SCIENCE ENVIRONMENT TECHNOLOGY TRANSPORT HISTORY SPACE

NEW

HOW IT WORKS

The Collection

1000s OF AMAZING FACTS INSIDE

Digital Edition

FUTURE

VOLUME 8

Feed your mind and learn more about the incredible world around you

Welcome to

HOW IT WORKS

The Collection

Volume 8

Welcome to our eight edition of the How It Works collection, a carefully curated volume of our favourite science, technology, history, transport, environment, and space articles. Between these pages you'll find something with particular appeal to you, if not everything: whether that's the danger of antibiotic resistant superbugs, lighter subjects like our debunking of nonsense conspriacy theories that still persist today, school curriculum-friendly features like the physics of geforce, teccy topics such as the inner workings of the classic Playstation 2 video games console, or a trip to the thirteenth century to see inside medieval houses. As always, they're accompanied by cool cutaway illustrations, a stunning selection of photos and images, and absolutey packed with fantastic facts. Now, turn the page and enjpy!

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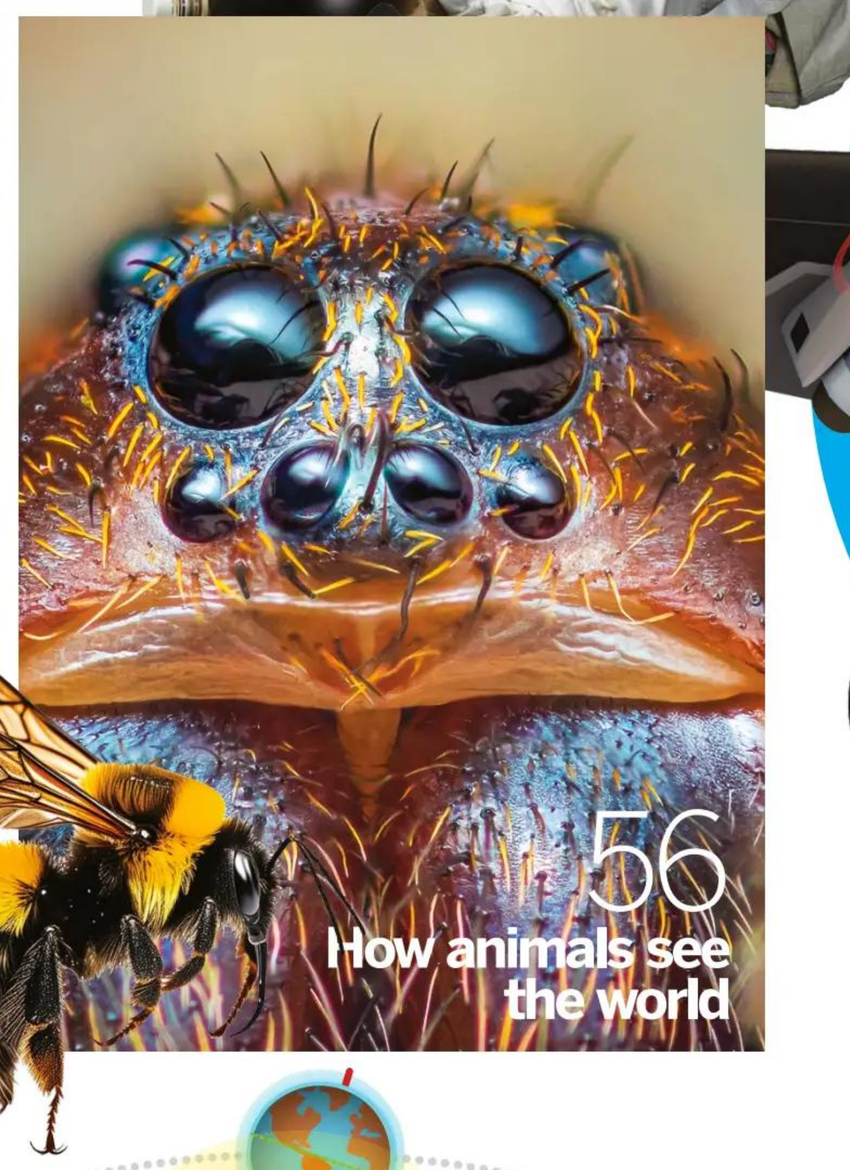
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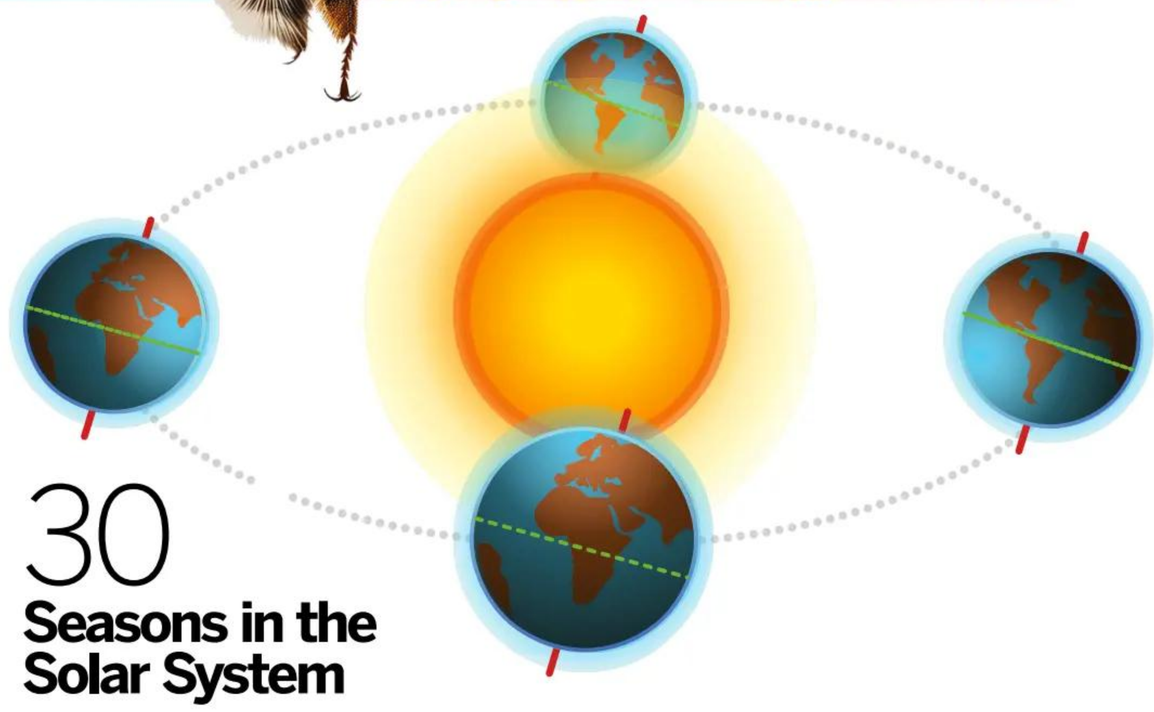
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SCIENCE

SCIENCE

RISE OF THE SUPER

DID YOU KNOW? Global use of antibiotics is expected to rise to 107,472 tonnes by 2030

Bacteria, viruses and fungi are fighting back against our antibiotics. How can scientists defend us from these increasingly dangerous pathogens?

WORDS SCOTT DUTFIELD

One of the greatest threats to humankind's survival is a problem we started over 100 years ago. In 1910 the world's first antibiotic, Salvarsan, was sent out into the world to tackle syphilis, a sexually transmitted infection caused by a bacterium called *Treponema pallidum*. However, the discovery of penicillin in 1928 marked the true beginning of the golden age of antibiotics. Until around the 1970s, the world erupted with new antibiotic medications to tackle a plethora of illness-inducing bacteria. By breaking down their protective membranes, disrupting their DNA and halting their growth, these medications can make easy work of destroying their targets. However, in the wake of the antimicrobial revolution, a new threat has emerged.

Did you know?

Bacterium populations can double every 4 to 20 minutes

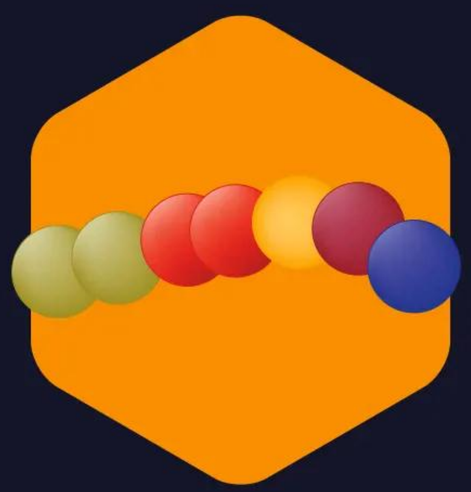
When bacteria, along with viruses or fungi, become resistant to the effects of antimicrobial medicine, it's known as antimicrobial resistance (AMR), with antibiotic resistance being the most common form of AMR. Every antibiotic used in clinical practice now has at least one strain of bacteria that's resistant to it, making them

BUGS

© Getty

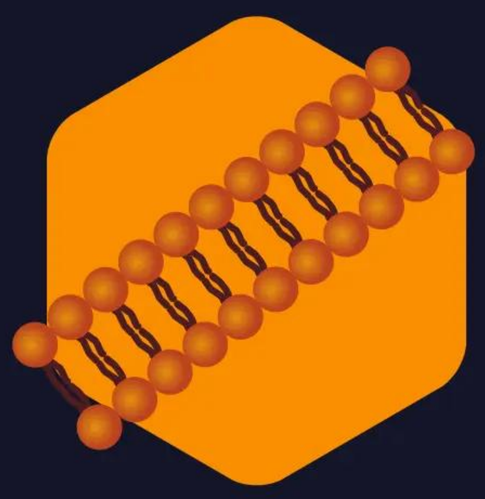
OBLITERATING BACTERIA

How antibiotics take down their microscopic foes



1 HALTING PROTEIN PRODUCTION

Some antibiotics inhibit the production of proteins in bacteria, preventing them from growing, which leads to their death.



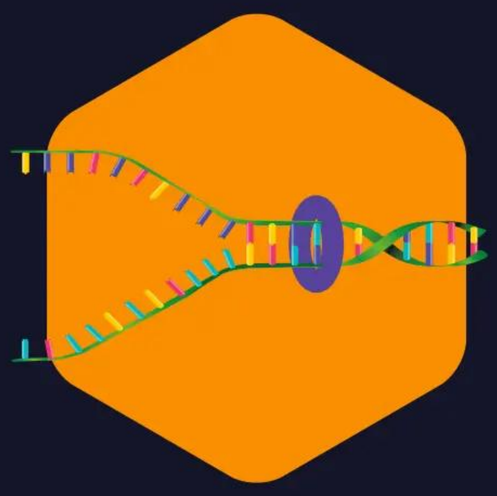
2 DNA DISRUPTION

By binding with the enzyme that transcribes bacterial DNA, some antibiotics stop DNA replication, causing bacteria to die.



3 BREAKING DOWN WALLS

The production of a cell wall-building polymer called peptidoglycan can be inhibited by some antibiotics. This causes the wall to open up, leading to osmotic lysis, where water fills the cell and pops it like a water balloon.



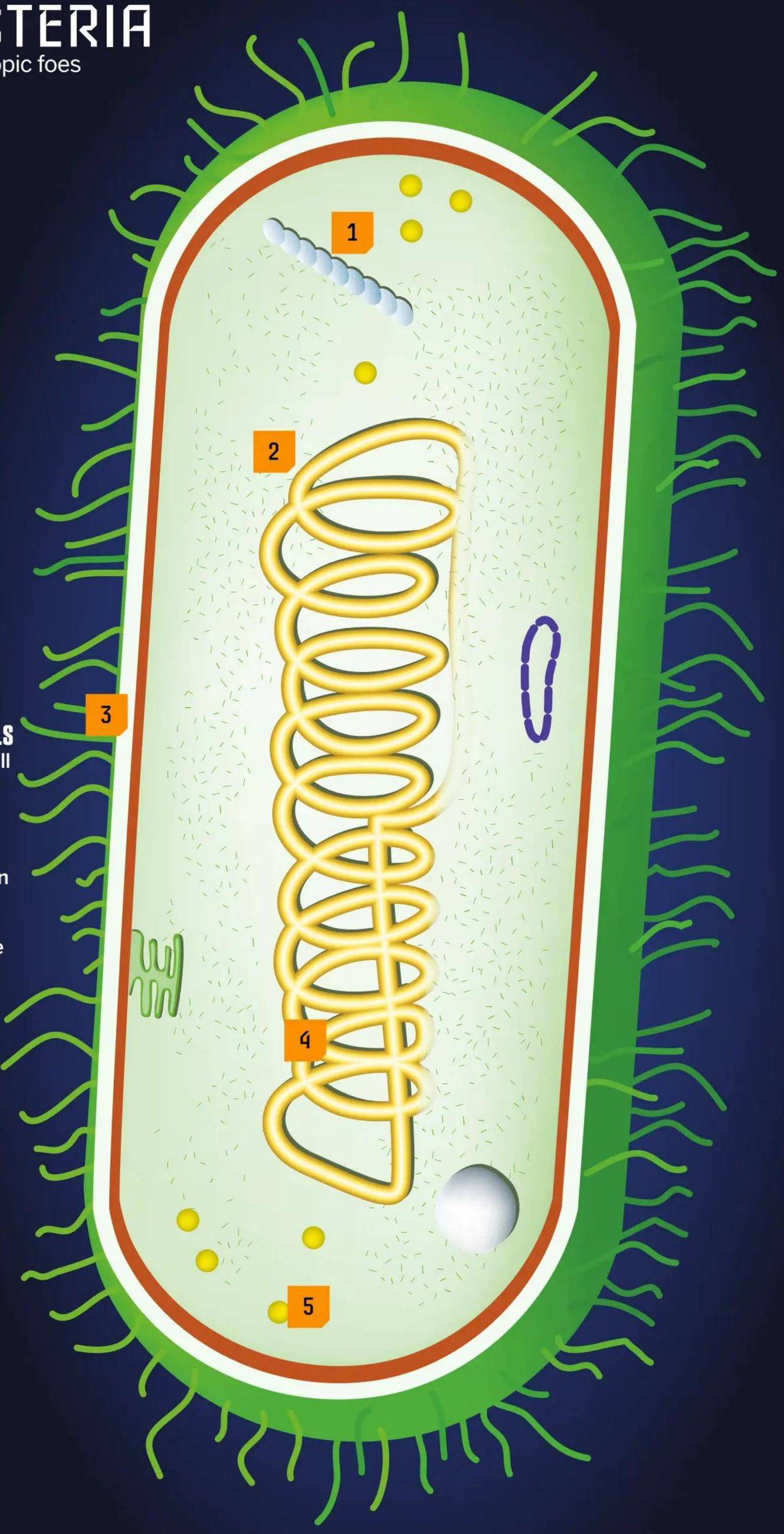
4 MEMBRANE MELTDOWN

Antibiotics can bind to the membranes of bacteria, reducing their functionality and causing them to redirect protein production to the membrane for growth and replication.



5 MESSING WITH METABOLISM

By inhibiting enzymes involved in bacteria's production of metabolites for DNA production, some antibiotics prevent them from growing.



increasingly difficult to treat. Commonly known as 'superbugs', these defiant microbes get their powers of antimicrobial resistance from mutations in their DNA that lead to changes in the structure of the enzymes, proteins and membranes that antimicrobials target. Some bacteria have even developed 'biochemical pumps' to evict antibiotics that enter their cells.

These genetic mutations, which are often referred to as 'spontaneous resistance', can occur randomly and at any time. Much like the changes that lead to the evolution of any other living organism, Darwin's evolutionary concept of the 'survival of the fittest' is at play here. For example, bacteria that aren't killed by antibiotics because of a mutation go on to multiply and become the remaining dominant strain of bacteria. To make matters worse, bacteria can also share these mutated genes with other bacteria. In a process called 'horizontal gene transfer', circular pieces of DNA called plasmids cross the membranes of bacteria when they come into direct contact with one another.

The other main causes of AMR include the misuse and overuse of antimicrobials. Not completing a course of antibiotics or misusing them can allow bacteria to multiply and form new DNA mutations that lead to resistance. Similarly, antibiotics can be misused to treat symptoms that are caused by another pathogen, like a virus. In a 2017 report released by the World Health Organization (WHO), researchers estimated that just 50 million of the 150 million prescriptions for antibiotics written by doctors in the US were necessary.

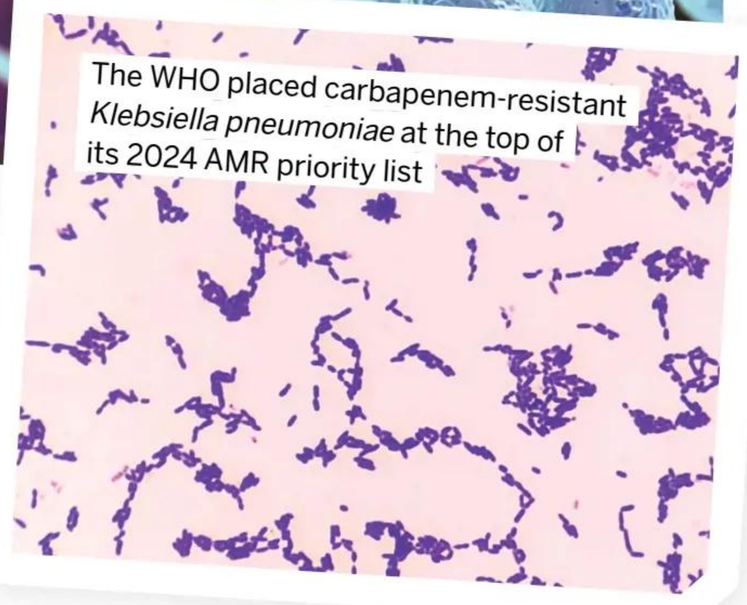
One of the most formidable bacteria that has kept scientists on their toes for decades is *Staphylococcus aureus*. As a widely found bacteria in our everyday environments, *S. aureus* doesn't typically cause infection when it comes into contact with healthy skin. However, when this persistent pathogen finds its way into the body's bloodstream or internal tissue it can cause serious infection and can lead to the development of serious complications, such as sepsis and respiratory failure, if left untreated.

Did you know?

S. aureus can grow in temperatures between 18 and 40 degrees Celsius



An illustration of the superbug fungus *Candida auris*



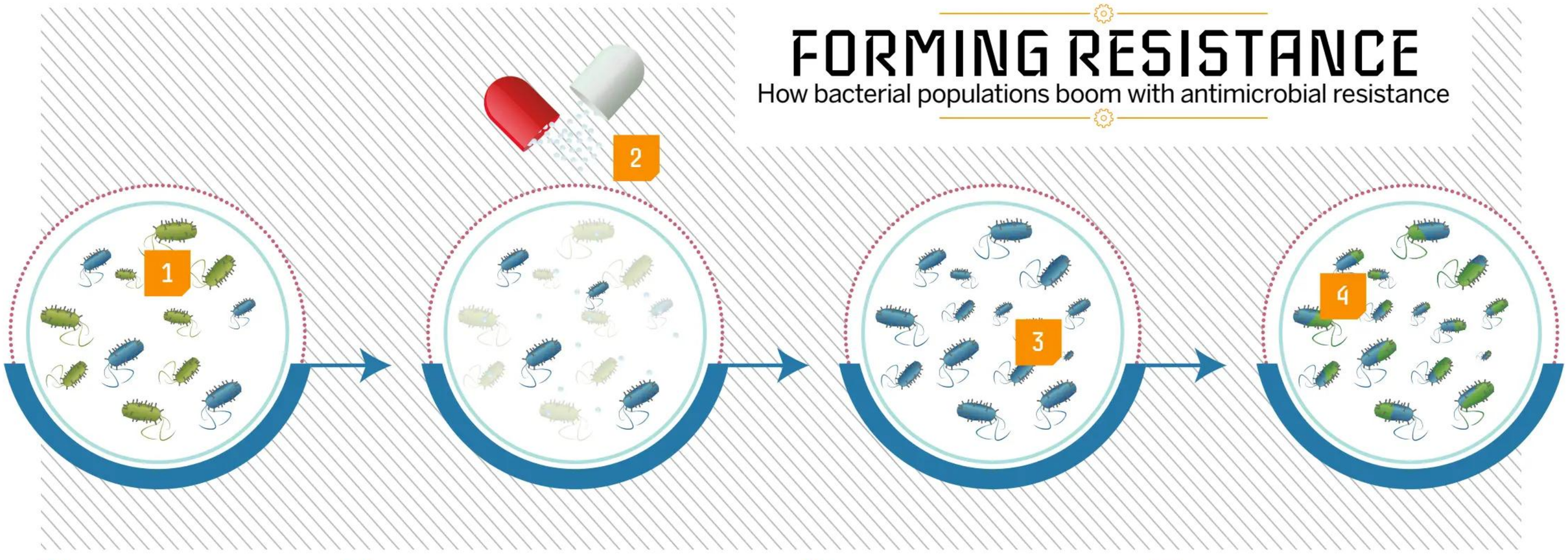
The WHO placed carbapenem-resistant *Klebsiella pneumoniae* at the top of its 2024 AMR priority list

Similarly, viruses have found ways to dodge the effects of antivirals by changing their genetic make-up. For example, changes in the DNA of human immunodeficiency virus (HIV) have led to instances of antiviral resistance, stopping this vital medication's ability to block

"Viruses have found ways to dodge the effects of antivirals"

FORMING RESISTANCE

How bacterial populations boom with antimicrobial resistance



1 MICROBE POPULATIONS
Microorganisms such as bacteria and fungi grow and spread, causing infection.

2 ANTIMICROBIAL MEDICINE
Medicines destroy the majority of harmful microbes but leave behind any that have mutated a resistance to the medicine.

3 REPOPULATE
The population of resistant microbes grows and spreads, unaffected by medicine.

4 SHARING RESISTANCE
Microbes can share their DNA with other microbes and essentially pass on their resistance.

© Shutterstock



We'll need to develop new ways to treat infections if current medicine no longer works

virus replication. Among the world's fungi species, *Candida auris* has emerged as a multidrug-resistant yeast that can lead to severe illness, particularly in sick people and those with invasive medical devices. Infections have been on the rise, especially in the US, which between January and December 2022 had 2,377 cases of this variety of superbug infection – a huge increase from the 476 cases in 2019.

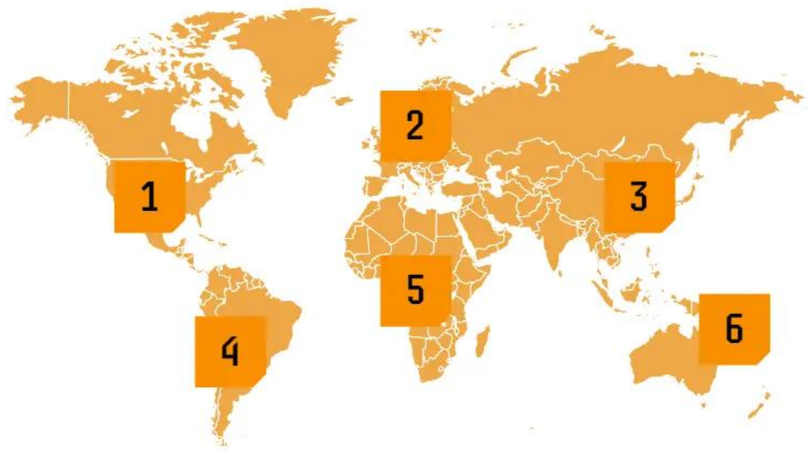
At present, the world is facing its greatest superbug threat, especially in the war against antibiotic resistance. It's estimated that bacterial AMR caused 1.27 million deaths worldwide in 2019 and contributed to the deaths of 4.95 million others. Across the European Union, Iceland and Norway, more than 35,000 die from antibiotic-resistant infections each year.

Superbugs pose an enormous threat, not only to healthy individuals, but for those with existing conditions, especially those who are undergoing surgeries and run the risk of contracting infections that doctors may struggle to treat with antimicrobials. Superbugs can have an effect on global economies, too. Without mass-produced medicines to take down infections, other more expensive and intensive measures are required to treat infected patients. The World Bank estimates that AMR could lead to $1 trillion (£800 billion) of additional health costs in the US alone by 2050.

Did you know?

Over 200 viruses are known to cause disease in humans

So how do you treat an infection that's become immune to the medicine designed to destroy it? In place of finding a new class of antibiotics – which hasn't happened since the 1980s – scientists have to rely on several other ways to subdue superbugs. From repurposing existing medicines to genetically altering bacteria to fight themselves, scientists have come up with a myriad of ways to ease the threat of AMR. However, one of the most effective ways to stop new superbugs from emerging is by protecting yourself from infection. Maintaining good food preparation hygiene and personal hygiene, especially regular hand washing, can help prevent the transmission of bugs that can cause an infection. Keeping yourself up to date with vaccinations can also help prevent the overuse of antibiotics.



SMALL BUT DEADLY

The annual predicted deaths attributed to AMR by 2050

1 North America
317,000

2 Europe
390,000

3 Asia
4,730,000

4 South America
392,000

5 Africa
4,150,000

6 Oceania
22,000

THE PERSISTENT RESISTANCE OF MRSA

1944 Penicillin was used to treat *Staphylococcus aureus* for the first time.

1946 Just two years after being treated with penicillin, the first cases of resistance were recorded.

1954 Vancomycin, a new class of antibiotic, was introduced to tackle bacterial resistance.

1959 A new antibiotic called methicillin was first used to combat penicillin-resistant *S. aureus*.

1960 In just a year, strains of methicillin-resistant *S. aureus* (MRSA) were detected.

1997 The first cases of an MRSA strain with reduced susceptibility to vancomycin were reported.

2002 Five years after MRSA showed resistance to vancomycin, the first cases of full vancomycin-resistance occurred.

2003 Daptomycin was introduced to treat skin infections caused by MRSA.

2005 Reports of resistance to daptomycin for MRSA strains emerged.

DID YOU KNOW? Each year the US records more than 2.8 million antimicrobial-resistant infections

TOP-TEN SUPERBUGS

In 2024 the WHO released an update to its 2017 'Bacterial Priority Pathogen List'. The WHO ranks bacterium as a priority on its hit list based on several factors, such as mortality, incidence and treatability, and places them into three groups: critical, high and medium. Here are the top-ten priority bacteria species in 2024



KLEBSIELLA PNEUMONIAE

Ranking in 2024	Ranking in 2017
1	5

DRUG RESISTANCE
Carbapenem-resistant

GROUP
Critical



ESCHERICHIA COLI

Ranking in 2024	Ranking in 2017
2	4

DRUG RESISTANCE
Third-generation cephalosporin-resistant

GROUP
Critical



ACINETOBACTER BAUMANNII

Ranking in 2024	Ranking in 2017
3	1

DRUG RESISTANCE
Carbapenem-resistant

GROUP
Critical



MYCOBACTERIUM TUBERCULOSIS

Ranking in 2024	Ranking in 2017
4	N/A

DRUG RESISTANCE
Rifampicin-resistant

GROUP
Critical



ESCHERICHIA COLI

Ranking in 2024	Ranking in 2017
5	10

DRUG RESISTANCE
Carbapenem-resistant

GROUP
Critical



KLEBSIELLA PNEUMONIAE

Ranking in 2024	Ranking in 2017
6	3

DRUG RESISTANCE
Third-generation cephalosporin-resistant

GROUP
Critical



SALMONELLA TYPHI

Ranking in 2024	Ranking in 2017
7	18

DRUG RESISTANCE
Fluoroquinolone-resistant

GROUP
High

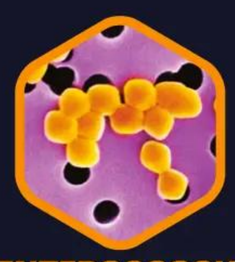


SHIGELLA SPECIES

Ranking in 2024	Ranking in 2017
8	25

DRUG RESISTANCE
Fluoroquinolone-resistant

GROUP
High



ENTEROCOCCUS FAECIUM

Ranking in 2024	Ranking in 2017
9	11

DRUG RESISTANCE
Vancomycin-resistant

GROUP
High



PSEUDOMONAS AERUGINOSA

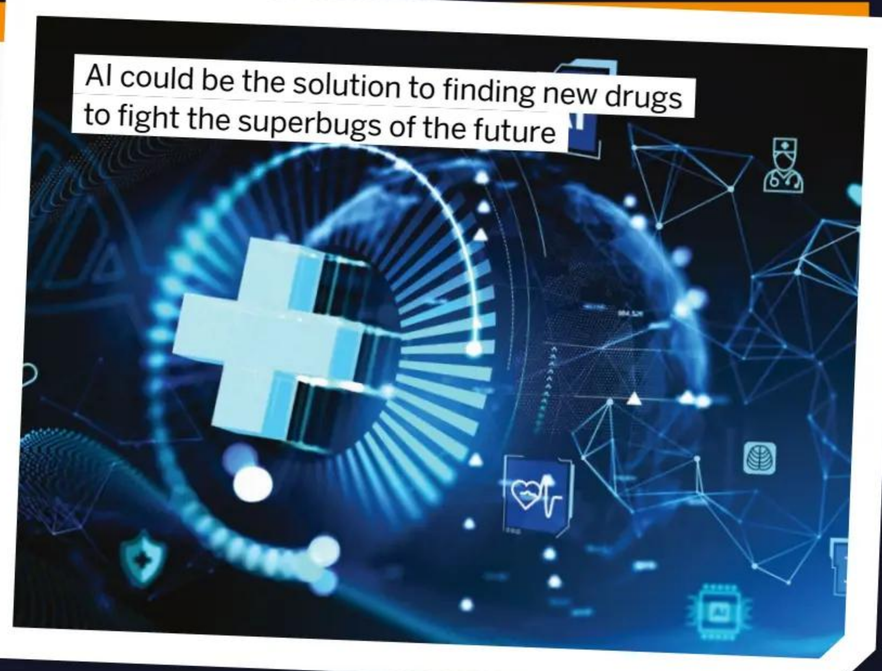
Ranking in 2024	Ranking in 2017
10	2

DRUG RESISTANCE
Carbapenem-resistant

GROUP
High

AI TO THE RESCUE

Artificial intelligence (AI) has proven to be an invaluable tool in finding the antibiotic answers doctors need to tackle superbugs. In 2023, researchers in Canada and the US released the results of a study that used AI to comb through thousands of compounds. These compounds had the potential to be a new antibiotic for a 'critical-threat' bacteria called *Acinetobacter baumannii*. In just an hour and a half, the AI program had sieved through 6,680 compounds and produced a shortlist – nine of which scientists discovered could be potential antibiotics. Due to the rigorous clinical testing potential new antibiotics have to undergo before general use, it's expected that the first 'AI antibiotics' will emerge around 2030.



AI could be the solution to finding new drugs to fight the superbugs of the future

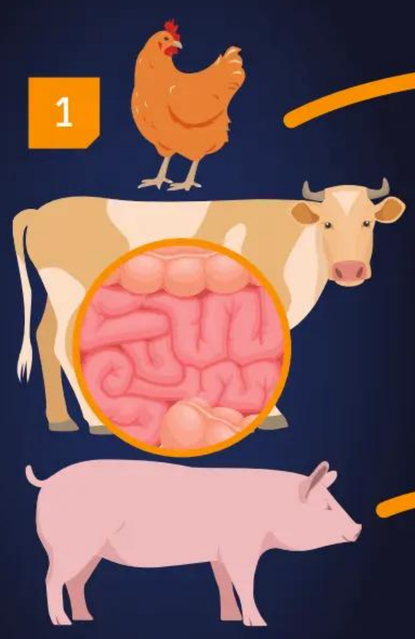
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THE SUPERBUG SPREAD

How antibiotic resistance finds its way around the world

1



1 ANIMAL ANTIBIOTICS

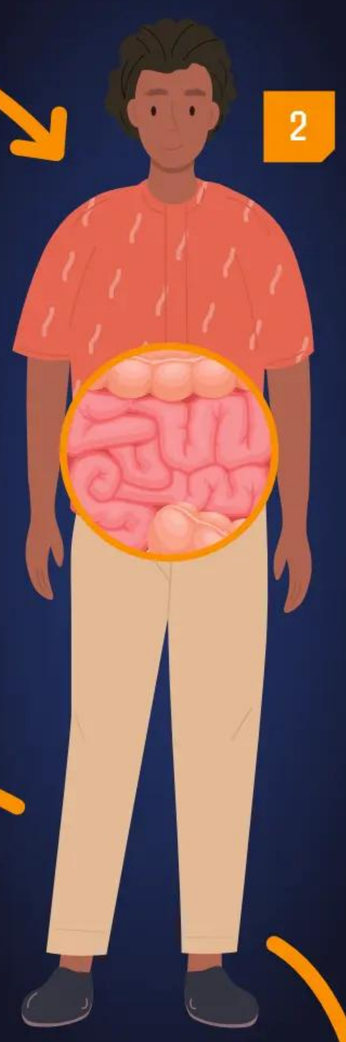
Farm animals, such as pigs and cows, are fed antibiotics, and resistant bacteria remain in the gut.



2 IN THE GUT

A person gets ill and takes antibiotics and resistance develops in their gut.

2



3



3 MEAT-FLAVOURED AMR

Resistant bacteria can be trapped in meat. When humans improperly cook or handle meat, they can become infected with resistant bacteria.

8



8 COMMUNITY SPREAD

Someone who doesn't realise they have resistant bacteria passes them on to others in their community.

"At present, the world is facing its greatest superbug threat"

4 FERTILISING WITH AMR

Crops fertilised with manure packed with resistant bacteria become contaminated.

4



5

5 VEGGIE AMR

Crops can pass on resistant bacteria when they're eaten by humans.



6

6 PATIENT SPREAD

Someone seeking medical attention who's harbouring resistant bacteria can introduce the bacteria to other patients.

7 DOCTOR SPREAD

Medical professionals treating a patient with resistant bacteria can unknowingly transfer them to another patient if the correct safety precautions aren't met.

7



Did you know?

There are currently 27 new antibiotics in clinical development

DID YOU KNOW? By 2029, the UK government has pledged to reduce total antibiotic use by five per cent from 2019 levels

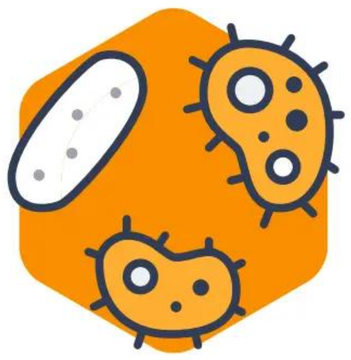
PREVAILING OVER PATHOGENS

This is the medical arsenal doctors can deploy to combat the growing threat of resistance



VACCINES

A helpful tool in fighting the spread of superbugs by blocking their transmission between an infected and healthy person. Curbing the spread of pathogens decreases the chance that one may mutate a resistance to antimicrobial drugs.



BIOTHERAPEUTICS

Doctors can use live probiotics as a way to outcompete AMR bacteria in the gut. Researchers have found that when treating a resilient bacteria called *Helicobacter pylori*, the use of probiotics improved eradication by ten per cent.



PHAGETHERAPY

Using a virus to treat an AMR pathogen might seem like a conflicting idea, but bacteriophage virus theory, or 'phage theory', is a promising path to tackling superbugs. Like sending troops to battle, viruses can be used to find bacteria that might harbour AMR genes, inject them with harmful DNA and ultimately destroy them.



GENETIC ENGINEERING

An emerging tool for tackling bacterial resistance is CRISPR-Cas9, which uses a bacterium's natural gene-sharing habit against it. CRISPR-Cas9 is a technology that allows scientists to 'edit' the genetic information of bacteria, especially the plasmids that they pass between each other.



ANTIMICROBIAL PEPTIDES

By disturbing the membranes of some pathogens, charged peptides, which are short chains of amino acids, can be used as an alternative to other antimicrobials. These are naturally occurring and are derived from many different organisms, such as amphibians, mammals and even insects.



DRUG REPURPOSING

Developing new drugs to tackle AMR is a costly endeavour and can take more than a decade to complete. However, repurposing or modifying existing medicines can deal a fatal punch to AMR infections. This approach comes with mixed success and has been found in some cases to increase AMR in pathogens.

BATTLING THE BUGS

We speak with the European Centre for Disease Prevention and Control (ECDC), who shed some light on how doctors fight superbug infections and how we can help ourselves

How is AMR monitored with so many pathogens in the world?

Data on antimicrobial resistance comes from laboratories that test for infections in humans and animals, and even from laboratories that test bacteria in the environment. This data tells us if the bacteria and fungi from humans, animals and the environment are resistant to treatment to the medicines used for infections with these pathogens. National public health agencies collect data on AMR that originate from laboratories to evaluate what AMR threats – sometimes known as superbugs – are looming.

What are the most effective methods that doctors are using to combat AMR?

Doctors know that taking the wrong antibiotic or taking unnecessary antibiotics can contribute to bacteria becoming resistant. Bacteria evolve to survive their environment, and when they're exposed to antibiotics, they can become resistant. Doctors restrict prescribing antibiotics for infections caused by viruses, as antibiotics don't work against viruses. They also test, when possible, to confirm that an infection is due to bacteria and use information from the laboratory that tells them which antibiotics could be effective for the infection.

What advice would you give people to help in the fight against superbugs?

Everyone has a role in fighting AMR. Antibiotics should be treated with respect: do not self-medicate with antibiotics. If you are prescribed antibiotics by your doctor, take them only in the amount, frequency and duration as prescribed by your doctor. Encourage others to treat antibiotics with respect as well. Controlling the spread of infections can also reduce AMR. Getting vaccinated, washing our hands appropriately and covering our coughs and sneezes all help reduce infections. When we reduce infections, we also reduce the need for antibiotics and the potential spread of resistant pathogens.

ecdc
EUROPEAN CENTRE FOR DISEASE PREVENTION AND CONTROL

"Bacteria evolve to survive their environment, and when they're exposed to antibiotics, they can become resistant"

© Getty / Shutterstock / ECDC

WHAT IS WIND CHILL?

How windy conditions can make you shiver, even on a warm day

WORDS AILSA HARVEY

When you check the predicted temperature, you may sometimes be greeted with two values: the air temperature and the 'feels like' temperature. The main temperature value represents how hot or cold the air is, but the second temperature takes the strength of the wind into account. Called wind chill, this value indicates how the air temperature will feel on your skin when you step outside. When there is more wind, heat escapes from you more quickly, lowering the wind chill temperature.

Displaying this value on forecasts means that people can make a more informed decision on what to wear and even whether to go outside. The calculation shows how cold the air would need to be outside to cause the same rate of heat loss from your skin if there was no wind at all. When wind chill reduces the temperature far into negative values, skin temperature will decrease rapidly, followed by your internal body temperature. This increases the chances of developing hypothermia and frostbite.

Did you know?

Buildings in cities can affect wind chill

Wind chill not only impacts humans, but other animals and plants. In plants, wind chill stresses don't come from heat loss, as they don't produce heat in the same way as humans. Rather, wind chill increases the plants' rate of evaporation, whisking water away from it instead. This increases the moisture loss from leaves and dries out the plant. Whether it's in the form of drying or freezing, wind chill calculations show the drastic influence of the wind on the temperature of your environment.



Frostbite can cause swelling



Wind anemometers can calculate temperature, wind speed and wind chill

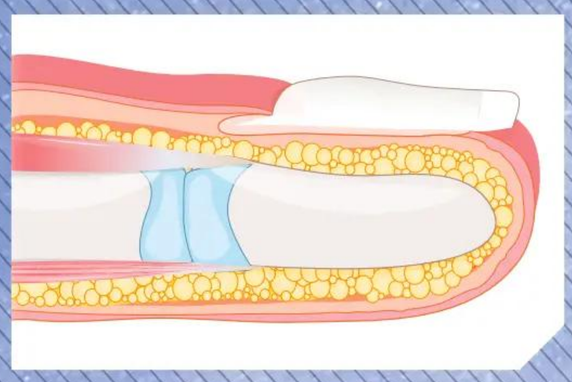
CALCULATING CHILL

In the UK, wind chill is determined by measuring how much heat is lost from a person's bare face when they walk at a speed of three miles per hour. This method of calculation is called the Joint Action Group for Temp Indices. Although this is how the calculations were first conducted, today meteorologists use a mathematical formula based on this data. There isn't a scientific instrument used to collect a value from the air – instead air temperature and wind speed are measured and incorporated into a formula to work out wind chill. The figures in the formula were first decided by scientists Paul Siple and Charles Passel in 1945. They used a plastic bottle filled with water and a thermometer, and measured the extent that the bottle's water cooled in different wind speeds. From their findings, they derived a common mathematical relationship between the known values.

DID YOU KNOW? The concept of wind chill originated in Antarctica

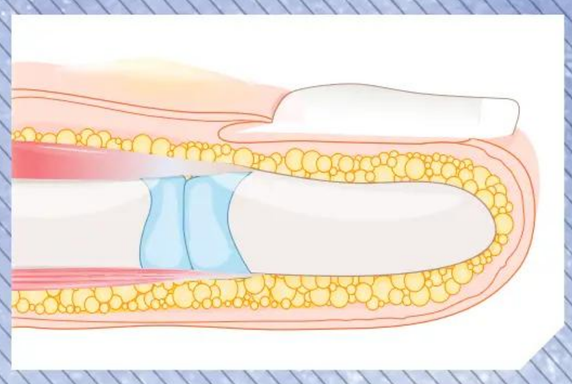
BITING COLD

In the worst cases of frostbite, limbs may be lost



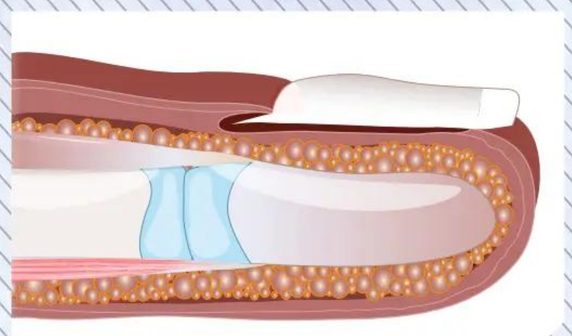
1 FROSTNIP

This is the earliest and mildest stage of frostbite. The surface of the body becomes numb, but the skin is only temporarily damaged. If the skin is warmed up after this stage, it can be painful, but full function returns.



2 SUPERFICIAL FROSTBITE

After losing feeling, the skin may also slightly change in colour, from a paler colour to blue. Oddly, the skin might begin to feel warmer as tissue damage begins and the extremities start swelling. If you rewarm the body at this stage, fluid-filled blisters are common.



3 DEEP FROSTBITE

This is the most severe stage of frostbite, after which joints and muscles may stop working as damage extends beyond the skin. The area affected becomes darker, blue or splotchy and stops relaying cold or pain sensations. Following rewarming, the dead tissue becomes black and hard, and often needs to be removed from the body.

HOW MUCH DIFFERENCE DOES WIND MAKE?

Check this chart to see how the wind alters the temperature your body feels

1 WIND IMPACT

When wind reaches 62 miles (100 kilometres) per hour, an air temperature of five degrees Celsius is felt by the skin as -3 degrees Celsius.

2 30 MINUTES

Skin exposed to wind chill temperatures as low as -30 degrees Celsius will begin to experience frostbite after just half an hour.

3 TEN MINUTES

For frostbite to set in within ten minutes, the air temperature needs to be at least as low as -20 degrees Celsius.

4 HIGH RISK

In extreme climates, where the wind chill temperature reaches at least -50 degrees, just five minutes of skin exposure can cause frostbite.

Wind chill chart (Celsius)

wind speed (kph) \ temperature (°C)	5	0	−5	−10	−15	−20	−25	−30	−35	−40
calm										
10	3	−3	−9	−15	−21	−27	−33	−39	−45	−51
20	1	−5	−12	−18	−24	−31	−37	−43	−49	−56
30	0	−7	−13	−20	−26	−33	−39	−46	−52	−59
40	−1	−7	−14	−21	−27	−34	−41	−48	−54	−61
50	−2	−8	−15	−22	−29	−35	−42	−49	−56	−63
60	−2	−9	−16	−23	−30	−37	−43	−50	−57	−64
70	−2	−9	−16	−23	−30	−37	−44	−51	−59	−66
80	−3	−10	−17	−24	−31	−38	−45	−52	−60	−67
90	−3	−10	−17	−25	−32	−39	−46	−53	−61	−68
100	−3	−11	−18	−25	−32	−40	−47	−54	−61	−69

1 2 3 4

wind chill (°C) = $13.12 + 0.6215T - 11.37(V^{0.16}) + 0.3965T(V^{0.16})$ T = air temperature (°C)

frostbite times 30 minutes 10 minutes 5 minutes V = wind speed (kph)

5 HEAT LAYER

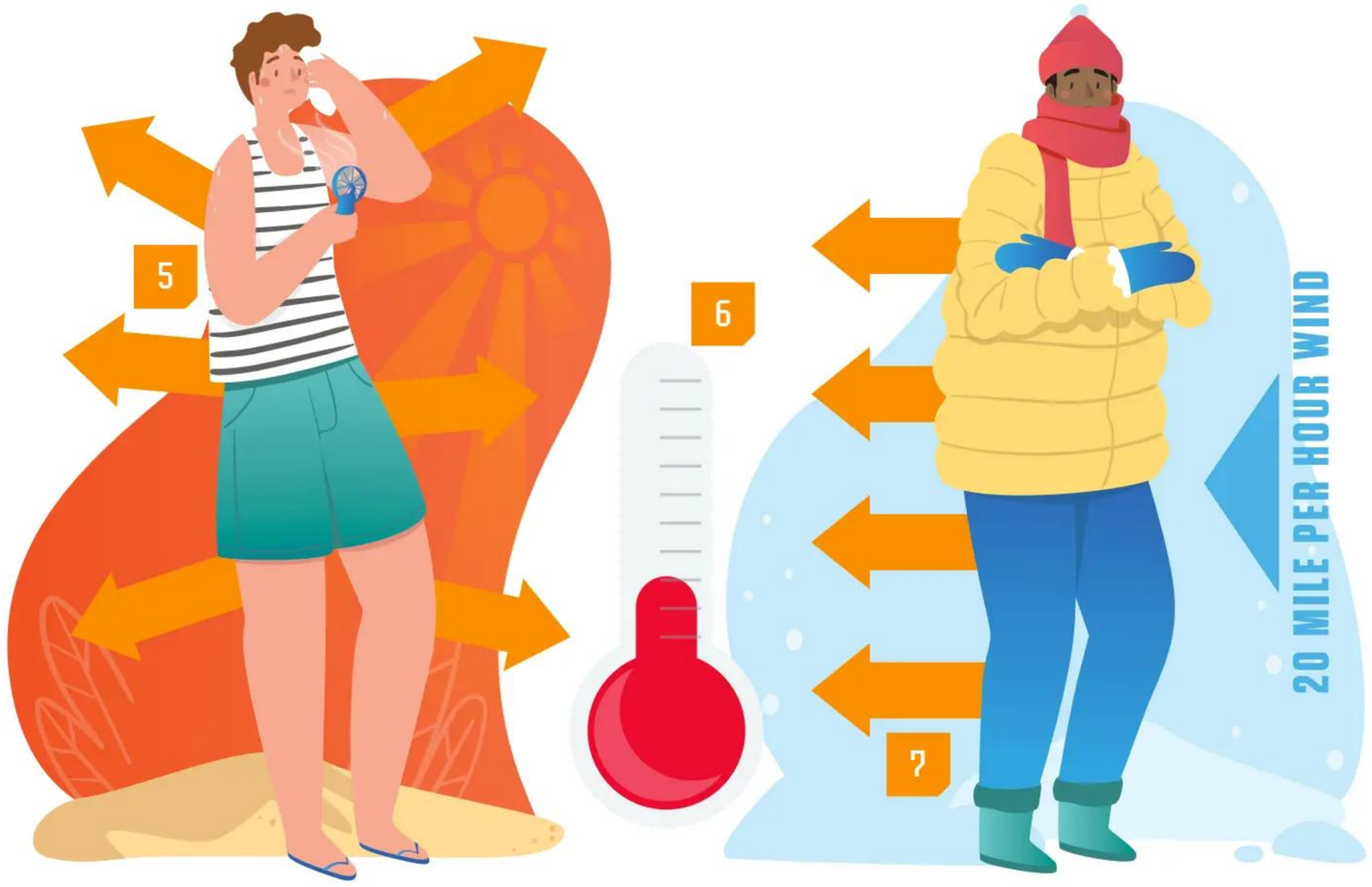
When there is no wind, the heat lost by the body stays in the air around the body for longer, maintaining the body temperature.

6 AIR TEMPERATURE

An outside air temperature of 20 degrees can feel cold or warm based on the wind conditions.

7 HEAT LOSS

On a windy day, air particles around the body are disturbed. The wind blows and carries heat released by a person away from the body. This makes you feel much colder.



© Alamy / Getty

IN THE AIR

These types of acceleration generate *g* while flying

1 LINEAR ACCELERATION
A change of speed in a straight line. Acceleration is typically experienced during landing and takeoff.

3 ANGULAR ACCELERATION
A simultaneous change in both speed and direction, such as during a climbing turn.

2 RADIAL ACCELERATION
Acceleration derived from changing direction, such as a sharp turn or dive.



WHAT IS G-FORCE?

WORDS SCOTT DUTFIELD

The faster you move, the more of this stomach-churning force you feel

Riding roller coasters and piloting planes are surefire ways to experience the push and pull of 'g-force'. This intense force results from rapid acceleration or deceleration and is all about the pull of gravity – the '*g*' in 'g-force'. A single *g* equals the force of gravity experienced by a stationary object on Earth's surface at sea level, equal to 9.8 metres per second squared. In other words, for every second an object falls due to Earth's gravity, its speed increases by 9.8 metres per second. However, the faster an object accelerates or decelerates, the more units of *g* it experiences.

For most, varying levels of g-force isn't a daily occurrence. It's fast-moving fighter jet pilots and race car drivers that have to be aware of its potential dangers. Fighter jet pilots, for example, have to tackle flying forces of up to around 10 *g* when making high-speed turns. Under the force of 10 *g*, the pilot will experience ten times the typical pull of gravity. Such a high change in gravity can be dangerous.

Known as 'fainting in the air' during World War I, the phenomenon of fainting pilots was later associated with the effects of g-force in the 1940s. Today, the same condition is known as gravity-induced loss of consciousness (g-LOC). Under high 'positive' g-force, this is caused by blood pooling towards the pilot's feet, which reduces the amount of blood circulating the brain. Positive g-force is the acceleration of the aircraft moving upwards, but pushing the blood downwards. Alternatively, when the aircraft moves downwards the body experiences 'negative' g-force, with blood rushing upwards into the eyes, causing what's known as 'red out'. Both conditions can cause the pilot to lose vision and mobility while flying, so they have compression adaptations in their flight suits and carry out muscle tensing exercises to hold their blood in place and prevent pooling.


Roller coasters exert g-force on their riders

DID YOU KNOW? NASA's X-43 is the fastest aircraft in the world, topping speeds over 7,396 miles per hour

"Such a high change in gravity can be dangerous"



Fighter jet pilots are trained to face enormous levels of g-force while flying at high speeds

4

4 POSITIVE *G*
When a plane accelerates or decelerates forwards or upwards, the pilot experiences positive g-force.

Did you know?
A mantis shrimp's strike generates 10,400 *g*

1

5

5 NEGATIVE *G*
When a plane accelerates or decelerates backwards or downwards, the pilot experiences negative g-force.

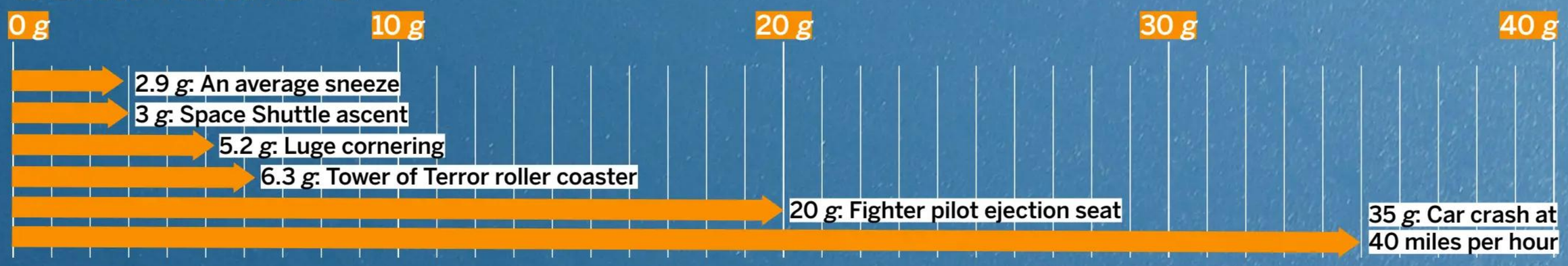
RECORD BREAKERS

While zipping along the Texas Motor Speedway during the Chevy 500 race in 2003, Indycar driver Kenny Bräck collided with another racer. Travelling at 220 miles per hour, Bräck hit the brakes, and for a split second experienced 214 *g* of deceleration, according to the 'crash violence recording system' within his car. Bräck survived the crash but suffered several fractures. This is the world record for the highest g-force survived. Among those purposely chasing *g*, no one has pulled as many as Eli L. Beeding. In 1958, the aerospace physiologist for the United States Air Force was conducting aircraft restraint tests on a water-braked rocket sled. During the test, Beeding experienced almost 83 *g* for a tenth of a second as the sled rapidly decelerated.



Kenny Bräck racing at the Chicago Motor Speedway in 2001

COMPARING *G*



© Getty / Alamy / Shutterstock

WHAT IS MORNING SICKNESS?

Why some pregnancies can cause nausea and vomiting

WORDS AILSA HARVEY

Despite its name, morning sickness can occur at any time of day during pregnancy. However, for many pregnant people, it can feel worse during the morning. The symptoms involve feelings of nausea, being sick or both, and commonly start around four weeks after conception. It's likely to ease or stop completely between weeks 12 and 20. Although it's an unpleasant addition to the early weeks of pregnancy, morning sickness usually doesn't harm a person or their child. But some cases are much more extreme. Severe vomiting during pregnancy, called hyperemesis gravidarum (HG), is more dangerous as it can cause dehydration and malnourishment. The cause of morning sickness comes down to multiple biological changes occurring at once. An influx of pregnancy hormones, blood pressure fluctuations and physical changes to the body are thought to contribute to the queasiness. Stronger scents and tastes can bring about morning sickness. To relieve this, pregnant people can stick to foods with mild flavours, eat small meals regularly, stay hydrated and rest.

SYMPTOM SEVERITY

Around 70 per cent of pregnant people experience morning sickness, but one person's experience can greatly differ from another's. This is largely dictated by the hormone GDF15, which is produced by the embryo or foetus. The more is released, the more nausea the parent will experience. Also, if a pregnant person has encountered more of this hormone before pregnancy, the more resilient to it they're likely to be. People with the inherited blood disorder beta thalassemia usually experience little or no morning sickness. This is because the disorder causes them to have high levels of GDF15 naturally, so their bodies are used to processing the protein.



Processed foods make morning sickness worse for most

EVOLUTIONARY PURPOSE

One theory behind the purpose of morning sickness from an evolutionary perspective is that it protects embryos from exposure to harmful substances in foods. Many feelings of nausea are brought about by strong-tasting vegetables and meat products. These are the most likely foods to contain toxins, and by vomiting a person is less likely to consume pathogen-contaminated products. Harmful microorganisms are far more deadly to the foetus in the early stages of organ development. Encountering contaminated foods in the wild through foraging and hunting was much more likely for our prehistoric ancestors, and expelling potent foods improved the chances of a healthy pregnancy.



Did you know?

Morning sickness is more likely with twins and multiple pregnancies

© Alamy / Shutterstock

DID YOU KNOW? Though rare on Earth, helium makes up about 24 per cent of the universe's mass

WHERE DOES HELIUM COME FROM?

WORDS SCOTT DUTFIELD

This lighter-than-air element could one day disappear from our planet

Helium is the second most abundant element in the known universe. However, on Earth it's rare, only found deep beneath the surface. Natural helium comes from the radioactive decay of other elements, such as uranium and thorium, over millions of years. As they decay, the particles of radiation they release can gather electrons to form new elements, including helium. This radioactive decay occurs in rock deep beneath the surface, releasing the gas into gaseous reservoirs. Once extracted, the gas is put through cryogenic distillation under high pressures and extremely low temperatures to extract the atoms from other natural gases to make over 99 per cent pure helium.

Along with inflating party balloons, helium is one of the most handy elements on Earth, especially when it comes to cooling stuff down. Unlike most elements, liquid helium can reach temperatures as low as -269 degrees Celsius, which can be beneficial for many different industries. For example, in hospitals, imaging systems such as magnetic resonance imaging (MRI) machines need liquid helium to cool down powerful magnets that let them look inside the human body. Space rocket launches also need to use helium to pressurise fuel tanks and cool down vital systems.

Did you know?
The US has 8.5 billion cubic metres of helium reserves

However, helium is an endangered element and a finite resource. With no known way to artificially create it, it's estimated that the world's supply of helium could run out in around 300 years based on the current rate of consumption.

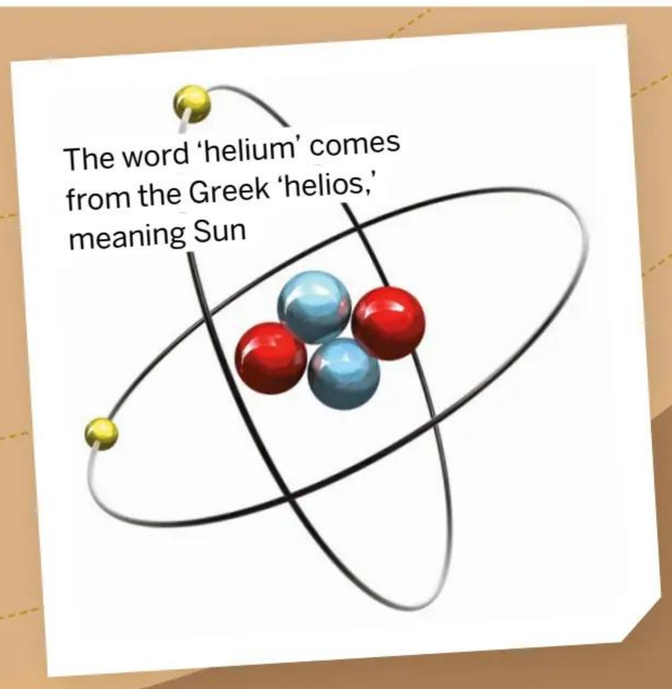
ELEMENTAL ESCAPE ARTIST

The same quality that brings us floating balloons is also one that makes helium easy to lose. Helium is mostly unreactive with other elements. This means that once helium is released into the atmosphere, it enters a natural cycle and doesn't find its way back into the ground. Once released, the extremely light element continues to move through the atmosphere, escaping Earth's gravity and floating away into space. This makes it difficult to harvest it from the atmosphere. Helium-recycling systems do exist to reuse the element and reduce the risk of helium escaping into space. However, these are quite costly endeavours.



Around 5,000 tonnes of helium is lost into space each year





2 HELIUM-4
The natural helium extracted from the Earth is an isotope called helium-4. This is the same element with a slightly different atomic structure.

5 EXTRACTION
Drills excavate past the rock that's capping off the reservoir before a piping system is installed to syphon the natural gas.

3 MIGRATION
Helium can filter through porous rock above its source until it reaches a bedrock that's impermeable.

4 GAS RESERVOIR
With nowhere to go, helium gas pools in enormous reserves along with any other gases that have made the same journey, such as nitrogen and methane.

1 SOURCE ROCK
Helium comes from rocks that contain uranium and thorium, such as granite.

DIGGING FOR HELIUM

How engineers pop underground bubbles of helium to extract the gas within

© Alamy / Shutterstock

SPACE

COULD A SUPERNOVA ENGULF EARTH?

WORDS ANDREW MAY

We put some intriguing, baffling and bizarre space questions under the spotlight

A supernova is what happens when a large enough star explodes. Such explosions are among the most dramatic of all astronomical events, and the resulting remnant can be a spectacular sight thousands of years later. Fortunately, supernovae are relatively rare, and we're very unlikely to get caught up in one. The most disastrous thing from our perspective would be if our own Sun went supernova, but this will never happen. Only two types of star are capable of exploding in such a dramatic fashion: super-dense white dwarfs orbiting larger companion stars, which can produce Type I supernovae, or stars with at least eight times as much mass as the Sun, which end their lives as Type II supernovae. Our Sun isn't in either of these categories.

