage of metal in them. While these don't need to be 100 per cent metal, they usually have to contain around 50 per cent to be accepted for processing. Metal may come from scrap metal collectors or public recycling collections. These are loaded into large vehicles for transport to the scrapyard.

AR zone SCAN HERE

Did you know?

The most commonly used metal is iron

DID YOU KNOW? Copper is 100 per cent recyclable, with its performance remaining the same each time



SEPARATING
Scrap metal can be either ferrous or non-ferrous. Ferrous metals are those that contain iron, such as steel, and are magnetic. Non-ferrous metals are all other metals, such as aluminium, copper and tin. To separate scrap metal into these two categories, large magnets are hung from crane vehicles. Operators control the magnet, lowering it onto a pile of metal. Any ferrous metal will be attracted to the magnet to be processed separately.

DELIVERING
Bars of solid processed metal are organised based on size and shape and packaged for delivery. These are then loaded onto delivery vehicles to be delivered to various factories and other customers. Car manufacturing, aerospace and robotics are examples of sectors that buy recycled metals.

PURIFICATION AND ADDITION

Metal scrapyards need to ensure that they're producing and selling materials of consistent quality to stay in business. In the latter stages of processing, metal is purified to remove any contaminants. One frequently used method of purification is called electrolysis. During electrolysis, an electric current is passed through the metal. This separates any impurities, depositing only the pure metal.

Sometimes a metal's impurities are removed as it's melted. Melting causes some of the impurities to rise to the top for easy separation. Electrolysis is necessary when returning the metal to near-new condition, and chemicals are often added to molten metals to increase their density.

The steel is sent to a steelworks as ingots after processing

Excavation grabbers sort whole metal items before processing begins

© Alamy / Getty / Illustration by Adrian Mann

THE FASTEST SHOES IN THE WORLD

How do carbon-plate running shoes reduce athletes' times?

WORDS **AILSA HARVEY**

Carbon-plate running shoes are the latest trainer trend, including a stiff carbon-fibre plate within the shoe designed to improve running economy. A shoe's running economy is the term used to describe the energy exerted by a runner to achieve a given velocity. In modern carbon-plate shoes, the light foam and carbon-fibre soles reduce the energy lost per stride.

This technology appears to be new in the running community. However, while the effectiveness of carbon-plate trainers has increased, gaining recognition in recent years, the concept first emerged in the late 1980s. Reebok released the Graphlite Road running shoe in 1989, with Adidas later producing something similar. While these shoes included carbon-fibre plates, the force that needed to be applied to them by the runner to improve energy efficiency was too great because the plates were too stiff.

Modern carbon-plate shoes, first released by sports footwear company Nike in 2017, revolutionised carbon-fibre shoes. The company's shoes claimed to improve running efficiency by four per cent, meaning that a given running speed could be sustained using four per cent less energy.

The key to these shoes' speedy results was the substantial foam soles that bulged from the base. When running, this foam is squished against the ground, but it bounces back easily to its original shape. In doing so, it utilises about 85 per cent of the energy that was transferred to the sole by the runner. The stiff carbon-fibre plate helps to give the soft foam shoe structure and stability. Today most running shoe brands have made their own versions of these carbon-plate shoes.

Running shoe brand ASICS released the Metaspeed Sky Tokyo carbon-plate shoe for the 2020 Olympics

AR zone

SCAN HERE

RUNNING SHOE TECH

These specialised trainers make running easier for athletes

LIGHT UPPER
The upper material of the trainer is thin and lightweight. The amount of water it can absorb is reduced to avoid added weight.

CURVED CARBON PLATE
Sandwiched between two layers of foam is the carbon-fibre plate. Being curved means that when the runner places force at the front of the shoe at an angle the resultant force is propelled upwards, almost like a spring.

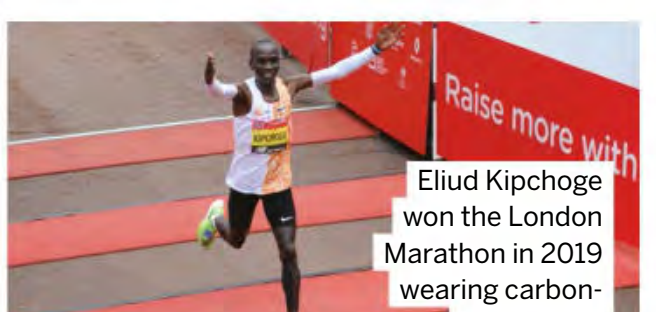
PEBAX FOAM
This nitrogen-infused foam is extremely lightweight, allowing for an increase in sole thickness.

MAXIMUM THICKNESS
Greater foam thickness allows for a steeper curve in the carbon plate. Until 2024 – when the limit will be reduced – this can be up to 40 millimetres for events such as road races.

RUBBER OUTSOLE
The rubber elements on the underside of the shoe provide grip.

Did you know?

Early sneakers were made out of leather, which wore out quickly



Eliud Kipchoge won the London Marathon in 2019 wearing carbon-plate shoes

SPEEDY MARATHON

In 2019, Kenyan runner Eliud Kipchoge made his second official attempt to run a marathon in less than two hours. Finishing in 1:59:40, Kipchoge achieved the fastest marathon in history. Kipchoge used a pair of Nike's Alphafly carbon-plate shoes. Because the conditions were tailored towards this achievement, with pacemaker runners keeping Kipchoge on target, the time doesn't count as a marathon world record. The significant impact that carbon-plate running shoes have had on running has caused controversy. For some runners, the increased performance is an exciting opportunity to maximise running potential. For others, the benefit changes what it means to be a good runner. Instead of prioritising physical talent, many believe running ability is now determined too much by the quality of the shoes runners own.

© Alamy / Illustration by Nicholas Forder

DISCOVER THE UNIVERSE

www.spaceanswers.com

Available from all good newsagents and supermarkets

Issue 130 on sale now!

Print and digital subscriptions available at

www.magazinesdirect.com/know3for3

/AllAboutSpaceMagazine @spaceanswers space@spaceanswers.com

TECHNOLOGY

COOL CARBON CAPTURE TECHNOLOGIES

These gadgets and tools could help undo our damaging emissions

WORDS **AILSA HARVEY**

DID YOU KNOW? Carbon capture has the potential to prevent 90 per cent of CO_2 emissions entering the atmosphere at industrial sites

A coal seam blazes underground in Jharkhand, India

Did you know?

Fossil fuels produce about 80 per cent of global energy

About 85 per cent of all human-made carbon dioxide (CO_2) is released into the atmosphere due to the burning of fossil fuels such as oil, natural gas and coal.

In 2020, a new high in global average atmospheric CO_2 levels was recorded, at 412.5 parts per million. This is an increase of 12 per cent since 2000. 412.5 parts per million may seem like a small percentage, but even these levels are causing a significant increase in global warming. As greenhouse gases in the air increase, the Sun's heat is trapped within Earth's atmosphere, warming the planet.

As well as trying to reduce the levels of CO_2 we emit, scientists across the globe are working on methods to collect the existing gas from the air and store it out of harm's way. Most of these methods include burying it deep underground. Carbon capturing and storing methods have been given heightened attention since the 2015 Paris Agreement was established. This is an international treaty on climate change, with one of the core goals being to reduce greenhouse gas emissions by 40 per cent by 2030.

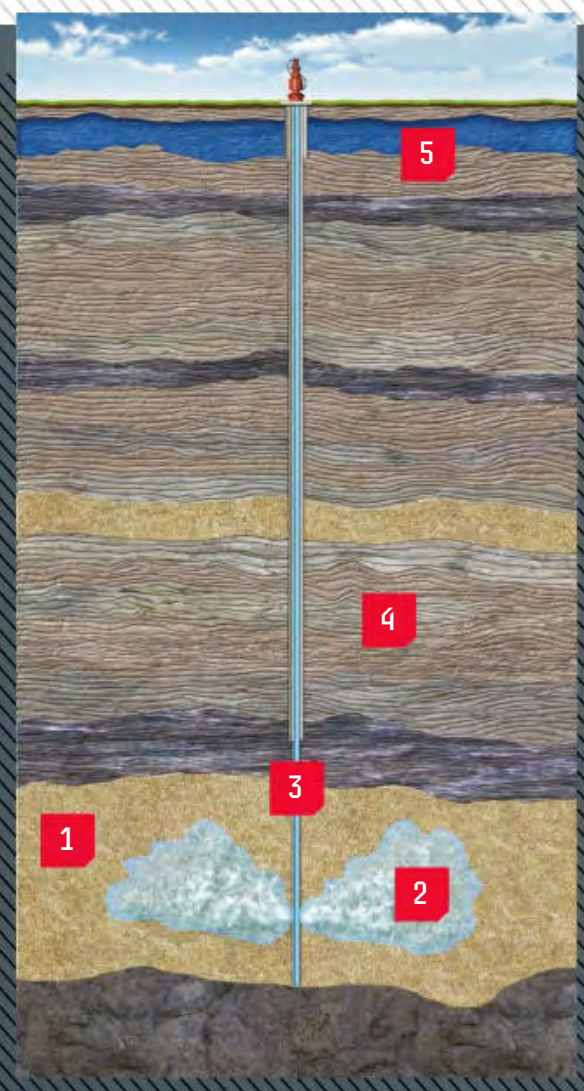
Carbon capture technology itself, however, isn't new. The idea of a carbon capture plant – to capture CO_2 and stop it from re-entering the atmosphere – was first suggested in 1938. Around four decades later in 1972, the first large-scale carbon capture plant was built in Texas. This involved injecting CO_2 emissions that were produced at the Sharon Ridge Oil Field into the ground below. In 2021, there were over 30 commercial carbon capture plants in operation, and 135 are planned for the near future.

TYPES OF CAPTURE

1 PRECOMBUSTION
Before combustion, fossil fuels are separated into a gaseous mixture of carbon dioxide and hydrogen. The hydrogen can be burned, while the CO_2 is compressed and stored.

2 POST-COMBUSTION
This is the capture of CO_2 from the exhaust gas after the fuel has been burned. A liquid solvent can absorb the CO_2 from the captured exhaust gas, preventing it from entering the atmosphere.

3 OXYFUEL
Combustion takes place in pure oxygen so that the exhaust gases are cleaner, consisting mainly of CO_2 and water. This makes the CO_2 easier to extract and capture.



UNDERGROUND STORAGE

How is carbon trapped in the ground?

1 POROSITY
Carbon capture locations are chosen for high rock porosity. This means that there are substantial gaps in the rock that can store volumes of CO_2.

2 PERMEABILITY
Permeability is the ability of a fluid to move through the rock. As CO_2 is often stored in a fluid state, it needs to be able to spread throughout the rock layer to fit in high volumes of carbon.

3 CRITICAL DEPTH
CO_2 is usually stored at depths over 800 metres.

4 CAPROCK
An impermeable layer, such as clays, needs to be present directly above the carbon storage layer. This is called caprock and prevents CO_2 from resurfacing.

5 SALINITY
Aquifers near the surface have lower salinity levels (salt concentration) and can be retrieved as drinking water. CO_2 needs to be stored at depths where aquifers have high salinity and aren't accessed for human use.

© Getty / Science Photo Library

AR ZONE

INDUSTRIAL-SCALE CAPTURE

Orca is a huge carbon capture plant operating near Reykjavik, Iceland

AR zone SCAN HERE

COLD WATER
The water used in the plant is returned to the ground in order to be heated and reused.

GEOTHERMAL POWER PLANT
The Orca plant is powered by electricity generated by naturally produced steam.

TRAPPED IN CONCRETE

Across the world, over 9 billion tonnes of concrete is produced each year. Some CO_2 removal technologies are targeting this large-scale process by trapping the gas within concrete. When used by concrete producers, these machines inject captured CO_2 into the concrete while it is being mixed. This causes the CO_2 to mineralise, meaning it becomes a solid mineral, like carbonate. As a solid mineral the carbon increases the overall strength of the concrete while preventing the CO_2 from being released back into the atmosphere.

CO_2 needs to be added to concrete mix before it solidifies

HOT WATER
Water that has been naturally heated below Earth's surface is pumped up. The change in pressure turns this water into steam, which can be used to turn the plant's turbines.

GROUNDWATER
Groundwater is pumped upwards towards the filter, where it combines with the captured CO_2.

DID YOU KNOW? The Orca plant can capture 4,000 tonnes of CO_2 in a year

LARGE FANS
The surrounding air is sucked through a filter by large fans.

FILTER
The filter material binds with CO_2 to capture it, while other particles pass straight through.

Did you know?
Orca increased Earth's carbon capture capacity by 40 per cent

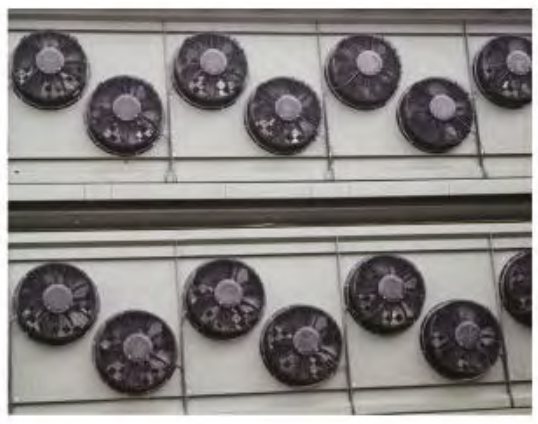
Orca began capturing carbon in 2021. It can suck 4,000 tonnes of carbon dioxide out of the air every year

PUMP
The combined CO_2 and water is pumped underground.

CAPTURED IN STONE
The CO_2 and water is directed into a basaltic rock layer. As the CO_2 reacts with the basalt rock, it cools and turns to stone within a few years.

MAKING MONEY FROM CARBON

As well as being the company to build the largest carbon capture factory in the world, Climeworks also produced the first commercial air capture plant. In 2017, the company launched a smaller carbon capture plant in Switzerland. Instead of disposing of the carbon below ground, the CO_2 extracted from the air at this plant is sold on to other companies. Some of the CO_2 is used by a nearby greenhouse to increase vegetable production, while some can be bought by food and drink industries. If more companies source their CO_2 from carbon capture plants, less will need to be produced by fossil fuels and the amount of CO_2 in the atmosphere can be reduced.


Climeworks uses direct air capture, drawing in air with large fans

© Getty / Illustration by Adrian Mann

OCEAN REMOVAL

This concept imitates the natural carbon capture process in shell and rock formation to remove dissolved CO_2 from Earth's oceans

1 SEAWATER INTAKE
Seawater is drawn into the device through a mesh, creating an electrical charge in the water.

2 CHEMICAL CHANGES
The electrical charge that's induced as the water passes through the mesh causes the dissolved CO_2 to combine with calcium and magnesium in the water.

