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AIRFIX

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SUPERMARINE SPITFIRE Mk.Vc

One of the most famous aircraft ever to take to the skies and one which is as familiar today as it was during the savage dogfights of the Battle of Britain, the Supermarine Spitfire was designed as a short range, high performance interceptor, taking inspiration from the inter-war seaplanes which had competed for the Schneider Trophy. Representing a significant advancement in aviation technology compared to the biplane fighters which were still in widespread service during the mid 1930s, the Spitfire would go on to see service throughout the Second World War, undergoing constant development to keep it at the forefront of fighter design. Introduced as something of an interim design, the Mk.V would go on to be the most heavily produced variant of Spitfire and featured the more powerful Merlin 45 engine and highly advanced 'universal wing', which allowed different armament options to be fitted to the fighter with relative ease.

Length 131mm Wingspan 157mm Pieces 26

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WELCOME

The magazine that feeds minds!

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"We will gain the power to repair, edit and rewrite our genes"

All about DNA, page 26

That a series of chemical compounds should determine so much about who we are, both physically and mentally, is a strange thought – though the DNA double helix is far from being a simple structure. That's part of the reason why it has taken scientists until the middle of the 20th century to successfully extract and define it. In this issue of **How It Works**, we explore the history of the scientific discovery of DNA, the chemical structure that allows it to store instructions on every facet of human anatomy, how we use our knowledge of DNA today and what we might be able to do with DNA science in the future.

Enjoy the issue!

Ben Editor

Meet the team...

Nikole
Production Editor
Origami is an ancient and intricate art form, but how did this papercraft develop? Find out and make your own creation on page 66.

Scott
Staff Writer
From regenerating amphibians to mind-controlling insects, meet the animals that put the X-Men to shame on page 50.

Baljeet
Research Editor
The International Space Station is a floating laboratory that houses astronauts. Learn how they get there on page 42.

Duncan
Senior Art Editor
From building the foundation, walls and tiling the roof, we take you through the process of building a house on page 76.

Ailsa
Staff Writer
Fire, serious injury or even quicksand? Emergency vehicles will rush to your aid. Discover the machines saving lives on page 68.

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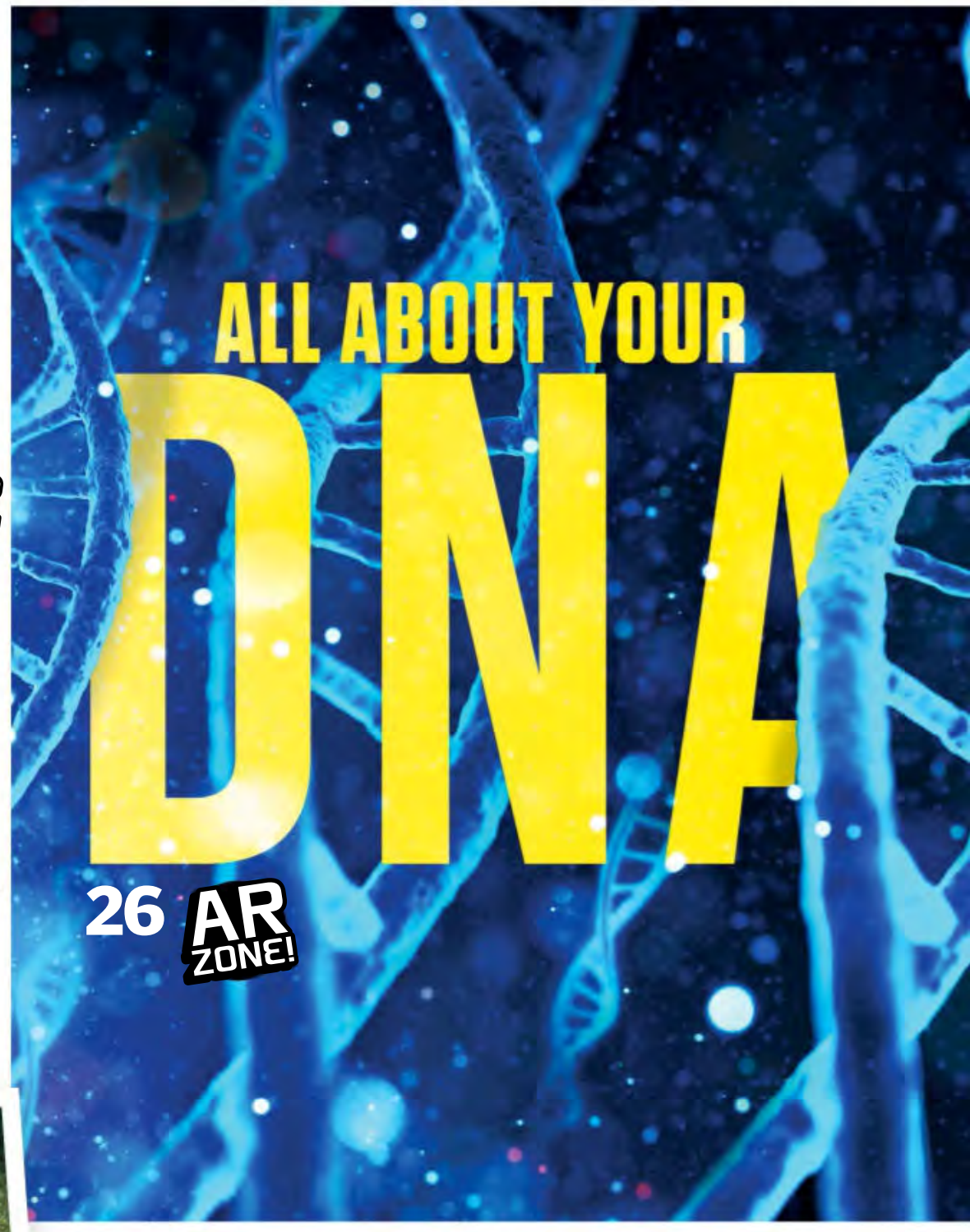
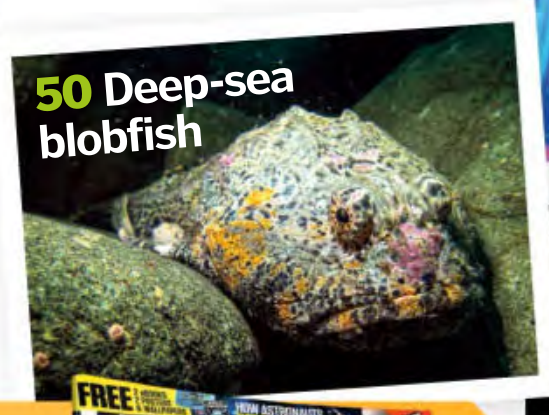




MEET THIS ISSUE'S EXPERTS...

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

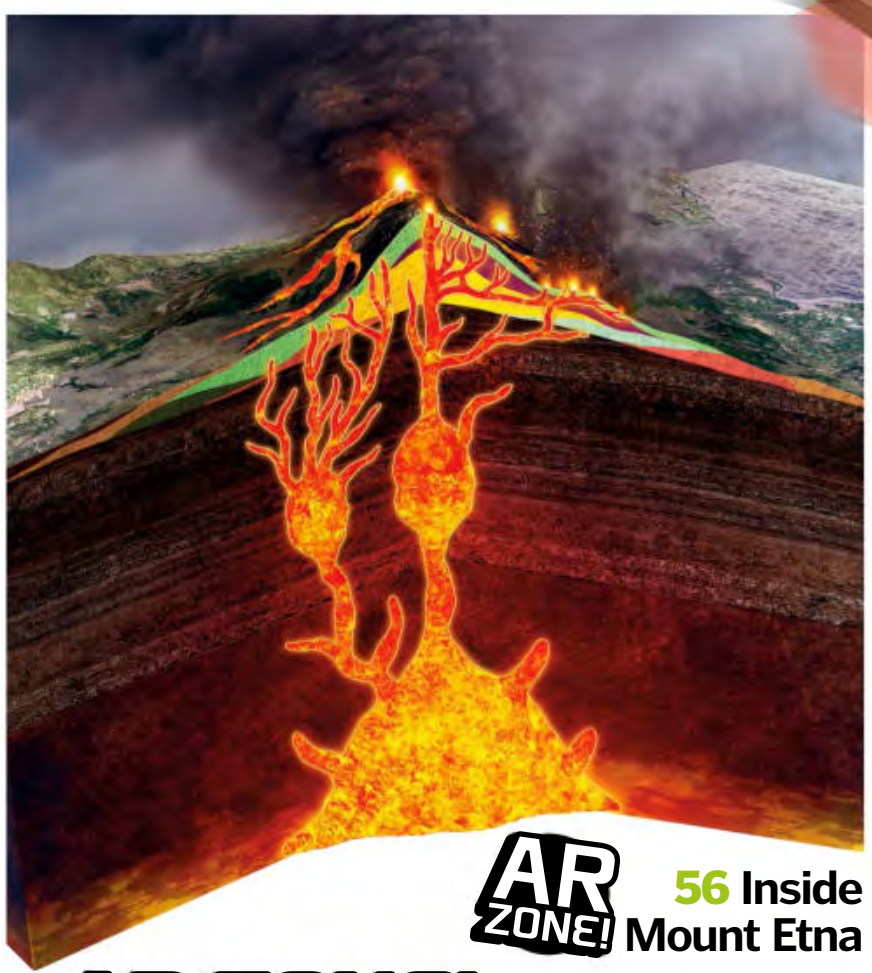
Dr Andrew May
Andrew has a PhD in astrophysics and 30 years in public and private industry. He enjoys space writing and is the author of several books.

Lauren Eyles
Marine biologist and PADI divemaster Lauren has been leading the fight against plastic pollution for over ten years. She's appeared on *BBC Coast*, *Springwatch* and other wildlife programmes.

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

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

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



REGULARS

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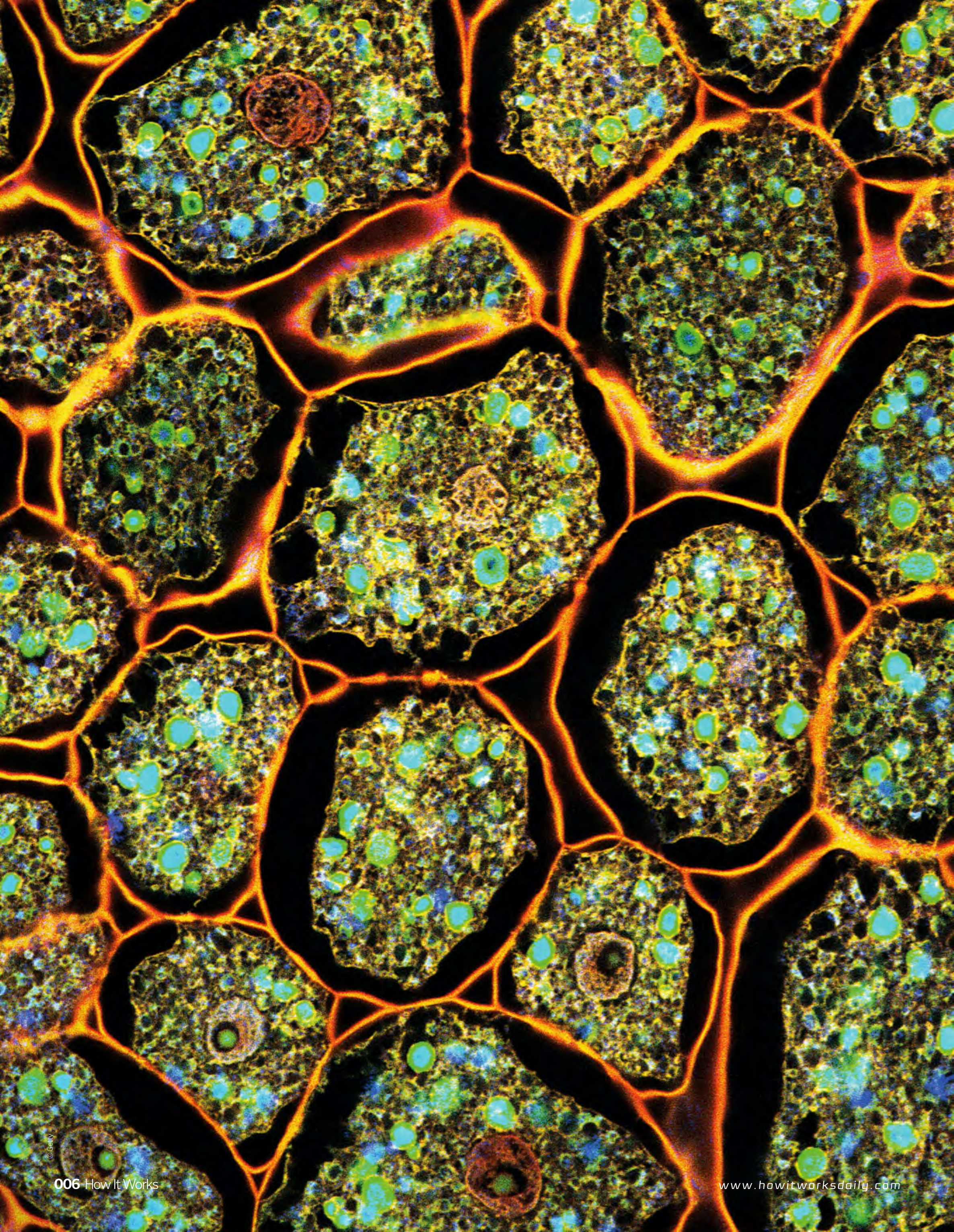


© Getty

PLANT SKIN

Speckled throughout each of these plant cells are flecks of green organelles called chloroplasts. These subcellular structures give plants the ability to make their own food, such as sugars. Autotrophs like plants, algae and cyanobacteria can convert a mixture of sunlight, water and carbon dioxide into sugar and oxygen. This process is called photosynthesis. All organelles are contained within cell walls, illuminated here as vibrant-orange borders, and all of their activities are controlled by the cells' nuclei, seen in this image as reddish-brown circles.

FISH ABOVE WATER

Zipping across the waves, flying fish have evolved a handy pair of wings to avoid being eaten. While swimming, these fish appear largely indistinct from many other torpedo-shaped fish. However, their pectoral fins spread like wings, allowing them to glide above the surface. Ramping up the speed underwater, when these fish reach around 37 miles per hour they can breach the surface, open their fins and glide around a metre above the waves. Flying fish, of which there are around 40 species, can sustain a single 'flight' for up to 200 metres. It's thought that they evolved their wing-like fins as a way to escape their many marine predators.

DEVIL'S BRIDGE

All across Europe are eerie bridges known as Devil's Bridges, with many said to have sprung up after being built by the devil himself. There are 49 of these in France alone. In this image is the German Rakotzbrücke, found in Saxony. The construction of this semi-circular bridge creates the appearance of a full circle in the water's reflection below. Its portal-like appearance and gravity-defying design have placed this bridge in fiendish fairy tales and folklore about devils and demons. It remains unclear who built the Rakotzbrücke, but it is believed to have been built by hand around 1860, including the spiky spires at either end.

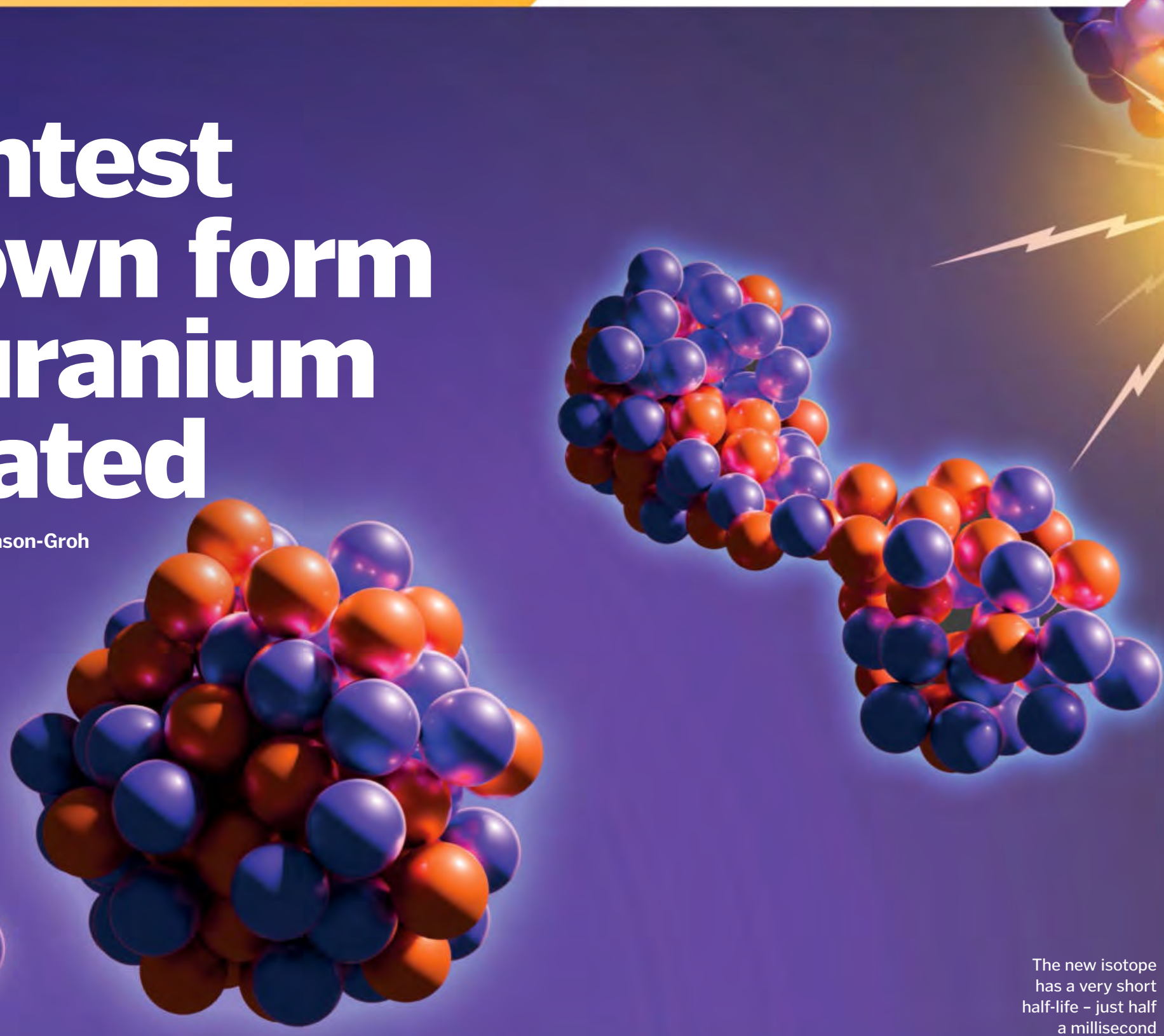
NEBULOUS NEIGHBOURS

Just outside the Milky Way in one of its satellite galaxies, the Large Magellanic Cloud, are these two nebulae. Floating around 163,000 light years away from Earth, the larger red nebula is called NGC 2014, and its smaller blue sidekick is called NGC 2020. These nebulae are the birthplace of massive stars, including rare Wolf-Rayet stars, which are around 15 times the size of our Sun. Near the centre of NGC 2020 you'll notice the bright Wolf-Rayet star HD 269748, which generates this blue bubble. This image, which has been given the name 'Cosmic Reef' because of NGC 2014's coral reef-like appearance, was taken by the Hubble Space Telescope.

SCIENCE

Lightest known form of uranium created

Words by **Mara Johnson-Groh**



The new isotope has a very short half-life – just half a millisecond

Scientists have discovered a new type of uranium – the lightest ever known. The discovery could reveal more about a weird alpha particle that gets ejected from certain radioactive elements as they decay. The newfound uranium, called uranium-214, is an isotope – a variant of the element – with 30 more neutrons than protons, one fewer neutron than the next lightest known uranium isotope. Because neutrons have mass, uranium-214 is much lighter than more common uranium isotopes, including uranium-235, which is used in nuclear reactors and has 21 extra neutrons.