Even so, this doesn't mean that Earth can never be harmed by a supernova – in theory, at least. As well as producing the visible remnant, a supernova creates a burst of high-energy radiation that travels outwards at the speed of light. This radiation, particularly the highest energy gamma rays, could damage Earth's biosphere if it came from the explosion of a nearby star. A sudden burst of gamma rays

DID YOU KNOW? The Crab Nebula, the remnant of a supernova seen to explode in the year 1054, is about 6,500 light years away

EFFECTS OF A SUPERNOVA

Just how deadly a supernova would be depends on how far away it is



DANGER ZONE

If a supernova exploded closer than about 50 light years from Earth, the effects would be devastating to life on the planet, comparable to the mass extinction event that occurred at the end of the Ordovician period 450 million years ago.

INTERMEDIATE ZONE

In this region, radiation reaching Earth from a supernova would likely have some kind of effect on the biosphere, but not enough to cause widespread extinctions of whole species.

SAFE ZONE

Although scientists don't know for certain, it's believed that a supernova occurring more than 160 light years from Earth would be too far away to have any adverse effects on life on our planet.

50 LIGHT YEARS

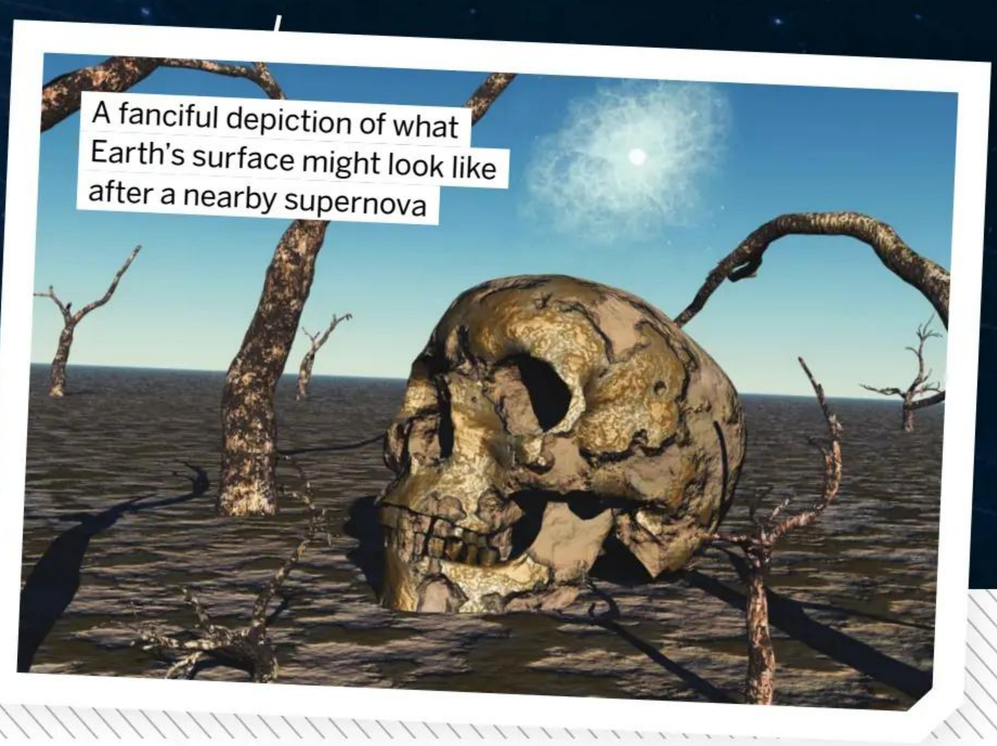
50 TO 160 LIGHT YEARS

OVER 160 LIGHT YEARS

INNER ZONE

INTERMEDIATE ZONE

OUTER ZONE



A fanciful depiction of what Earth's surface might look like after a nearby supernova

hitting the upper atmosphere could convert nitrogen and oxygen into smog-like nitrogen oxides, as well as damaging the ozone layer that protects Earth's surface from the deadliest frquencies of ultraviolet radiation.

These effects would be particularly catastrophic for marine life. Scientists have speculated that just such a gamma-ray burst around 450 million years ago caused the Late Ordovician mass extinction, which saw the death of around 60 per cent of all oceanic life on Earth.

The big question is how close a supernova has to be to produce effects like these on our planet. There's plenty of uncertainty around the exact figures, but the graphic on this page shows the current best guess as to the danger zone. Fortunately, astronomers aren't aware of any imminent supernovae close to us. The best known star likely to produce a Type II supernova any time soon is Betelgeuse, which is a perfectly safe 642 light years away. The closest of all the known 'supernova progenitor candidates' is a star called IK Pegasi B, which could potentially create a Type I supernova – but even this is a borderline-safe 150 light years away.

© Getty / Alamy

HOW DO WE SEE BLACK HOLES?

In the literal sense we can never see a black hole, because it's a region of space from which no light – or anything else – can ever escape. However, this region does contain mass – sometimes a very large amount of it. For example, the supermassive black hole at the centre of our galaxy, known as Sagittarius A* (Sgr A*), has a mass around 4 million times that of the Sun. This mass exerts a gravitational effect on the surrounding matter, and we can deduce the black hole's presence by observing this effect. In the case of Sgr A*, astronomers first realised it was there when they saw an empty spot with stars circling around it, as though they were orbiting a very massive but invisible object. When the Event Horizon Telescope took a zoomed-in photograph of this region, it didn't show the black hole itself, but the superhot disc of gas swirling around it.

The Event Horizon Telescope's image of the region around Sgr A*

Did you know?

Spacecraft landing on Mars also need heat shields

WHY DON'T SPACECRAFT BURN UP IN EARTH'S ATMOSPHERE?

Most spacecraft – the ones that don't make headlines – do indeed burn up on re-entry. These are things like disused satellites or non-reusable resupply craft, which don't need to get back to Earth in one piece. They burn up because they hit the atmosphere with such enormous velocities they temporarily heat the air around them to very high temperatures. While this is a great way to get rid of unwanted space junk, it would be a disaster in the case of a crewed spacecraft, or one that's returning an asteroid sample or other valuable payload to Earth. In these cases, special precautions have to be taken to ensure the spacecraft don't burn up or have their interiors heated to dangerously high temperatures. This involves using a sophisticated heat shield, of which perhaps the most famous was the Space Shuttle's thermal protection system, made up of 24,300 specially constructed tiles.



The heat shield of NASA's Orion crew capsule

DID YOU KNOW? The word ablative, as applied to a heat shield, means eroding bits of it away by vaporisation or charring

DO ANTIMATTER GALAXIES EXIST?

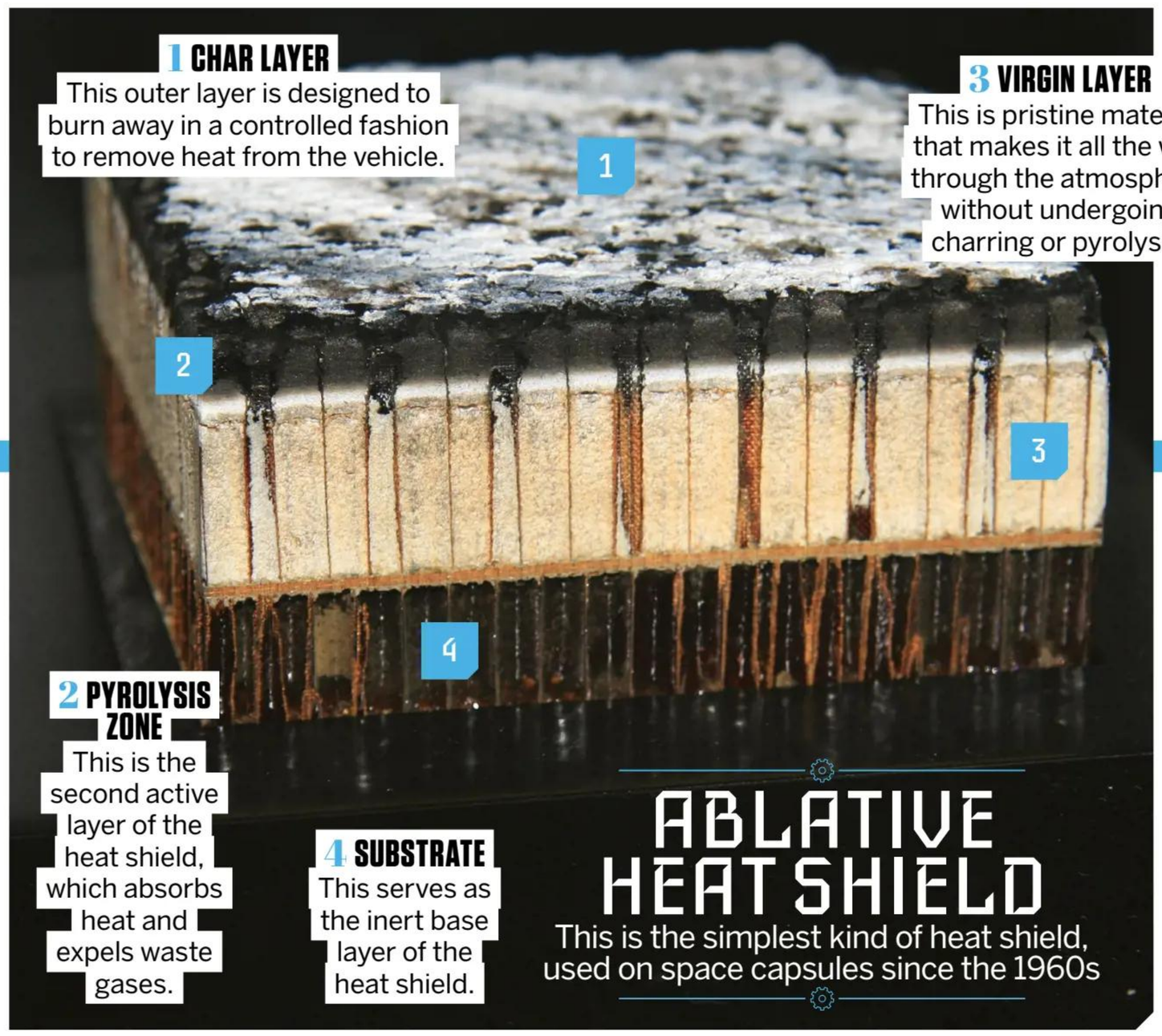
All the matter we see around us is made from the same basic set of subatomic particles, such as protons and electrons. But we know from theory – together with experiments in particle accelerators like the Large Hadron Collider – that all these particles have 'antimatter' counterparts, which famously annihilate in a flash of high-energy radiation if they come into contact with the corresponding normal-matter particle. We know there's very little antimatter in our immediate cosmic neighbourhood for the obvious reason that we don't see these explosive annihilations happening all the time. But scientists don't really know why the universe seems so biased against antimatter, and it's been speculated that some distant galaxies – well away from any normal matter – might be composed purely of antimatter. The answer to this question is 'maybe', although there's no direct evidence for it.



This time-lapse photograph clearly shows how stars appear to revolve around the pole star

WHY DOESN'T THE POLE STAR ROTATE IN THE SKY?

As most people know, the stars don't really rotate around Earth once every 24 hours as the ancients used to think. This apparent motion is a consequence of the fact that the Earth itself rotates once a day about its north-south axis. For all practical purposes the stars remain fixed relative to each other; any real motion they have is so small it can only be detected by very sensitive astronomical instruments. But if you picture Earth rotating against this fixed backdrop, you'll realise that there are two points, precisely above the north and south poles, that always remain fixed. These are called the 'celestial poles', and the northern one happens to lie very close in the sky to the star Polaris – the pole star. That's the reason this particular star seems to remain fixed while all the others rotate around it.



IS THERE AN ALTERNATIVE TO ROCKETS FOR LAUNCHES?

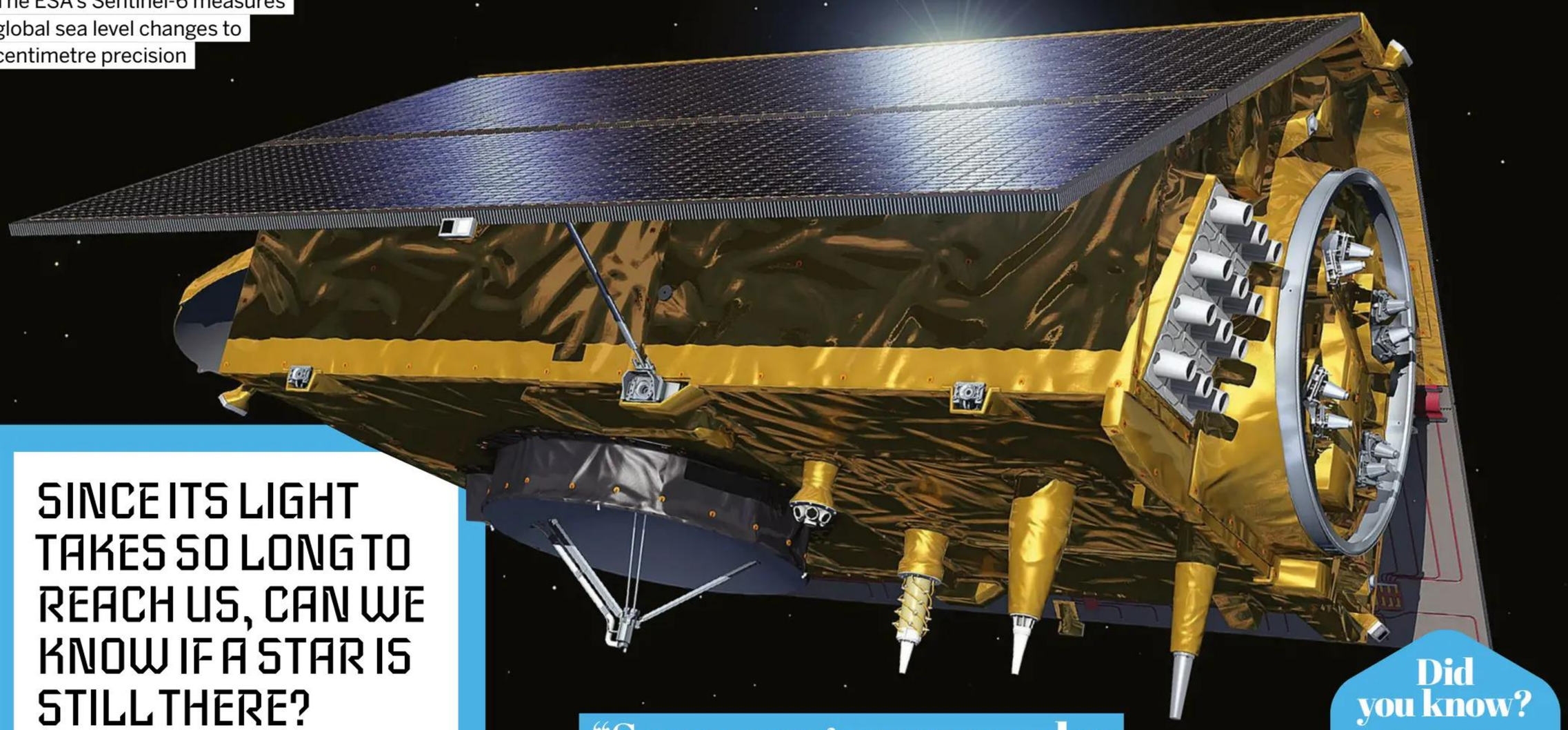
Rockets are the only self-contained craft capable of functioning outside Earth's atmosphere. Balloons, aeroplane wings and jet engines all fail to work if there isn't enough air. It's possible to launch payloads into space by means of a hybrid system, in which a balloon or aircraft is used for the first part of the flight, but it's still necessary for a rocket engine to take over at higher altitudes. Several ideas have been proposed, ranging from electromagnetic 'railguns' – in which a capsule would be steadily accelerated as it whizzes down a long, railway-like track – to 'space elevators' reaching vertically upwards all the way to space.

© European Southern Observatory / NASA / Getty

HOW DO SPACE AGENCIES BENEFIT THE WORLD?

The primary mission of organisations like NASA and the European Space Agency (ESA) is to carry out scientific research, aimed at widening and deepening our knowledge of the universe around us. At one end of the scale, this tackles the biggest questions of all, such as the origin of the universe and the possibility of life beyond Earth. Such questions have always fascinated humankind, but space travel is beginning to give us real answers rather than mere speculations. Plenty of important science is done in laboratories down here on Earth – and exciting, high-profile space missions serve a secondary purpose in stimulating young people to think about careers in such places; which they might not otherwise have done.

Space programs can also benefit humanity at the more practical end of the spectrum. We may take things like GPS satellite navigation and communication satellites for granted, but they're products of space research too. They're not idle luxuries either, with GPS being essential to modern sea and air travel and Starlink-type satellites bringing broadband internet to isolated communities that couldn't access it any other way. Equally important are the many Earth-observation satellites that keep constant track of our planet's changing climate.



The ESA's Sentinel-6 measures global sea level changes to centimetre precision

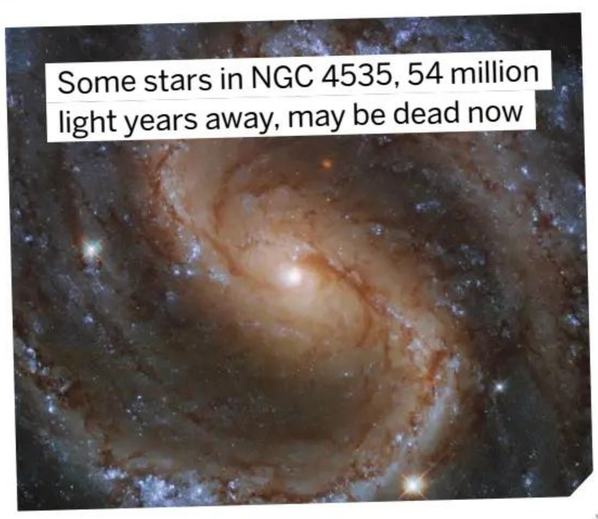
"Space programs can also benefit humanity at the more practical end of the spectrum"

Did you know?

Around 4 billion people rely on GPS for navigation

SINCE ITS LIGHT TAKES SO LONG TO REACH US, CAN WE KNOW IF A STAR IS STILL THERE?

The simple answer is no, we can't. When we look at a star X light years away, we see it as it was X years ago. That's just a consequence of the finite speed that light – and all other forms of electromagnetic radiation – travels at. But we need to bear in mind that stars have very long lives, measured in millions or billions of years. Even the most distant stars that are visible at night with the unaided eye are only a few thousand light years away, and most of them are much closer than that, so there's a pretty good chance they're all still there.



Some stars in NGC 4535, 54 million light years away, may be dead now

NASA SPIN-OFF TECHNOLOGIES

Over the years, several inventions developed by NASA for space applications have found wider use



1960s

FOOD SAFETY STANDARDS

It's essential that the food provided for space missions is free from disease-carrying bacteria, and the standards developed to ensure this are now used throughout the United States.

1960s

IMPROVED WATER FILTERS

The technology that NASA developed to sanitise astronauts' drinking water has since found other uses on Earth, for example in purifying pool water.

1961

CORDLESS HEADPHONES

The technology used in modern wireless headphones was originally developed for use in the space helmets worn by NASA's Mercury astronauts.

DID YOU KNOW? While NASA popularised the use of Velcro and Teflon, it's a common misconception that it invented them

WHAT IS A LAUNCH WINDOW?

One of the things that makes space travel uniquely difficult is that objects in space never stay in fixed locations relative to each other. Earth spins on its axis and orbits around the Sun, the Moon and the International Space Station (ISS) orbit around Earth and Mars and all the other planets have their own orbits around the Sun that aren't synchronised with Earth's. This means that in order to get to your desired destination, the launch has to be carefully timed so that everything lines up in the right way. The 'launch window' refers to a period of time during which the alignments are just right for launch. It's usually the case that launch windows of a few hours each are available on several different days, so it's not a disaster if a problem during countdown to liftoff causes a particular launch window to be abandoned.



Launch windows are particularly tight for interplanetary missions

WHY AREN'T WE SUCKED IN BY THE MILKY WAY'S SUPERMASSIVE BLACK HOLE?

The enormous black hole at the centre of our galaxy exerts a powerful gravitational pull, but we can't fall into it for much the same reason Earth can't fall into the Sun. In the latter case, it's because our planet has a large sideways motion – about 67,000 miles per hour – when viewed from the Sun. Only if that motion could be cancelled out, involving a huge expenditure of energy, would Earth fall into the Sun. In a similar way, the Sun, Earth and whole Solar System are moving sideways through the galaxy at a whopping 515,000 miles per hour, so there's no way they could fall down all the way to its centre.



Stars aren't literally 'sucked' into black holes; they break into pieces that spiral in gradually

WHAT IF AN ASTRONAUT DROPS AN ITEM IN SPACE?

If an astronaut working outside the ISS managed to let go of an object so carefully that it didn't acquire any additional velocity, it would remain stationary from their perspective and they could just pick it up again. More realistically, if the object was dropped with a slightly different velocity from the rest of the station, it would drift off onto a different orbit of its own, circling Earth. This is what happened in November 2023 when a pair of spacewalking astronauts dropped a tool bag. This tool bag will eventually re-enter the atmosphere and burn up.



Mid-1960s
FREEZE-DRIED FOOD

NASA started freeze-drying astronauts' food to reduce weight and increase shelf life, but the same technology has now found other uses, for example for home-bound people.



1964
FOIL BLANKETS

These items, often found in first-aid kits or used by emergency services, are still colloquially known as 'space blankets' to reflect their origins in the early space program.

1966
MEMORY FOAM

Now used in everything from pillows and mattresses to sports equipment and theme park rides, this was originally developed by NASA as a crash-protection technology.



1968
CMOS IMAGE SENSOR

While the name may not be familiar, you probably have one of these in your smartphone or digital camera, and it uses technology originally developed for interplanetary space missions.

Early 1970s
IMPROVED RADIAL TYRES

The Goodyear company has always been known for its tyres, but the extra-strong materials it uses today were originally developed under contract to NASA for spacecraft parachute shrouds.



Late 1980s
EAR THERMOMETERS

Now a popular way to measure body temperature, particularly in children, these employ infrared sensors originally developed for space applications.

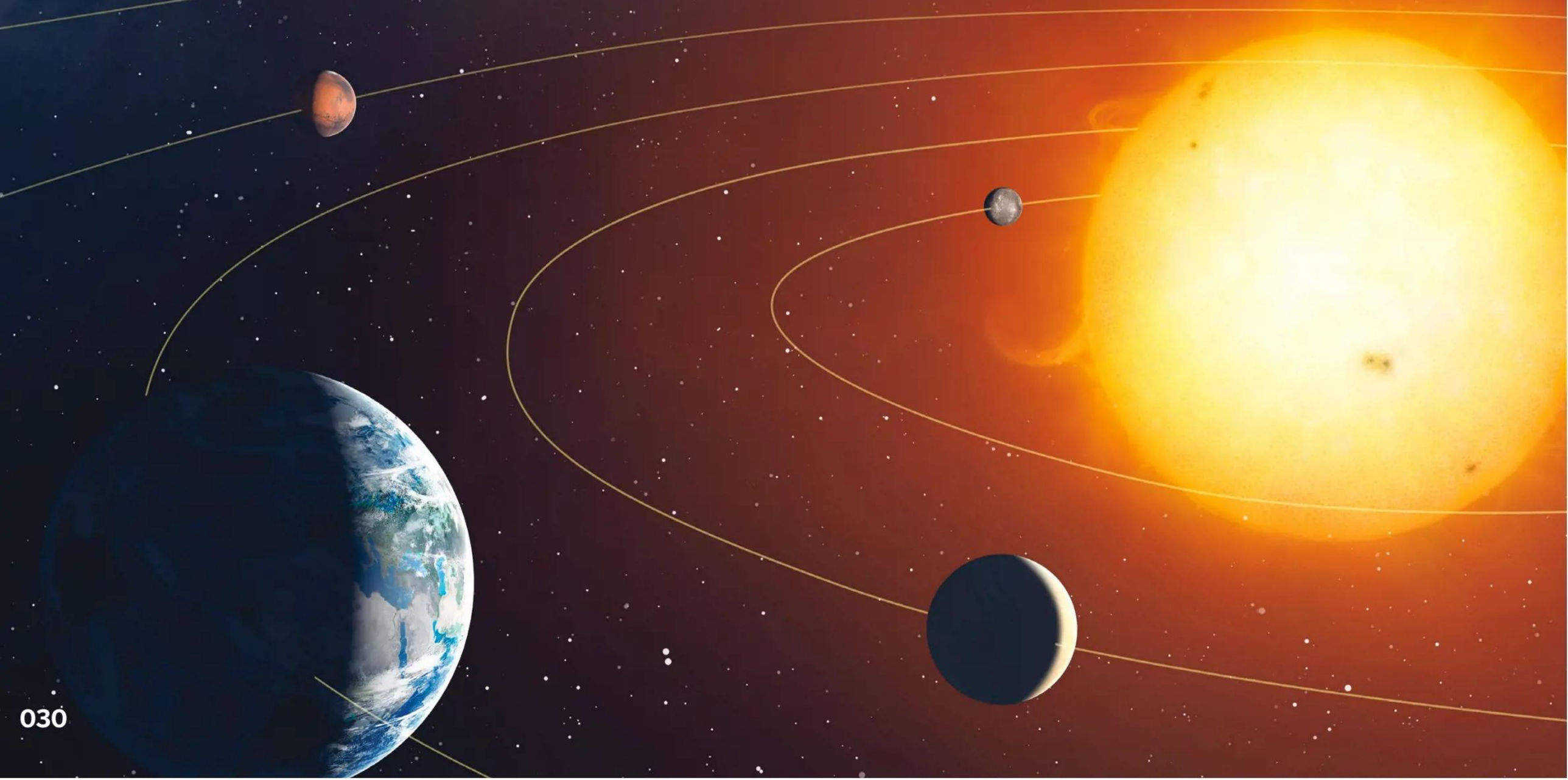
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SEASONS IN THE SOLAR SYSTEM

Do other planets have a spring, summer, autumn and winter?

WORDS SCOTT DUTFIELD





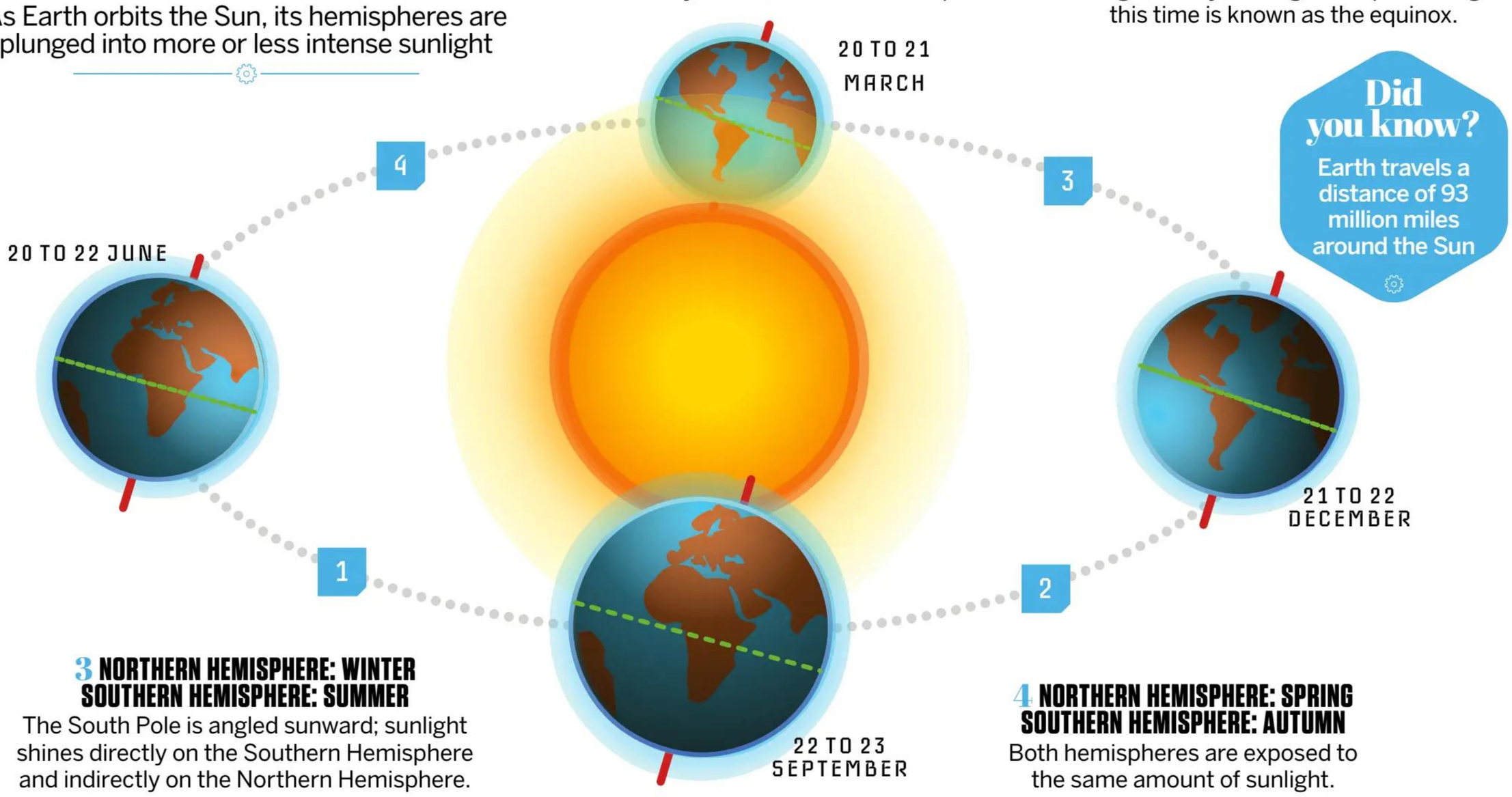
DID YOU KNOW? The shortest day in the Solar System is on Jupiter – it lasts just under ten hours

Every three months or so, Earth shifts from one of its four seasons into the next. This can mean a shift from summer sunshine to a colder autumn. But wherever you are in the Solar System, the seasons change in line with the planet's movement around the Sun. As Earth zips along its 365-day solar orbit, it also spins on a fixed axis which is slightly tilted, at 23.5 degrees. Known as its obliquity, a planet's degree of tilt determines the exposure of sunlight that reaches each of its hemispheres as it orbits the Sun. It's measured using the planet's axis, which runs through its poles, and an imaginary vertical line that runs through it perpendicular to the Sun's equator, referred to as the orbital plane.

When a planet is tilted, either its northern or southern hemisphere is angled more towards the Sun than the other. This difference in exposure to sunlight is what shapes the planet's seasons. During summer Earth's Northern Hemisphere is facing sunward, while the Southern Hemisphere is tilted away from the Sun and experiences winter. As Earth orbits, the Sun-facing hemisphere shifts through the spring and autumn months, when both hemispheres bask in sunlight. Earth's tilt also results in the creation of seasonal weather patterns. When a hemisphere is exposed to more sunlight it increases the temperature on the surface and within the atmosphere, which in turn causes pressure fluctuations and

FROM SUMMER TO WINTER

As Earth orbits the Sun, its hemispheres are plunged into more or less intense sunlight



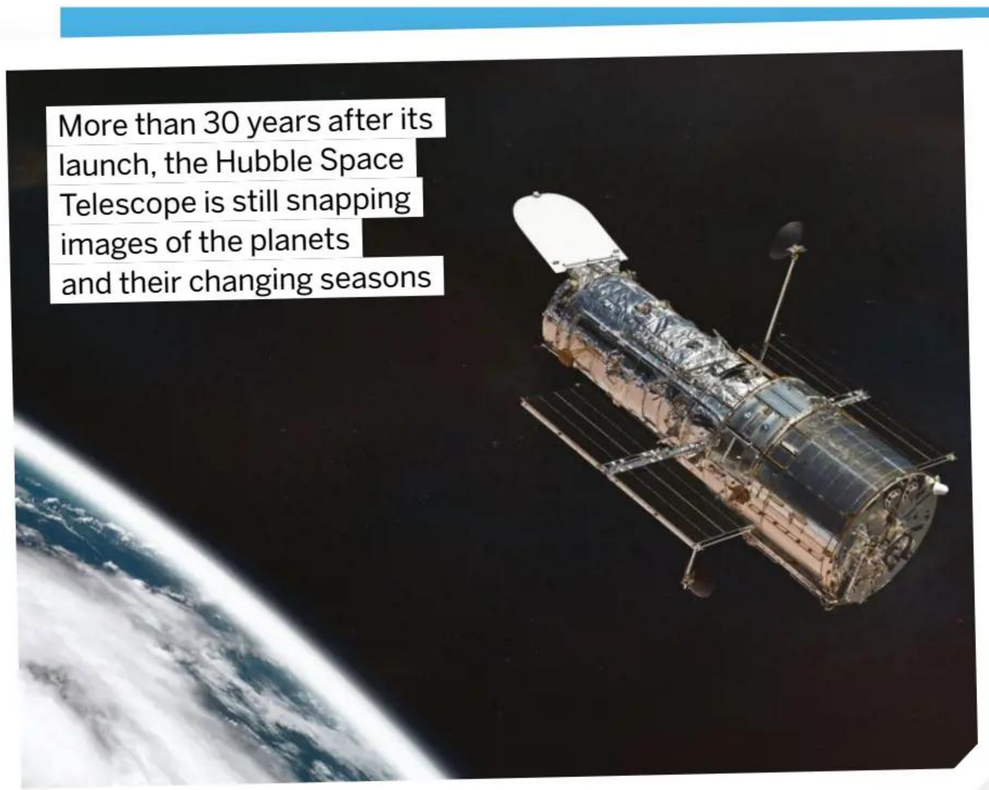
1 NORTHERN HEMISPHERE: SUMMER
SOUTHERN HEMISPHERE: WINTER
The North Pole is angled sunward; sunlight shines directly on the Northern Hemisphere and indirectly on the Southern Hemisphere.

2 NORTHERN HEMISPHERE: AUTUMN
SOUTHERN HEMISPHERE: SPRING
The Sun shines equally on both hemispheres. The point at which the length of day and night is equal during this time is known as the equinox.

Did you know?
Earth travels a distance of 93 million miles around the Sun

3 NORTHERN HEMISPHERE: WINTER
SOUTHERN HEMISPHERE: SUMMER
The South Pole is angled sunward; sunlight shines directly on the Southern Hemisphere and indirectly on the Northern Hemisphere.

4 NORTHERN HEMISPHERE: SPRING
SOUTHERN HEMISPHERE: AUTUMN
Both hemispheres are exposed to the same amount of sunlight.



More than 30 years after its launch, the Hubble Space Telescope is still snapping images of the planets and their changing seasons

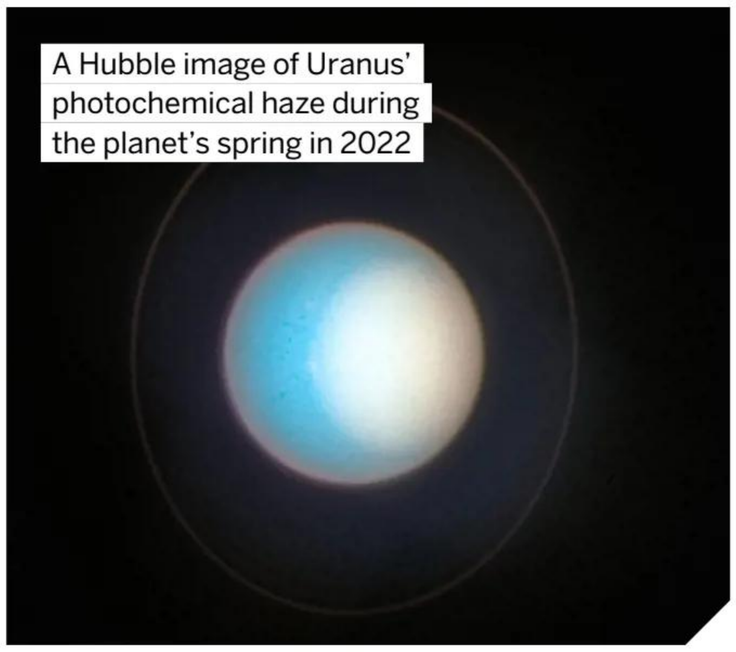
WATCHING PLANETS SPIN

To keep tabs on a planet's seasonal changes, NASA and the European Space Agency (ESA) use data collected by the trusty Hubble Space Telescope, which was launched in 1990. Over the years, Hubble's onboard cameras have captured images of seasonal activities in the Solar System, particularly on Jupiter and Uranus. In 2022 Hubble captured a thick, high-altitude photochemical haze on Uranus, similar to the smog of a bustling city, created during the planet's stormy spring.

Scientists hope that the haze will return even brighter when the planet enters its summer solstice in 2028.

In 2014, during Uranus' spring, Hubble snapped an image of the clouds of methane ice crystals that paint the planet's atmosphere a light cyan colour. The space observatory has also been used to help identify changes in wind speed, which dropped from 1,000 miles per hour to 800 miles per hour at Saturn's equator as it transitioned from summer to autumn.

© Getty / Alamy / Shutterstock



A Hubble image of Uranus' photochemical haze during the planet's spring in 2022

seasonal weather patterns. However, the outer planets beyond Mars don't have a solid surface and receive less sunlight to drive circulation in their atmospheres – factors which govern the seasonal weather changes on Earth.

While there are some planets that are tilted in a similar way to Earth, and thus have similar seasonal changes, not every planet or celestial object in the Solar System does. The Moon has a small tilt of around 1.5 degrees, meaning it doesn't experience different seasons. However, many moons in the Solar System do, such as Saturn's Titan, which shares roughly the same tilt as its parent planet, meaning it also shares its seasonal changes.

As for trying to explain why a planet tilts, scientists have several theories. Planets like Earth and Venus may have been impacted by another celestial object at some point in their history, causing them to be knocked from a vertical axis. Mars, on the other hand, got its axial tilt around 3.5 billion years ago thanks to an enormous volcanic structure known as Tharsis. Under the mounting mass of Tharsis' colossal dome, which is thought to span more than 3,000 miles, the planet's axis shifted by around 20 degrees. For the Solar System's favourite dwarf planet, Pluto, a 600-mile-wide region known as Sputnik Planitia may have been the cause of its dramatic tilt. When the region filled with ice and gained enough mass, it's believed to have caused the dwarf planet's axis to shift.



Due to its 119.5-degree tilt and 248-year orbit, Pluto's seasons last for over a century

SUMMER IN THE SOLAR SYSTEM

How the seasons shift for each planet as it orbits around the Sun

NO SEASONS

Three of the planets within our Solar System aren't subjected to seasonal changes. Mercury, Venus and Jupiter all have a fairly vertical rotating axis, meaning their exposure to sunlight while they orbit the Sun remains fairly uniform and they don't experience much in the way of seasons. However, there is something a bit odd about the way Venus spins. Even though its axis is only a few degrees from being completely perpendicular to its orbit, the planet appears to spin upside down and in the opposite direction to all the other planets in the Solar System. Scientists think a sizable collision with an object during Venus' history caused it to flip. This upside-down orientation means that if you were to stand on its surface you would see the Sun move in the opposite direction to how it's viewed on Earth, rising in the Venusian sky in the west and then setting in the east.

NO-SEASON PLANETS



MERCURY
Orbit: 88 days
Tilt: 2.0 degrees

VENUS
Orbit: 225 days
Tilt: 177 degrees

JUPITER
Orbit: 12 years
Tilt: 3.1 degrees

EXTREME SEASONS



EXTREME-SEASON PLANET

URANUS
Orbit: 84 years
Tilt: 97.8 degrees
Spring: 21 years
Summer: 21 years
Autumn: 21 years
Winter: 21 years

Around 1.8 billion miles from the Sun is lop-sided Uranus, spinning almost horizontally. Like many of the other planets, Uranus is thought to have been impacted by a long-lost moon that threw it off its axis, causing it to ultimately lay on its side. However, other theories suggest that Uranus entered into a gravitational dance with a neighbouring moon, shifting the planet's axis before the moon impacted it. Due to its oddball axis, seasons on Uranus are extreme: for the entirety of the 21 years of its summer the planet is constantly illuminated by sunlight. But in winter the planet is plunged into complete darkness, which also lasts 21 years. During the transitional seasons of spring and autumn, Uranus experiences a day-to-night cycle every 17 hours.

EARTH-LIKE SEASONS

With Earth-like tilts, Mars, Saturn and Neptune follow a similar seasonal pattern, but for much longer periods. Due to Neptune's 165-year orbit around the Sun, each of its seasons lasts more than 40 years. Not every planet has the same roughly circular orbit around the Sun as Earth. Mars has an elliptical orbit that alters the length of its seasons. Mars passes its closest point to the Sun during summer in the southern hemisphere. A summer day in the southern hemisphere on Mars can be as warm as 20 degrees Celsius. The higher summer temperatures can lead to more of the planet's dusty surface being whipped into its atmosphere, creating larger dust storms than any other time. Also during its summer, Mars' carbon dioxide ice caps melt away almost entirely and reform in the next frigid winter, which can plummet the poles into temperatures of -80 degrees Celsius.

EARTH-LIKE-SEASON PLANETS



EARTH
Orbit: 365 days
Tilt: 23.5 degrees
Spring: 92 days
Summer: 94 days
Autumn: 89 days
Winter: 90 days

MARS
Orbit: 687 days
Tilt: 25 degrees
Spring: 199 days
Summer: 183 days
Autumn: 146 days
Winter: 159 days

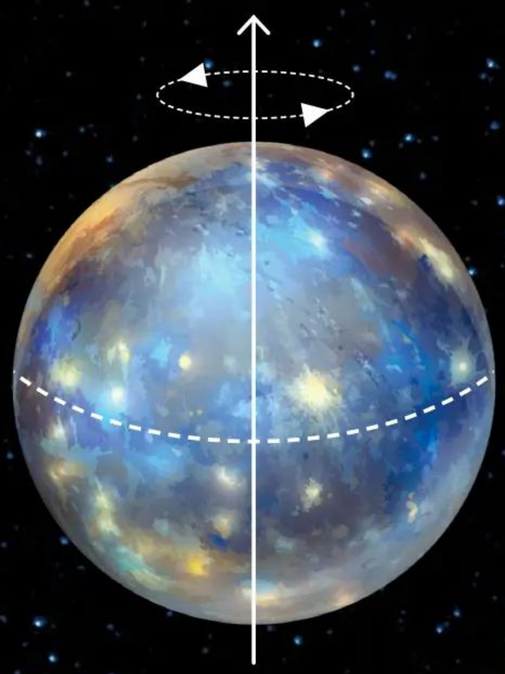
SATURN
Orbit: 29.4 years
Tilt: 27 degrees
Spring: 7 years
Summer: 7.5 years
Autumn: 7 years
Winter: 7.5 years

NEPTUNE
Orbit: 165 years
Tilt: 28 degrees
Spring: 40 years
Summer: 40 years
Autumn: 40 years
Winter: 40 years

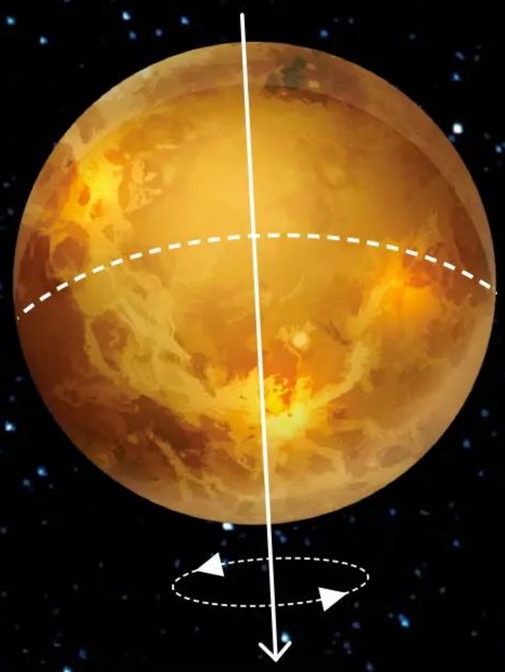
DID YOU KNOW? On Mercury, it takes 176 days for the Sun to rise, set and then rise again in the sky

Did you know?

Neptune's summer started in 2005 and ends in 2045



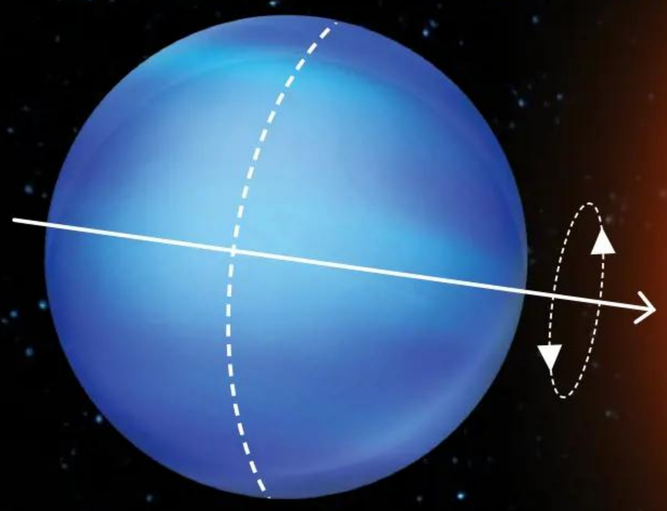
MERCURY
2.0 DEGREES



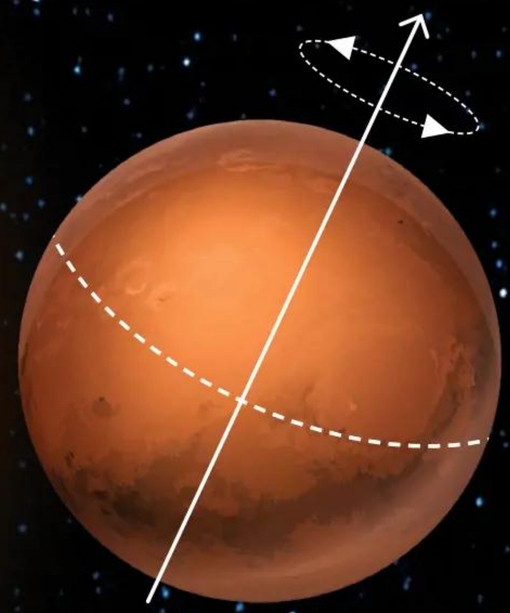
VENUS
177 DEGREES



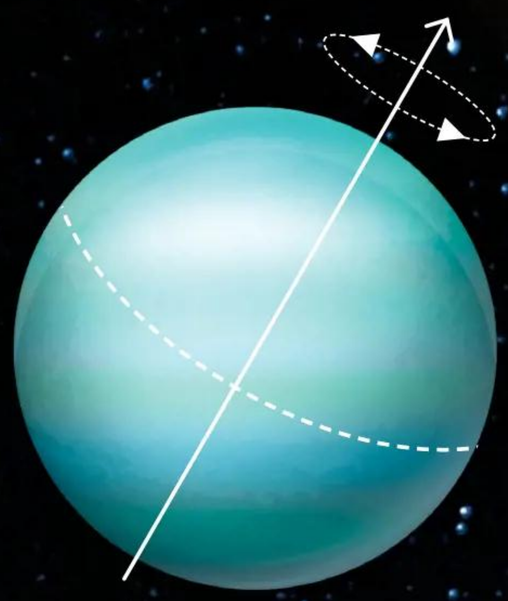
EARTH
23.5 DEGREES



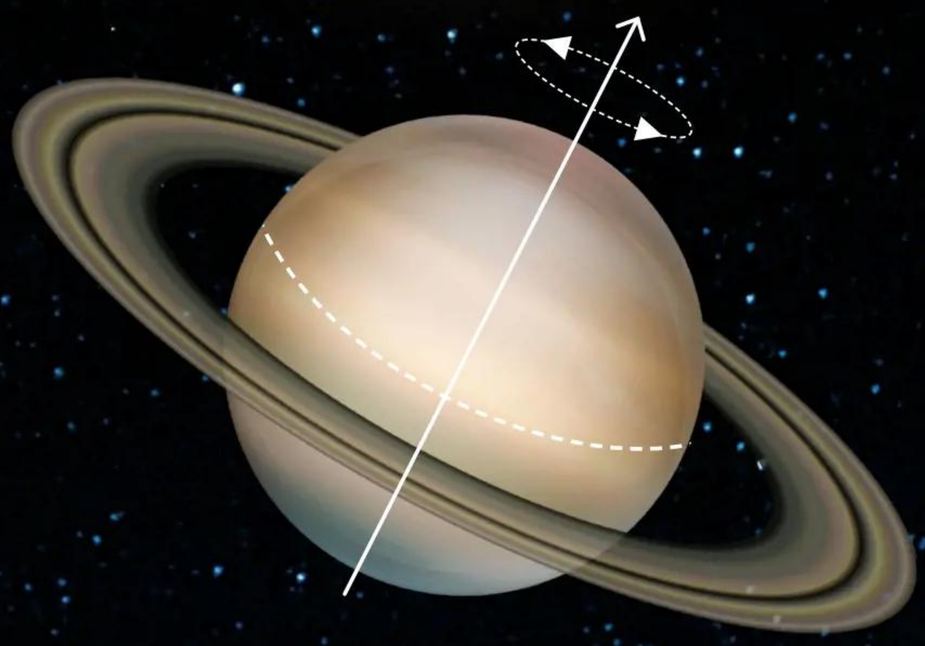
NEPTUNE
28 DEGREES



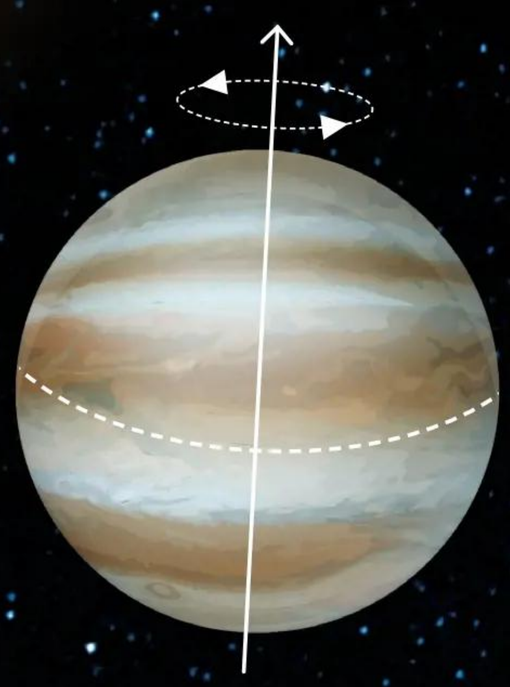
MARS
25 DEGREES



URANUS
97.8 DEGREES



SATURN
27 DEGREES



JUPITER
3.1 DEGREES

© Alamy / Getty / nasa. esa. stsci. A. Simon, nasagsfc, M. H. Wong UC Berkeley, J. Depasquale


CUP1_W2
CUP1_W1
futura
esa
European Space Agency

DID YOU KNOW? Cristoforetti was the first person to make a TikTok video on the ISS

ESA ASTRONAUT SAMANTHA CRISTOFORETTI

Emergencies, spacewalks and bossing it: the first female European commander of the ISS tells us what it's like to be in charge of a space station

INTERVIEWED BY **BEN BIGGS**



Above: The expedition patches Cristoforetti has earned for her missions into space

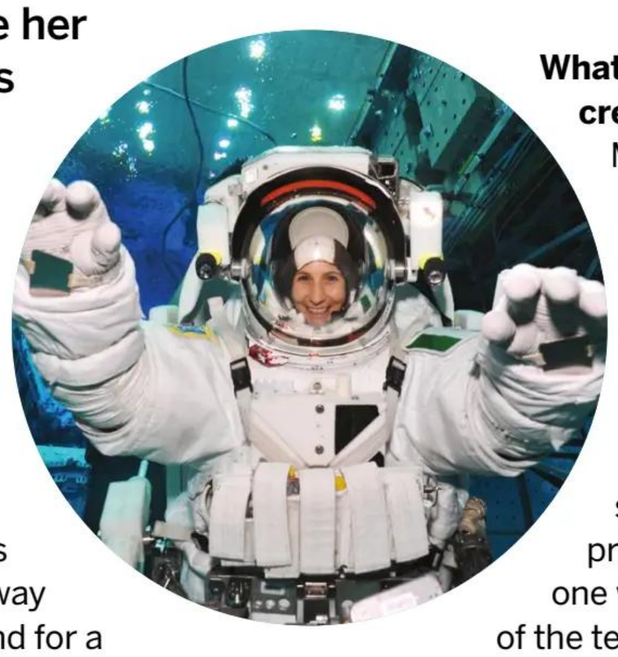
Opposite: Cristoforetti floating in microgravity

Left circle: Like all ESA astronauts, Cristoforetti was trained for spacewalks on Earth in NASA's Neutral Buoyancy Lab – a specialised diving pool

Samantha Cristoforetti joined the Italian Air Force in 2001, gained her fighter pilot wings in 2006 and flew fighter jets until 2009, when she passed astronaut selection and joined the European Space Agency. As an astronaut, Cristoforetti was a flight engineer on her first mission to the International Space Station (ISS), 2014's Expedition 42/43, and served as commander for Expedition 68 in 2022. Since her return to Earth, Cristoforetti has co-authored *The Astronaut Diaries*, a book about a young girl's journey into space based on her own experiences.

In *The Astronaut Diaries*, Andi Futura fantasises about going into space. Were you dreaming about the same things as a child?

Yeah. I mean, there was no ISS when I was 11 years old. I guess that's going to give away how old I am since the ISS has been around for a while, but I did dream about going to space – at that age, for sure, even at a younger age. When I was growing up, it was the time of the Space Shuttle and things like that. You know, there was no social media, the communication was more about the mission and the adventure part of it, and that's what was appealing to me more than any thoughts about all daily life concerns. I thought going into space would be like this majestic, great adventure. And I was very adventurous as a child. I wanted to do cool stuff and go to cool places.



What would you have done if you weren't selected to be an ESA astronaut?

Like every astronaut, we kind of all have a job or a career from which we are then selected to become an astronaut. So when I was selected, I was a combat pilot in the Italian Air Force, and so it's pretty clear that I was quite early on in my career, and I would have continued to pursue that career, I would say, for at least another ten years or so. I don't know what I would be doing now, but I would say for the next decade or so I would have continued, I think, my career as a combat pilot.

What's the difference between being an ISS crew member and being commander?

Multiple aspects. I guess you're a little bit of a team leader. You need to make sure that if people have any issues that they're struggling with, or they have concerns, they would normally come to you. Then you have to make sure that communication among the team functions in a smooth way if there are problems. In the end, you're the one who has to coordinate the work of the team to come up with a solution.

There's an aspect of being like the point of communication with the ground. Because we are this very small team in orbit, but then there is a gigantic team on the

Did you know?

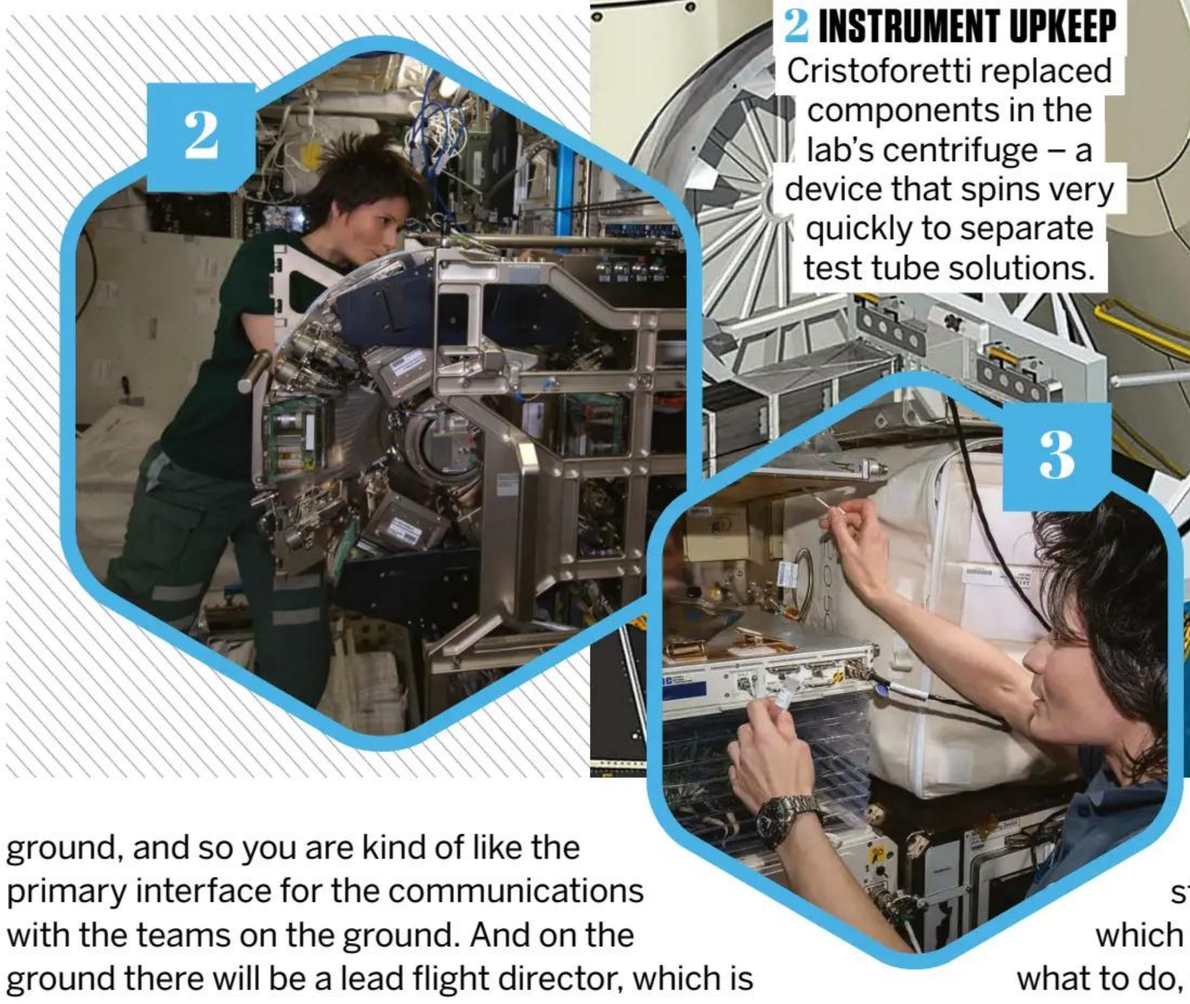
Cristoforetti can speak six languages

"You have to be careful about this whole idea of control because in orbit we are not too much in control in general, right?"

© ESA

REMOTE WORKER

Being an ISS astronaut doesn't mean you get to lark around in microgravity. The station's science module, the Columbus laboratory, is where astronauts conduct experiments



ground, and so you are kind of like the primary interface for the communications with the teams on the ground. And on the ground there will be a lead flight director, which is like the equivalent for the ground team, then we've got all the flight controllers and everyone. You've got the flight directors, and then there is a lead flight director, which is assigned to your crew. It's like this communication between the US commander and the lead flight director on the ground that you know that you have to take care of.

Then there is a case of an emergency, which doesn't happen every day, thankfully – quite rarely – but it's a big chunk of our training in how to react to a situation where you've got a fire in orbit, or you've got a depressurisation when you're losing air or you've got a toxic spill in the cabin. That's something that typically doesn't happen. That's why we call them emergencies. But we spend a lot of time on the ground training for those kinds of situations. Even before you leave, then you would be kind of in charge of the crew response, also during all those simulations on the ground. Then, of course, in orbit, should something like that happen, you would be the one ultimately responsible for the response of the crew.

Although there was never an emergency when you were on the ISS, was there a situation where you didn't feel like you were in full control?

You have to be careful about this whole idea of control because in orbit we are not too much in control in general, right? Outside of an emergency, the vehicle is very much under the control of the ground controllers. The schedule is determined from the ground. You don't have to imagine that you're in space and you do what you want – it's quite the opposite. You're there to execute tasks that are part of the activities that need to happen on the space station. But if you're talking about a situation in which I felt like I was in danger and I didn't know what to do, then no, that wouldn't be the case.

Did you feel claustrophobic in the smaller modules?

No, the ISS is actually really big. I mean, the only place that is cramped is the Soyuz, the Russian vehicle that we used on our first launch on my first flight, we launched in Soyuz. That's cramped to be there. You barely have enough space to fit the three people in there. I'm kind of small, so I guess it's okay. But some people who are taller, they really sit with their knees almost up in their chest. But other than the Soyuz, for the rest I never had the feeling that it was cramped. The space station... it's like this long axis of modules attached one to the other. We call it the stack, and from the forward side of the stack to the aft, it's 100 meters. It's quite long, and then you have modules protruding to the sides. So yeah, it might look [cramped] when you see pictures, especially if there's a lot of stuff around. Sometimes we get issues with storage and that there's just a lot of, maybe bags, big bags stowed in the front of the rack. Maybe in the pictures it looks like it's cramped, but in reality it's not the way I felt about it. You also have to imagine you're weightless, so all of that volume is available to you – you're in three dimensions so all of that volume is available to you.