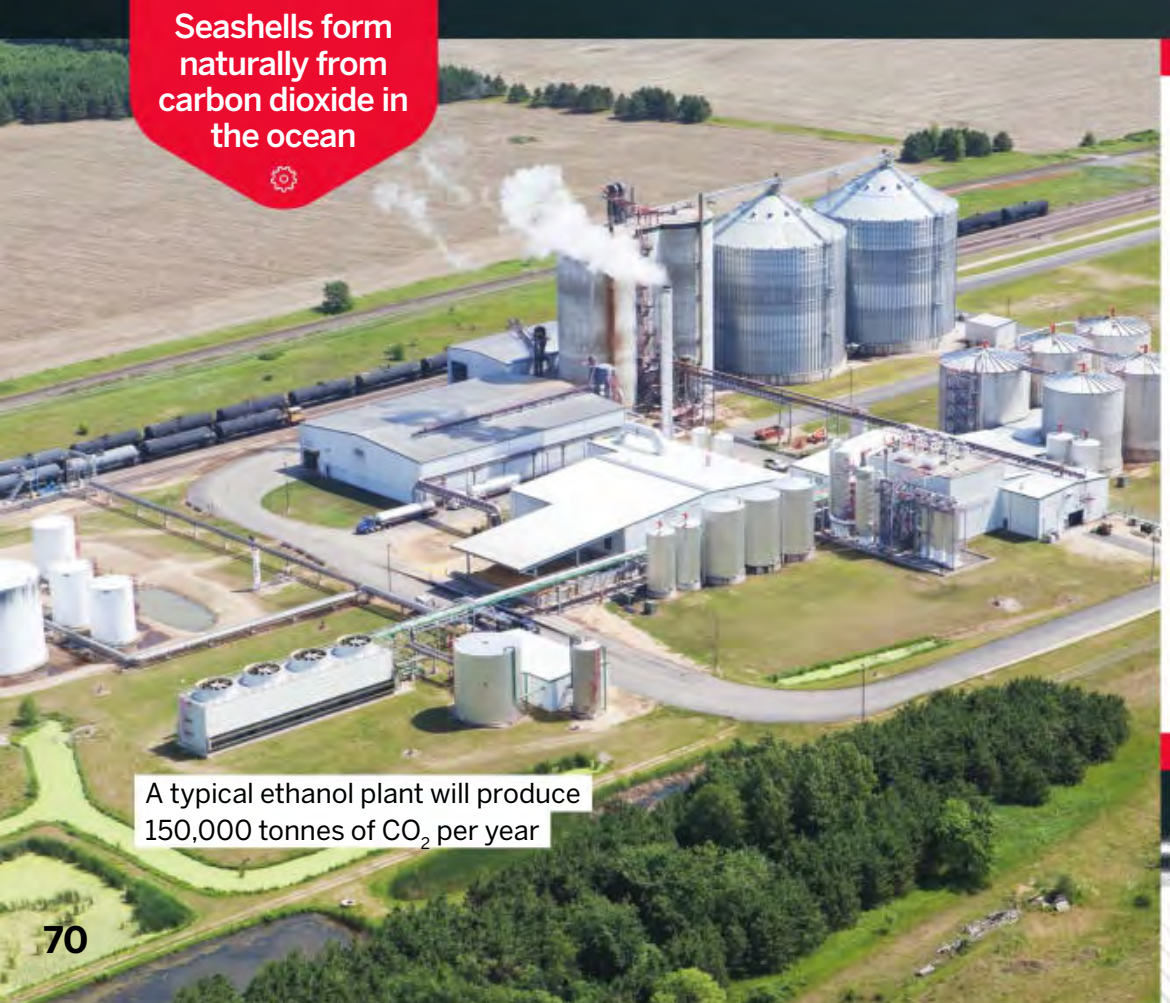
3 DEPLETED SEAWATER
As the water passes through the system, its CO_2 content is reduced.

4 DEPOSITS
In a similar way to the formation of shells, the CO_2, magnesium and calcium become limestone and magnesite when combined. These are deposited as solids.

5 RETURN TO OCEAN
After passing through the device, the water is depleted of dissolved CO_2. This space can be filled with more CO_2, removing more from the atmosphere.

AR zone
SCAN HERE

Did you know?
Seashells form naturally from carbon dioxide in the ocean



A typical ethanol plant will produce 150,000 tonnes of CO_2 per year

CARBON-NEGATIVE PRODUCTS

Some commercial products use captured CO_2 to make the manufacturing process carbon negative. One example is the company Air Eau de Parfum, a perfume company that makes ethanol from captured CO_2. Ethanol is one of the main ingredients of perfume products. Instead of fermenting crops such as corn – a method which often produces high volumes of CO_2 – this unique ethanol production is carbon negative.

Another example is protein powder. Some manufacturers are working with microbes with the aim to reduce the environmental impact of the food industry. The process involves the microbes absorbing captured CO_2 and turning it into protein. One kilogram of protein produced this way could remove 0.2 kilograms of CO_2 from the atmosphere. In comparison, the same volume of protein produced in beef adds 100 kilograms of CO_2.

DID YOU KNOW? Studies show that CO_2 can be stored underground for thousands of years

GLOBAL PROJECTS

How are scientists around the world working to solve the carbon problem?

1 IN SALAH STORAGE PROJECT
ALGERIA

For almost two decades, the Algerian state oil and gas company has been separating CO_2 from the natural gas it mines from the depths of the Sahara Desert. To extract gas in this way, the CO_2 impurities need to be separated. Instead of releasing this by-product into the atmosphere, the In Salah gas field works to compress the CO_2 and pump it back into the ground, below the sandstone.

2 GORGON PROJECT
AUSTRALIA

In the gas fields of Western Australia, a project that could continue for 40 years has been launched. The plan is to inject up to 4 million tonnes of CO_2 each year underneath Barrow Island. Barrow Island is a 78 square mile island off Australia's Pilbara Coast. CO_2 has been injected 1.2 miles underneath the island since 2019. The area of injection is known as the Dupuy Formation, which is made up of sandstone and siltstone of thicknesses between 200 and 500 metres.

3 SHUTE CREEK GAS PLANT
WYOMING, US

This carbon capture and storage plant is the largest in operation, with a storage capacity of over 7 million tonnes. However, its size doesn't necessarily make it the most successful. Since it opened in 1986, half of the CO_2 captured has been released back into the atmosphere. About 120 million tonnes of CO_2 has been captured at Shute Creek since it was opened.

4 ALBERTA CARBON TRUNK LINE
CANADA

This 150-mile pipeline can transport 14.6 million tonnes of CO_2 from industrial plants into old oil reservoirs per year. Here it's stored for future use. Although the pipeline isn't yet operating at full capacity, when it achieves its maximum capacity the amount of CO_2 captured by the system will be the equivalent of the CO_2 produced by 2.6 million cars in the area.

© Alamy / Getty / Illustration by Adrian Mann

"The NFT market rocketed in value in 2021 to $25 billion (£20 billion)"

WHAT ARE NFTS?

Non-fungible tokens are creating a unique digital marketplace for artists and buyers

WORDS **MARK SMITH**

From the *Mona Lisa* to the very first print run of the *Harry Potter* books, nothing creates value like being one – or few – of a kind. Buyers will spend huge sums to acquire and collect something if it is unique or special. But imagine if instead of a physical object like a book or a painting, that 'uniqueness' and the value it created could be replicated for something digital like a YouTube video or even a Tweet? This is where non-fungible tokens (NFTs) come in. You've probably heard of cryptocurrencies like Bitcoin, digital money whose transactions are stored on a type of database called a blockchain. But where each Bitcoin has the same value and are 'fungible', meaning each one can be traded for another, NFTs each have a unique digital signature. Being 'non-fungible' means each is one of a kind and can't be swapped with something else. So while you can swap one dollar for another dollar because they have the same value, you can't swap a Mona Lisa for another Mona Lisa because there's only one. This gives it unique, collectable value.

In much the same way, an NFT's digital signature means they can be used as 'tokens' that can be used to represent ownership of unique digital items. NFTs can be anything digital, a video or a song and anything in-between. And they have been around since 2014, with the first being minted by Kevin McCoy, a digital artist. Called *Quantum*, it was a pulsating pixelated octagon filled with different shapes. It was sold last year by Sotheby's auction house for $1.4 million (£1.12 million). So if someone creates a GIF or a piece of animation that goes viral, you can buy the original NFT and everyone will know that yours is the original, which in certain circumstances could give it value – sometimes huge value. Anyone who purchases an NFT also gets exclusive ownership rights. An NFT can only have one owner at a time, and their data makes it easy to verify ownership and transfer tokens between different owners. In addition, the creator of the NFT can store information in them too, signing their artwork with a digital signature, just like they would a real painting.

Did you know?

Asia has the world's top five countries for NFT adoption

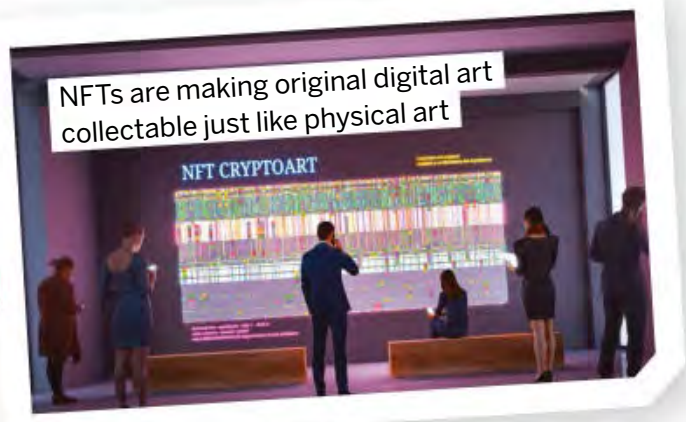
The NFT market rocketed in value in 2021 to $25 billion (£20 billion). In March last year, a JPG called *Everydays: The First 5,000 Days* was made by Mike Winkelmann, a digital artist known as Beeple – it was sold

Above left: Blockchain entrepreneur Vignesh Sundaresan showing his digital artwork *Everydays: The First 5,000 Days*

Above: Imagine a digital piece of art that was just as collectable as the Mona Lisa

WHAT ARE THEY REALLY WORTH?

There are signs that interest in NFTs is cooling. Last March crypto entrepreneur Sina Estavi purchased the NFT of Twitter founder Jack Dorsey's first tweet for $2.9 million (£2.3 million). In April this year he listed it on NFT marketplace OpenSea and hoped to raise $48 million (£38.5 million). He even vowed to donate half to charity. But as of the middle of this April, the largest bid stood at less than $7,000 (£5,600). According to figures posted on CryptoSlam, total NFT sales in March came in at a value of $2.435 billion (£1.95 billion), their lowest since July last year, and there were 661,748 NFT items bought, the lowest number since last September.



NFTs are making original digital art collectable just like physical art

DID YOU KNOW? NFTs are stored on a blockchain made of cryptocurrency Ethereum but they can be stored on other types of blockchain

by Christie's Auction House for $69.3 million (£55.5 million). NFTs can be beneficial to artists because it allows them to set up an extra source of income. It also removes the middle man because they don't have to rely on galleries to sell their work. They can sell their creations directly to the buyer online. This also means they can keep more of the profits. But it's not just digital artists taking advantage of the demand for NFTs – celebrities and corporations have also been cashing in. The *Star Trek* NFT collection recently launched, with fans able to purchase algorithmically generated ship designs for $250 (£200) each – with the whole 20,000 selling out in minutes.

Anyone looking to buy an NFT just has to set up a digital wallet similar to the ones needed to store cryptocurrency. Since most NFTs are bought with cryptocurrency, they will then have to get hold of some compatible cryptocurrency the NFT provider accepts that they can then use for the transaction. Fees can be an issue, too, because most exchanges charge a percentage of the transaction. NFTs can be bought at marketplaces like OpenSea, Rarible, Foundation and Nifty Gateway.

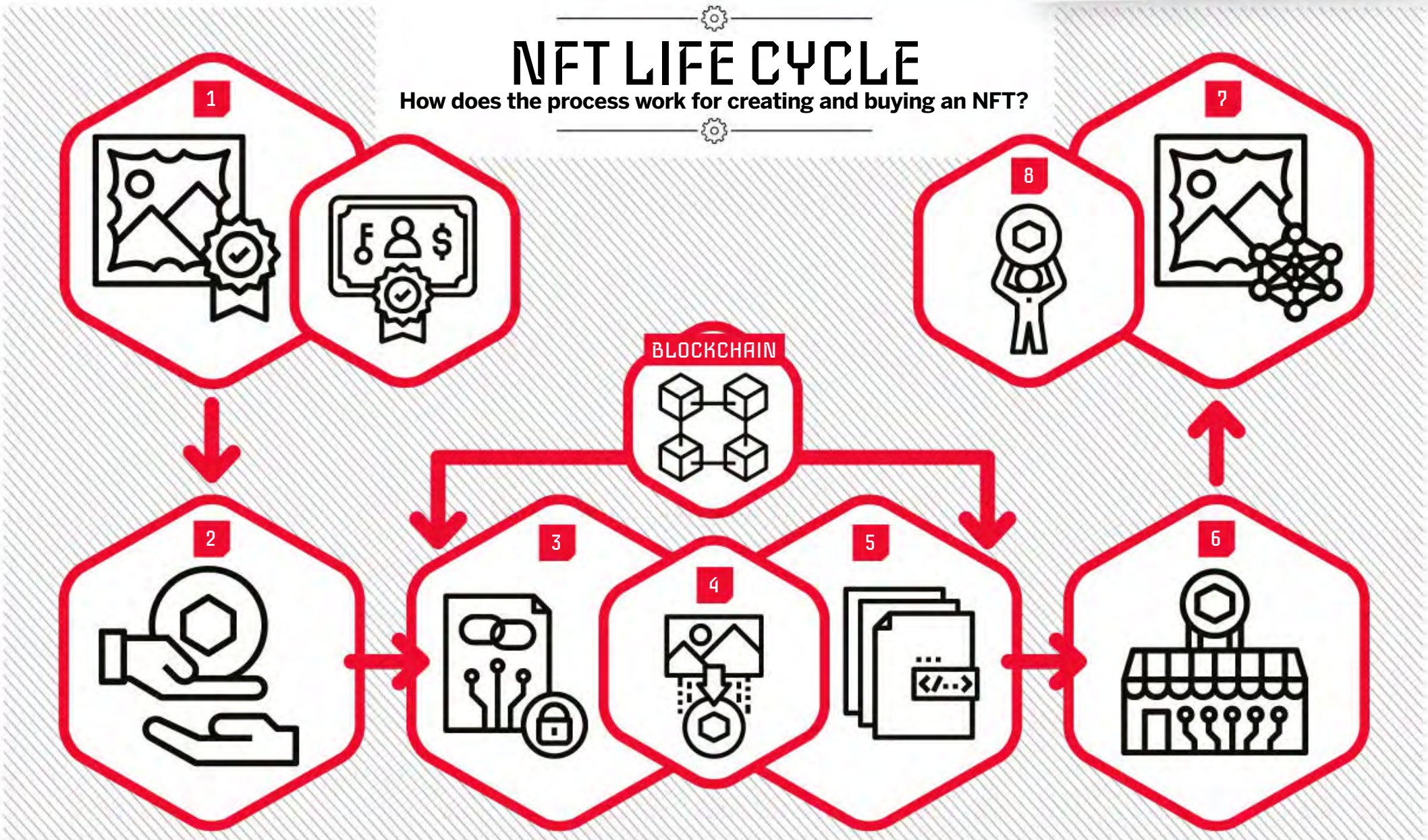
NFTS EXPLAINED

An NFT is generated and managed by something called a smart contract on a blockchain – a shared database where changes have to be verified by those with access. That smart contract gives each token a unique ID number and it becomes associated with one address on that blockchain. This means a digital certificate of ownership has now been created so everyone with access to the blockchain can verify it is unique and who its owner is. When the NFT changes hands, the new owner acquires the unique token that goes along with it. The metadata for each NFT provides additional information about the digital asset and can include things like the creator's signature. The way NFTs are stored also means – theoretically – that they can't be hacked or counterfeited.

NFTs can be purchased online from specialised digital auction sites

NFT LIFE CYCLE

How does the process work for creating and buying an NFT?



1 CONTENT CREATION
The creator produces the original content but they retain the original copyright.

2 STARTING THE PROCESS
NFTs are typically traded with cryptocurrency, so the first stage is for the creator to pay to list their NFT.

3 MINTING
The term for creating an NFT is known as 'minting' the digital asset.

4 UNIQUE TOKEN
On the Ethereum blockchain the NFT is given a corresponding unique token.

5 OWNERSHIP DATA
The blockchain records history of transactions, while metadata includes background information on the asset.

6 GOING TO MARKET
The NFT can be listed on specialist sites, but they have also been sold at famous 'real-world' auction houses.

7 MAKING THE SALE
A buyer spots the NFT they want and pays for it, usually with cryptocurrency. The transaction is recorded on a blockchain.

8 TAKING OWNERSHIP
The buyer gets the digital token, which ratifies their ownership of the NFT digital asset. This is their 'proof'.

© Getty

STEROIDS: NATURAL, MEDICINAL AND ILLEGAL

WORDS JAMES HORTON

Meet the small chemical messengers that govern our mood, determine our growth and maintain the balance of nutrients within our bodies

The term ‘steroid’ is synonymous with the idea of making something bigger. This idea stems from the misuse of synthetic anabolic steroids, which have been made famous by athletes who have abused steroids to run faster, lift heavier, and grow to enormous, unnatural proportions. But steroids are neither unnatural nor alien to the human body, instead they are essential for it to function. Humans naturally produce a vast array of steroids responsible for an equally diverse spectrum of functions. Steroids are key to defining our sex, they are instrumental in triggering and guiding our maturity, and they are essential to maintaining our health. However, our knowledge and capability to artificially synthesise steroids in the laboratory has unlocked yet more potential for these tiny compounds. Many synthetic steroids are used to bolster medicinal treatments, helping to alleviate symptoms and combat disease. Others are harnessed for more nefarious means, such as gaining an unfair advantage in sports competitions. By helping the body to build beyond its natural means, steroids can allow athletes to achieve the near-impossible, but this comes at the expense of their health.