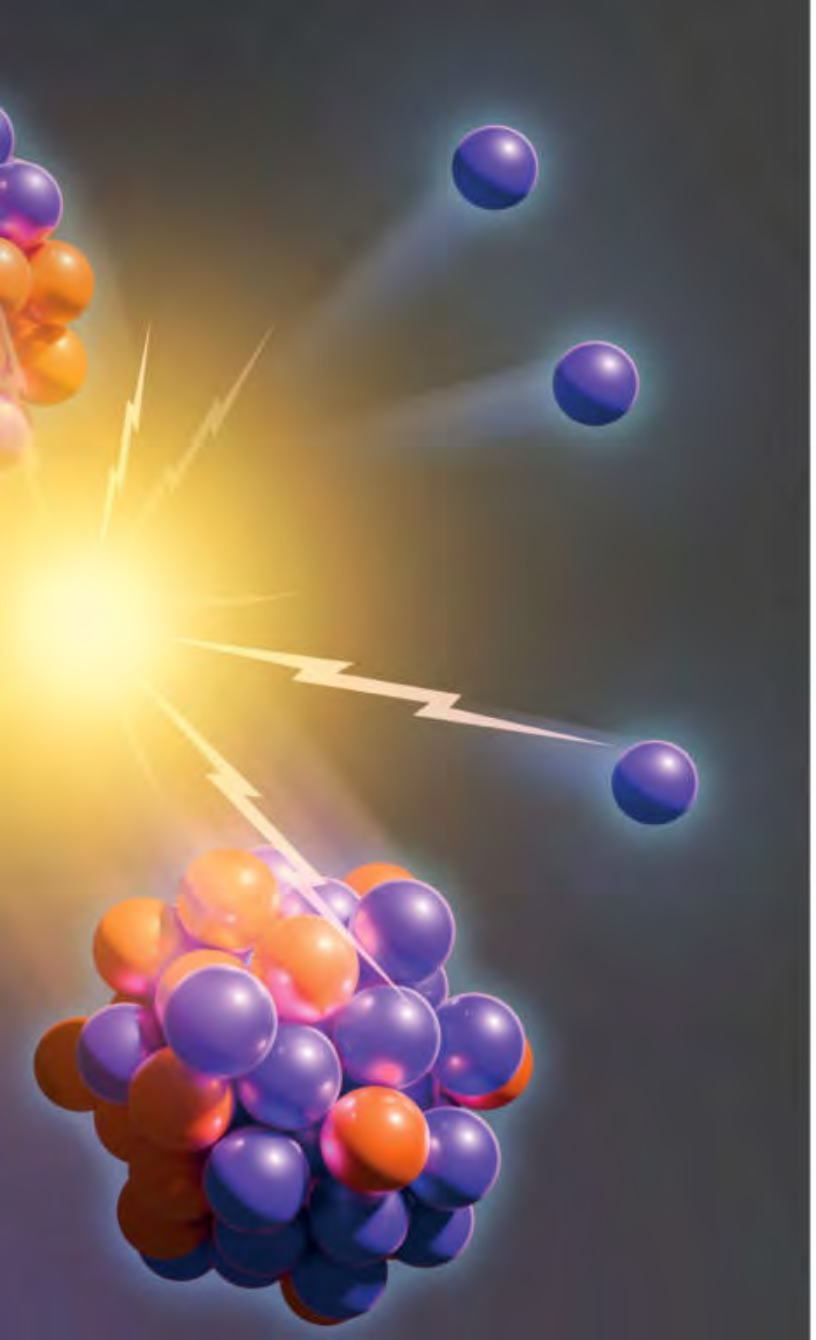
This newfound isotope isn't just lighter than others, it also showed unique behaviours during its decay. As such, the new findings will help scientists better understand a radioactive decay process known as alpha decay, in which an atomic nucleus loses two protons and two neutrons, collectively called an alpha particle. Though scientists know that alpha decay results in the ejection of this alpha particle, after a century of study they still don't know the exact details of how the alpha particle is formed before it gets ejected.

The researchers created the new uranium isotope at the Heavy Ion Research Facility in Lanzhou, China. They shone a beam of argon at a target made of tungsten inside a machine called a gas-filled recoil separator, in this case the Spectrometer for Heavy Atoms and Nuclear Structure, or SHANS. By shining a laser at the tungsten, the researchers effectively added protons and neutrons to the material to create uranium.

The new uranium-214 isotope had a half-life of just half a millisecond, meaning that's the amount of time it takes for half of the radioactive sample to decay. The most common isotope of uranium, called uranium-238, has a half-life of about 4.5 billion years, which is about the age of Earth.

By carefully watching how the isotopes decayed, the scientists were able to study the strong nuclear force, one of the four fundamental forces that hold matter together, acting on the alpha particle parts – the neutrons and protons – on the surface of the uranium. They found that the proton and neutron in each alpha particle interacted much more strongly than in isotopes and other elements with a similar number of protons and neutrons that have been previously studied.

This is likely due to the specific number of neutrons inside the nucleus of uranium-214, the researchers said. The new isotope has 122 neutrons, nearing the 'magic neutron



"Because neutrons have mass, uranium-214 is much lighter than common isotopes"

number' of 126, which is especially stable due to the configuration of the neutrons in complete sets, or shells. With this configuration, it's easier for scientists to calculate the strong force interaction between the protons and neutrons. That makes these isotopes particularly interesting to scientists, since studying these interactions can reveal features related to nuclear structure and decay processes, said Zhiyuan Zhang, a physicist at the Chinese Academy of Sciences.

Scientists suspect this proton-neutron interaction could be even stronger in heavier radioactive elements such as isotopes of plutonium and neptunium. These elements have a few more protons, and the configuration of their orbits suggests they could have even stronger interactions than the uranium isotopes.

Scientists discovered a new species of dinosaur called *Tlatolophus galorum*

HISTORY

New species of dinosaur talked to each other

Words by **Yasemin Saplakoglu**

Palaeontologists have discovered fossils of a plant-eating dinosaur that belonged to a previously unknown species, one that was likely 'talkative' based on the ear structure, which would've been adept at picking up low-frequency sounds.

The tail of the dinosaur, which lived about 73 million years ago, was first discovered in 2005 in the Cerro del Pueblo formation near Presa de San Antonio in Coahuila, northern Mexico. About eight years later, palaeontologists from the National Institute of Anthropology and History (INAH) in Mexico and the National Autonomous University of Mexico (UNAM) worked together to recover the tail and any other remains. They needed to quickly rescue the tail, which was protruding from the surface of the Earth and exposed to rain and erosion.

"Although we had lost hope of finding the upper part of the specimen, once we recovered the tail we continued digging under where it was located," said Ángel Alejandro Ramírez Velasco from UNAM's Institute of Geology. "The surprise was that we began to find bones such as the femur, the scapula and other elements."

The dinosaur remains were well preserved, suggesting the individual had died in a sediment-rich body of water that would have been quick to blanket and protect the remains. Palaeontologists were able to recover 34 bone fragments, making up 80 per cent of the dinosaur's skull, including its crest, its lower and upper jaws, palate and neurocranium, the part of the skull that would have housed the brain.

Because the researchers could recover so much of the dinosaur's skull, they were able to compare this individual with other known species. At first, based on its tail alone, the researchers knew the dinosaur belonged to a family of duck-billed dinosaurs called hadrosaurs. But they quickly realised that the crest and nose differed from those of any known hadrosaurs, and what they had in their hands represented a new genus and species.

The researchers named the species *Tlatolophus galorum*. They named the genus after the Nahua indigenous group's word tlahtolli, which means 'word', and the Greek word lophus, which means 'crest'. The name is fitting, as the dinosaur's crest is shaped like a 'virgula', "a symbol used by Mesoamerican peoples to represent communicative action and knowledge in itself in codices," said researchers.

By examining the structure of the ear bones, the researchers were even able to get a glimpse at how the dinosaurs may have communicated. "We know that they had ears with the ability to receive low-frequency sounds, so they must have been peaceful but talkative dinosaurs," said Ramírez Velasco.

HEALTH

Genetically modified mosquitoes released in the US

Words by **Nicoletta Lanese**

The biotech firm Oxitec has released its genetically modified mosquitoes in the Florida Keys with the goal of suppressing wild, disease-carrying mosquito populations in the region. This is the first time genetically modified mosquitoes have been released in the US.

Oxitec previously released its modified *Aedes aegypti* mosquitoes in Brazil, the Cayman Islands, Panama and Malaysia, and the company reported that local *A. aegypti* populations fell by at least 90 per cent in those locations. *A. aegypti* can carry diseases such as Zika, dengue, chikungunya and yellow fever, and releasing modified mosquitoes offers a way to control the population without using pesticides.

Oxitec's modified mosquitoes, all male, have been engineered to carry a lethal gene; when the modified pests mate with wild female mosquitoes, the lethal gene gets passed to their offspring. Though the gene does not affect the males' survival, it prevents female offspring from building an essential protein, and thus causes them to die before reaching maturity. Only female mosquitoes bite people – male mosquitoes exclusively drink nectar – so the modified mosquitoes and their surviving male offspring can't pass diseases to humans.

***A. aegypti* mosquitoes make up about four per cent of the mosquitoes in the Florida Keys, but cause the vast majority of mosquito-borne disease transmitted to humans in the area. The Florida Keys Mosquito Control District (FKMCD) board typically budgets $1 million (£710,000) a year to control the pest, resorting to costly measures such as spraying aerial insecticides. Releasing hundreds of millions of genetically modified mosquitoes may be a less expensive and more effective option, the board concluded, especially as mosquito populations become resistant to pesticides over time.**

FKMCD first approached Oxitec in 2010, and after a decade of regulatory assessments and local pushback, both the board and the US Environmental Protection Agency (EPA) finally approved the plan to release the genetically modified mosquitoes in the Keys.

In late April 2021 the company placed boxes of mosquito eggs at six locations in Cudjoe Key, Ramrod Key and Vaca Key. Over the preceding 12 weeks, about 12,000 newly hatched male mosquitoes should emerge from the boxes each week.

This release will serve as an initial trial so that Oxitec can collect data before running a second trial with nearly 20 million mosquitoes later this year. The company will capture mosquitoes throughout the trial to observe how far the insects travel from their boxes, how long they live and whether female mosquitoes are actually picking up the lethal gene and dying off.

To make it easier to track the modified mosquitoes, Oxitec also introduced a gene that causes the mosquitoes to glow under a specific colour of light.

"Modified mosquitoes and surviving male offspring can't pass diseases to humans"

Aedes aegypti mosquito larvae hatch in water before metamorphosing into adult insects © Getty

ANIMALS

Deep-dwelling ‘Emperor Dumbo’ octopus discovered

Words by **Cameron Duke**

A new species of Dumbo octopus, equipped with the telltale fins on its head, has been dredged from the deep. Nicknamed the Emperor Dumbo, the adorable creature was discovered in 2016. Alexander Ziegler of Friedrich Wilhelms Universität in Bonn, Germany, was aboard the German survey ship RV Sonne as the resident biologist when a strange creature was caught in one of its nets near the Aleutian Islands.

“It was a really lucky find,” said Ziegler, “because we weren’t really looking for it. Plus the whole animal came to the surface intact.” Such nets typically damage animals made predominantly of soft tissue, like octopuses. This one, however, was in immaculate condition, an impressive feat considering it was fished from the crushing depth of roughly 4,500 metres.

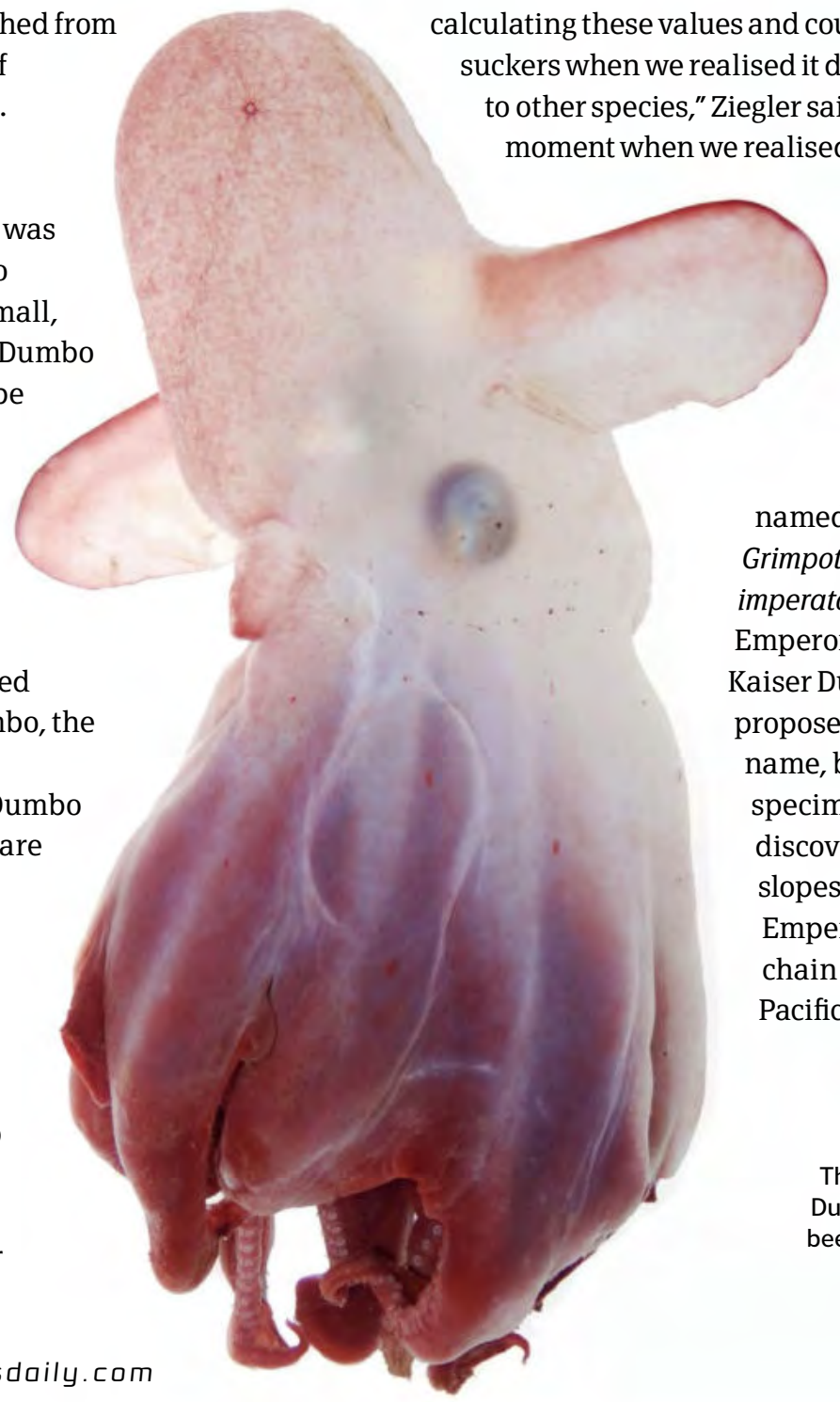
On board the ship, Ziegler quickly determined that this was an adult male Dumbo octopus, a group of small, deep-sea octopuses. Dumbo octopus species can be identified by the umbrella-like webbing joining their tentacles and their cartoonishly ear-like fins that resemble the oversized ears on Disney’s Dumbo, the flying elephant.

Finding an intact Dumbo octopus is rare. They are the deepest-living octopuses known to science, and they are usually dredged from the deep as fishing bycatch, often too damaged to be identified. To identify an octopus to the species level or to characterise it as a new species typically requires destructive techniques. “You have to look at the internal structure, which would mean disassembling the specimen in order to describe it,” Ziegler said.

Instead, Ziegler and Christina Sagorny, currently a doctoral student in Ziegler’s lab, used magnetic resonance imaging (MRI) and micro-computed tomography (micro-CT) scans to non-invasively examine the internal organs and structure of the octopus without making a single cut, except to extract a DNA sample.

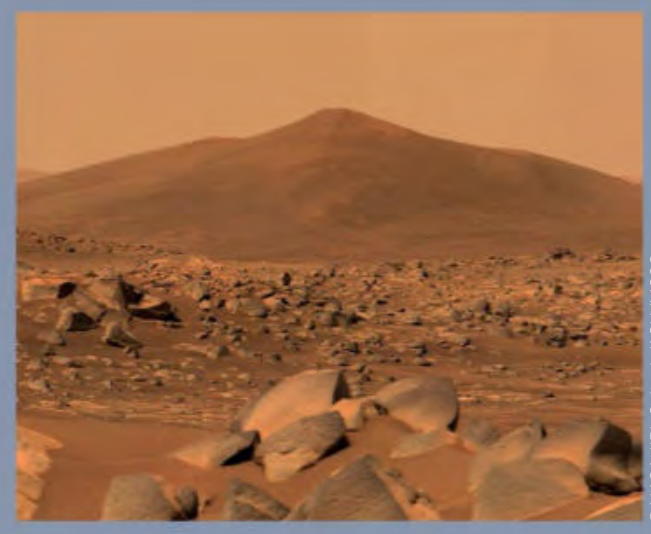
By using these techniques, Sagorny and Ziegler found that their endearing deep-sea dweller didn’t match any known species. The number of suckers on its tentacles, along with the shape of the gills and beak, suggested something totally new. “Christina was calculating these values and counting the suckers when we realised it didn’t compare to other species,” Ziegler said. “That moment when we realised we were describing a new species, obviously that was a pretty good moment.”

The duo named the species *Grimpoteuthis imperator*, with Emperor Dumbo or Kaiser Dumbo as a proposed common name, because the specimen was discovered along the slopes of the Emperor seamount chain in the Pacific Ocean.



The new species of Dumbo octopus has been nicknamed the Emperor Dumbo

© Alexander Ziegler



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Perseverance captured this image of ‘Santa Cruz’, a hill within Jezero crater

SPACE

Mysterious rocks found by Mars rover

Words by **Mike Wall**

NASA’s Mars rover Perseverance is starting to take the measure of its new Red Planet home.

Perseverance has been focused primarily on supporting and documenting the pioneering flights of its little cousin, NASA’s 1.8-kilogram Mars helicopter Ingenuity. But the car-sized rover has been doing science work of its own in the background as well.

For example, Perseverance has extensively photographed its surroundings, the boulder-studded floor of Mars’ 28-mile-wide Jezero crater, where the rover and chopper touched down on 18 February, with its high-resolution Mastcam-Z imaging system.

Perseverance has also studied nearby rocks in greater detail using two other instruments: its rock-zapping SuperCam laser and the WATSON (Wide Angle Topographic Sensor for Operations and eNgineering) camera at the end of its robotic arm.

The mission team is keen to know whether the stones are volcanic or sedimentary in origin. Volcanic rocks can serve as geological clocks, allowing researchers to better understand the history and evolution of Jezero, which hosted a lake and river delta billions of years ago. Sedimentary rocks, which form through the deposition of dirt and sand over time, have greater potential to preserve signatures of Mars life, if it ever existed at Jezero.

IN ASSOCIATION WITH LIVESCIENCE

HISTORY

Ancient tombs uncovered in Corsica

Words by **Owen Jarus**

An ancient necropolis with 40 tombs, including cylindrical jars filled with human remains, has been discovered on the French island of Corsica. The people buried in the cemetery range from infants to adults, archaeologists said. Located in the town of L'Île-Rousse on the island's northern coast, the cemetery seems to have been used between the third and fifth centuries CE, a time in which the Roman Empire was gradually declining.

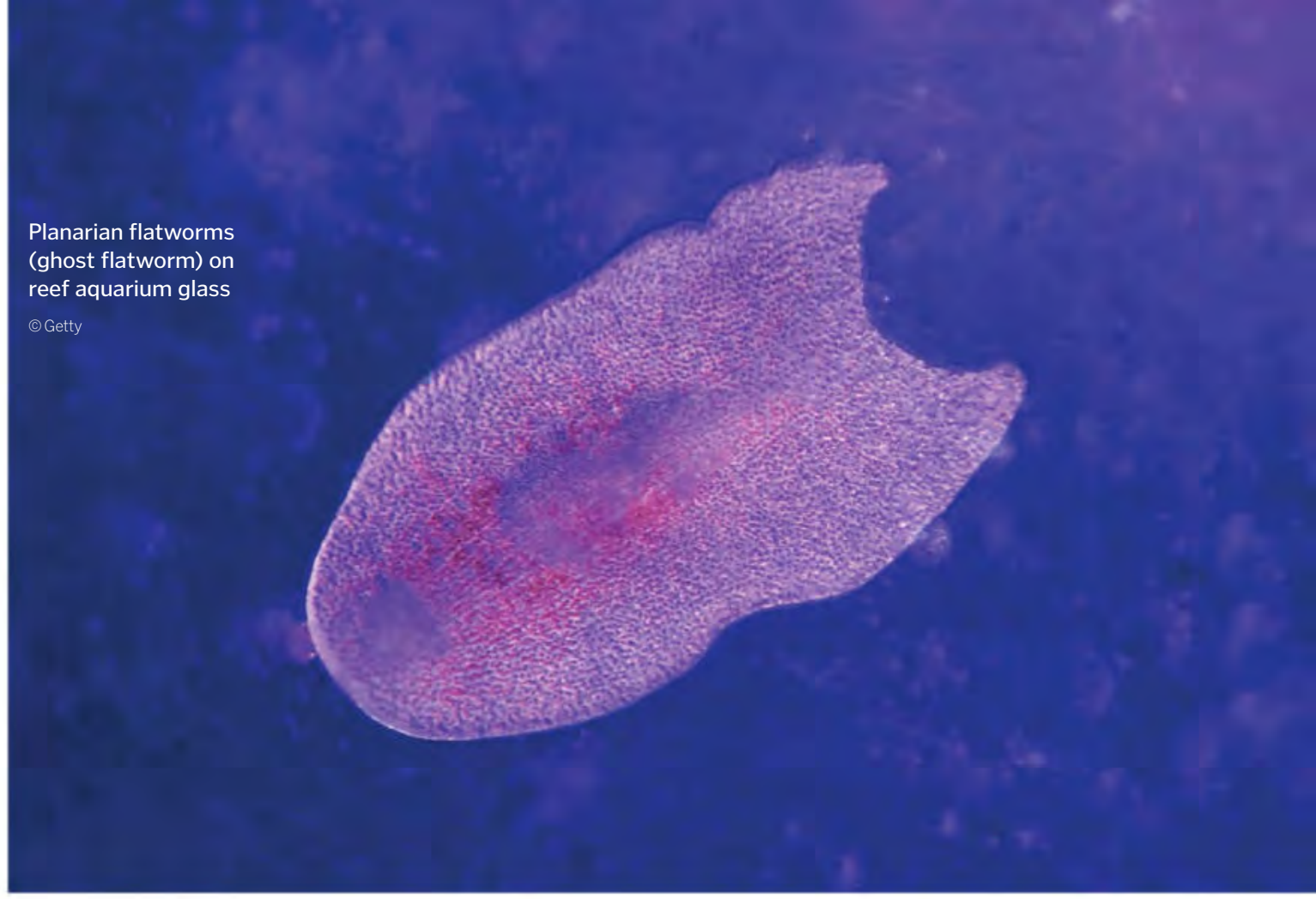
Many of the deceased were found buried inside amphoras, large vessels that would normally be used to carry goods such as olive oil, wine or pickles. The design of the amphoras indicates that they are from North Africa, with some possibly being manufactured in Carthage.