Did you get excited about spacewalks?

Oh, definitely. That was something

Opposite centre: After spending 200 days in space, Cristoforetti took this photo inside the ISS' Cupola

Below: Expedition 42 crew members Samantha Cristoforetti, Anton Shkaplerov and Terry Virts were immortalised as LEGO Minifigures in 2015



DID YOU KNOW? As a child, Cristoforetti was a huge fan of *Star Trek*

that I was really looking forward to doing. I had the chance of doing an EVA [extravehicular activity, or spacewalk] on my second mission. I didn't on my first – that was a big disappointment for me on my first mission that I didn't have a chance to go out on an EVA. But hey, I had something to look forward to for my second flight. It's the one really, really special thing that you do on board as an astronaut. I think everyone wants to have that experience of actually going out on an EVA.

Would you say that's the peak of being an astronaut?
Yeah, I would say so.

When you return to Earth, what's it like to wait for the rescue crews to pop the hatch, open the module and take all the astronauts out?
Well, it goes very fast. Both my flights went very fast. I guess it would be different if they're not waiting for you for some reason, like you don't land in the right place or whatever. That's an emergency landing and so people are actually not expecting you. But you know, in both of our cases, we landed when and where we were supposed to, so people were there for us. I remember landing in the Soyuz, you know, we were just in there, and I was peeking out from the window and I would see people outside. And it was very quick. They had that hatch open within a few minutes, I think.

And then on the Dragon it was very, very similar. I can't remember exactly, but I don't have any recollection of having waited for a long time. They were on the vehicle very quickly from a boat. On the Soyuz in Kazakhstan, they literally set up a camp: they have a big hospital tent and they're there with the helicopters and the rescue team and everything. And in the water is kind of like the same thing. I've got the rescue boat that is standing nearby and then they have these speed boats with the divers that come close to the vehicle to secure it. They don't get you out in the water. They just secure the propulsion system and make sure that there's nothing toxic going around. And then they will actually hoist you onto the ship, and then you get onto the vehicle on the ship. It's actually nice.





THE ASTRONAUT DIARIES
by Samantha Cristoforetti and Emma Roberts, published by DK, is on sale now




An uncrewed Progress resupply vehicle undocking on its return to Earth

RECORD BREAKER

In early May 2015, the Russian space agency's Progress M-58 resupply freighter burned up in Earth's atmosphere in an uncontrolled re-entry. As a result, subsequent launches to the space station were put on hold until this failure could be properly investigated. This meant that the six astronauts on board, including Cristoforetti, were effectively stranded on the station until further notice.

The crew had supplies for many weeks, so their health and wellbeing aboard the ISS wasn't affected. With her return to Earth postponed for a month, it meant Cristoforetti's stay on the ISS beat the previous record holder, Sunita Williams, by four days. Cristoforetti is still the record holder for longest time spent on the ISS in a single mission for a female astronaut at 199 days and 16 hours.

© ESA / NASA / DK

WHERE TO FIND EXTRATERRESTRIAL LIFE

The number of places across the cosmos that could be concealing life are too many to count

WORDS SCOTT DUTFIELD

In our home galaxy alone there are millions – if not billions – of Earth-like planets that could be home to extraterrestrial life, not to mention all of the planets and moons in the billions of other galaxies in the known universe. But rather than looking for a civilisation of little green aliens, scientists are hunting for signs of microscopic life, which are often referred to as biosignatures. Biosignatures are any elements, compounds or characteristics that could suggest the existence of life as we know it, both past and present. There are two key biosignatures for life: water and organic carbon.

Luckily, the universe is full of these essential components in various states, along with the myriad of chemical elements, such as hydrogen, nitrogen and oxygen, necessary for sustaining life. Using an array of space telescopes and ground-based observatories, scientists have been on the hunt for life beyond Earth since the early 1900s. Here are just a few of the spots that scientists have earmarked as sites of interest, which may one day reveal the first evidence of life in space.

Did you know?

Jupiter's moon Ganymede is 46 per cent water

1 TOO HOT TO HANDLE MERCURY

At just 36 million miles from the Sun, Mercury receives the most intense solar radiation of any planet in the Solar System. It's also one of the hottest, with surface temperatures in excess of 430 degrees Celsius. Scientists have concluded that these conditions make it highly unlikely for life as we know it to exist on Mercury.

2 CLOUDS OF LIFE VENUS

Researchers have discovered clouds of phosphine gas floating above the surface of Venus. On Earth, phosphine gas is produced by microbes deprived of oxygen. While Venus is far too hot to support life on its surface, phosphine-producing organisms could possibly reside in its atmosphere, but much more research is needed to confirm this.

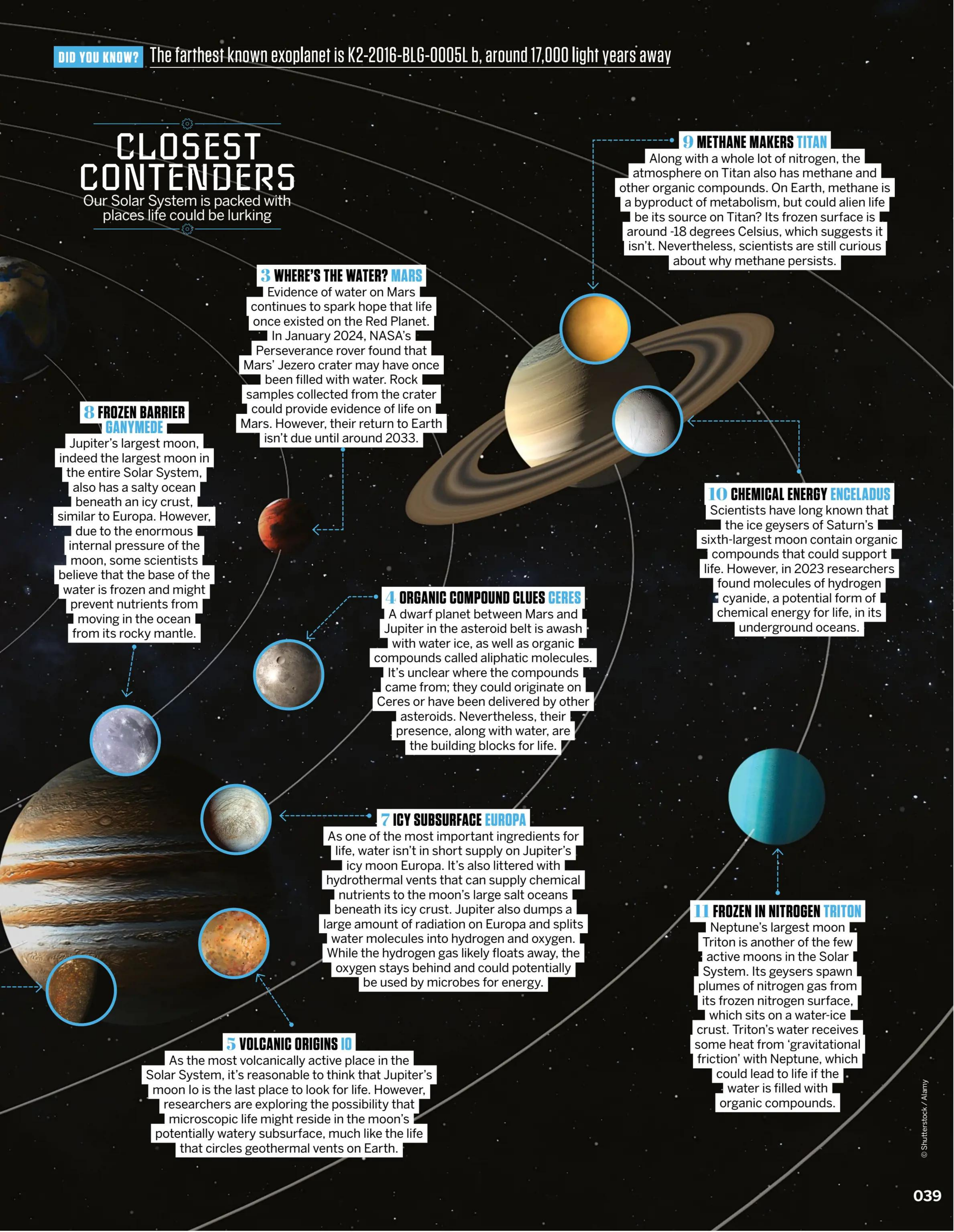
6 SALTWATER SANCTUARY CALLISTO

Around 155 miles below the icy surface of Jupiter's second-largest moon, scientists think a salty ocean may exist, and it could be interacting with rocks to create a possible habitat for life. Oxygen has also been detected in Callisto's atmosphere – a vital ingredient for sustaining life.

DID YOU KNOW? The farthest known exoplanet is K2-2016-BLG-0005L b, around 17,000 light years away

CLOSEST CONTENDERS

Our Solar System is packed with places life could be lurking



3 WHERE'S THE WATER? MARS

Evidence of water on Mars continues to spark hope that life once existed on the Red Planet. In January 2024, NASA's Perseverance rover found that Mars' Jezero crater may have once been filled with water. Rock samples collected from the crater could provide evidence of life on Mars. However, their return to Earth isn't due until around 2033.

8 FROZEN BARRIER GANYMEDE

Jupiter's largest moon, indeed the largest moon in the entire Solar System, also has a salty ocean beneath an icy crust, similar to Europa. However, due to the enormous internal pressure of the moon, some scientists believe that the base of the water is frozen and might prevent nutrients from moving in the ocean from its rocky mantle.

4 ORGANIC COMPOUND CLUES CERES

A dwarf planet between Mars and Jupiter in the asteroid belt is awash with water ice, as well as organic compounds called aliphatic molecules. It's unclear where the compounds came from; they could originate on Ceres or have been delivered by other asteroids. Nevertheless, their presence, along with water, are the building blocks for life.

7 ICY SUBSURFACE EUROPA

As one of the most important ingredients for life, water isn't in short supply on Jupiter's icy moon Europa. It's also littered with hydrothermal vents that can supply chemical nutrients to the moon's large salt oceans beneath its icy crust. Jupiter also dumps a large amount of radiation on Europa and splits water molecules into hydrogen and oxygen. While the hydrogen gas likely floats away, the oxygen stays behind and could potentially be used by microbes for energy.

5 VOLCANIC ORIGINS IO

As the most volcanically active place in the Solar System, it's reasonable to think that Jupiter's moon Io is the last place to look for life. However, researchers are exploring the possibility that microscopic life might reside in the moon's potentially watery subsurface, much like the life that circles geothermal vents on Earth.

9 METHANE MAKERS TITAN

Along with a whole lot of nitrogen, the atmosphere on Titan also has methane and other organic compounds. On Earth, methane is a byproduct of metabolism, but could alien life be its source on Titan? Its frozen surface is around -18 degrees Celsius, which suggests it isn't. Nevertheless, scientists are still curious about why methane persists.

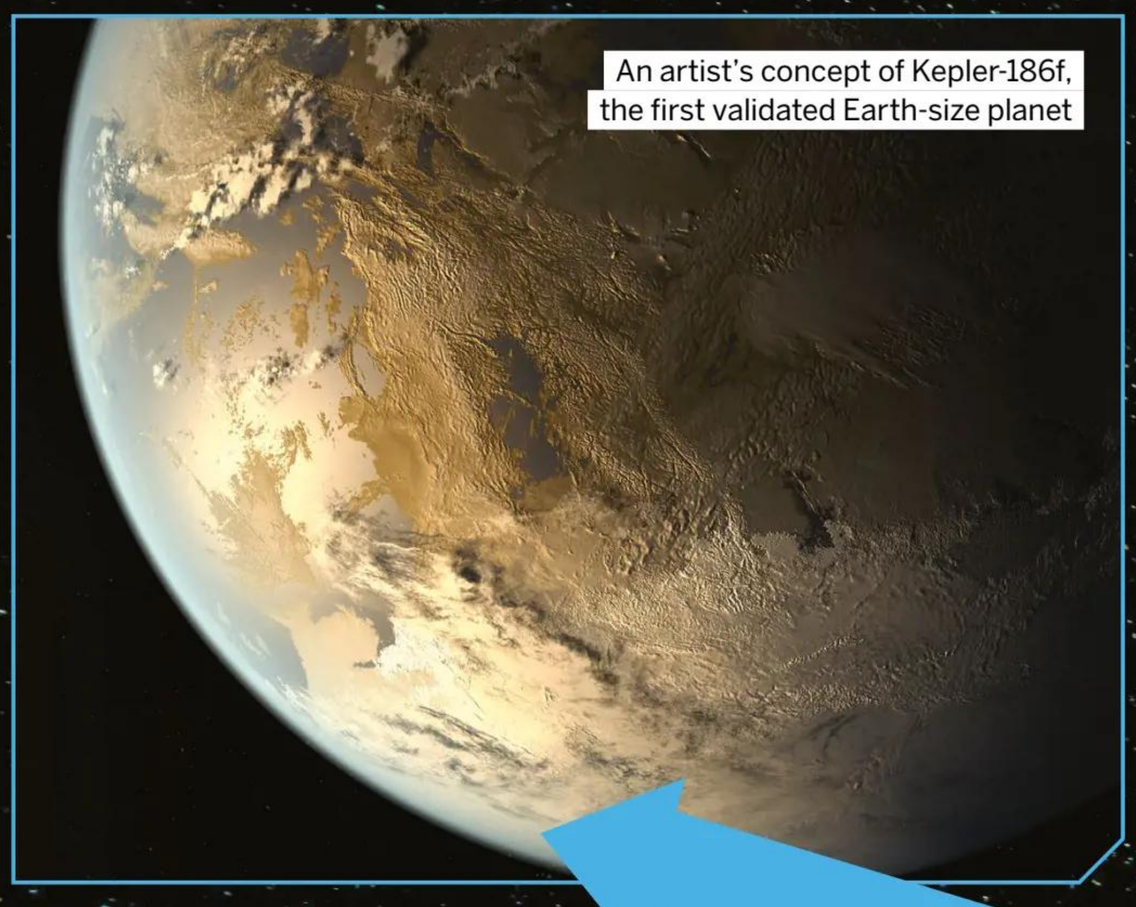
10 CHEMICAL ENERGY ENCELADUS

Scientists have long known that the ice geysers of Saturn's sixth-largest moon contain organic compounds that could support life. However, in 2023 researchers found molecules of hydrogen cyanide, a potential form of chemical energy for life, in its underground oceans.

11 FROZEN IN NITROGEN TRITON

Neptune's largest moon Triton is another of the few active moons in the Solar System. Its geysers spawn plumes of nitrogen gas from its frozen nitrogen surface, which sits on a water-ice crust. Triton's water receives some heat from 'gravitational friction' with Neptune, which could lead to life if the water is filled with organic compounds.

© Shutterstock / Alamy



An artist's concept of Kepler-186f, the first validated Earth-size planet

KEPLER-186F

558 LIGHT YEARS AWAY

The first of Earth's exoplanet 'cousins' was discovered in 2014 in the constellation of Cygnus. Like Earth, this exoplanet has a rocky surface, may have liquid water and an atmosphere. However, the planet lives at the edge of a region of space known as the 'Goldilocks zone', meaning it receives just a third of the energy that Earth receives from the Sun, casting doubt over its likelihood of supporting life. There are countless planets in the universe zipping around stars like the eight major planets that orbit the Sun. Some have comparable compositions to the planets in our Solar System. The best chance exoplanets have of supporting life is to orbit within their parent star's Goldilocks zone, named because its distance from its star is 'just right' for life. Earth exists within the habitable zone of the Solar System, where it's not too hot or too cold for water to remain liquid and its atmosphere stable. The hope is that exoplanets in a similar zone in their own systems could look like Earth and share its life-supporting properties.

BEYOND THE SOLAR SYSTEM

These exoplanets might mimic Earth enough to support life of their own

K2-18 B 124 LIGHT YEARS AWAY

In 2023, researchers at Cambridge University announced possible biosignatures on K2-18b. Using data collected by the Near Infrared Spectrograph (NIRSpec) on the James Webb Space Telescope, they detected methane, carbon dioxide and, more surprisingly, dimethyl sulphide (DMS) in the planet's atmosphere. DMS plays an important role in forming clouds, and on Earth is a metabolite of marine algae that release the gas into the atmosphere. Along with the other life-supporting gases, it gave hope to scientists that one day we will find evidence of life in space. However, in 2024, researchers at the University of California, Riverside, challenged the 2023 study's findings and suggested that Webb can't differentiate between methane and DMS. The scientists speculate that for Webb to detect DMS, 'life' on K2-18 b would have to produce 20 times more DMS than is present on Earth. But all hope for finding life or DMS on K2-18 b is not lost. Webb is also equipped with the Mid-Infrared Instrument (MIRI), which can identify DMS from methane. Scientists think that as soon as the end of the year, more information about the exoplanet's atmosphere can be confirmed,



The biosignatures still need to be confirmed

2.37

K2-18 b is more than twice as wide as Earth

8.92

You'd need nine Earth masses to outweigh this exoplanet

K2-18 B HAS A HYDROGEN-RICH ATMOSPHERE

39.2 DAYS

It takes just over a month for K2-18 b to orbit its star

0.01% TO 50%

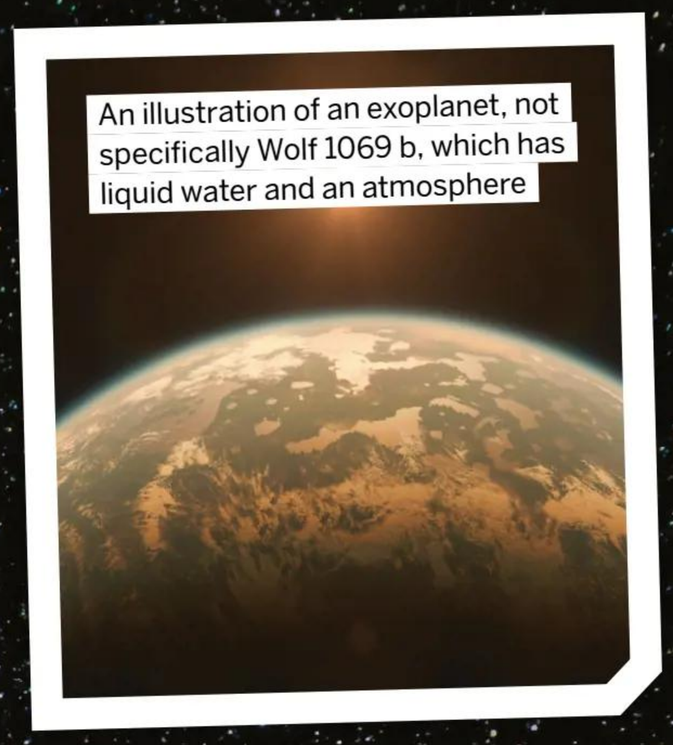
Up to half of the composition of K2-18 b's atmosphere could be water

DID YOU KNOW? It would take a billion years to reach K2-18 b from Earth travelling at 60 miles per hour

WOLF 1069 B

38 LIGHT YEARS AWAY

Orbiting a red dwarf star that is much smaller than our Sun, Wolf 1069 b only receives around 65 per cent of the solar energy that Earth gets from the Sun. It only takes 15.6 days for Wolf 1069 b to orbit its much smaller and cooler star. The exoplanet is also tidally locked to its star, meaning it doesn't spin on an axis like Earth, with one face constantly facing the star. Nevertheless, scientists speculate that the rocky exoplanet has a mass that's comparable to Earth, could support liquid water and maintain a partial atmosphere that could theoretically shield life from harmful space radiation.



An illustration of an exoplanet, not specifically Wolf 1069 b, which has liquid water and an atmosphere

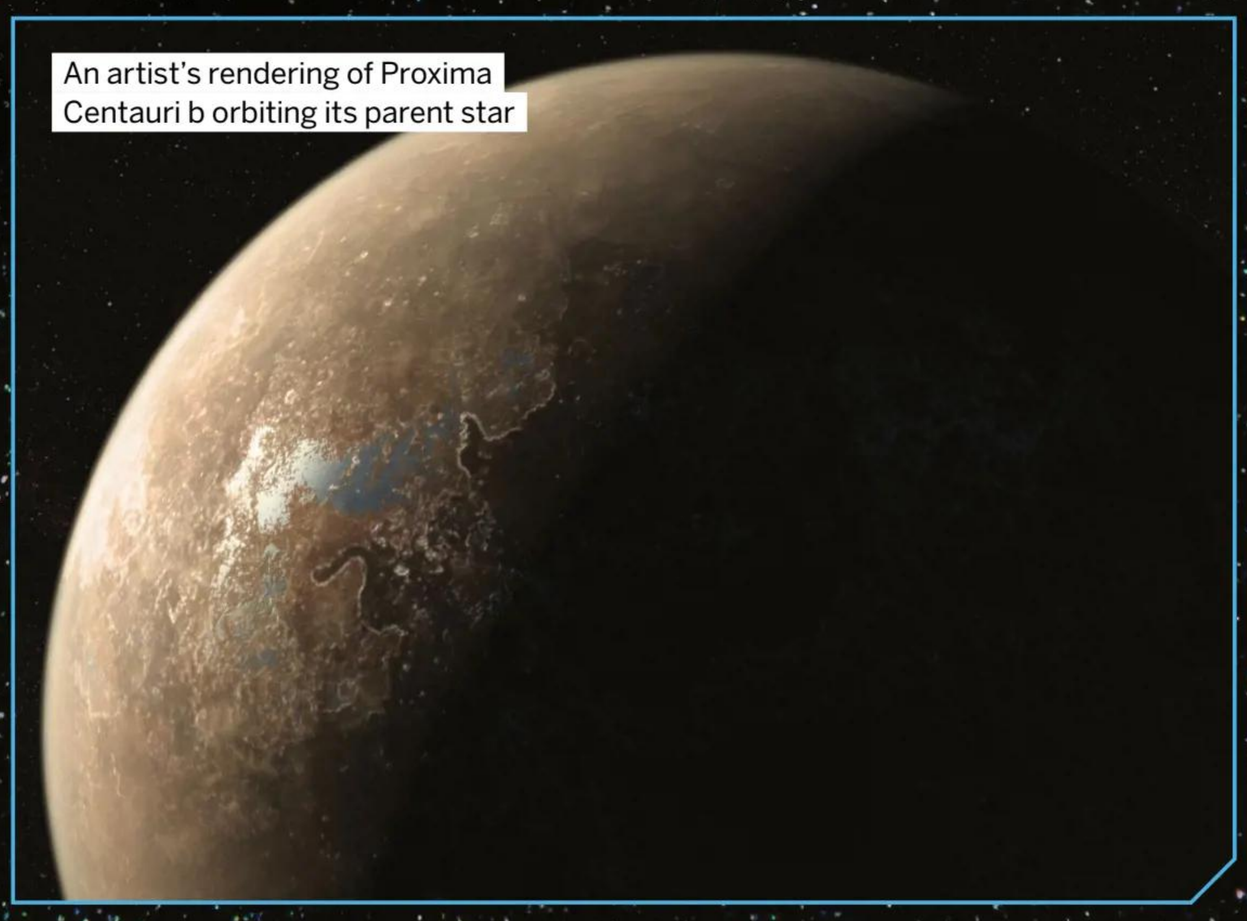
PROXIMA CENTURI B

4 LIGHT YEARS AWAY

Did you know?

The Kepler space telescope found over 2,600 exoplanets

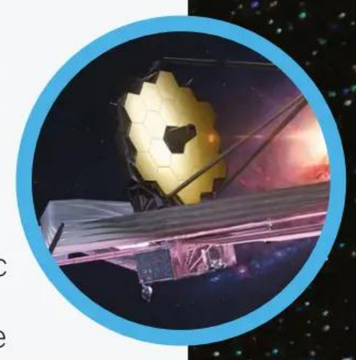
As the closest exoplanet to Earth, Proxima Centauri b orbits the nearest star to our Solar System. Like Wolf 1069 b, Proxima Centauri b also orbits a red dwarf star and receives around 65 per cent of the solar energy that Earth gets. This means liquid water and an atmosphere might be possible, and thus possibly life. However, Proxima Centauri b has thwarted scientists' attempts to spy on its atmosphere. Typically, researchers use a technique called the transit method to study exoplanets. This method involves waiting for the planet to pass in front of its star from the perspective of the observing instrument, like a telescope. When the planet 'transits' across the star, the star's light illuminates the exoplanet and reveals its atmosphere as the light passes through it. However, the gravitational pull of Proxima Centauri b causes its red dwarf star to 'wobble' and prevents scientists from identifying an atmosphere, just the planet's rough size and mass.



An artist's rendering of Proxima Centauri b orbiting its parent star

5 FACTS LIFE HUNTERS

1 THE JAMES WEBB SPACE TELESCOPE



One of Webb's main missions is to hunt down exoplanets in the hope of finding signs of life. Webb uses its onboard scientific instruments, such as spectrographs, to analyse the composition of a planet's atmosphere.

2 EUROPA CLIPPER



Focused on Jupiter's moon Europa, this next-generation satellite will closely study the composition of its oceans and its geology. Europa Clipper is due to launch in October 2024, but won't reach the icy moon until April 2030.

3 TRANSITING EXOPLANET SURVEY SATELLITE



Launched in 2018, TESS is a satellite that images around 75 per cent of the sky and has surveyed thousands of exoplanets in the universe. It's currently in its second extended mission period since its initial mission completion in 2020.

4 EXTREMELY LARGE TELESCOPE



The ELT could be the largest ground telescope ever built. It consists of five mirrors, the largest of which is 39 metres wide and consists of 1,000 hexagonal segments. The ELT is currently under construction and is due to start scientific observations in 2028.

5 CARMENES



Dubbed the 'Calar Alto high-Resolution search for M dwarfs with Exo-earths with Near-infrared and optical Échelle Spectrographs (CARMENES) program, this project uses a 3.5-metre telescope at the Calar Alto Observatory in Spain to hunt down exoplanets.

© NASA, ESA, CSA, Joseph Olmsted (STScI) / ESO, M. Kornmesser / ESO / NASA, Ames, SETI Institute, JPL-Caltech

ENVIRONMENT

ENVIRONMENT

WHAT WAS THE FIRST LIVING THING?

How the origin of everything alive on Earth today points to one ancient organism

WORDS SCOTT DUTFIELD

DID YOU KNOW? The first animal fossil evidence dates back to 574 million years ago

Humans have been trudging around the planet for the last 300,000 years or so, which is a mere fraction of the 4 billion years that life has existed on Earth. Less than 4 million years after the Earth formed, something brought the ingredients for life together. It may have triggered a biological domino effect, culminating in life's abundance in every corner of the planet. But where and how did it all begin?

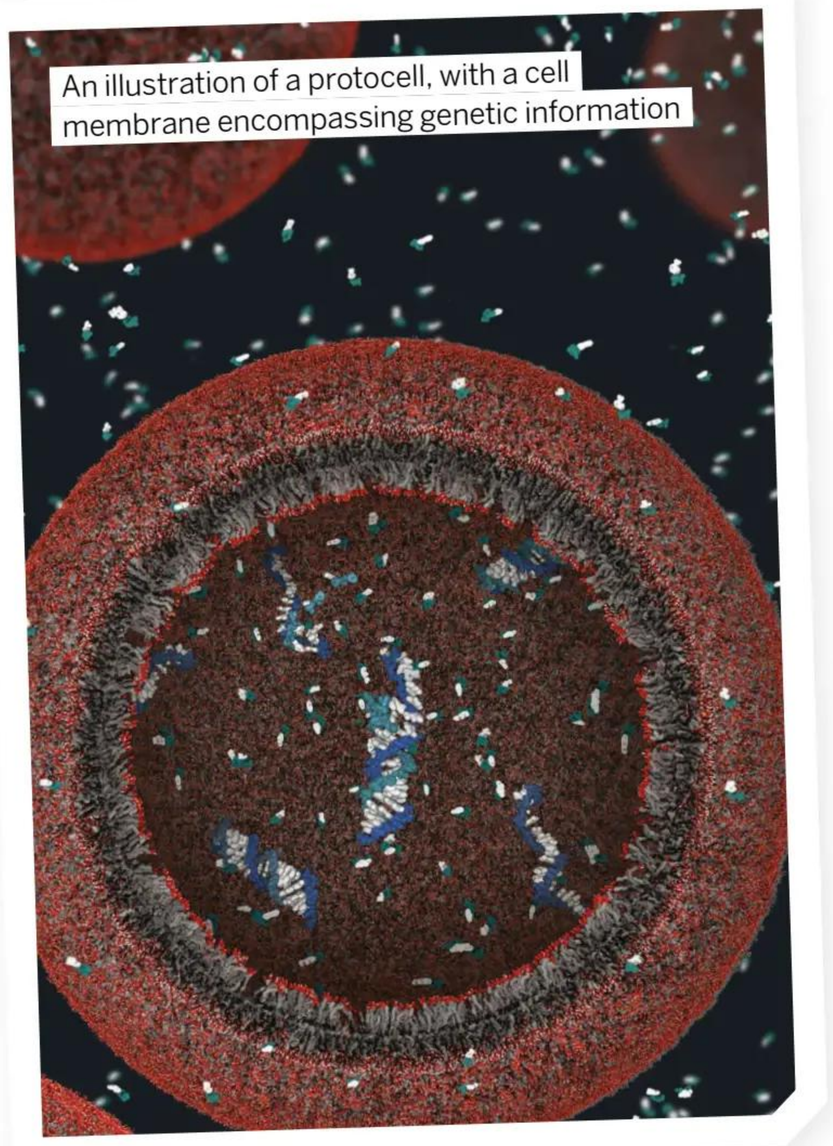
If you ask a biologist, they'll likely tell you that a single cell named the last universal common ancestor (LUCA) is the first organism to have ever existed. This theoretical single-celled organism likely had a simple membrane and used RNA (ribonucleic acid) to store genetic information, much like our DNA (deoxyribonucleic acid). LUCA may have started as a precursor to biological cells, called a protocell. Whereas biological cells are self-contained, gene-filled and able to reproduce, protocells are merely a collection of non-living components.

Did you know?

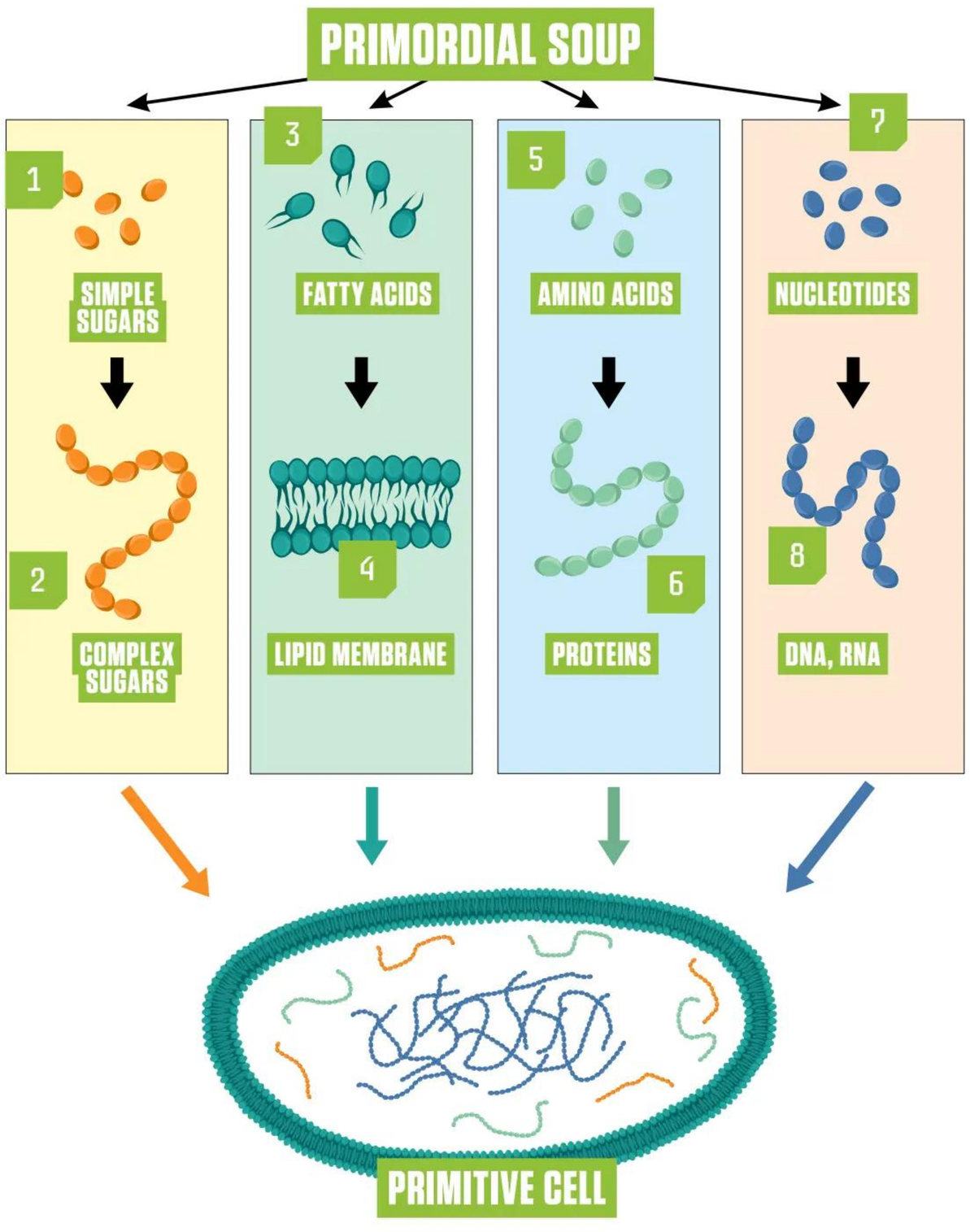
A typical human cell divides every 24 hours

It's taken scientists a long time to put an age on a hypothetical cell, but in 2024, researchers added an extra 300 million years to previous age estimates. Now it's believed that the ancestral origin of all life came about 4.2 billion years ago. This new birthday came from comparing the shared genetic mutations of 700 living species of bacteria and microbes called archaea.

LUCA may have been born from an oceanic concoction of organic compounds commonly known as the 'primordial soup'. The theory of a life-creating soup of organic molecules was proposed by Russian biochemist Alexander Oparin and British geneticist John B. S. Haldane in the 1920s. The theory suggests that a lightning strike or ultraviolet radiation brought together atmospheric methane, ammonia and ocean water, creating the



An illustration of a protocell, with a cell membrane encompassing genetic information



LIFE'S BUILDING BLOCKS

Why the specific ingredients that made the first living cell are so important

1 SIMPLE SUGARS
Scientists are still unsure where simple sugars came from, but many believe they likely emerged from a small molecule called glyoxylate.

2 CARBOHYDRATES
When simple sugars join together, they form cellular carbohydrates that supply energy to a cell for growth and reproduction.

3 FATTY ACIDS
The origins of fatty acids on Earth remain unknown. However, it's been suggested their creation is linked to carbon delivered by meteorite impacts.

4 MEMBRANE
When fatty acids bond to an alcohol called glycerol and phosphate, they form a membrane that controls what can move in and out of the cell.

5 AMINO ACIDS
Amino acids are composed largely of nitrogen, which may have been derived from early atmospheric sources of nitrogen, such as ammonia.

6 PROTEINS
When amino acid molecules link up they form proteins, which carry out almost every task done within a cell, such as metabolism.

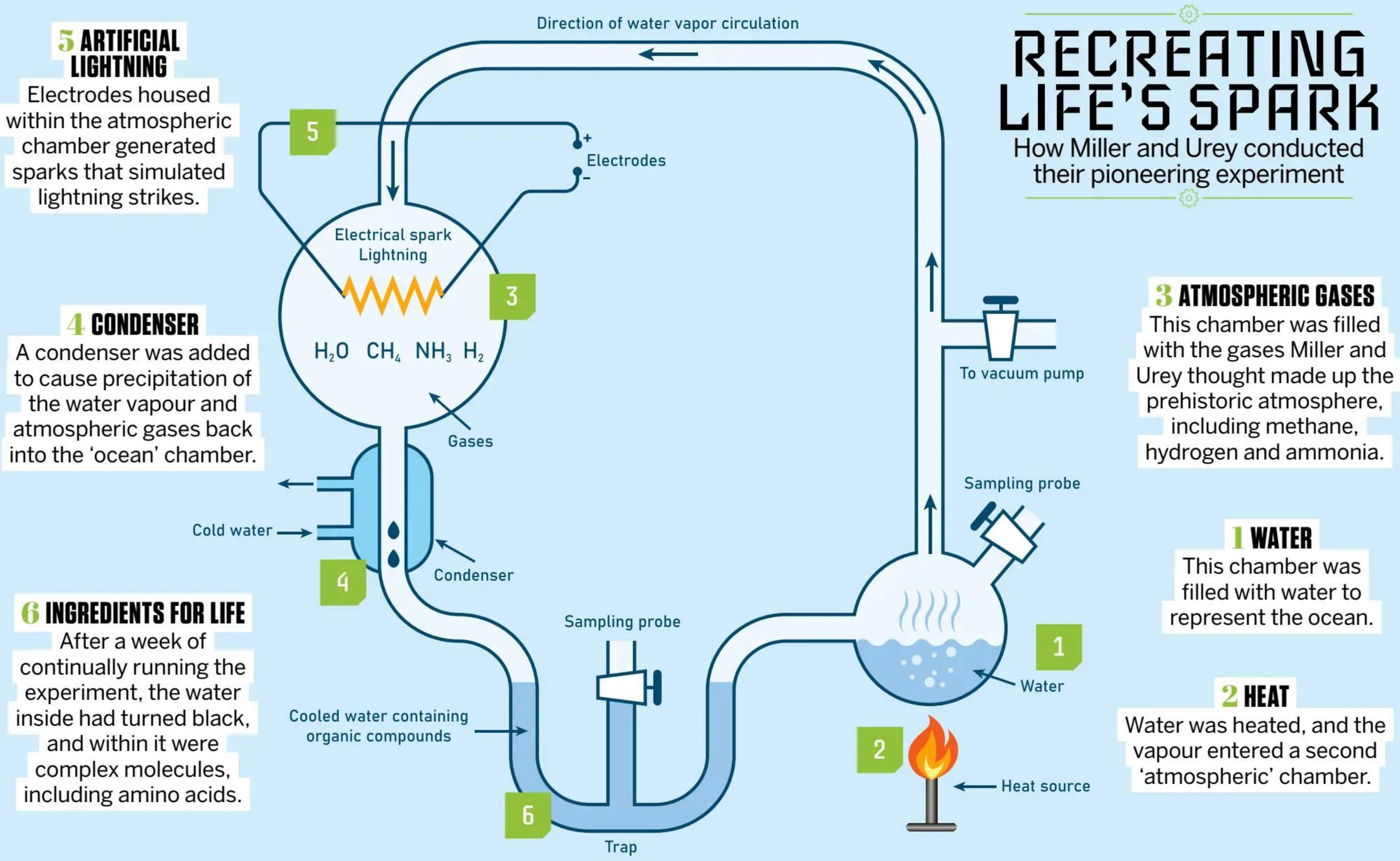
7 NUCLEOTIDES
The precursors to DNA and RNA may have originated from gaseous molecules of hydrogen cyanide.

8 DNA
As the cell's instruction manual, DNA sets out the genetic rules for how the cell operates and develops.

© Shutterstock / Alamy

RECREATING LIFE'S SPARK

How Miller and Urey conducted their pioneering experiment



5 ARTIFICIAL LIGHTNING
Electrodes housed within the atmospheric chamber generated sparks that simulated lightning strikes.

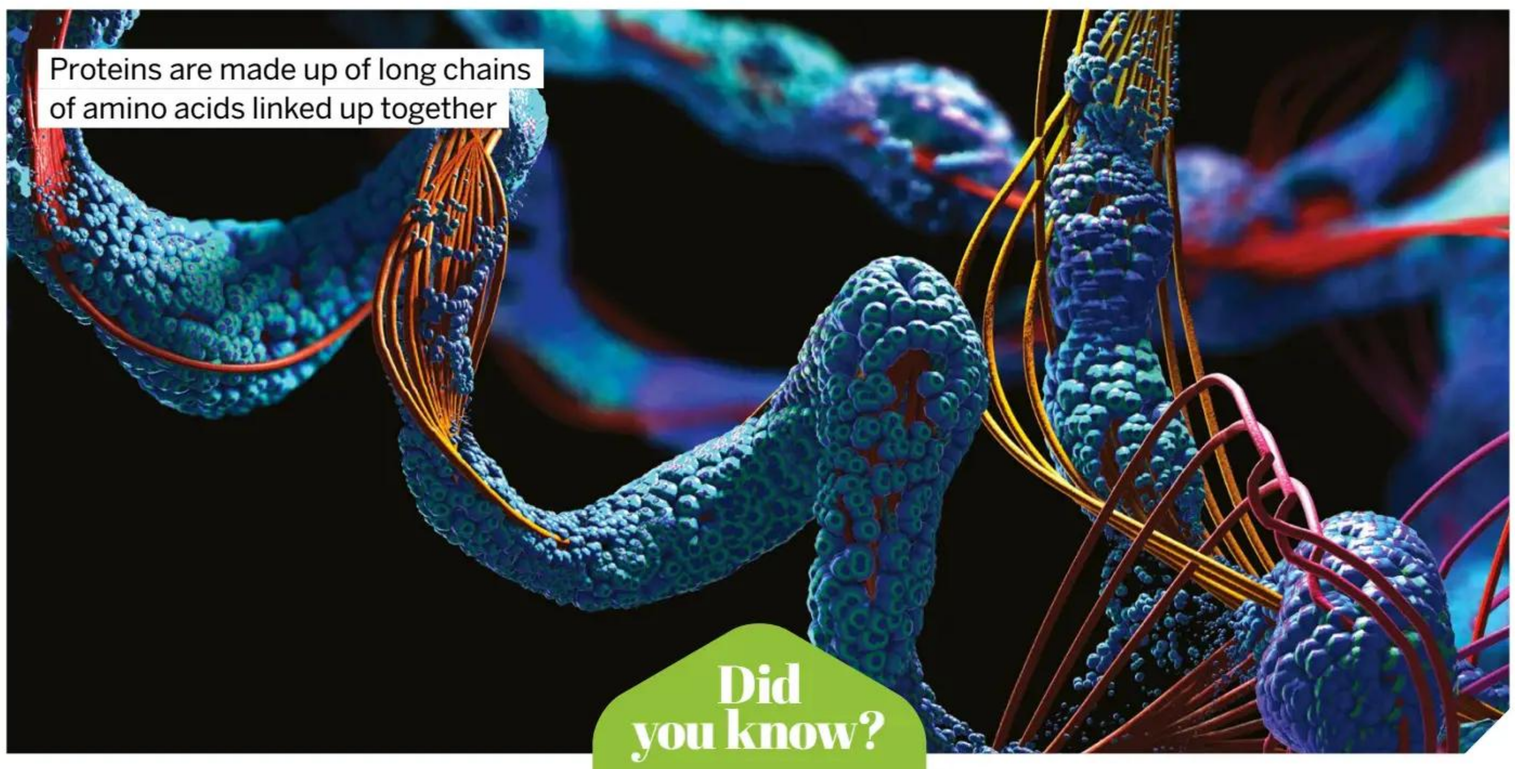
4 CONDENSER
A condenser was added to cause precipitation of the water vapour and atmospheric gases back into the 'ocean' chamber.

6 INGREDIENTS FOR LIFE
After a week of continually running the experiment, the water inside had turned black, and within it were complex molecules, including amino acids.

3 ATMOSPHERIC GASES
This chamber was filled with the gases Miller and Urey thought made up the prehistoric atmosphere, including methane, hydrogen and ammonia.

1 WATER
This chamber was filled with water to represent the ocean.

2 HEAT
Water was heated, and the vapour entered a second 'atmospheric' chamber.


Proteins are made up of long chains of amino acids linked up together

Did you know?
Hydrothermal vents were discovered in 1977

molecular building blocks or 'prebiotic' components for life, such as simple sugars, amino acids and fats. Why these ingredients first came together to form the structure of a cell is unknown – it may even have occurred spontaneously. However, scientists believe that protocells might have arisen from the creation of self-replicating RNA that became encapsulated by a fatty membrane, and over time this evolved and grew using proteins to become a living cell.

Putting the primordial soup theory to the test, in 1952, American chemist Stanley Miller created an experiment to simulate the origins of life. With the help of Harold Urey, the pair created the composition of an early atmosphere and ocean in a flask, then introduced a continuous source of energy to simulate lightning. After a week of conducting the experiment, the scientists discovered up to 15 per cent of the carbon in the flask had been converted into organic compounds, along with amino acids. While the experiment had created some of life's building blocks, scientists have questioned where a comparable energy source in the real world would have come from.

"Why these ingredients first came together to form the structure of a cell is unknown"

In 2010, a team of researchers published a study which turned the theory on its head. "Despite bioenergetic and thermodynamic failings, the 81-year-old concept of primordial soup remains central to mainstream thinking on the origin of life," said William Martin, an evolutionary biologist from Heinrich Heine University in Düsseldorf. "But soup has no capacity for producing the energy vital for life." Instead, many scientists have turned their attention to another potential source of life in the deepest parts of the oceans.

Some of the oldest evidence of life on Earth comes from a place where the majority of the world's modern-day life would not be able to visit, or even survive. Deep on the ocean floor, where the continental plates are pulling away from one another, are plumes of black smoke billowing from rocky vents. These underwater chimneys are called hydrothermal vents and spew out extremely hot water and sediment that have been heated by Earth's mantle. Despite the extreme environment, scientists believe

DID YOU KNOW? Around 25 per cent of Earth's internal heat is passed into the ocean via hydrothermal vents

BORN AT THE BOTTOM OF THE OCEAN

How underwater chimneys cycle water and potentially create an environment for new life

1 HYDROTHERMAL SYPHON
Ocean water falls through sediment and porous volcanic rock before entering Earth's crust.

2 CHANNELS
Water flows through channels in the crust, which were likely created by previous volcanic activity.

3 SUPER-HEATED
The molten magma in Earth's mantle heats the water in the crust up to 400 degrees Celsius.

4 CHANGE IN PH
When the water escapes through hydrothermal vents, it becomes alkaline and is packed with dissolved hydrogen.

5 OCEAN WATER
Ocean water is cold, acidic and packed with dissolved carbon dioxide.

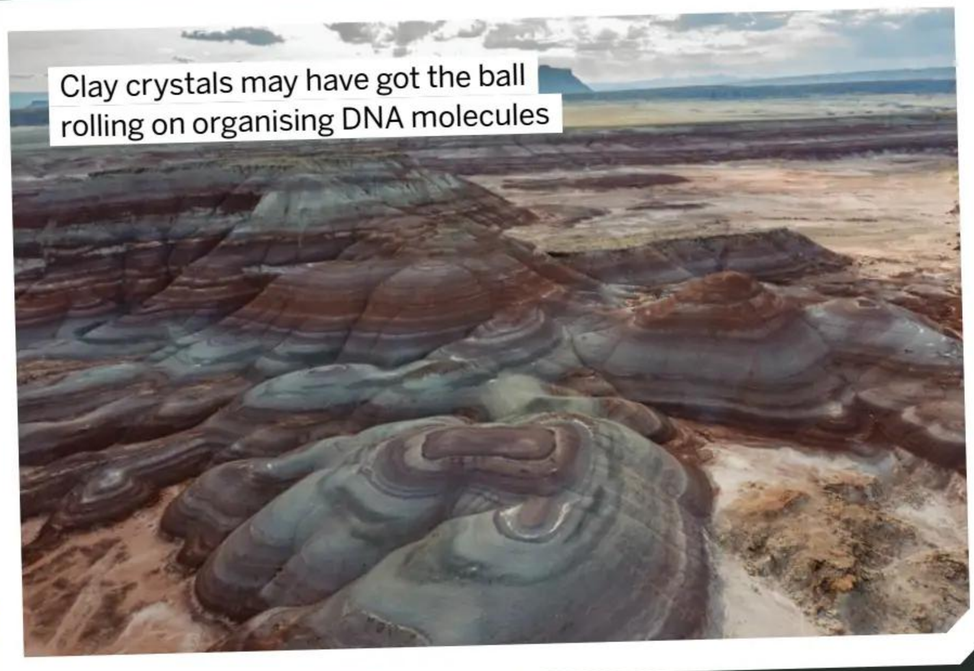
6 CHAIN REACTION
When the vent water and ocean water interact, they exchange electrons and trigger a chemical reaction that leads to the creation of protocells, building fatty acids.

7 DEPOSITS
Flowing water deposits minerals from the crust onto the seabed, forming chimneys up to around 60 metres tall.

1km
2km
3km
4km
5km

CLAY CREATIONS

Could life have emerged from clay? In 1985, chemist Graham Cairns-Smith proposed that clay crystals may have provided an environment for early life to thrive. In Cairns-Smith's controversial book *Seven Clues to the Origin of Life*, the chemist suggests that the structure of these crystals may trap molecules on their surface and arrange them in a way that's similar to the structure of DNA. After some time, these molecules would perform a 'genetic takeover', independently replicating. Although Cairns-Smith's clay theory has offered an alternative explanation for the origins of life, it has not been widely accepted by the scientific community.



Clay crystals may have got the ball rolling on organising DNA molecules

© Shutterstock / Science Photo Library

that these might be some of the most likely places where life emerged.

Hydrothermal vents are like underwater cauldrons where the vital ingredients for life can be mixed together and combined. As cold seawater falls through channels in the seafloor and down into Earth's crust, it's heated and driven upwards, erupting into the ocean through hydrothermal vents. Along the way, gases and minerals containing carbon and hydrogen are dissolved in the water.

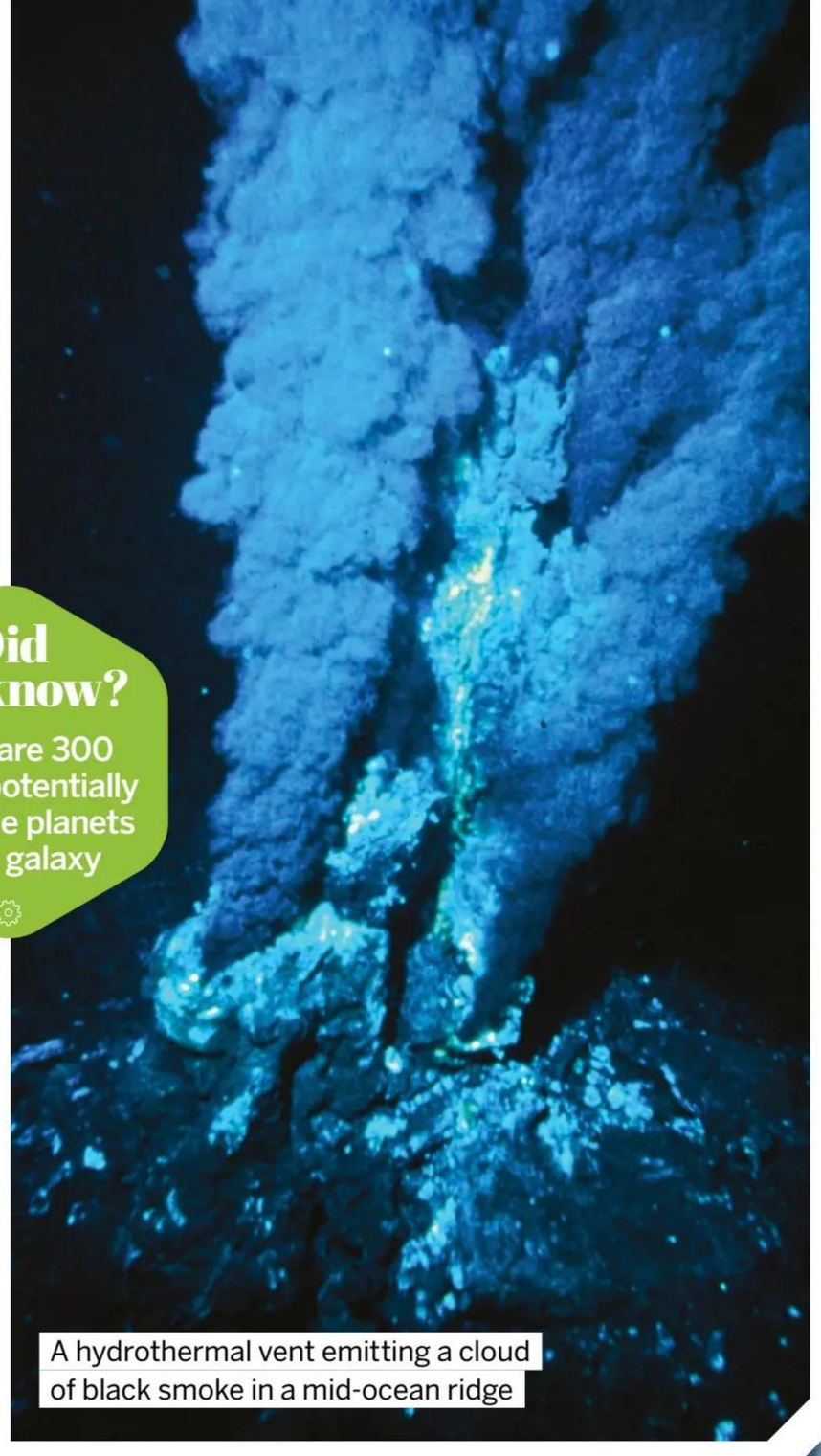
Scientists have suspected that a change in the pH of the water may have sparked enough chemical energy to transform carbon dioxide and hydrogen atoms in the water into complex molecules of amino acids or proteins. After acidic ocean water enters a vent, it emerges as an alkaline fluid. At the point where this alkaline water meets the acidic seawater, a natural charged gradient forms, much in the same way that a battery generates chemical power.

But if life didn't cook up from a primordial soup or erupt from the bottom of the ocean, could it have flown in from space? Since the time of ancient Greek philosophers, people have pondered the possibility that life may have originated on another world and found its way to Earth. This extraterrestrial origin theory has been dubbed 'panspermia'. Panspermia suggests that life is distributed throughout the universe and may have hitchhiked on an object that brought it to Earth. As to the driver of that cosmic ride, scientists have two theories: lithopanspermia suggests that bombardment by life-carrying meteorites may have brought life to Earth, while radiopanspermia suggests that early microorganisms were propelled by the radiation of stars to the surfaces of celestial bodies, including the early Earth.

Over the years, scientists have uncovered some evidence that might suggest life has an extraterrestrial past – organic molecules such as amino acids and sugars have been found in meteorite samples. However, there's been no evidence of actual life travelling on meteorites between planets. But the idea that life could exist in the vacuum of space isn't far-fetched. Since 1998, when the International Space Station (ISS) was being assembled in orbit, bacteria have been dwelling on its exterior. Possibly carried up from Earth on a rocket launch or transferred during an astronaut's spacewalk, these 'extremophile' bacteria can survive the harsh conditions of space. Scientists have studied different space-bound bacteria over the years and found that some species can survive, reproduce and grow in space.

Did you know?

There are 300 million potentially habitable planets in our galaxy



A hydrothermal vent emitting a cloud of black smoke in a mid-ocean ridge

OUTER-SPACE DELIVERY

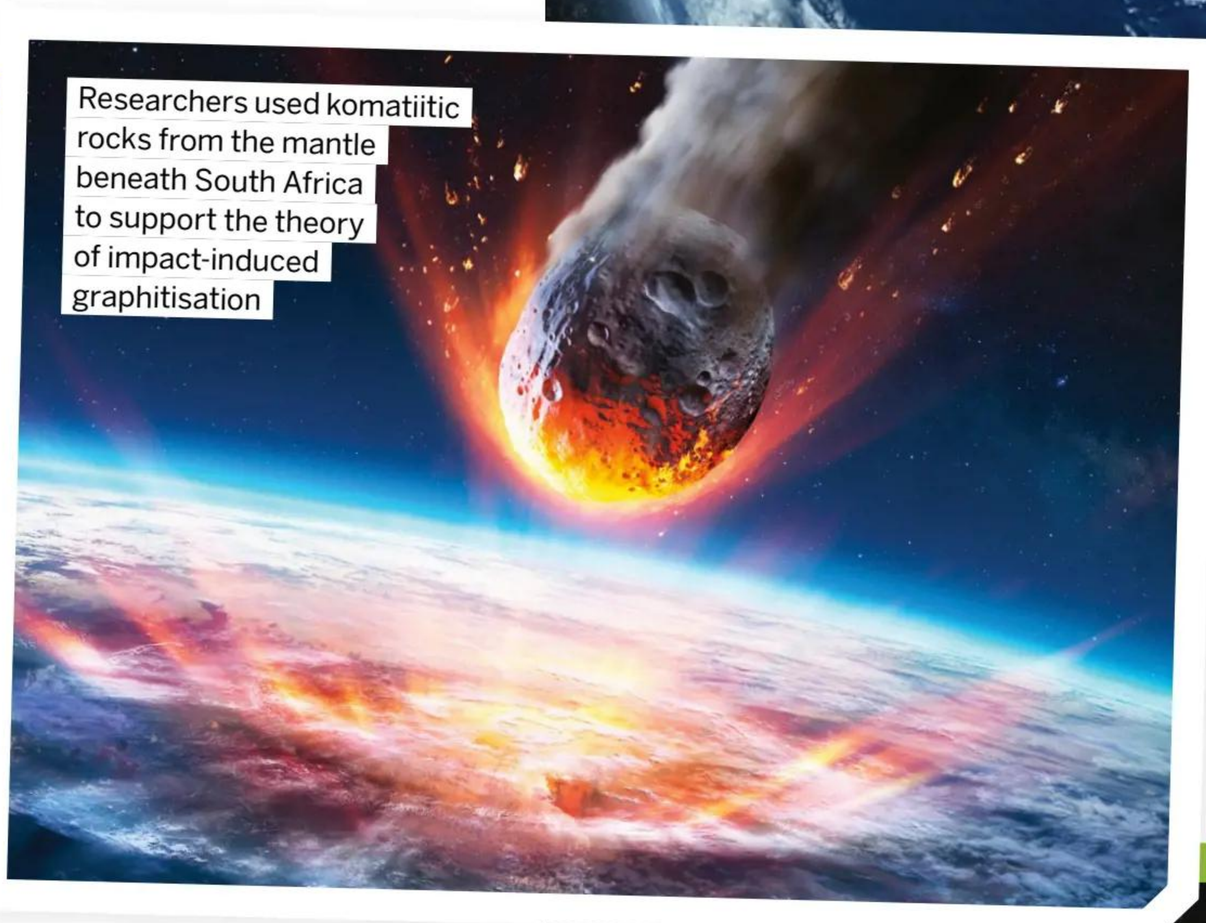
How early life might have travelled to Earth from another world

3 SPACE TAXI

The rocks thrown up in the impact contained microbes from the donor planet, which hitched a ride on these new asteroids.

4 ANOTHER IMPACT

The microbe-carrying meteorites hit the recipient planet, delivering new life or life's building blocks along the way.



Researchers used komatiitic rocks from the mantle beneath South Africa to support the theory of impact-induced graphitisation

SPACE-INDUCED LIFE

Scientists at Cambridge University have conducted research that suggests the molecules needed to form life may have been formed through a process called 'graphitisation'. Researchers think a Moon-sized object could have collided with Earth around 4.3 million years ago, delivering enormous amounts of iron and other minerals to the surface. Upon impact, the iron may have reacted with Earth's water and potentially condensed into tar. Magma beneath Earth's crust may have reacted with the newly formed tar and superheated it, converting the carbon within into graphite. What makes this process a potential catalyst for life is that it releases nitrogen-rich compounds as a byproduct, called nitriles and isonitriles, which are vital for creating the building block of life.

DID YOU KNOW? Microscopic tardigrades have survived after being exposed to space for up to ten days



2 IMPACT
A meteorite collided with the donor planet, chipping its surface and throwing chunks of rock into space.

1 SEED
Life or its building blocks emerged on a 'donor' planet somewhere else in the universe.

6 ROUGH JOURNEY
Any life aboard a meteorite would have had to survive intense radiation, extreme heat and fluctuations in gravity to reach Earth.

5 SEEDING NEW LIFE
Life-making materials entered Earth's oceans, and may have broken down to release molecules into the water that could be used to form protocells.