All steroids are small chemical compounds derived from the lipid cholesterol. Cholesterol is important but has to be regulated by our cells, as too much can cause harm. Excess cholesterol, for example, causes the accumulation of plaque in our arteries, which can lead to angina and heart attacks. So while cholesterol is synthesised within our liver, this occurs less when we ingest more from our diet. Usually, around 80 per cent of our cholesterol is produced in the liver, providing ample building material for steroid derivatives. Steroids are produced in multiple locations in the body, including the gonads and the brain’s adrenal cortex. The adrenal cortex is divided into three regions, with each specialising as the production centres for a

“Humans naturally produce a vast array of steroids responsible for an equally diverse spectrum of functions”

DID YOU KNOW? Adult men produce approximately seven milligrams of testosterone each day – roughly 15 times more than women

Androgenic steroids are critical for regulating adolescent development during puberty

given class of steroids. The zona glomerulosa produces steroids known as mineralocorticoids, which regulate the amount of salt and water in the circulatory system. The zona fasciculata is primarily responsible for producing steroids known as glucocorticoids, which regulate the effects of the immune system. And the zona reticularis secretes androgenic steroids, otherwise known as sex hormones, which govern the development of traits associated with the two sexes. The male and female gonads also produce androgens, but the amount and type of androgen produced differs depending on the reproductive organ. Some androgens, such as testosterone, are anabolic steroids. This means that they signal for the production of lean muscle tissue. Mineralocorticoids and glucocorticoids, however, belong to a different group of steroids known as corticosteroids. These steroids maintain healthy bodily functions and are routinely used in prescription medicines.

As lipids, steroids are not soluble in water and therefore cannot be readily and stably carried to cells unaccompanied in the bloodstream. Instead, steroids are first synthesised in their precursor forms and, once the cell has received a signal for their release, they are converted into their active form and readily diffuse out of the cell. Then, once they are in the blood plasma, they attach to transport proteins that keep them stable as they are carried through the circulatory system to their target cell. Upon arriving at a cell with receptors on its surface that recognise the steroid, the compound can bind to it and trigger a cell response.

This response often includes a change in gene expression, which leads to the production of proteins that carry out new functions in the cell, changing its behaviour. Therefore steroids are the mobile messengers of the body that despite being tiny compounds, can bring about massive changes.

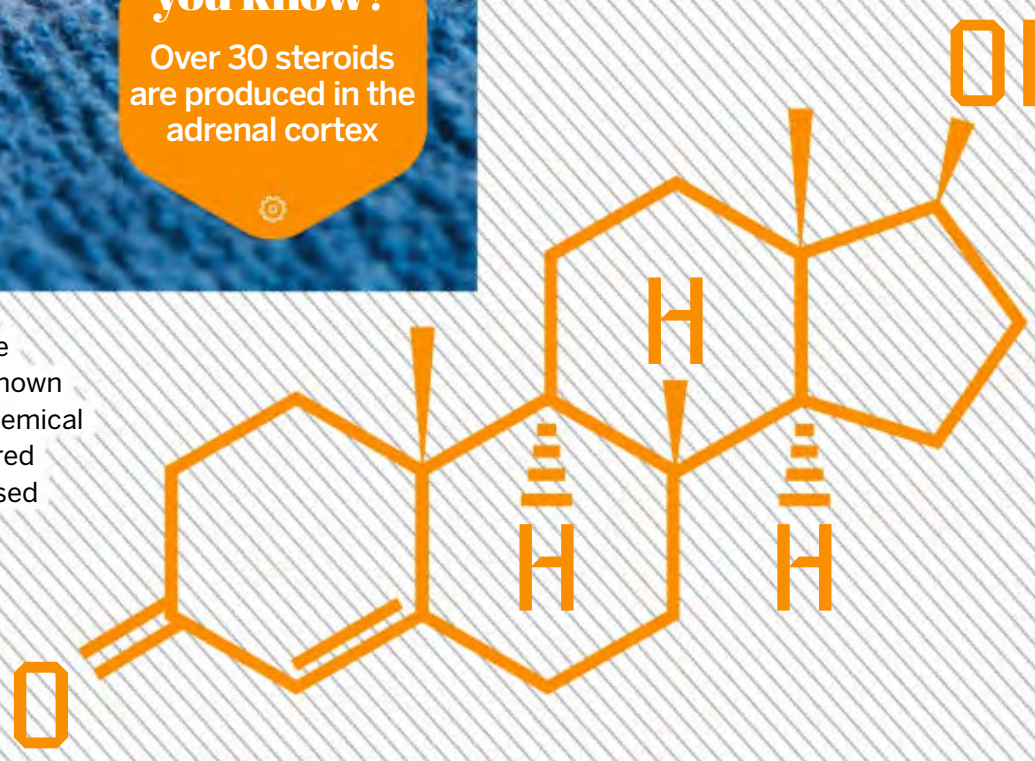
Dexamethasone is one of the most common steroids used to treat cancer in the UK

TREATING CANCER

Corticosteroids are involved in regulating many bodily functions in a healthy body. These include reducing inflammation, regulating mood, and controlling the balance of water and nutrients from food. When suffering from cancer, both the tumour itself and the treatment can negatively impact these processes, causing harmful side effects such as nausea and fatigue. Synthetic steroids can help restore balance and combat certain cancers such as lymphoma in a number of ways. They can be administered before treatment to help bolster a patient's appetite. During treatment they can be used to combat an allergic reaction to another drug, reduce the side effects of chemotherapy, or to increase the effectiveness of chemotherapy. This latter aspect can be achieved in lymphoma patients by combining steroid treatment with chemotherapy treatment, as steroids can destroy lymphocytes. Sometimes the steroid treatment strategy can even be effective enough on its own to tackle specific types of cancers, meaning that chemotherapy isn't required.

Did you know?

Over 30 steroids are produced in the adrenal cortex



All steroids, like testosterone shown here, have a chemical structure centred around four fused carbon rings

CHEMICAL STRUCTURE

Steroids are a class of lipids, which means they are insoluble in water but soluble in organic solvents. They all share a common main structure consisting of four fused rings of connected carbon atoms. These include three cyclohexane rings consisting of six carbon atoms, and one cyclopentane ring consisting of five carbon atoms, yielding seventeen in total. These 17 carbons atoms are numbered to help describe differences in steroid structures. Seemingly subtle changes at just a couple of the carbon positions can yield vastly different steroids. Cholesterol, from which all other steroids are derived, comes equipped with a hydrocarbon tail off its 17th carbon atom. This is removed when cholesterol is converted into either testosterone or oestrogen. Despite these two steroids controlling vastly different cell behaviours, structurally they are very similar and differ at only four carbon positions.

© Alamy

HOW STEROIDS ARE ADMINISTERED

INJECTION
Injecting steroids directly into muscle tissue allows doses to be lower than they would be for oral tablets, reducing the risk and severity of side effects.

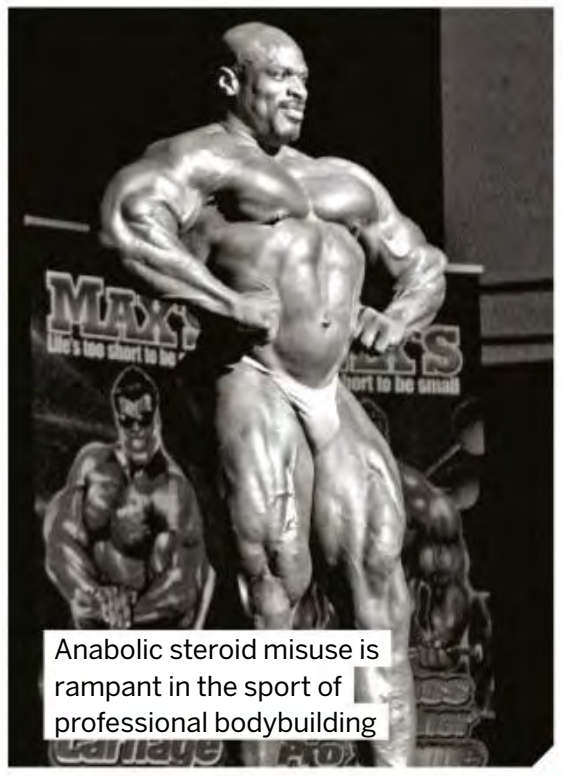
ORAL TABLETS
For some diseases oral administration of steroids is just as effective as injections. Tablets can also be self-administered, making them preferable for conditions where steroids need to be taken for longer periods.

INHALERS
As with injections, inhalers administer steroids to localised areas, allowing the dosage to be lower. Like oral tablets, they can also be self-administered. They are most effective for conditions affecting the airways.

CREAMS
Topical steroids such as creams and ointments, which are administered directly onto the skin, offer similar benefits to inhalers for the external organs.

STEROID MISUSE

After the first synthesis of testosterone in 1935, it took less than two decades for anabolic steroids to be misused in professional sporting competition. In the years since they have been used in a myriad of sports and are still predominant in unregulated sports today, such as bodybuilding. Synthetic testosterone is the most infamous anabolic steroid for misuse, or 'doping'. Our bodies synthesise testosterone naturally, with men producing more than women, which helps us build lean muscle. But synthetically increasing the amount of testosterone in our cells can trigger the production of more lean muscle than is achievable by our natural limits. While testosterone doping can increase lean muscle mass and improve strength, it can also cause severe side effects. In men these include shrunken testicles, breast development, and an increased risk of prostate cancer. In women these include growth of facial hair, severe acne, and period problems. Both genders are also at additional risk of heart attacks and strokes.



Anabolic steroid misuse is rampant in the sport of professional bodybuilding

Did you know?
Progesterone helps expand the uterus during pregnancy

Above: Needle sharing between anabolic steroid abusers increases the risk of disease transmission, including HIV

Right: Many sporting bodies now routinely test their athletes' blood and urine for evidence of steroid misuse

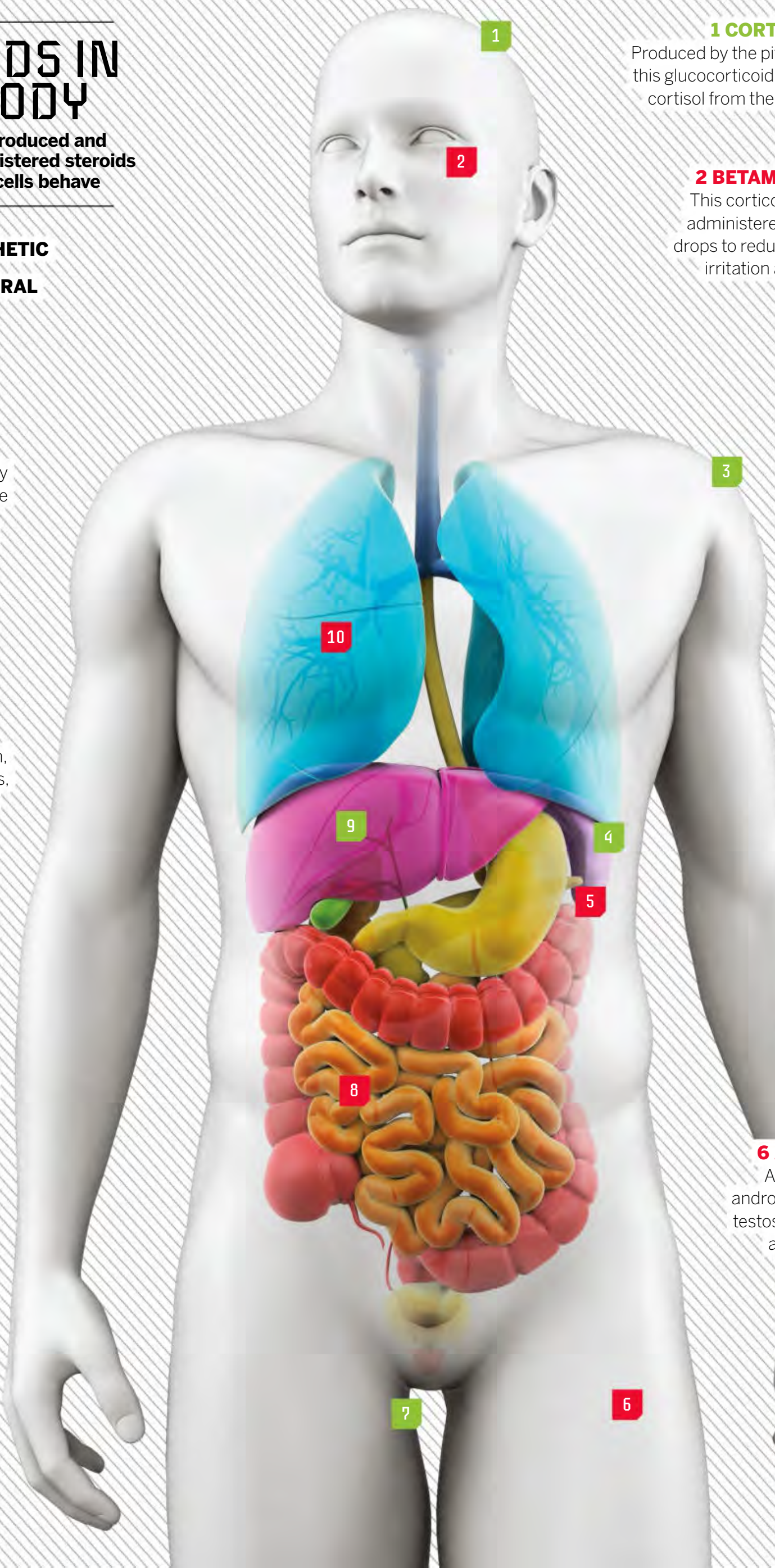
DID YOU KNOW? Females produce more oestrogen during one pregnancy than their entire fertile life while not pregnant

STEROIDS IN THE BODY

Both naturally produced and synthetically administered steroids affect how our cells behave

SYNTHETIC

NATURAL



1 CORTICOTROPIN

Produced by the pituitary gland in the brain, this glucocorticoid controls the secretion of cortisol from the brain's adrenal cortex.

2 BETAMETHASONE

This corticosteroid can be administered to the eye via drops to reduce inflammation, irritation and redness.

3 TESTOSTERONE

This androgen, or sex hormone, regulates male secondary sexual characteristics such as voice deepening and facial hair. It drives skeletal-muscular growth in both sexes.

4 ALDOSTERONE

A type of steroid known as a mineralocorticoid, aldosterone regulates the amount of salt retained in the body, which determines blood pressure.

5 FLUDROCORTISONE

Those with Addison's disease, or people who've had their adrenal glands removed, lack natural aldosterone production. Fludrocortisone can be used to regulate blood salt levels in its place.

6 ANDROSTENEDIONE

A testosterone precursor, androstenedione is converted into testosterone within the body after administration, boosting testosterone levels.

7 ESTRADIOL

This androgen regulates female secondary sexual characteristics and governs fertility in both sexes. Estradiol regulates sperm production in males, and ovary development in females.

8 BUDESONIDE

Like other corticosteroids, budesonide reduces inflammation. However this steroid does not readily escape into the bloodstream, making it an effective treatment for inflamed gut tissue.

9 CORTISOL

This wide-acting glucocorticoid forms part of the stress response. Cortisol decreases inflammation, decreases protein stores, and increases protein synthesis in the liver.