Even so, the people buried in the necropolis, including those inside the amphoras, likely lived near the necropolis in Corsica. Archaeologists also found that some of the burials were covered with terracotta tiles that the Romans called 'tegulae' and 'imbrices'. The Romans often used such tiles to cover the roofs of buildings, and at times to cover burials.

The necropolis is located at the foot of the Immaculate Conception church, constructed in 1893. Other burials found on the island, such as those at the sites of Mariana and Sant'Amanza, have been linked to buildings of worship. More research needs to be done to determine what ancient towns or cities were located near this necropolis.

© Getty

Archaeologists found that some of the human remains had been buried in amphora pots



Planarian flatworms (ghost flatworm) on reef aquarium glass

© Getty

ANIMALS

Decapitated worms 'see' with headless bodies

Words by **Mindy Weisberger**

Tiny worms can 'see' light without their eyes, or their heads. Planarians are a type of flatworm, soft-bodied creatures that lack complex organs. They have two eyes that connect to a centralised bundle of ganglia in their heads that acts as a brain, and those eyes are sensitive to ultraviolet (UV) light. In the presence of UV light, the worms use their cilia, tiny hairlike structures on their bodies, to wriggle away. However, it turns out the worms, measuring just a few millimetres long, don't need their eyes or their brains for light detection. When researchers lopped off planarians' heads, the worms were still capable of sensing UV light.

Removing an animal's head might seem like an odd way to conduct behaviour experiments. But planarians are known for not only surviving decapitation, but also for easily regenerating missing body parts. Amputation is no big deal for a planarian; cut one into multiple pieces and each piece will regenerate into a new worm. Decapitated planarians easily grow new heads, and scientists can even tweak the worms' genetic instructions to coax them into growing the heads of different species.

Researchers found planarian bodies contain cells that produce a type of light-sensitive protein called an opsin. Arrays of these cells found around the periphery of the planarians' bodies expressed two opsins: NC R-opn 1 and NC R-opn 2, while the more centrally located cell populations only expressed NC R-opn 1.

The cells producing just one opsin were pigment cells. In the peripherally located cells, the two opsins first detected UV light and then triggered movement in the headless worm, which wriggled away in response to that light. Only mature worms possessed this light-sensing superpower; newly hatched worms couldn't detect UV light after their heads were snipped off, hinting that light-sensing cells in the worms' bodies develop after hatching.

> "The worms were still capable of sensing UV light"

The scientists also found that when whole planarians were resting in an inactive sleep-like state, they would perk up in the presence of UV light, even when they didn't respond to other visual stimuli. This suggests that whole-body light sensing helps to protect snoozing worms from harmful UV rays by activating movement when the worm is at rest and its vision is temporarily offline.

"Such a mechanism may be distinctly advantageous to a water-dwelling, light-aversive organism that is likely nocturnal and would rest during the day," the researchers wrote. The discovery of a whole-body light-sensing infrastructure in planarians that doesn't require a central brain or eyes represents "a major advance spanning virtually all facets of photosensory biology".

SPACE

Astronauts to clean space underwear with microbes

Words by **Mindy Weisberger**

Sharing your unwashed underwear with another person isn't ideal. However, for astronauts on board the International Space Station (ISS), performing a spacewalk requires that they share not only the spacesuits, but also a piece of clothing that's worn underneath, known as the liquid cooling and ventilation garment (LCVG).

Access to a freshly laundered LCVG isn't an option on the ISS, but technicians with the European Space Agency (ESA) are taking steps to improve the antimicrobial properties in LCVG materials to keep these shared garments clean and fresh for longer.

In a new two-year project called Biocidal Advanced Coating Technology for Reducing Microbial Activity (Bacterma), ESA researchers are collaborating with the Vienna Textile Lab, a private biotechnology company in Austria that produces fabric dyes from bacteria. Compounds generated by these bacteria can also make textile fibres more resistant to certain types of microbes.

Astronauts on the ISS keep their hands and bodies clean with no-rinse cleaning solutions and dry shampoo, but laundering clothes, including underwear, would require too much water, and is simply not possible. Nor is there enough room on the ISS for astronauts to pack a fresh change of clothes for every day of their mission.

When it comes to dirty underwear, astronauts don't have the luxury of being squeamish, and may wear a pair more than once. American astronaut Don Pettit wrote that he changed his underwear once every three or four days when he was on the ISS. And when Japanese astronaut Koichi Wakata tested bacteria-resistant underwear coverings in space in 2009, he wore one pair for about a month. When clothing becomes too soiled or smelly for an astronaut to wear, it is either returned to Earth as rubbish or is packed up into a capsule, ejected into space and burnt up in Earth's atmosphere.

LCVGs are only worn during spacewalks, but astronauts are working harder than usual when they wear this communal undergarment. An LCVG is very form-fitting, covering the limbs and torso, and it keeps astronauts cool during the extreme physical exertion of working in the vacuum of space. An adult diaper is worn underneath, in case the astronaut needs to relieve themselves during a spacewalk. Gas ventilation draws moist air away from extremities, while flexible tubes that are sewn into the garment circulate cooling water around the body and help to remove excess heat, maintaining a comfortable core body temperature.

ESA scientists were already investigating candidate materials for upgrading outer spacesuit layers, so this new initiative "is a useful complement, looking into small bacteria-killing molecules that may be useful for all kinds of spaceflight textiles, including spacesuit interiors," said ESA material engineer Małgorzata Hołynska.

Scientists will test the performance of antimicrobial properties in the new textiles by exposing them to sweat, lunar dust and radiation to simulate conditions that could accelerate aging and deterioration of the fabric in space.

Astronaut undergarments, known as liquid cooling and ventilation garments, designed for the Space Shuttle and International Space Station Extravehicular Mobility Unit

© NASA

© NASA

The Necklace Nebula shines like jewellery, but it's just a load of star farts

SPACE

'Necklace Nebula' formed by drowning star

Words by **Brandon Specktor**

Two stars, bound together in orbital matrimony, are slowly ripping each other apart, and like many relationship squabbles, this stellar spat ends with jewellery.

Meet the Necklace Nebula, also known as PN G054.203.4. This planetary nebula is located about 15,000 light years from Earth, inside the Sagitta constellation. To telescopes like Hubble, the nebula looks like an emerald oval ringed with sparkling clusters of jewel-like gas. A binary star forms a bright speck at the centre.

That speck looks like a single star, but it's no bachelor; about 10,000 years ago, the star grew so large that its outermost layer of gas actually swallowed up a smaller companion star. That smaller companion star is still orbiting inside its larger partner's gassy sheath, known as a common envelope. As the smaller star orbits through its larger partner, the gas surrounding the duo begins to rotate faster and faster. At some point the gas surrounding this stellar couple started swirling so fast that huge swaths of it started spilling out into space.

That runaway gas escaped in an oval shape, gushing outwards for trillions of miles in every direction, thus creating the necklace shape. As for the sparkling jewels running along the outside of the ring? These are areas where the stellar gas bunched up into dense clusters.

For now the two stars at the centre of the nebula will continue their mad ballroom dance around each other, completing a full orbit in a little more than an Earth day. But their end is uncertain. Many binary couples end their relationships with immense supernova explosions.

For more of the latest stories, head to **livescience.com**

HEALTH

Too much salt messes with your immune cells

Words by **Yasemin Saplakoglu**

Eating too much salt may reduce the amount of energy that immune system cells can make, preventing them from working normally. Eating an excess of sodium has previously been linked to many different problems in the body, including high blood pressure and a higher risk of stroke, heart failure, osteoporosis, stomach cancer and kidney disease.

"Of course the first thing you think of is the cardiovascular risk," said Markus Kleinewietfeld, an associate professor at Hasselt University in Belgium. "But multiple studies have shown that salt can affect immune cells in a variety of ways." If salt disrupts immune functioning for a long period of time, it could potentially drive inflammatory or autoimmune diseases in the body, he added.

A few years ago, a group of researchers in Germany discovered that high salt concentrations in the blood can directly impact the functioning of a group of immune system cells known as monocytes, which are the precursors of Pac-Man-like cells called phagocytes that identify and devour pathogens and infected or dead cells in the body.

Kleinewietfeld and his colleagues conducted a series of experiments to figure out how. First they zoomed in on that link in the lab using mouse and human monocytes. They found that within three hours of exposure to high salt concentrations, the immune cells produced less energy, or adenosine triphosphate (ATP).

Mitochondria, the cells' power plants, produce ATP from energy found in food using a series of biochemical reactions. ATP then fuels many different cellular processes, such as powering muscles or regulating metabolism.

The researchers discovered that high salt concentrations inhibit a group of enzymes known as complex II in the chain reaction that produces ATP, which leads the mitochondria to produce less ATP. With less ATP (energy), the monocytes mature into abnormal-looking phagocytes.

The researchers found that these unusual phagocytes were more effective at fighting off infections. But that's not necessarily a good thing, the researchers say, as an increased immune response can lead to more inflammation in the body, which in turn can increase the risk of heart disease.

The researchers then conducted multiple experiments in people. In one, healthy male participants took daily salt supplement tablets of 6,000 milligrams for two weeks. In another experiment, a group of participants ate a whole pizza from an Italian restaurant.

They found that after eating the pizza, which contained 10,000 milligrams of salt, participants' mitochondria produced less energy. But this effect wasn't long-lasting; eight hours after the participants ate the pizza, blood tests showed that their mitochondria were back to functioning normally again.

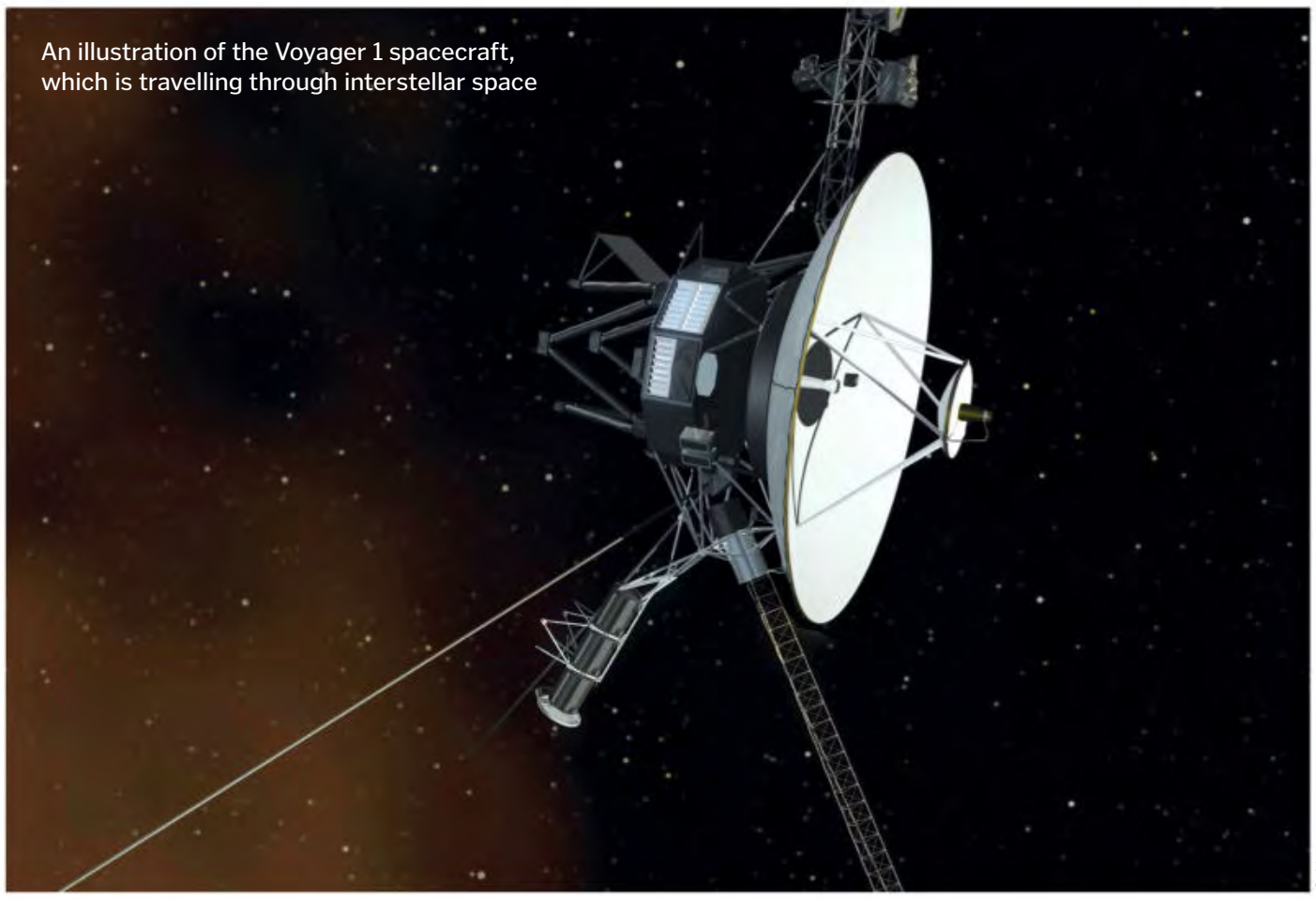
"That's a good thing," said Dominik Müller, a professor at the Max Delbrück Center for Molecular Medicine in the Helmholtz Association and the Experimental and Clinical Research Center in Berlin. "If it had been a prolonged disturbance, we'd be worried about the cells not getting enough energy for a long time."

Still, it's not clear whether mitochondria are affected in the long-term if a person consistently eats a high-salt diet. The researchers hope to understand whether salt can impact other cells, because mitochondria exist in almost every cell in the body.

High-salt diets have been linked to many different problems in the body

© Getty

"Salt can affect immune cells in a variety of ways"



An illustration of the Voyager 1 spacecraft, which is travelling through interstellar space

© Alamy

SPACE

Voyager 1 records mysterious 'hum' in interstellar space

Words by **Stephanie Pappas**

44 years after it rocketed off from Earth, Voyager 1 is detecting the background 'hum' of interstellar space for the first time. Voyager 1, launched in 1977, left the bounds of the Solar System, known as the heliosphere, in 2012. The heliosphere is the bubble of space influenced by the solar wind, the stream of charged particles that emanates from the Sun.

Since popping out of this bubble, Voyager 1 has been periodically sending back measurements of the interstellar medium. The Sun sends off bursts of energy known as coronal mass ejections that disturb this medium, causing the plasma, or ionised gas, of interstellar space to vibrate. These vibrations are quite useful, as they allow astronomers to measure the density of the plasma. The frequency of the waves through the plasma can reveal how close together the ionised gas molecules are.

Now, however, researchers have realised that Voyager 1 is also sending back a far more subtle signal: the constant 'hum' of the interstellar plasma. This low-level vibration is fainter, but much longer lasting than the oscillations that occur after coronal mass ejections. The hum lasts at least three years. "Now we don't have to wait for a fortuitous event to get a density measurement," said Stella Ocker, a doctoral student in astronomy at Cornell University.

Voyager 1 is currently over 152 astronomical units from the Sun. An astronomical unit is the distance between the Sun and Earth, so that means that the antennae-studded spacecraft is now 152 times as far away as Earth is from the Sun. The far-flung craft is one of a pair originally designed to fly by Jupiter, Saturn, Uranus and Neptune, taking advantage of a rare planetary alignment that would allow Voyager 1 and 2 to use the gravity of each planet to propel themselves to the next.

Both Voyager 1 and 2 are still transmitting from interstellar space. Voyager 2 made it past the heliosphere in 2018. Ocker and her colleagues combed through data from the last five years of Voyager 1's transmissions to find the subtle hum of interstellar space. They were surprised to find that the vibrations occur on a narrow set of frequencies, unlike the vibrations from the coronal mass events, which tend to show up more broadly. The researchers don't yet know exactly what causes the low-key plasma vibration, but it probably has to do with the 'jitter' of electrons in the medium due to their basic thermal properties.

ANIMALS

Parasitic wasps sniff out females bursting from their hosts

Words by **Ben Turner**

Of all the places to find the love of your life, hidden inside the shell of a still-developing fly probably ranks low in most expectations. However, for a male jewel wasp this is the first place to go. According to new research, males of the species can detect potential mates from inside their host flies, even before they've burst out of the host.

Jewel wasps (*Nasonia vitripennis*) can be found across North America, and they reproduce by injecting their eggs, along with a paralysing venom, inside the shells of still-developing flies. The wasp eggs take roughly two weeks to mature to adulthood within the fly shell. Broods are all male if the eggs haven't been fertilised, or a mixture of male and female if some of the eggs have been. Upon maturity, the wasps devour as much as they can of the host fly for a boost of energy before emerging to mate.

But males exit a few hours earlier than females. So if the males want to mate, they need to wait around. The research shows males choose to wait where they are more likely to find the most females.

"Our best guess is that they are capable of detecting the scent of adult females inside the hosts," said Rhitoban Raychoudhury, an evolutionary geneticist at the Indian Institute of Science Education and Research Mohali (IISER).

Source: Wiki/M.E.Clark

A female jewel wasp (*Nasonia vitripennis*)

WISH LIST

The ultimate **Father's Day** gift guide

Galaxy Watch3

Price: **£349 / $399.99**
www.samsung.com

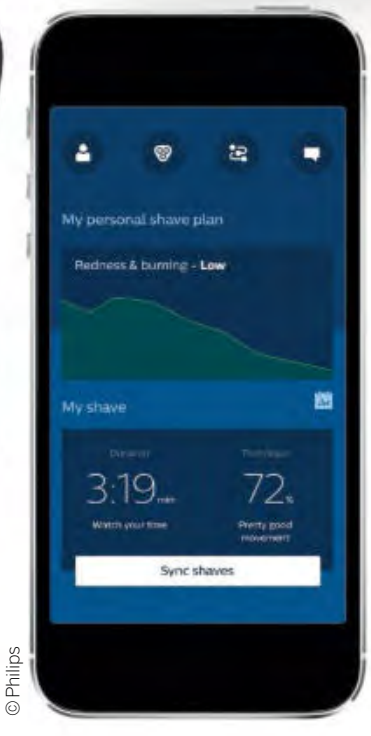
This is a great gift for tech-savvy dads that want to control their day from their wrist. The Galaxy Watch3 by Samsung lets the wearer control their schedule, messages, contacts, make contactless payments and much more. It also provides a convenient and sophisticated health analysis with its built-in sensors. An ECG can monitor your heart rate to track your daily rates, as well as monitoring the amount of oxygen in the bloodstream. It can also watch you while you sleep, scoring your REM cycle and offering tips for a better night's sleep.

© Samsung

Philips Shaver Series 7000

Price: **£259.99 / $179.99**
www.philips.co.uk / usa.philips.com

Designed with sensitive skin in mind, the Series 7000 shaver by Philips is a great gift for dads looking to give their morning routine an upgrade. This shaver isn't like other typical shavers – it's been built to include an array of high-tech features. For example, the Series 7000 can connect with a smartphone, and using the companion app allows the user to track their shave time and any skin issues related to shaving, such as razor burn or ingrown hairs. The built-in sensors will also auto-adjust the speed of the shaver blade to tackle the full range of beard densities it faces.



© Philips

The Smart Garden 3

Price: **€99.95 (approx. £86 / $120)**
www.eu.clickandgrow.com

The Smart Garden 3 is the perfect present for a keen cook or a budding gardener. From kitchen herbs, fruits and vegetables to vibrant flowers, this indoor garden can grow a wide range of plants with minimal effort. Simply place the plant pods in the smart garden, add a little water to the tank, switch on the LED lights and you're good to go. The smart garden will automatically water the seedlings until they become lush plants, and the pods contain all the nutrients and root oxygen they need to thrive.

© Click & Grow

SoundLink Revolve II

Price: **£179.95 / $199**
www.bose.co.uk / bose.com

This smart speaker by Bose offers 360 degrees of sound and much more. It's a compact and portable speaker that's durable and water resistant, perfect for outdoor use. The impressive rechargeable battery boasts a playtime of up to 13 hours. The Revolve II is also much more than just a speaker, and through voice activation acts as an assistant so you can send messages and make calls using it.

GoCube

Price: **$99.95 / £79.95**
www.getgocube.com

The humble Rubik's Cube has been given a high-tech makeover with the GoCube. This smart-connected cube wirelessly pairs with your phone or tablet for a whole host of fun and interactive games. From timing your ability to solve the cube to battling your buddies, the GoCube offers the same challenge and fun of a regular Rubik's Cube with a modern twist. The cubes can also transform into a controller for mini-games and missions on the companion app.

Turntable with Bluetooth connectivity

Price: **£230 / $199.99**
www.sony.co.uk

Give the gift of the authentic sound of vinyl, completely cable-free, with this Bluetooth-enabled turntable by Sony. This wireless creation allows you to take music from any vinyl collection and play it through any paired device, such as headphones, speakers and soundbars. Sleek and stylish, this vinyl player features a sturdy aluminium arm for a clear sound and powerful bass.

APPS & TOOLS

MasterClass

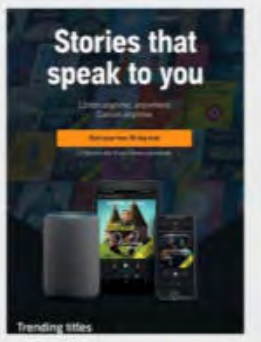
Developer: **MasterClass Inc.**
Price: **£14.17 a month / Google Play / App Store**

Learn new skills from some of the greatest minds, including the likes of Neil deGrasse Tyson, Gordon Ramsey and Serena Williams.