"The idea that life could exist in the vacuum of space isn't far-fetched"

© Alamy / Shutterstock / Illustration by Nicholas Forder



DID YOU KNOW? Bananas are berries – fruits that develop from a single ovary – but strawberries are not

FRUIT OR VEGETABLE?

Test your botanical brain in our edible plant quiz as you explore common plant confusions

WORDS **AILSA HARVEY**

As some of the simplest foods in the human diet, you might assume that the difference between a fruit and a vegetable can be easily determined. However, distinctions between the two can be blurred due to two conflicting classification systems. The culinary system, which classifies foods based on their properties for cooking, is practical for producing meals, but holds discrepancies between cultures and diets.

Scientifically, the difference between the two types of food centres around the anatomy of the plant it was sourced from. A fruit is the mature ovary of a flowering plant. Usually this is the seed-bearing part, which is responsible for reproducing more plants. Some examples of fruits include apples, peppers and bananas. The remaining edible parts of a plant are classified as vegetables. This gives vegetables an array of appearances based on the structure of the plant they were taken from. Some are leafy greens, while others are colourful bulbs that were pulled from the ground, such as onions and leeks.

Did you know?

Figs have an equal calcium content to milk

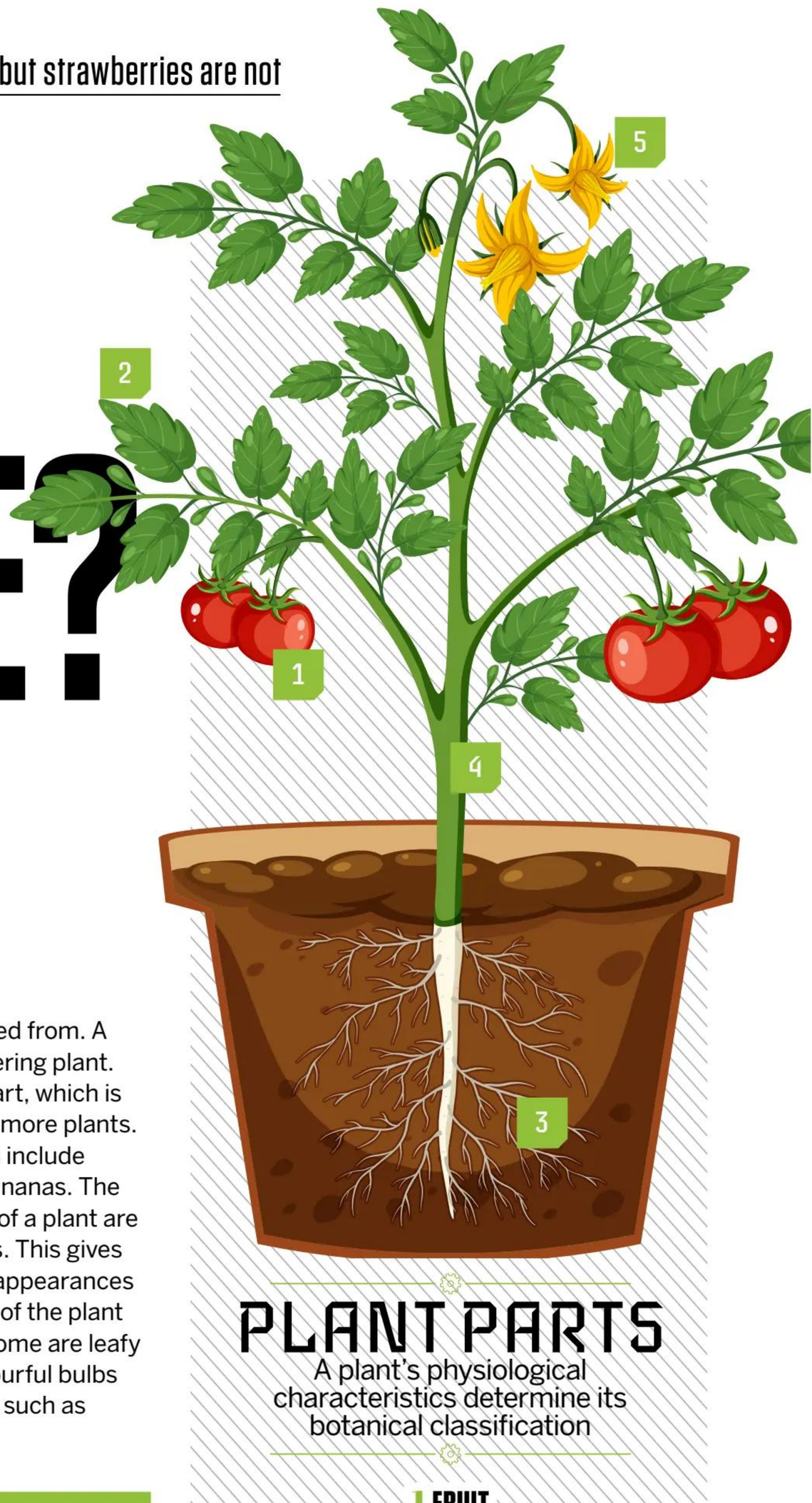
CULINARY CLASSIFICATIONS

When using foods in the kitchen, the botanical definitions are less useful to consider than the taste. This has led to culinary classifications that differ from scientific labels when it comes to grouping fruit and vegetables. Generally speaking, fruits are considered those with a sweeter or tart flavour and vegetables more savoury. A chef will consider those that can be used for desserts to be a fruit and those that make up a main meal to be vegetables.

Other properties that fall under the definition of 'vegetable' to nutritionists and chefs include tougher textures and usually a requirement to cook. Heating vegetables softens them to make them more palatable, while fruits are eaten raw. Tomatoes, which are botanical fruits, can be eaten raw but are commonly used in savoury dishes. This is why culinary classification systems define tomatoes as vegetables.



A courgette is actually a fruit, despite being considered a vegetable in the kitchen



PLANT PARTS

A plant's physiological characteristics determine its botanical classification

1 FRUIT

The tomato is the fruit of the plant – the seed-bearing structure.

2 LEAF

The leaves of many plants are edible, such as spinach, lettuce and cabbages. These are all vegetables.

3 ROOTS

Edible roots are vegetables. Some examples include turnips and beets.

4 STEM

Food that comes from the stem of a plant is a vegetable, such as asparagus.

5 FLOWER

Before turning into a fruit, flowers blossom on some plants. Edible flowers are classed as vegetables, such as cauliflower and broccoli.

© Shutterstock / Alamy

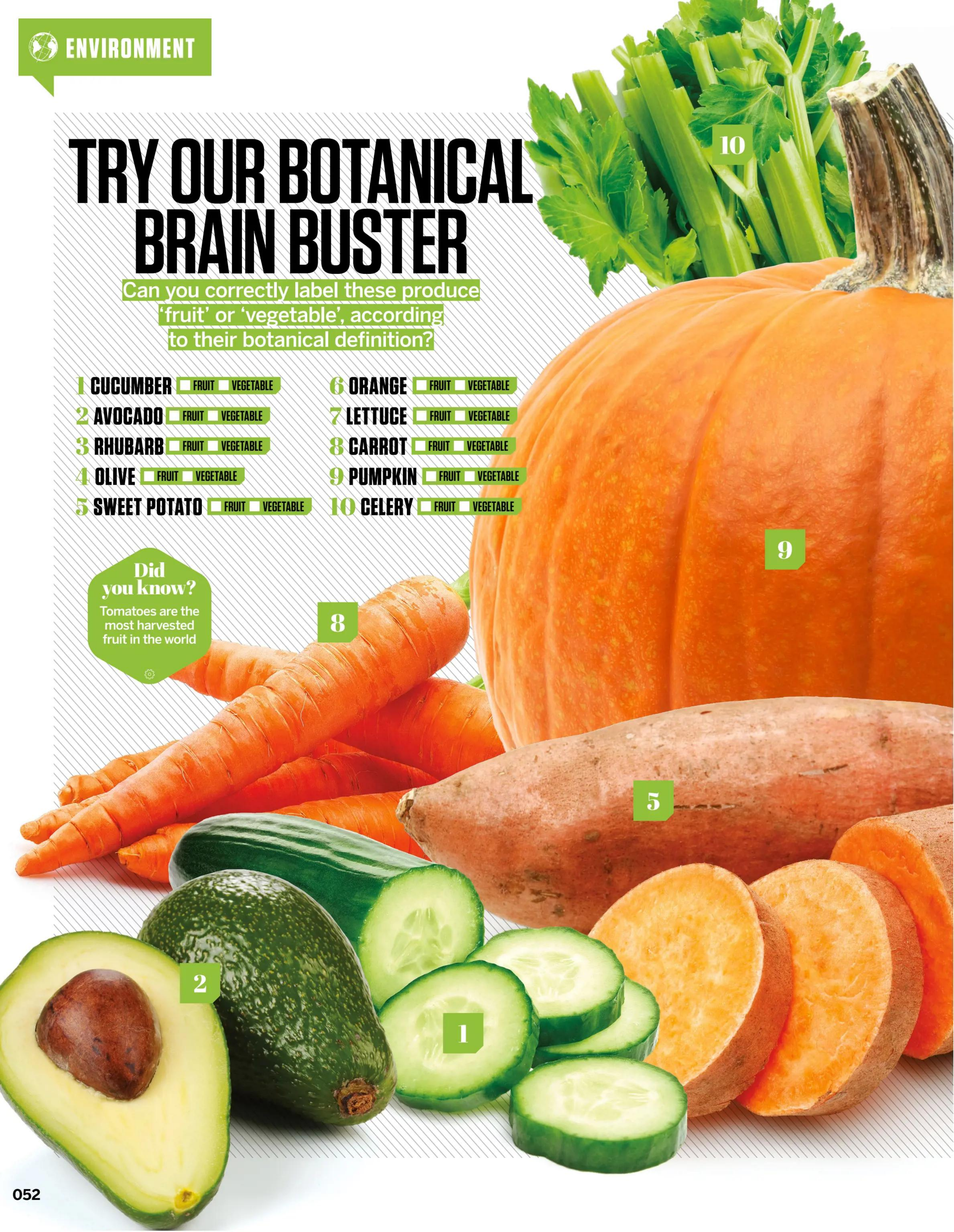
TRY OUR BOTANICAL BRAIN BUSTER

Can you correctly label these produce 'fruit' or 'vegetable', according to their botanical definition?

1 CUCUMBER ☐ FRUIT ☐ VEGETABLE
2 AVOCADO ☐ FRUIT ☐ VEGETABLE
3 RHUBARB ☐ FRUIT ☐ VEGETABLE
4 OLIVE ☐ FRUIT ☐ VEGETABLE
5 SWEET POTATO ☐ FRUIT ☐ VEGETABLE
6 ORANGE ☐ FRUIT ☐ VEGETABLE
7 LETTUCE ☐ FRUIT ☐ VEGETABLE
8 CARROT ☐ FRUIT ☐ VEGETABLE
9 PUMPKIN ☐ FRUIT ☐ VEGETABLE
10 CELERY ☐ FRUIT ☐ VEGETABLE

Did you know?

Tomatoes are the most harvested fruit in the world



DID YOU KNOW? India grows almost half of the world's mangoes



RESULTS

Count your correct answers to see which gardening title you earned

10
GARDEN GENIUS
You produced perfection

8-9
HORTICULTURE HERO
Blooming with knowledge

6-7
PLANT PUNDIT
Well-cultivated skills

4-5
HARVEST HOPEFUL
You're getting greener

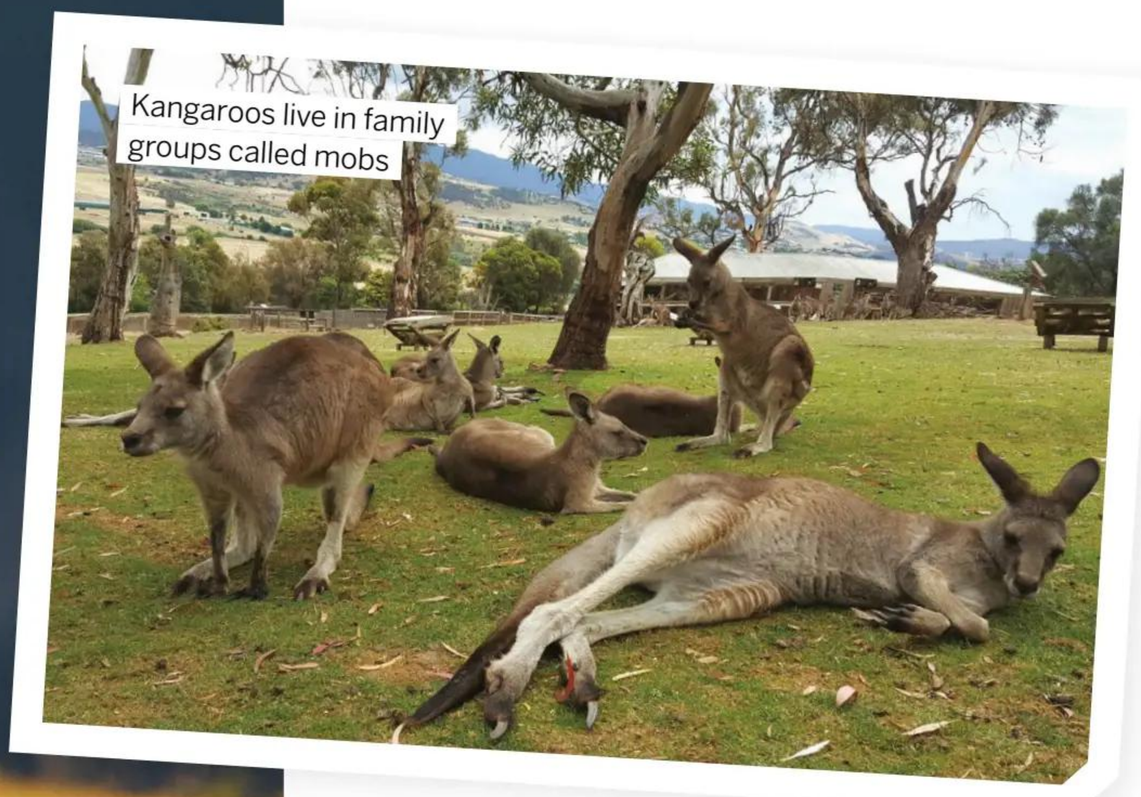
2-3
PRODUCE PUPIL
There's room to grow

0-1
BOTANICAL BEGINNER
Grand plants start as sprouts

ANSWERS 1: Fruit **2:** Fruit **3:** Vegetable **4:** Fruit **5:** Vegetable **6:** Fruit **7:** Vegetable **8:** Vegetable **9:** Fruit **10:** Vegetable

© Getty





HOW KANGAROOS BOUNCE

These marsupial mammals spring effortlessly across the Australian continent using specially adapted limbs

WORDS AILSA HARVEY

A kangaroo's posture and hopping movements are instantly recognisable. They have short arms hanging high on their chest and a thick tail that serves as an extra limb for standing and walking. But what they lack in arm length they make up for in their substantial feet and elongated back legs. Kangaroos can reach hopping speeds of over 30 miles per hour and have hearts twice as big as other mammals their size to provide them with high-speed endurance.

Kangaroos have strong, elastic tendons in their hind legs that act as springboards. When on the ground, these tendons compress and store the energy from impact. This is then released in a rebounding jump as they launch themselves into the air, similar to the way a spring releases its kinetic energy. Almost half of the power for the following jump is recycled energy from these tendons, with the rest generated from the muscles.

Unlike humans, who need to move their legs quicker to accelerate into a run, a kangaroo can increase its bouncing speed without increasing the speed of its leg movements. As a result, moving faster doesn't mean using more muscle energy. Instead, a kangaroo alters the angle of takeoff to vary the distance travelled between jumps. Kangaroos haven't always been hoppers, however. Fossil evidence suggests that 25 million years ago, their ancestors didn't need to travel long distances, and instead climbed trees for food. As Australia's rainforests diminished and transformed into flat, grassy plains, kangaroos evolved to jump across the continent in search of food.

Did you know?

Kangaroos can travel nine metres in a single hop

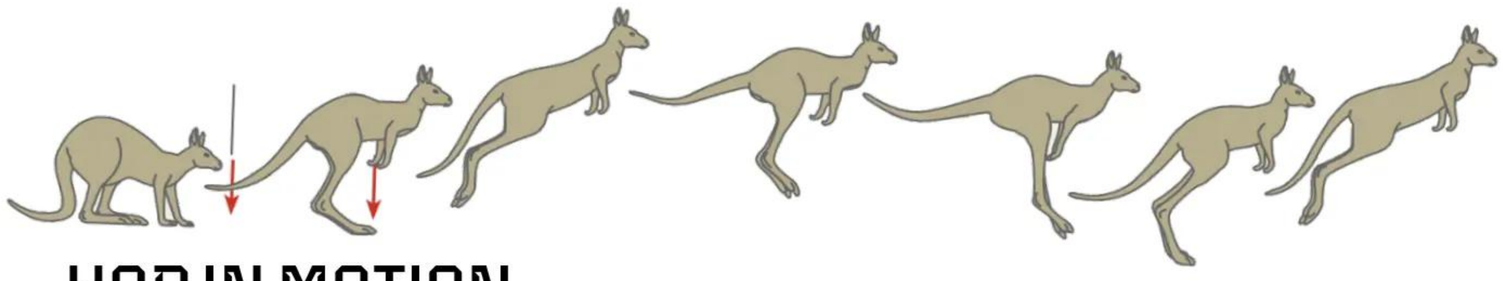
OUT OF THE POUCH

A young kangaroo is called a joey. When it's born, a joey is only two centimetres long, making it very vulnerable if it were to navigate the world alone. After birth, the joey climbs across the mother's fur and into the pouch at the front of her body, where it stays and feeds on her milk for a further few months. When a joey first leaves the pouch, this will only be for short outings. And before learning to bounce, they learn to walk. This involves transferring their weight from their back legs to their arms while adjusting their back legs forwards. As they repeat this, they begin advancing in a crawl-like manner. When a kangaroo becomes more used to being mobile, they begin to remove their arms from the process, stand more upright and begin jumping. At eight months old, a young kangaroo is usually able to live fully outside the pouch.



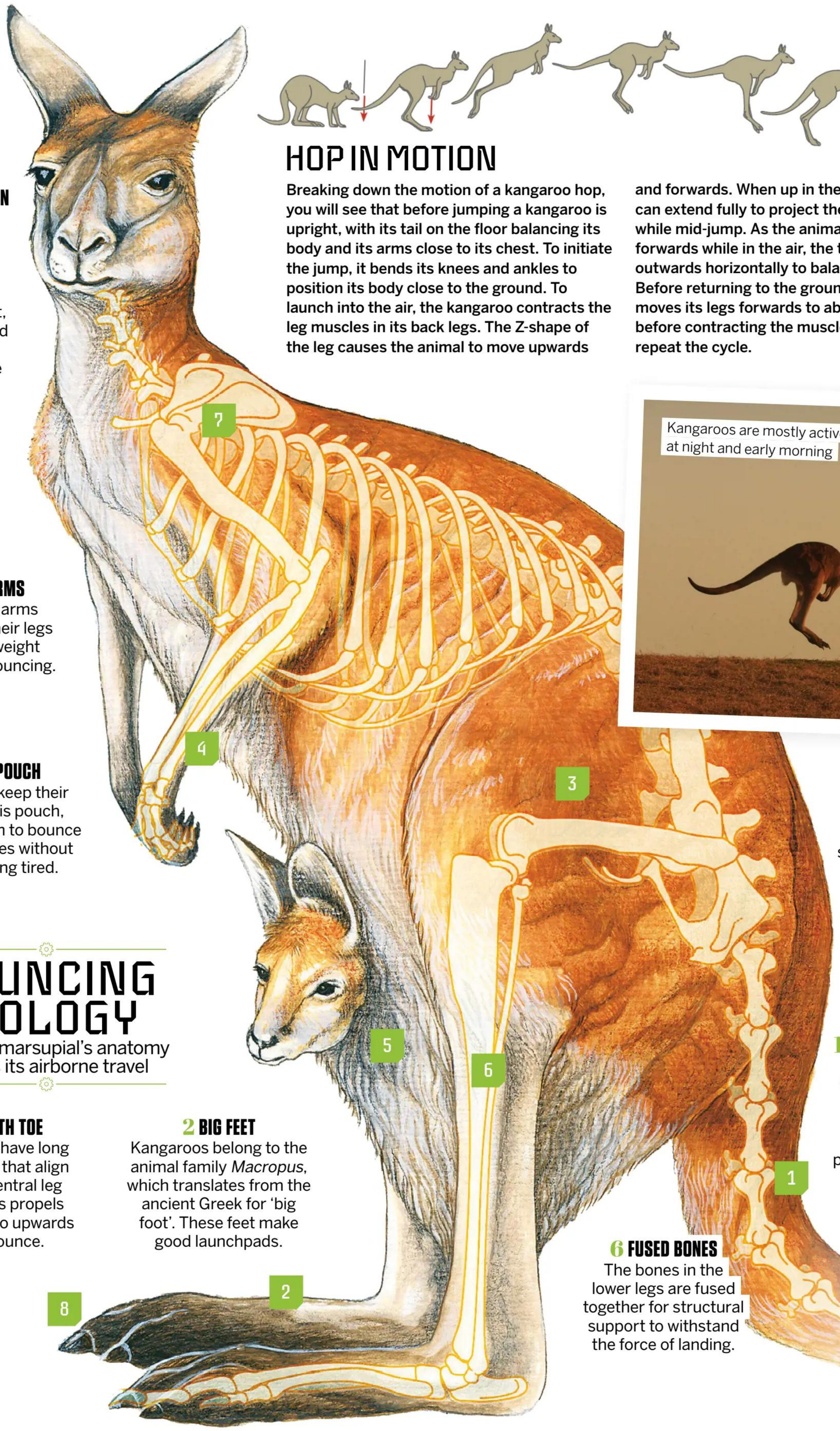
A joey has short trips outside the pouch from around six months old

DID YOU KNOW? Bouncing pushes a kangaroo's gut up and down and against the lungs, helping it breathe



HOP IN MOTION

Breaking down the motion of a kangaroo hop, you will see that before jumping a kangaroo is upright, with its tail on the floor balancing its body and its arms close to its chest. To initiate the jump, it bends its knees and ankles to position its body close to the ground. To launch into the air, the kangaroo contracts the leg muscles in its back legs. The Z-shape of the leg causes the animal to move upwards and forwards. When up in the air, the legs can extend fully to project the animal further while mid-jump. As the animal is slightly tilted forwards while in the air, the tail stretches outwards horizontally to balance the animal. Before returning to the ground, the kangaroo moves its legs forwards to absorb the impact before contracting the muscles again to repeat the cycle.



7 LIGHT SKELETON
Compared to other animals their size, kangaroos' skeletons are lighter in weight, increasing speed and energy efficiency while reducing joint strain.

4 SHORT ARMS
Having short arms compared to their legs reduces the weight carried when bouncing.

5 JOEY POUCH
Kangaroos keep their young in this pouch, enabling them to bounce long distances without joeys getting tired.


Kangaroos are mostly active at night and early morning

3 HIND LEGS
Their legs have powerful muscles and stretchy tendons to spring them into the air.

BOUNCING BIOLOGY
How this marsupial's anatomy assists its airborne travel

8 FOURTH TOE
Kangaroos have long fourth toes that align with the central leg bones. This propels the kangaroo upwards into a bounce.

2 BIG FEET
Kangaroos belong to the animal family *Macropus*, which translates from the ancient Greek for 'big foot'. These feet make good launchpads.

1 BALANCING TAIL
Measuring up to one metre in length, a kangaroo's muscular tail provides stability during a jump.

6 FUSED BONES
The bones in the lower legs are fused together for structural support to withstand the force of landing.

© Alamy / Shutterstock

HOW ANIMALS SEE THE WORLD

Take a tour of the world through the eyes of animals that have a very different perspective

WORDS SCOTT DUTFIELD

DID YOU KNOW? Mantis shrimp can see ten times as many colours than the human eye



Just like humans, in animals the ability to see comes from cells called photoreceptors, which are found in a light-sensitive layer at the back of the eye called the retina. When excited by light, these cells generate an electrical signal that travels along nerve cells to the brain to create an image. Among these are two types of photoreceptors, called rod and cone cells. Rod cells are responsible for communicating brightness and the contrast between light and dark. Cone cells, on the other hand, perceive a wide array of colours. Within the human eye, there are around 6 million cone cells, of which there are three types: blue, green and red. Rod cells, however, dominate the retina, with around 120 million cells in each eye.

When the photoreceptor cells are excited by photons of light, it triggers the cells to release a neurotransmitter molecule called glutamate. These molecules then travel across a short junction to reach an adjacent bipolar cell, generating an electrical impulse that is sent to the brain for the translation and formation of an image.

Did you know?

Ostrich eyes are bigger than their brains

Not all animals have eyes, but many can still 'see' the world around them. For example, sea urchins use light-sensitive cells on the tubular feet covering their bodies. The photoreceptors across the sea urchin's body provide a 360-degree 'view' of changes in light levels around it.

© Shutterstock

THE ANATOMY OF SIGHT

How rod and cone cells perceive colour and brightness

1 DISCS
Flat discs that are densely packed with light-sensing molecules to absorb light.

6 LIGHT
A pigment called rhodopsin in the rod cell discs is responsible for perceiving light and dark.

5 COLOUR
A pigment called photopsin in the cone cell discs is responsible for detecting different wavelengths of light.

2 MITOCHONDRIA
As they do in any cell in the body, mitochondria supply the rod and cone cells with chemical energy to function.

3 NUCLEUS
This organelle houses all the genetic information needed for cone and rod cells to grow and regenerate when damaged.

4 SYNAPTIC ENDING
When the cell is stimulated by light, a series of chemical reactions within the cell cause it to release a neurotransmitter called glutamate from the synaptic ending, to bind with adjacent nerve cells.

ROD

CONE

Did you know?
A dragonfly's eye has 28,000 lenses

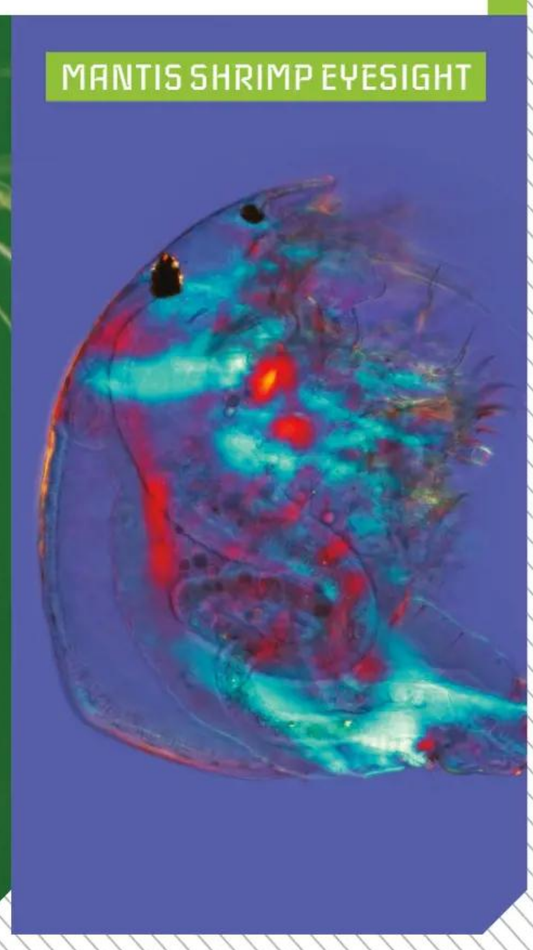


SEEING THE POLAR OPPOSITE

Ordinarily, ambient light travels in wavelengths that move in every possible direction and orientation. However, light is 'polarised' when its wavelengths all travel in the same direction. The polarisation of light can be caused by a lot of things – sometimes when it's scattered by the atmosphere or reflected by a surface – but only certain groups of animals are able to see it. Among those are mantis shrimp, bug-eyed crustaceans living in coral reefs. Unlike our single-lensed eyes, mantis shrimp have 'compound eyes' with thousands of individual lenses and photoreceptors.

Within each photoreceptor are tiny projections called microvilli. Some of the microvilli can align in such a way that they can act as a polarising filter for light. They work similarly to how sunglasses can filter polarised light. Mantis shrimp are thought to have evolved this ability to spot prey at greater distances. Scientists have also found that certain parts of the shrimp's bodies can reflect polarised light as a way to communicate with one another.

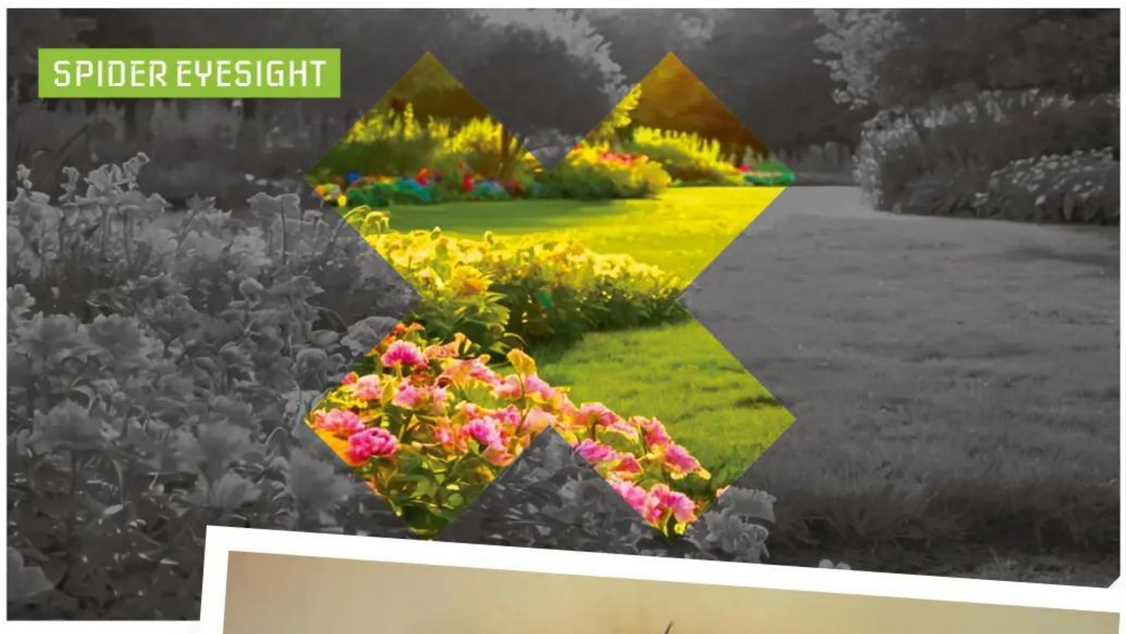




DID YOU KNOW? A moth's eyes are covered in a water-repellent and anti-glare coating

X MARKS THE SPOT

With the same number of eyes as legs, spiders have an array of sight organs in their head to spot potential prey and any incoming predators. There are two types of spiders in the animal kingdom: those with two rows of eyes, such as wolf spiders, or a single row like jumping spiders. Of their eight eyes, the two largest are set in the front of the head and are used for focusing on an image, but each only has a narrow boomerang-shaped view. The remaining eyes gather information from their peripheral vision. The front principal pair of eyes can observe the full range of colours humans can and more, including ultraviolet light. However, the secondary adjacent eyes lack colour-sensitive cells. They can only see in black and white and don't have the same high acuity the two primary eyes have. All eight eyes work together to create an almost-360-degree view of the world.



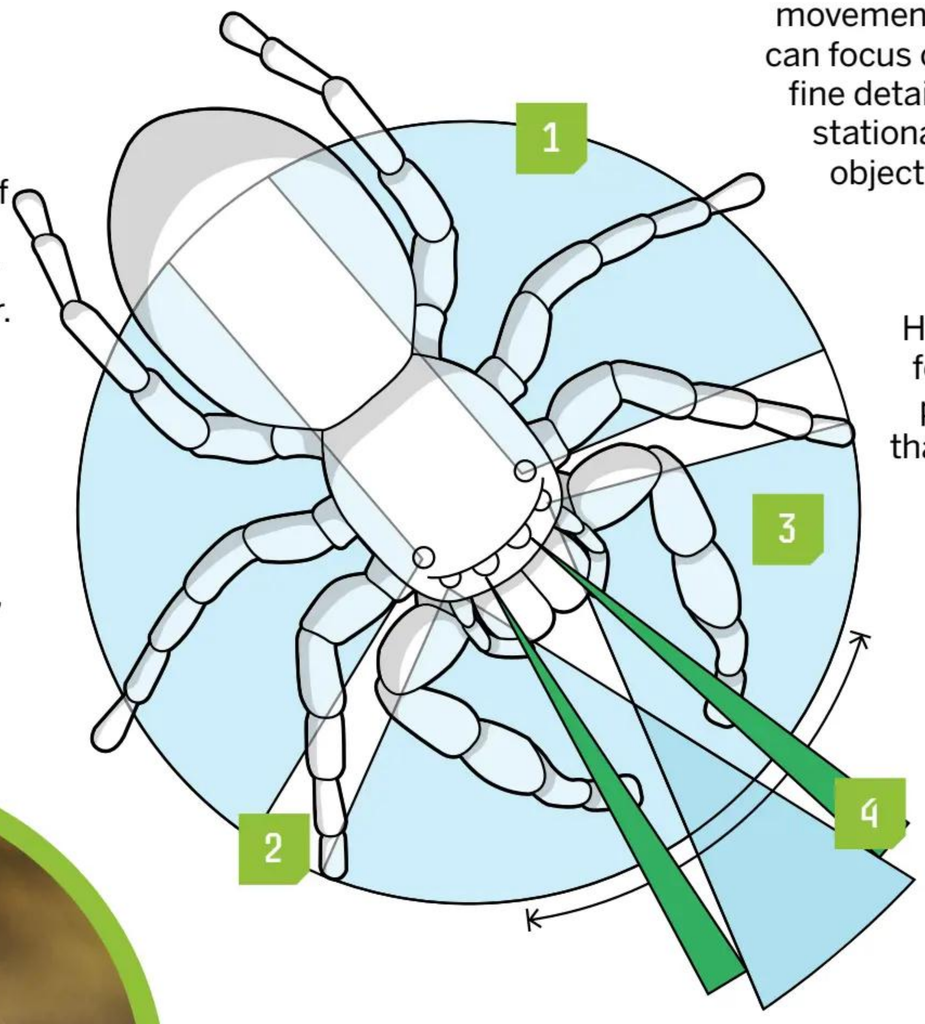
EIGHT-EYED

Having more than two eyes gives these animals an advantage when it comes to hunting



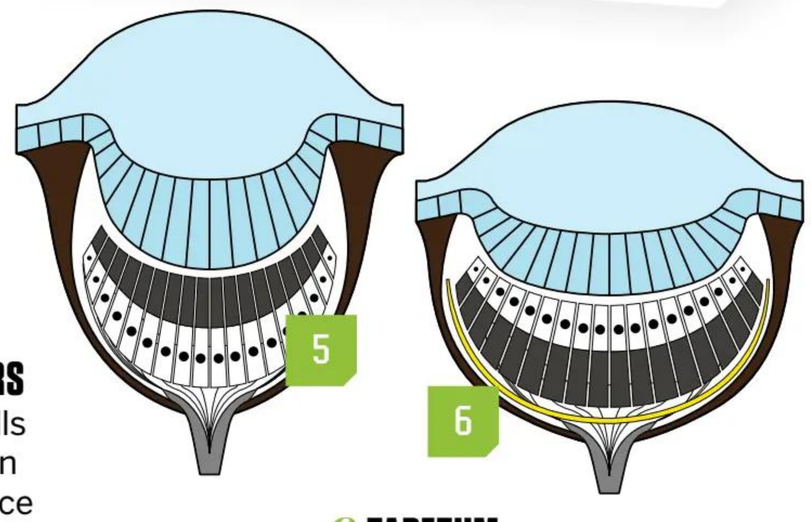
1 POSTERIOR LATERAL EYES
Sat at the back of the head, these monitor the rear view of the spider.

2 POSTERIOR MEDIAL EYES
Found on the sides of the head, these are highly sensitive to low light.



3 ANTERIOR LATERAL EYES
These are highly sensitive to movement and can focus on the fine details of stationary objects.

4 ANTERIOR MEDIAL EYES
High-resolution, forward-facing principle eyes that see in colour.



5 PHOTORECEPTORS
Photoreceptor cells in the retina within the primary eye face towards the light, but are inverted within the secondary eyes in some species of jumping spiders.

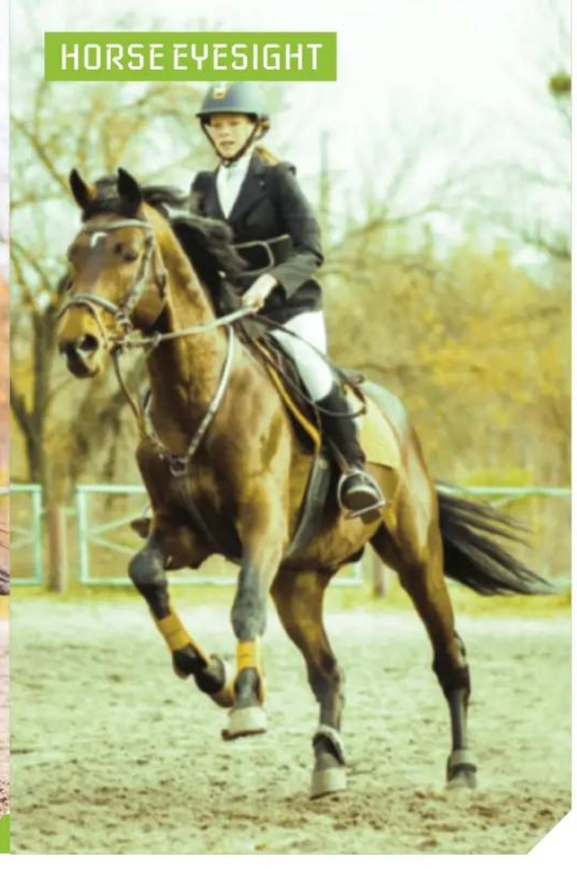
6 TAPETUM
A reflective tissue found at the back of the eyes used to increase the amount of light detected by the inverted photoreceptor cells in the secondary eyes.



A GREEN WORLD

Unlike humans, horses only have two of the three colour cone cells in their eyes. Without any red-light cone cells, our equine pals can only see blue and yellow wavelengths, with all the variety of shades associated with those colours – mostly greens. But what they lack in their ability to see colour, they make up for in night vision. Horses have a ratio of around 20:1 rod to cone cells. For comparison, a human eye has a ratio of about 9:1 rod to cone cells. As rod cells are responsible for detecting light at low levels, having so many rod cells gives horses excellent night vision. Horses also have a layer of reflective tissue called the tapetum lucidum at the back of the eye, something our eyes aren't equipped with. It reflects light through the retina to enhance the horse's night vision, but it can blur images whenever the eye is overloaded with light.





© Alamy / Shutterstock / Illustration by Ed Crooks



INFRARED VISION

A snake's vision is dichromatic, meaning they have just two types of cone cells in their retinae that allow them to see blue and green. However, snakes have evolved another organ that assists their eyes and creates a thermal image in their heads. Between a snake's eyes and nostrils are heat-sensitive depressions called the pit organ. Scientists still aren't completely sure how, but this organ can pick up on the infrared waves emitted from the snake's environment and nerve impulses to create a thermal image of the world around it in the snake's brain.

As fearsome predators, this gives these animals an advantage over their prey during the dark of night. The warm bodies of prey such as small rodents or birds emit a lot of infrared, which the snake is sensitive to, allowing them to detect their prey's movements in the darkness to ambush them.





ULTRAVIOLET SIGHT

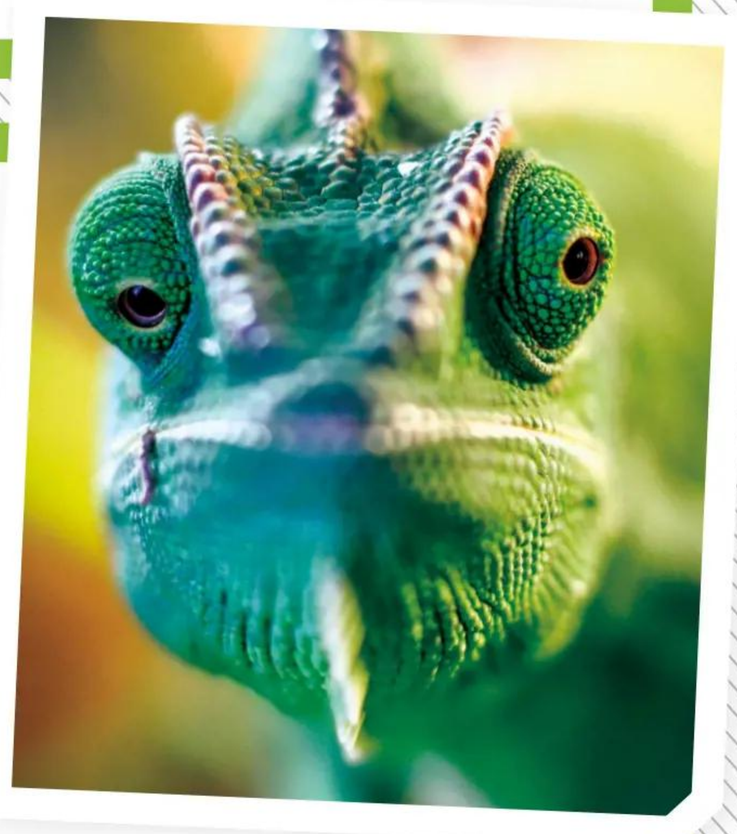
Many insects, including the humble bumblebee, have a talent for seeing in a range of light wavelengths much narrower than we do. Our vision allows us to see light in wavelengths of around 380 to 700 nanometers. However, insects like bees can observe light wavelengths of around 300 to 650 nanometres. While bees miss out on longer wavelengths of light, such as red light, they can see shorter wavelengths of ultraviolet light. As an important pollinator, bees rely on their ultraviolet vision to locate flowering feeding sites. Many flowering plants have evolved ultraviolet patterns on their petals to grasp the attention of passing pollinators. Bees use these patterns as landing sites to locate delicious nectar within the flower, gathering pollen along the way.



SEEING EVERY ANGLE

The ability to see the whole world around you without needing to move a muscle is an ability few animals have. Chameleons, however, have evolved a pair of eyes that can do just that. The cone-shaped eyes of these reptiles have adapted to move individually and can pan around their surroundings to create a 360-degree view of their environment. They can also switch between binocular and monocular vision so that they can see an object with both eyes or using just one.

Chameleons see the full spectrum of light that humans do, as well as viewing extras, including ultraviolet and infrared. Ultraviolet light in particular is a handy way to spot pollinator prey at nighttime. Chameleons have no rod cells in their retinae, which means they are almost completely blind at night. Their ability to see ultraviolet light is the only way they can see in the dark. Studies have also shown that chameleons have ultraviolet patterns on their bodies, which might be used for attracting a mate.





DID YOU KNOW? Colossal squid have the largest eyes in the animal kingdom, measuring up to 27 centimetres wide

THE SHARPEST SIGHT IN NATURE

If you find yourself scoring 20/20 vision at your next opticians appointment, don't be too smug, because there's a group of animals that are sure to have you beat. Eagles have 20/4 or 20/5 vision, meaning these birds can see things at around six metres that a person with normal vision could only see at around 1.5 metres. This talent comes in handy when soaring high in the sky looking down to spot unsuspecting prey.

What separates human and eagle eyes are the many 'foveae' within them. Within the retinae are depressions of these tightly packed photoreceptor cells, responsible for creating the sharpness, or 'high acuity', of an image. The human eye has a single fovea in each eye, whereas an eagle has two. The number of photoreceptors within each fovea is also worlds apart for humans and eagles, with just 200,000 cone cells per millimetre in a human fovea and around a million cone cells in an eagle's fovea. Their collection of cones also allows them to see a wider range of colours than humans can, including ultraviolet light.



Did you know?

Butterflies have 15 different types of cone cells

5 FACTS COLOUR-BLIND CREATURES

1 WHALES
Living in oceans and waterways made up of different shades of grey, all species of whale swim without the ability to see colour, but they can distinguish between light and dark.

2 SEALS
Like most other marine mammals, seals can also only see in black, white and grey. Their vision is well suited to life underwater, but less so on land.

3 SNAILS
Known to have poor eyesight, snails have a very blurry image of the world that is completely black and white.

4 PRIMATES
Many primates have trichromic vision similar to our own. However, some nocturnal monkeys, such as the owl monkey, have monochromatic vision. With more rod cells than cone cells, these monkeys have excellent night vision.

5 SHARKS
With only one type of cone cell and one type of rod cell in their retinae, it's thought that sharks are monochromatic seers. Scientists have found that at least ten species of sharks have no cone cells at all.

HOW DO WE KNOW WHAT ANIMALS SEE?

When it comes to estimating what colours animals might be able to see, peering into the anatomy of their eyes is crucial. While examining the cellular composition of the animal's retina, scientists can locate and count the number of colour-sensitive cone cells. If the retina is missing these cells, then scientists know that the animal is most likely colour blind. The same conclusion can be drawn by scanning the brain activity of animals to see how the activity changes when the animal is exposed to different colours. When it comes to identifying the perception of different light wavelengths, such as ultraviolet or polarised light, scientists often set up experiments for animals to interact with objects that are known to reflect or emit those wavelengths of light. For example, one of the first experiments to prove mantis shrimp could see polarised light used food containers that reflected polarised light and others that didn't. The shrimp were more likely to interact with the containers that reflected polarised light.



Scientists use a combination of anatomical and behavioural studies to determine an animal's sight

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Hippopotamuses have 36 teeth to crush and grind up food



MUNCHING MOLARS AND FEROCIOUS FANGS

AI generated jungle background: Adobe Photoshop & Adobe Stock

Peer inside the mouths of animals to discover how they use their teeth to eat, hunt and fight

WORDS SCOTT DUTFIELD

Whether they're chewing on grass, tearing through flesh or fighting off a foe, teeth are an essential survival tool for the world's animals. A tooth is a layered structure made from hardened calcium carbonate that erupts from a vertebrate's jaw and is used to puncture, cut and grind food. For many animals, such as primates, teeth emerge after birth; others, such as rabbits, are born sporting permanent gnashers.

The shape and size of a species' teeth are specific to their lifestyle. In carnivorous members of the animal kingdom, teeth are sharp – even serrated in sharks – to allow them to tear through meat. The mouth of a herbivore favours flatter and sturdier molars to grind down the volume of plant matter they consume. For omnivores, a balance of the two types of teeth allows them to consume both plants and prey.

Did you know?

Giant armadillos have 74 teeth

Teeth aren't just used to tackle food, but as tools and built-in weapons. As dedicated herbivores, elephants need only a set of robust molars to munch down on fruits and leaves. Nevertheless, these mighty giants have evolved a pair of enormous incisors, commonly known as tusks. With no need to spear prey, elephants use these teeth to strip bark, lift objects, fend off predators and settle elephant arguments. Snakes have a pair of elongated teeth known as fangs, and many snake species have adapted fangs that are hollow and can deliver venom to any unfortunate prey that they puncture with them.

MISMATCHED TEETH

Fish are no strangers to sporting a few teeth, as seen in the razor-sharp mouth of a piranha or the needle-lined jaw of an anglerfish. However, an unusual little fish swims through the Gulf of Mexico with a set of human-like teeth in its mouth. Known as the sheepshead fish (*Archosargus probatocephalus*), these ray-finned creatures have evolved to hunt the hard-shelled bodies of crustaceans and molluscs. To crack through their tough exoskeletons, sheepshead fish have evolved a jaw full of molars and incisors that are arranged in three rows – one in the upper jaw and two in the lower jaw. Accompanied by powerful jaw strength, the crushing force of this fish's teeth can easily break into any exoskeleton, allowing them to feast on the flesh within.

No, this sheepshead fish hasn't stolen someone's dentures



DID YOU KNOW? Over the course of its life, a great white shark will grow as many as 20,000 teeth

CARNIVORES VS HERBIVORES

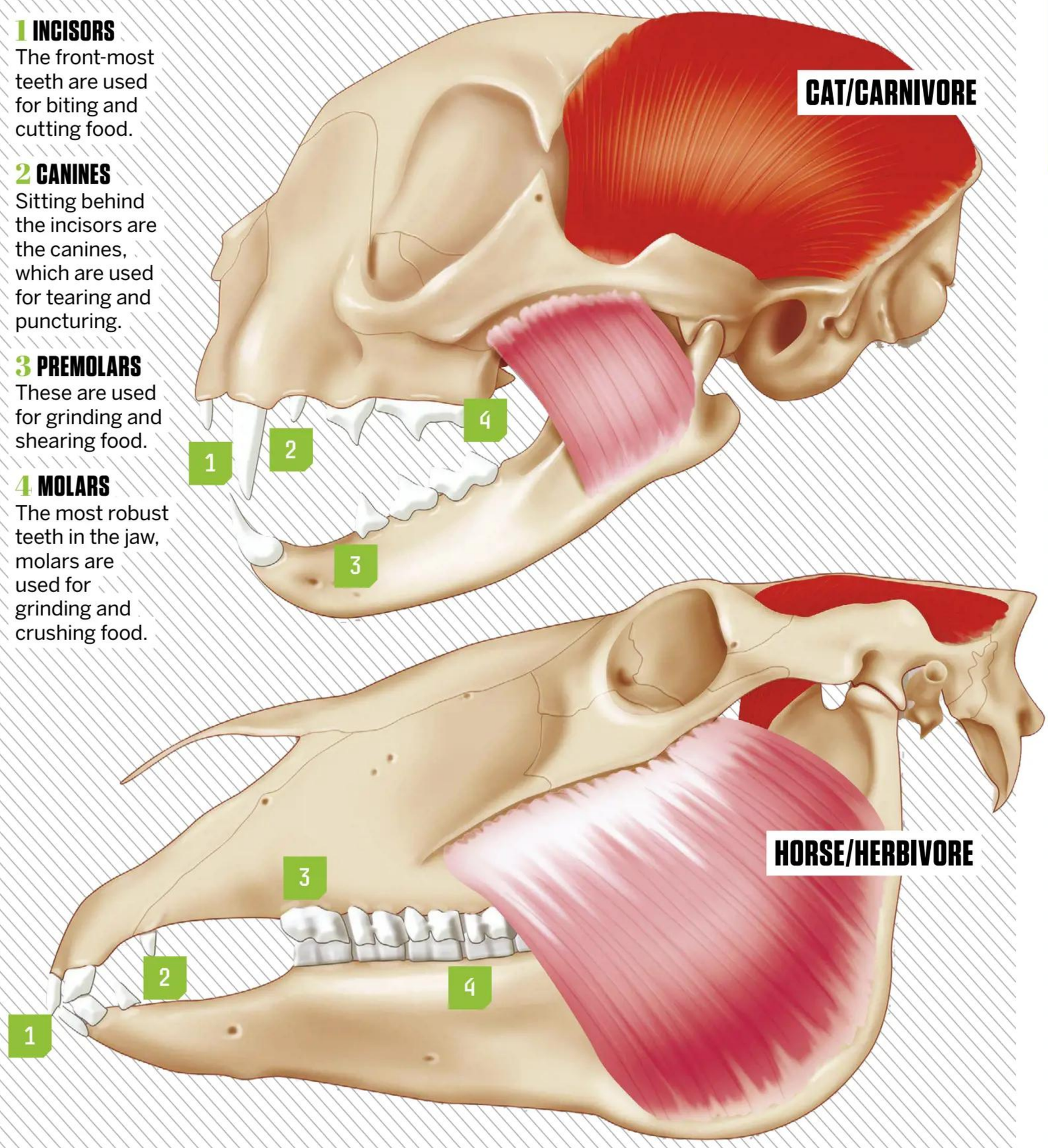
They both have teeth, but with varying dental proportions and purposes

1 INCISORS
The front-most teeth are used for biting and cutting food.

2 CANINES
Sitting behind the incisors are the canines, which are used for tearing and puncturing.

3 PREMOLARS
These are used for grinding and shearing food.

4 MOLARS
The most robust teeth in the jaw, molars are used for grinding and crushing food.



5 FACTS DIFFERENT DENTITION

1 HOMODONT
Many non-mammalian vertebrates, such as sharks and reptiles, have a mouth full of teeth which are all the same shape but vary in size.



2 HETERODONT
These animals have different teeth structures, such as incisors, canines and molars. This covers most mammalian species, including humans.



3 ACRODONT AND PLEURODONT
Many reptiles have teeth that are fused to the surface of the jawbone. Acrodont animals have teeth that emerge straight up from the jaw, while the teeth of pleurodont animals show up on the sides of the jawbone.



4 POLYPHYODONT
Whereas humans and some other mammals have baby and adult teeth, many animals, such as sharks and crocodiles, continually lose and regrow teeth.

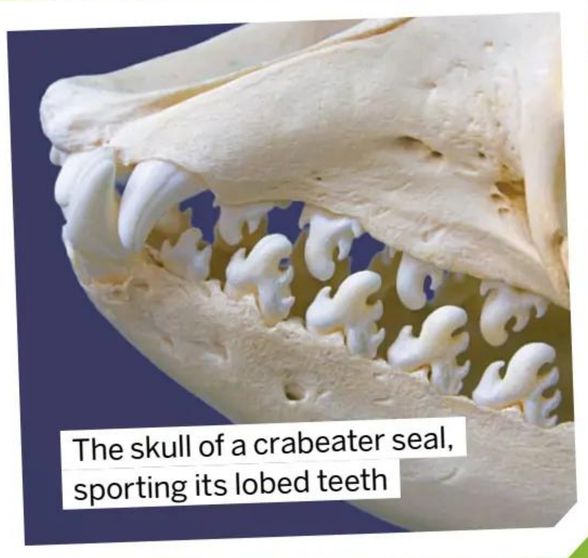


5 AGLYPHOUS
The teeth of snakes are oriented to face backwards, away from the mouth opening. This prevents prey from climbing back out of their mouths.



CARVED CANINES

The crabeater seal (*Lobodon carcinophaga*) has arguably the strangest looking teeth in the animal kingdom. Despite their name these seals don't eat crabs, instead feasting on krill that swim around the Antarctic. Early whalers mistook the specialised lobed teeth of these marine mammals as an adaptation used to crack open crustaceans. The truth is that the unusual shape of their teeth acts like a sieve that filters out krill while they swim through the water. Unfortunately, the crabeater's name stuck long before the truth about their teeth was discovered.


The skull of a crabeater seal, sporting its lobed teeth

© Alamy / Getty / Shutterstock



HISTORY

INSIDE MEDIEVAL HOMES

Step inside the grand designs of the Middle Ages and discover what life was like

WORDS SCOTT DUTFIELD

Following the fall of the Roman Empire, Europe was propelled into a new era commonly known as the medieval period, or the Middle Ages, which lasted until around 1500. Without emperors to dictate society, new feudal systems slowly emerged throughout the continent, where kings would bestow land and residences on nobles and lords, and ultimately the creation of the early class system was born. With that came a new way of life for different people.

At the bottom of the social ladder were peasants, also known as serfs, who lived in the most desolate of conditions. During the early medieval period, peasants' homes were made of sticks and earth. Heat and a means of cooking food were provided by a fire, the smoke from which would billow through the thatched roof. These often single-room occupancies were sparsely furnished, with straw beds usually shared with livestock. Life as a serf during the Middle Ages was profoundly impacted by the movement of the Sun. Those who lived in basic homes were not able to live by expensive candlelight, instead resorting to the fleeting illumination of a rushlight. To make a rushlight, a long stick from a rush plant was dipped in spare animal fat, called tallow, and lit so that it burned horizontally. Unlike the hours of light a wax candle can provide, these homemade lights would burn for less than an hour.

Did you know?

Prague Castle covers around 70,000 square metres

On the next rung of the ladder were the middle classes, such as doctors and merchants, who were often found in townhouses enjoying some luxuries, such as fireplaces and canopied beds, which emerged during the 13th and 14th centuries. Wood remained the prominent building material, with timber frames forming the bones of many townhouses, farmhouses and



DID YOU KNOW? Livestock were tried in court for killing people during medieval times



© Getty

guildhalls. Walls were formed using a combination of wattle and daub – rows of short timber or stacks, known as wattles, were woven together and packed with a malleable clay-and-mud plaster called daub. Once dried, the wattle-and-daub walls hardened, creating a waterproof barrier from the outside world. Many homes were built as large open spaces, where families gathered within the main living space, called the hall. There were few internal walls, meaning privacy was a novel concept until the use of hallways and separated rooms became popular during the 1200s. Within two-storey homes, a separate private room called the solar was constructed above the hall and included bed chambers.

The upper echelon of society – nobility and the royal head of the feudal pyramid – occupied Europe's many manors and the first stone castles from the 11th century. Seen as an unyielding and permanent building material, the use of stone was reserved for castle-making. Some of the first stone castles in Europe, such as Colchester Castle in England, were even built on top of the foundations of Roman temples. Manors and castles boasted separate bedrooms throughout connected wings, often placing the king's room at the highest point in the castle for protection. Unlike the public bathhouses used by the lower classes, the nobility enjoyed private bathrooms to wash themselves. Similarly, while peasants did their business in the woods and the middle classes used outhouses or public latrines, the nobility used constructed castle 'garderobes' or 'privy chambers' to release their waste into the encompassing moat.

Did you know?

The world's first mechanical clock was invented in the 13th century

To fill the long dining tables of the great hall, food was plentiful in medieval kitchens and pantries. Throughout the thousand years of medieval history, people invented new and innovative ways to store food, both in the royal kitchens and humble pantries. Pickling, salting and smoking were some of the many ways people kept food safe. Some purpose-built 'still houses' were constructed to dry out fruits and herbs in places where domestic homes didn't receive enough sunlight to dry them out.

Before the stove was invented during the 18th century, medieval cooking was carried out directly over a fire. Among the poorer members of society, community kitchens were built to provide public sustenance, whereas wealthy homes were kitted out with pots and pans for private meals. To redirect the smoke produced from cooking on an open fire, outdoor chimneys were invented in Western Europe during the 12th century.



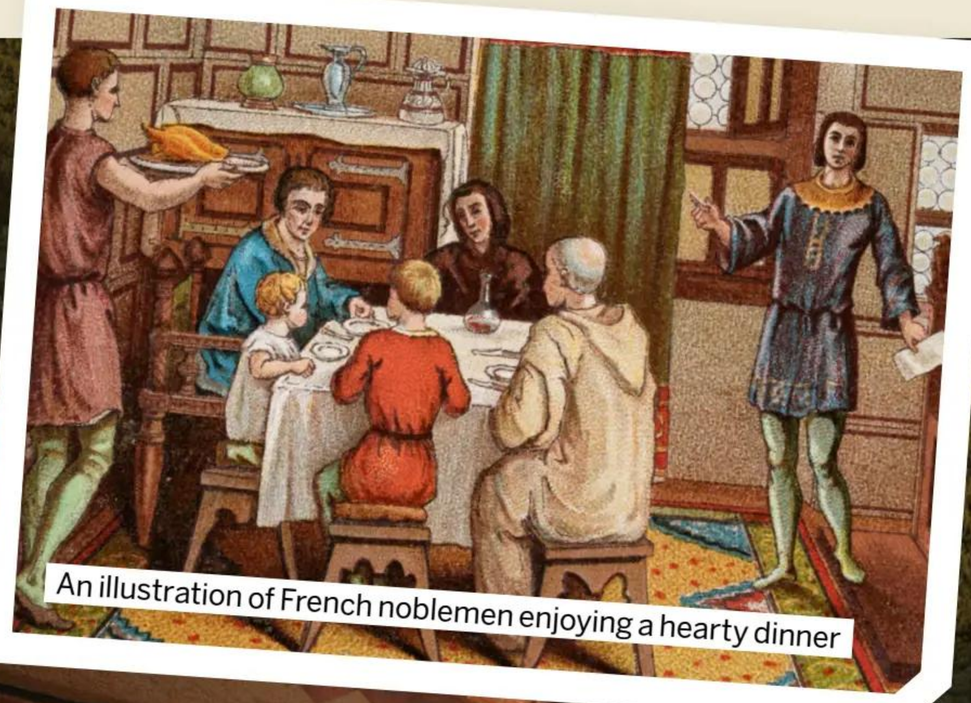
DID YOU KNOW? Between 1000 and 1347 CE, the population of Europe grew from 35 to 80 million people

9 ROOF

A variety of materials were used to build the roofs of European medieval homes, inducing clay and slate. Water reeds were commonly used on farmhouses to create thatched roofs.

5 BED

The construction of beds differed across the classes in the Middle Ages. Peasants stuffed mattresses with straw and wool, whereas the wealthy lay on mattresses made from feathers.