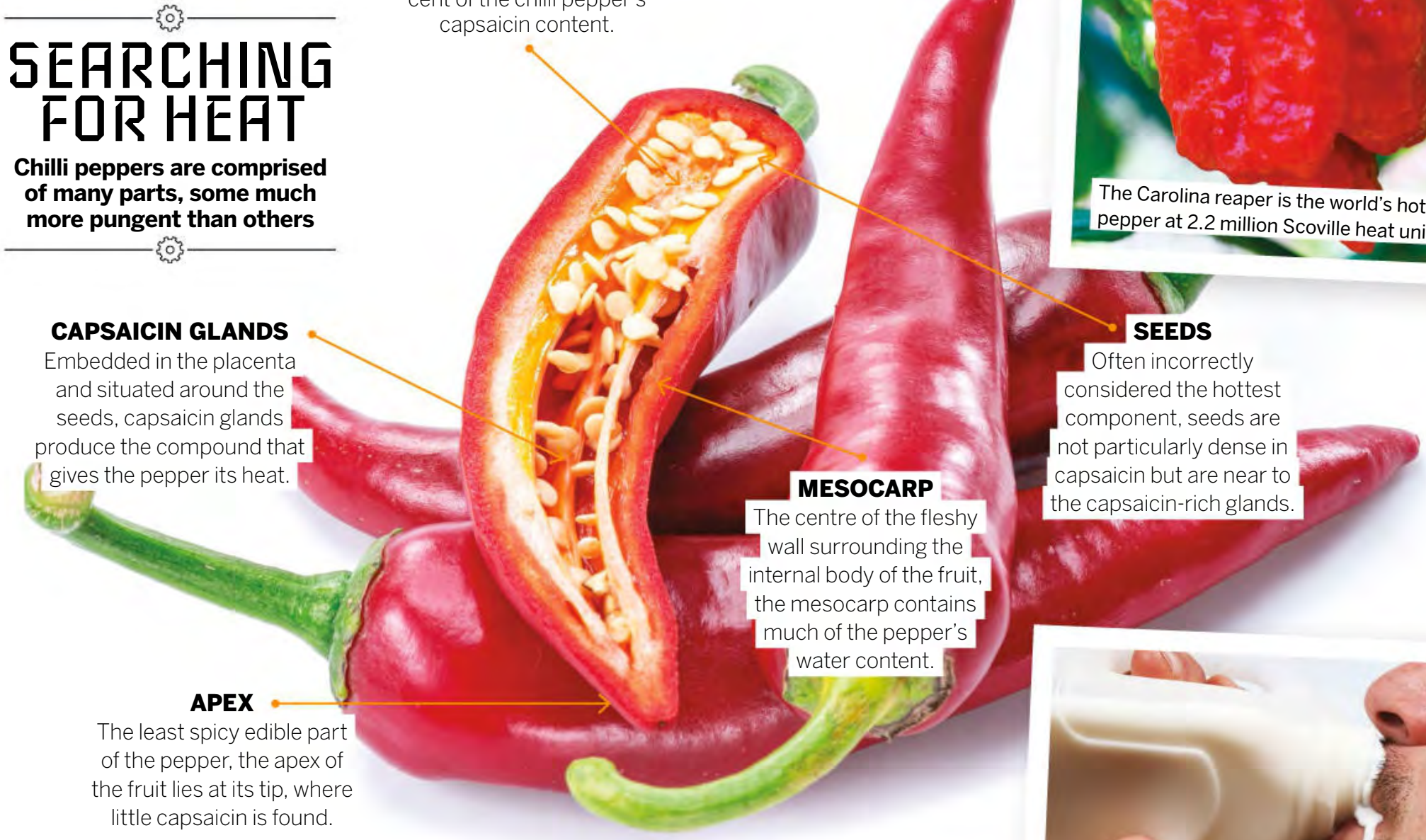
10 PREDNISONE

A corticosteroid that mimics naturally produced cortisol. It reduces inflammation by suppressing the immune response and can be used to treat asthma.

© Alamy / Getty / www.localfitness.com.au

SEARCHING FOR HEAT

Chilli peppers are comprised of many parts, some much more pungent than others



The Carolina reaper is the world's hottest pepper at 2.2 million Scoville heat units


Milk contains a protein called casein that can carry away capsaicin, making it much more effective at combating spice than water

WHAT MAKES CHILLI PEPPERS SPICY?

Meet the tasty chemical compounds that pull sweat from foreheads, force tears from eyes and make tongues feel like they're on fire

WORDS **JAMES HORTON**

Spices have been part of human diets for thousands of years, and chilli peppers are now staple ingredients in many parts of the world. Chilli peppers are fruits and are part of the nightshade family, which contains members such as tomatoes, avocados and potatoes. Within this family lies the genus *Capsicum* that hosts peppers, a group of related species that are carefully cultivated to produce fruits with a spectrum of flavour and heat. From the mild bell pepper and the lively jalapeño to the unrelenting brutality of the Trinidad Moruga scorpion and Carolina reaper, peppers come in all ranges of spiciness. The heat, or pungency, of a chilli pepper is a product of its DNA, the environment it's grown in and its ripeness. DNA can be changed by cross-breeding two species, followed by selective breeding of the offspring where the progeny with the desired traits are bred further. The stress imposed on the pepper, such as the temperature it's grown in and the amount of water available to it, can likewise affect its pungency. Peppers also become spicier as they ripen from green to red.

While humans have learnt to manipulate and enrich pepper qualities, their spicy trait first evolved naturally as a defence mechanism. Rodents and mammals are equipped with receptors in their mouths that recognise the compound capsaicin – and other compounds collectively known as capsaicinoids – produced within chilli peppers. Capsaicin surrounds the seeds, which are needed for the plant to germinate its progeny, and the compound triggers the sensation of burning when consumed. This helps dissuade rodents and mammals from eating too much, with the latter being particularly threatening to the plant as they can grind and destroy the seeds as they eat the fruit. But birds, which do not grind the seeds and instead are useful helpers in dispersing them, are not sensitive to capsaicin and so are not discouraged from feeding. Capsaicin also wards off microorganisms from invading and decomposing the plant matter from the inside.

Did you know?

Eating spicy foods can change your gut flora

If capsaicin production and its spicy heat have evolved to deter hungry mammals from munching through peppers, then why do many humans ravenously ingest them? Spice serves a practical role in food by helping to prevent spoilage, but many of us who enjoy spice also like the challenging heat. While capsaicin triggers the sensation of burning and all its accompanying symptoms, such as sweating and mouth breathing, it can also trigger

DID YOU KNOW? Capsaicin has been investigated as a treatment option for obesity, gastric disorders, diabetes and cancer

THE SCOVILLE SCALE

In 1912, Wilbur Scoville created the Scoville Organoleptic Test as a means of measuring the amount of heat in a pepper. The method he developed was part quantitative and part subjective. Scoville gathered taste testers and asked them to taste a pepper's capsaicin content – dissolved in an alcohol solution – mixed with sugar water. The capsaicin solution would be continually diluted with sugar water until heat could no longer be detected, which provided Scoville heat units (SHU). A pepper measuring 5,000 SHU would need to be diluted by 5,000 before no heat could be detected. Jalapeños measure between 3,000 and 10,000 SHU, whereas pure capsaicin measures 16,000,000.

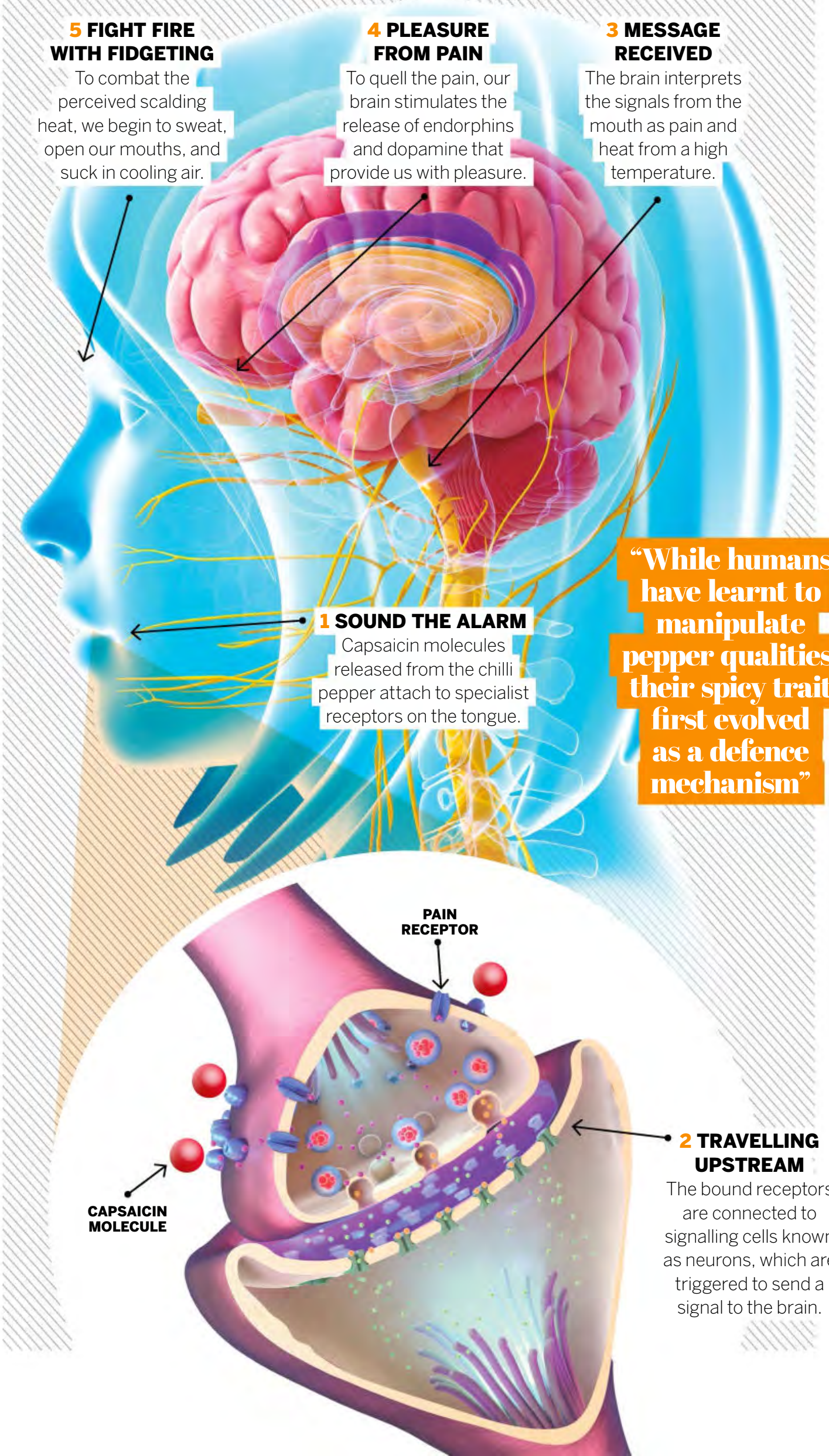
Scoville was a chemist who invented the scale measuring pepper pungency

the release of endorphins that provide pleasure as a means to combat the pain.

However, the pleasure of eating spice is not there for all of us. The endorphin release does not happen for everyone equally, and for those who are sensitive to spice – or for spice lovers who overindulge – the pleasure can quickly recede while the pain intensifies. Unfortunately, the damage of too much spice doesn't end in our mouths, as capsaicin can bind to receptors in our stomach and intestines. This can trigger diarrhoea as our body acts to protect itself by rapidly funnelling the irritant compound through the gut as quickly as possible. And in a case of true polar symmetry, the receptors that interpret capsaicin as heat at the beginning of our gastrointestinal tract are also there at the end, which is why we can also feel burning as we eliminate stool. Finally, as capsaicin is an irritant that also affects our outer organs, the abundant compounds in the spiciest peppers can elicit burning sensations when they come into contact with our skin and eyes. Chilli peppers can be as delicious as they can be harmful; the experience we have when eating them is determined by our tolerance – and the amount of capsaicin putting our receptors to the challenge.

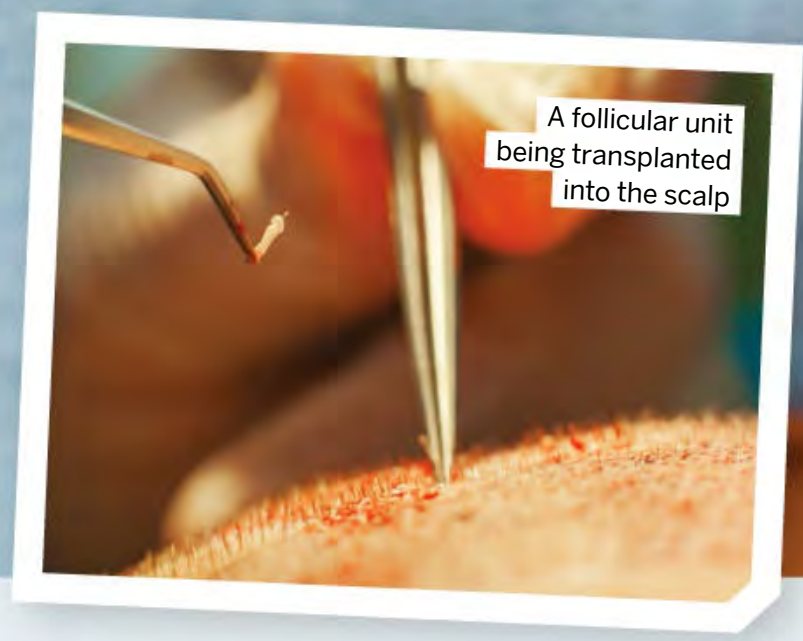
FEEL THE BURN

The presence of capsaicin provokes a reaction from our brain as if we've come into contact with a high-temperature food



"While humans have learnt to manipulate pepper qualities, their spicy trait first evolved as a defence mechanism"

© Alamy / Getty


A follicular unit being transplanted into the scalp

HOW IS HAIR TRANSPLANTED?

This technique allows surgeons to use healthy hair to regrow hairs that were lost

WORDS **SCOTT DUTFIELD**

Every hair on the human body sprouts from the cellular anchor that extends deep into the dermis of the skin, called a follicle. Hair follicles are the body's hair factory and gather together all the ingredients to grow hair and replace them once they finish their natural cycle and fall away every two to three years. Over time, hair follicles may become damaged or cease to work resulting in hair loss, commonly experienced on the head. One of the most common causes of hair loss, particularly in men, is androgenetic alopecia, also known as pattern baldness. However, in 1952 an American dermatologist named Dr Norman Orentreich revolutionised a way to battle pattern balding when he completed the first hair transplant surgery. Hair transplantation is a surgical procedure that takes healthy follicles from one part of the scalp and transplants it to another where hair no longer grows.

There are two types of hair transplant surgeries typically used. The first is called Follicular Unit Transplantation (FUT). Also known as the strip method, this transplant technique involves a thin strip of skin bearing thousands of hairs from the back of the head. The strip is then dissected into smaller follicular units that contain between one and four hairs. These units will then be implanted into a small cut made in the scalp at the desired location, while the strip's harvest site is stitched closed.

Did you know?

The normal rate of hair loss is 50 to 100 hairs a day

The second form of transplant surgery is called Follicular Unit Extraction (FUE). This procedure involves individual follicular units being harvested using a punch extractor, a drill-like device that takes circular extractions. Each hair is then implanted into one of thousands of tiny cuts made into the scalp. Once implanted, the first two weeks following the surgery are vital as the hair grafts are not yet fully attached to the scalp. After a few weeks the transplanted hairs will often fall out and then start to grow back. By six months new hair typically begins to emerge and by 18 months the full results of the surgery should be visible.

BODY HAIR TRANSPLANTS

Typically, hair transplant surgeries use healthy donor hair follicles found somewhere on the patient's head. However, that's not always the most viable option, for example: in patients with advanced androgenetic alopecia, studies have shown that hairs taken from alternative areas of the body might be an alternative donor source. The majority of hair that covers the human body is fine and short – known as vellus hair – whereas the hairs in from the beard, torso, extremities and pubis are known as terminal hairs and have shown some successful result in hair transplants. The anagen (growth) phase of terminal body hair is much shorter than scalp hair and therefore, the transplant regrowth is thinner and shorter when compared to straight scalp transplants.


Beard hair regrows much thicker than scalp hair after transplantation

DID YOU KNOW? A hair transplant can cost anywhere between £1,000 and £30,000 ($1,232 and $37,000) in the UK

FUE VS FUT

What are the differences between the two hair transplant procedures?

1 HAIR PUNCH
A surgeon uses a tool to punch out donor hair grafts, called follicular units, typically from the back or sides of the scalp.

2 EXTRACTION
Hair follicular units include only a few individual strands removed in random patterns to prevent strips of visible scarring.

3 PRESERVATION
Once extracted, grafts are cleaned, sorted and submerged into a solution to preserve them before implantation.