Audible

Developer: **Audible, Inc**
Price: **£7.99 per month / Google Play / App Store**

The perfect app for keen readers, get access to thousands of audiobooks and podcasts on your mobile device with Audible.



Peloton – at home fitness

Developer: **Peloton Interactive, Inc**
Price: **£12.99 a month / Google Play / App Store**

This fitness app offers workouts for a range of activities, including outdoor running, cycling, yoga, meditation and much more.

Slumber

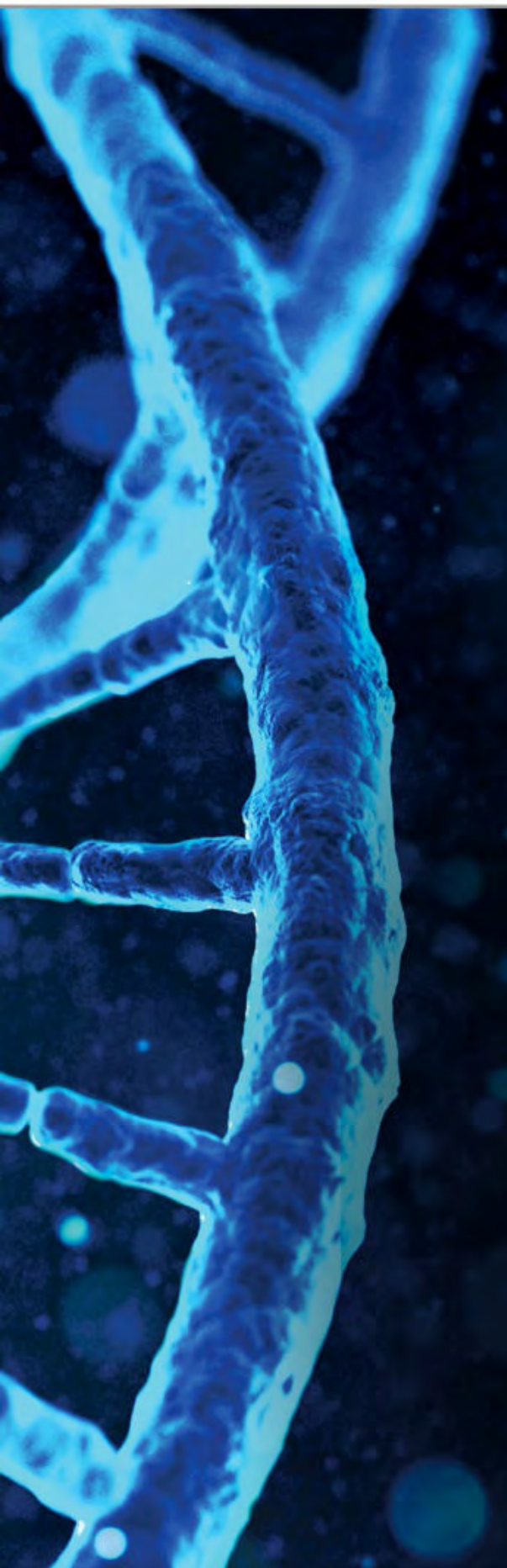
Developer: **Slumber**
Price: **$39.99 a year / Google Play / App Store**

Relaxing sounds to aid sleep, the library includes ASMR soundscapes, meditation guides, background sounds and over 350 stories.

ALL ABOUT YOUR DNA

UNLOCKING THE SECRETS OF OUR GENETIC CODE WILL MAKE US MASTERS OF OUR OWN BIOLOGY

Words by **Laura Mears**



DNA is one of the greatest inventions of the natural world. It's a chemical library, capable of storing vast quantities of data for billions of years. Passed from one generation to the next, this microscopic structure is the engine of evolution. Every living creature uses DNA as its instruction manual. The genes contained within it tell cells how to make the proteins they need to survive, grow and reproduce.

DNA also records history, tracing the path evolution has taken to create the plants and animals we see today. Unlocking the secrets of DNA not only allows us to read our own life story, it also gives us the ability to predict – and even change – the future.

DNA is a treasure trove of information that we're only just beginning to explore. Scientists didn't even know it existed until the late 1800s, and it wasn't until the 1950s that they really started to understand how it worked. In the 1970s, scientists finally developed a technique that allowed them to read the letters of the genetic code. Suddenly it was possible to look inside our own instruction manual and see how humans are made.

It took over ten years to complete the first map of the human genome, and the results that came out of it were a huge surprise. Scientists had predicted that it would take as many as 100,000 genes to build and maintain a human body. But the Human Genome Project revealed that we have less than a quarter of that number. Even rice plants have more genes than we do.

> *"DNA is a treasure trove of information that we're only just beginning to explore"*

Today's gene sequencing technology is so advanced that machines can read off an entire human genome in a matter of hours. There are millions of individual sequences now on public record, allowing researchers to investigate the tiny genetic differences that make us who we are. These differences are the key to understanding everything from our family history and our physical features to our risk of developing diseases.

At the moment our understanding of DNA is still in its infancy, but we are standing on the precipice of a genetic revolution. Tracing our biology back to the level of our DNA will one day make it possible to customise our genetic code and even cure genetic diseases. But before we reach that point, we need to work out what every letter of that code is for.

The link between some genes and the traits they control is simple and clear, but for most the relationship is complex. With so few genes in the human genome, it is inevitable that many have more than one role to play in building a body. Genes work together in complex and interconnected networks to shape the people that we become.

To complicate matters further, genes make up only around one or two per cent of the human genome. The rest of our genetic code controls how, when and why we use our genes. How that works is mostly a mystery. Understanding gene networks – and learning to edit them – is the next step on the path to becoming masters of our own biology.

What is DNA?

DNA is the most famous molecule in the world, but what goes on inside that double helix? At the heart of it are four chemicals called nucleotides. Each contains a pentagon-shaped sugar molecule, a structure called a phosphate group and a protein fragment called a base.

The sugar and the phosphate group are the same for every nucleotide. They join together side by side to form the backbone of each DNA strand. Like LEGO bricks, they only connect one way round; the phosphate of one nucleotide slots into the sugar of the next. This means that DNA strands have a definite 'up' and 'down'. The top is called the five prime (5') end, and the bottom the three prime (3') end.

The two strands of a DNA helix face in opposite directions, one running five prime to three prime, and the other three prime to five prime. They twist together in a right-handed helix. If you look closely you'll notice that the alternating twists are uneven: one big (the major groove) and one small (the minor groove).

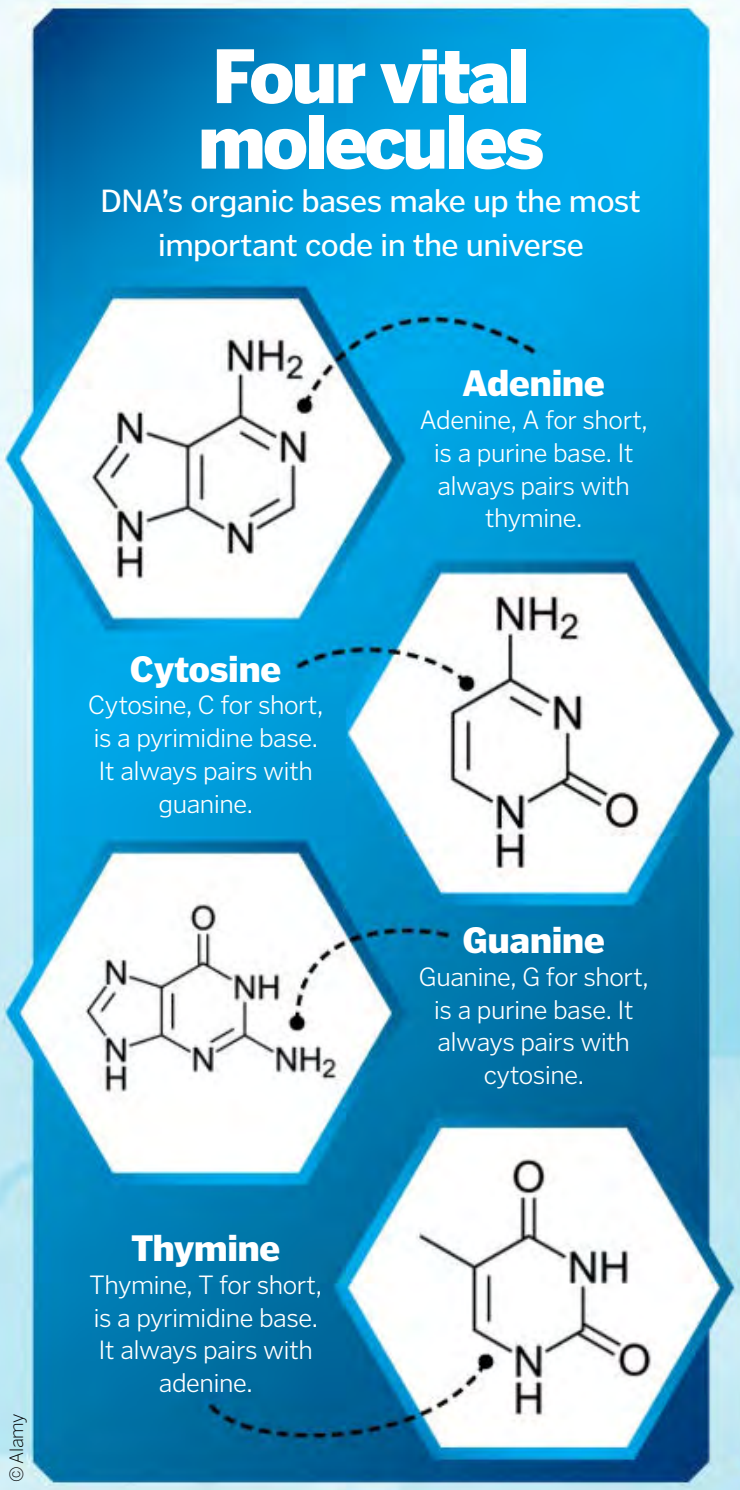
The bases connect the two DNA strands together like the rungs of a ladder. They form pairs, known as base pairs, linked by strong interactions called hydrogen bonds. There are four bases – adenine (A), cytosine (C), guanine (G) and thymine (T) – and they are extremely picky about the bonds they will form. Adenine will only pair with thymine, and guanine will only pair with cytosine. This means that if one strand carries the sequence ATGC, the other has to have the sequence TACG.

This strictness allows a cell to easily make copies of its genetic code. It simply unzips the two strands and uses them both as templates to assemble two new strands, copying the matching nucleotides into the empty slots.

The most important role for DNA is to carry information from one generation to the next. This information is written in code, using the

Four vital molecules

DNA's organic bases make up the most important code in the universe



Adenine
Adenine, A for short, is a purine base. It always pairs with thymine.

Cytosine
Cytosine, C for short, is a pyrimidine base. It always pairs with guanine.

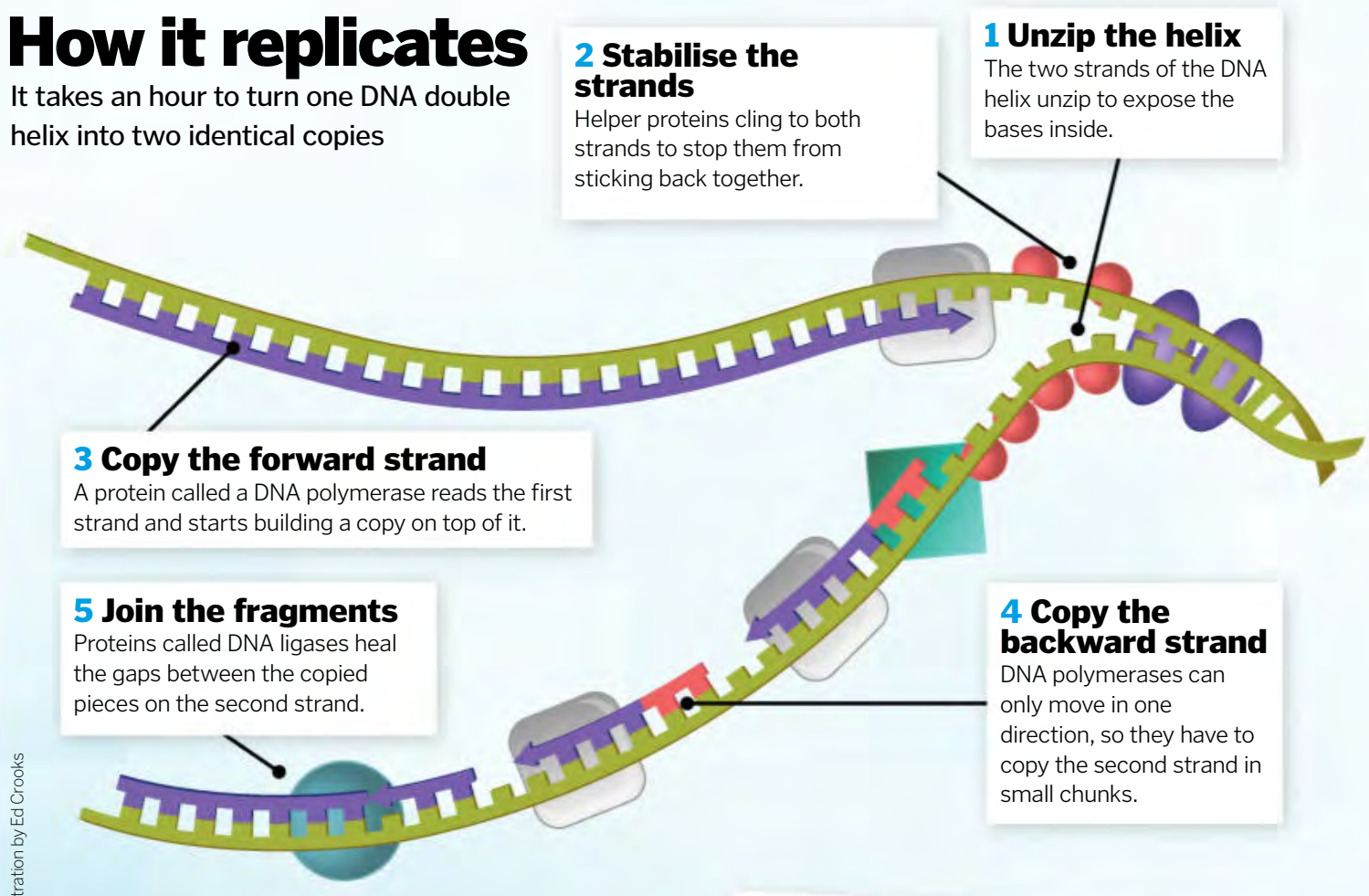
Guanine
Guanine, G for short, is a purine base. It always pairs with cytosine.

Thymine
Thymine, T for short, is a pyrimidine base. It always pairs with adenine.

© Alamy

How it replicates

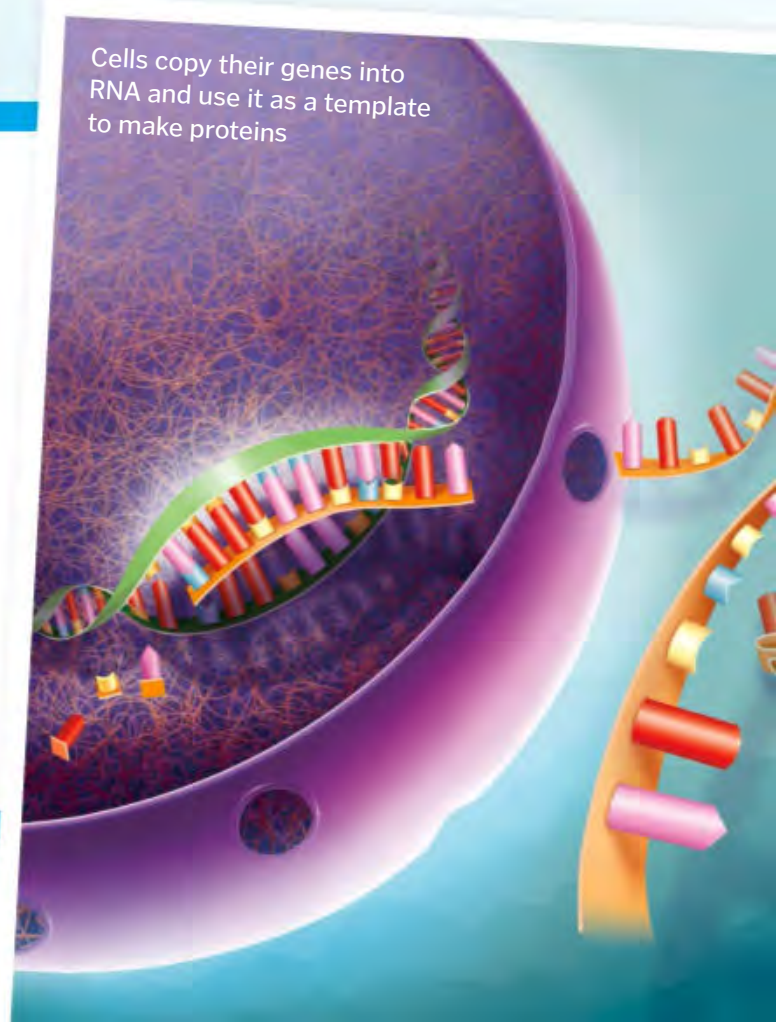
It takes an hour to turn one DNA double helix into two identical copies



© Illustration by Ed Crooks

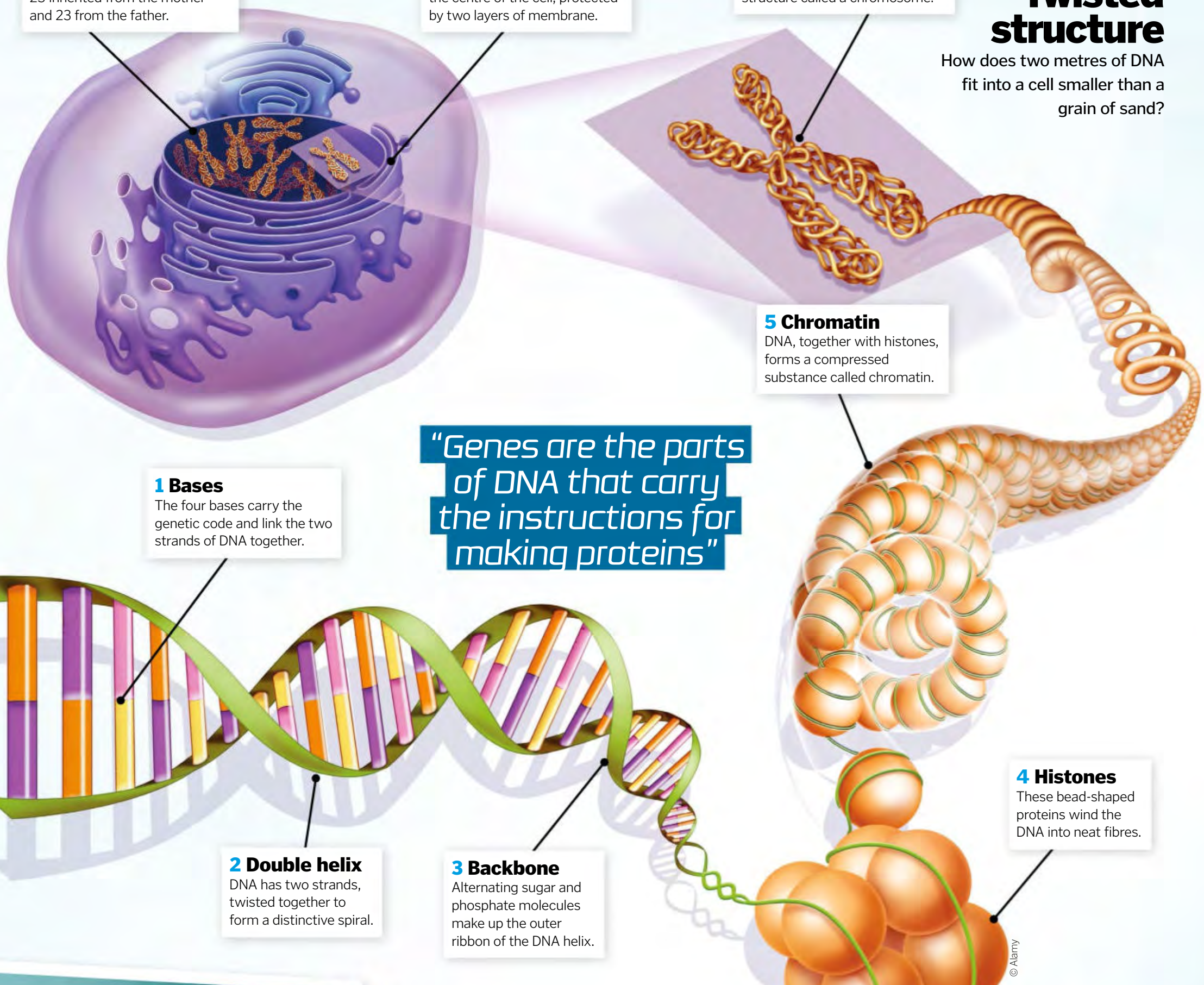
WHAT IS RNA?

DNA is not the only genetic molecule in nature; organisms also make strands of genetic material called RNA. Chemically the two molecules are quite similar, but they have very different roles to play. DNA forms stable double strands that carry the entire genome safely from one generation to the next. RNA forms unstable single strands that carry smaller amounts of genetic data for shorter amounts of time. Cells use RNA to make temporary copies of their genes. These copies act as templates for the molecular machines that make proteins. The machines read through the code three bases at a time, adding the corresponding amino acid to a growing protein string.