An illustration of French noblemen enjoying a hearty dinner

9

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4 HALL

Homes during this time were built as open spaces that generally included some sort of hall in which the residents gathered to eat and sit aside a roaring hearth.

6 WINDOWS

Despite the Romans' use of glass windows, many homes in medieval Europe weren't privy to the methods of glass-making until later in the era, so they resorted to using wooden shutters and even linen soaked in tallow for transparency.

10 FURNITURE

Home decor consisted of basic wooden tables, chairs and trunks until a flurry of new furniture, such as cupboards and four-poster beds, emerged during the 14th and 15th centuries.

LOST HEATING SYSTEM

During the reign of the Romans, countless quality-of-life inventions were made, including an underfloor heating system known as a hypocaust. Hypocausts lay beneath the floors of Roman homes, which were raised by pillars called pilae, which themselves were placed on a tiled floor. The hot air produced by adjoining fires circulated through the hypocaust and heated the floors of the home. However, during the Middle Ages, this technology was lost in many countries throughout Europe, including Britain. Unaware of the heating abilities of the Roman hypocaust, the Saxons that came to Britain's shores destroyed or ignored the systems, resorting to the less efficient method of smoke-billowing open fires for heat.



A view through the tiles of a Roman home showing hypocaust underfloor heating

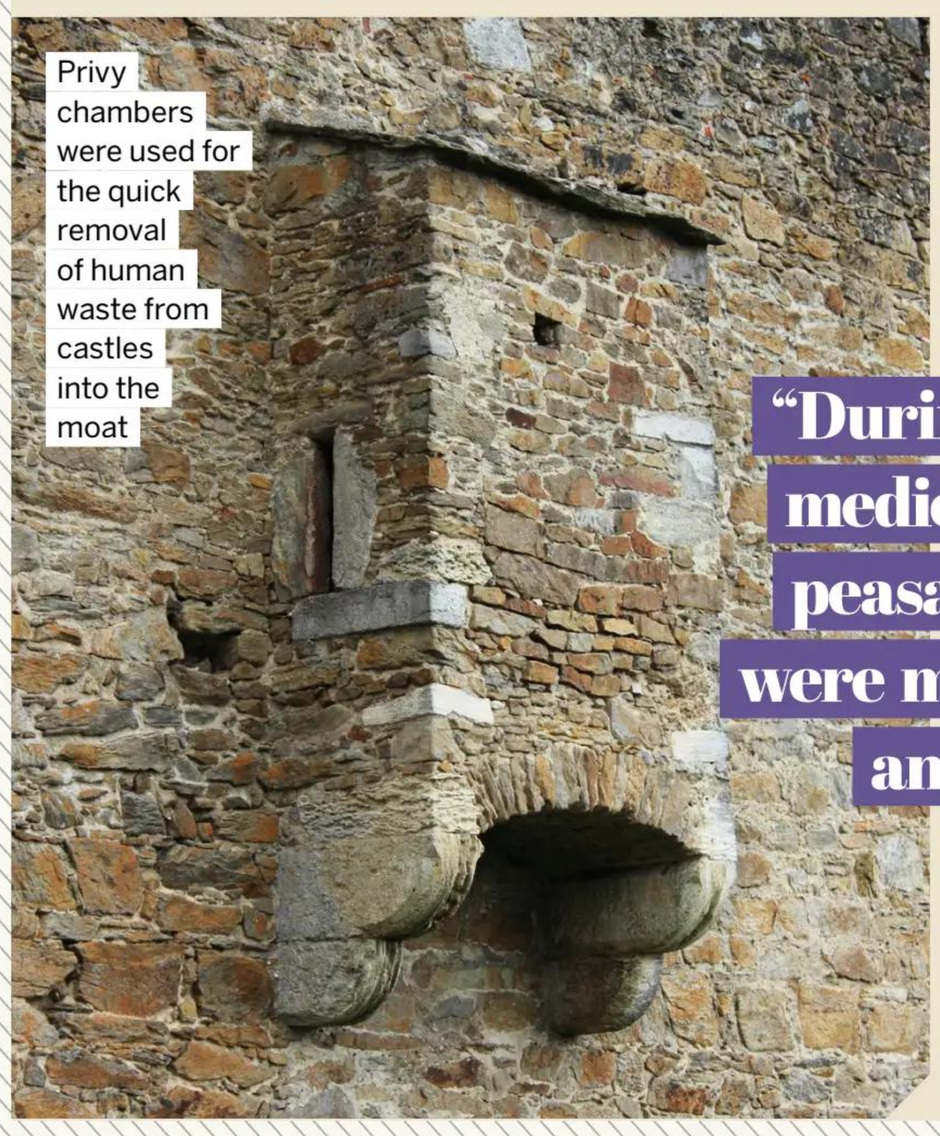
© Alamy / Illustartion by Nicholas Forder



An example of a peasant's home during the Middle Ages

HOMES AROUND THE WORLD

Delve into the many different dwellings of the Middle Ages



Privy chambers were used for the quick removal of human waste from castles into the moat

"During the early medieval period, peasants' homes were made of sticks and earth"



3 RUSSIA

Traditional peasant homes called izba were found across the rural landscapes of Russia during the Middle Ages. Until the 10th century, simple homes were made from stacking logs of wood, with no windows or doors – just a small entrance hole. With a stone hearth, smoke was vented through the only opening. As time progressed, the izba developed to include wooden windows and doors, as well as a brick Russian stove for heating and cooking.

Did you know?

Peasants made up 90 per cent of the English medieval population

DID YOU KNOW? The average life expectancy during the Middle Ages was 33 years old



2 MONGOLIA

During the 13th century, when the empire of Genghis Khan controlled Mongolia, many nomadic families resided in a circular tent-like structure called a ger, also known as a yurt. Their ingenious design allowed people to erect their wooden skeletons quickly while on the move. Layers of sheep wool felt were then draped over the wooden frame and secured using animal hair rope.



5 KOREA

A traditional private Korean home during the Middle Ages was known as a hanok. Timber formed the interior of the supporting structure of the hanok, while its walls were made of brick and stone. Clay tiles coated the roofs and windows were made from interlocking pieces of wood. Interior rooms were divided by sliding paper doors called changhoji and heated with a similar underfloor heating system to the hypocaust, called the ondol system.



1 JAPAN

Between 1185 and 1606 CE, many who lived outside of the lavish castles and villas of Japan's most wealthy resided in traditional homes known as minka. Minka came in a variety of categories, such as farmhouses called nōka, mountain houses called sanka and urban homes called machiya. Each type was different in its construction, but usually featured a hardened earth floor, called a doma, for the purpose of cooking and a raised wooden platform for sleeping.



4 CHINA

Siheyuan, which translates to 'quadrangle', were common homes in China during the Middle Ages. Built around a central courtyard, a siheyuan is typically made up of four one-storey buildings connected in a rectangle, with one front gate. These buildings were traditionally constructed from simple materials such as wood and tile.

© Alamy / Getty / Shutterstock

WHAT WAS THE BOSTON TEA PARTY?

Why American colonists attacked British tea ships 250 years ago

WORDS AILSA HARVEY

On May 1773, the British government passed the Tea Act, making the British East India Company the exclusive tea seller to its American colonies. In the years leading up to this, many people in America avoided buying British tea due to the hefty tax on it. Instead, tea was smuggled into the country so the drink could be enjoyed without having to pay the British government. When parliament passed the Tea Act and gave a single company all the business, prices were dropped to less than what was being paid for smuggled tea. But even this didn't solve the problem the British had. Many people in America were unhappy about paying a government based thousands of miles away, whose actions and rule they had no say in.

A few months later, there was retaliation. Anger boiled over when the British East India Company arrived in Boston with its cargo of tea following requests by the governor of the Province of Massachusetts Bay, Thomas Hutchinson, for them to leave. The protest that unfolded is today known as the Boston Tea Party. On the evening of 16 December 1773, a large group forced their way onto three British tea ships docked at Boston Harbour. The protesters ransacked the tea chests and threw them overboard. After the Boston Tea Party boycott, the British government shut down Boston Harbour until the chests were paid for. American colonists continued to boycott the British East India Company, and many switched from tea to coffee. Today, the legacy of this fallout remains, as Americans still drink more coffee than tea.

Did you know?

Some Sons of Liberty dressed as Native Americans

DID YOU KNOW? Hundreds took part in the Boston Tea Party, but only 116 names are known today

5 FACTS ABOUT SPILLING THE TEA

1 OVERBOARD
342 chests of tea were dumped into the harbour's waters.

2 TEA TYPE
The tea thrown overboard was Chinese tea, and around 22 per cent was green tea.

3 MULTIPLE PARTIES
Ten similar events occurred along the shoreline from Philadelphia to Charleston.

4 PROTESTORS' PROMISE
The protesting colonists had made a pact of silence, so no one was ever officially named for their involvement.

5 LOST SHIPMENT
Four tea ships set sail for Boston. The three that were targeted docked at the harbour, but the fourth was lost in a storm on the way.

WHO WAS INVOLVED?

Only a select few are known to have been involved in the protest, and just one person, Francis Akeley, was caught and arrested. Samuel Adams led the Boston Tea Party along with Sons of Liberty member John Hancock. Sons of Liberty was a group of colonist tradesmen formed to retaliate against the taxation of the American colonies in 1765. Other named members who took part were Benedict Arnold, Patrick Henry and Paul Revere. However, most of the participants didn't know each other, and they decided to keep it that way to reduce the chance of being turned in. The protesters were ordered to first cut open the tea chests before tossing them into the water. This was so that the water would infiltrate the tea and turn the harbour into one large tea bath.

Boston Tea Party leader Samuel Adams was born in Boston in 1722

STIRRING UP

The dumping of tea was a big statement to the British government, but this was only the start. As the first significant opposition to British rule, it had a domino effect that resulted in the beginning of the American Revolution in April 1775. The first response by the British government to punish those involved in the tea rebellion was to introduce the Coercive Acts (1774). These acts involved blocking the harbour to all trade except for imports for the British Army, giving the British government and army more power over the state of Massachusetts. The new laws were meant to serve as a warning and deter other colonies from plotting something similar. Instead it unified other British colonies, marking the start of the revolution and America's independence in 1776.



An artist's depiction of the signing of the American Declaration of Independence in 1776

© Alamy / Getty

HOW MAGICIANS PERFORM TRICKS

Breaking the spell to reveal the workings behind some of the greatest illusions in history

WORDS NIKOLE ROBINSON

Even the simplest magic tricks enthral and bewilder audiences the world over, but it's difficult to pinpoint exactly when emulating the supernatural became a form of entertainment. Ancient Egyptian writings tell of the magician Djedi, who could reattach the severed heads of animals and bring them back to life. But even though this feat can be replicated today, there is still doubt cast on this story. There's evidence that sleight-of-hand skills were performed in ancient Rome, most notably at banquets, but after



Sleeves and pockets are used to cleverly conceal objects

DID YOU KNOW? David Copperfield made the Statue of Liberty disappear in 1983



This 1502 oil painting by Hieronymus Bosch depicts an early cups and balls trick

this era magic as a form of entertainment seems to have become heavily intertwined with the occult.

By the Middle Ages, people had begun to fear magic, believing it to be the work of witches and the devil. To dispel this association and stop innocents from being persecuted and burnt at the stake, Reginald Scot published his book, *The Discoverie of Witchcraft*, in 1584. It is considered the first text written about performance magic. Within it, he described the methods behind many magic tricks, distancing them from witchcraft and the paranormal by revealing their secrets and deceptions. Travelling performers and street magicians would continue to perfect the craft, developing new techniques and apparatus to improve upon well-known illusions while also coming up with new ideas.

The sophisticated stage performances of today can be traced back to the French clockmaker Jean-Eugène Robert-Houdin, often referred to as the 'father of modern magic'. With his opening of a theatre in Paris in 1845, he took performance magic from the streets to the stage, raising its reputation. As well as showing off the classics, he used his expertise to make mechanical marvels that really did seem like magic. By the end of the 19th century, magic acts on stage had become commonplace, with people from all walks of life wishing to be amazed by the seemingly impossible. Those who mastered magic could gain complete control over an audience, and the best began rising to fame. This continued with the invention of television, with celebrity magicians performing on the screen as well as stage. The enduring popularity of magic tricks has seen them become bigger, more technical and often more dangerous than ever before. It's a testament to the curious nature of humans – we're desperate to discover the deceptions behind what we're seeing, while still desiring to be deceived.

Did you know?

In 2008, David Blaine held his breath underwater for 17 minutes

PULLING A RABBIT FROM A HAT

When most people think of magicians, images of wands, top hats and rabbits are conjured in their minds, all thanks to this famous trick that has been repeated for hundreds of years. It's said that Louis Comte was the first to perform this for King Louis XVIII in 1814, though John Henry Anderson is credited with the first stage performance. Taking off their hat and presenting it to the audience, the crowd can clearly see the hat is empty, but the magician soon suspends their disbelief by pulling a cute creature from its depths. In reality, the rabbit is sometimes hidden in a secret compartment in the hat, or the hat has a false bottom the rabbit can slip through. In some iterations, the bunny is hidden beneath a tablecloth, with expert sleight of hand able to make it appear as though it really is pulled into existence by way of magic.



White rabbits are particularly popular for performing this trick



Balducci levitation is viewed at an angle

King levitation is done by slyly removing a shoe

© Wiki: Tigerpaw62289

LEVITATION

Magicians are adept at defying gravity, but once again it's deception. One of the simplest methods of self-levitation was described by Ed Balducci in 1974. In it, the performer stands at an angle to the crowd and lifts themselves up on the front of the foot farthest from the audience. If they stand correctly, this point of contact is hidden by the other foot and the back of the foot touching the ground, creating a hovering effect.

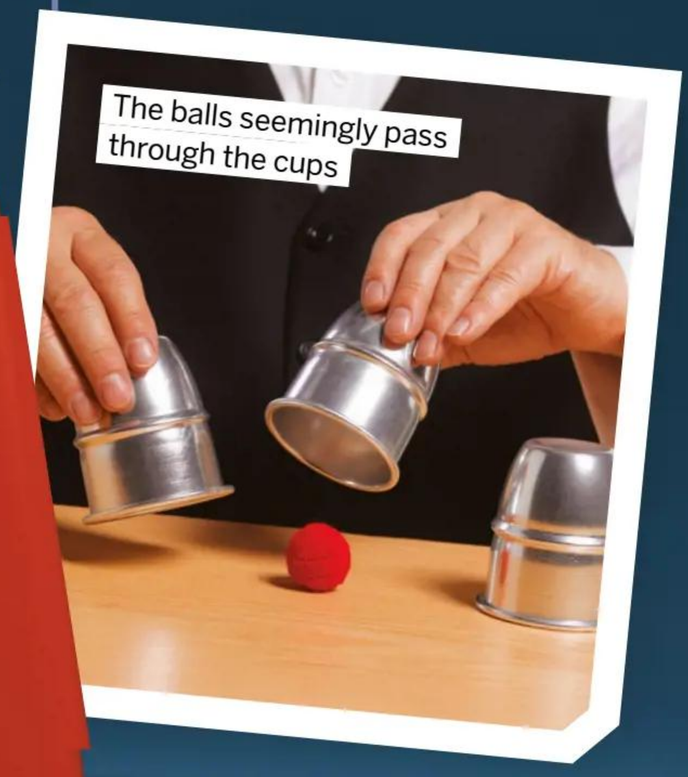
King levitation produces a similar effect using a different technique. A cloth or jacket briefly covers the magician's feet, and when it is removed they float a few inches above the stage, their body side-on to the crowd. What the crowd didn't see was the entertainer remove their shoe and wedge it between their foot and the heel of the other, which is twisted away so the bare toes they are balancing on are disguised.

© Alamy / Getty



Did you know?

The Magic Circle was formed in 1905



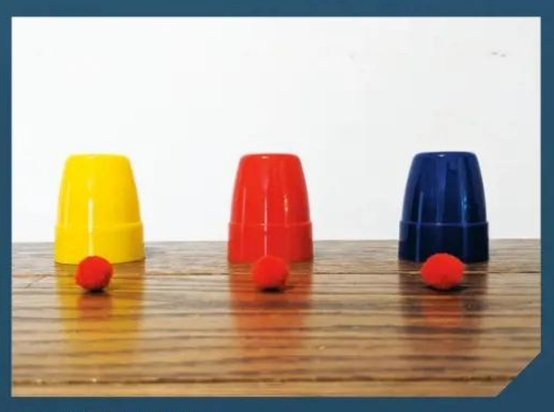
CUPS AND BALLS

Due to a depiction on a burial chamber wall in Beni Hasan that shows two men kneeling over inverted bowls, some Egyptologists claim this trick dates back over 3,500 years. Though this is debated, the trick was performed in ancient Greece and Rome, making it one of the oldest – and it's still a favourite today. Different versions have been performed around the world under various names, such as the Japanese 'Owan To Tama', using bowls, and the Chinese 'Immortal Sowing Beans', which used three to ten beans rather than balls. Performed by street magicians since antiquity, its history is intertwined with gambling, used to con mystified viewers out of their money as they incorrectly guessed which cup an object was under. Due to its relative simplicity, the trick has endured for thousands of years, with many gimmicks being added by conjurers to make it their own.

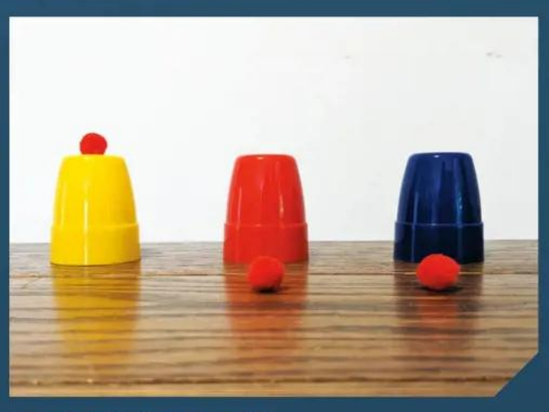
"Due to its relative simplicity, the trick has endured"

THE OLDEST TRICK IN THE BOOK

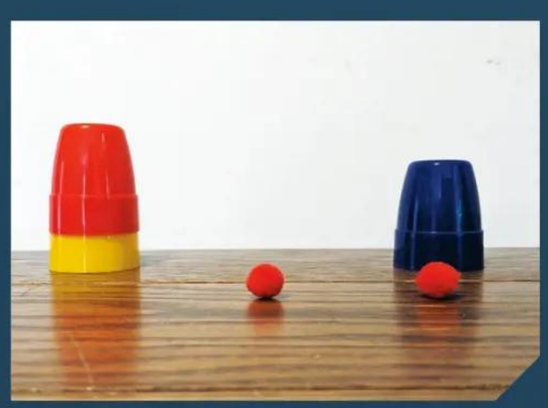
An extra ball is all it takes to pull off this ancient trick



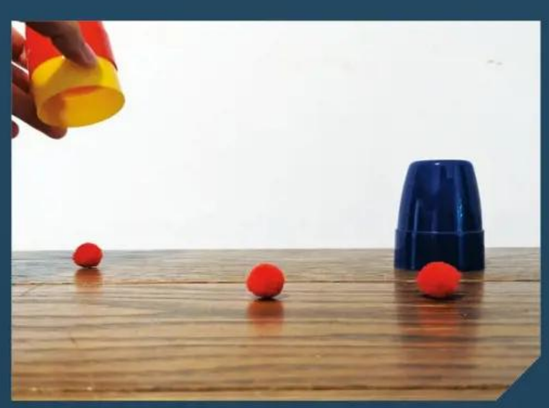
1 SETTING UP With three balls in view, a fourth ball is hidden under the left cup. Turning the cup keeps the ball inside.



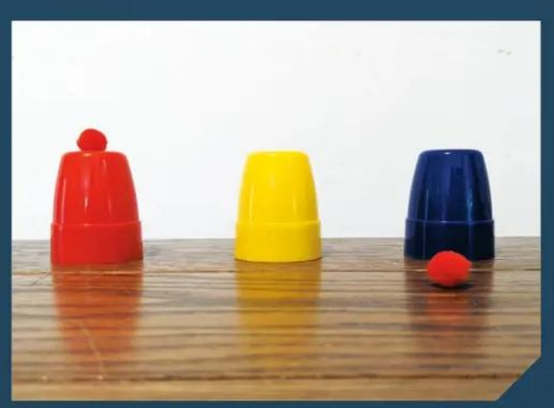
2 MOVING A BALL One of the three visible balls is placed on top of the cup with the concealed ball inside.



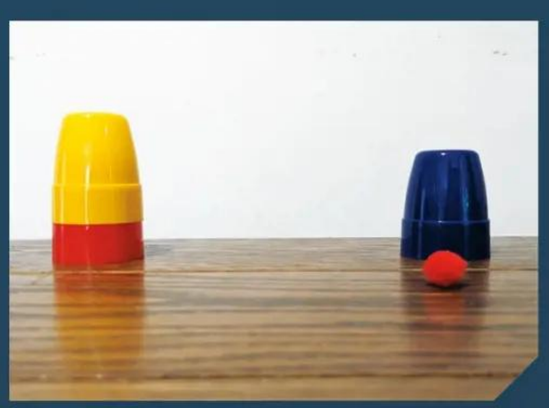
3 CUP ON TOP The middle cup is placed on top of the left cup, hiding the ball that was just placed there underneath it.



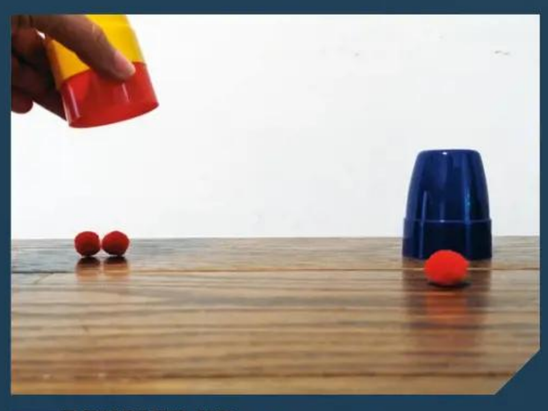
4 PASSING THROUGH As the cups are lifted, the ball appears to have moved through – but it's actually between the two cups.



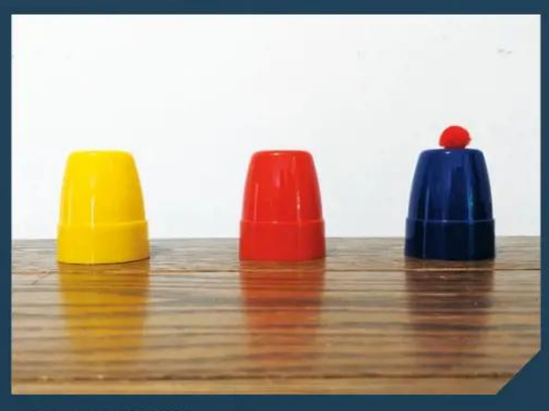
5 TRICKERY The cup that now has a ball inside is swiftly placed on top of the ball on the left, and the trick is repeated.



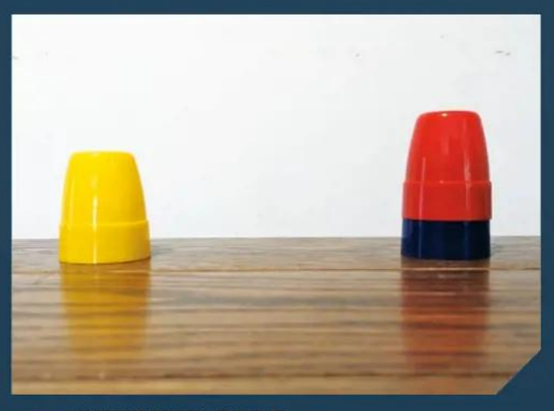
6 REPETITION The second ball is placed on top of the cup with the balls underneath it, and the middle cup is placed on top.



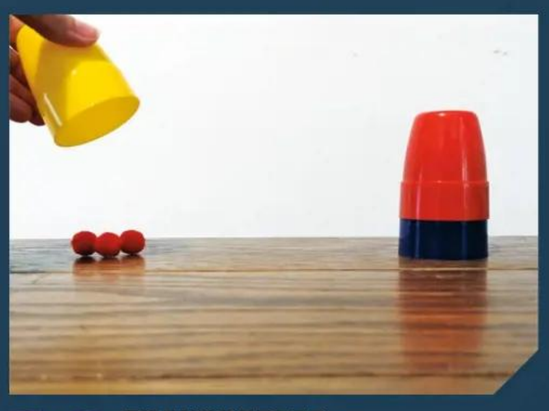
7 DOUBLED UP Lifting the cups, the second ball appears to have passed through. The hidden ball is once again in the cup that was stacked on top.



8 A TWIST The cup with the ball inside is placed over the other balls. Rather than repeating the same trick, the remaining ball is placed on the cup on the right.

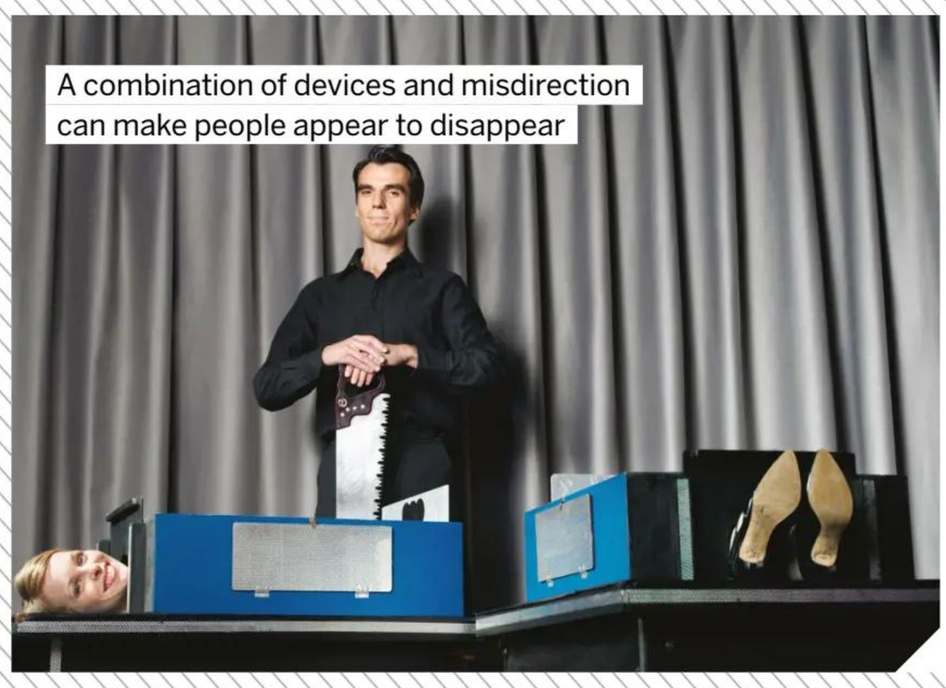


9 STACKED CUPS The empty cup is put over the ball on the right cup and tapped with a finger or wand. The performer then taps the left cup and lifts it.



10 TRANSPORTED This time it appears as though the ball has jumped from one side of the table to the other, with three balls now on the left.

DID YOU KNOW? Harry Houdini took his stage name from 19th-century magician Jean-Eugène Robert-Houdin



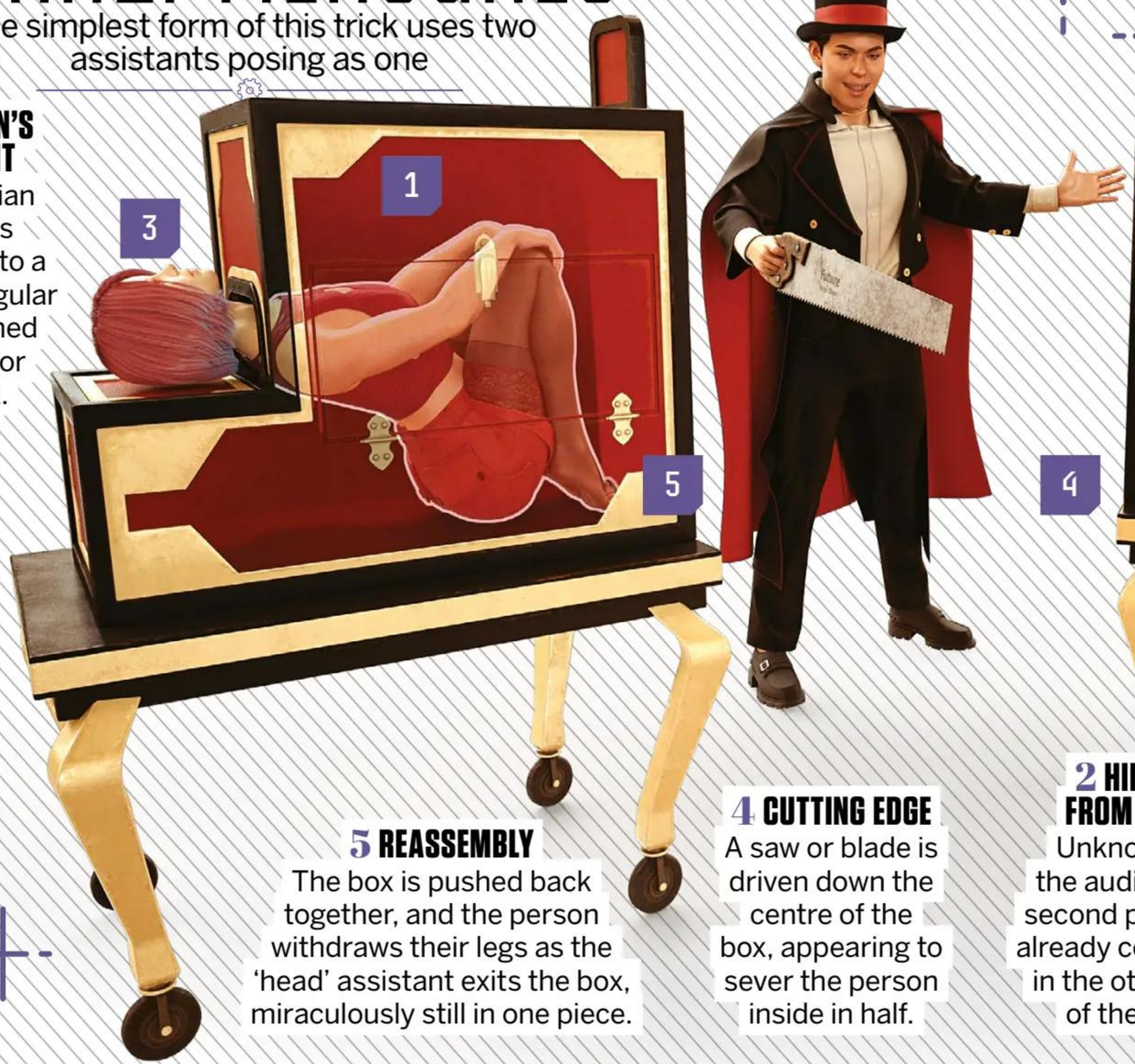
A combination of devices and misdirection can make people appear to disappear

SAWING SOMEONE IN TWO

The real magic of this illusion isn't in the sawing itself, but the putting back together of the person after the fact, or restoration. The trick has possible origins in the 19th century, but rose to popularity in the 1920s after being performed by British magician P. T. Selbit. However, in his version the box the assistant entered was closed, hiding her completely. The American Horace Goldin was first to use apparatus that is recognisable today, where the head, arms and legs of the assistant remain visible as the cut is made, an impressive improvement that drew more attention to the trick. Enduring to this day, the trick has been embellished with giant buzz saws, transparent boxes and even no box at all, creating a truly mystifying experience for the audience. The secrets of this magic lie in hidden compartments, cleverly arranged mirrors and very flexible assistants who are able to contort their bodies into tight spaces.

NO HALF MEASURES

The simplest form of this trick uses two assistants posing as one



1 MAGICIAN'S ASSISTANT

The magician guides his assistant into a long, rectangular box, designed specially for this trick.

2 HIDDEN FROM VIEW

Unknown to the audience, a second person is already concealed in the other half of the box.

3 HEAD AND FEET

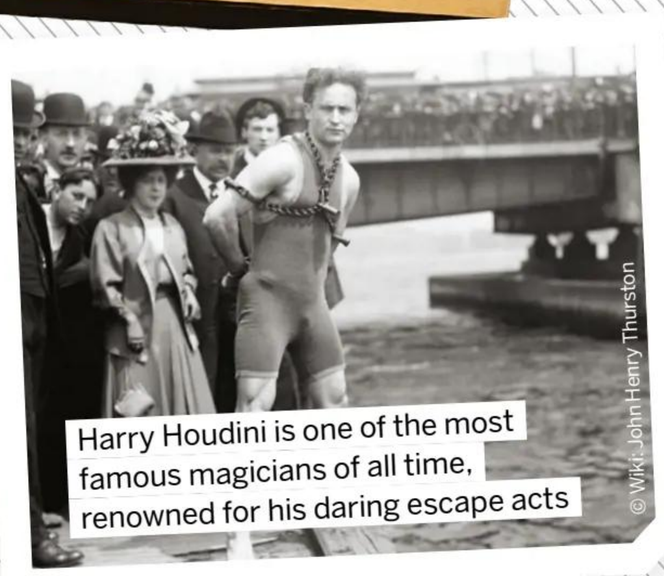
As the assistant gets into place, with their head poking out of the box, the other person sticks their legs out to make it look like they are one person.

4 CUTTING EDGE

A saw or blade is driven down the centre of the box, appearing to sever the person inside in half.

5 REASSEMBLY

The box is pushed back together, and the person withdraws their legs as the 'head' assistant exits the box, miraculously still in one piece.



Harry Houdini is one of the most famous magicians of all time, renowned for his daring escape acts

© Wiki: John Henry Thurston

PICK A CARD

Playing cards have been synonymous with magic for a long time, with the earliest recorded card tricks dating back to the 15th century. Born from card manipulation in gambling, skilful shuffling and sleight of hand soon gave rise to a new form of entertainment, with magicians gaining mastery over a deck of cards to perform a whole host of tricks. But there's psychology at work here as well as dexterity. Magicians can manipulate both the cards and their audience to influence their target and work towards a desired outcome, such as a predetermined card being chosen. There are ways to shuffle and cut a deck to keep track of a card that has been placed there and sneaky manoeuvres that can make cards disappear entirely. Making use of such a versatile prop, card tricks have endured as one of the most widely performed types of magic, with thousands of different variations.



Card tricks are deft deceptions that use sleight of hand

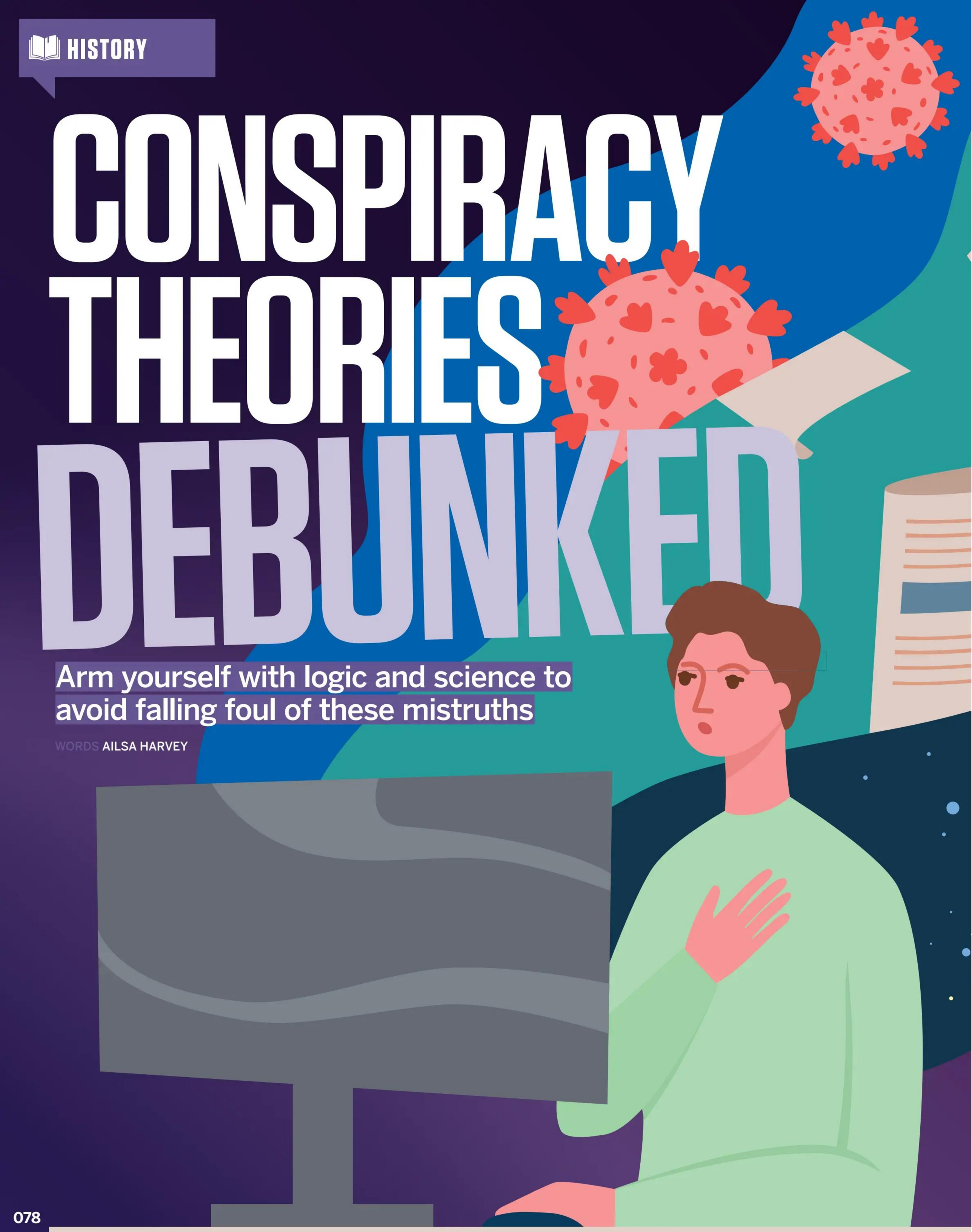
© Getty / Shutterstock / Illustration by Nicholas Forder

HISTORY

CONSPIRACY THEORIES DEBUNKED

Arm yourself with logic and science to avoid falling foul of these mistruths

WORDS AILSA HARVEY



DID YOU KNOW? A 2021 study showed that India had the highest proportion of conspiracy theory believers and Denmark the lowest

In the world of science, there are many concepts which have been explored, tested, written into scientific theory and widely accepted. However, some people choose not to believe the science and instead speculate about how we're being deceived. A conspiracy theory is an attempt to explain an event alternatively, often involving the concealment of the truth by powerful beings and government groups.

Many struggle to understand how others believe a fictitious storyline with no evidence to back it up, but someone is more likely to be a conspiracy theorist if they possess specific psychological traits. Studies show that a combination of personality traits and motivations make you more likely to believe a conspiracy theory. These include paranoia, impulsivity, insecurity and manipulation. The average conspiracy theory believer relies on their own intuition much more than other personalities do, striving for a better personal understanding of the world and often looking to feel safer in their environment. Many also want to feel superior in their views of the world by straying from the more widely accepted worldview.



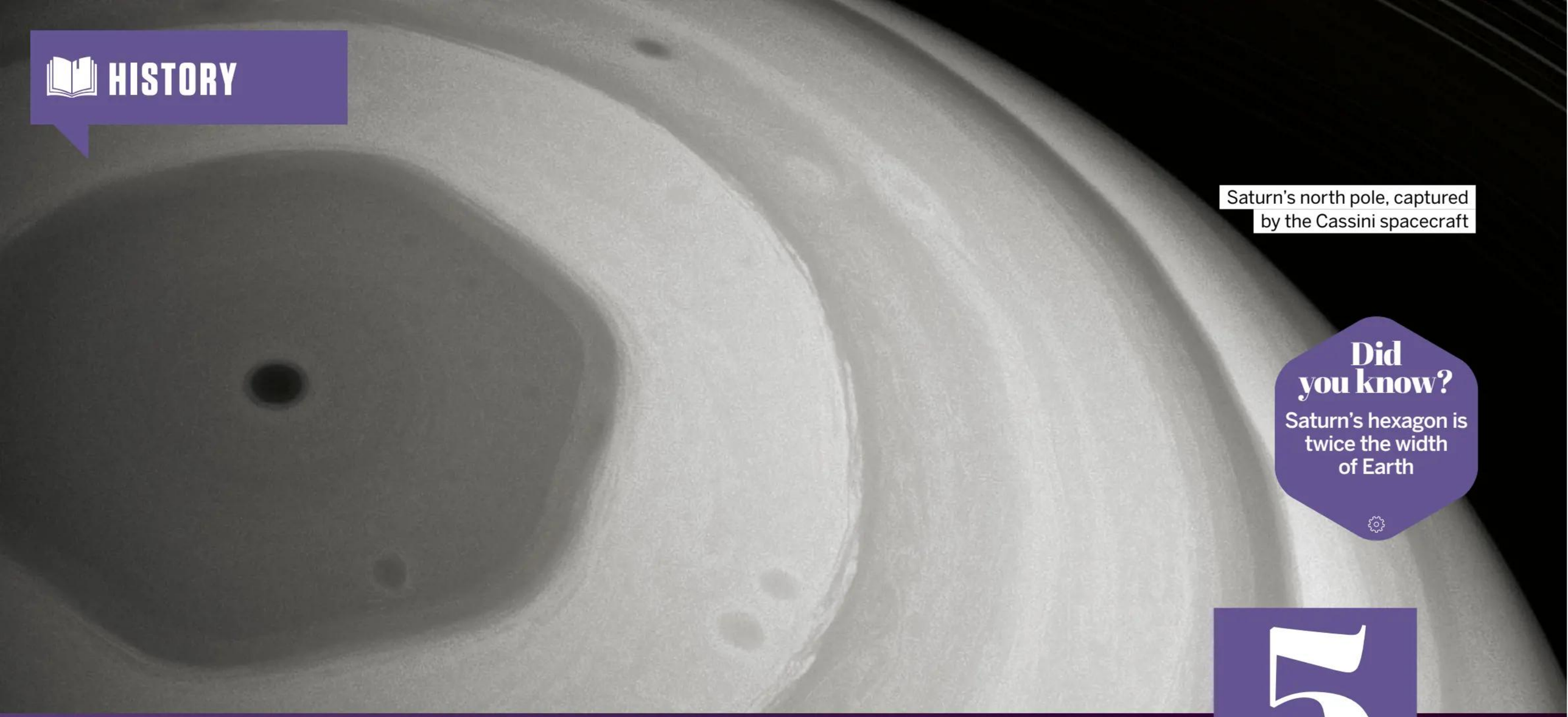
Contrails can remain visible in the sky for hours

AEROPLANE CONTRAILS ARE MIND-CONTROL CHEMICALS

When aircraft soar through the sky, they leave behind lingering white trails in a range of shapes and sizes. Depending on an aircraft's height, size and flight path, these trails can vary in appearance. A small percentage of the population are suspicious about the contents of these puffy trails, believing that those in power are poisoning the people of Earth with chemicals for various reasons. Some of the theories include weather control to create rain and prevent droughts, mind control to influence the population's thoughts for cooperation with the government and population control, including chemicals that reduce fertility.

In reality, they're just contrails – clouds that form when fine soot particles from aircraft engines freeze into crystals in the air's water vapour. Where the air is highly humid, these ice crystals are unable to disperse as easily and remain in streaks in the sky for longer. This is why the trails are inconsistent in their duration – it's not because they contain mysterious substances.

© Shutterstock



Saturn's north pole, captured by the Cassini spacecraft

Did you know?

Saturn's hexagon is twice the width of Earth

SATURN'S STORM IS ALIEN TECHNOLOGY

If you've seen any close-up images of Saturn, you may have noticed a hexagonal-shaped patch located at the planet's north pole. While most would assume that this is a natural feature, the unusually uniform six-sided shape has led some conspiracy theorists to jump to the conclusion that Saturn has advanced alien technology. Despite a hexagon being a rare shape in nature, this patch is the result of a planetary storm.

Closer inspection of the hexagon by NASA's Cassini spacecraft debunked any claims of alien technology that could be suggested from seeing a photograph. of the phenomenon. Close-up footage of the hexagon showed it to be a rotating storm around 50 times larger than a hurricane on Earth. Saturn's north polar jet stream spins above the planet's atmosphere at around 300 miles per hour. At this speed, the storm has settled into a symmetrical shape that we are unfamiliar with in nature on Earth. Unlike Earth's uneven surface, Saturn is a gas giant and has no solid surface to impact gas flow.

SCIENTISTS HAVE DISCOVERED A KILLER PLANET

An object capable of destroying our entire world would be one to be feared. And those who are highly sceptical of the authorities believe that not all the important information about the world is shared. A combination of fear and scepticism has created the ultimate conspiracy theory that the world is ending. Conspiracy theorists say that there is a planet called Nibiru that is on a trajectory to collide with Earth and that people need to know. The planet is believed to orbit the Sun every 3,600 years. Doomsday predictions were set to the year 2003 and then 2012, but the end of the world has not occurred. But is there any truth to this theory? Mathematicians have predicted that there may be another large planet in our Solar System – Planet Nine. However, this is entirely hypothetical based on the orbital patterns of known objects. There is yet to be any evidence of Nibiru's existence, let alone any suggestions of a collision path.



People have been wrong about the end of the world multiple times before

5 FACTS REASONS EARTH CAN'T BE FLAT

1 SHADOW ON THE MOON
During a lunar eclipse, Earth casts a round shadow onto the Moon, as would be expected from a spherical object.

2 SHIPS ON THE HORIZON
When a ship sails over the horizon, it disappears gradually from the bottom up. This gradual disappearance confirms Earth's curved shape.

3 TIME ZONES
The Sun sets and rises at different times around the world. If it were flat, these events would be simultaneous everywhere.

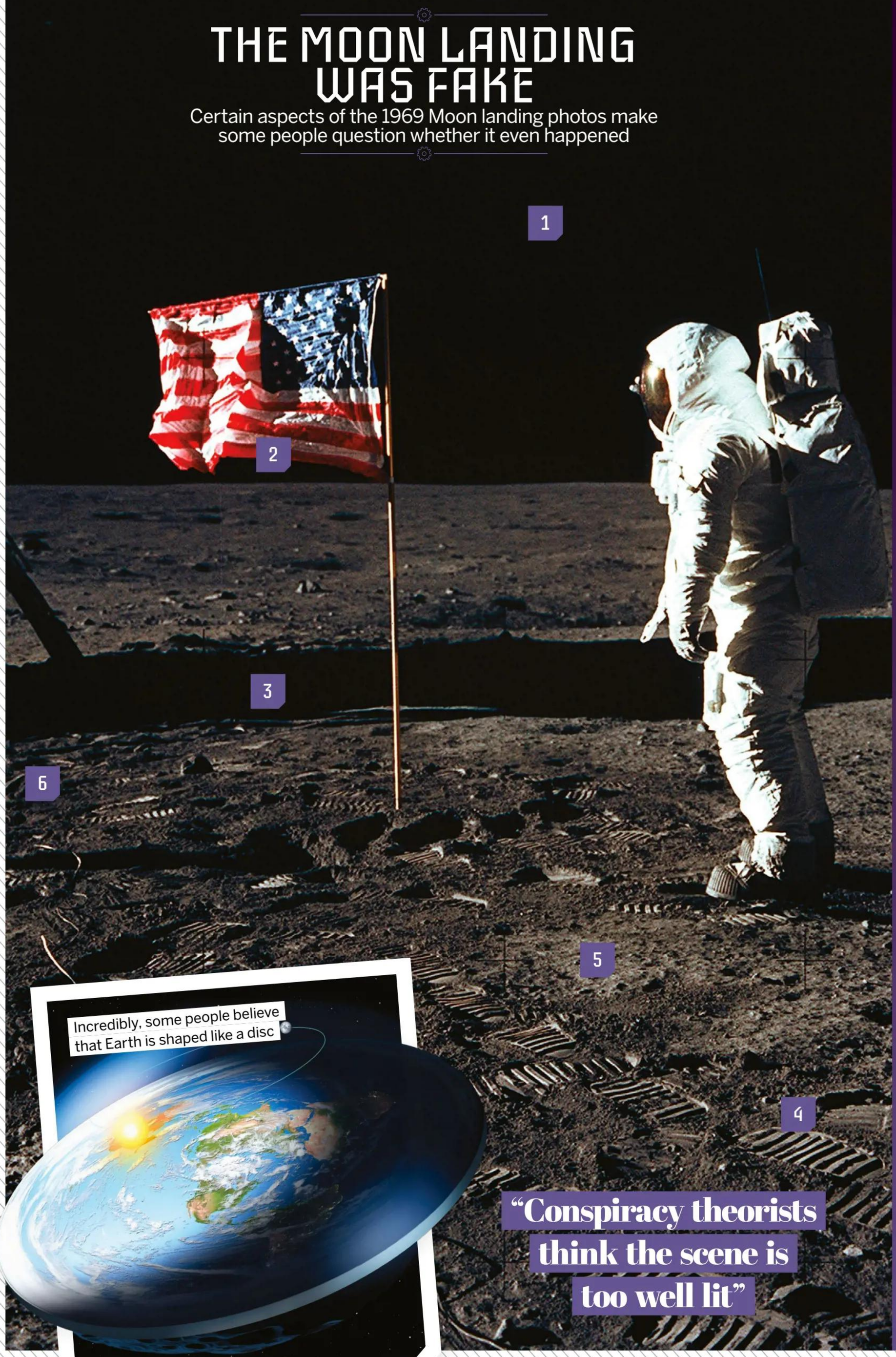
4 THE DIRECTION OF GRAVITY
Gravity pulls objects on Earth towards the centre of the planet. If Earth were flat, gravity wouldn't pull you 'down' towards the ground in all countries.

5 SPACE OBSERVATIONS
Now that space travel is commonplace, the number of people who have seen Earth's curvature first-hand is increasing.

DID YOU KNOW? A 2022 study found that around half of people born between 1997 and 2012 get their news from social media

THE MOON LANDING WAS FAKE

Certain aspects of the 1969 Moon landing photos make some people question whether it even happened



1 STARLESS SKY

To prevent overexposure, the cameras had short exposure times to capture the bright lunar surface. This prevented the stars from showing up in photographs, but they were there.

2 WAVING FLAG

Why is the flag waving if there is a thin atmosphere and no wind on the Moon? It's simply because NASA designed a flag with an extra pole along the top edge so that the flag would stand out and the stars and stripes could be seen.

3 TOO MANY SHADOWS

There should only be one light source – the Sun – so why aren't the shadows parallel? In reality, the uneven ground and different perspectives can cause this illusion.

4 CLEAR FOOTPRINTS

Should the footprints be this defined without moisture? Being made up of fine particles, the lunar surface compacts well to form these well-defined prints.

5 WELL LIT

Conspiracy theorists think the scene is too well lit to not be staged. However, the Moon's surface is highly reflective and brightly lit by the Sun.

6 NO CRATER CREATED

Why are there no visible signs of disturbance from the Lunar Module's descent to the ground? The lander was slowly lowered, and didn't make a crater when tested on Earth either. The lack of an atmosphere on the Moon also limits dust dispersal.

© Alamy

THE BERMUDA TRIANGLE HAS HIDDEN TRUTHS

There are multiple theories surrounding the Bermuda Triangle, and many attempt to explain the large number of missing aircraft and boats in the area



1 ALIEN ABDUCTION

Theories suggest that extraterrestrial life is capturing human ships and planes. There has been no evidence of this in this area, or in the entire explored universe.



2 A LOST CITY

Legends describe an advanced city called Atlantis that was destroyed by a large cataclysmic event. Some think the ruins lie beneath the Bermuda Triangle and that the government is keeping its advanced technology a secret, even though there is no archaeological evidence of Atlantis.



3 TIME WARP

Are missing vehicles caused by accidents or a disruption in the space-time continuum? One theory is that ships are sucked into another dimension by time warps. This is a popular concept in fiction, but is not fact.



4 SUPERNATURAL ACTIVITY

Could sea monsters or paranormal activity be to blame for disappearances? Some people think authorities could be covering this up to avoid panic, but paranormal activity has not been scientifically proven, and it's unlikely that large creatures wouldn't be seen elsewhere.



5 WEATHER PHENOMENA

Large earthquakes and storms could impact this region of ocean more than other areas. It is an area known for frequent rogue waves – steep and unexpected waves that some scientists think are the true culprits responsible for some of the missing and sunken ships.

Did you know?

50 ships have disappeared in the Bermuda Triangle



VACCINES CAUSE AUTISM

In 1988, Dr Andrew Wakefield published a study linking the mumps, measles and rubella (MMR) vaccine with an increase in autism cases. This was a flawed study that included false data and was consequently retracted. However, news outlets picked up on this story and spread fear among the public about the impact of vaccinations. Many studies have been carried out since this incident, and each one has concluded that there is no link. Despite this, people are more likely to remember and believe the alarming headlines, regardless of their inaccuracy, and question what studies are truthful. Spreading misinformation caused vaccination rates to decrease. This is harmful as it lowers populations' immunity to certain diseases and makes dangerous outbreaks more likely to occur.



DID YOU KNOW? Scientists have known the Earth is round since the 3rd century BCE



5G IS HARMFUL

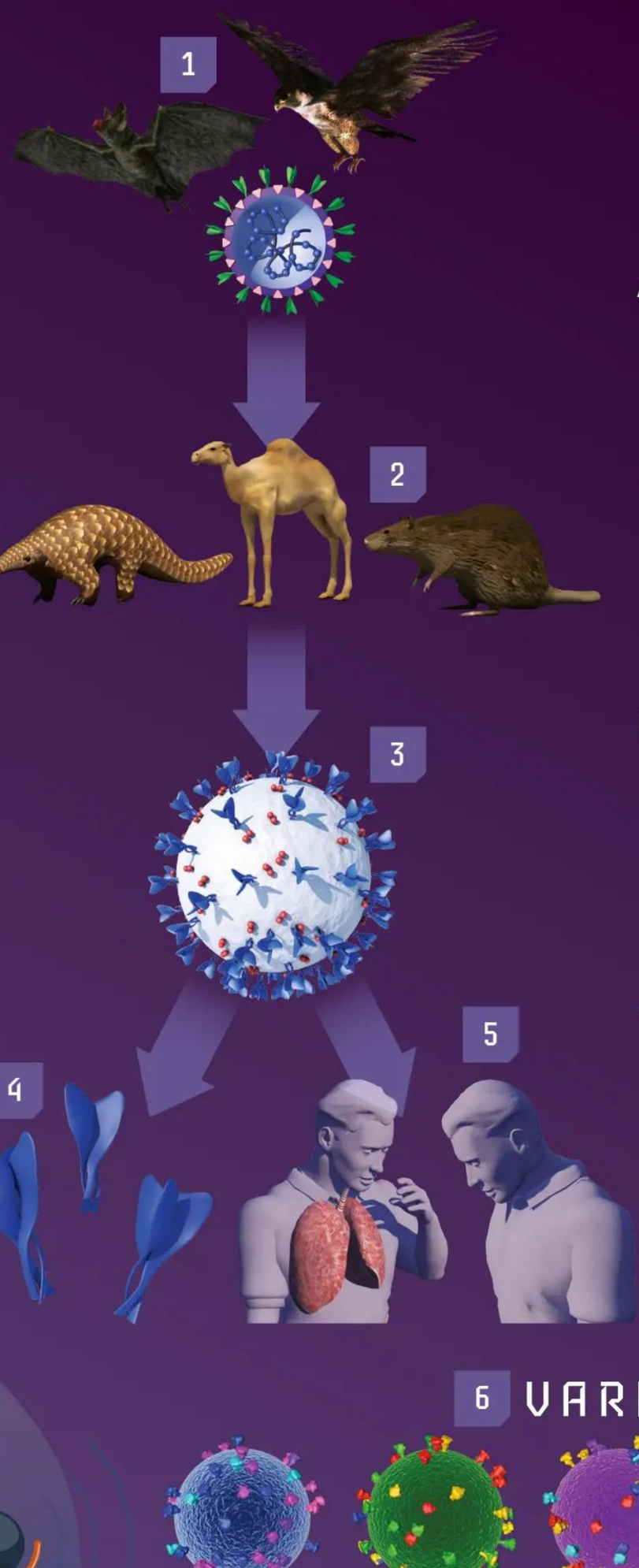
5G is the fifth-generation mobile network, making mobile communications quicker and more consistent. To some people, the advancement in mobile technology and the ease with which we can communicate with people across the globe seems too good to be true. And from this technology, conspiracy theories have been born. Perhaps the most dominant 5G conspiracy theory is that it has harmful health implications. 5G accesses a higher frequency of radio waves than previous generations for speedier data transmission, leading some members of the public to question whether the radio frequencies are harmful. But there is no need to fear the 5G masts being constructed for data transmission. 5G mostly uses the same radio waves as previous generations. The main difference is that 5G uses higher frequencies, although it still falls far short of the harmful ionising part of the electromagnetic spectrum.

Other 5G conspiracy theories include the government using the technology for large-scale surveillance



COVID-19 WAS CREATED IN A LABORATORY

How nature produced this virus through evolution



1 ANIMAL ORIGIN

COVID-19 originated in bats. Bat coronavirus RaTG13 has genome sequences with 96.2 per cent similarity to the COVID-19 virus.

2 INTERMEDIATE HOST

As the virus began subtle mutations, it was eventually able to infect wild animals that come into contact with humans.

3 SARS-COV-2

The COVID-19 virus SARS-CoV-2 is 10 to 20 times more likely to bind to human cells than SARS-CoV-1 – the virus responsible for the 2002 coronavirus outbreak.

4 SPIKE PROTEINS

Proteins on the outside of coronavirus interact with the host cells. Mutations in spike proteins altered the virus in bats, making them more efficient at infecting human cells.

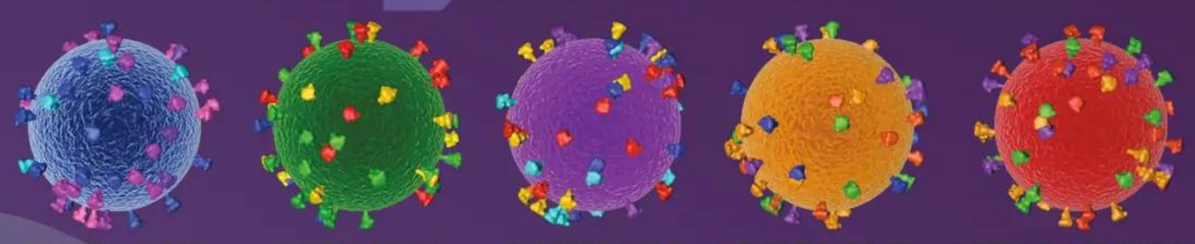
5 HUMAN TRANSMISSION

An infected human can spread COVID-19 through close contact. The virus can live outside the human body for a short time, such as in small airborne droplets of breath.

6 CONSTANT CHANGE

As the COVID-19 virus copies itself to replicate, small errors are made, changing the genetic code slightly and altering how well the virus can infect different species.

6 VARIANTS



ALPHA B117 | BETA 1351 | GAMMA P1 | DELTA 1617 | OMICRON 11529

“Mutations in spike proteins altered the virus in bats”

© Getty / Shutterstock / Alamy / Illustration by Adrian Mann

WHO WERE THE FIRST AMERICANS?