4 IMPLANTATION
Extracted units are then implanted into very small cuts in the scalp in areas where regrowth is desired.

5 GRAFT INSERTION
Follicular units are inserted into cuts made in the scalp and the donor strip is sewn or stapled together.

6 DISSECTION
Follicular units are then dissected and prepped, ready to be implanted into the intended area.

7 SLIVERING
The dissected strips are then further sliced into even smaller strips ahead of implantation.

8 EXTRACTION
A strip of skin is surgically removed in the donor zone, typically at the back of the head.

ROBOTIC TRANSPLANTS

Meet ARTAS, the robotic FUE hair transplant surgeon. ARTAS uses artificial intelligence and 3D mapping technology to scan a patient's grid of donor hair and select the best hair follicles to harvest for transplantation. ARTAS will then autonomously move through the donor portion of the head and make a single millimetre or less extractions. The extractions are always evenly spread out over the donor area to prevent linear scarring. Once the hairs have been extracted they are inserted into a cartridge within the robot, ready for transplant. Using the same advanced technology, ARTAS then implants the follicle grafts into the mapped-out recipient site.

ARTAS robot extracting donor hair follicles

© Getty / Alamy

Win!

ONE OF TEN BUILD YOUR OWN BINOCULARS KITS

This month we're giving you the chance to win one of ten Build Your Own Binoculars kits, the eco-friendly STEAM-inspired toy for the whole family to enjoy. The binocular is easy to assemble and made from robust sustainable cardboard. Each binocular offers 6x magnification and is equipped with a focusing eyepiece for detailed outdoor exploration

For your chance to win, answer the following question:

Which of these planets is the biggest?

A: JUPITER B: MERCURY C: EARTH

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

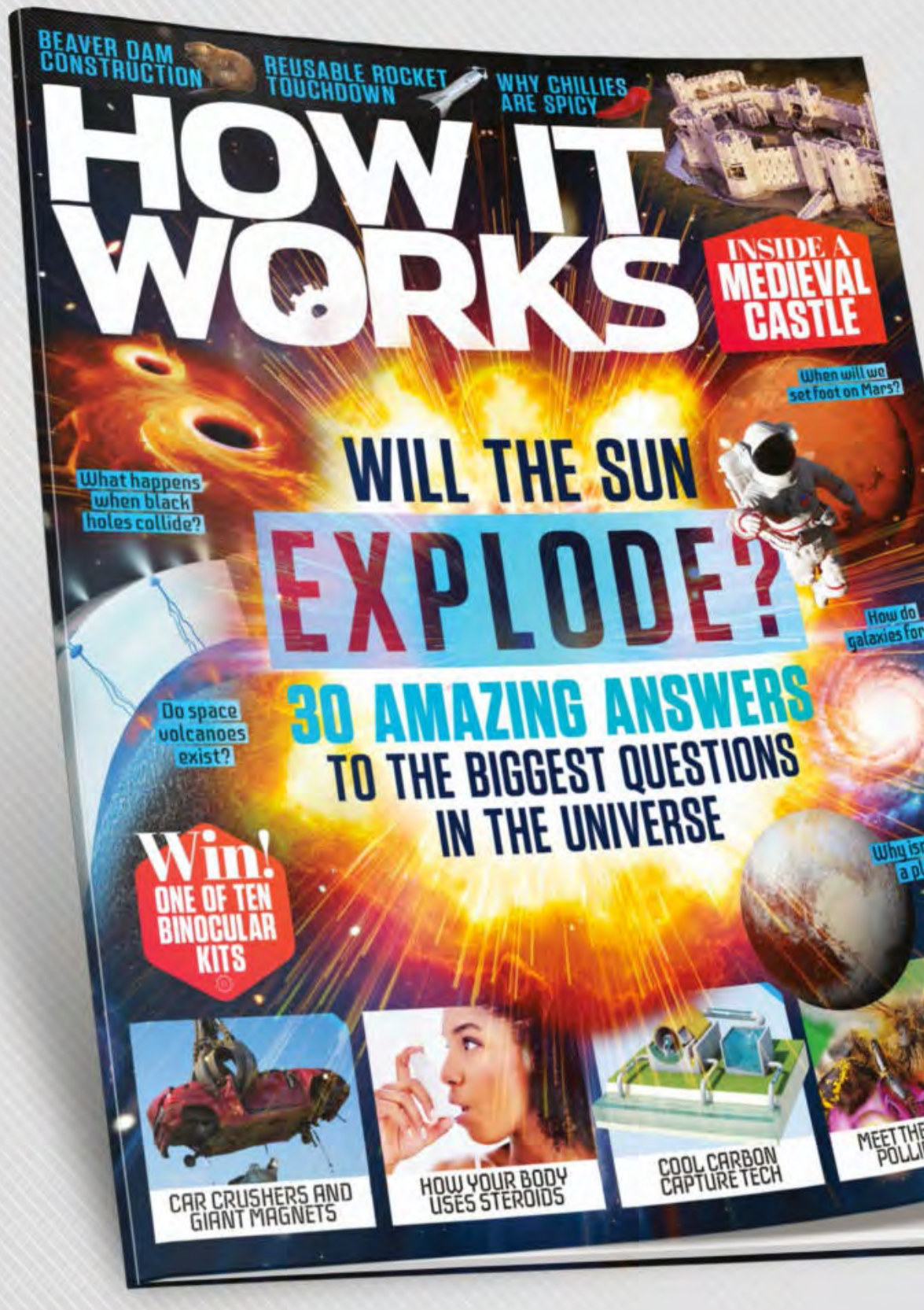
Terms and Conditions: Competition closes at 00:00 BST on 30 June 2022. By taking part in this competition you agree to be bound by these terms and conditions and the Competition Rules: **www.futuretcs.com**. Entries must be received by 00:00 BST on 30/06/2022. Open to all UK residents aged 18 years or over. The winner will be drawn at random from all valid entries received, and shall be notified by email or telephone. The prize is non-transferable and non-refundable. There is no cash alternative.

© Buildyourownkits.com

SPECIAL OFFER FOR READERS IN NORTH AMERICA

4 FREE ISSUES

WHEN YOU SUBSCRIBE*



"The action-packed science and technology magazine that feeds minds"

Order hotline **+44 (0) 330 333 1113**

Online at **www.magazinesdirect.com/hiw/79as**

***Terms and conditions** Offer closes 31/08/2022. Offer open to new subscribers only. Direct Debit offer is available to UK subscribers only. This price is guaranteed for the first 12 months, and we will notify you in advance of any price changes. Please allow up to six weeks for delivery of your first subscription issue, or up to eight weeks overseas. The full subscription rate is for 12 months (13 issues) and includes postage and packaging. If the magazine ordered changes frequency per annum, we will honour the number of issues paid for, not the term of the subscription. For full terms and conditions visit **www.magazinesdirect.com/terms**. For enquiries please call: +44 (0) 330 333 1113. Lines are open Monday to Friday 9am to 5pm UK time or e-mail: **help@magazinesdirect.com**. Calls to 0330 numbers will be charged at no more than a national landline call, and may be included in your phone provider's call bundle.

OFFER EXPIRES 31 AUG 2022

Why does the sky look red at sunrise and sunset?

Did you know?
The Sun also looks bigger when it's near the horizon

Hilda Dixon

A phenomenon called Rayleigh scattering causes light from the Sun to bounce off tiny particles in the atmosphere and scatter in different directions. Sunlight consists of many different colours, from red, which has the longest wavelength of all visible light, through to violet at the blue end of the spectrum, which has the shortest wavelength. Due to this short wavelength, blue light is scattered more effectively than other colours, and this is why the sky normally appears blue to us.

At sunrise or sunset, however, when the Sun is low on the horizon, the light rays must pass through more of the atmosphere – and therefore bounce off more molecules – than at other times of the day. This means that more blue light gets scattered away before the light reaches your eyes. Other colours – such as red, orange and yellow – can therefore continue to pass through the atmosphere unaffected, creating beautiful colours at the start and end of the day.

At sunset, most of the blue light has bounced away before reaching your eyes

WHY DO CAR WHEELS LOOK LIKE THEY'RE SPINNING BACKWARDS AT HIGH SPEEDS?

Sam Peters

This is due to an effect known as 'aliasing', often seen on TV. Video cameras work by capturing lots of still images in a very short space of time. For example, TV cameras capture roughly 50 frames a second. This is quite sufficient to fool our eyes and brain into thinking we are seeing a continuous moving image. Now imagine a wheel and its spokes, and focus on the spoke in the 12 o'clock position. If, by the time the next frame captures an image, that spoke has moved clockwise almost one whole revolution to 11 o'clock, your brain will interpret the spoke as having moved anti-clockwise, making the wheel appear as if it is rotating backwards. This effect can also be seen under a strobe light, as the strobe is doing the same thing as the camera, giving you lots of snapshots of an image. Under certain conditions, streetlights can highlight this effect as they are constantly flickering on and off about 50 times a second due to the alternating current.

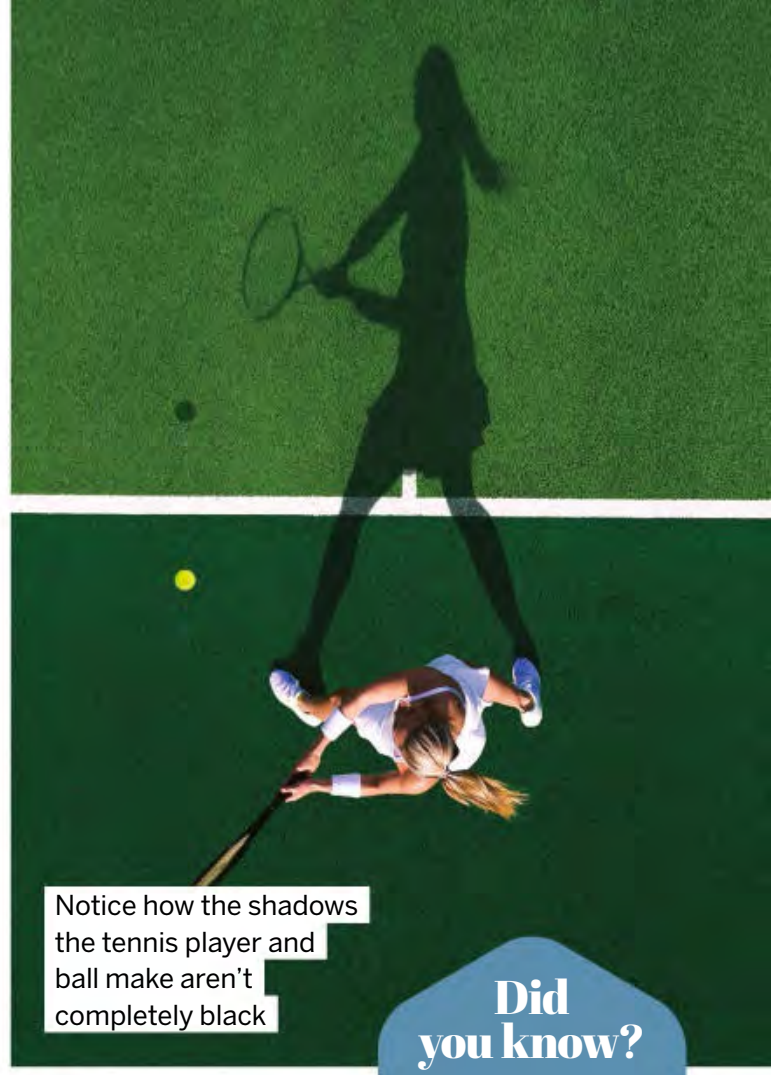
WHY ARE SHADOWS BLACK?

Lucinda Kidney

Shadows occur when an object blocks the light falling on it so the light can't reach the surface on the other side of the object. Shadows most often appear black because the visible light cannot make its way past the obstruction, if there is no light falling on an object then it will be black as there is no light to reflect. Shadows are very rarely completely black as reflections off surfaces and other light sources often make their way into the shadowy area.

As to why black is the absence of light, it just is, and we have to accept that. We could delve into philosophy and talk about 'does black look the same to me as it does to you?' but since there is no way of actually knowing and experiencing things from other people's immediate perspective, we would really just be going around in circles.

Coloured shadows can form if there are multiple coloured light sources or if the light goes through certain translucent objects such as stained glass windows, where only some of the light is blocked.



Notice how the shadows the tennis player and ball make aren't completely black

Did you know?
A candlemaker is also called a chandler

HOW DO COLOUR-CHANGING CANDLES WORK?

James Desmond

The coloured lights need a power source, usually in the form of a lithium battery at the bottom of the candle, separated from the wax so the battery won't burn. Connected to this battery inside the candle are LEDs, most commonly three, which give off the three primary colours of light – red, blue and green. Different combinations of brightness in these LEDs causes the light to mix, which yields many different colours.

So how do the coloured LEDs switch on when the flame is lit? An optical sensor runs from the top to the bottom of the wick in the candle, connected to the LEDs and battery at the bottom. As soon as the wick is lit, the optical sensor detects light from the flame, which activates the circuit.

LED-aided candles can make a birthday even more colourful

Anything fried in oil can be high in calories

What's the most high-calorie meal you can eat?

Jen Kirby

Calories are essentially a measurement of the energy that fuels our bodies – we all need them to function. Fat contains the most calories, at about nine kcal per gram. Examples of foods with the highest fat content are oils, butter, lard, cheese, batter, dark chocolate, nuts, seeds and processed meats. As for the highest calorie meal you could eat, this will vary depending on the individual as everyone's metabolism is different, therefore breaking fats down into energy can take longer for some people than for others. In parts of America there is a popular snack or meal that involves deep-frying butter balls and cheese – not exactly the snack of choice for the health-conscious!

© Getty

BRAINDUMP

FLOUNDERS CAN CHANGE COLOUR TO ADAPT TO THEIR SITUATION UNLESS THEY'RE BLIND - WHY IS THIS?

Gina and Jeff Gillard

Adaptive camouflaging to the surrounding environment occurs widely in the animal kingdom, with many examples found in the marine world, including cephalopods – octopus, cuttlefish and squid – and flatfish, such as some flounders particularly in the *Paralichthys* and *Ancylopsetta* genera. These animals all use groups of pigmented cells in the skin called 'chromatophores' to alter their colour and simulate their surroundings. In flatfish these cells can be either black (melanophores) or shades of yellow (xanthophores). In conjunction with other groups of cells called 'iridocytes', which reflect light to produce a white appearance, the fish can assume the colour of the surrounding background. To produce these changes within the skin cells, light stimuli is received through the eyes at the retina and passed through nerves to specialised skin cells. The colouration is a response to the ratio of reflected to incident light directed at the retina, and is generally a mix of the inputs from both eyes. While a flounder with one eye is still able to change colour effectively, a fully blind flounder cannot simulate the background in shade, colour or pattern.

A flounder perfectly blended with sand on the seabed

What's in the glue that seals envelopes?

Roger Pilgrim

I assume you are talking about the glue that needs moisture to seal the envelope. This type of glue is made from gum arabic, which is a product of the hardened sap from two different kinds of acacia tree, which can be found in west Africa and northwestern India. It is edible for humans and has E number E414. As well as being useful for sealing envelopes it is also a staple ingredient in certain sweets such as M&Ms, marshmallows and gumdrops. Non-edible applications also include the binding of watercolour paint and an important ingredient of shoe polish. Pretty useful stuff.

WHEN IT'S FROSTY OUTSIDE, WHY DON'T WILD ANIMALS DIE?

Katy Willis

Wildlife in the UK is well prepared for wintery conditions and have adapted in a variety of ingenious ways to cope with the cold. Some, such as the hedgehog and dormouse, have opted to skip winter altogether by hibernating. Others, such as squirrels and jays, anticipate the short supplies of food by caching stores to see them through. Thick fur coats, layers of fat and insulating feathers help shield stoats, seals and swans from the biting cold much more efficiently than clothing ever could, and birds such as thrushes switch their diet to berries high in sugar to generate essential warmth.

Hedgehogs hibernate from December to March

WHY DO SUNFLOWERS ALWAYS FACE THE SUN?

Joe Harman

Sunflowers are among several plant species – especially desert plants – that have the ability to either grow or move in response to stimuli from sunlight to maximise the amount of direct solar radiation received for photosynthesis and growth. Known as heliotropism, the phenomenon can either make a plant move to face the Sun (diaheliotropism) or away from sunlight (paraheliotropism).