Cells copy their genes into RNA and use it as a template to make proteins

Twisted structure

How does two metres of DNA fit into a cell smaller than a grain of sand?



8 Chromosomes
Humans have 46 chromosomes: 23 inherited from the mother and 23 from the father.

7 Nucleus
The chromosomes are found in the centre of the cell, protected by two layers of membrane.

6 Chromosome
Each strand of chromatin forms a structure called a chromosome.

5 Chromatin
DNA, together with histones, forms a compressed substance called chromatin.

4 Histones
These bead-shaped proteins wind the DNA into neat fibres.

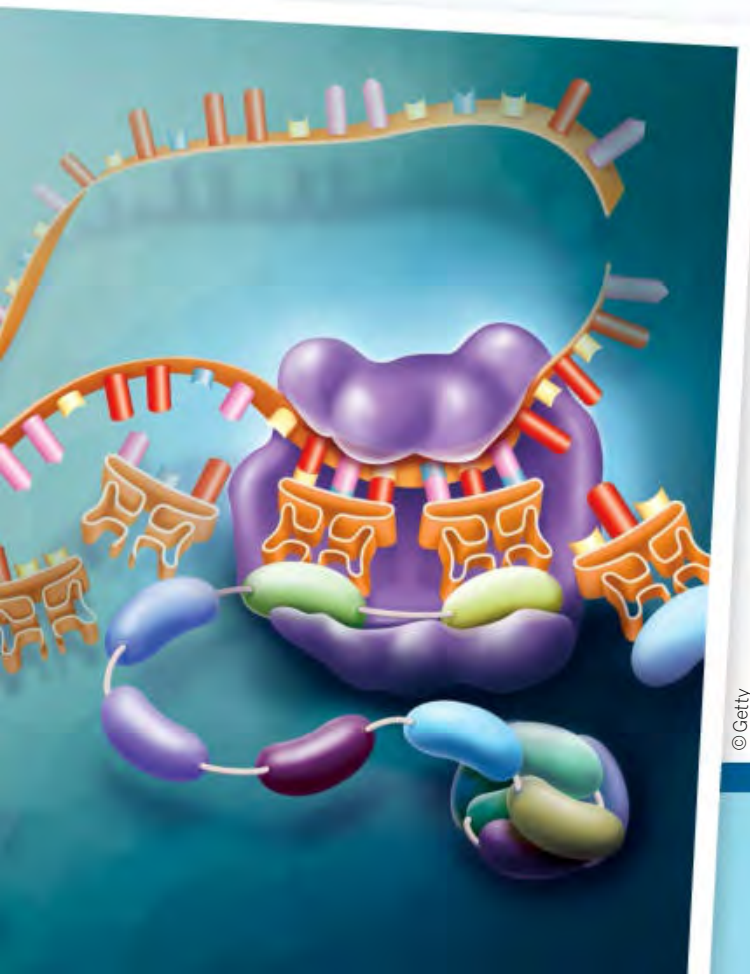
1 Bases
The four bases carry the genetic code and link the two strands of DNA together.

2 Double helix
DNA has two strands, twisted together to form a distinctive spiral.

3 Backbone
Alternating sugar and phosphate molecules make up the outer ribbon of the DNA helix.

© Alamy

> *"Genes are the parts of DNA that carry the instructions for making proteins"*



© Getty

four bases as chemical letters. Scientists have yet to decode the meaning of the entire human genome, but they have cracked the code that makes up our genes.

Genes are the parts of DNA that carry the instructions for making proteins: the molecules that build our bodies and do the hard biochemical work that keeps us alive.

The building blocks of proteins are amino acids, and there are 20 different types of amino acid to choose from. The order of amino acids in a protein dictates how the protein folds up to form a 3D structure and how it behaves inside the body.

The instructions for building proteins are written into our genes as strings of three-letter words called codons. It is possible to make 64 three-letter words using the four DNA bases. This means that, just like in English, some genetic words have the same meaning.

The codon ATG means 'start', signalling that the instructions to build a protein begin here. The codons TAA, TAG and TGA mean 'stop', signalling that the protein ends here. The rest correspond to different amino acids. Cells copy the genes they want to use and read through the codons one by one, selecting the matching amino acid and connecting it to a growing string. When they reach a stop codon, they know that the string is complete, and the protein is ready to fold into its 3D shape.

History of DNA

HOW WE'VE COME TO UNDERSTAND MORE ABOUT IT SINCE ITS DISCOVERY

Source: Wiki/Leonard Darwin

1859

Charles Darwin publishes *On the Origin of Species*, describing how life evolves through natural selection.

> *"They base their breakthrough on the work of dozens of other scientists"*

© Alamy

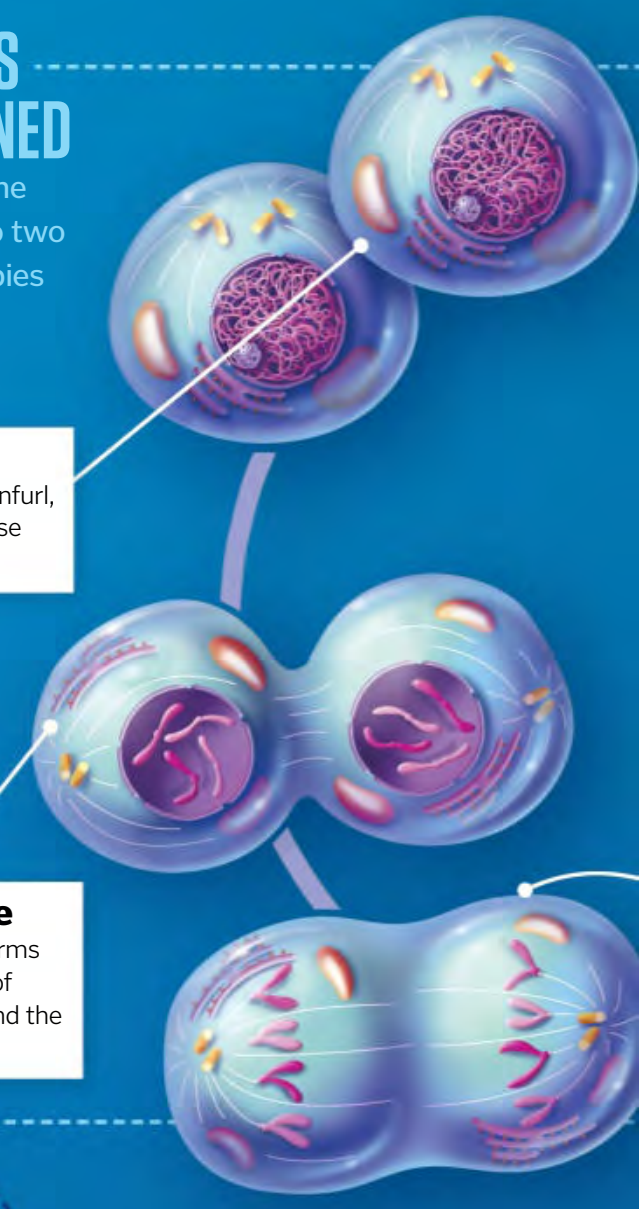
1879

WALTHER FLEMMING

Flemming becomes the first person to observe cell division, or 'mitosis'. He dyes salamander DNA with a chemical called aniline. He then watches as the chromosomes in the nuclei turn into thick threads, which line up across the middle of the cell. The threads then separate into two groups, and the cell splits in half.

MITOSIS EXPLAINED

How does one cell split into two identical copies of itself?



5 Interphase
The chromosomes unfurl, allowing the cell to use and copy its genes.

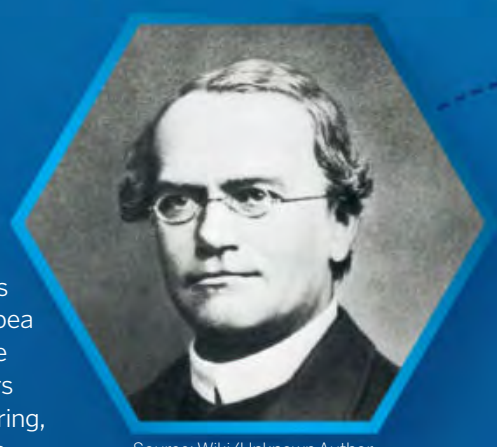
4 Telophase
A new nucleus forms around each set of chromosomes, and the cell splits in two.

1800 1810 1820 1830 1840 1850 1860 1870 1880 1890 1900 1910

1865

GREGOR MENDEL

Mendel, a monk, presents his work on dominant and recessive genes after performing experiments on nearly 30,000 pea plants. He cross-pollinates pea plants to find out how traits like colour and texture pass from one generation to the next. He discovers that some traits always pass from parent to offspring, while others sometimes seem to skip a generation.



Source: Wiki/Unknown Author

Source: Wiki/TBD

1869

FRIEDRICH MIESCHER

Miescher finds a strange substance while examining the pus inside used bandages. Pus contains white blood cells, and inside their nuclei, Miescher discovers a chemical that contains phosphorous and nitrogen. He names it 'nuclein'. The substance is part protein, part acid, so scientists later rename it 'nucleic acid'.

MENDEL'S PEAS

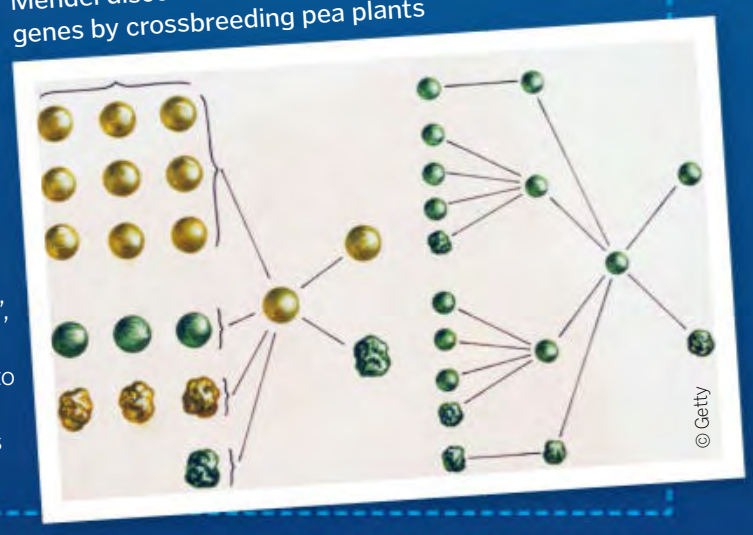
PARENT GENERATION
Mendel starts his experiment with two pure-bred peas: a smooth variety and a wrinkly variety. The gene that determines texture has two variants, known as 'alleles'.

F1 GENERATION
When Mendel crosses the pea plants, they inherit one allele from each parent: a smooth allele and a wrinkly allele. The smooth allele is 'dominant', so all the peas are smooth.

F2 GENERATION
When Mendel crosses these plants, 25 per cent inherit two smooth alleles, 25 per cent inherit two wrinkly alleles and the rest inherit one of each.

RECESSIVE GENES
The wrinkly allele is 'recessive', which means that the peas have to have two copies of it to end up with wrinkly skin. Peas with one smooth allele always end up smooth.

Mendel discovered dominant and recessive genes by crossbreeding pea plants



© Getty

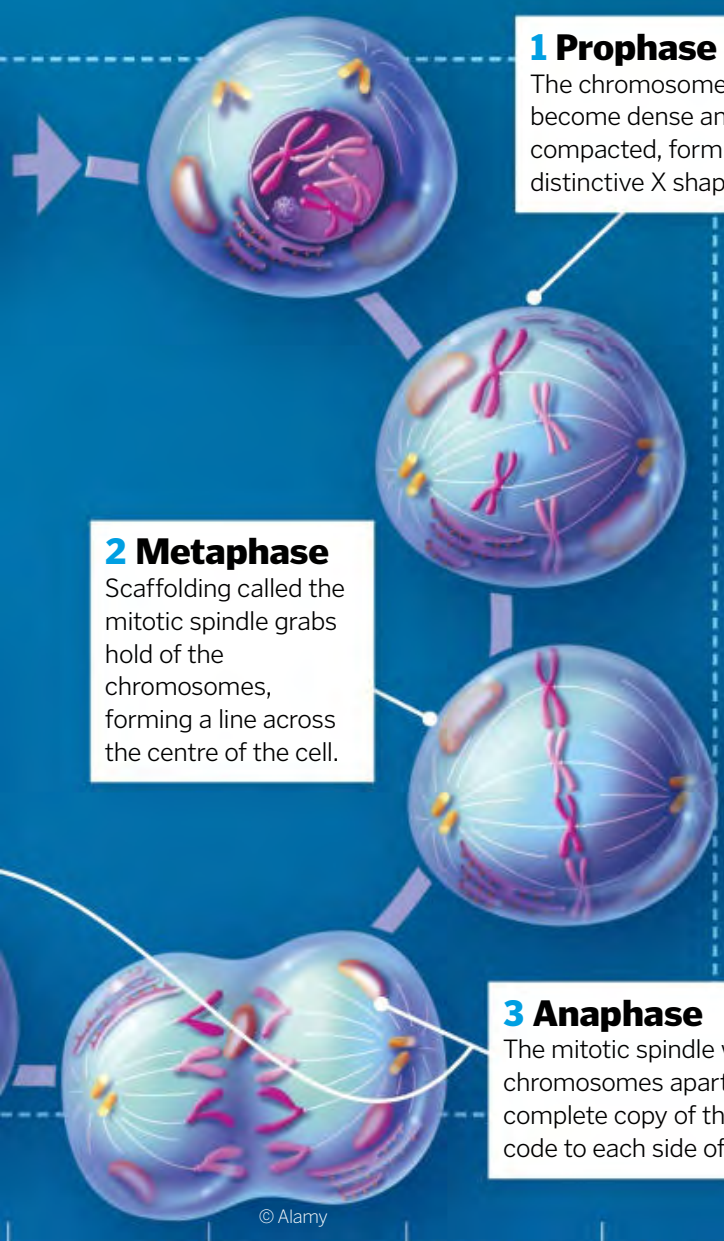
1910

© Getty

ALBRECHT KOSSEL

Kossel receives a Nobel Prize for discovering nucleic acids. He works together with his students to analyse the chemical components of nuclein, discovered by Miescher. They find that this strange chemical contains five types of nucleic acid: adenine, cytosine, guanine, thymine and uracil. The first four are the bases that make up DNA.

DID YOU KNOW? *The organism with the smallest genome is a bacterium called Carsonella ruddii, with just 182 genes*

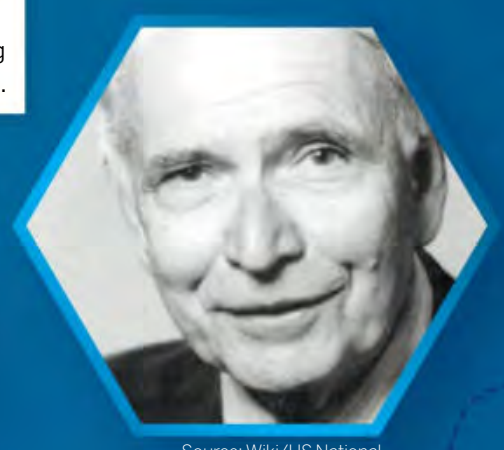


1 Prophase
The chromosomes become dense and compacted, forming distinctive X shapes.

2 Metaphase
Scaffolding called the mitotic spindle grabs hold of the chromosomes, forming a line across the centre of the cell.

3 Anaphase
The mitotic spindle wrenches the chromosomes apart, carrying a complete copy of the genetic code to each side of the cell.

© Alamy



Source: Wiki/US National Academy of Sciences

1953

© Getty © Getty

FRANCIS CRICK & JAMES WATSON
Crick and Watson solve the structure of DNA, revealing a ladder of bases surrounded by two ribbons of phosphates and sugars. They base their breakthrough on the work of other scientists, crucially Rosalind Franklin. Using Photo 51 for reference, they construct 3D models of DNA. They know from the work of Chargaff that bases come in pairs, and from the work of Linus Pauling that bonds between specific chemicals stick out at specific angles. At first they get the shape of thymine and guanine wrong, which makes fitting the pieces impossible. When Jerry Donohue suggests a different layout, the parts finally slot into place.

1950

Erwin Chargaff publishes his work on bases. He notices that DNA contains equal amounts of adenine and thymine and equal amounts of guanine and cytosine.

1959

Severo Ochoa and Arthur Kornberg receive a Nobel Prize for working out how cells make DNA.

1961

Marshall Nirenberg cracks the genetic code, working out how the letters correspond to the building blocks of proteins.

1977

Frederick Sanger invents Sanger sequencing, a way to read the letters of the genetic code.

1996

Scientists in the UK become the first to clone a mammal from an adult cell: Dolly the sheep.

2003

An international team publishes the first complete map of the human genome.

1910 1920 1930 1940 1950 1960 1970 1980 1990 2000 2010 2020

Source: Wiki/UnknownAuthor

1919

Phoebus Levene publishes his 'polynucleotide model', suggesting that DNA is a string of four types of nucleic acid.

© Getty

1952

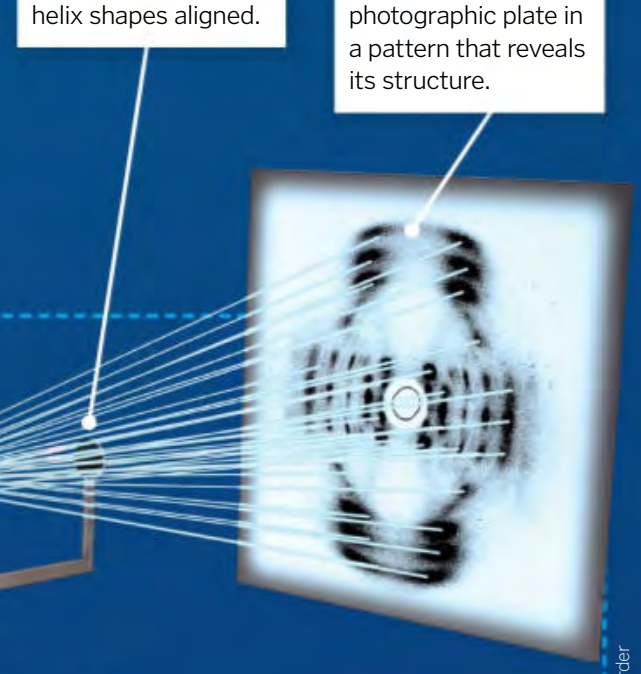
MAURICE WILKINS
After working on radar during World War II, Wilkins moves to King's College London to capture images of DNA. Working together with graduate student Ray Gosling and biophysicist Rosalind Franklin, he uses X-rays to photograph the genetic code. He shares one of Franklin's photographs with Watson and Crick in Cambridge.

Source: Wiki/Laboratory of Molecular Biology

1952

ROSALIND FRANKLIN
Franklin captures Photo 51, revealing the helix shape of the DNA molecule. Her clear and striking photograph is instrumental in deciphering the structure of DNA, although Watson doesn't acknowledge that until after her death from ovarian cancer in 1958. Crick, Watson and Wilkins receive the Nobel Prize for the discovery of the structure of DNA four years later.

HOW X-RAY CRYSTALLOGRAPHY WORKS



DNA crystal
The crystal contains thousands of DNA molecules, packed together with all their helix shapes aligned.

Photographic plate
The crystal diffracts the X-ray beam, scattering it onto a photographic plate in a pattern that reveals its structure.

X-ray beam
A slit focuses the X-rays into a narrow beam that strikes the crystal.

X-ray tube
High-speed electrons collide with a metal plate, generating X-rays.

AR ZONE! SCAN HERE

© Illustration by Nicholas Forder

DNA TODAY

THE SCIENCE OF DNA HAS ALREADY CHANGED THE WORLD WE LIVE IN

Taking samples

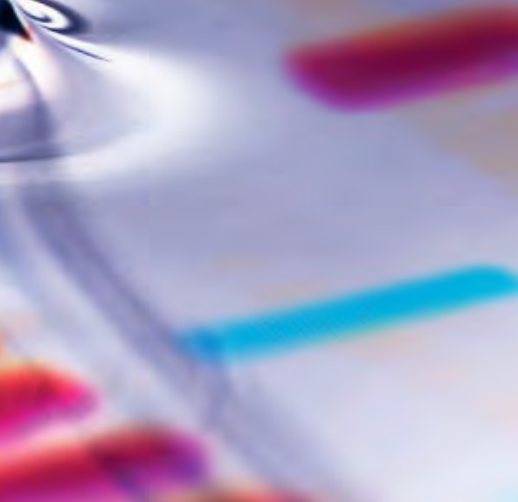
Cells and fluids taken in different ways hold the key to your unique genetic identity

CHEEK SWAB

Gently rubbing the inside of the cheek removes the top layer of skin cells, providing enough DNA for testing.

BLOOD TEST

Red blood cells don't contain DNA, so blood tests look at the genes in white blood cells.



SALIVA SAMPLE

Saliva contains cells from the cheeks, making spit samples an easy way to collect DNA at home.

HEEL PRICK

Tiny blood samples taken when babies are just a few days old can reveal problems in the blood caused by genetic conditions.

ARCHAEOLOGY

REBUILDING HISTORY

Skeletal remains can contain traces of ancient DNA for thousands of years. Extracting and sequencing this genetic material can reveal not only the sex of the individual – whether they had a Y chromosome or not – but also their ethnicity. This can help to retrace the steps taken by our ancestors as they spread across the world.

FORENSICS

SOLVING CRIMES

Forensic scientists identify DNA by examining sequences called 'short tandem repeats'. These sequences occur in the gaps between genes and contain three or four DNA letters, repeated a different number of times in different people. Scientists count the number of repeats and compare them to repeats in a suspect's DNA.