The first humans in the Americas were thought to have travelled across a land bridge from Asia 13,000 years ago, but new evidence suggests otherwise

WORDS LAURA GEGGEL AND BEN BIGGS



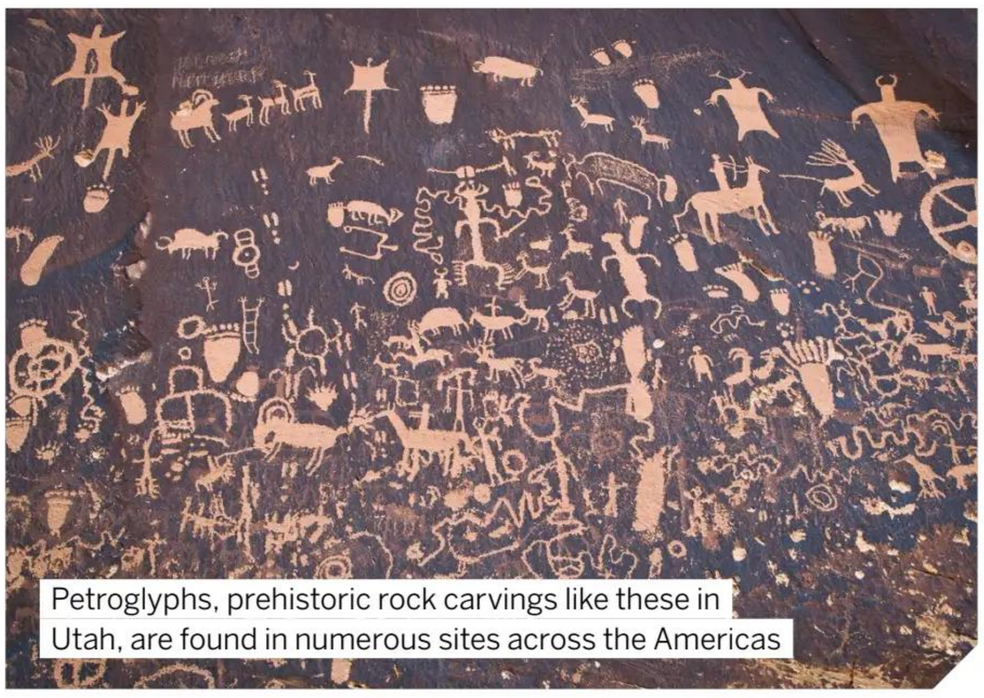
DID YOU KNOW? One theory claims that the first Americans arrived by boat from across the Atlantic

During the last ice age, humans ventured into two vast and unknown continents: North and South America. For nearly a century, researchers thought they knew how this wild journey occurred. The first people to cross the Bering Land Bridge, a massive swath of land that connected Asia with North America when sea levels were lower, were the Clovis, who made the journey shortly before 13,000 years ago. According to the Clovis First theory, every Indigenous person in the Americas could be traced to this single inland migration. But in recent decades, several discoveries have revealed that humans first reached the so-called New World thousands of years before we initially thought, and probably didn't get there by an inland route. Who were the first Americans, and how and when did they arrive?

Genetic studies suggest that the first people to arrive in the Americas descended from an ancestral group of Ancient North Siberians and East Asians that mingled around 20,000 to 23,000 years ago. They crossed the Bering Land Bridge sometime between then and 15,500 years ago. But some archaeological sites hint that people may have reached the Americas far earlier than that. For instance, there are fossilised human footprints in White Sands National Park in New Mexico that may date to 21,000 to 23,000 years ago. That would mean humans arrived in North America during the Last Glacial Maximum, which occurred between about 26,500 and 19,000 years ago, when ice sheets covered much of what is now Alaska, Canada and the northern US.



Mammoths, like this well-preserved baby mammoth found in Alaska, were still roaming the Arctic islands 4,500 years ago



Petroglyphs, prehistoric rock carvings like these in Utah, are found in numerous sites across the Americas

Other more equivocal data suggests the first people arrived in the Western Hemisphere by 25,000 or even 31,500 years ago. If these dates can be confirmed, they would paint a much more complex picture of how and when humans reached the Americas. Almost all scientists agree, however, that this incredible journey was made possible by the emergence of Beringia – a now-submerged 1,100-mile-wide landmass that connected what is now Alaska and the Russian Far East. During the last ice age, much of Earth's water was frozen in ice sheets, causing ocean levels to fall. Beringia surfaced once waters in the North Pacific dropped roughly 50 metres below today's levels; it was passable by foot between 30,000 and 12,000 years ago.

From there, the archaeological picture gets muddier. The older version of the story originated in the 1920s and 1930s, when Western archaeologists discovered sharp-edged, leaf-shaped stone spear points near Clovis, New Mexico. The people who made them, now dubbed the Clovis people, lived in North America between 13,000 and 12,700 years ago, based on a 2020 analysis of bone, charcoal and plant remains found at Clovis sites. At the time, it was thought that the Clovis travelled across Beringia and then moved through an ice-free corridor, or a gap between the continental ice sheets in what is now part of Alaska and Canada. Once they left the corridor, they spread quickly throughout the Americas, bearing a signature stone tool known as the Clovis spear point. This was likely used to hunt megafauna, such as mammoths and bison, as well as smaller game. For decades, it was challenging to suggest that the first Americans arrived any earlier than 13,000 years ago.

Did you know?

Today there are around 381 million people living in North America

Slowly, new discoveries began turning back the clock on the first Americans' arrival. In 1976, researchers learned about the site of Monte Verde II in southern Chile, which radiocarbon dating showed was about 14,550 years old. It took decades for archaeologists to accept the dating of Monte Verde, but soon other sites also pushed back the date of human arrivals in the Americas. The Paisley Caves in Oregon contain human coprolites, or fossilised poo, dating to about 14,500 years ago. Page-Ladson, a pre-Clovis site in Florida with stone tools and mastodon bones, dates to about 14,550 years ago. And Cooper's Ferry – a site that includes stone tools, animal bones and charcoal – dates to around 16,000 years ago. Then, in 2021, scientists announced much more ancient traces of human occupation: fossilised footprints in White Sands, New Mexico, dating to between 21,000 and 23,000 years ago.

There are dozens more sites, although some of the older ones are controversial. For instance, some archaeologists said 31,500-year-old rocks in a remote Mexican cave were stone tools made by humans, but there was an argument against that theory that suggested the rocks got their shapes naturally. Another site in Brazil holds giant sloth bones that may have been modified by humans at least 25,000 years ago, but a narrow hole in the bones could also have occurred naturally. And 50,000-year-old stone tools at Pedra Furada in Brazil may have actually been made by capuchin monkeys. Sites such as White Sands and Cooper's Ferry have big implications for how the first people arrived in the Americas. It's thought that the ice-free corridor through North America didn't fully open until about 13,800 years ago. If humans were in the Americas long before then, they likely travelled there along the Pacific Coast. That coastal journey could have been made by

© Alamy / Getty



A prehistoric human coprolite, or fossilised poo. One of 700 such examples found at Paisley Caves

WHAT'S NEXT

Archaeologists would like to find more sites from all of these genetic branches, especially any remains that could explain the genetics behind the people at White Sands between 23,000 and 21,000 years ago. But when they do uncover exceptionally preserved sites, they find that over 90 per cent of what people made and used was perishable: plant fibres, feathers, animal skins and the like. These organic artefacts and remains typically preserve well only in rare circumstances – extremely wet, dry or cold places such as caves, rock shelters or water-logged sites.

Even if there are other sites, many scientists aren't looking for them. They are stuck in a Clovis mindset, hunting for the stone tools ancient people crafted. But evidence of these long-lost people can also be found in the remains of the animals they butchered, the charcoal they burned, the tools they crafted and the loved ones they buried... even fossilised footprints these ancient individuals left behind. The field can only move forward when more archaeologists focus on this kind of evidence.

foot, by watercraft or both. But no fossil or archaeological evidence of this journey has been unearthed. No boat nor submerged site has been found on a 16,000-year-old shoreline in British Columbia. Still, the coastal route isn't outlandish. A lot of evidence suggests that people were capable of large ocean crossings. For instance, people were using boats to reach Australia by around 50,000 years ago.

Despite these uncertainties, researchers have ruled out some of the wildest theories. For instance, the first Americans weren't Pacific Islanders who boated across the open ocean, because people didn't migrate to Polynesia until around 3,000 years ago and genetic evidence shows that the first Americans are only very distantly related to Polynesians. Likewise, genetic studies rule out the 'Solutrean hypothesis' that suggests that Paleolithic Europeans came across the Atlantic around 20,000 years ago.

Geneticists studying the first Americans tend to paint a more consistent picture than archaeologists do, mainly because they're using the same human remains and genetic datasets. Genetic analyses have found that Ancient North Siberians and a group of East Asians paired up around 20,000 to 23,000 years ago. Soon after, the population split into two genetically distinct groups: one that stayed in Siberia, and another, the basal American branch, which emerged around 20,000 to 21,000 years ago. Genetic data suggests the descendants of this basal American branch crossed the Bering Land Bridge and became the first Americans.

The basal American branch then split into three groups: unsampled population A, a mysterious genetic 'ghost' that has only been detected indirectly from the genomes of the Mixe people of what is now Mexico; Ancient Beringians, who have no known living descendants, and Ancestral Native Americans, whose descendants live on today. All three of these groups ultimately made it to North America, but their diverging genetics suggest that they crossed in separate movements. Some didn't make it very far – the Ancient Beringians entered Alaska but never made it south of the continental ice sheets. The last known Ancient Beringian, known as the 'Trail Creek individual', died around 9,000 years ago in Alaska.

Did you know?

Giant beavers lived in North America when humans arrived there

Meanwhile, the Ancestral Native American lineage underwent several splits, suggesting that these people settled in different areas of North America as they had limited gene flow between them. There was one split that took place between 21,000 and 16,000 years ago and then a second one around 15,700 years ago. During this second split, the Northern Native Americans – whose living descendants include speakers of the Algonquian, Salishan, Tsimshian and Na-Dené language groupings – separated from the Southern Native Americans, who spread southward and whose descendants include the Clovis. According to this theory, every known living and deceased Indigenous individual south of Canada belongs to the Southern Native Americans.



Mastodon were shorter than elephants, but were stockier and covered with thick hair

PREHISTORIC MIGRATIONS WORLDWIDE

First humans
Migration: **Africa to the Arabian Peninsula**
Date: **150,000 BCE**

First Europeans
Migration: **Arabian Peninsula to Europe**
Date: **50,000 BCE**

First Australians
Migration: **Timor to Australia**
Date: **70,000 BCE**

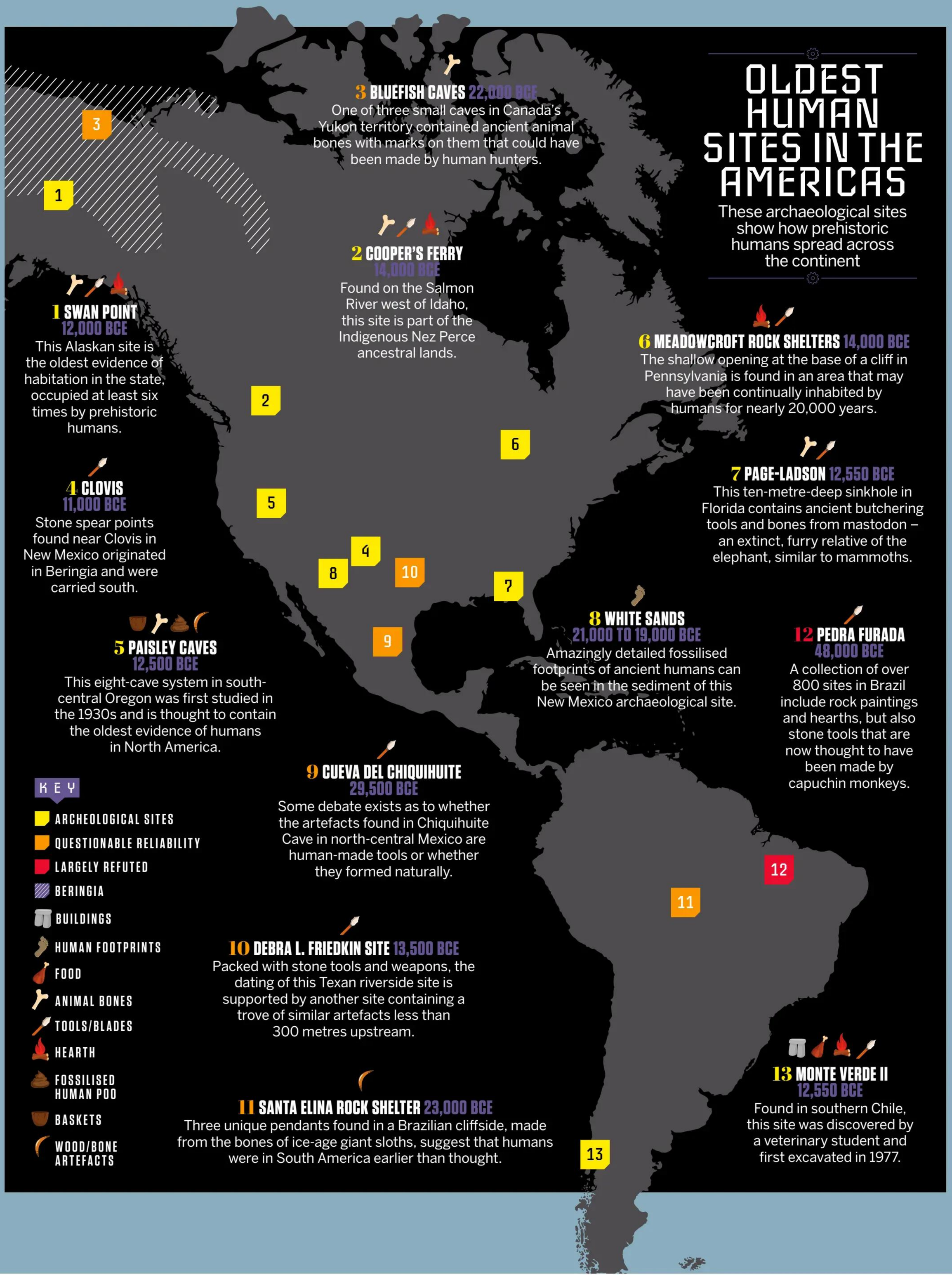
Beringia migration
Migration: **Siberia to Alaska**
Date: **25,000 BCE**

South America inhabited
Migration: **North America to Chile**
Date: **12,500 BCE**

DID YOU KNOW? A 9,500-year-old skeleton found in Washington strongly resembles the ancient Japanese Ainu people

OLDEST HUMAN SITES IN THE AMERICAS

These archaeological sites show how prehistoric humans spread across the continent



1 SWAN POINT 12,000 BCE
This Alaskan site is the oldest evidence of habitation in the state, occupied at least six times by prehistoric humans.

2 COOPER'S FERRY 14,000 BCE
Found on the Salmon River west of Idaho, this site is part of the Indigenous Nez Perce ancestral lands.

3 BLUEFISH CAVES 22,000 BCE
One of three small caves in Canada's Yukon territory contained ancient animal bones with marks on them that could have been made by human hunters.

4 CLOVIS 11,000 BCE
Stone spear points found near Clovis in New Mexico originated in Beringia and were carried south.

5 PAISLEY CAVES 12,500 BCE
This eight-cave system in south-central Oregon was first studied in the 1930s and is thought to contain the oldest evidence of humans in North America.

6 MEADOWCROFT ROCK SHELTERS 14,000 BCE
The shallow opening at the base of a cliff in Pennsylvania is found in an area that may have been continually inhabited by humans for nearly 20,000 years.

7 PAGE-LADSON 12,550 BCE
This ten-metre-deep sinkhole in Florida contains ancient butchering tools and bones from mastodon – an extinct, furry relative of the elephant, similar to mammoths.

8 WHITE SANDS 21,000 TO 19,000 BCE
Amazingly detailed fossilised footprints of ancient humans can be seen in the sediment of this New Mexico archaeological site.

9 CUEVA DEL CHIQUIHUITE 29,500 BCE
Some debate exists as to whether the artefacts found in Chiquihuite Cave in north-central Mexico are human-made tools or whether they formed naturally.

10 DEBRA L. FRIEDKIN SITE 13,500 BCE
Packed with stone tools and weapons, the dating of this Texan riverside site is supported by another site containing a trove of similar artefacts less than 300 metres upstream.

11 SANTA ELINA ROCK SHELTER 23,000 BCE
Three unique pendants found in a Brazilian cliffside, made from the bones of ice-age giant sloths, suggest that humans were in South America earlier than thought.

12 PEDRA FURADA 48,000 BCE
A collection of over 800 sites in Brazil include rock paintings and hearths, but also stone tools that are now thought to have been made by capuchin monkeys.

13 MONTE VERDE II 12,550 BCE
Found in southern Chile, this site was discovered by a veterinary student and first excavated in 1977.

KEY

- ARCHEOLOGICAL SITES
- QUESTIONABLE RELIABILITY
- LARGELY REFUTED
- BERINGIA
- BUILDINGS
- HUMAN FOOTPRINTS
- FOOD
- ANIMAL BONES
- TOOLS/BLADES
- HEARTH
- FOSSILISED HUMAN POO
- BASKETS
- WOOD/BONE ARTEFACTS

© Getty / Alamy

TECHNOLOGY

IS THIS THE HUMAN OF TOMORROW?

HOW WIRES AND CIRCUITS ARE MINGLING WITH BLOOD VESSELS AND NERVES TO CHANGE THE COURSE OF HUMAN EVOLUTION

The world as we know it is on a one-way trajectory to a technological overhaul. With each year that passes, cybernetics and artificial intelligence are finding their way into every nook and cranny of society. Even the human body isn't exempt from this mechanical makeover: our smartphones have become an unintentional extension of our hands, while robotic limb enhancements and nanobot immunity are on the horizon. But why would we let this technology take over our physiology?

The most common reason is to replicate an ability that has been lost or was missing at birth. Prosthetics are the best example of this, helping people regain motor functionality and movement. Since the early 1800s, engineers have created mechanical devices to mimic the function of missing limbs or appendages. But today some of the most advanced prosthetics in the world can tap into the signals zipping around the body's nervous system, allowing the user to control their prosthetic limb by will alone. Many battery-powered prosthetics can use the electrical signals of existing muscles

WORDS SCOTT DUTFIELD

DID YOU KNOW? The world's first brain-controlled virtual-reality game, *Awakening*, was launched by Neurable in 2018



HeroWear's Apex 2 exoskeleton can help workers lift efficiently

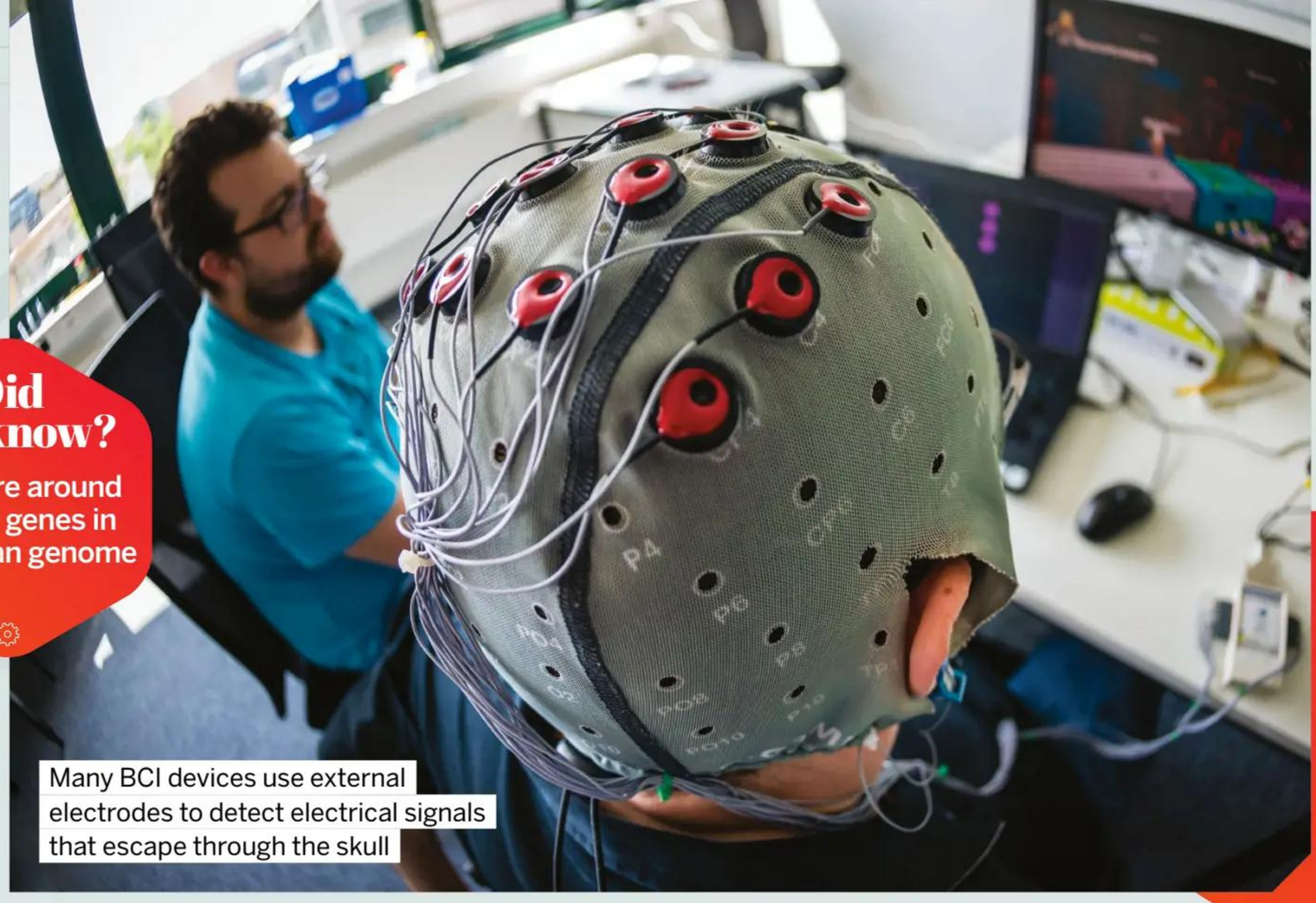
© AdobeStock / Getty / HeroWear

to operate robotic fingers and arms. They're known as myoelectric prostheses, and they depend upon a series of electrodes in the socket of the device that make contact with the skin and muscle of the residual limb. When the wearer contracts the muscles involved in a certain action, such as grasping individual fingers, bending an elbow or rotating the wrist, the device can distinguish the electrical signal for each action and carry them out.

Then there's the possibility of human augmentation to give an individual enhanced, possibly superhuman abilities. For example, wearable devices called exoskeletons act as an external frame around the body to not only assist those with limited movement, but can also enhance the function of their limbs. With the use of motors and advanced machine learning, 'active' exoskeletons, such as the Apogee ULTRA by German Bionic, can increase our lifting potential. The Apogee ULTRA provides lifting support of up to 36 kilograms, as well as walking support, making walking six miles feel like five miles. 'Passive' exoskeletons like the HeroWear Apex 2 are designed to solve the same problems, but use a system of elastic bands and strings. They can reduce body fatigue while lifting and moving objects before returning to a standing position.

Did you know?

There are around 20,000 genes in the human genome



Many BCI devices use external electrodes to detect electrical signals that escape through the skull

Brain-computer interfaces (BCIs) are a new but rapidly advancing area in human augmentation. The technology reads your brain waves and passes this data to a computer. With the help of electrodes – which can either be spread out over the head or implanted in the brain itself – scientists can pick up on electrical energy emitted by the billions of neurons in the brain. Each signal can be interpreted as an action. For example, signals generated while thinking about moving a cursor on a screen can be identified and then actioned by the computer to move the cursor. This technology has been traditionally used to help those with debilitating diseases navigate the internet and even translate their thoughts into text to regain speech.

Companies such as Paradromics and Synchron are among those leading the way in BCI technology. Paradromics has created the Connexus Direct Data Interface (DDI) to help motor-impaired people regain their voice through computers. The Connexus DDI device uses hundreds of tiny 'microwires' that penetrate just over a millimetre into the brain's cortex to collect the strongest signal, and thus the most information possible.



German Bionics' Apogee ULTRA exoskeleton can help workers increase their lifting efficiency

THE FIRST 'CYBORG'

Since 2004, artist Neil Harbisson has been walking around with an unusual adornment on his head: an antenna. Born with an impairment that means he can't see colours, Harbisson still wanted to experience the full visual spectrum the world has to offer, and thanks to his cybernetic instalment, he can. At the tip of his antenna is a colour-detecting sensor that's connected to a computer chip attached to the back of his skull. The sensor detects different wavelengths of light, and the chip converts the information into unique vibrations. These vibrations then travel through his skull and are delivered to his eardrum to be heard as different sounds. Over the last two decades, Neil has learnt to distinguish the 'sound of colours' and differentiate between them.

Harbisson spends every day of his life using an antenna to 'hear' colours

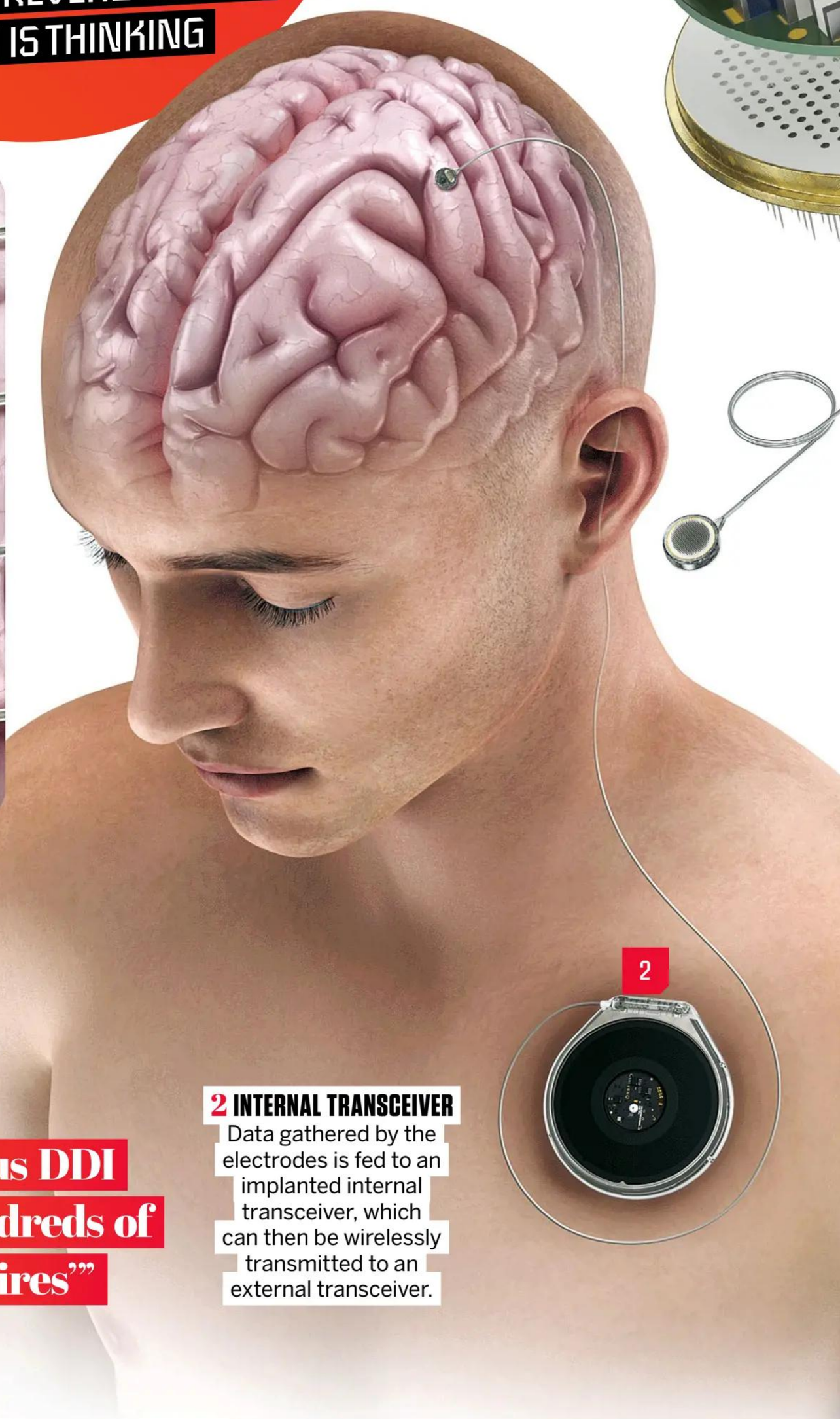
DID YOU KNOW? Neuralink was founded in 2016 by Musk and a team of eight scientists and engineers

READING MINDS

HOW THE CONNEXUS DIRECT DATA INTERFACE TAPS INTO BRAIN ACTIVITY TO REVEAL WHAT A PERSON IS THINKING



1 CORTICAL MODULE
The intercortical electrodes are made from platinum-iridium and are placed directly onto the brain to gather precise data on neural activity.



2 INTERNAL TRANSCEIVER
Data gathered by the electrodes is fed to an implanted internal transceiver, which can then be wirelessly transmitted to an external transceiver.



3 MICROELECTRODES
Each of the four modules has 421 microelectrodes that are 1.5 millimetres long and thinner than a strand of human hair.

4 CASING
The device casing is made from ceramic and is hermetically sealed, or airtight.



5 CONNECTING LEAD
Data from the implanted cortical modules is fed along a thin, flexible lead to the internal transmitter.

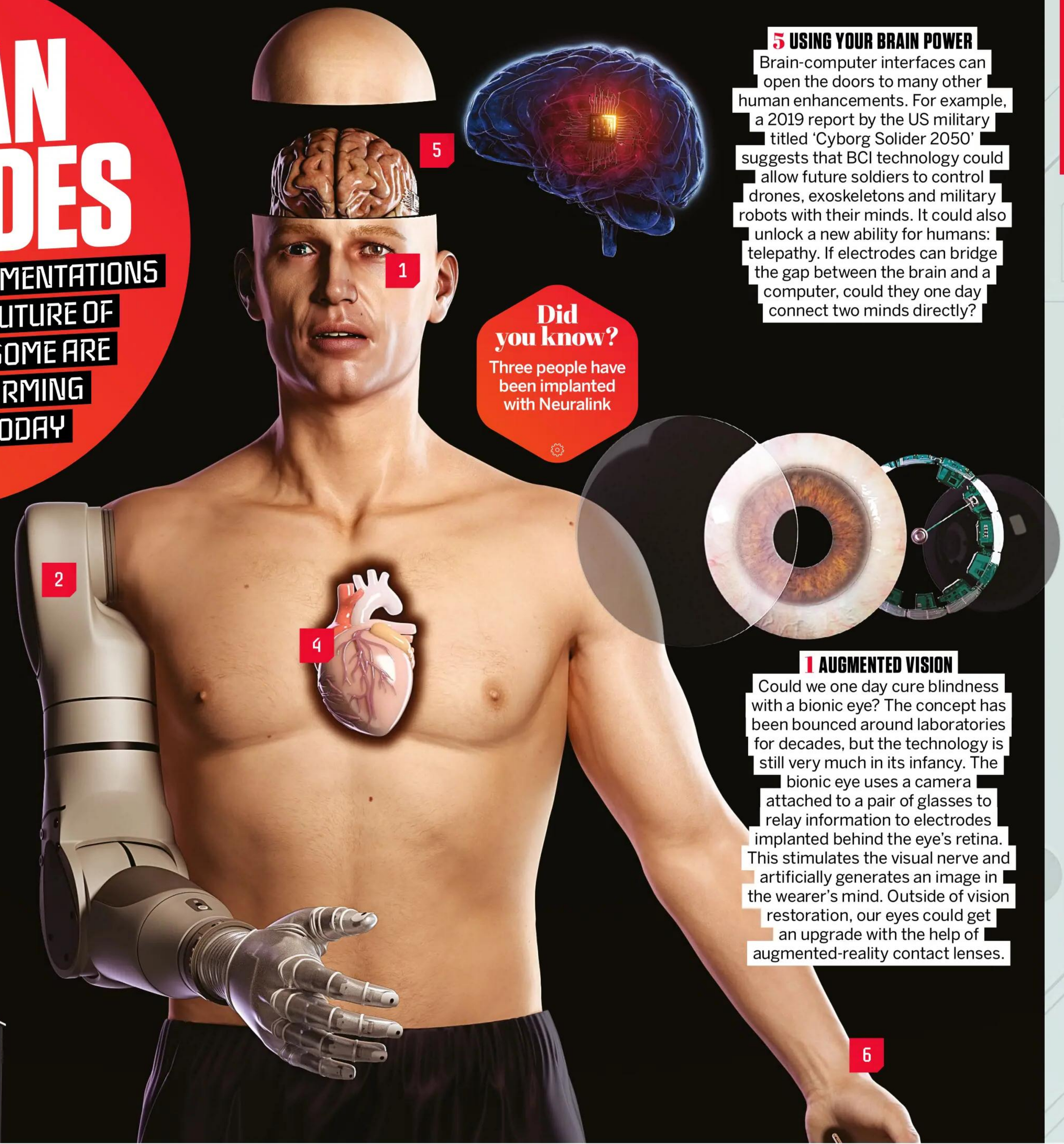
"The Connexus DDI device uses hundreds of tiny 'microwires'"

Did you know?
The term 'human augmentation' was coined in 1962

© Getty / German Bionic / Paradromics

HUMAN UPGRADES

THESE REAL-WORLD AUGMENTATIONS COULD CHANGE THE FUTURE OF HUMANITY, THOUGH SOME ARE ALREADY TRANSFORMING PEOPLE'S LIVES TODAY



5 USING YOUR BRAIN POWER

Brain-computer interfaces can open the doors to many other human enhancements. For example, a 2019 report by the US military titled 'Cyborg Solider 2050' suggests that BCI technology could allow future soldiers to control drones, exoskeletons and military robots with their minds. It could also unlock a new ability for humans: telepathy. If electrodes can bridge the gap between the brain and a computer, could they one day connect two minds directly?

Did you know?

Three people have been implanted with Neuralink

2 HIGH-TECH LIMBS

One of the most advanced prostheses available today is the LUKE arm from Mobius Bionics. This full-arm prosthetic uses a technique called targeted muscle reinnervation, which involves a complex surgical procedure to rewire the nerves that would typically control hand, wrist and elbow motion, relocating them to adjacent muscles. Electrical signals are then detected by the LUKE arm, which means the wearer simply has to think about limb movement and the prosthetic should follow suit. In place of neural activity, battery-powered prosthetic legs and feet use sensors and artificial intelligence to determine the leg's position in real time, triggering motors in the joint to enable walking.



1 AUGMENTED VISION

Could we one day cure blindness with a bionic eye? The concept has been bounced around laboratories for decades, but the technology is still very much in its infancy. The bionic eye uses a camera attached to a pair of glasses to relay information to electrodes implanted behind the eye's retina. This stimulates the visual nerve and artificially generates an image in the wearer's mind. Outside of vision restoration, our eyes could get an upgrade with the help of augmented-reality contact lenses.

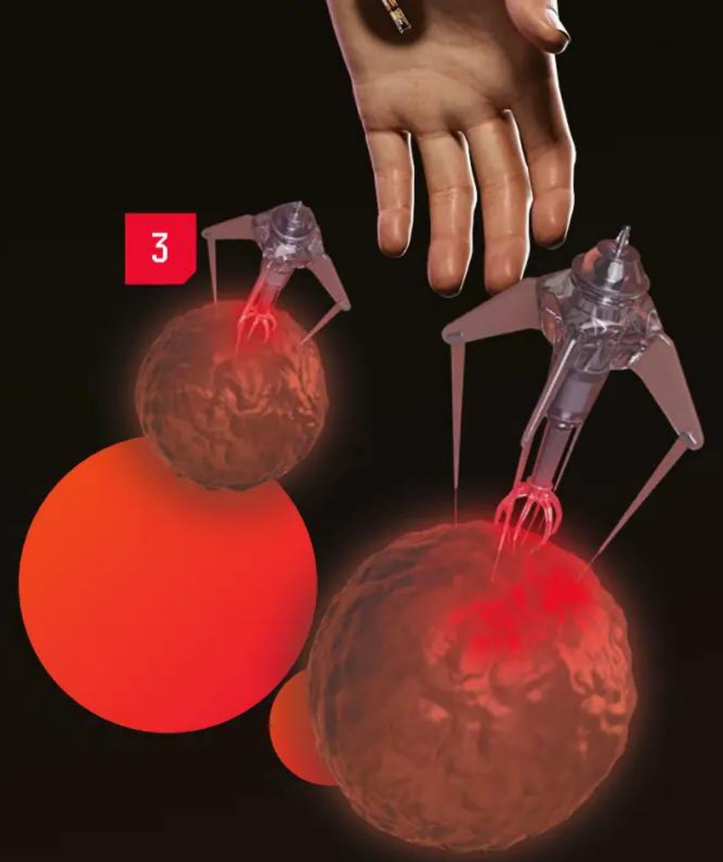
DID YOU KNOW? In 2024, surgeons successfully implanted the first 3D-printed windpipe



4 3D-PRINTED ORGANS

Around 150,000 organ transplants are performed worldwide each year, with thousands more people still on the waiting list. But what if instead of waiting for organ donation, we could just print a new one? Researchers across the world have been developing new technologies that could, in the not-so-distant future, make 3D-printed or bio-printed organs available. Using stem cells, which can transform into different cell types, some scientists have created a kind of biological ink that can be used to 'print' organs such as bladders and kidneys.





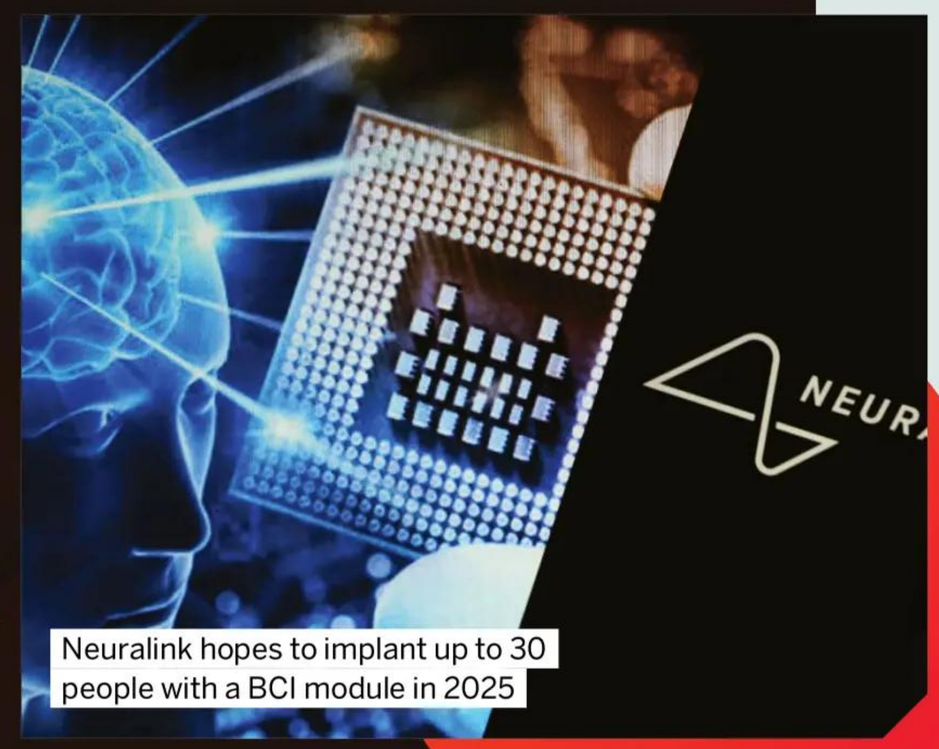
3 BLOODSTREAM BOOST

Nanotechnology might one day enhance our immune system in its fight against infection and deadly diseases by delivering medicine directly to specific organs or diseased cells like cancers. Blood could also get an efficiency update with the invention of respirocytes. These hypothetical nanodevices could mimic the function of red blood cells but carry much more oxygen than them. For decades, researchers have outlined how these devices might operate. However, there are many hurdles to overcome in their creation, including power supply and the body's immune response to artificial blood.



6 RFID

Would you trade your house key and credit card for a chip implant that can do the same job? Around 50,000 people worldwide have already done so. Using radio-frequency identification (RFID) and near-field communication (NFC) microchips implanted just underneath the skin, their hands double up as keycards and contactless payment devices that can pay for goods with just a wave. The size of a grain of rice, these devices can transmit personal and financial data to a reader automatically.



Neuralink hopes to implant up to 30 people with a BCI module in 2025

© Shutterstock / Illustration by Nicholas Forder

The data is then wirelessly transmitted to action controls on a computer to access speech software. Meanwhile, Synchron has developed a BCI device called Stentrode, a similar solution to the Connexus DDI which instead of brain implants uses a mechanical stent electrode inserted into the brain's blood vessels to pick up neuron signals.

One of the most talked-about BCI technologies is the Neuralink N1, one of Elon Musk's many scientific endeavours. Like other BCIs, Neuralink is designed to translate a person's brain activity into digital actions. About the size of a pound coin, the device is implanted beneath the skull with an electrode that detects neural activity and interprets these as commands for a computer. It enables hands-free access to the internet and playing video games, but the scope of Neuralink may be limitless with the help of artificial intelligence (AI). Like having ChatGPT installed in your head, an AI-powered BCI implant could theoretically allow you to access online data just by thinking about it, giving you the answer to questions you've barely even thought about. Musk has hinted at the idea of humans one day merging with software, saying at the World Government Summit in Dubai in 2017: "Over time, I think we will probably see a closer merger of biological intelligence and digital intelligence."

"Neuralink may be limitless with the help of artificial intelligence"



Mark Clayton Daniel representing the US during the exoskeleton race at the 2016 CYBATHLON

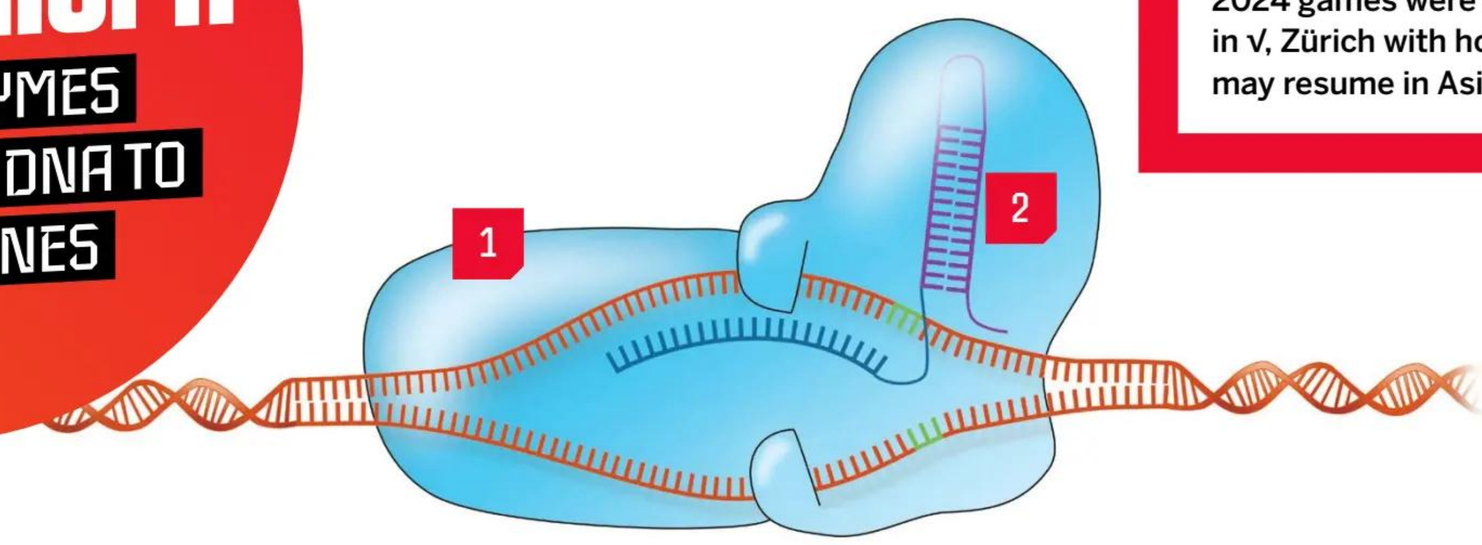
At present, the majority of BCI technology involves completing tasks on a computer screen. However, there have been some incredible advancements in recent years that marry the brain power of BCI with the dexterity of a prosthetic. In January 2025, a research project led by the University of Chicago showcased the possibility of a user feeling the object their prosthetic limb is holding. The BCI element of the technology placed electrodes on both sides of the head, with one half focused on areas of the brain responsible for the movement of the limb and the other on areas dedicated to the sense of touch.

THE CYBORG OLYMPICS

Since 2016, people from around the world have come together to compete in one of the most unique sporting events in history: the CYBATHLON. Founded at Swiss university ETH Zürich, the event showcases groundbreaking technology that enhances the lives of people with disabilities. There are lots of different races at this event, including the arm prosthesis race, exoskeleton race and assistance robot race. There's even a brain-computer interface race, where participants use their brain power to complete ten tasks such as piloting a wheelchair through a course or operating a virtual robotic arm. Last year's BCI race winner was Phillip Mckenzie, who completed all ten event tasks in just over two minutes. The 2024 games were the last to be held in √, Zürich with hope that the event may resume in Asia in 2028.

CUTTING WITH CRISPR

HOW ENZYMES OPERATE ON DNA TO ALTER GENES



1 CAS9
This enzyme is placed into a cell to cut through a double strand of DNA.

2 RNA
Ribonucleic acid (RNA), a molecule attached to Cas9, locates and binds to the portion that needs to be edited.

3 ENZYME CHOP
Cas9 cuts both strands of the DNA, leaving a gap in the strand behind.

4 NEW DNA
Scientists insert a new section of DNA into the cell, which will automatically fill the gap within the DNA strand.

DID YOU KNOW? Around 100 million people worldwide have a prosthetic limb



Did you know?
77 per cent of devices use some form of AI

Myoelectric prostheses read the electrical signals generated by muscle contractions to interpret actions

Feedback sensors were placed in the arm, triggering electrical pulses called 'intracortical microstimulation' that gave the sensation of touch to the brain-bound electrodes.

In the future, these human enhancements might even extend to our generic makeup. Currently, genetic engineering is mostly reserved for the production of food and medicine. Using a technique called CRISPR-Cas9, scientists are able to cut and paste desirable genes from one organism and insert them into the DNA of another. For example, corn can be genetically edited to produce its own pesticides or pineapple can be engineered to increase the production of lycopene, a red pigment that can turn the fruit pink. While humans aren't currently getting any genetic tailoring, it's not far from the realms of possibility.

One of the biggest issues with genetic editing of the human genome is overcoming the fact that editing or removing a single gene doesn't have a single consequence. But there's also a larger ethical issue at play. Do we have the right to edit the genes of an embryo? And would gene-editing embryos lead to cosmetic changes rather than medical ones? Currently, genetically altering human embryos is largely outlawed around the world. However, this hasn't stopped some scientists from trying.

In 2018, the science community was left stunned when a Chinese researcher named He Jiankui claimed to have altered the genomes of twin baby girls using CRISPR-Cas9. Despite being in violation of Chinese law, the researcher altered the twin embryos by removing a gene called CCR5, which has been associated with increased risk of contracting HIV, in the hope it would help prevent the twins from contracting the disease in the future. In 2024, Jiankui told the Japanese newspaper *The Mainichi* that the twins "are perfectly healthy and have no problems with their growth".

THE FUTURE OF HUMAN AUGMENTATION

DR DAVID CHENELER, SENIOR LECTURER IN ENGINEERING AT THE UNIVERSITY OF LANCASTER, SHEDS SOME LIGHT ON HOW AUGMENTATION MIGHT ALLOW US TO LEARN MORE ABOUT OURSELVES



Could implanted devices monitor the health of different organs?

Absolutely. Some of the stuff I'm working on are sensors for personalised health monitoring, but drug release as well. This will be a system that's implanted and releases drugs on command. You can currently get drugs that are implanted in the skin that slowly release the drug over time as they dissolve in the blood. But we can also have more active systems that can release drugs when necessary. This could be controlled by an external device. It could be controlled as a closed-loop system, as in it could be the sensors themselves responding and therefore could be fully automated. Imagine a scenario whereby the sensors are monitoring health signals, and these signals go up to a doctor or a care provider. They could trigger a response as a result.

How long might it be before this type of technology starts to emerge in hospitals?

It depends. In a scenario similar to that of an insulin pump where somebody wears the sensor, that already exists. But extensions of that paradigm, such as sensors that monitor osteoarthritis over time, are more like ten years or so. The technologies aren't quite there.

How would this technology extend to healthy individuals?

The classic thing will be training athletes – certainly with joint health and muscle health. So things like gait analysis could very much be combined with the sort of data they're getting now. For example, a runner would quite often have a smartwatch that monitors pace, GPS and slopes, that sort of thing. If you can combine that with your gait analysis and also joint health, you can see if you are doing damage to your knees because you're running up hills wrong, that sort of thing. You can change your stance or change your habits.

Could the technology be used in other industries, such as in the military?

Obviously I can't talk too much about specifics, but you can imagine the military are very much concerned about their personnel's health. Again, it's probably more for planning purposes, because if your army is becoming fatigued, injured or under attack, finding out what's going on remotely is of critical importance. Real-time data and the ability to do real-time and obviously predictive interventions is far better. Imagine a complex battlefield scenario where there could be a range of injuries with potentially limited medical personnel nearby. Being able to triage remotely could be quite significant.

© Getty / Alamy / David Cheneler



WHAT'S INSIDE...

A PLAYSTATION 2?

We crack open this retro console to discover the hardware that made it so popular

WORDS BEN BIGGS

Sony's 1994 entrance into the video games console market with the PlayStation 1 was an industry game changer, but no one could have envisaged just how popular its successor would be when it launched in 2000. The PS2 stood out from other consoles in the same generation by offering backwards compatibility with the PlayStation 1's controllers, as well as its predecessor's entire back catalogue of games. It featured a central processing unit (CPU) that notably rivalled PC CPUs of the day, plus a graphics processor with dedicated video memory and an optional 40-gigabyte hard drive for storage. Its games were DVD-based and it had an internal DVD drive that doubled up as a movie player. At a time when standalone DVD playback devices were costly, it made sense for a lot of consumers to buy the PS2 and effectively get two entertainment systems for the price of one.

Besides the DualShock controller, the PS2 spawned a variety of peripherals, including an eight-megabyte memory card for game saves, a network adapter for online play, the motion-detecting EyeToy camera, a remote control for DVD movie playback and even an LCD screen attachment for the PS2 itself. Over 12 years, an outlandishly long manufacturing period meant that the PS2 would eventually sell over 160 million units, becoming the best-selling console ever.



One of the PlayStation 2's most popular titles, the fighting game *Soulcalibur 2*, was an arcade hit that ported smoothly to Sony's new console

Did you know?
There are over 4,000 PS2 games

5 INTERNAL VS EXTERNAL
A two-tined C7 lead delivers mains electricity to the original PS2's internal power supply. The newer Slimline PS2 uses an external power pack.

6 KEEPING COOL
Cooling is vital, or an overheating console will shut down and possibly be damaged. This fan exhausts air that has been heated by the internal components, particularly the processing chips.

2 MEMORY
Two 16-megabyte blocks of RDRAM (Rambus Dynamic Random Access Memory) feed into the Emotion Engine's memory controller for a total of 32 megabytes of memory.

3 GRAPHICS
The Graphics Synthesiser chip is directly responsible for processing the console's 3D display output. It has four megabytes of embedded memory and is fed with bitmap graphics data from the Emotion Engine.

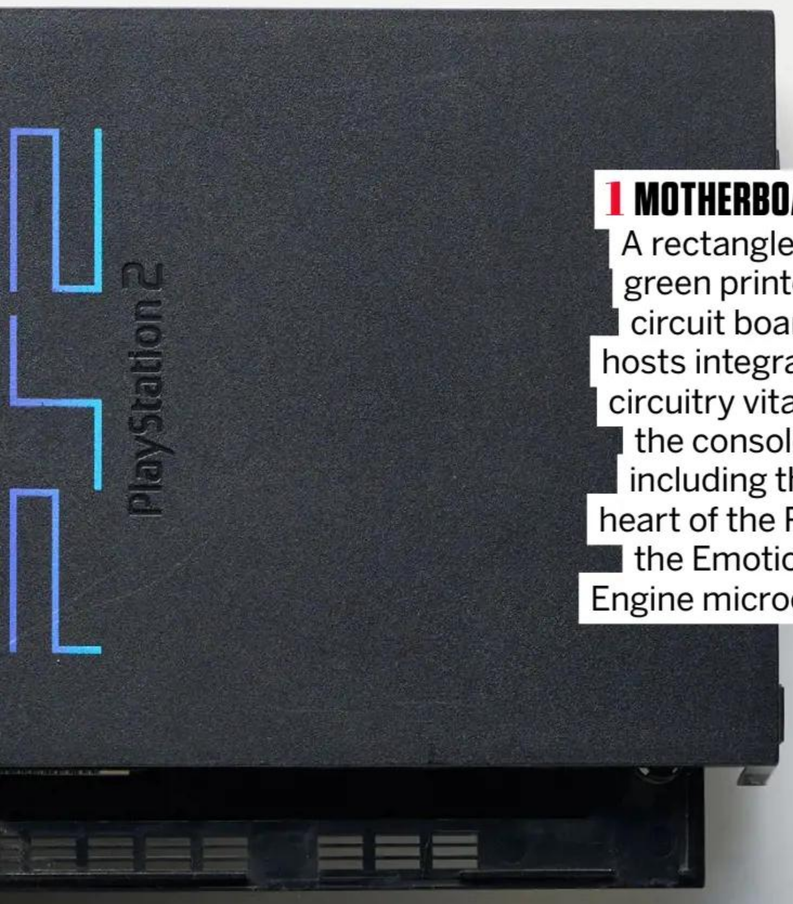
10 INPUT-OUTPUT
The I/O chip provides an interface for most of the PS2's input and output, including the sound processor and DVD drive.

"No one could have envisaged just how popular its successor would be when it launched in 2000"

DID YOU KNOW? By the time the PS2 was discontinued in 2013, nearly 1.6 billion PS2 games had been sold worldwide



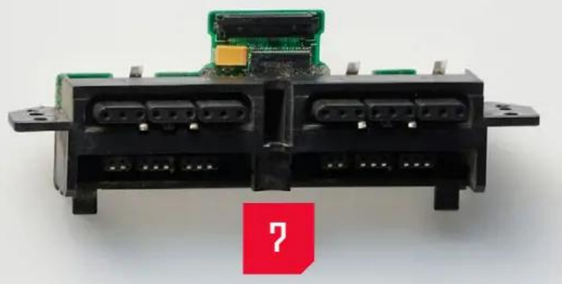
The Emotion Engine (right) runs at nearly 300 megahertz and consists of a CPU, coprocessors and a memory controller, all dedicated to 3D gaming



1 MOTHERBOARD
A rectangle of green printed circuit board hosts integrated circuitry vital to the console, including the heart of the PS2, the Emotion Engine microchip.

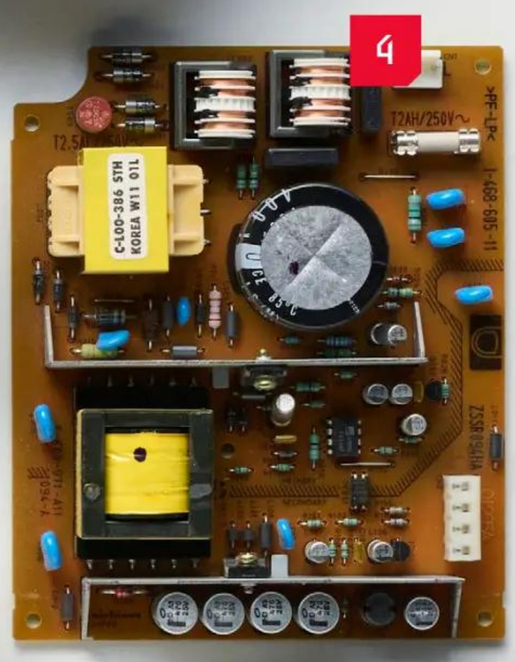
BITS 'N CHIPS

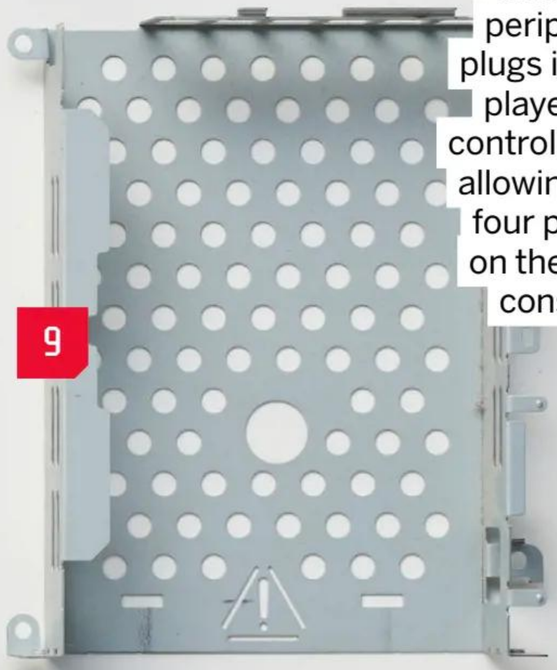
A trio of integrated circuits form the PlayStation's heart, brains and looks

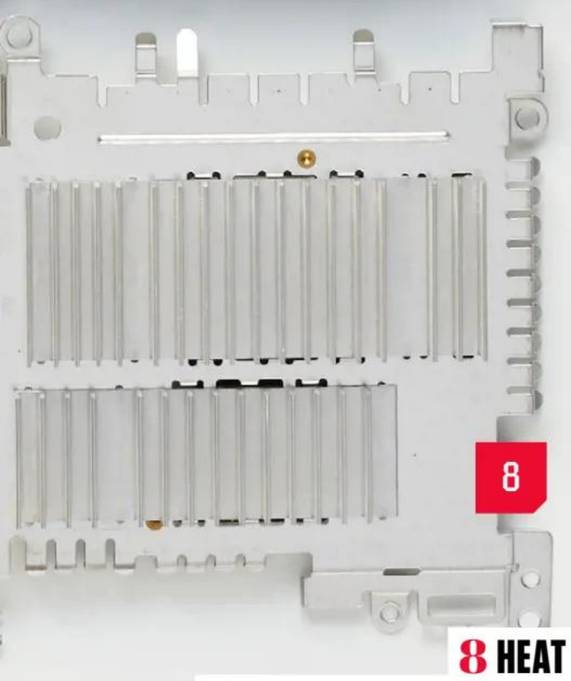


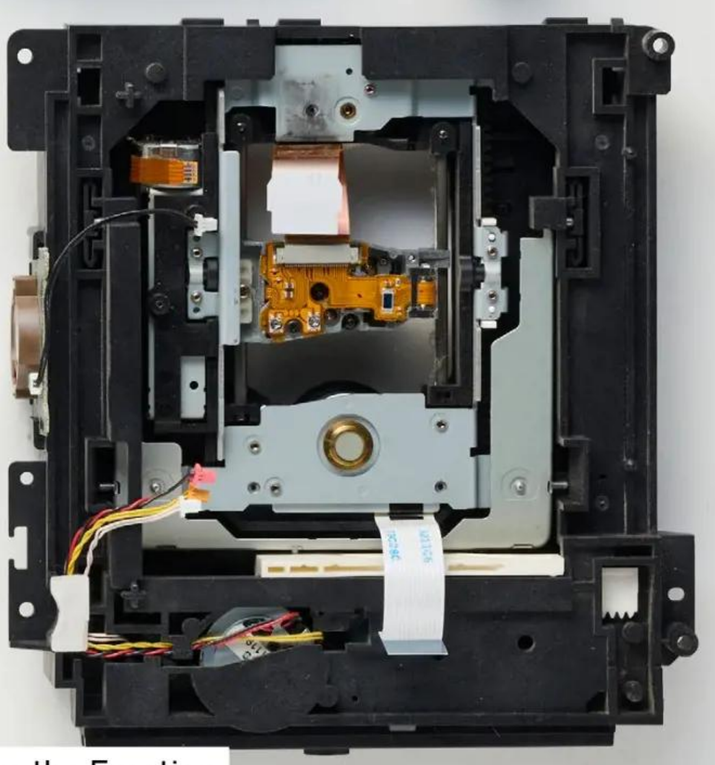
7 CONTROLLER INPUT
The original PS2 has just two controller inputs for single or two-player games. The Multitap peripheral plugs into the player two controller port, allowing up to four players on the same console.











8 HEAT SINK
The main integrated circuits, like the Emotion Engine, are passively cooled by aluminium heat sinks that transfer heat away from the chip.

4 POWER SUPPLY
The original PS2 is a 48-watt device, while the later Slimline edition of the PS2 is much more efficient, rated at 12.5 watts.

9 EXPANSION
Later models of the original PS2 include an expansion bay that houses the internal hard disk drive and network adapter.



A PlayStation 2 plus DualShock controllers, games and an EyeToy peripheral

KEY TECH

BACKWARDS COMPATIBILITY

In the hype leading up to the launch of the PlayStation 2, Sony put its Emotion Engine and Graphics Synthesiser front and centre, touting its revolutionary visual capabilities. While there was mass-market appeal in the central processing unit's catchy name and 3D graphics, the unassuming I/O chip gave the new console another string to its bow. It allowed full backwards compatibility with PlayStation 1 games and controllers, which meant that from launch day, customers could play thousands of existing, CD-based games on Sony's new console in addition to PS2 launch titles, while using their old PlayStation 1 controllers. This was great news for both budget-conscious gamers with an eye on the PS2 and for PS1 fans alike. At the time, no other video games console manufacturer had offered anything like this level of support for its legacy devices.