The plant equivalent of a muscle is the pulvinus, which is a specialised organ found at the base of the leaf. The pulvinus consists of extensor cells (for stretching) and flexor cells (for bending), which swell or shrink in response to changes in turgor (pressure) determined by the amount of water in the cell. As extensor cells swell and flexor cells shrink, the leaf will move to track the Sun's journey across the sky, from sunup to sundown.

How do evergreen trees keep their greenness throughout the winter?

Daniel Price

Leaves take carbon dioxide from the atmosphere and use sunlight as an energy source to turn the CO_2 and water taken in by the roots into glucose to provide food for the plant; this process is called photosynthesis. A chemical called chlorophyll helps make this process happen and chlorophyll is what gives leaves their green colour.

In winter, the days are too short and there is too little sunlight for effective photosynthesis. Leaves are also quite delicate and prone to frost damage, so deciduous trees choose to shed their leaves and remain dormant until spring. In contrast, evergreen trees keep most of their leaves during the winter. They have special leaves, resistant to cold and moisture loss. Some, such as pine and fir trees, have long thin needles. Others, such as holly, have broad leaves with tough, waxy surfaces. Evergreens may continue to photosynthesise during the winter as long as they get enough water, but the reactions occur more slowly at colder temperatures.

But even evergreen leaves are prone to damage, from weather or insects, and will need replacing over time, but the tree does this gradually in intervals so that the trees always retain enough leaves to continue to function.

Did you know?
Roman scholar Pliny first used the word ‘pilula’

HOW DO TIME-RELEASE PILLS WORK?

Kirsty Sorenson

Time-release pills are designed to release a steady stream of a drug into your system over a certain period of time – usually six to eight hours – instead of an instant ‘hit’ of the drug in one go.

This can be especially useful for continual suppression of unwanted symptoms of certain diseases or when painkillers need to be administered over a long length of time rather than the effects of the drug wearing off quickly. The active ingredient is usually concealed in a ‘web’ of insoluble substances, so that the dissolving substance has to find its way through the gaps in the web. Alternatively, the drug can be combined with other substances that, once ingested, swell up to form a gel with a near-impenetrable outer coating, therefore releasing the active ingredient slowly.

Some drugs will naturally dissolve slowly and therefore don’t need to be embedded in other less soluble substances.

What a pill is made of can affect its time-release effect

© Getty

Is it ever okay for a species to die out?

Daniel Bixby

Fewer than 2 million species have been properly collected, identified and classified and given a name. Based on this, and what is known about the distribution of species in forests, oceans and other environments, scientists believe there are probably around 10 million or more species out there yet to be identified. Most of these are small creatures but it is still fairly common that a new plant, bird, fish, mammal or other vertebrate is also found. All species have taken many millions of years to evolve, and they all play particular roles in the ecosystems in which they live. So while we still have a long way to go in identifying all species, we can see where species are being lost. We know this is at a rate much faster than evolution can replace them, so we also know there is real cause for concern.

The variety of life we are losing contains crucial genetic resources on which we rely for the development of medicines as well as for the development of our crops and farm animals. Equally important, the natural ecosystems of the world made up of this diversity provide our oxygen to breathe, distribute and clean water, provide fertile soils as well as a host of other services upon which humans depend, including buffering the environments from the extremes of climate.

Tigers are among many endangered species

WHAT IS DÉJÀ VU?

Andrew Gear

Déjà vu is French for 'already seen'. It describes the sensation many of us experience from time to time when we are sure a certain situation has happened before. It could be visiting a place you've never been but getting a feeling that it's very familiar or having a conversation you feel like you've had before, even down to minute details. There is no definite answer as to why déjà vu happens, as it is a difficult subject to study. One theory is that it happens due to a mismatch in the brain mistaking the present for the past. It is worth noting that a déjà vu feeling commonly precedes temporal-lobe epilepsy attacks and has also been found to be common in patients with certain psychiatric conditions. Déjà vu can be commonly confused with a similar sensation, which we may feel if a similar situation has happened before but has been forgotten. Our brains are full of forgotten and buried memories, and they're always trying to find patterns so may link a new experience with a similar forgotten memory, creating the eerie sensation that you have 'been there' or 'done that' before.

HOW DO BIRDS KNOW WHEN TO MIGRATE?

Neil Howarth

The timing of migration for long-distance migrants is regulated by a range of factors, which may vary greatly depending on the species involved. Studies by Peter Berthold and others on passerine species – such as perching birds or song birds – have shown that birds have an innate response to changes in day length, which is a highly reliable indicator of the changing seasons. And the Wildfowl and Wetlands Trust's detailed studies of Bewick's swans wintering at Slimbridge have similarly found that day length is important for regulating when the Bewick's swan migration happens. Back in the 1970s and early 1980s, prolonged floodlighting at the swans' roost site at Slimbridge meant they set off on their spring migration relatively early.

Did you know?
The Arctic tern has the longest migration of any bird

Once day length has signalled the onset of the migratory season, more immediate factors such as weather conditions – and particularly wind direction – determine the precise day on which they migrate. Day length is particularly useful for birds occurring at relatively high latitudes. However, waterbirds that breed in tropical and subtropical regions, where day length is more or less the same all year round, are more likely to respond to regular cycles of rainfall and to exploit temporary wetlands created by flooding.

WHAT'S CHEWING GUM MADE OF?

Lesley Ogilvie

The main ingredient for chewing gum is the 'gum base' which is essentially a synthetic type of rubber. These gum bases are then mixed with sweeteners and flavourings – either natural or artificial – to make chewing gum. About 60 to 70 years ago, the gum base was commonly made from chicle, a milky white sap, which can be found on the sapodilla tree native to southern Mexico, Central America and the Caribbean. Swallowing small pieces of gum is quite harmless as the gum should pass through your system like any other food. The sweeteners and flavourings will be digested but the 'gum base' cannot be broken down so all that happens is it will pass through the digestive system intact at about the same rate as the broken-down food.

Herbicide being sprayed on a field of crops

How do weed killers kill off only weeds?

Mark Pendleton

Some weed killers, also called herbicides, will kill most plant life they come into contact with, but others are more selective. They vary in the types of weed they kill, the most common being broad-leafed plants while leaving grassy plants unscathed.

Herbicides work by inhibiting the growth of cells in the plant. They do this by targeting the enzymes responsible for fat formation, thus halting the development of the cells. The enzymes that promote cell growth in broad-leafed plants are not the same enzymes as those in grassy plants, therefore the herbicides take advantage of this by targeting and disrupting one type of enzyme and not the other.

How effective the herbicide is depends on the application. If more than the recommended dose is applied then the herbicides could damage the plant you want to save.

© Getty

THE LIBRARY

The latest book releases for curious minds

ROMANS MAGNIFIED

ZOOM IN ON EVERYDAY ROMAN LIFE

AUTHOR **DAVID LONG**
ILLUSTRATOR **DANIEL ŠPAČEK**
PUBLISHER **WIDE EYED EDITIONS**
PRICE **£16.99 / $26**
RELEASE **OUT NOW**

"Romans Magnified brings history to a new level of interactivity"

This is a Roman history book for younger readers, but to call *Romans Magnified* just that would be to do it a great disservice. Riffing off the *Where's Wally* series of illustrated books – or *Where's Waldo* if you're in North America – *Romans Magnified* brings history to a new level of interactivity that we'd argue is necessary to properly engage students of a certain age. A different facet of life in ancient Rome is explored on each new spread via a short section of introductory text and a highly detailed comic illustration – everything from the senate and a map of the Roman Empire to the Roman navy, a villa and the world-famous gladiatorial arena that is the Colosseum.

With each new scene there are ten things to spot, which is where the *Where's Wally* comparisons feel particularly appropriate. The reader pores over Špaček's meticulous illustrations to find tiny, historically accurate details of Roman life. If the reader is struggling, the solutions are next to the glossary at the back of the book. There's a gimmick with this: the physical edition of *Romans Magnified* comes with a little magnifying glass so that the reader can literally bring the illustrations off the page. Not that the book needs this extra interactive element, but scouring the pages with a magnifying glass takes the experience to the next level.

We're not going to bang on about how important it is for learning to be fun, but the whole package – engaging editorial, comic illustrations and magnifying glass – is a wonderfully cohesive concept and great fun. Reading *Romans Magnified* as an adult brings warm and fuzzy memories of picking stripy, bespectacled men out of a sea of cartoon people doing silly things, and we can imagine younger readers having a similarly joyful experience discovering Roman soldiers building snowmen in Vindolanda or a noble purging over the side of his lectus at a feast in a grand villa. Everyone will be learning while having a giggle, and that's the whole point.

AROUND THE WORLD IN 80 TREES

DISCOVER THE WORLD THROUGH ITS TREES

AUTHOR **BEN LERWILL**
ILLUSTRATOR **KAJA KAJFEZ**
PUBLISHER **WELBECK PUBLISHING GROUP**
PRICE **£14.99 / $17.95**
RELEASE **OUT NOW**

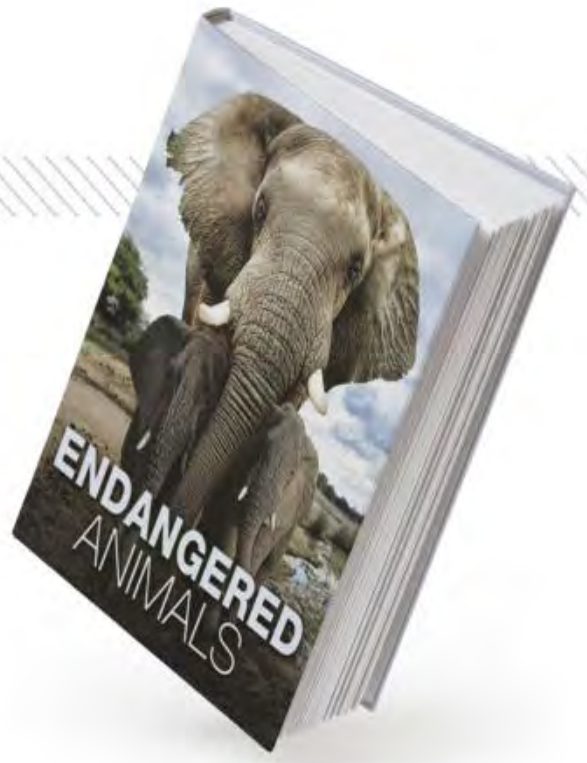
From the North American sugar maple to the Japanese cherry blossom, you can cross the world discovering a myriad of trees in this fascinating book. Although there are more than 70,000 species of trees on Earth, author Lerwill and illustrator Kajfez have captured their enormous diversity in only 80 examples. Along with the identifying physical characteristics of each tree, this book explores their history and the impact that some species have had on the world.

For example, African baobabs are seen by locals as sacred, with them even offering gifts to the trees, such as honey. Baobabs also offer moisture to thirsty elephants while they chew on its bark. *Around the World in 80 Trees* teaches a young audience about the science behind a tree's life cycle, their role in the food chain, how they aid medicine production and their role in impacting environmental health.

ENDANGERED ANIMALS

MEET THREATENED SPECIES

AUTHOR **TOM JACKSON**
PUBLISHER **AMBER BOOKS**
PRICE **£19.99 / $29.99**
RELEASE **14 JUNE**



In 200 stunning images, this book reveals around 100 animal species that are on the brink of extinction around the world. Using information produced by the International Union for the Conservation of Nature (IUCN), author Tom Jackson has compiled an album of images that show these animals in their natural habitats before they're lost from the world.

In a celebration of life and wild diversity, readers can expect some shocking statistics about wildlife populations, such as the black rhino, which has only around 3,500 specimens left in the wild. There's also a whole host of animals that readers may discover for the first time, such as one of the rarest birds on Earth, the New Zealand kakapo. What's poignant about this book is that its chapters are split into all the world's continents, signifying that no matter where you are in the world, there are animals that are on the verge of extinction.

BUTTERFLIES

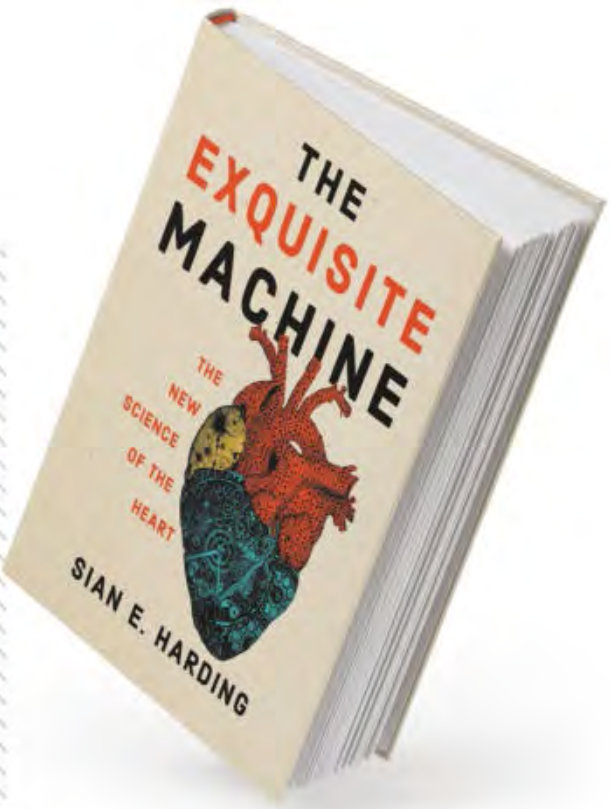
A WORLD OF BEAUTIFUL FLYING INSECTS

AUTHOR **JULIANNA PHOTOPOULOS**
PUBLISHER **AMBER BOOKS**
PRICE **£19.99 / $29.99**
RELEASE **14 JUNE**

There are over 17,000 species of butterflies on Earth, and 160,000 moths. While the author of this book acknowledges that butterflies generally hold the reputation of most beautiful, this book captures the elegant charm of both. *Butterflies* is photography-led, compiling the most captivating images of these creatures in all stages of their unique life cycles. Accompanying the stunning photography, the text covers fascinating details about the behaviours of butterflies and moths. From their anatomy and life cycles to their habitats and unusual habits, the information contained gives each image a sense of awe.

For anyone who experiences that burst of joy whenever a pair of striking butterfly wings flutters past, the images capture that moment of delicate vibrance. Each species is photographed in mesmerising detail, displaying fine textures, feathered antennae or brilliant, bold eyes. Whether you open the page to find the fluffy candy-floss-coloured face of the rosy maple moth or the camouflage champion that is the dead leaf butterfly, *Butterflies* will fully immerse you into the vast world of these insects and allow you to explore their diversity up close.

***Butterflies* is photography-led, compiling the most captivating images of these creatures**



THE EXQUISITE MACHINE

THE NEW SCIENCE OF THE HEART

AUTHOR **SIAN E. HARDING**
PUBLISHER **MIT PRESS**
PRICE **£25 / $28.95**
RELEASE **20 SEPTEMBER**

The heart is that pump in your chest that keeps you alive – but its complexity is underrated. Although the core mechanics are important, there's so much more to learn about this organ, and this book will keep you up to date with the latest and most significant scientific findings. Delivered by Sian Harding, a leading cardiac researcher, it includes advanced knowledge written in a conversational and captivating manner. *The Exquisite Machine* includes facts and findings such as information about how new hearts can be made from stem cells and what can be done to an old and failing heart to keep it functioning. The book explores not just the evolution of the heart's functional traits, but also how our knowledge of its traits and adaptations have evolved.

How have we learned that the heart can regenerate itself, or that people's hearts can fail to function after severely emotional events? Incredible discoveries, new to the average reader and research scientists alike, reveal how emotion is both controlled by and can control the heart's functions. Using a combination of exact figures pulled from recent studies and more generally known facts, the author explains which features of the heart are predetermined by factors such as biological sex or hormones and how we can improve our heart health through lifestyle and treatment.