PATERNITY

IDENTIFYING FATHERS

Children inherit half of their genes from their mother and half from their father. In a paternity test, scientists compare around 15 genes from the mother, child and potential father to see how similar they are. Statistical analysis gives a score called a 'combined paternity index' – the likelihood of the person tested being the father.

GENETIC HERITAGE (ANCESTRY)

ESTIMATING ETHNICITY

Ancestry is written into DNA like a fingerprint. Different populations of humans, separated by geography, develop their own unique mutations. These pass along from one generation to the next, leaving traces in genetic code. Comparing a genome against thousands of others can reveal where a person's ancestors came from.

GENE THERAPY

REPAIRING GENES

A handful of gene therapies are now licensed for use in human patients. These cutting-edge treatments use harmless viruses to carry healthy human genes into cells with genetic faults. The viruses paste these healthy genes into human DNA, fixing rare genetic disorders or killing cancer cells.

PERSONALISED MEDICINE

MEDICINE FOR YOU

Tiny differences in our genes change the way illnesses affect us. A tumour might shrink in response to chemotherapy in one patient and not respond at all in another. Genetic testing can reveal which drugs might work best for which person, allowing doctors to match treatments to patients based on their unique genetic make-up.

"We will gain the power to repair, edit and rewrite our genes"

DNA testing can help to reveal the identity of unknown human remains

© Getty

© Getty

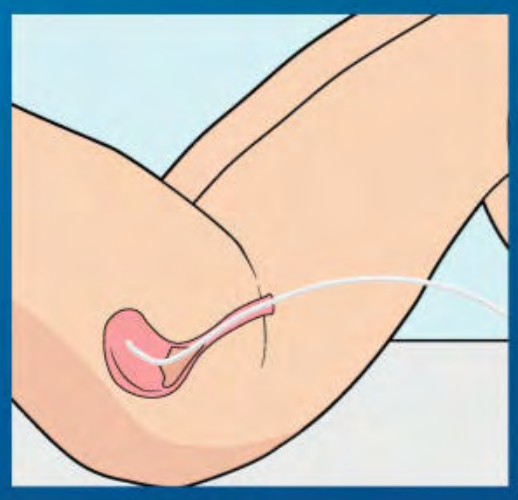
Genetic engineering can make plants resistant to pests and climate change

© Getty

Gently swabbing the cheek dislodges enough cells for a DNA sample

THE FUTURE OF DNA SCIENCE

Over the next century, advances in DNA science are set to change the world forever. Armed with hundreds of thousands of unique human genome sequences, scientists are now working on the painstaking task of deciphering our genetic code. Understanding how each section of sequence controls the traits we inherit could lead to breakthroughs across dozens of different fields. It will tell us how we evolved, why we get sick and what happens as we age. As genetic engineering improves, we will gain the power to repair, edit and even rewrite our genes. Research scientists can already change the genes of laboratory animals, editing the letters to erase dangerous mutations and to enhance the traits that nature evolved on its own. As these techniques become safer, and as our understanding of our own genetics grows, we will gradually gain the power to change the genetic destiny of our species.



© Illustrations by Ed Crooks

AMNIOCENTESIS

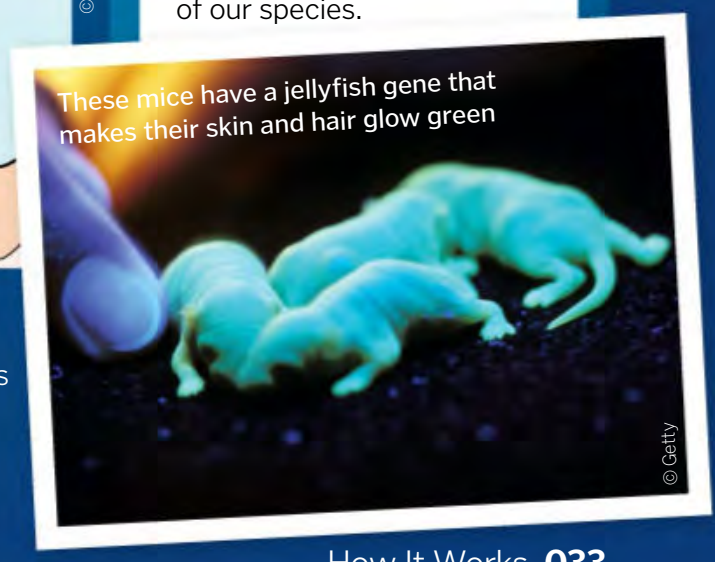
Amniotic fluid contains skin cells from a developing baby. Extracting a small sample allows doctors to test for genetic conditions.

CHORIONIC VILLUS SAMPLING

The placenta is genetically identical to the developing foetus. Cells from the placenta can reveal genetic conditions early in pregnancy.

FINE NEEDLE ASPIRATION

Extracting a small number of cells from inside the body can reveal genetic changes in diseases like cancer.



These mice have a jellyfish gene that makes their skin and hair glow green

© Getty

DNA BY NUMBERS

99.9%

We share almost all of our DNA with other humans

6.41 PICOGRAMS

The male human genome weighs the same as six *E. coli* bacteria cells

6.51 PICOGRAMS

The female human genome is a tiny bit heavier than its male equivalent

SPERM AND EGGS ONLY HAVE ONE SET OF CHROMOSOMES EACH

48 MILLION

The smallest human chromosome contains 48 million base pairs

249 MILLION

The biggest human chromosome contains 249 million base pairs

56,000 BASES

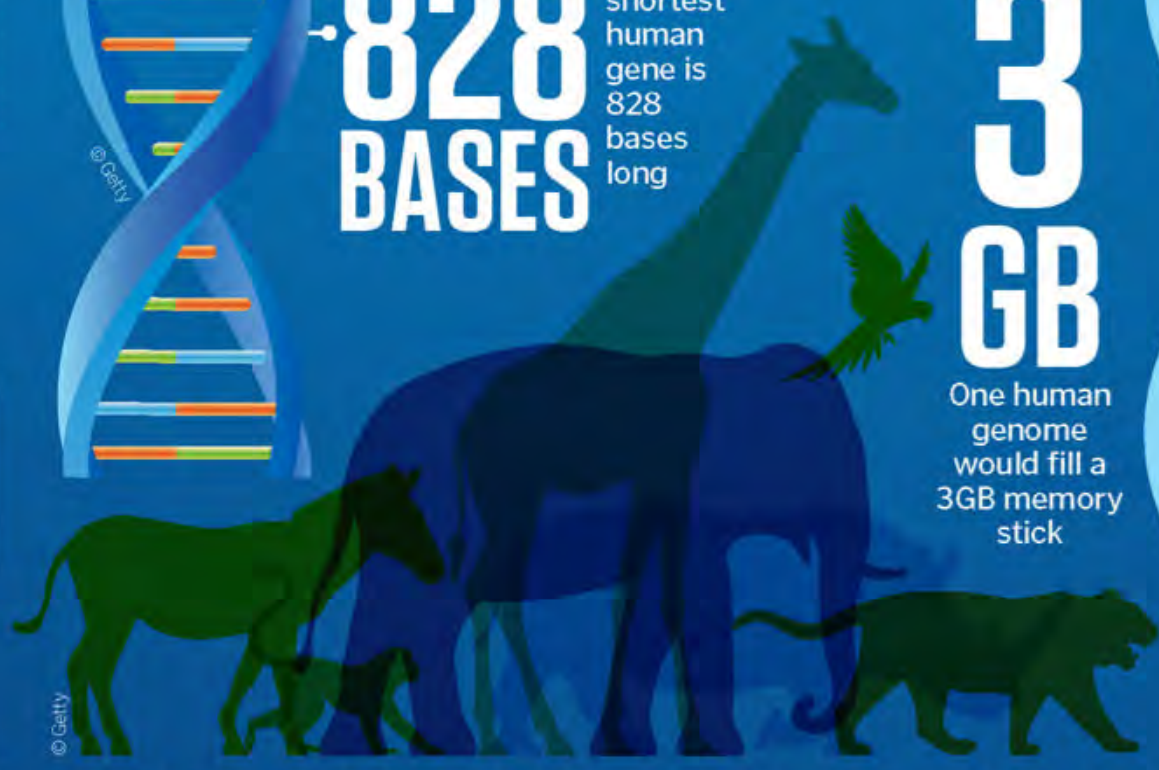
The average human gene is 56,000 bases long

2,400,000 BASES

The longest human gene is 2,400,000 bases long

828 BASES

The shortest human gene is 828 bases long



3 GB

One human genome would fill a 3GB memory stick

3 BILLION

It would take you around 300 years to count each of DNA's base pairs

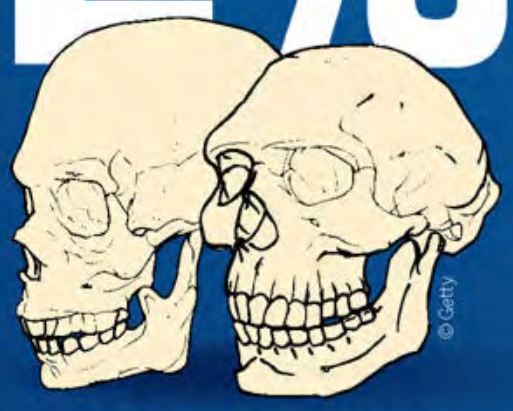
25,000

The human genome contains around 25,000 genes

3

Each human gene codes for an average of three proteins

2%



NON-AFRICAN HUMANS SHARE TWO PER CENT OF THEIR DNA WITH NEANDERTHALS

ASIDE FROM SOME VIRUSES, EVERY ORGANISM ON EARTH HAS DNA

DNA STANDS FOR DEOXYRIBONUCLEIC ACID

$9,500 (£6,800)

It cost $9,500 (£6,800) to sequence a human genome in 2020

$300 (£216) MILLION

It cost $300 (£216) million to sequence a human genome in 2001

52,000

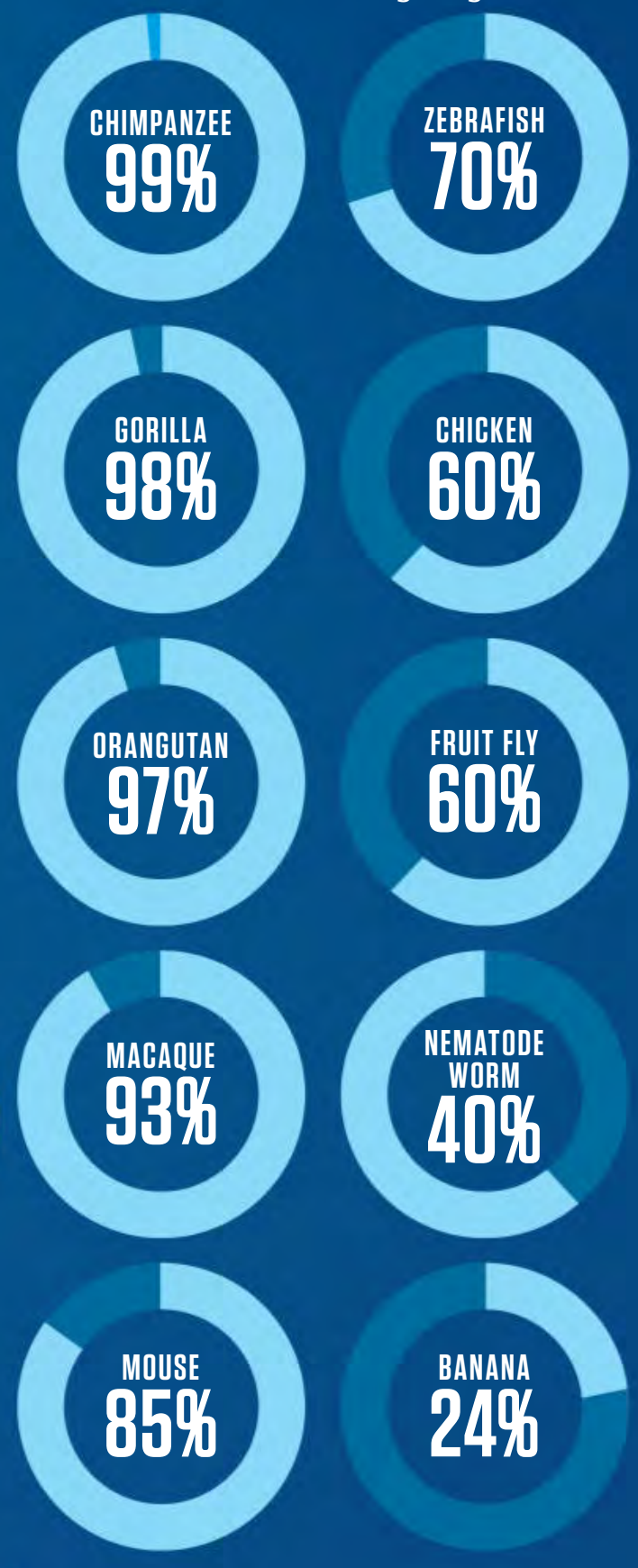
In 2012 scientists copied a 52,000-word book into DNA

98.5%

98.5% OF OUR DNA DOESN'T CONTAIN ANY GENES

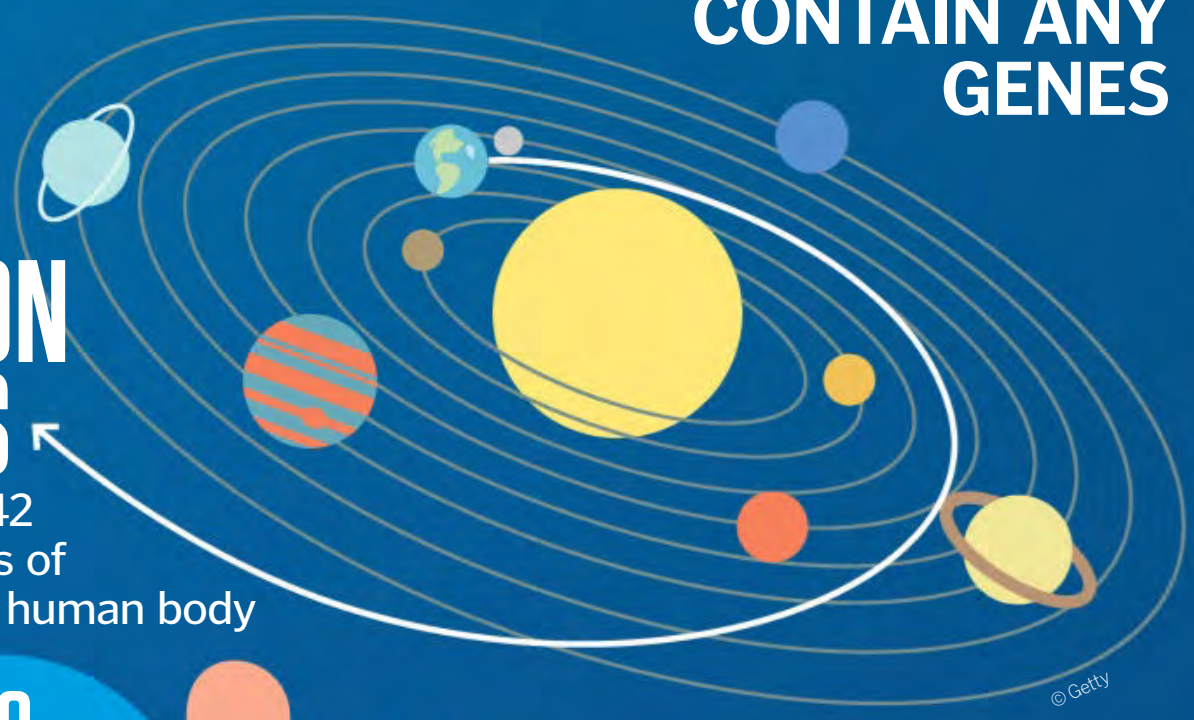
NOT SO UNIQUE AFTER ALL

Humans share a surprising amount of DNA with other living things



42 BILLION MILES

There are 42 billion miles of DNA in the human body



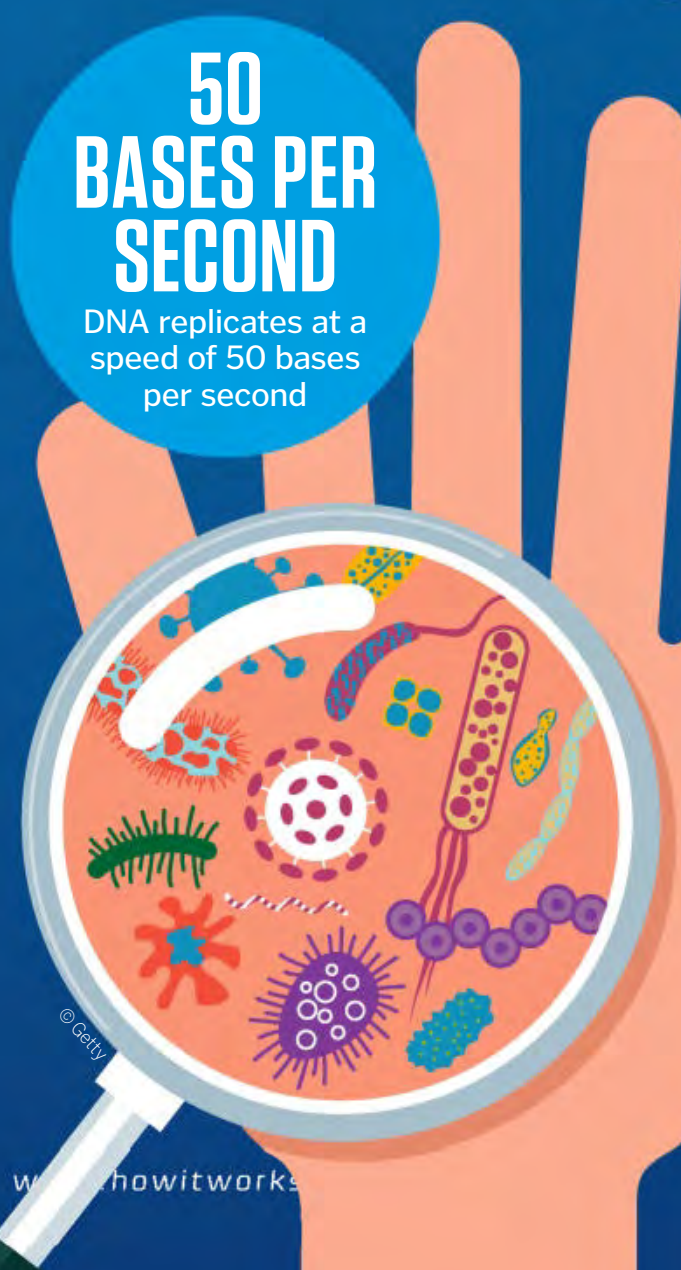
50 BASES PER SECOND

DNA replicates at a speed of 50 bases per second

CHROMOSOMES ARE ONLY X-SHAPED JUST BEFORE CELLS DIVIDE

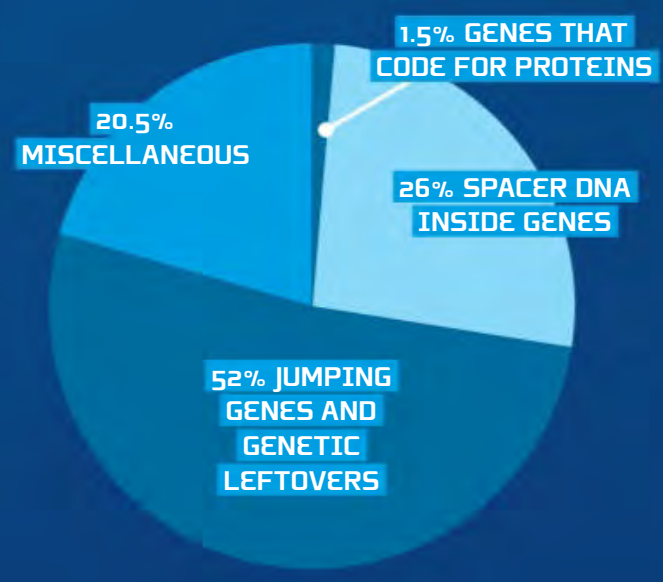
215 MILLION GIGABYTES

One gram of DNA can store 215 million gigabytes of data



ALMOST A TENTH OF OUR DNA COMES FROM ANCIENT VIRUSES

WHAT'S IN A HUMAN GENOME?



Cosmetic chemistry

The science behind the products you put on your skin

Words by **Scott Dutfield**

It's well documented that the people of ancient Egypt were pioneers in cosmetics some 5,000 years ago. Cleopatra is often depicted sporting the original smokey eye, using a blue-and-green powder made of malachite or ground-up lazuli stone. However, the purpose of this glamour was much more divine than in modern-day applications: the ancient Egyptians believed that it offered protection from illnesses by appeasing the gods Horus and Ra.