A PlayStation 1 controller and a few of the most popular titles for the console, all of which could be used on the PS2

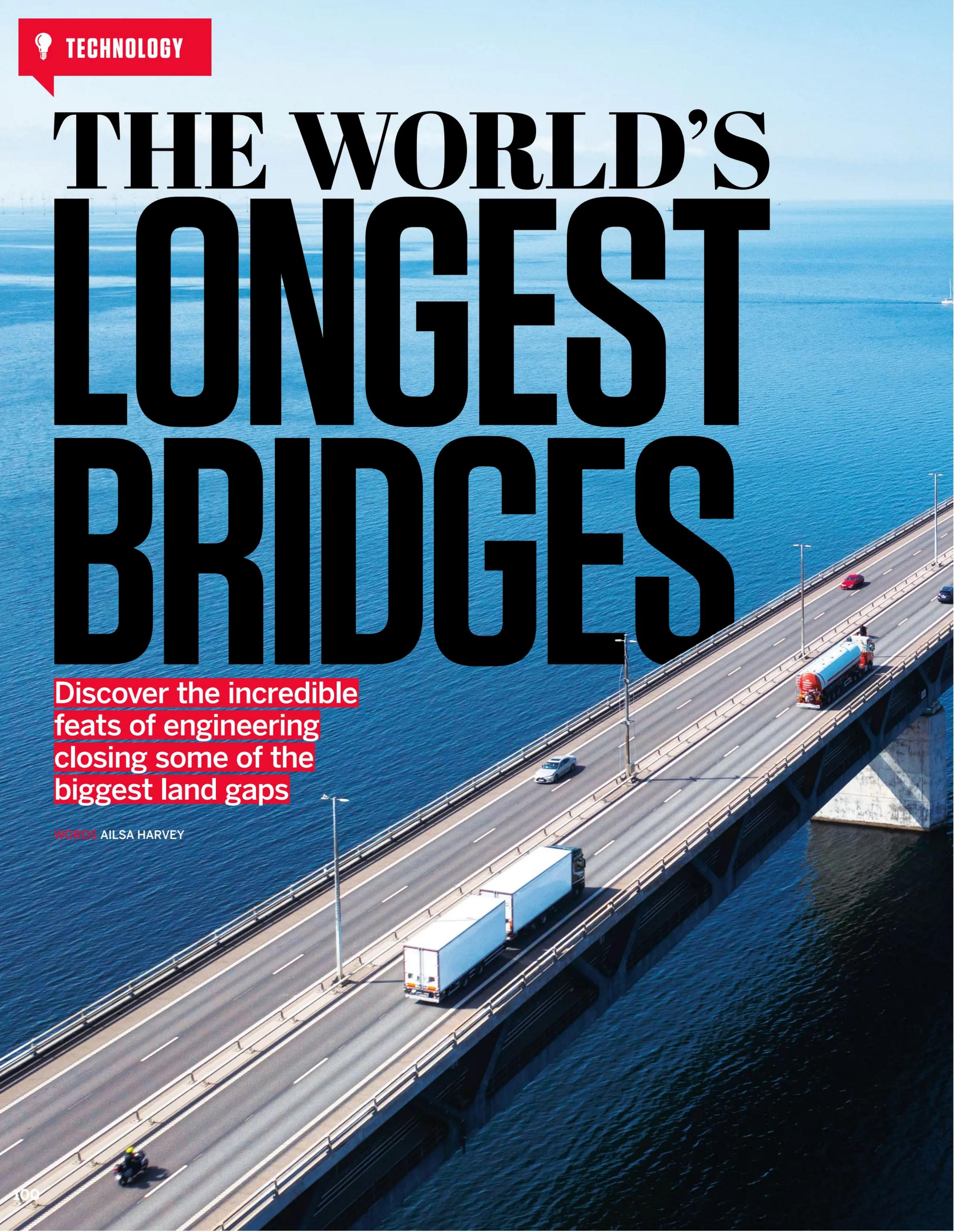
© Shutterstock / Alamy

TECHNOLOGY

THE WORLD'S LONGEST BRIDGES

Discover the incredible feats of engineering closing some of the biggest land gaps

WORDS AILSA HARVEY



DID YOU KNOW? At 391 metres, Hartland Bridge in Canada is the longest covered bridge, with a roof to stop the wood rotting

Humans have constructed bridges for thousands of years, helping establish trade routes across rivers and deep valleys to keep communities connected. Today's modern bridges may be bigger and longer, using advanced building techniques and materials that weren't available to ancient engineers, but they're still constructed to make isolated islands and tricky terrain more accessible.

Building record-breaking bridges is only possible with high-strength materials such as advanced steel alloys – low-alloy steel with a high strength-to-weight ratio and better corrosion resistance. Choosing this steel over alternatives allows for longer structures to be built with lower weight stress. And the corrosion resistance helps give a bridge longevity. Computer structural simulations that take into account variables such as the specific location, bridge length, shape and type of materials can be used to determine whether a mammoth bridge project is actually viable before builders invest more time and money into the project.

Did you know?

Arkadiko Bridge is thought to be the world's oldest crossable bridge

To date, the world's longest completed bridge is China's Danyang-Kunshan Grand Bridge, measuring over 100 miles in length. It's designed to support high-speed trains travelling at around 186 miles per hour. China's high-speed railway network is revolutionising travel efficiency, with the bridge assisting in reducing a journey between Beijing and Shanghai that once took 12 hours to just 4.5 hours.

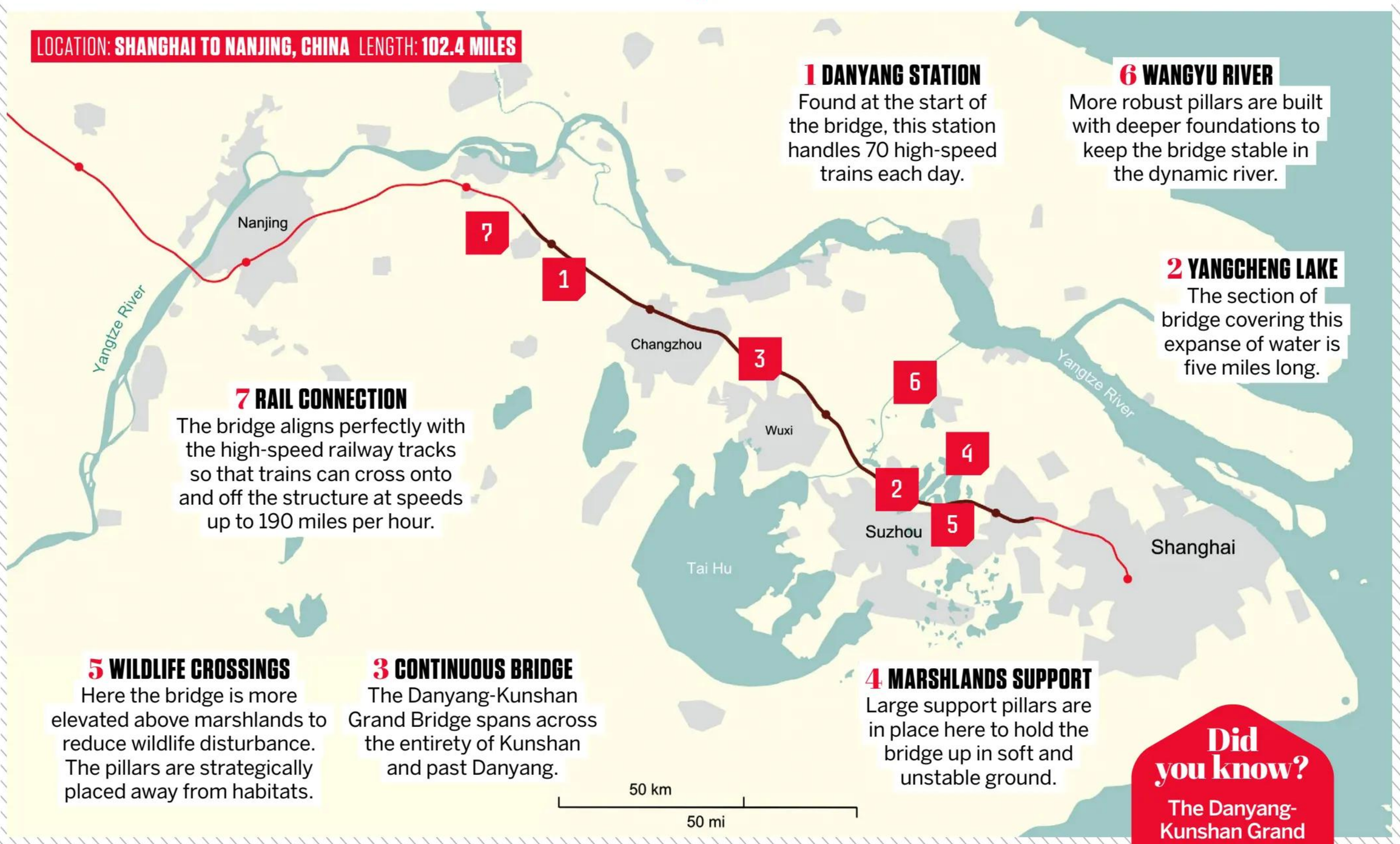


A bullet train on the Beijing-Shanghai high-speed railway crosses China's enormous Danyang-Kunshan Grand Bridge

© Getty / Alamy

THE WORLD'S LONGEST BRIDGE

The Danyang-Kunshan Grand Bridge is the longest across all categories, forming part of China's high-speed rail network



© Wikimedia Commons/ Pechristener

Did you know?

The Danyang-Kunshan Grand Bridge has 2,000 piers

RUNNERS UP



CHANGHUA-KAOHSIUNG VIADUCT

LOCATION: **TAIWAN**
LENGTH: **97.7 MILES**

The second-longest bridge makes up part of Taiwan's high-speed rail network. It was completed in 2007 with a focus on minimising earthquake damage. To do this, the bridge absorbs and dissipates the energy of an earthquake away from the structure itself. In doing so, it protects trains and passengers by providing a safe space for the vehicle to come to a stop.



TIANJIN GRAND BRIDGE

LOCATION: **CHINA**
LENGTH: **70.6 MILES**

When it opened in 2011, this bridge was the second longest in the world. It's made up of 32 separate sections, each weighing 860 tonnes, that were built and installed individually. Tianjin Grand Bridge, which was completed four years after the project launched, connects Langfang and Qingxian in China and makes up another part of the Beijing-Shanghai high-speed railway.



CANGDE GRAND BRIDGE

LOCATION: **CHINA**
LENGTH: **65.7 MILES**

This section of the Beijing-Shanghai railway is supported by 3,092 piers. Sometimes Cangde Grand Bridge's length is listed at 72 miles, as this includes other support structures and viaducts that connect to the bridge at either side.



© Wiki: Xinxinworm

WEINAN WEIHE GRAND BRIDGE

LOCATION: **CHINA**
LENGTH: **49.5 MILES**

Connecting Zhengzhou and Xi'an in Weinan, China, this bridge crosses the Wei River twice. It was completed in 2008, though it was another two years before its railway line was opened. 10,000 people constructed Weinan Weihe Grand Bridge using 45,000 tonnes of steel and over 2,000,000 cubic metres of concrete.

DID YOU KNOW? The Danyang-Kunshan Grand Bridge cost £8 billion ($10 billion) to build

SUSPENSION RECORD-BREAKER

LOCATION: **1915 CANAKKALE BRIDGE, TURKEY** LENGTH: **2,023 METRES**

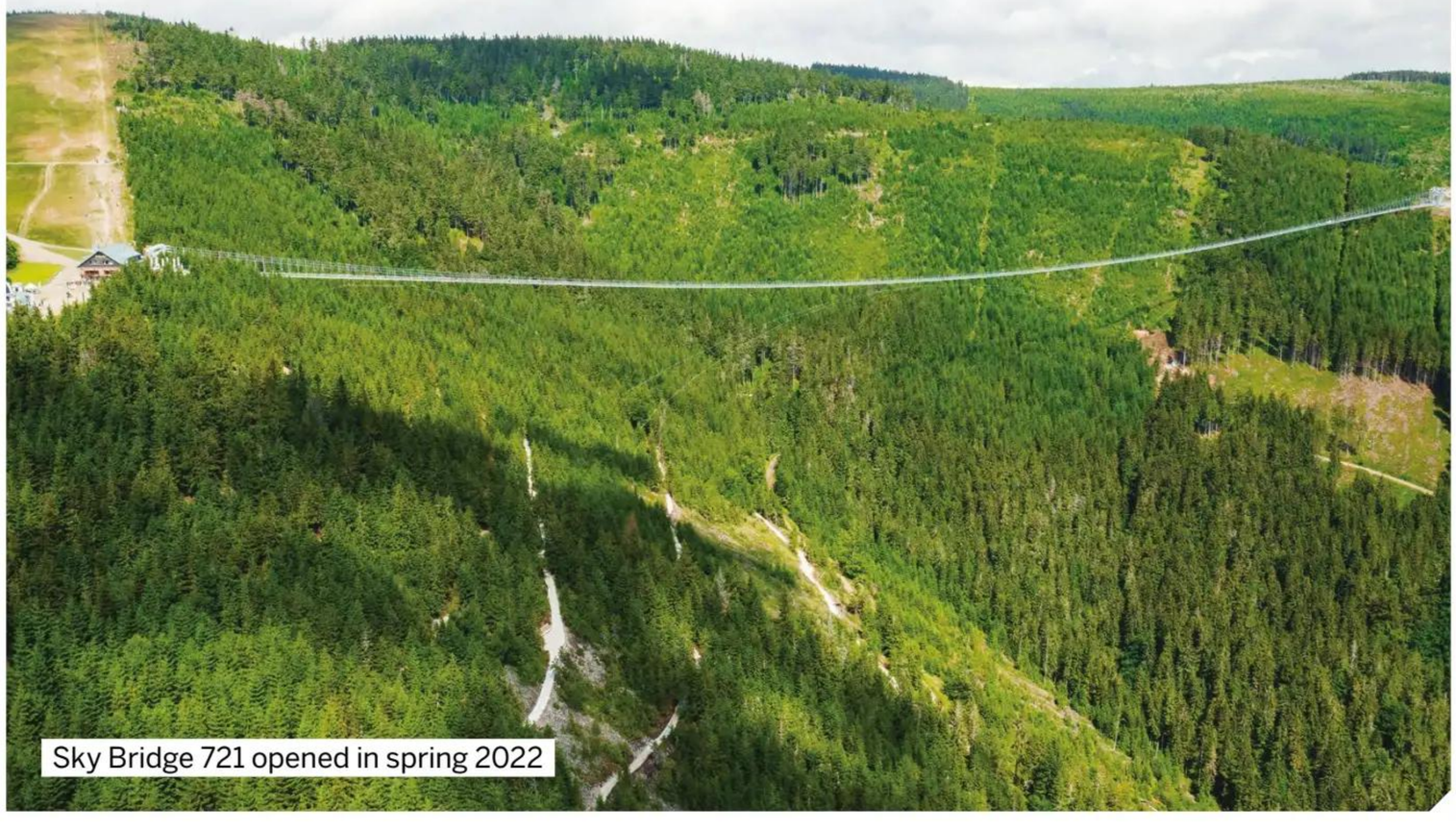
Despite its name, the 1915 Canakkale Bridge was opened in 2022. It's named after the year the Turkish Navy defeated Britain and France in World War I and connects the Asian and European land of the country on either side of the Dardanelles Strait. This makes travel across the region much easier by eliminating the need for a 30-minute ferry. In addition to holding the title of longest suspension bridge, the 1915 Canakkale Bridge is also the tallest bridge of its type, with 318-metre-tall towers holding up the suspended steel deck.

The 2,023-metre bridge commemorates 2023, the 100th anniversary of the Republic of Turkey

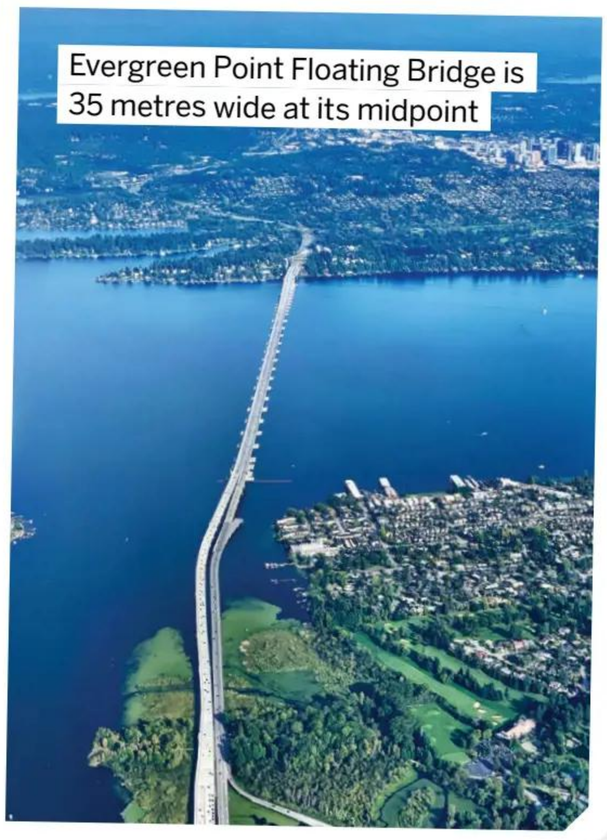
SKY WALKING

LOCATION: **SKY BRIDGE 721, CZECH REPUBLIC** LENGTH: **721 METRES**

The longest pedestrian bridge in the world is a suspension bridge that dangles 95 metres above a drastic mountain valley drop. For those unphased by heights, this narrow crossing is a ticketed tourist attraction that has been designed as an educational experience as well as a captivating view. The total crossing time takes around 1.5 hours, but this includes time to take in information about the history of the surrounding area, a three-hour drive from the country's capital city of Prague. The bridge took two years to build and consists of six main supporting ropes and 60 wind ropes to keep the structure in place.



Sky Bridge 721 opened in spring 2022



Evergreen Point Floating Bridge is 35 metres wide at its midpoint

FLOATING ON WATER

LOCATION: **EVERGREEN POINT FLOATING BRIDGE, WASHINGTON**
LENGTH: **2,350 METRES**

In Seattle, the world's longest floating bridge supports the weight of State Route 520 over Lake Washington. Floating bridges are also called Pontoon bridges and are supported only by pontoons on the water's surface. These structures are usually built when more permanent options aren't feasible. In the case of the Evergreen Point Floating bridge, the water is too deep and the silt on the lakebed too soft to build a secure bridge into. The 77 concrete pontoons are instead anchored to the bottom of the lake to keep the dual carriageway stable on the great lake.

© Shutterstock / Alamy

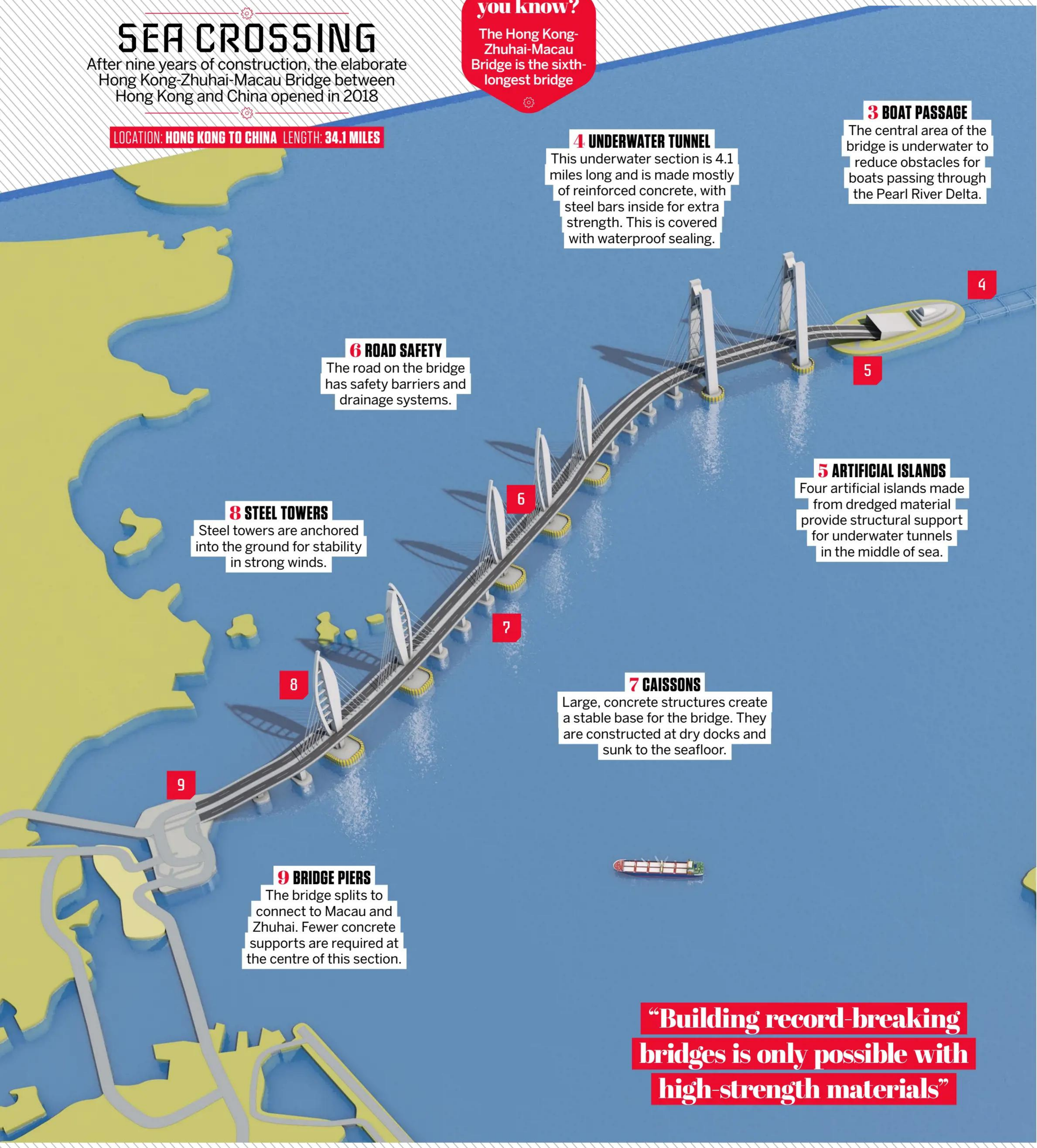
SEA CROSSING

After nine years of construction, the elaborate Hong Kong-Zhuhai-Macau Bridge between Hong Kong and China opened in 2018

LOCATION: **HONG KONG TO CHINA** LENGTH: **34.1 MILES**

Did you know?

The Hong Kong-Zhuhai-Macau Bridge is the sixth-longest bridge



4 UNDERWATER TUNNEL
This underwater section is 4.1 miles long and is made mostly of reinforced concrete, with steel bars inside for extra strength. This is covered with waterproof sealing.

3 BOAT PASSAGE
The central area of the bridge is underwater to reduce obstacles for boats passing through the Pearl River Delta.

4

6 ROAD SAFETY
The road on the bridge has safety barriers and drainage systems.

5

5 ARTIFICIAL ISLANDS
Four artificial islands made from dredged material provide structural support for underwater tunnels in the middle of sea.

6

8 STEEL TOWERS
Steel towers are anchored into the ground for stability in strong winds.

7

7 CAISSONS
Large, concrete structures create a stable base for the bridge. They are constructed at dry docks and sunk to the seafloor.

8

9

9 BRIDGE PIERS
The bridge splits to connect to Macau and Zhuhai. Fewer concrete supports are required at the centre of this section.

"Building record-breaking bridges is only possible with high-strength materials"

DID YOU KNOW? 420,000 tonnes of steel was used to build the longest sea crossing – the equivalent of 60 Eiffel Towers




Krämerbrücke Bridge has a width of 25 metres and a clear width of 5.5 metres between houses

BRIDGE LIFE

LOCATION: **KRÄMERBRÜCKE BRIDGE, GERMANY** LENGTH: **125 METRES**

Along the Krämerbrücke Bridge in Erfurt, Germany, are 32 houses across both sides of the crossing, making it the world's longest inhabited bridge. It was originally built in the 12th century, and its tall, narrow homes are still inhabited today. The early version of this bridge was made of wood, but kept catching fire and was rebuilt several times. Today's more substantial Krämerbrücke Bridge was constructed from stone in the late-13th century. When this bridge became one of the only constructions to survive the ongoing fires, it became the safest place to call home. Each of the houses has three storeys, and today the ground level homes have largely been converted into river-top shops.

CABLE-STAYED

LOCATION: **RUSSKY BRIDGE, RUSSIA**
LENGTH: **1,104 METRES**

A cable-stayed bridge is one that has its deck weight supported by straight or diagonal cables. These connect the deck directly to the vertical towers that are spaced along it, as opposed to suspension bridges that have cables suspended between the towers. The longest cable-stayed bridge, Russky Bridge, connects Russky Island and the Muravyov-Amursky Peninsula across the Eastern Bosphorus Strait in the far east of Russia. When it was constructed in 2008, it had the longest cables manufactured for a bridge at 582 metres. These long cables were essential in supporting the deck and to meet the height of the tall 320-metre towers.


The deck of Russky Bridge is 70 metres above the water

© Alamy / Illustration by Adrian Mann

TECHNOLOGY

HOW AIRPORTS ARE GETTING SMARTER

Discover the latest smart airport technology that's making air travel a safer and smoother process

WORDS AILSA HARVEY

Every day, enough passengers filter through the world's airports to fill the seats of around 100,000 commercial flights. With thousands of people airborne at any given time, every process at an airport needs to be executed with efficiency and safety. This includes swift transportation from car parks and entrances to terminal buildings, regimented air-traffic control management and thorough checks of all people and items being transported around the globe.

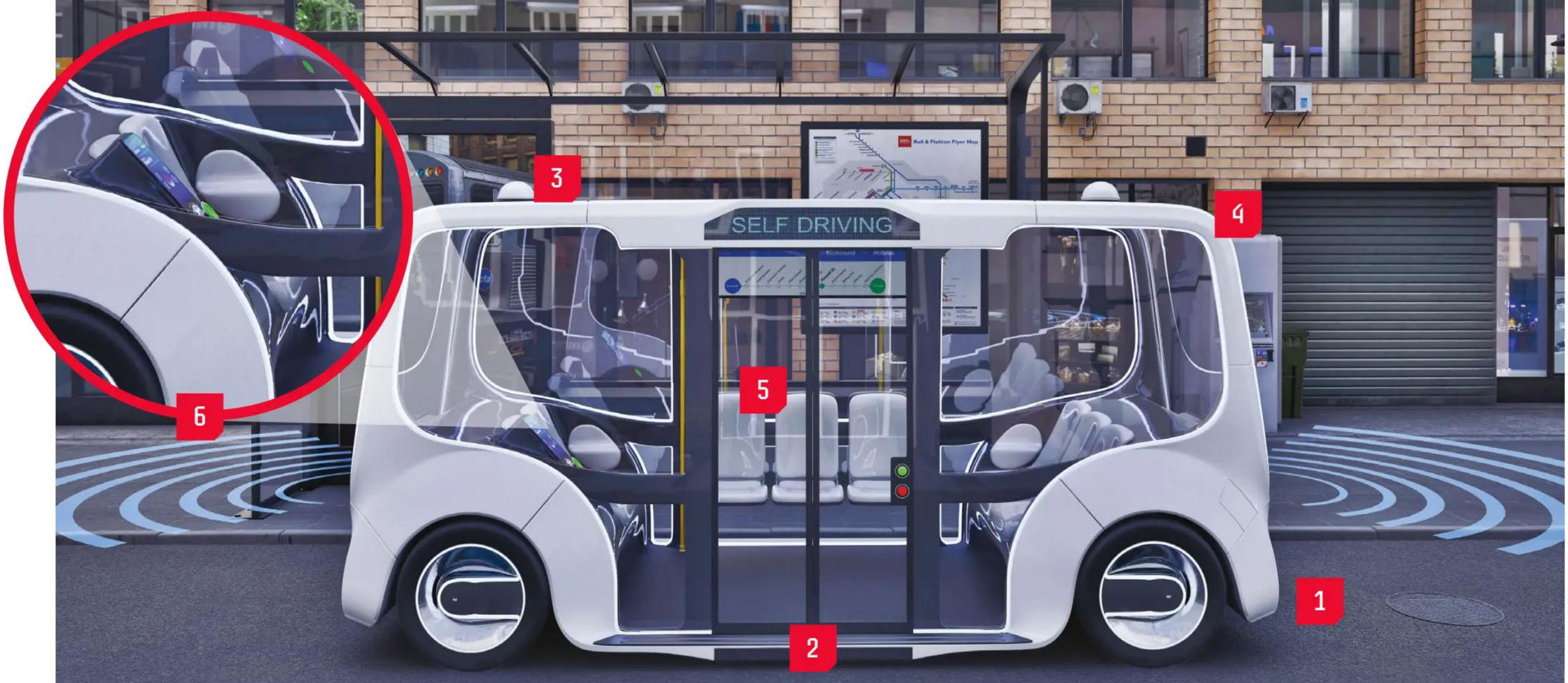
Airport traffic is trending upwards. As more flights are scheduled each year, airports have become more sophisticated to maintain control of departures and arrivals. In recent years, one of the most significant technological changes to take off was the conversion of air travel documentation from paper to electronic. This transition has massively reduced the time it takes to process passengers as more reliable computer systems ensure many of the manual checks at airports can be carried out by machines. In areas where human error could have devastating results, facial-recognition technology, autonomous vehicle systems and data prediction have all been welcome changes in terminals.



ROBOT REVOLUTION

Did you know?

Millimetre wave scanners emit less energy than a mobile phone



DRIVERLESS TAXIS

Autonomous shuttles carry passengers between car parks and airport terminals around the world

1 LIDAR
Light detection and ranging sensors release infrared waves. These are reflected off nearby objects so the vehicle can determine where obstacles are.

2 ODOMETRY
The distance the vehicle has travelled is calculated by a computer using the number of tyre rotations.

3 SATELLITE POSITIONING
Satellites in the global navigation satellite system communicate with the shuttle to determine the exact location of the vehicle.

4 CAMERA VISION
Live camera footage from the front and back records what obstacles surround the vehicle for safety.

5 PASSENGER SEATING
The seating area inside these pods usually has space to fit four passengers and their luggage.

6 CONTROL SCREEN
Upon entering the self-driving pod, passengers usually select the terminal they wish to travel to and the shuttle begins the journey automatically.

BAGGAGE-HANDLING BOTS

A city's main airport can operate over 1,000 takeoffs every day. On each of these planes are between 20 and 900 passengers, all trusting the respective airlines to handle their luggage and deliver it to their destination safely. One way in which the baggage-sorting task is achieved is through autonomous robots. These robots, which were first launched at Rotterdam The Hague Airport in the Netherlands, are being tested in various locations around the world, such as Dallas Fort Worth Airport in Texas. Following check-in, a passenger's bag is placed onto a conveyor belt and delivered to the baggage sorting area behind the check-in desk. Bags are dropped onto the surface of these wheeled robots, which sort them so that they are taken to the correct departure gates. They can handle 450 suitcases every hour.



Baggage-handling robots retrieving suitcases in Munich, Germany

© Alamy / Getty / Shutterstock

FAST SECURITY

How improvements in bag and body scanners can reduce airport security queues

2 PRIVACY PROGRESS
Software to protect passenger privacy is now in place at most airports. The screens being checked show where suspicious items are on the body, but only display a generic body outline.

3 METAL DETECTOR
Every person needs to walk through a metal detector, which can detect concealed weapons and other metal items.

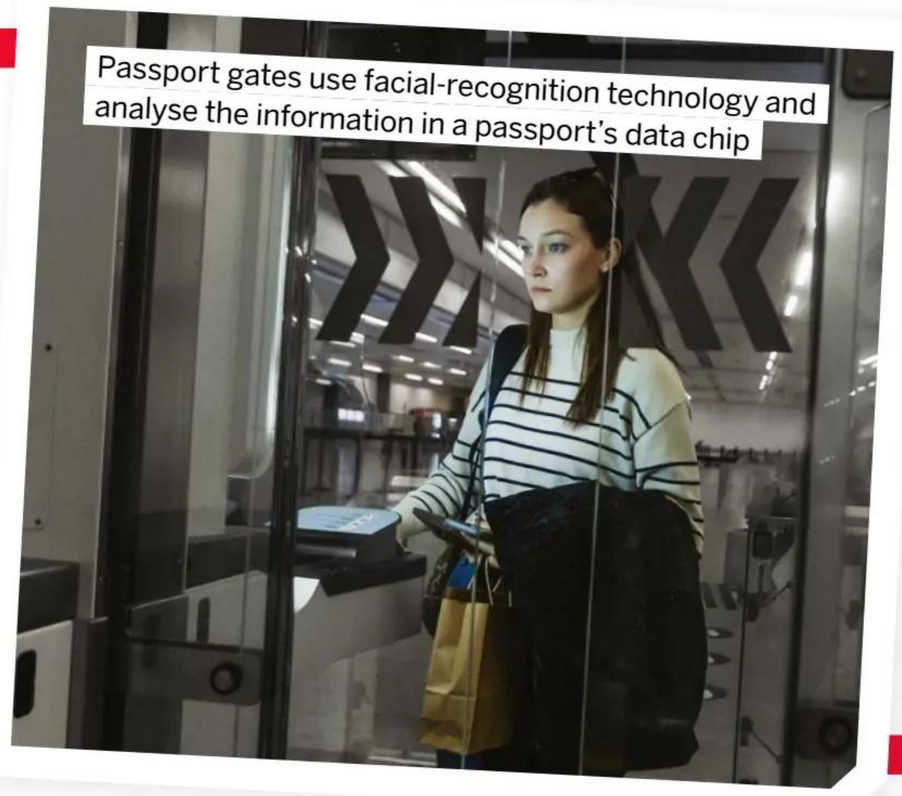
1 MILLIMETRE WAVE SCANNER
Since the 2010s, millimetre wave body scanners have been used in most airports instead of X-ray technology. These non-ionising waves bounce off the body and return to the machine. Any objects being worn on the body will be revealed.

4 CONTENT CHECKER
A computer tomography (CT) scanner is the latest technology to replace X-ray luggage machines. These produce a 3D image from different angles, enabling passengers to keep liquids and electronics inside their suitcases for the entire process.

Did you know?
Over 1,000 dogs work in US airports detecting contraband

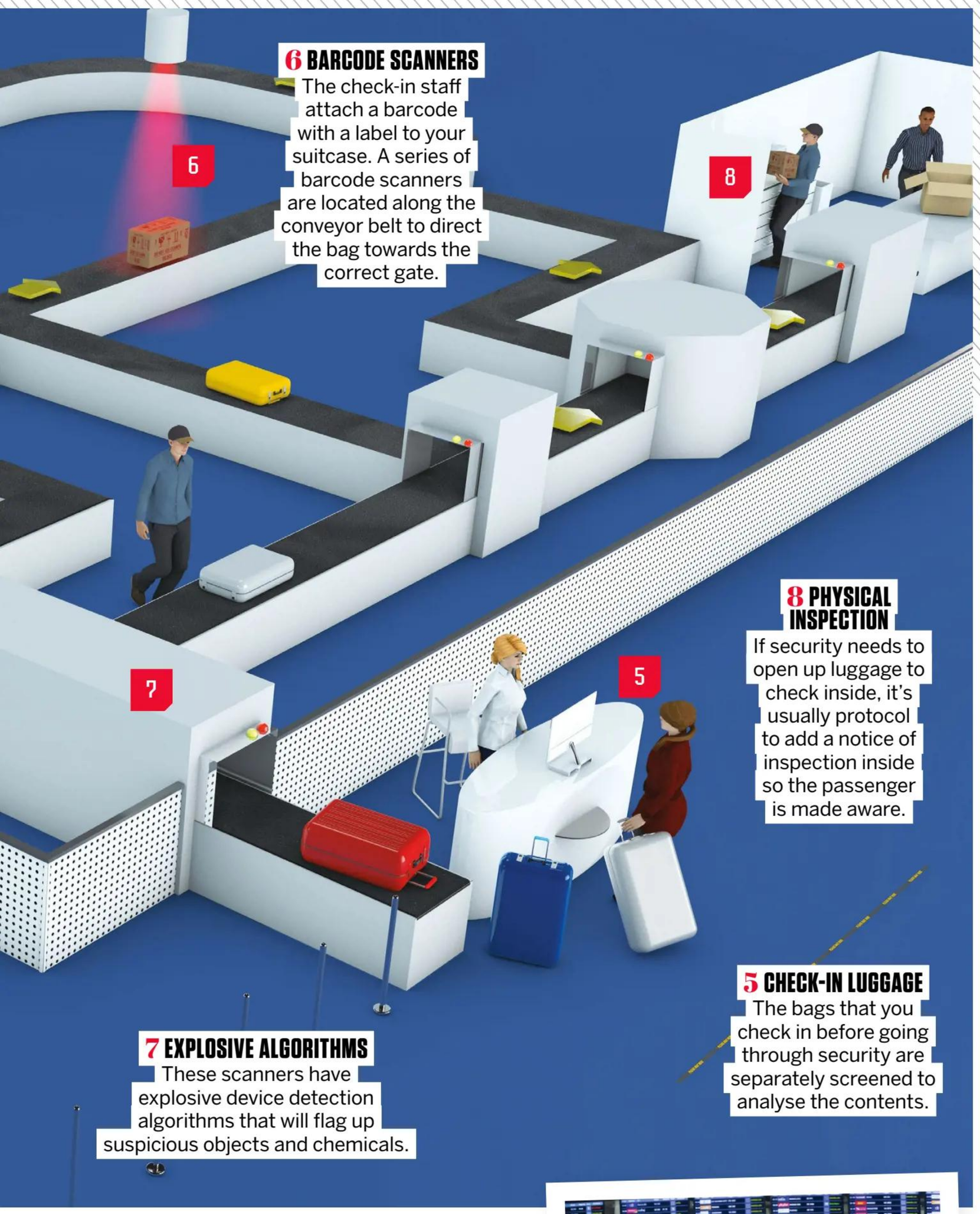
STOPPING STAMPING

Any citizen of a country outside the European Union (EU) has a limited number of days that they can be in the EU in a certain period. To keep track of exactly when each passenger enters and exits the region, border control staff stamp each person's passport with the date. This is a low-tech system compared to the intelligent machines in most modern airports. Soon this system will be replaced with the Entry/Exit System (EES). This will consist of passport-scanning machines that record the passenger's movements instead. Unlike the electronic passport machines already in place in most airports, which just check the validity of the document and match it with the person's face on camera, the EES will also be able to record their location. When in place, these machines will store this data and alert authorities when they come across a passenger who has overstayed in the EU.



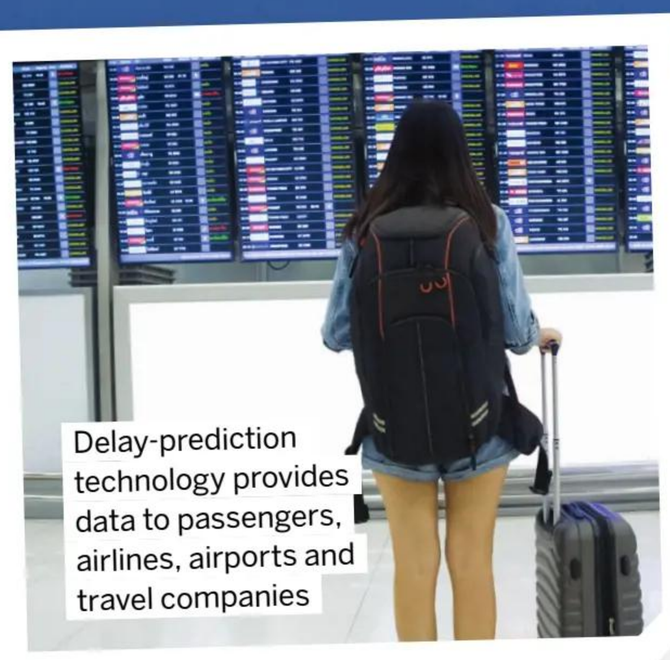
Passport gates use facial-recognition technology and analyse the information in a passport's data chip

DID YOU KNOW? Dubai International Airport served 41.6 million passengers in the first six months of 2023



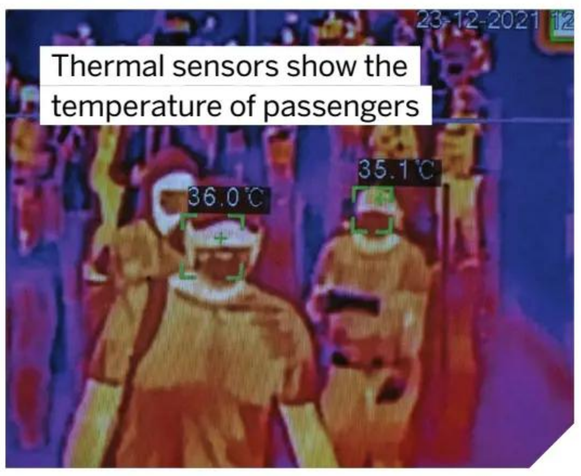
AI DELAY PREDICTIONS

You've arrived early for your flight and have just about had your fill of the terminal entertainment and refreshments. But when you check the gate number at the time instructed, the number is replaced with the word 'delayed'. This misfortune doesn't just impact the passenger, but throws off the busy schedule of the runways and flights in all connecting airports. Using artificial intelligence (AI) and machine learning, computers can combine weather data, aircraft live locations and other data to predict how likely each flight is to be delayed. This software can even convert radio communications from pilots and airport towers into text, analyse it and then incorporate the events from hundreds of these conversations into its prediction. If used across the world's connected airports, disruptions could be managed in advance, which could create more efficient airport spaces.


Delay-prediction technology provides data to passengers, airlines, airports and travel companies

DEPARTURES SURVEILLANCE

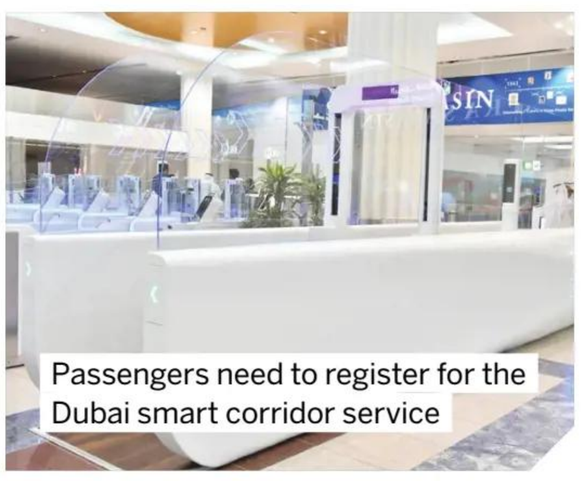
Departure lounges are adorned with cameras. Security guards monitor the live footage – but what happens if a guard isn't watching as a dangerous individual makes a move? Today's cameras are increasingly intelligent and can automatically notify airport staff of unusual activity. This includes thermal cameras that detect any unusual items or weapons that have been smuggled onto the site. Artificial intelligence can also detect particular shapes and movements. Modern airports use AI cameras that actively search for the shapes of weapons in their live footage.



Thermal sensors show the temperature of passengers

INTELLIGENT BORDERS

Most countries have strict checks in place to make sure authorities know who's within their borders at all times. At airports this often forms long queues as each visa and passport is checked manually by a border control officer. However, in Dubai a new smart corridor has been launched that can process 12 passengers in a minute. As each passenger walks through, biometric cameras scan their faces and computers instantly approve or reject the individual. For this to work, passengers have to log all their travel documents and information before their flight and arrival.


Passengers need to register for the Dubai smart corridor service

© Alamy / Getty / Shutterstock / Emaratech

HOW A BOWLING ALLEY WORKS



Explore its inner mechanisms and discover how pins and balls quickly resume position

WORDS AILSA HARVEY

Many sports in which you throw, aim or knock down objects also require you to collect the items and reset the playing zone. But anyone who has tried their hand at indoor bowling will have seen the mechanical efficiency in which a strike is cleaned up and the lane reset. A sophisticated robotic system cycles the pins and sets them up with precision for another game.

Bowling dates back over 5,000 years to the ancient Egyptians, who used stones as balls and various materials for pins. Since then, the game has evolved drastically. Before this machinery was perfected, the role of pinsetter was held by a person who stood just beyond the firing line at the back of each lane. The mechanical pinsetter that replaced this job was invented in 1936 and has become increasingly efficient with the invention of new autonomous functions and data-collecting sensors. Infrared sensors on the bowling lane flag up any player who steps past the foul line, while bowling pin detection sensors can be used in some lanes to track the movement and position of pins for rapid automatic scoring.

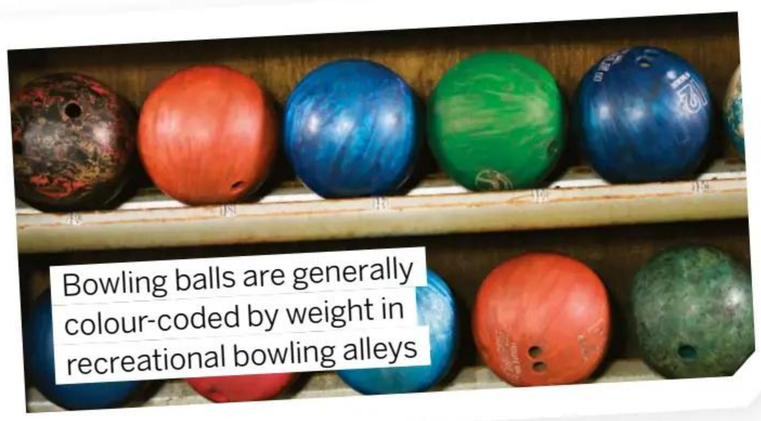
Did you know?

Pins that are knocked over are called 'deadwood'

Another adaptation to the pin-setting machine is an energy-saving function, which shuts off the pin distribution system if there is a gap in play for a minute or longer. This saves power and reduces the wear and tear on a machine that would otherwise be on a continuous and unnecessary cycle. With the efficiency of the new technology systems found in the alleys, bowling has advanced to create a game of high skill and ease of play while maintaining the core elements of the ancient sport.

BALL BASICS

Balls have different weights, finger grip positioning and subtle adaptations for different lanes and bowling styles. The balls you use when playing recreationally will be between three and seven kilograms. Professional bowling balls are custom made, with manufacturers measuring a player's hand to achieve an optimal design. They're also designed to achieve 'hooking' of the ball, which makes the ball roll in a curved shape to attack pins from a sharper angle. House balls generally aren't as capable of hooking as custom-made balls. The centre of a ball is usually made with different percentages of metal oxides and resin. This core gives the ball its weight and determines its ability to roll down the lane. Materials are poured into a mould and left to harden. Once solid, the outer layer, or coverstock, is added. The materials for this are generally polyester, urethane or resin. The coverstock makes contact with the lane and can impact performance. Plastic is ideal for beginners as it produces less friction. Urethane offers more friction, while resin is reserved for more advanced players.



Bowling balls are generally colour-coded by weight in recreational bowling alleys

PIN POSITIONING

Between throws, machinery restores pin configurations. This illustration shows what occurs behind the scenes

1 SWEEP
After each roll, this lowers in front of the pins and moves towards the back of the lane to clear all knocked pins.

2 PIN ELEVATOR
There are more than 20 pins in the machine, so there are always some pins readily available at the setter. This elevator consists of two pulleys and trays that each hold one pin. When the trays reach the top, the pin is released and the empty tray returns to the bottom for collection.

3 PIN DISTRIBUTOR
When the pin table has fully risen after a player's second roll, the pins that have climbed the elevator are released into the ten free slots, ready for the next player.

4 PIN TABLE
This holder has enough slots for each pin. It's lowered onto the lane and clamps around the top of each remaining pin. As it does this, it relays the points scored to the automatic scoring software. The pin table lifts the standing pins out the way of the sweeper and lowers them to resume play.

5 SENSOR
A sensor lies slightly in front of the pins. When it detects the movement of a rolling ball, it will trigger the pinsetter's actions after two seconds have passed and the bowl is complete.

6 CONVEYOR BELT
This belt is constantly moving towards the back of the lane. It rolls swept pins onto the pin elevator. It is tilted slightly so that the ball rolls towards the ball return tunnel underneath the lane.

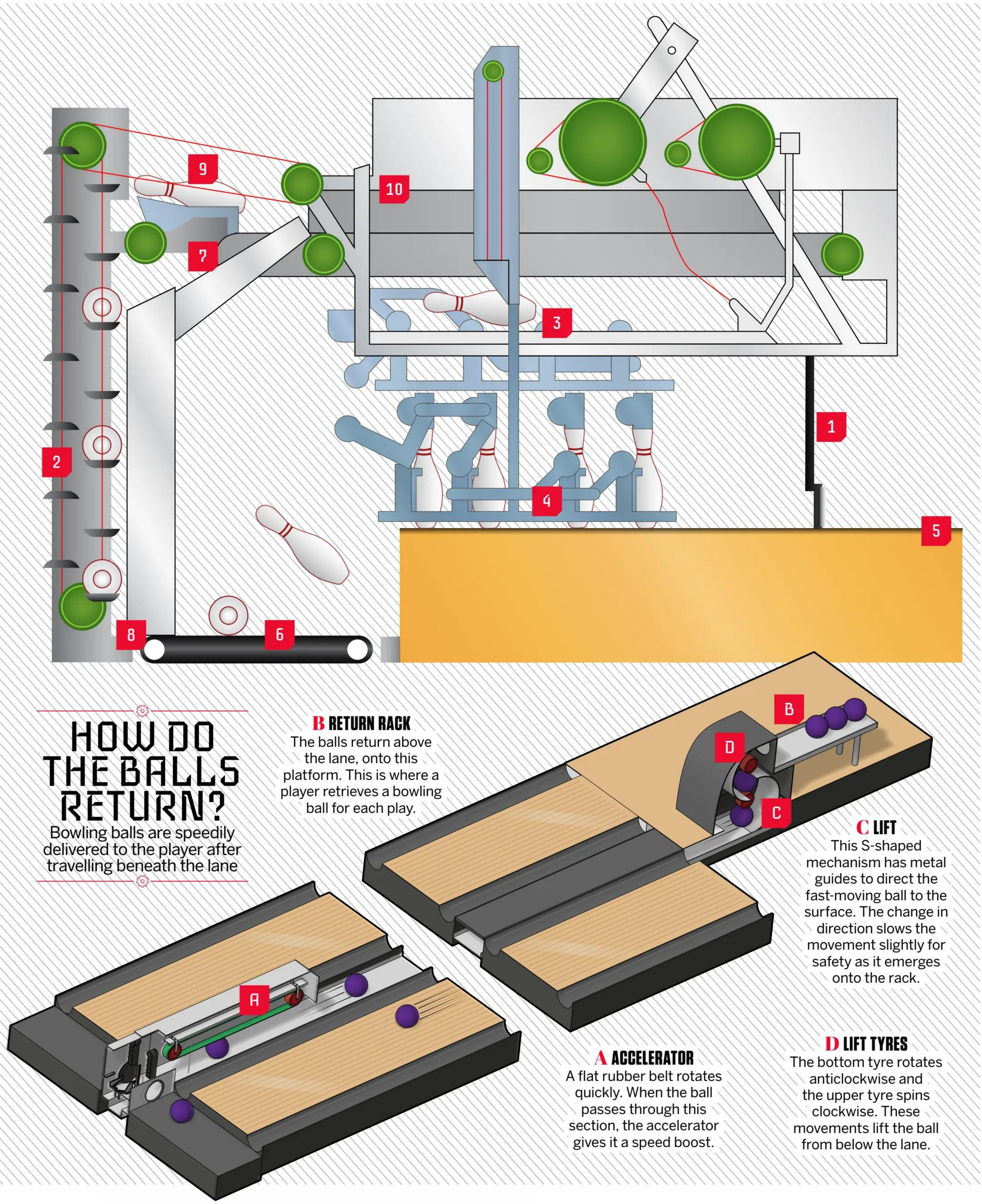
7 FILTERING BARRIER
This component is set at a specific height to work as a filter. It makes a gap big enough for the pins to roll through to the elevator, but not the ball.

8 PIN FEED DEFLECTORS
The sides of the elevator are angled to guide the pins to the centre of the lane. This lines them up perfectly to enter the pin elevator.

9 PIN COUNT SWITCH
As pins roll off the elevator, they move a switch. Each movement is relayed to the next part of the machine to record how many pins are returning.

10 OVERFLOW CHUTES
If all the spaces in the pin distributor are filled, the pins fall down these chutes to the base of the elevator, ready to rise back to the top.

DID YOU KNOW? More than 4,000 individual parts make up the pin-setting mechanism



HOW DO THE BALLS RETURN?

Bowling balls are speedily delivered to the player after travelling beneath the lane

B RETURN RACK
The balls return above the lane, onto this platform. This is where a player retrieves a bowling ball for each play.

C LIFT
This S-shaped mechanism has metal guides to direct the fast-moving ball to the surface. The change in direction slows the movement slightly for safety as it emerges onto the rack.

A ACCELERATOR
A flat rubber belt rotates quickly. When the ball passes through this section, the accelerator gives it a speed boost.

D LIFT TYRES
The bottom tyre rotates anticlockwise and the upper tyre spins clockwise. These movements lift the ball from below the lane.

© Getty / Illustration of bowling lane: Ed Crooks





TRANSPORT

RESCUE AT SEA

From the hammering surf to the ocean's depths, these vehicles retrieve the missing and stranded

WORDS **AILSA HARVEY**

During the summer season, more than 10,000 incidents at sea are reported to lifeguards in the UK. Meanwhile, between 1,500 and 2,000 people go missing each year while travelling on sea vessels. The world's oceans can be violent and unpredictable, catching out many who enjoy and explore it. When this happens, there are specialised sea vehicles and technologies on hand to save lives. But there are many factors that contribute to their success. Firstly, where a person is stranded determines the time frame that rescuers are working with. Without food and water, a person floating in the ocean could survive for up to three days. However, when being churned by waves, lifeguards need to resurface swimmers within a matter of seconds.

Sea rescues also include those below the surface. Just as people enjoy the thrill of surfing the tide, the exploration of the ocean thousands of metres down has also risen in popularity. But this venture comes with increased safety complications. The further underwater a vessel travels, the lower the visibility for navigation is. More significantly, the water pressure increases with every metre descended, so humans can't survive beyond a certain depth without a pressure chamber. One of the highest profile deep-sea rescues to take place occurred on 18 June 2023, when a submersible called Titan went missing in the Atlantic Ocean while carrying tourists to the site of the Titanic shipwreck. Unfortunately, the submersible was found to have imploded shortly after its descent, with no survivors. However, during the documented three days of searching, the mission demonstrated how aircraft surveillance, remotely operated vehicles, ships and sonar technology can be used to track down people and technology lost at sea.

DID YOU KNOW? Tidal currents can travel at speeds of over nine miles per hour



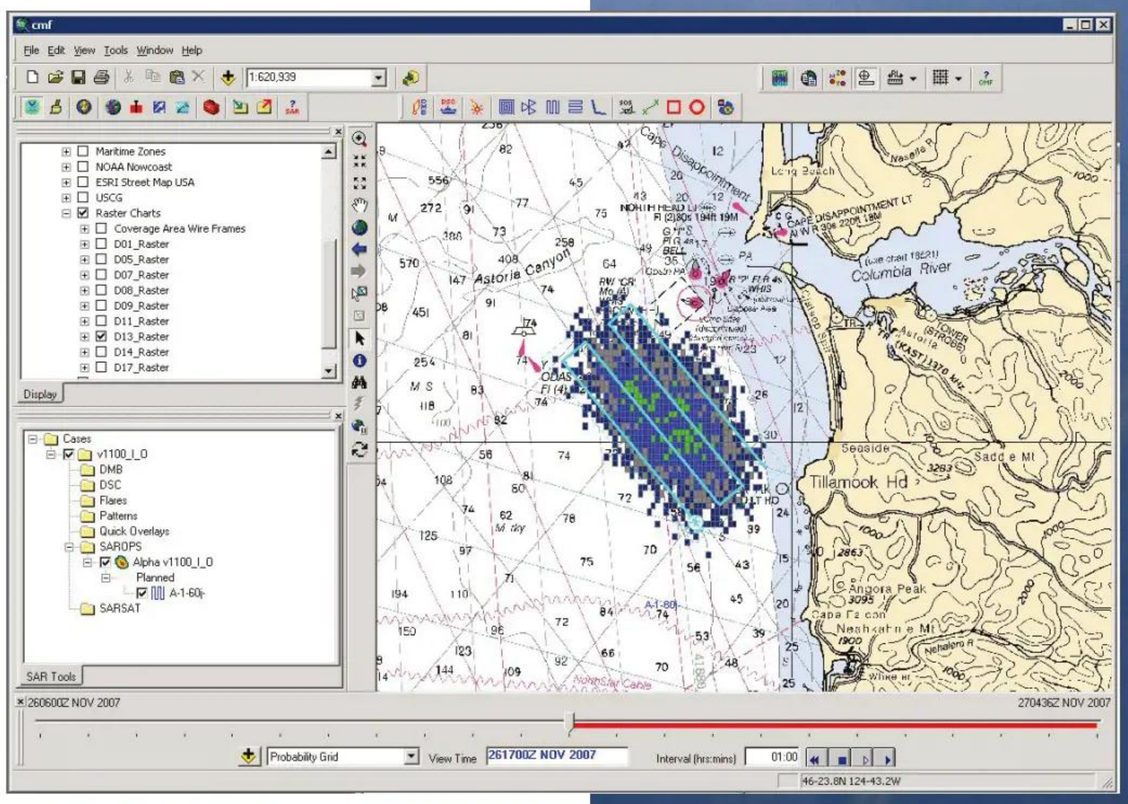
© Getty

COASTGUARD CALCULATIONS

When a person or watercraft goes missing, how do coastguards know precisely where they should look first? Using data of the area where the missing people were last seen, local weather events, ocean temperature and ocean movement patterns, rescuers can consult an artificial intelligence (AI) algorithm. This data-analysis tool informs them of the most likely locations the missing people could be found if they're floating with the tides.

When an individual has fallen overboard, crucial extra information, such as the person's height and weight, increases the accuracy of tracking their movements and their chance of recovery. Beyond narrowing down the search area, this will also inform coastguards of the estimated time frame they are working in. Based on a person's biological data and the ocean temperature, the algorithm will deduce how long the individual is likely to survive before hypothermia or exhaustion take hold.

When all of the data is inputted into a computer algorithm, a map displays the best area to search

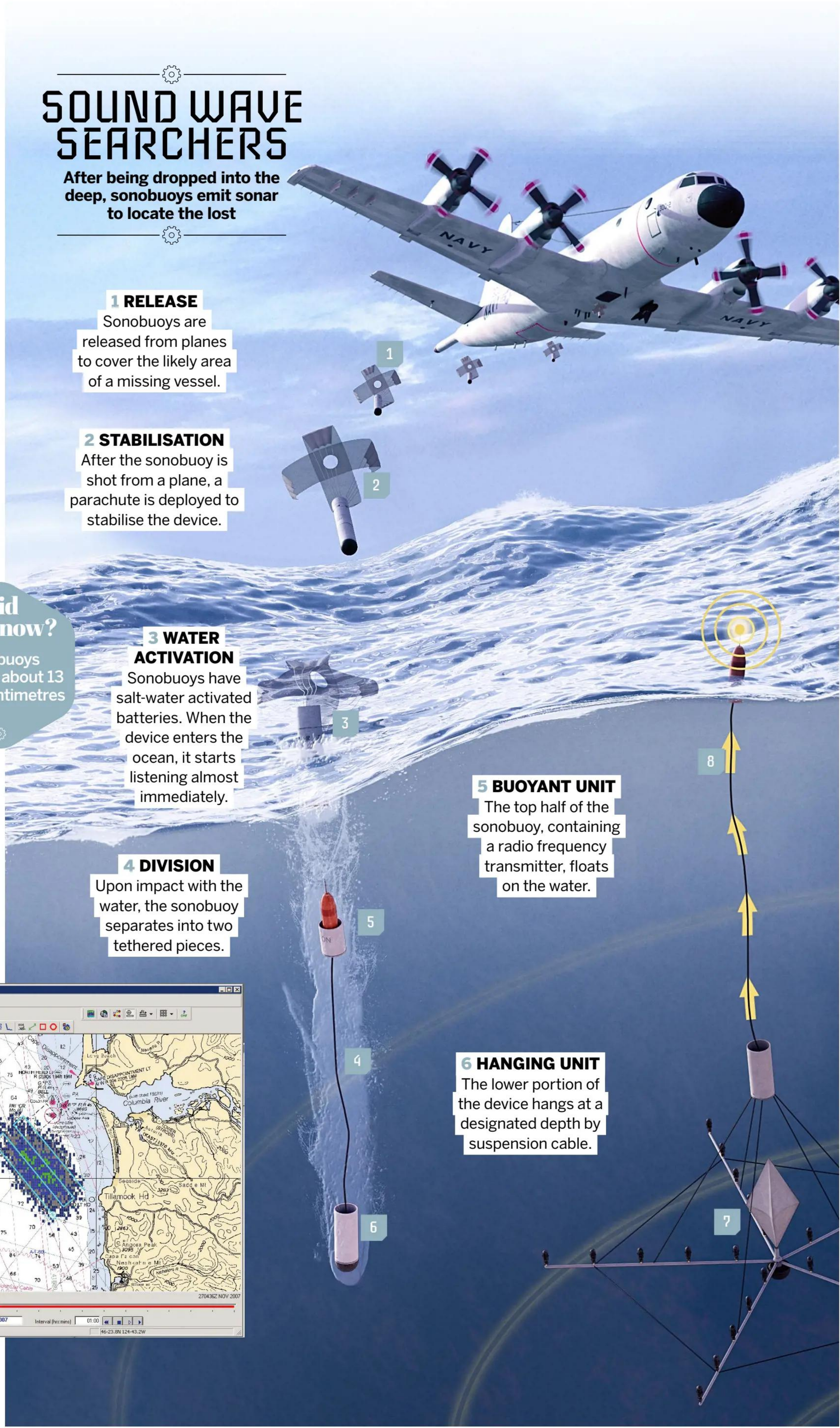


Did you know?