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

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

MEDIUM

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

HARD

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

Word search

Find the following words

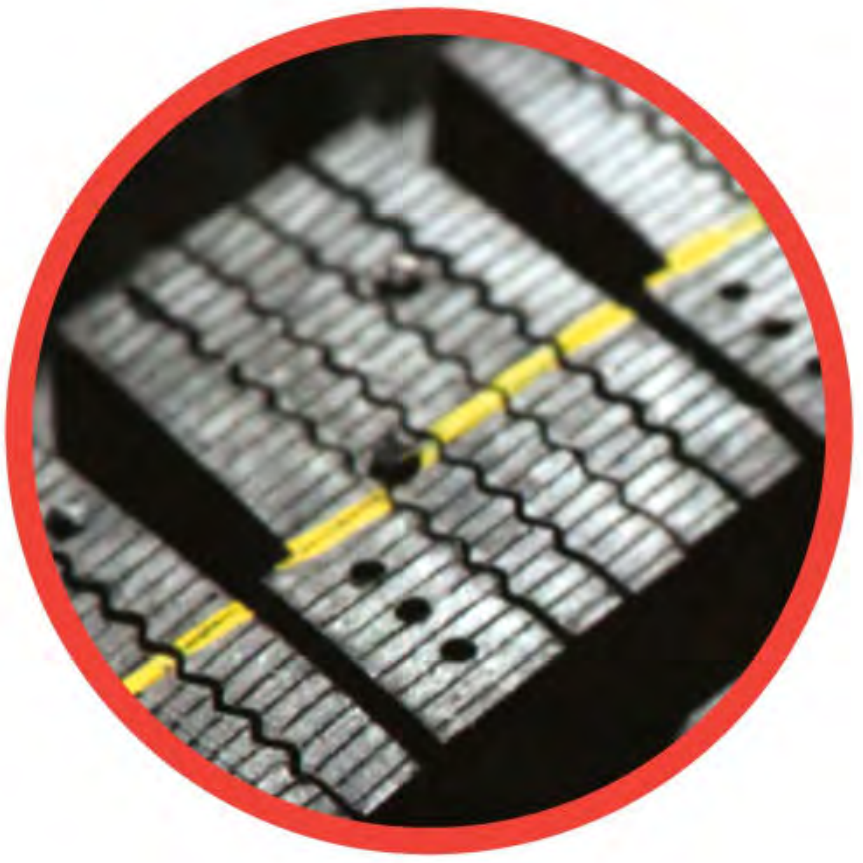
ROCKET
CASTLE
POLLEN
SCRAP
STEROIDS
CARBON
SPACE
CHILLI
SHOE
MOON
FUEL
CRUSH

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

What is it?

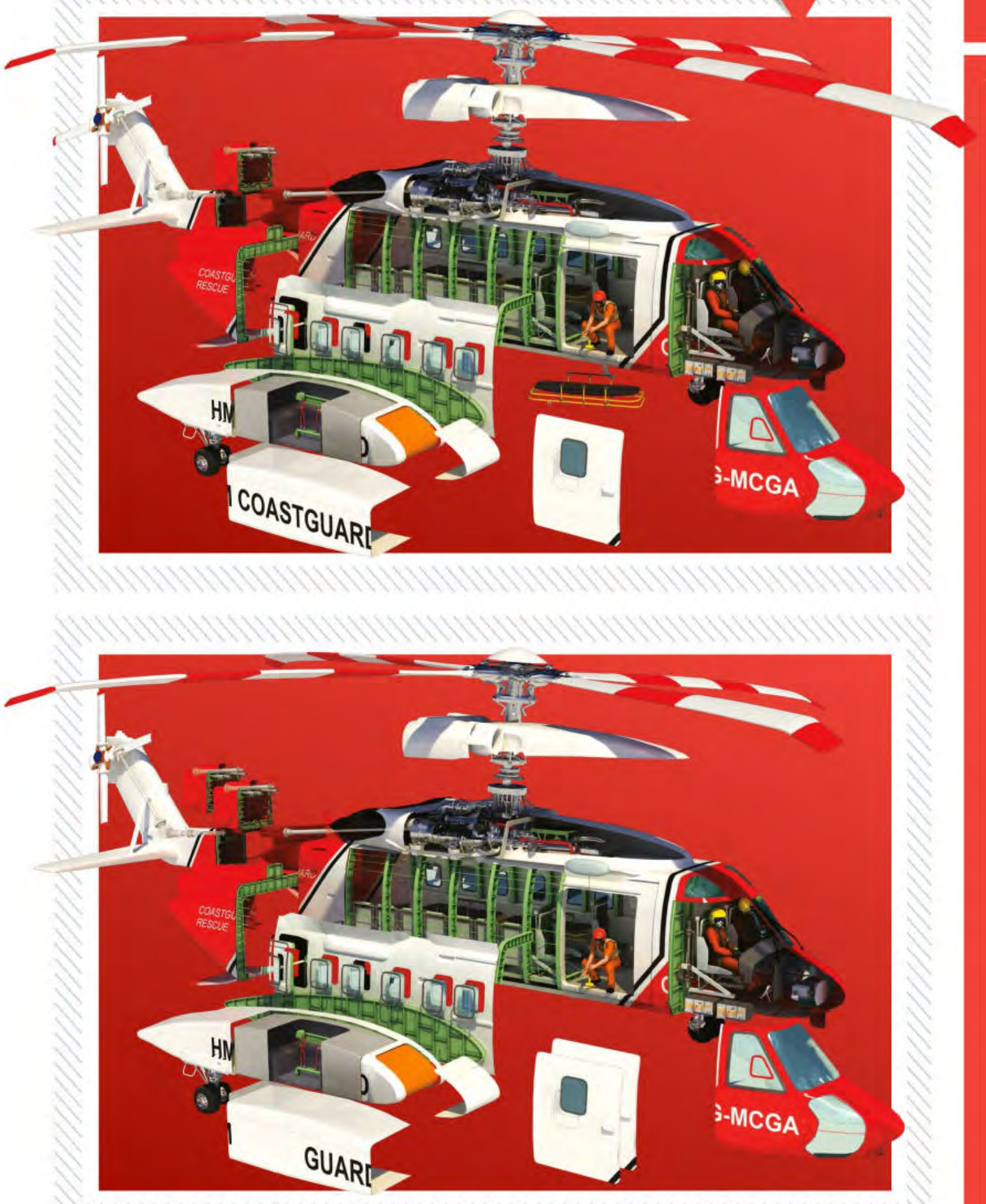
Hint: Too tired to walk?

A



Spot the difference

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



QUICKFIRE QUESTIONS

Q1 In which country would you find the Forbidden City?

- Britain
- South Africa
- Japan
- China

Q2 What gives egg yolk its orange colour?

- Iron
- Oranges
- Carotenoids
- Cholesterol

Q3 What is a group of bats called?

- Gang
- Colony
- Herd
- Flight

Q4 How many loaves are in a baker's dozen?

- 24
- 12
- 13
- 11

Q5 Where would you find the tragus on your head?

- Eyes
- Ears
- Nose
- Lips

Q6 Which of these types of rock is granite?

- Sedimentary
- Igneous
- Metamorphic
- Progressive

Answers

Find the solutions to last issue's puzzle pages

Q1 ZARYA
Q2 CHICKEN
Q3 FRANCE
Q4 AMAZON
Q5 EAR
Q6 PEPPERMINTS

What is it?

AMBER

Spot the difference

© Alamy / Getty

GROW BACTERIA IN A HOMEMADE PETRI DISH

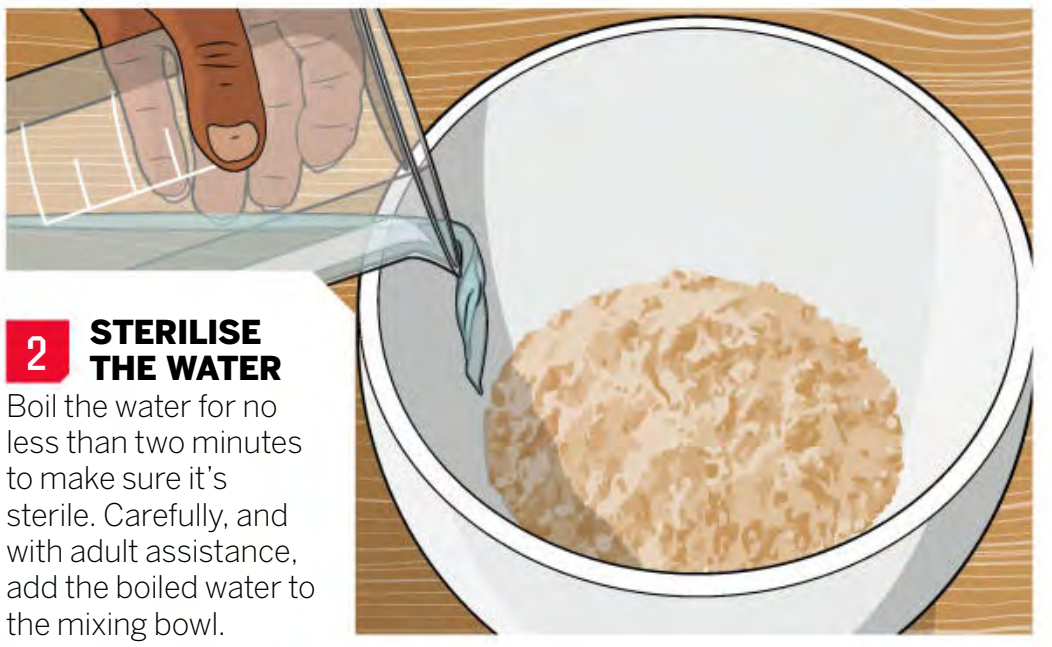
This experiment can be done at home with a few simple ingredients

KIT LIST

- Two small packets of powdered gelatine (five teaspoons)
- One packet of low-sodium beef bouillon
- One teaspoon of sugar
- Cling film
- Mixing bowl
- Shallow transparent dishes (one per sample)
- Cotton swabs (one per sample)
- 250ml boiled water

1 ADD THE FIRST INGREDIENTS

Into your mixing bowl, add the gelatine, beef bouillon and sugar. The nutrients in these ingredients are needed to help the bacteria grow.

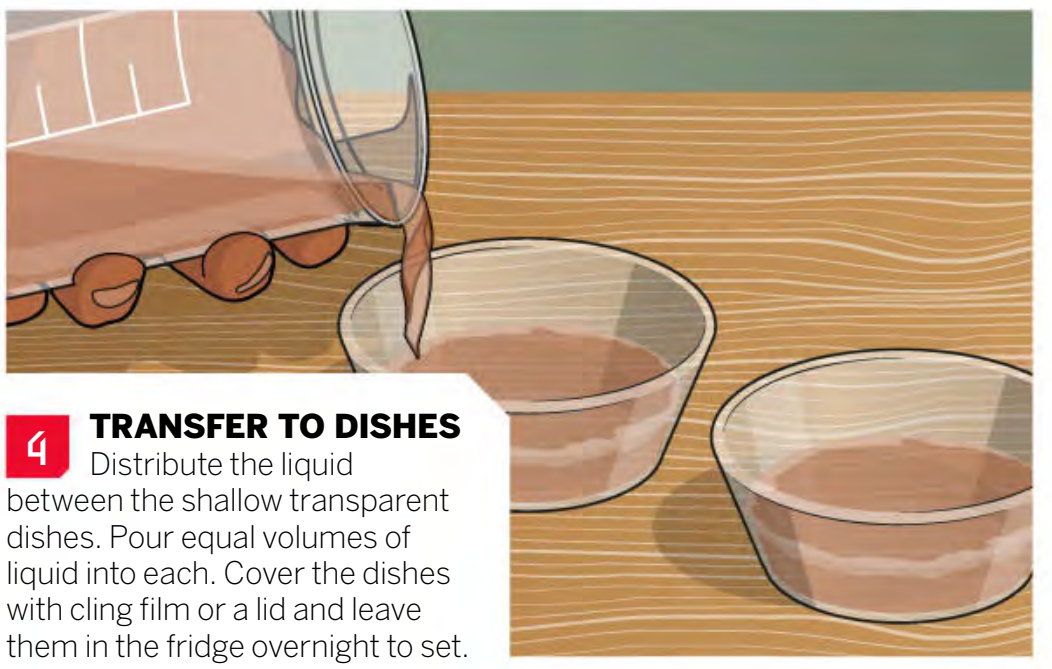


2 STERILISE THE WATER

Boil the water for no less than two minutes to make sure it's sterile. Carefully, and with adult assistance, add the boiled water to the mixing bowl.

3 DISSOLVE THE CONTENTS

Mix the contents of the mixing bowl until the solid ingredients are completely dissolved in the water. This means that you can't see any granules collected at the bottom of the bowl.

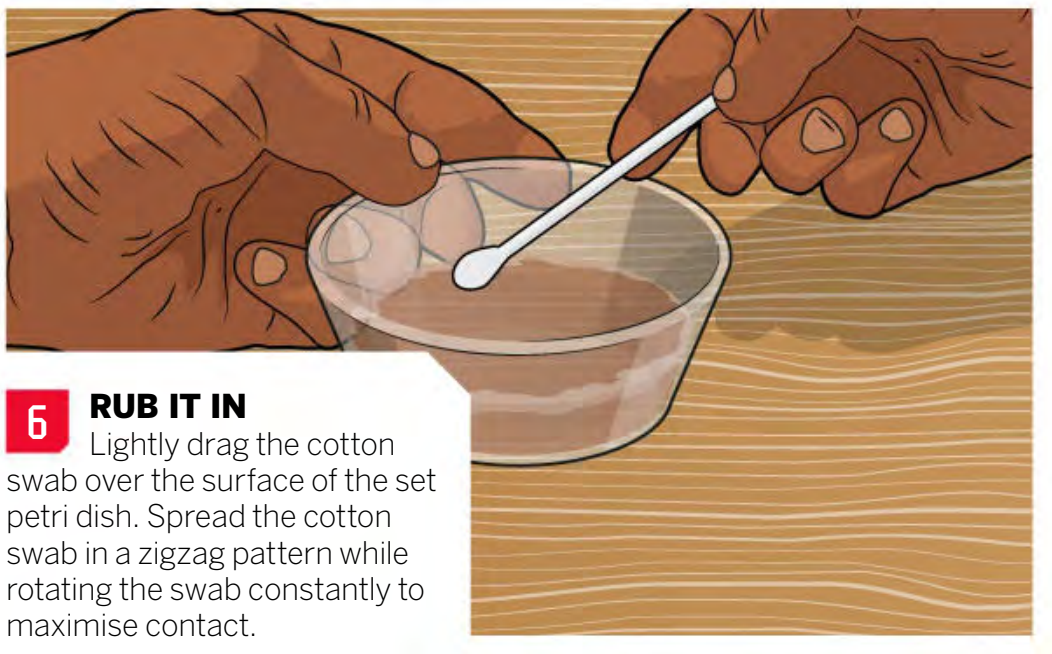


4 TRANSFER TO DISHES

Distribute the liquid between the shallow transparent dishes. Pour equal volumes of liquid into each. Cover the dishes with cling film or a lid and leave them in the fridge overnight to set.

5 CHOOSE YOUR SAMPLES

Using a new cotton swab for each sample, rub the tip on the surface of your sample a few times. You might want to try the inside of your mouth, a door handle or coins.



6 RUB IT IN

Lightly drag the cotton swab over the surface of the set petri dish. Spread the cotton swab in a zigzag pattern while rotating the swab constantly to maximise contact.

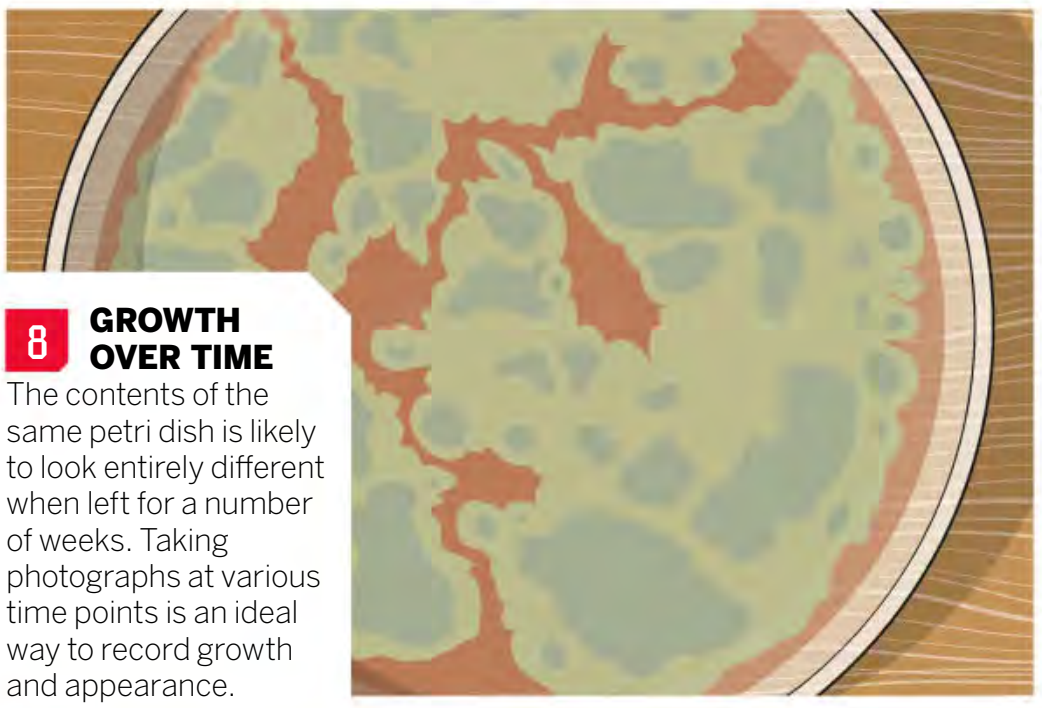
NEXT ISSUE
MAKE BUBBLE SNAKES

DON'T DO IT ALONE!