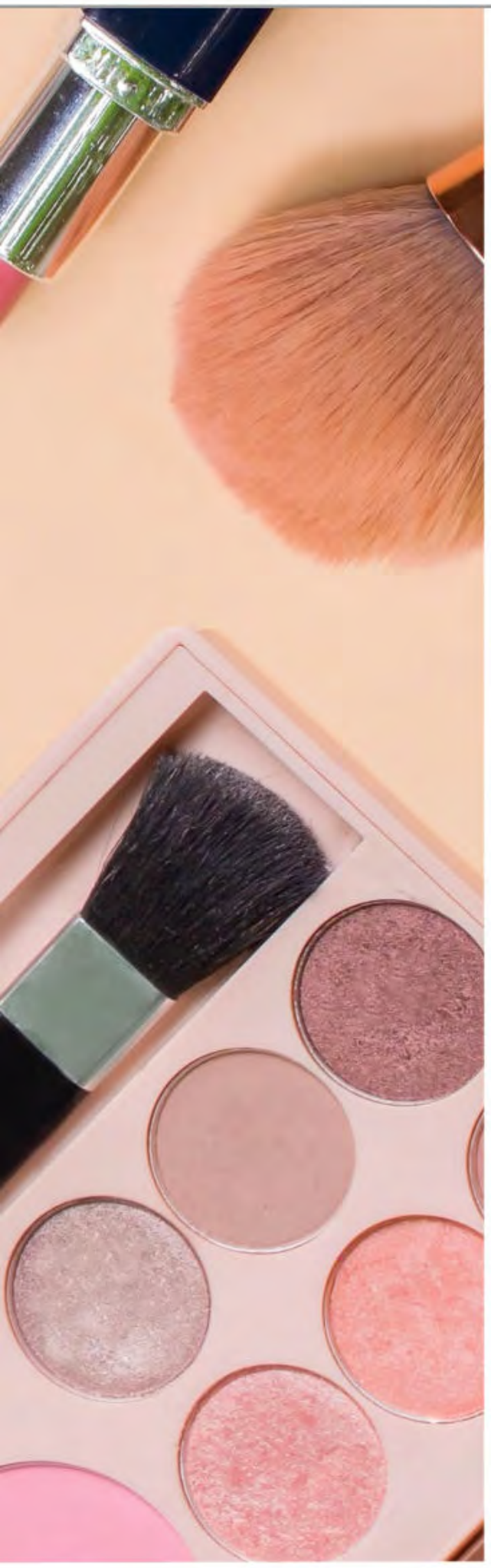
In the time since the pharaohs ruled, people all over the world have undergone countless cosmetic makeovers. From the painted faces of the ancient Greeks, the dyed hair during the Byzantine period or battling blemishes in the Middle Ages, cosmetics have always played a role in society.

> *"Only in the last couple of centuries have cosmetics become a commercial product"*

However, only in the last couple of centuries have cosmetics become a commercial product. Previously cosmetics remained firmly a homemade affair, often including ingredients toxic to the wearer. For example, the ancient Romans applied toxic mercury ore as rouge, while Queen Elizabeth I famously wore ceruse, a toxic white lead foundation.

It wasn't until 1920 that the term 'makeup' was even used. The word was coined by cosmetic mogul Max Factor when the brand launched a cosmetic range called Society Makeup. Since then makeup has continued to diversify, and its use has grow exponentially. In the modern era, the cosmetics industry is one of the largest in the world, and by 2025 the global cosmetics market is projected to be valued at around $758.4 billion (£548 billion).

As makeup has evolved, so too have its ingredients. As a result, countless new products are being created, and some old ones are being



Inside lipstick

What makes up one of the most used cosmetic products in the world

Oil

65% Castor oil is typically used in lipsticks as a method of moisturising the lips, and even offers antibacterial properties.

Wax

25% Several types of wax can be used in lipsticks, including beeswax and carnauba, also known as palm wax, derived from the Brazilian *Copernicia prunifera* palm tree.

Lanolin

5% This is wax derived from sheep-sheared wool. The wool is spun to separate the wax from the wool fibres. For sheep this wax works like the lubricating sebum oil on human skin. Lanolin is used in lipstick to moisturise, and also has adhesive properties.

Dyes

5% There are a myriad of dyes used to make the array of lipstick shades on the market. If your lipstick is scarlet red there's a chance that it may contain carmine red, which is made from crushed-up insects.

Capsaicin

Not found in all lipstick, capsaicin has been known to be included on the ingredients list of lipstick for its plumping ability. This chemical gives chillies their spicy heat, and can cause lips to swell.

5 FACTS ABOUT THE FIRST TO HIT THE SHELVES

1 Lipstick 1884
The first commercial lipstick to be sold was created by a French cosmetic brand called Guerlain. It was made from deer tallow (rendered fat), beeswax and castor oil and wrapped in silk paper.

2 Mascara 1917
Lash-Brow-Ine, a tinted petroleum-based mascara, is said to have been created by Maybelline founder Thomas Lyle Williams after he watched his sister Mabel mix burnt cork with petroleum jelly and apply it to her eyelashes and eyebrows.

3 Nail polish 1932
The first opaque coloured nail enamel commercially sold was created by Charles and Joseph Revson, who founded cosmetics company Revlon. The pair worked with Michelle Menard, who adapted the enamel formula used in car paint to create nail polish.

4 Foundation 1938
Although theatrical 'greasepaint' was available for actors to blend their wigs into their skin, commercial foundation didn't hit the shops until Max Factor created a pressed powder talc called 'Pan-Cake'.

5 Concealer 1954
Max Factor once again made history with the creation of the first commercially sold concealer stick, called Erace. The white skin-coloured concealer offered the ability to cover blemishes and lines.

reinvented. One of the most long-standing cosmetic products is lipstick. Over the years lipstick has undergone arguably the most transformation in terms of its range of colours, styles and applications.

Some brands have even incorporated some science 'magic' into their products. Several years ago, clear lipsticks appeared on shop shelves. When applied, these lipsticks magically changed colour on the lips thanks to a clever ingredient called Red 27. This colour-changing chemical works in the same way as litmus paper. Red 27 reacts with the moisture and pH of your lips and will change shades depending on the composition of your skin.

Pigments such as iron oxide are used to change the skin tone of foundation

Creating cosmetics

The ingredients that make up makeup

Adhesives

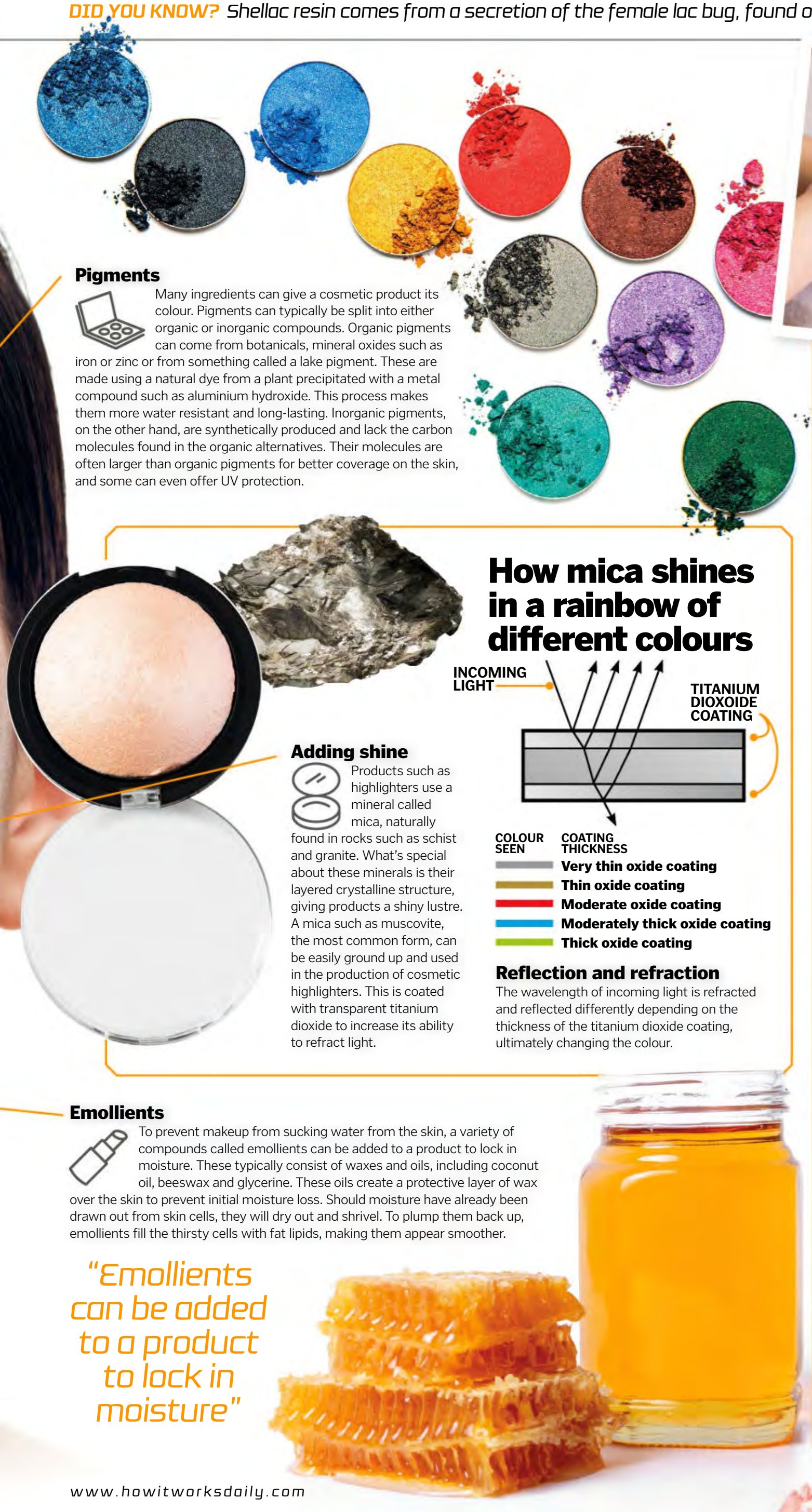
Lash extensions continue to grow in popularity. There are three types on the market: synthetic lashes are made of plastic fibres, such as polybutylene terephthalate. Some extensions are made from human hair, and there are some products still made from mink fur. For shop-bought lashes, tacky glue is applied along the eyelid and easily removed with water and soap. However, professionals use a glue adhesive also found in superglue, called cyanoacrylate, for long-lasting extensions. Although these might contain similar ingredients, never use superglue or other glues on your own false eyelashes at home.

Preservatives

Cosmetics come with a sell-by date. To prevent the growth of any fungi and bacteria, antimicrobial ingredients are used. These include alcohols and acids, including parabens. These are chemical compounds extracted from para-hydroxybenzoic acid found in fruits and vegetables. In recent years these compounds have been studied for their potential role in causing some cancers. Although studies haven't shown a direct link, experts are concerned about a link between the cumulative use of paraben-based products and developing certain cancers.

Thickeners

To control the viscosity of some cosmetic products, thickeners are added to the list of ingredients. However, there isn't one universal thickener on the market – brands have several options to choose from. Natural thickeners such as gelatine, xanthan gum or plant-derived cellulose can create very thick products, but are easily diluted by water or alcohol to become thinner. Mineral thickeners, such as clay-rich bentonite, can absorb water and oils to create a thicker consistency. It's also used in cat litter for the same reason. Similarly, long-molecular polymer synthetic thickeners, such as acrylic acids, can be used to create thicker gels.



Pigments

Many ingredients can give a cosmetic product its colour. Pigments can typically be split into either organic or inorganic compounds. Organic pigments can come from botanicals, mineral oxides such as iron or zinc or from something called a lake pigment. These are made using a natural dye from a plant precipitated with a metal compound such as aluminium hydroxide. This process makes them more water resistant and long-lasting. Inorganic pigments, on the other hand, are synthetically produced and lack the carbon molecules found in the organic alternatives. Their molecules are often larger than organic pigments for better coverage on the skin, and some can even offer UV protection.

Adding shine

Products such as highlighters use a mineral called mica, naturally found in rocks such as schist and granite. What's special about these minerals is their layered crystalline structure, giving products a shiny lustre. A mica such as muscovite, the most common form, can be easily ground up and used in the production of cosmetic highlighters. This is coated with transparent titanium dioxide to increase its ability to refract light.

How mica shines in a rainbow of different colours

COLOUR SEEN	COATING THICKNESS
	Very thin oxide coating
	Thin oxide coating
	Moderate oxide coating
	Moderately thick oxide coating
	Thick oxide coating

Reflection and refraction

The wavelength of incoming light is refracted and reflected differently depending on the thickness of the titanium dioxide coating, ultimately changing the colour.

Emollients

To prevent makeup from sucking water from the skin, a variety of compounds called emollients can be added to a product to lock in moisture. These typically consist of waxes and oils, including coconut oil, beeswax and glycerine. These oils create a protective layer of wax over the skin to prevent initial moisture loss. Should moisture have already been drawn out from skin cells, they will dry out and shrivel. To plump them back up, emollients fill the thirsty cells with fat lipids, making them appear smoother.

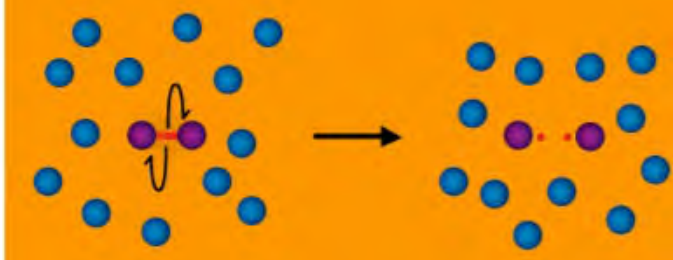
"Emollients can be added to a product to lock in moisture"

Exposure to the UV lamps has been viewed by the US Food and Drug Administration (FDA) as low risk

Plastic polish

Nail polish comes in many different forms. The most basic paint and draw polishes are made predominantly with an ingredient called nitrocellulose, which is made from mixing cotton fibres and nitric acid. However, over the years cosmetic chemists have created stronger nail gels for a more robust manicure with the help of compounds called photoinitiators. Most gel polishes require the wearer to place their hand underneath a UV lamp to cure their manicure. The gel polish goes into the lamp fluid, and after a couple of minutes is completely hard. This is because the photoinitiators in the polish absorb the UV light, releasing a free radical – an unbonded molecule. Free radicals then attach to small chains of plastic molecules called monomers, forcing them to combine with other monomers to form polymers. This causes a chain reaction, building polymers until the molecules are all stitched together, hardening the polish.

Polymerisation in action

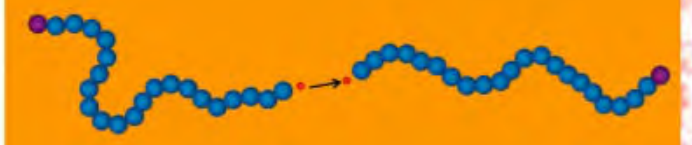


1 Freeing the radical

The bonds between monomer molecules are broken – by UV radiation in the case of polish curing – and a free radical is released.

2 Chain reaction

Free radicals then act like sewing needles, threading molecular beads together to form elongated molecular chains called polymers.



3 All together

Once all the monomers have been used up or the free radical has found another free radical to join with, the process of polymerisation stops.

All Images © Getty

Hydrogen: the unifying element

The most common element in the universe is actually quite rare here on Earth

Words by **Andy Extance**

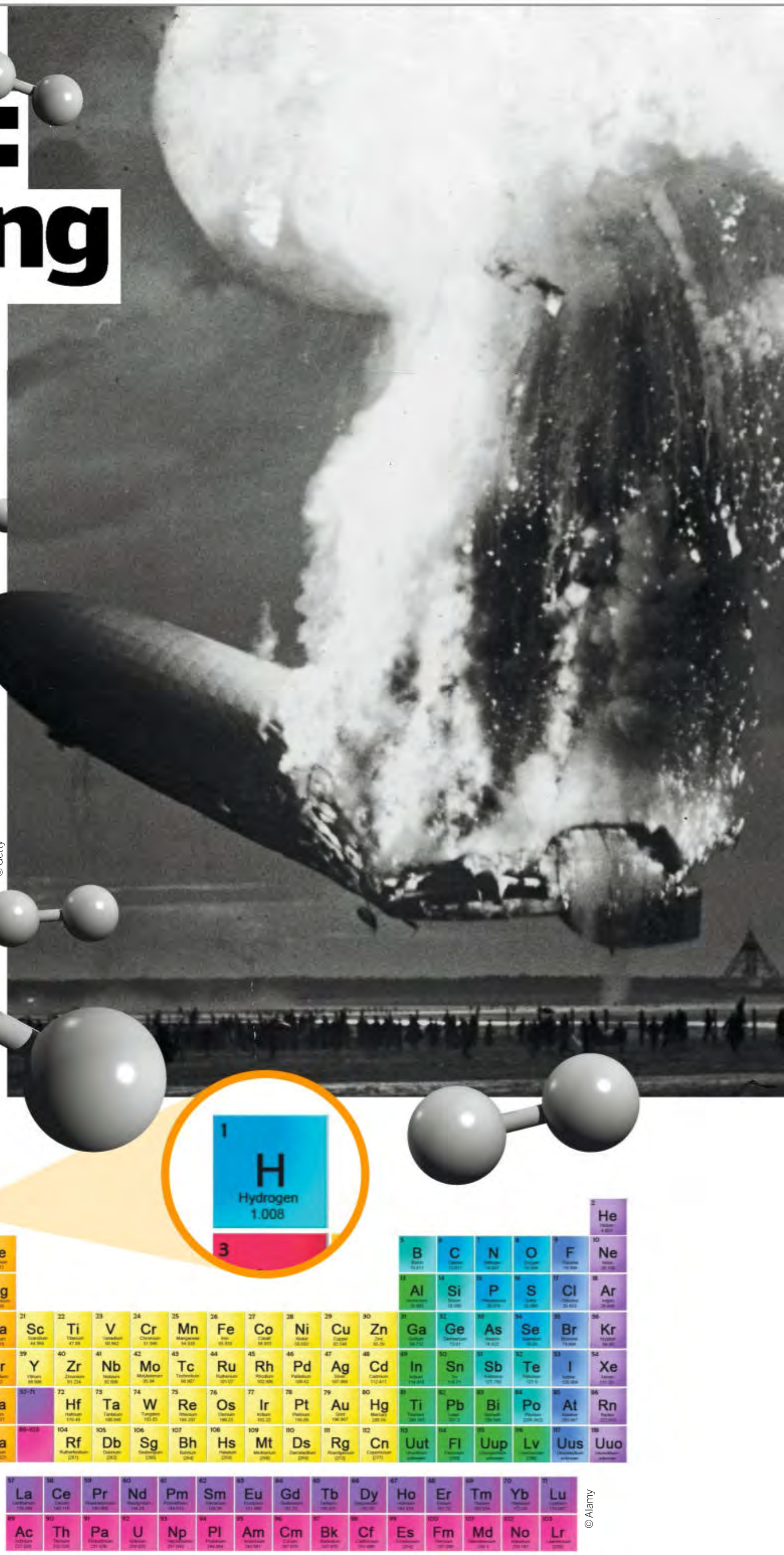
Hydrogen is the most important element there is. It is both dangerous and essential at the same time – just two of its amazing qualities. Hydrogen can be found in our bodies and many things around us. Also, hydrogen connects us all to the start of the universe – and all other things!

The special qualities of hydrogen start from its building blocks. In its most familiar form, hydrogen is the simplest element. Its atoms have just one proton and one electron. Like most other elements, it has isotopes with extra neutrons. But hydrogen is the only element with named isotopes. It's called deuterium when it has one neutron and tritium when it has two. This is more than just a curious fact – our lives rely on hydrogen's isotopes.

That's because at the heart of the Sun, hydrogen atoms fuse together to make deuterium. One proton becomes a neutron in the process, releasing energy that becomes the heat and light we rely on. This is a similar process to the one that happened following the Big Bang, making hydrogen and leading to all the other elements. Most of the hydrogen in our bodies and everything else was made then, tying us to the start of the universe.

This simple atomic structure makes hydrogen much lighter than air. It enabled human flight in airships until another of hydrogen's key properties had its say: it combines so well with oxygen that it burns easily, infamously destroying an airship called the Hindenburg in 1937. Yet as they burn, hydrogen and oxygen make water, which we need to stay alive.

Hydrogen reacts similarly well with many elements, making important substances. The materials hydrogen makes with carbon are the building blocks of living things like us. With so many important roles, hydrogen is truly the first among the elements.