Sonobuoys measure about 13 by 90 centimetres

SOUND WAVE SEARCHERS

After being dropped into the deep, sonobuoys emit sonar to locate the lost



1 RELEASE
Sonobuoys are released from planes to cover the likely area of a missing vessel.

2 STABILISATION
After the sonobuoy is shot from a plane, a parachute is deployed to stabilise the device.

3 WATER ACTIVATION
Sonobuoys have salt-water activated batteries. When the device enters the ocean, it starts listening almost immediately.

4 DIVISION
Upon impact with the water, the sonobuoy separates into two tethered pieces.

5 BUOYANT UNIT
The top half of the sonobuoy, containing a radio frequency transmitter, floats on the water.

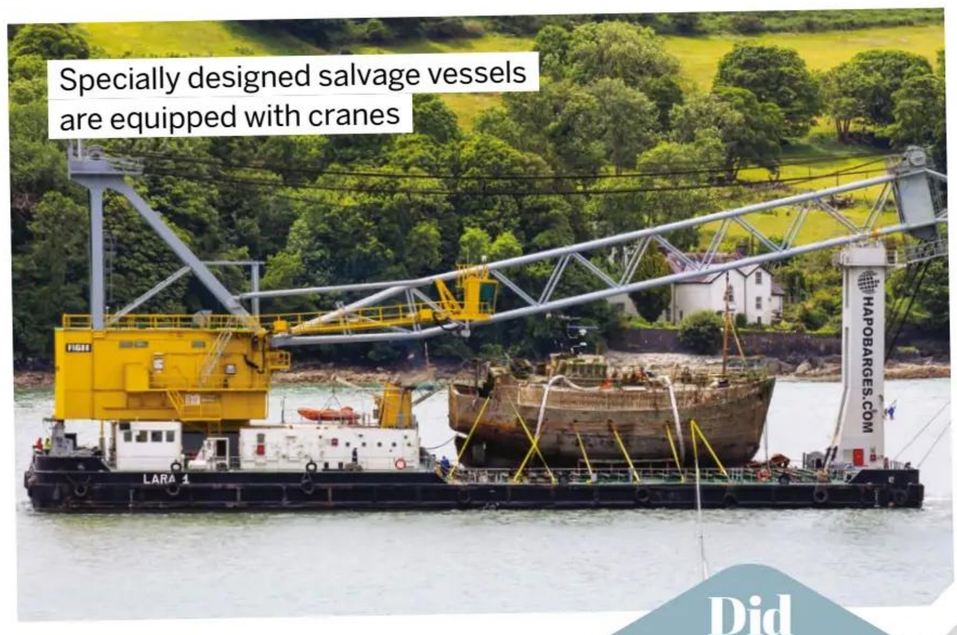
6 HANGING UNIT
The lower portion of the device hangs at a designated depth by suspension cable.

DID YOU KNOW? The first navy submarine rescue took place in 1939, saving 33 people from the sinking USS Squalus

WHAT IS MARINE SALVAGE?

A vessel can face difficulties at any stage in its voyage, whether it's docked or out to sea. The process of salvaging a ship can involve towing a boat, extinguishing any fires, repairing a ship at sea, refloating a sunken or sinking vessel or rescuing any of the cargo on board. Professional coastguards and specially trained engineers are usually called to salvage missions, and some of the equipment they may deploy includes tugboats, cranes and floating docks to support sinking vessels.

However, there isn't always enough time for support to be called in. In some instances, other ships that happen to be passing by might take part in marine salvage. According to marine salvage law, someone who helps save another vessel should receive a reward, as they have put their safety at risk purely to help another. This law is the reason some captains decline any help offered to them, as they don't want to risk handing over their ship or its valuable contents.



Specially designed salvage vessels are equipped with cranes

Did you know?

There are around 3 million shipwrecks on the ocean floor

RETRIEVING SUBMARINERS

How submarine rescue bells collect survivors from trapped vessels

1 PRESSURE GAUGES
The internal pressure of the bell is monitored to make sure it remains close to atmospheric pressure.

2 MATING SKIRT
This skirting at the base of the bell seals onto a submarine's escape hatch, and the water between the two vessels is pumped out.

3 RESCUEES
About six people can enter the rescue vehicle through the submarine escape hatch and sit on the bench inside.

4 WINCH
The bell is attached to a vessel at the surface, which lowers it to the rescuees and hoists it back to the surface again.

5 HANDLES
To limit the chances of the occupants being injured, there are handles they can use for support during the ascent to the surface.



6 UMBILICAL CABLE
A thick support cable keeps the rescue bell from sinking. The chamber can descend to around 300 metres.

7 OXYGEN TANK
High-pressure oxygen is stored in this small tank. It's released into the chamber during the course of the rescue for breathing and adjusting the pressure inside.

8 SCRUBBER
Excess carbon dioxide exhaled by the bell's occupants is removed from the chamber through this device.

9 HATCH
There are hatches at the top and bottom of the bell. These close when the skirts aren't sealed onto another vessel to prevent the main chamber from flooding with water.

8 RELAYING SIGNALS
Sound wave signals are relayed through the cable to the floating device, which transmits the data to crew on other craft.

7 HYDROPHONE ARRAY
Each arm of the array has five evenly distributed hydrophones. These emit sound energy and receive data from returning sound waves that have bounced off submerged objects.



© Illustration by Nicholas Forder and Adrina Mann / U.S. Coastguard / Alamy / James Fisher and Sons plc

DEPLOY THE UNDERWATER DRONES

Sending an entire crew into unknown danger to search for missing swimmers, vehicles or boats puts rescue teams at risk. Sometimes it's a much quicker and safer option to search beneath the surface with a drone first. Drones are operated remotely and are ready to travel immediately, while a rescue diver will take time to mentally and physically prepare for descent. If an exact location is unknown, drones can cover extensive areas of water within a short space of time while relaying video. Ultimately, these machines can reduce the time taken to locate individuals when there are less people available to dive. Some drones are even equipped with robotic arms that can lift items to the surface. In less time-critical missions, drones can be deployed to scour smaller spaces and dangerous zones. The deep sea can be treacherous to navigate, with body-crushing pressures and narrow trenches. Btu small drones can investigate these with no risk to human life.



Small underwater drones are the most practical and safest way to record deep-sea footage

DEEP-SEA RESCUE

This deep search and rescue (DSAR) submarine scours the dark ocean depths at 500 metres

1 PORTHOLE
The crew use this viewing window to navigate through the murky water.

2 LAUNCH
Within 15 minutes of hearing of a missing vessel or vessel in distress, the DSAR submarine is lowered into the ocean.

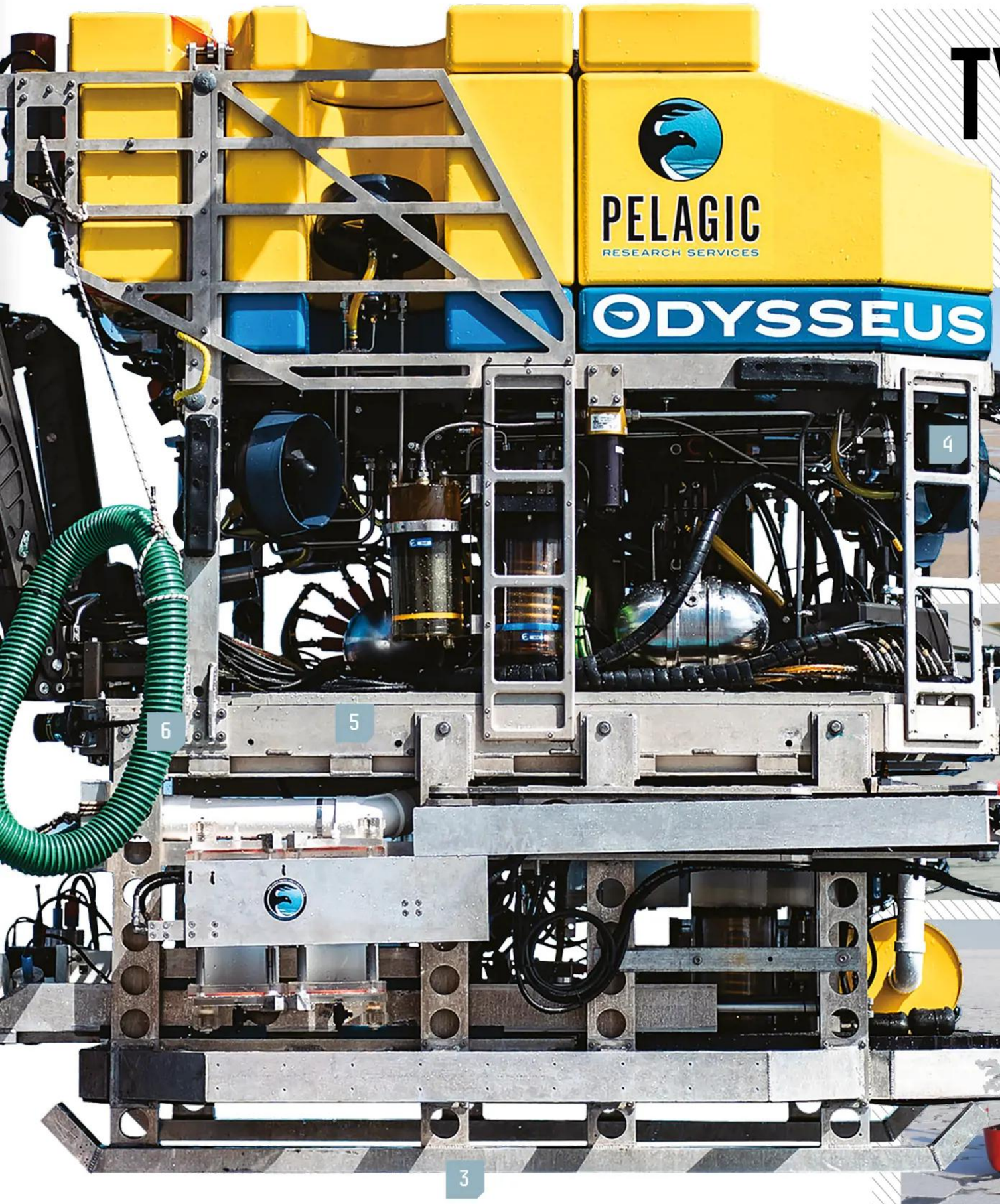
3 SIZEABLE RESCUE
The DSAR is designed to retrieve an entire crew in one descent. Around 27 people can be returned to the surface in this vessel.

4 CONNECTING HATCH
When a stranded submarine is located, the DSAR seals itself to the top of it via this hatch.

5 TREATMENT ON BOARD
After the rescued passengers are returned to the launching vessel, they will usually be medically assisted in a pressurised hyperbaric chamber to regulate oxygen levels in the body.

6 PROPELLERS
The maximum speed of the vessel is around 13 miles per hour.

DID YOU KNOW? Odysseus 6K is attached to a 7,500-metre umbilical cable



ODYSSEUS' OPERATION

How the remotely operated vehicle (ROV) Odysseus 6K discovered debris of the Titan submersible

1 4K CAMERAS
A panel of cameras and lights relayed imagery of the deep sea in real time to crew on board the ship at the surface.

2 ARTICULATED ARMS
Two robotic arms were controlled from the mothership to manipulate and explore any discovered objects.

3 MAXIMUM DEPTH
The ROV can navigate to depths up to 6,000 metres below the surface. The Titan submersible debris was retrieved at 3,810 metres.

4 THRUSTERS
Odysseus 6K has four forward thrusters and three vertical thrusters.

5 VEHICLE WEIGHT
The ROV weighs 1,700 kilograms, so it needs to be lifted off the mothership by a large crane and be placed in the water.

6 SUCTION SAMPLER
This tube sucked up small samples from the ocean that were analysed at the surface.

TYPES OF RESCUE CRAFT



LIFEBOATS

For inshore sea rescues, lifeguards board an inflatable lifeboat. One lifeguard will focus on steering the boat through crashing waves to the casualty, while a second has their hands free to reach and rescue those in need.



HELICOPTERS

When someone needs to be retrieved from the sea during rough sea conditions – or a severely injured person from on board a boat – coastguards may perform an air-sea rescue. This involves lowering down one of the coastguards with a harness or stretcher.



SHIPS

While smaller ships owned by coastguards can be deployed in specific emergencies, larger ships sail the ocean for longer periods and patrol the seas. Coastguards will also conduct some training on these vessels.



HOVERCRAFT

Hovercraft trap a layer of air underneath them as they move, preventing them from getting stuck in mud and shallow water. They can whizz over water and difficult terrain to reach those who have become caught in estuaries and mudflats.



JET SKIS

Jet skis speed across the sea at up to 70 miles per hour and are often used to help surfers. Platforms with handles are attached to the back of jet skis so that surfers who have lost their boards can hold on and be pulled out of danger in a matter of seconds.

© Alamy / US Navy / Pelagic RS / Getty

HOW HUMANS CAN FLY

These ingenious inventions have given people wings to soar through the air

WORDS SCOTT DUTFIELD

A lack of wings and inability to fly hasn't stopped people from finding ways of soaring through the sky. The bravest have fought the forces of gravity by using a 'wingsuit' to glide down from planes and jump from cliffs. Commercially used since the late 1990s, a wingsuit is a full-body suit incorporating aerodynamic fabrics between the arms and legs. Following an airborne jump or BASE jump – Building, Antennae, Span (bridge) and Earth (typically a cliff top) – gliders extend their arms and legs outwards, stretching the adjoining material.

Transforming skydivers into human flying squirrels, the wingsuit exploits a force called lift to control their descent through the air to glide horizontally rather than fall vertically. A wingsuit does this by increasing the surface area of the body, along with increasing the air resistance pushing up against the wings. For optimal gliding and lift generation, the wingsuit helps transform the shape of the body into what's called an 'airfoil'. Much like the wings and propellers of an aircraft, the curved shape of an airfoil creates an environment where the air crossing over the top of the airfoil experiences lower pressure than the air moving beneath it. This difference in pressure generates enough lift for the wingsuit to glide around three metres horizontally for every metre it falls vertically. To steer, the wingsuit wearer only needs to change the shape or angle of the wingsuit to change direction. Towards the end of the jump, gliders deploy a parachute strapped to their back to gently lower them to the ground safely.

Did you know?

The highest wingsuit BASE jump was 7,700 metres

However, that's not always the case. Wingsuit jumps are one of the most dangerous sports in the world, and it takes advanced skill and experience to execute one successfully. Between 2002 and 2019, there were 344 recorded wingsuit flying fatalities, with an overall wingsuit death of around one in every 500 jumps. What separates a wingsuit from an aircraft is its inability to generate enough lift to ascend during flight. However, with the help of some electrified thrusters, wingsuits can quickly soar through the sky.

BMW created the world's first electrified wingsuit, which stuntman Peter Salzmann took for a spin in 2020. The dual chest-mounted electric turbines gave Salzmann a 186-mile-per-hour speed, compared to a typical non-electrified descent of around 62 miles per hour. To control his speed in the air, Salzmann could operate a two-finger throttle, as well as a cutoff switch in the event of an emergency. Similarly, skydiving company SkyVibraton has created the 'E-Wings' project



Wingsuits increase air resistance

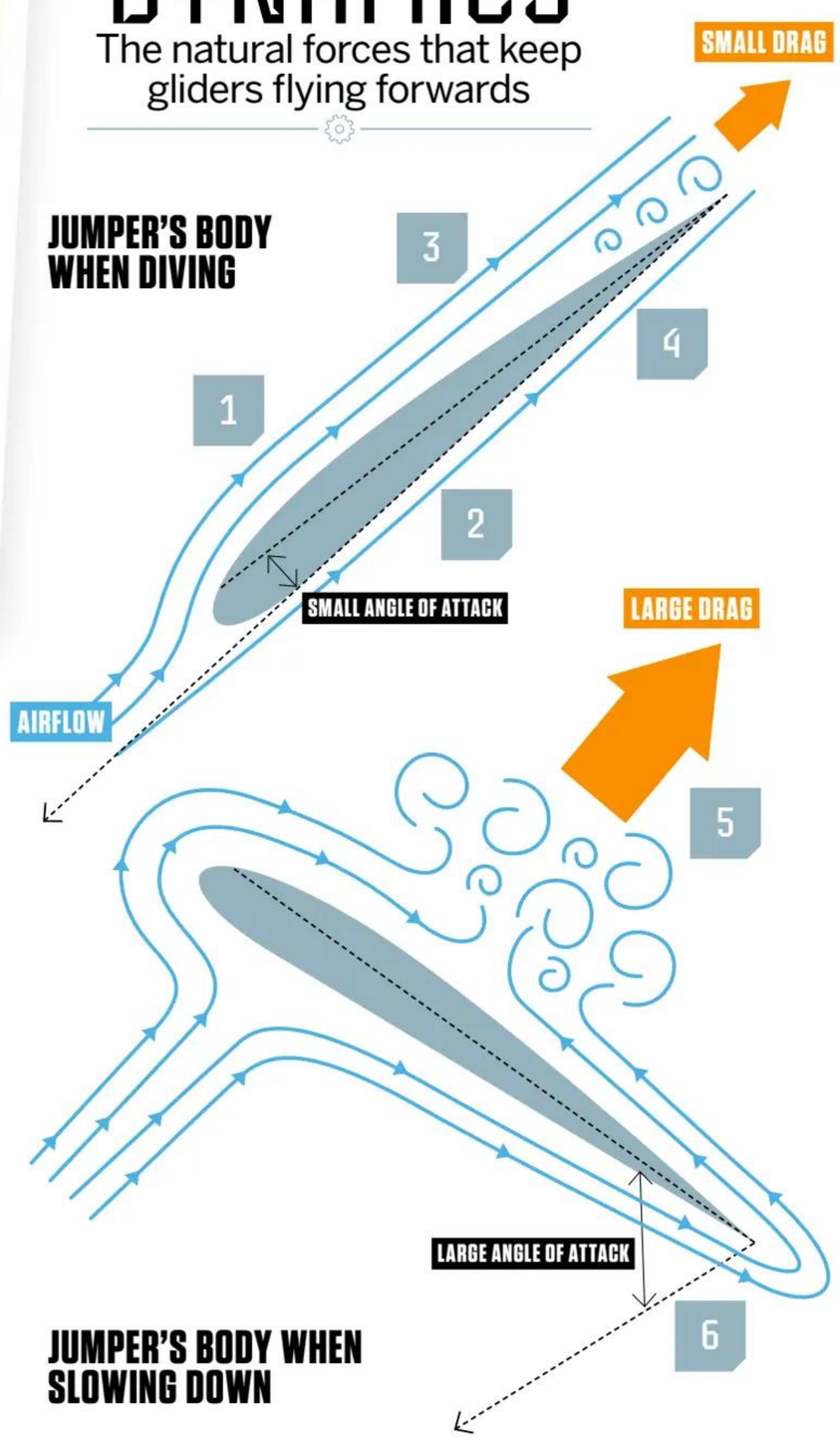
DID YOU KNOW? In 2016, former helicopter pilot Kyle Lobpries travelled 19.94 miles in a wingsuit



An electrified wingsuit on display at the Greentech Festival in 2021

WINGSUIT DYNAMICS

The natural forces that keep gliders flying forwards



1 LOW PRESSURE
During flight, low air pressure forms over the top of the wing.

2 HIGH PRESSURE
The air beneath the wing seeks to equal out the lower pressure on top and increases to compensate.

3 DIVE
Airflow faces the least resistance over the airfoil during a dive and generates little lift.

4 GLIDE
The airflow pressure beneath the airfoil is greater than above it, generating more lift to slow its descent.

5 CREATING DRAG
A vortex forms at the wingtips that disturbs airflow and creates air resistance, or drag.

6 POSITIONING
When the airfoil is at an almost 90-degree angle to the direction of motion, it experiences maximum drag, and thus the slowest descent.

5 FACTS: EVOLUTION OF WINGSUITS



1 FIRST FLIGHT IDEA
Leonardo da Vinci was first to study the potential of human flight in the late-15th century. Among hundreds of da Vinci's sketches on theories of flight was the winged 'ornithopter' flying machine. However, the design was never built.



2 FAILURE TO LAUNCH
French tailor Franz Reichelt designed a suit for pilots that, like a parachute, would expand if they were ejected from an aircraft. In 1912, he tested the suit by leaping from the Eiffel Tower. Sadly, the suit didn't open, and Reichelt died.



3 THE 'BIRD MAN'
In 1937, parachute jumper Clem Sohn put his wingsuit to the test, jumping from an aircraft at around 3,650 metres altitude. While the fabric wings gave him some movement through the air, his parachute failed, and Sohn fell to his death.



4 WOODEN WINGS
In the 1950s, French daredevil Léo Valentin made a wooden wingsuit attached to a tubular steel corset. In 1954 he glided with the suit for three miles from around 2,700 metres to around 900 metres altitude before parachuting to the ground.



5 1990S BIRDMAN
The first commercial wingsuit was created by professional skydiver Jari Kuosma. Kuosma showcased the new BirdMan wingsuit in 1999 when he carried out the suit's first BASE jump from cliff tops in Arco, Italy.

© Alamy / Getty / Shutterstock

– a wingsuit equipped with two batteries and four turbines, each capable of generating up to 14 kilograms of thrust and flight speeds of more than 173 miles per hour.

But if gliding with a fabric wingsuit doesn't scratch your itch to fly, then strapping on a mini jet backpack might be just the ticket. In 2006, Yves Rossy, an Air Force pilot from Switzerland, created a jet-powered 'hard wingsuit' that soared through the air for six minutes. Two years later, Rossy became the first person to fly over the English Channel using the same suit, now known as the Jetwing. It took the Swiss pilot less than ten minutes to cross the Channel after being dropped from a plane 2,500 metres above Calais, France. Rossy reached speeds of around 186 miles per hour to make the crossing before deploying his parachute for a safe landing in St Margaret's Bay, England. Over the years, Rossy has used the Jetwing to cross parts of the Alps and even the Grand Canyon, and in 2015 set up the Jetman Dubai company to develop and manufacture more Jetwings.

In 2020, the company launched its first autonomous human flight from the ground up to 1,800 metres. The hard carbon-fibre wings are propelled by four mini jet engines that can generate enough thrust to propel the pilot up to around 250 miles per hour. With the ability to hover, roll and reach altitudes of up to 6,100 metres, the Jetwing transforms the pilot into their own aircraft.

Did you know?

The wingsuit speed record is 246.6 miles per hour

THE ORIGINAL JETMAN

The technology aboard Yves Rossy's pioneering Jetwing

1 FUEL
Each of the engines are powered by kerosene fuel, which is stored in tanks on each side of the wings.

2 SAFE DESCENT
Pilots are equipped with a parachute, like any other wingsuit, to be deployed before landing.

3 ROBUST WINGS
Carbon-fibre panels make up the suit's wings, which have a span of 2.4 metres.

7 TURBINES
Internal turbines within each engine spin at around 98,000 revolutions per minute to generate thrust.

Pilot Yves Rossy flying his jet-fitted wingsuit in the region of Bex, Switzerland

DID YOU KNOW? The record time for the longest wingsuit flight is nine minutes and six seconds

"Rossy became the first person to fly over the English Channel using the same suit, now known as the Jetwing"



5 EMERGENCY CUTOFF
In the event of an emergency, a release handle can be pulled to immediately cut the engines and separate the pilot from the suit.

4 HEAT RESISTANCE
Pilots wear heat-resistant flight suits to protect their bodies from the heat of the engines.

6 ENGINES
Four JetCat P400 jet engines deliver the thrust to propel the Jetwing through the air.

WINGLESS FLYING

The era of real-life jetpacks is here. Taking flight without the need to launch from an airborne plane or strapping on a pair of wings has now been made possible thanks to a company called Gravity Industries. Using five gas turbines, the company has developed the Daedalus Flight Pack, which can lift pilots from the ground and into the air to altitudes of up to 3,658 metres. The jet suit can top speeds of over 50 miles per hour and has a range of around three miles. Along with being used for recreational flight experiences, Gravity Industries has shown the suit's possible use in military and search-and-rescue operations. In 2022, Gravity Industries took part in the NATO mountain warfare rescue exercise to deliver blood plasma to injured soldiers.

Richard Browning, founder of Gravity Industries, flying the Daedalus Flight Pack in Wiltshire, England



© Alamy / Shutterstock / Illustration by Adrian Mann

BUILDING THE WORLD'S DEEPEST CAR PARK

Australia's most famous landmark is often marvelled at from ground level, but its innovative spiral substructure is a hidden gem

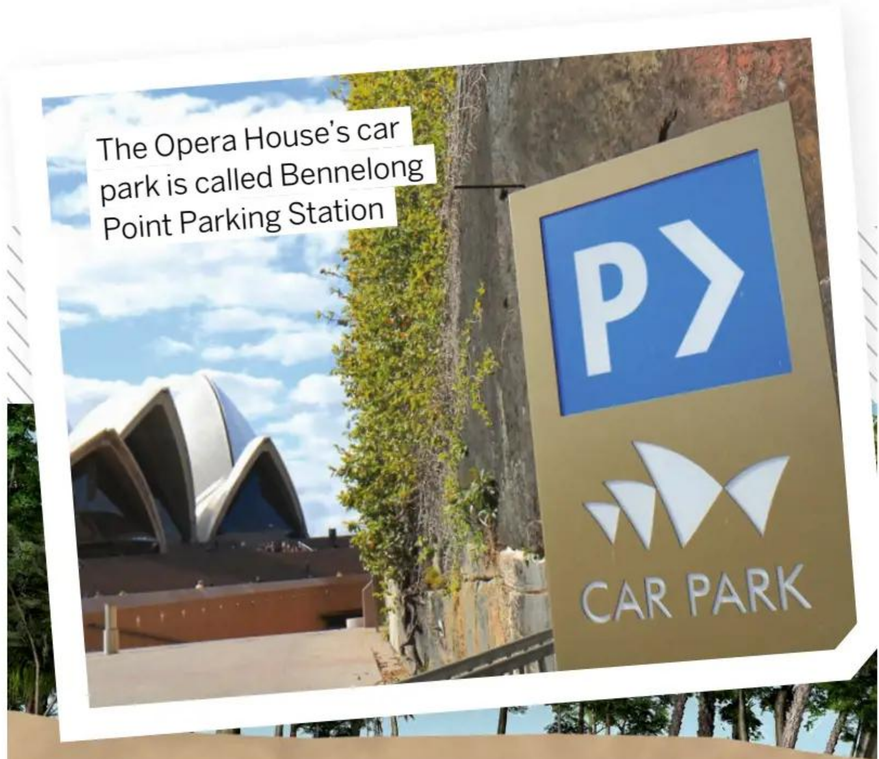
WORDS **AILSA HARVEY**

Most underground car parks consist of four or five storeys. But beneath the Sydney Opera House there are more than double that, with 12 storeys that extend 37 metres deep. Within this structure, there is space for 1,100 cars to park, serving visitors of both the Opera House itself and the surrounding botanic gardens. It's not only the deepest car park in the world, but the widest shallow-cover rock cavern, too. This means it's the widest underground space that has been evacuated with a relatively thin layer of soil above it. The soil and rock between the car park and ground surface is just seven metres thick, and the cavern spans up to 19 metres wide. The shallower the cover, the more advanced engineering that's required to prevent the structure from collapsing.

The original car park design was planned to be rectangular in shape and consisted of two substructures to cover the parking demands of the Opera House. However, this meant valuable space would be taken up to build the two fire escapes needed to meet safe exit requirements in an emergency. This plan radically changed when a circular double-helix design was proposed. Not only was this a unique shape for a car park at the time in the early 1990s, but the circular shape evenly distributed weight, making it stronger. This meant it could be built deeper and would only need one fire escape that could be accessed centrally on all levels. The double-helix shape reduced the planned footprint from 7,900 square metres to just 2,950 square metres. From the time of building, the car park was commissioned with a life span of 50 years. In 2043, this record-breaking construction will need to be reviewed again to see if any changes to its design need to be made.

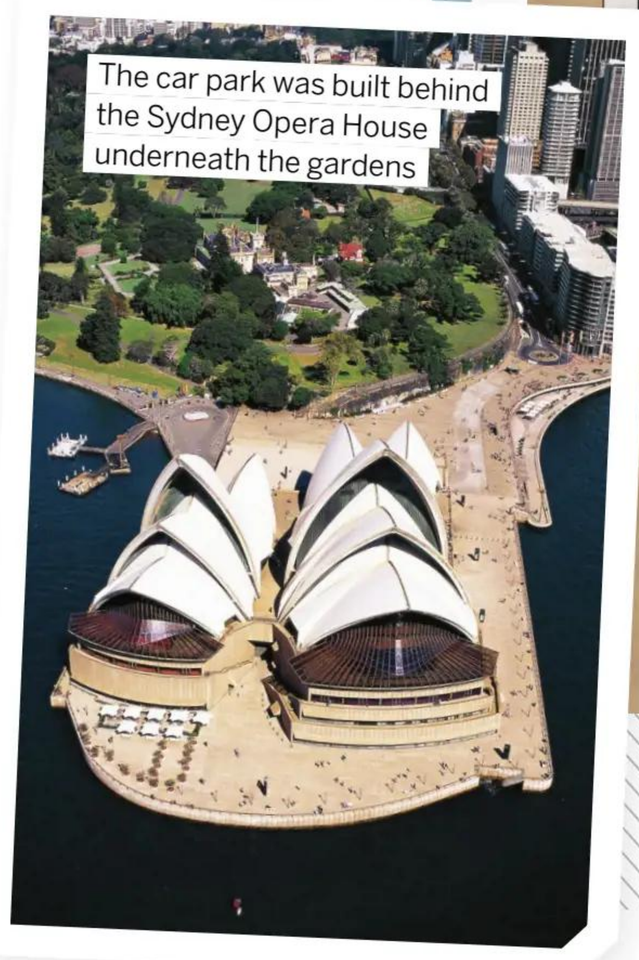
Did you know?

10.9 million people visit Sydney Opera House annually



SPIRAL INSPIRATION

Australian architect Ken Woolley is credited with the initial design of the Sydney Opera House car park. Woolley was previously involved in the design of the main building of the Sydney Opera House, but was commissioned separately to focus on the underground car park. He was chosen as one of the top architects in the country, known for combining aesthetics with functionality. He was also part of the planning process to design the wide, shallow-covered cavern, which became his main achievement. It was architect Ron Barelle who changed the original design, proposing a circular helix structure to the team. Barelle later met with project leader Neil Fimeri and another engineer, Tony Barry, at their local pub. There they discussed the design further, and it was at the pub that they tweaked the spiral suggestion into the double helix that's there today. The team's use of spiralling car ramps and the helix, preserving the landmark's surroundings and natural landscape, have been admired since the structure was built.


The car park was built behind the Sydney Opera House underneath the gardens

DID YOU KNOW? Construction was secret, so there was no media coverage of the car park while it was being built



HIDDEN HELIX

How this hidden structure is stacked below ground

5 FIRE STAIRS
In an emergency, pedestrians can climb these stairs to exit at ground level.

1 ROYAL BOTANIC GARDENS
The gardens above the car park host rare and endangered plants, so construction was planned to leave soil and root structures undisturbed.

9 CROSS RAMPS
Ramps direct cars across the helix so they can go straight to the exits without driving through every floor.

6 BENNELONG DRAIN
Any storm water drains out of the car park here, preventing flooding.

4 RAMP UP
A separate ramp intertwines with the ramp leading down, reducing congestion.

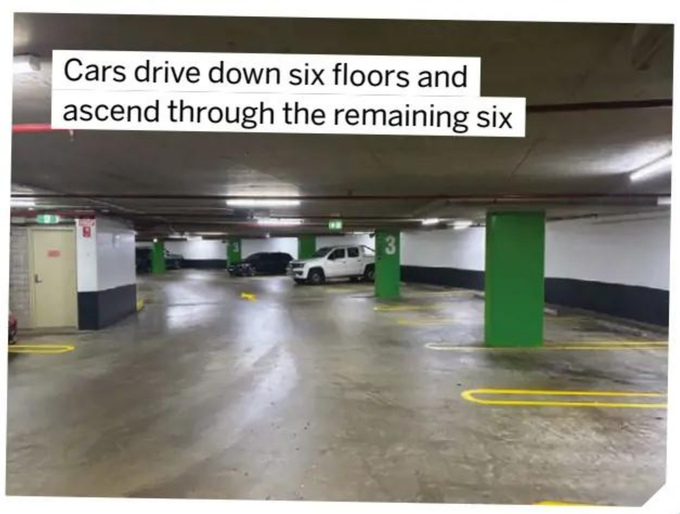
3 RAMP DOWN
Vehicles descend using a one-way system, spiralling down through the levels.

7 PEDESTRIAN EXIT
A pedestrian pathway leads above ground to the Opera House and Botanic Gardens.

8 LIFT AREA
Lifts can be accessed in this area from all floors, bringing people to the surface quickly.

BREAKING GROUND

Constructing this underground structure was a mammoth task, with a total cost of 45 million Australian dollars. The first step in building was to remove 130,000 cubic metres of sandstone from the ground, leaving a large space for the floors to spiral into. One of the main challenges that construction workers faced was to leave the ground surface above the carpark untouched, maintaining the natural landscape. This meant that workers only had access to the cavern through two nine-metre-wide access tunnels. The dug-out cavern has a radius of 75 metres. Within this concealed space, the entire project took 27 months. In 1992, the car park was completed nine months ahead of schedule.

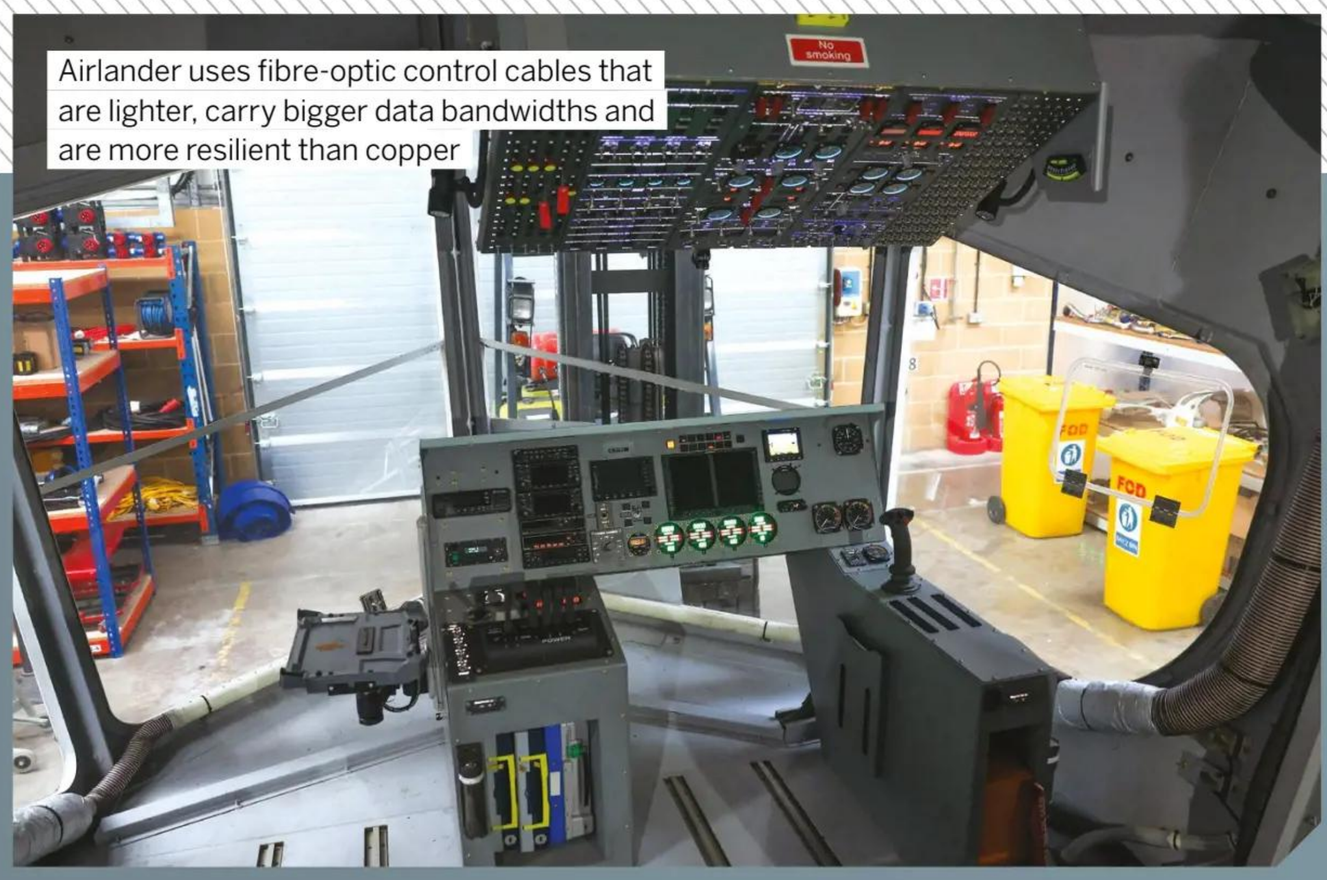


Cars drive down six floors and ascend through the remaining six

© Alamy / Illustration by Adrian Mann / Wikimedia Commons: Chris.sherlock2



It may look funny, but the Airlander is efficient, effective and may take flight soon



Airlander uses fibre-optic control cables that are lighter, carry bigger data bandwidths and are more resilient than copper

ON BOARD THE 'FLYING BUM'

The HAV Airlander 10 is exciting, ambitious and one of the world's biggest aircraft, but will the project ever get off the ground?

WORDS MIKE JENNINGS

You wouldn't guess it from the name, but the Hybrid Air Vehicles Airlander 10 is a unique piece of kit – a revolutionary hybrid airship that's one of the world's longest and largest aircraft. There's another notable aspect about this aircraft: its shape. From certain angles it looks a bit rude, which is why it's been nicknamed the 'Flying Bum'. Go beyond the bum, though, and there's a remarkable story about military projects, luxury travel and incredible technology. Airlander 10 began life in June 2010 when Hybrid Air Vehicles, a British company, won a contract with the US Army to develop a craft for long-range surveillance, communications and transport.

As a hybrid airship, Airlander 10 met many of the US Army's requirements. These craft combine conventional airship design – a huge balloon filled with helium – with engines or rotors. They can carry cargo or passengers over a wide range, often for multiple days, and they're more fuel-efficient than planes. However, by October 2011, test flights were delayed, and the US Army raised concerns about safety, deployment and even the fabric. In February 2013, the US Army ran out of patience and cancelled the project.

That could have grounded the Flying Bum, but HAV bought the prototype back and shipped it to Cardington Airfield in Bedfordshire. And while development was blighted by crashes in 2016 and 2017 – with the latter writing off the aircraft – Airlander 10 was officially completed in January 2019. HAV is now manufacturing Airlander 10, which is viable for luxury travel, short journeys, logistics and communications. A Spanish airline has placed an order for 20 units, and Scottish and French transport companies have signed tentative agreements. British defence giant BAE Systems is also exploring the possibility of using Airlander. Its popularity is no surprise when you consider its capabilities. It can carry up to ten tonnes of cargo, stay airborne for five days and take 100 passengers on trips with huge reductions in emissions compared to planes.

Did you know?

The Airlander can fly for two weeks without a crew

TAKING FLIGHT

Airships and the idea of lighter-than-air travel have long been a romantic dream of people who look to the skies, but they're a relatively modern invention. The first steam-powered airship flight took place in 1852. In July 1900, the famous Zeppelin LZ1 debuted, launching a series of ships that became incredibly successful thanks to their designs, which featured multiplane tails for improved stability and separate gas cells.

Various militaries used airships for scouting and bombing during World War I, and after the war they were used extensively for military and leisure purposes – that is until the 1937 Hindenburg disaster destroyed their popularity and saw usage switch towards planes. Today, they're mostly used for advertising, surveillance and research.

Modern hybrid airships began to emerge in the 1970s, combining the advantages of gas-filled airships with improvements to stability, safety, speed, capacity and efficiency.



Airships were frequently used by militaries until planes took over

DID YOU KNOW? Airlander 10 weighs 20,000 kilograms before any cargo

RISING TO THE OCCASION

The Airlander 10 has two hulls – hence the Flying Bum shape – and they're made from composite materials designed for strength and helium retention. The hull uses three layers of materials: Tedlar for weather protection, Mylar to keep helium inside and Vectran for structural strength.

On the inside, it's not just helium: smaller, malleable compartments called ballonets are filled with oxygen and maintain the craft's pressure as the helium expands and contracts due to temperature and altitude changes. The pilots can adjust those ballonets as necessary, and if the hull is damaged there's an automatic pressure management system that gives the pilots enough time to fly the Airlander to an airfield for repairs.


The hull withstands small weapons fire, and can even survive a missile strike

INSPECT THE TECH

Airlander is packed with revolutionary tech



LIFTING UP

Airlander has a curved top and flatter underside. The pressure differences help the craft generate 40 per cent of its lift.



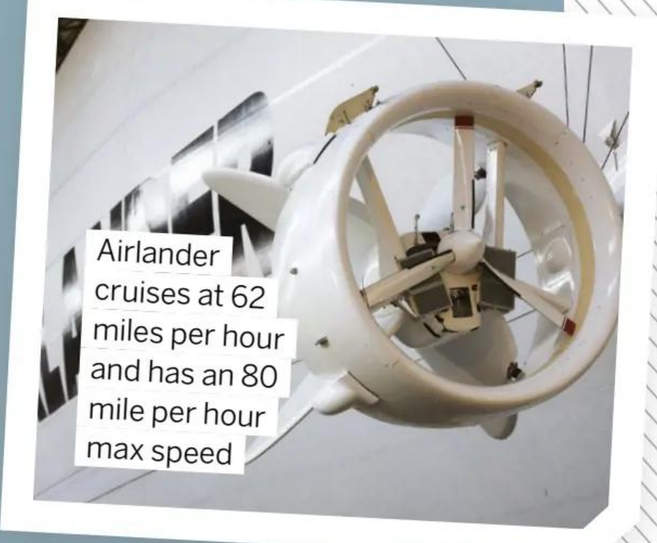
ENGINES

Changing directions using engine power is called vectored thrust. The two side-mounted engines do this with 20-degree pivoting.



LIGHTER THAN AIR

Helium is lighter than air, and it offsets the weight of the entire airship. This provides most of Airlander's lift.


Airlander cruises at 62 miles per hour and has an 80 mile per hour max speed

4 EFFICIENT MOVEMENT

Strakes – long fins down Airlander's hull – improve stability. They also keep movement more efficient, which reduces carbon footprint.

7 SOFT LANDINGS

Airlander lands using six 'cushions'. They retract during flight, improving efficiency, and Airlander can land without runways and on water.

5 OFF THE GROUND

The side engines, which help steer, are vital during takeoff and landing, but they're typically turned off during flight.

3 STEERING CLEAR

The tailfins are made of fibreglass for rigidity, ensuring smoother steering. Vanes also direct air over the fins more efficiently.

1 A FULL VIEW

Four floor-to-ceiling windows provide visibility for two crew members, and CCTV helps them keep an eye on all the engines.

2 CARGO HOLD

There's space for ten tonnes of cargo in the adjustable payload module, and the weight is distributed using weight-bearing cables.

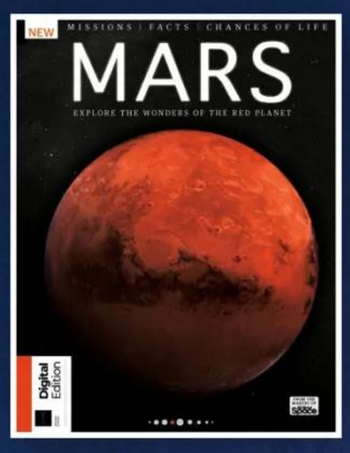
6 ELECTRIFYING ENGINES

The two rear engines provide forward movement during flight. Two of the craft's engines will be electric by 2028.

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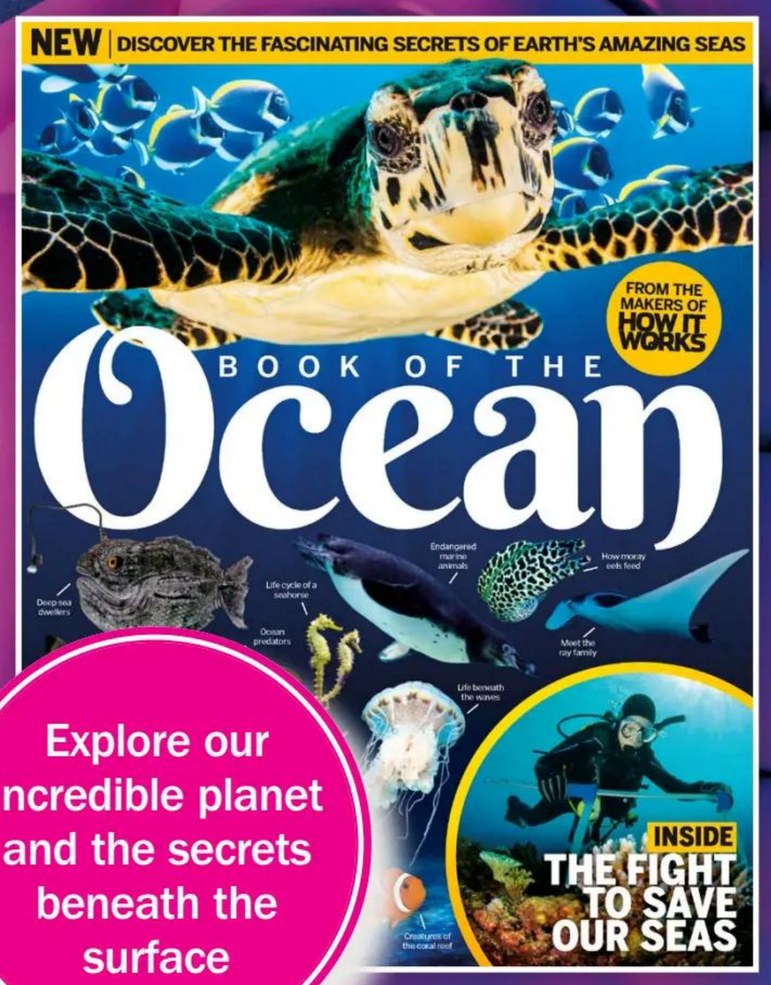
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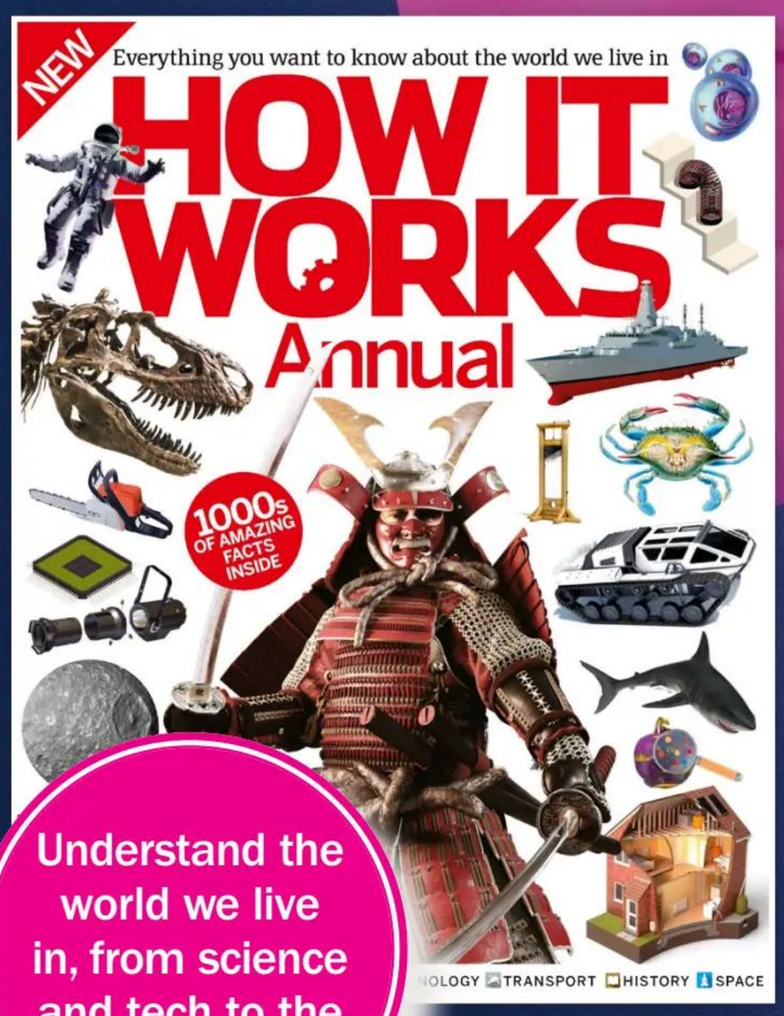
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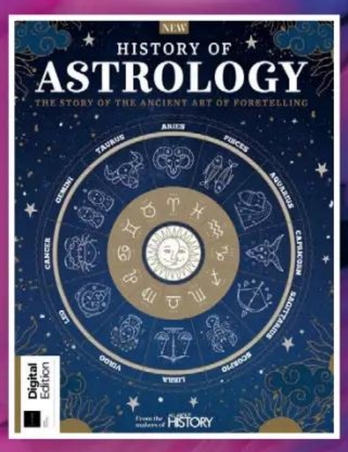








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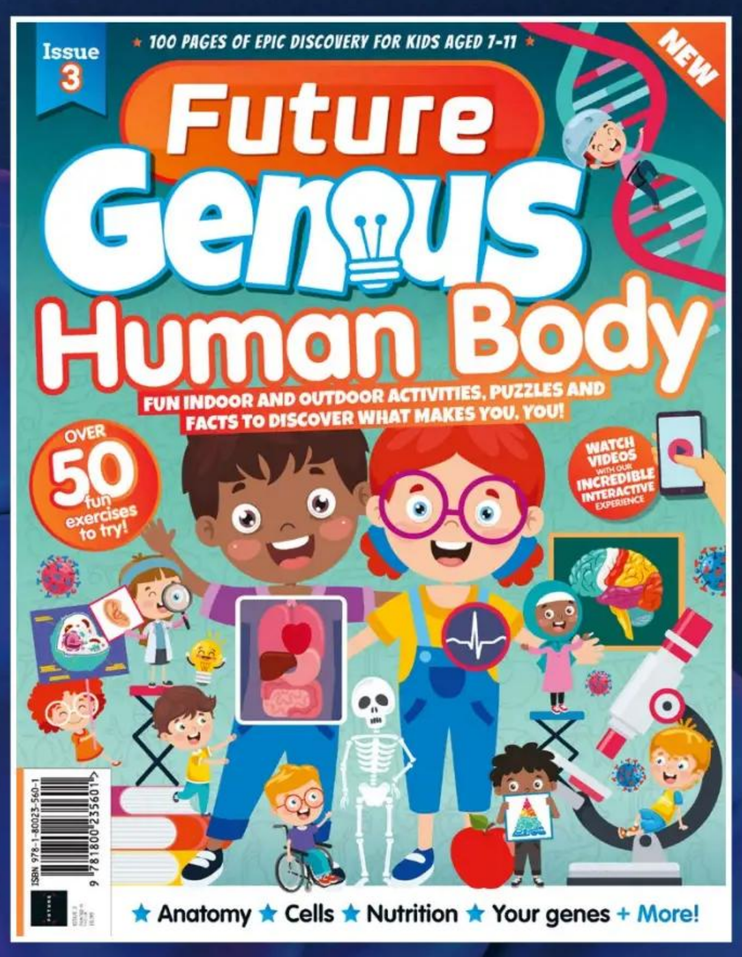


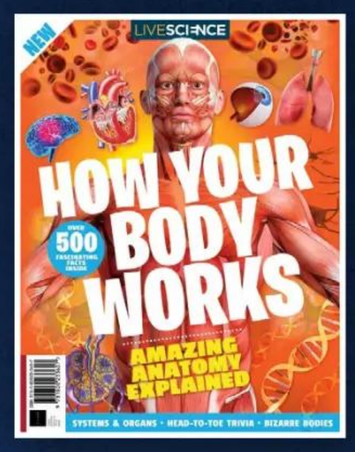
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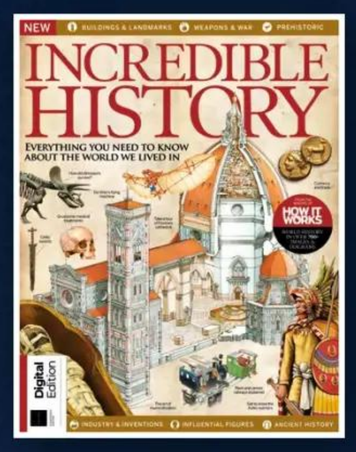
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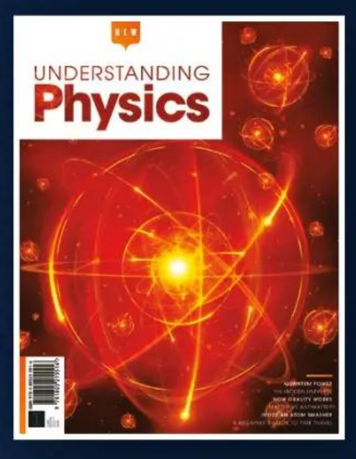










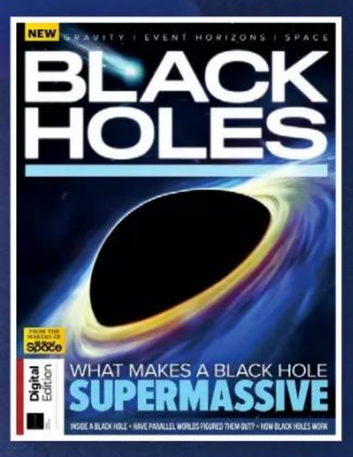


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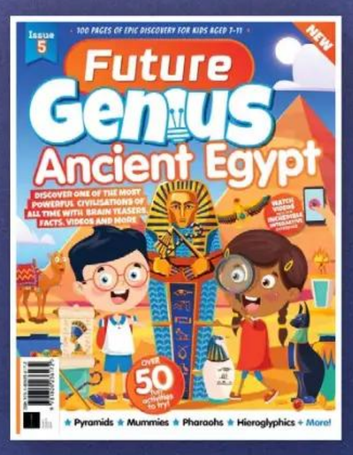
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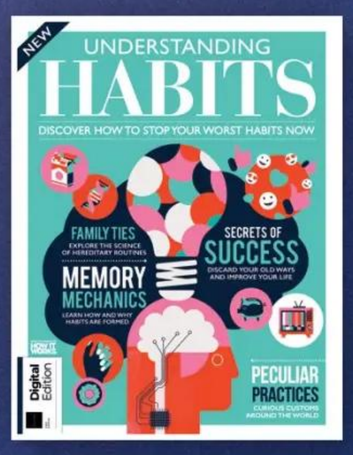


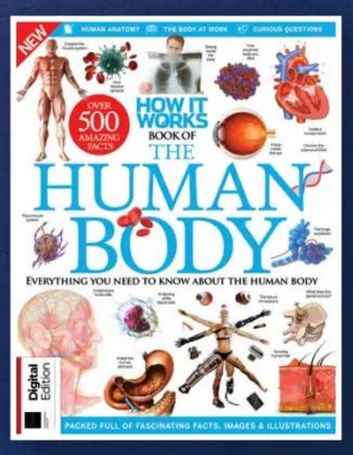












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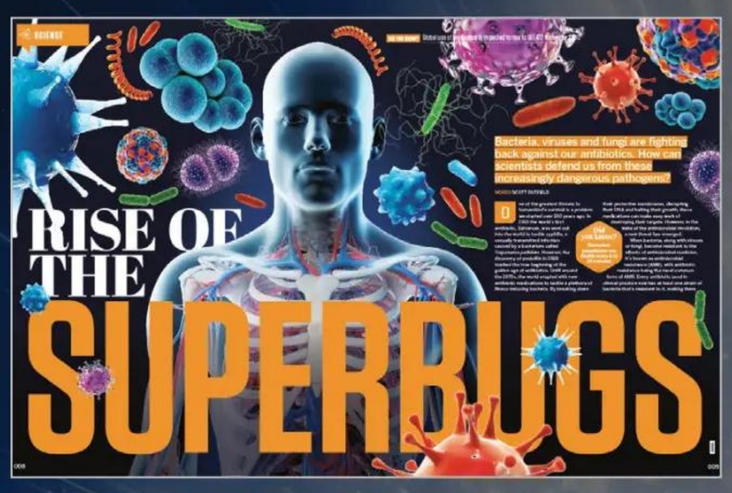
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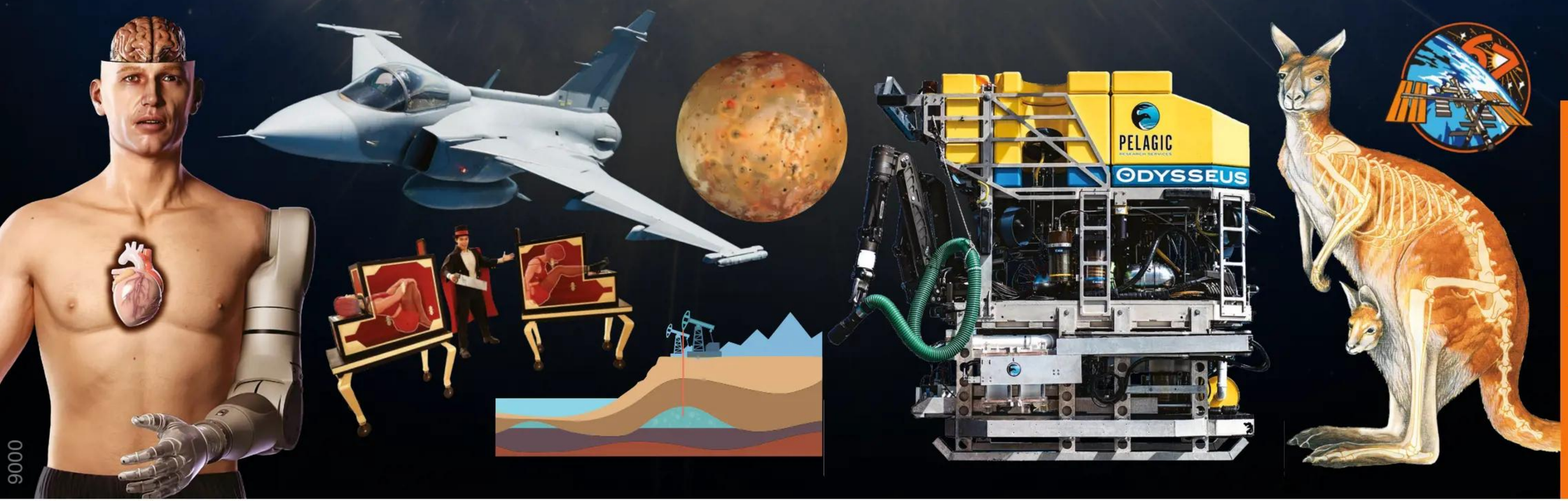
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