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

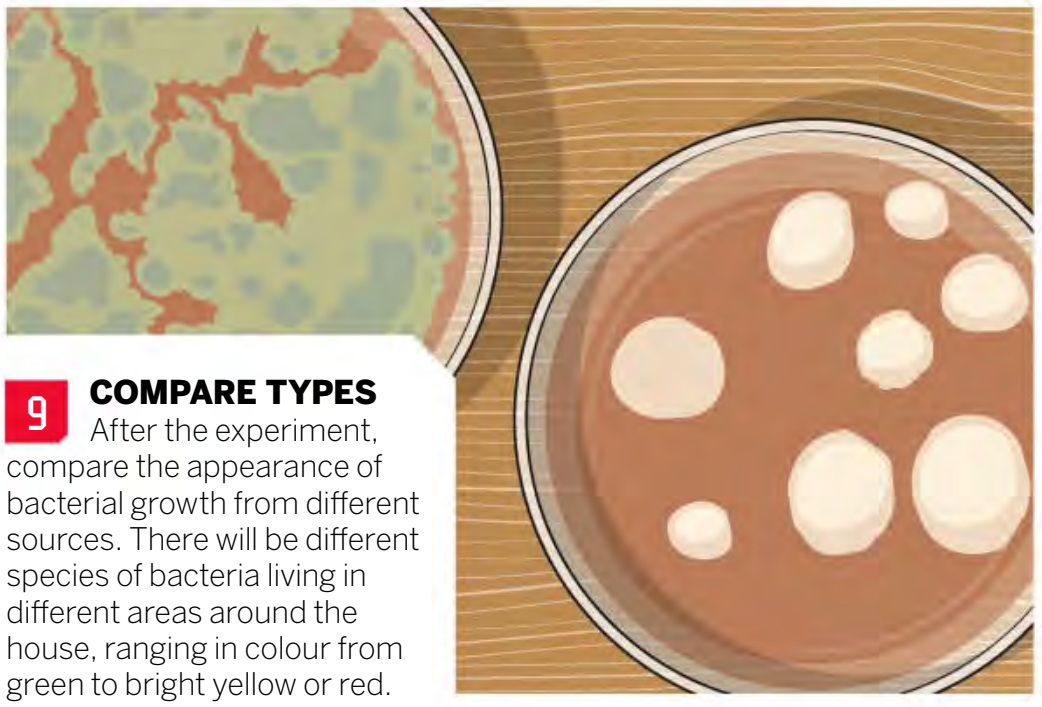
7 CHECK DAILY

Cover the petri dishes with cling film and place them somewhere relatively warm and dark. After a few days, you should begin to see significant growth in the petri dish.



8 GROWTH OVER TIME

The contents of the same petri dish is likely to look entirely different when left for a number of weeks. Taking photographs at various time points is an ideal way to record growth and appearance.



9 COMPARE TYPES

After the experiment, compare the appearance of bacterial growth from different sources. There will be different species of bacteria living in different areas around the house, ranging in colour from green to bright yellow or red.

SUMMARY

The average bacteria cell is about two micrometres long, which is hundreds of times smaller than a single grain of sand. This means that individual bacteria are invisible to the naked eye. In this experiment, a variety of bacteria are given the nutrients needed to help them grow and divide. In large numbers, also known as a colony, they become visible as the blotches of colour on the petri dish.

When making your homemade petri dish, low-sodium bouillon is used. This is to encourage bacterial growth. High sodium levels can dehydrate bacteria and prevent them from growing and increasing in number. The sugar, gelatine and bouillon provide nutrients and energy for bacterial growth, and the set gelatine provides a hardened surface for the species to gather on, making them easy to see.

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.

© Illustrations by Ed Crooks

INBOX

Speak your mind

LETTER of the MONTH

THE BIOLOGY OF SKIN

Dear **HIW**,
How much melanin determines our bodies' skin pigmentation?
Shathiswaran R.

Melanin plays a core role in determining our pigmentation. This substance is responsible for producing the colour of our hair, eyes and skin, and the more of it that's produced, the darker these features will appear. The amount of melanin our bodies make isn't decided by chance, but involves genetics and how much Sun exposure you have.

Melanin plays a vital part in protecting us from the Sun's radiation. The substance absorbs its ultraviolet (UV) rays to protect our cells from damage. Three different types of melanin make up our bodies' pigmentation. Eumelanin can be black or brown in colour and produces darkness in eyes, skin and hair.

Melanin absorbs UV radiation

Pheomelanin produces the pinker pigments that can be seen in areas such as the lips and nipples, and neuromelanin controls the colour of neurons, which you can't see. Everyone has a similar number of the cells that produce melanin, but these cells produce different amounts of melanin in each person. The combination of eumelanin and pheomelanin produced determines the colours we can see on our bodies. Some people are born with clusters of melanin-producing cells – this displays as freckles.

WIN!

AN AMAZING PRIZE FOR LETTER OF THE MONTH

ROMANS MAGNIFIED

Zoom in to discover what life was like for ancient Romans in this innovative and interactive illustrated title that takes you into their fascinating world

TREE DISEASES

Dear **HIW**,
Can trees and plants develop cancer?
Andy Hardman

Cancer is a disease that only animals get. However, plants can grow tumours in a similar way. These are cells that excessively multiply to produce an uneven growth. The cells in plants can't spread to other areas of the tree because unlike human cells, the cell walls of plants stop them from moving around. Tumours in trees are often caused by bacteria, such as *Agrobacterium tumefaciens*. These are less deadly than cancer in humans because plants don't have individual organs that are essential for life. If a tumour takes over a person's brain, or another essential organ, they will die. However, when plants lose a part of them, they can usually bounce back by growing another branch or root.

Abnormal tree growths are sometimes called crown galls

REALLY COOL INVENTION

Dear **HIW**,
Who invented air conditioning?
Ken Woytisek

Willis Carrier was an engineer who became known as 'the father of air conditioning'. When working at the Buffalo Forge Company as chief engineer between 1902 and 1915, Carrier was asked to help improve conditions in a humid printing plant. Carrier designed a system that would cool and cleanse the air by circulating it, sending air through coils filled with cold water. The first portable AC unit was invented by a man named Frederick Jones. These gained importance through use in military hospitals, keeping soldiers cool after being wounded on the battlefield.

5.6 billion buildings will have air conditioning by 2050

NEXT ISSUE

ISSUE 166

ON SALE 7 JULY 2022

Available in print from all good newsagents and **magazinesdirect.com**, or as a digital edition for iOS and Android. To enjoy savings on the RRP and to make sure you never miss an issue, check out our subscription offers on pages 18 (UK) and 69 (US).

EXPLOSIVE SCIENCE

Dear **HIW**,
How do nuclear bomb makers find out the critical mass of the uranium used before it explodes? If they were to get it wrong, surely they would be killed in a premature explosion.
Stephen

The first controlled fission experiment to determine the critical mass of uranium for a nuclear chain reaction was carried out by physicists Enrico Fermi and Leo Szilard in 1942. Critical mass is how much material is needed in order to start a nuclear reaction. They used 40,000 graphite blocks coupled with 19,000 pieces of uranium to conduct their experiment. They found that the critical mass of uranium-235 was around 50 kilograms. They also found that the shape and type of fuel changed its critical mass. During construction, the fuel is kept separate within the bomb in masses below the critical mass. Only when they are detonated do these masses combine to trigger a reaction.

NAIL-BITING QUERY

Dear **HIW**,
I keep biting my nails without realising. Is there a way I can make them grow back faster?
Gemma Shales

Nails grow at a consistent rate of around one millimetre a month. The best solution is to increase the strength of your nails to prevent breakage. You can take a B vitamin called biotin. This vitamin aids the body in turning food into energy, but has also been shown to strengthen brittle nails. You can increase biotin-rich foods in your diet, such as nuts, whole grains, beans, cauliflower, bananas and mushrooms. Another idea is to buy nail hardeners, which are painted onto the nails. Some are designed especially for nail biters, with an unpleasant taste.

WE ASKED YOU

This month on social media, we asked you: What is the most impressive castle you've seen or visited?

@SAMSHATHIS
Kellie's Castle

@DEFINITELY.NOTMAX
Edinburgh Castle due to it being one of the oldest fortified places in Europe

@MAX.FX.SHORTS
Hohenzollern Castle in Germany because of its size and unique look

@MAIA_H3
The castle in Carcassonne! The whole city is inside the castle walls

@SCIMAXFACTS
The bouncy castle at my birthday party years ago due to it being really fun back then

@AESTHETICALLY_AJ
Lindisfarne Castle – the road to get there is covered twice a day

© Getty

HOW IT WORKS

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

Editorial
Editor **Ben Biggs**
Senior Art Editor **Duncan Crook**
Production Editor **Nikole Robinson**
Senior Staff Writer **Scott Dutfield**
Staff Writer **Ailsa Harvey**
Editor-in-Chief **Tim Williamson**

Contributors
Andrew May, Jo Elphick, Robert Lea, Mark Smith, James Horton, Brandon Specktor, Callum McKelvie, Jonathan Gordon, Ben Turner, Rachel Rettner, David Crookes, Tia Ghose

Cover images
Getty / SpaceX

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

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

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

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

Disruption remains within UK and international delivery networks. Please allow up to seven days before contacting us about a late delivery at **help@magazinesdirect.com**

Circulation
Head of Newstrade **Tim Mathers**

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

Management
Managing Director **Sarah Rafati Howard**
Content Director **Gemma Lavender**
Commercial Finance Director **Tom Swayne**
Head of Art & Design **Greg Whittaker**
Chief Growth Officer **Claire MacLellan**

Printed by William Gibbons & Sons Limited
26 Planetary Road, Willenhall, Wolverhampton, West Midlands, WV13 3XB

Distributed by Marketforce, 5 Churchill Place, Canary Wharf, London, E14 5HU
www.marketforce.co.uk
Tel: 0203 787 9001

ISSN 2041-7322

All contents © 2022 Future Publishing Limited or published under licence. All rights reserved. No part of this magazine may be used, stored, transmitted or reproduced in any way without the prior written permission of the publisher. Future Publishing Limited (company number 2008885) is registered in England and Wales. Registered office: Quay House, The Ambury, Bath, BA1 1UA. All information contained in this publication is for information only and is, as far as we are aware, correct at the time of going to press. Future cannot accept any responsibility for errors or inaccuracies in such information. You are advised to contact manufacturers and retailers directly with regard to the price of products/services referred to in this publication. Apps and websites mentioned in this publication are not under our control. We are not responsible for their contents or any other changes or updates to them. This magazine is fully independent and not affiliated in any way with the companies mentioned herein.

If you submit material to us, you warrant that you own the material and/or have the necessary rights/permissions to supply the material and you automatically grant Future and its licensees a licence to publish your submission in whole or in part in any/all issues and/or editions of publications, in any format published worldwide and on associated websites, social media channels and associated products. Any material you submit is sent at your own risk and, although every care is taken, neither Future nor its employees, agents, subcontractors or licensees shall be liable for loss or damage. We assume all unsolicited material is for publication unless otherwise stated, and reserve the right to edit, amend, adapt all submissions.

We are committed to only using magazine paper which is derived from responsibly managed, certified forestry and chlorine-free manufacture. The paper in this magazine was sourced and produced from sustainable managed forests, conforming to strict environmental and socioeconomic standards. The manufacturing paper mill holds full FSC (Forest Stewardship Council) certification and accreditation.

ipso. Regulated

Widely Recycled

FUTURE
Connectors. Creators. Experience Makers.

Future plc is a public company quoted on the London Stock Exchange (symbol: FUTR)
www.futureplc.com

Chief executive **Zillah Byng-Thorne**
Non-executive chairman **Richard Huntingford**
Chief financial officer **Penny Ladkin-Brand**
Tel +44 (0)1225 442 244

FAST FACTS

Amazing trivia that will blow your mind

200

Google uses a huge herd of goats to maintain its headquarters lawn

1 MILLION

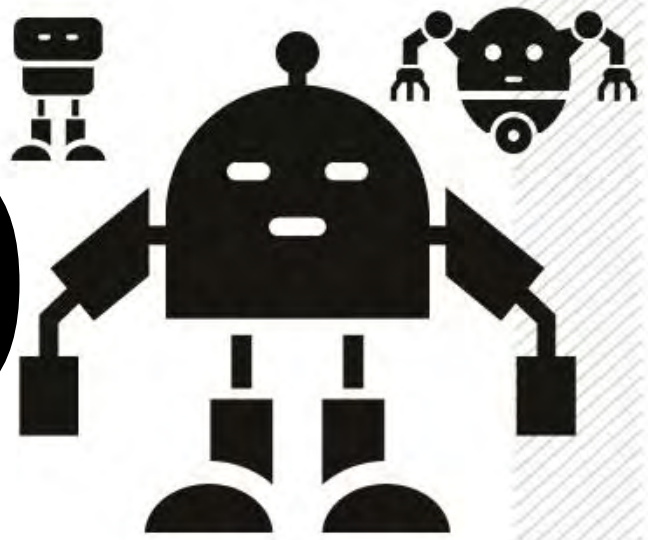
You could fit this many Earths inside the Sun

8 HOURS

The first photograph in 1826 took a full working day to expose

1920

The word ‘robot’ was coined over 100 years ago from the Czech word for ‘forced labour’



-273 DEGREES

When cooled to almost absolute zero, helium flows without friction

An iPhone can be hacked with a laser pointer

300 DEGREES

Horses can see nearly completely around themselves

WASTE PLASTIC CAN BE TURNED INTO VANILLA FLAVOURING

10%

People read words on a digital screen slower than a paper magazine

145

The human genome contains dozens of genes that have jumped from other species

IT’S IMPOSSIBLE TO BURP IN SPACE

© Getty

CELESTRON®

LABS

MICROSCOPES IDEAL FOR BEGINNERS

DISCOVER HIDDEN WORLDS

LABS S20 STEREO

RRP £79.99

- For viewing 3D objects such as leaves insects or coins
- 20x magnification
- Battery powered upper LED illumination

LABS CM400C COMPOUND

RRP £169.99

- For viewing prepared glass slides
- 40x, 100x, 400x magnifications
- Battery or mains powered lower LED illumination

LABS S10-60 STEREO

RRP £249.99

- For viewing 3D objects, e.g. leaves insects or coins
- 10x, 20x, 30x, 60x magnifications
- Mains powered upper and lower LED illumination

LABS CB1000CF COMPOUND

RRP £339.99

- For viewing prepared glass slides
- 40x, 100x, 400x, 1000x magnifications
- Mains powered lower LED illumination with abbe condenser and iris diaphragm

FOR MORE INFORMATION,
VISIT CELESTRON.COM

AIRFIX

QUICK BUILD

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

J6036
FORD MUSTANG GT

Ford Mustang GT
Build an Iconic Model

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

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

No glue!
No paint!
Just build!

Collect them all! Check out the rest of the range online.

J6019 Lamborghini Aventador

J6025 Yellow VW Beetle

J6020 Bugatti Veyron

9001

9000

Airfix.com and all good retail stockists YouTube

HORNBY HOBBIES
Official Product