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Hydrogen came first in the universe, and does in the periodic table too

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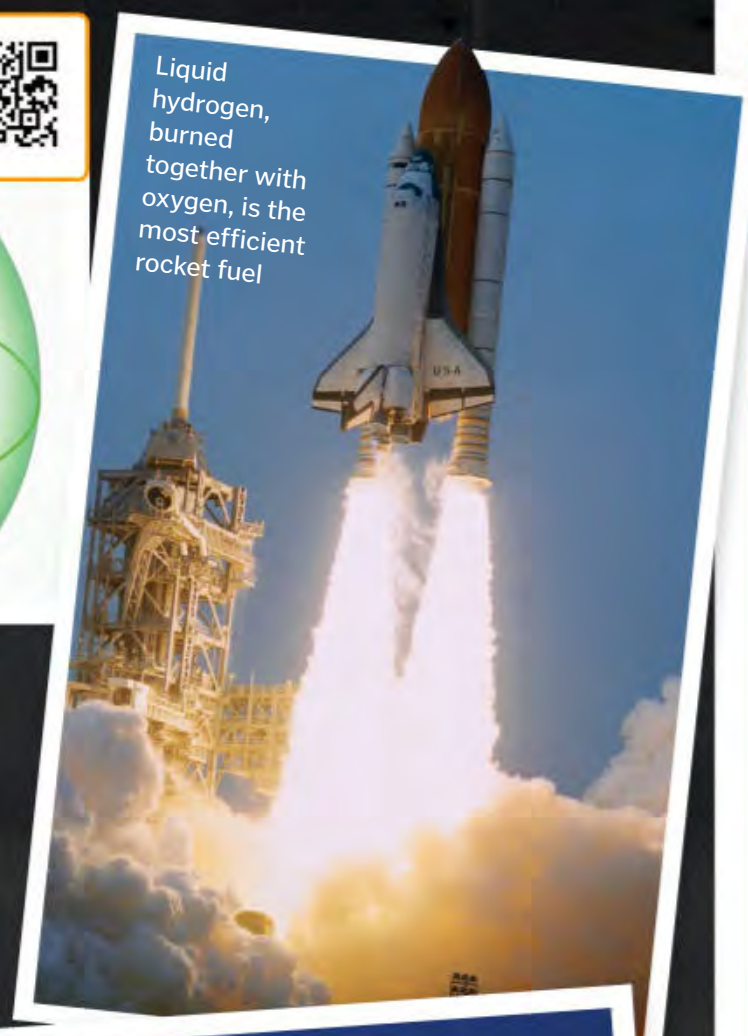
"Hydrogen connects us all to the start of the universe"



Liquid hydrogen, burned together with oxygen, is the most efficient rocket fuel

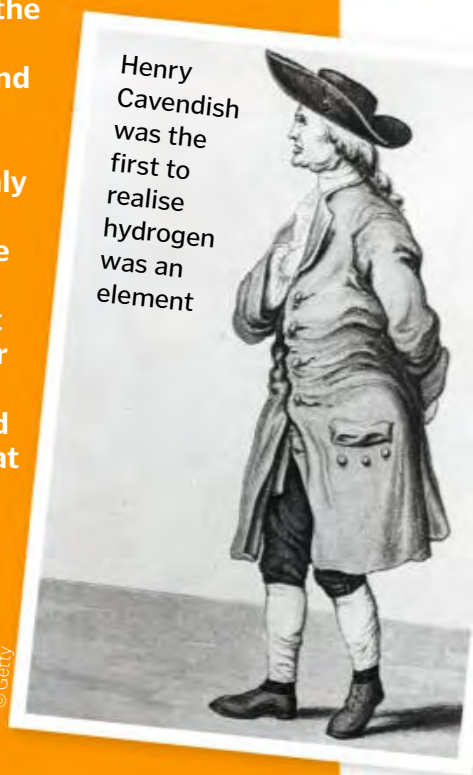
Lots of hydrogen is used to remove polluting sulphur from natural gas

x3 Images © Getty

An elementary discovery

Some credit for discovering hydrogen goes to Theophrastus Philippus Aureolus Bombastus von Hohenheim. Better known as Paracelsus, around 1520 he recorded that dropping metals into strong acids released bubbles of gas. In 1650 Théodore de Mayerne repeated the experiment, discovering that the gas burned easily. But it wasn't until 1755 that people realised different types of gases existed.

Soon after, the first person to work out that hydrogen was a unique substance was Henry Cavendish, who called it 'inflammable air'. At the time, some people thought that water and 'dephlogisticated air' – what we now call oxygen – were the only basic elements. In experiments from the 1760s and 1780s, Cavendish found that when inflammable air burned, it combined with dephlogisticated air to form water. That led French chemist Antoine Lavoisier to propose calling the gas hydrogen, as it is the gene, or creator, of hydro, which is Greek for water.

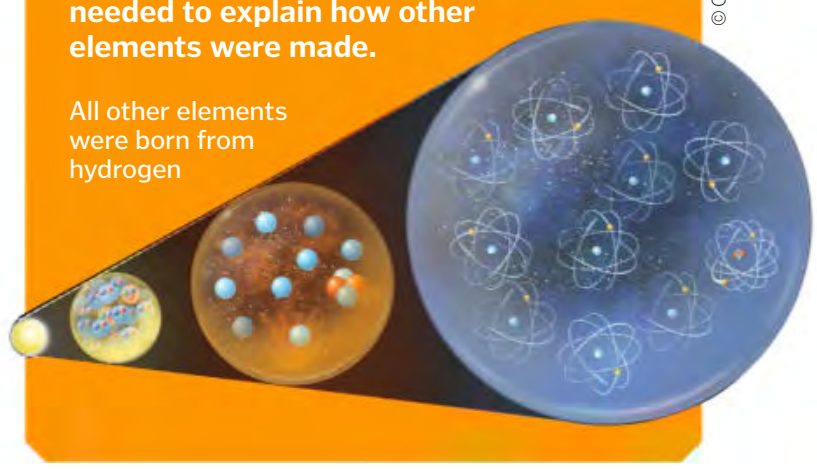


Henry Cavendish was the first to realise hydrogen was an element

© Getty

Born in the Big Bang

When he first thought it up, not everyone believed George Gamow's idea of how the elements were created. He suggested they formed by adding protons and neutrons together one at a time in the Big Bang. This happened when the universe was hot and dense, before it expanded and cooled rapidly. Working mainly with Ralph Alpher, Gamow saw the early universe as a highly compressed soup of neutrons. As the universe expanded, there would be room for neutrons to escape the soup and decay to make protons and electrons. From there hydrogen and deuterium might form, and then the other elements. Today this idea explains the large amount of hydrogen in the universe. However, other ideas were needed to explain how other elements were made.



All other elements were born from hydrogen

© Getty

How we use hydrogen

© Alamy

Rocket fuel

When burned together with oxygen, hydrogen is the most efficient rocket fuel there is. It has powered many space launches, including NASA's Space Shuttles. It's used as a liquid, meaning it must be kept very cold, which is difficult to do.

© Alamy

Oil refining

The UK alone uses 100,000 tonnes of hydrogen a year to turn natural gas and oil into useful products. When they come out of the ground, gas and oil contain sulphur, which creates pollution when it's burned. Hydrogen helps remove the sulphur.

© Alamy

Making fertiliser

Farmers can produce much more food than in the past thanks to fertiliser. This gives plants the nitrogen they need to grow in the form of ammonia. Large factories make ammonia from hydrogen and nitrogen from the air using the Haber-Bosch process.

© Alamy

Mining metals

A lot of the metals we use come out of the ground locked up together with oxygen in rocks. Because hydrogen reacts so well with oxygen, it can pull it away from the rock. This leaves pure metal in a usable form, and the only by-product of this is water.

HOW TO GET TO THE ISS

Explore the key steps that take astronauts from Earth to the International Space Station

Words by **Ailsa Harvey**

Since the first piece of the International Space Station (ISS) was launched into orbit in November 1998, it's become the ideal laboratory to test and explore our space knowledge. Orbiting Earth at an altitude of around 250 miles, the station has housed astronauts every day since November 2000.

Some of the most important knowledge the ISS has provided us with is how prolonged exposure to the space environment can affect the human body. It has also proven that a long-term human presence in space is possible. Over 240 people have experienced life aboard this satellite, carrying out experiments on machines, plants, animals and themselves. But how did these astronauts make it from our planet to their temporary low-gravity home?

Three types of spacecraft have taken astronauts to the ISS: the Space Shuttle, Soyuz and now SpaceX vehicles. Each of the three share the success of delivering people to the space station, but they differ greatly in design. The Space Shuttle was the first to carry astronauts to the ISS, and was shaped like a plane, but after the tragic Columbia disaster in 2003, it was retired from service. Subsequent designs put more emphasis on safety, and both Soyuz and SpaceX vehicles are capsule-shaped.

To ensure a safe voyage, an astronaut's journey begins a long time before walking up to the launch pad. They need to be confident about working on the ISS and controlling a spacecraft mid-flight before going into space. Although experience in these exact conditions is impossible before launching into the real environment, water-filled pools provide astronauts with adequate low-gravity training on Earth, while simulators can prepare them for a range of scenarios that could occur in flight.

Leaving Earth

How rockets carry astronauts into space during the first leg of their trip

Sergei Krikalev (left), Bill Shepherd (centre) and Yuri Gidzenko (right) became the first people to travel to the space station two decades ago

Payload section
Before launch, stairs are placed next to the rocket. Astronauts climb up to their capsule, which sits at the top of the rocket.

Launch mount
The rocket is held steady and straight by this structure. It releases its hold shortly before liftoff.

Stage 3 engine
When the propellant runs out during launch, the first stage of the rocket is removed. This rocket has three stages, each with its own engine.

Emergency escape system
If there is an emergency during launch, this system is automatically or manually triggered. It separates the capsule from the main rocket and launches this rocket at the top.

Boosters
Stage 1 is responsible for powering the rocket off the ground. As the rocket fuel is burned, it creates momentum, launching the rocket upwards.

Launch pad
Launch sites have slightly different procedures before liftoff. Some spacecraft are carried horizontally to the launch pad before being placed vertically, while others are constructed and transported vertically.

© NASA/Getty Images

The launch window

The ISS completes an orbit of Earth every 90 to 93 minutes, meaning that 15 full orbits are made in a day. Each time the station crosses the equator, its position moves over 22 degrees to the west. This happens because Earth is constantly rotating. The planet completes one 360-degree rotation every 24 hours, moving 15 degrees each hour. In the hour and a half taken for the space station to reach the same latitude again, Earth will have completed a 22.5-degree rotation, moving the orbital path to a new location.

For missions to the ISS, liftoff needs to be achieved within the 'launch window'. This is around the time that the station flies directly above the launch site. If the station is slightly east or west of the launch area, additional steering is needed, but docking at the space station can still be achieved.

Scan the QR code to track the International Space Station's live location

Q&A

Steve Swanson

A NASA astronaut, Swanson's three missions to the International Space Station delivered and installed two of the station's Truss Segments

Swanson has spent over 195 days in space during ISS missions

How many ISS missions have you been sent on?

I was on three different missions. The first two were on the Space Shuttle and the third was the Soyuz. On the first I was a flight engineer, on the flight deck with two minor pilots of the shuttle. I had to go through the checklist for launch and landing and all the phases of flight. For that mission I did a spacewalk and used the space station's robotic arm. On the second mission I was a spacewalker, and did the engineering jobs too. We all have other little jobs alongside the main ones. There were over 300 experiments going on while I was up there, and I probably worked on 120 of them myself. We then spent about 40 per cent of our time maintaining the space station.

What is a journey to the space station like?

It's an exciting ride. Probably the most dangerous part of the mission is the launch. Certainly for NASA, that's where we've had major catastrophes, so that gets you a little more nervous. But it's also a really fun trip, and well worth it. On the shuttle, the launch was often aborted. I think 50 per cent of the time it didn't launch the day it was planned to. You'd get all suited up, get out to the

launch pad, get in the vehicle and it wouldn't launch. I treated all launches as practice runs that weren't going to launch that day – that way I was never disappointed. When it actually did get close and it looked like we were going, I could change my mindset and say, 'Okay, we're launching today. Let's get it all figured out'.

Does experience make the process easier?

The process gets easier because you understand it more and you understand what's happening, but the odds of survival are still the same no matter what. That always gets to you a little bit as you go, no matter how many times you do it.

What's it like travelling inside a space capsule?

The Soyuz was much smaller. You don't have a lot of room to stretch out and move in a capsule. The Space Shuttle was much better for that. You just have to deal with that time frame, and you're usually pretty busy making sure all systems are working well. It's mainly just a process of keeping the vehicle going to explore the destination correctly and keeping the vehicle safe.

How much control do you have over the spacecraft?

A lot of it is pre-programmed manoeuvres, which we can set up or even load into the memory. We then execute them and watch them play out. Usually the computer controls almost everything, and the ground will send up a lot of the data needed to do the manoeuvres. Our job was to initiate the burns through keystrokes, just to make sure that everything was set up correctly and ready to go. You're still doing the work to get everything done, but you're not having to do the math to figure out what manoeuvre you need to do and when. That's already been done by Mission Control on the ground. They need to figure out exactly where you are and how to get you to your final destination. We didn't have that knowledge on board.

Docking precision

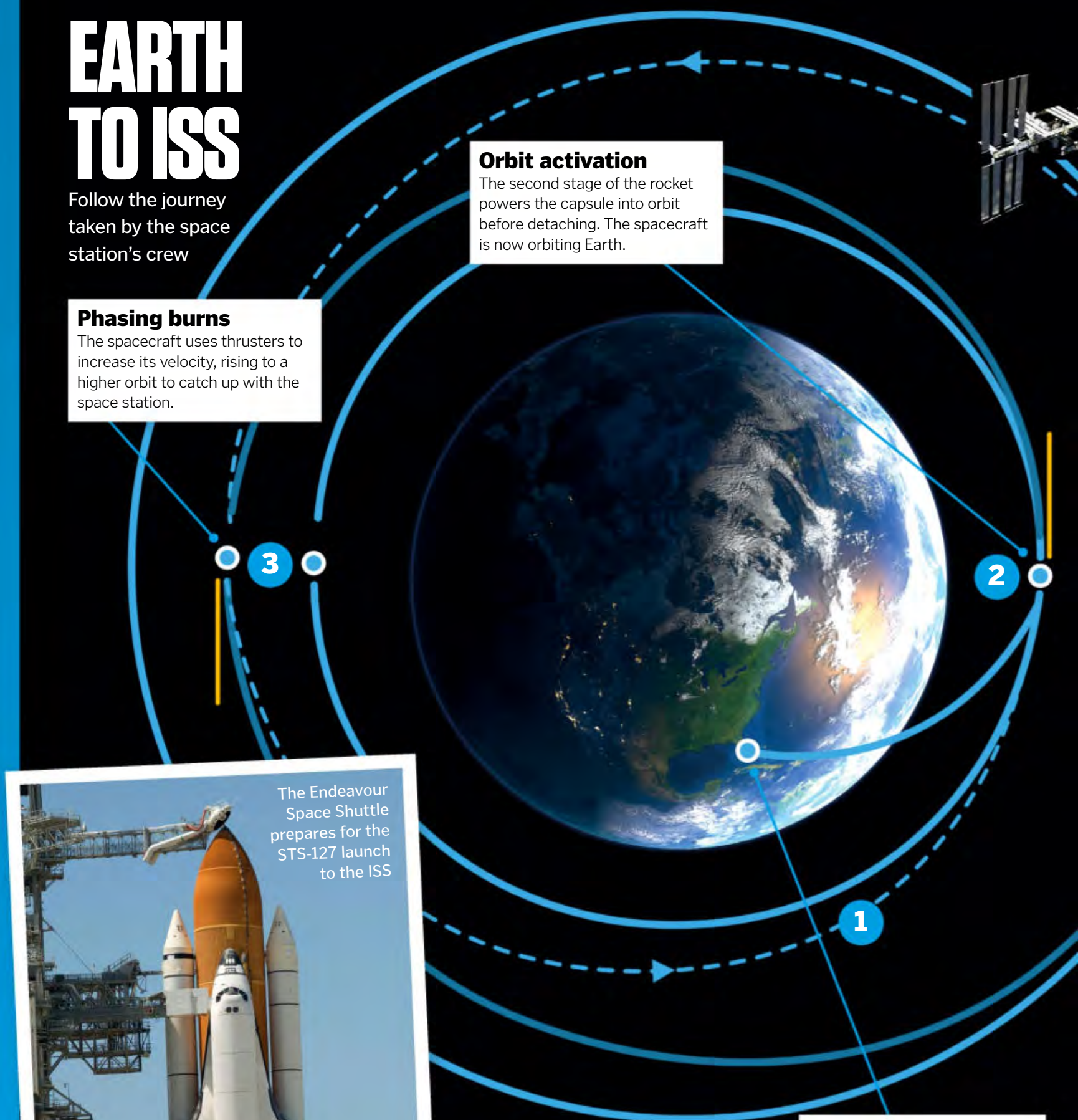
When lining up a spacecraft to dock with the ISS, accuracy is key. Astronauts can only be up to eight centimetres out of a perfect alignment to successfully attach the spacecraft. Before docking, one of the crew checks the speeds of both their spacecraft and the space station. The spacecraft has to match that of the ISS before increasing speed in relation to the space station in order to approach. When within 300 metres of the docking target, the spacecraft commander points the back of the spacecraft just above the docking ring on the ISS. The vehicle then slowly approaches the ISS backwards and upside down, slotting into the docking grooves.

© Alamy

The SpaceX Crew Dragon capsule docking with the ISS

EARTH TO ISS

Follow the journey taken by the space station's crew



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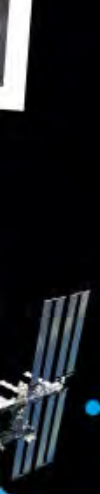
The Endeavour Space Shuttle prepares for the STS-127 launch to the ISS

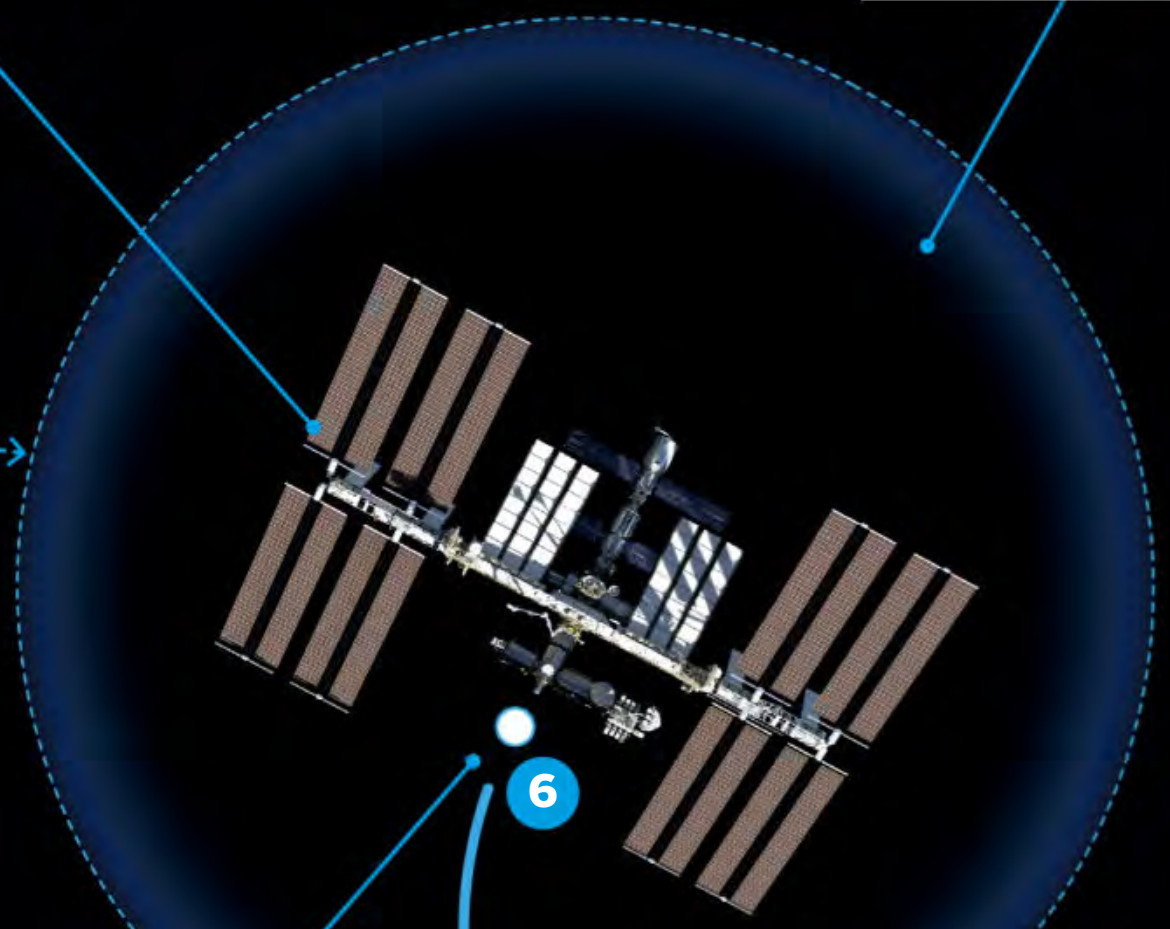
DID YOU KNOW? *The record for the most people on board the ISS at one time is 13, set in 2009*

AR ZONE! SCAN HERE

Arrival
Upon arrival the astronauts unfasten themselves from their capsule and move through the hatch, where they are welcomed by the ISS crew.

Keep-out sphere
This imaginary boundary extends 200 metres outside the ISS. For safety, only prearranged arrivals are allowed to travel beyond this boundary.





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3

Docking
In constant communication, the final step of the rendezvous is to make contact. When the two vehicles are connected, the spacecraft hatch can open.

5

Proximity operation
Operators on board the ISS give the go ahead for the spacecraft to approach the 200-metre mark. From this proximity, the spacecraft moves slowly to align with the station.

Approach initiation
Firing its thrusters again, the spacecraft is brought within 2.5 miles of the ISS and begins communication with those on board the space station.

4

5 FACTS ABOUT PREVIOUS MISSIONS

1 Building the base
It took around 40 missions to assemble the ISS over the course of three decades. The first segment was launched into space in 1998.

2 Quickest journey
In October 2020 a Soyuz capsule docked with the ISS just three hours and three minutes after liftoff.

3 First residents
In November 2000, Yuri Gidzenko, Sergei Krikalev and Bill Shepherd became the first people to travel to and stay on the ISS.

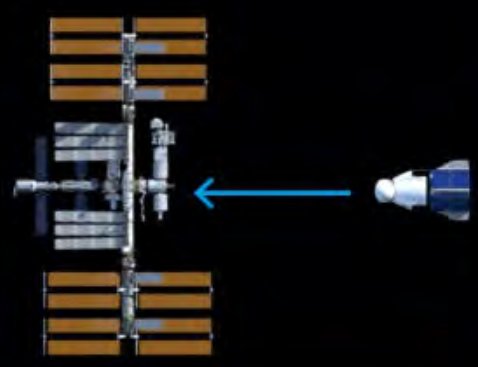
4 Varied visitors
As of April 2021, 244 people from 19 countries have flown to the International Space Station.

5 Most watched
The launch of the first crewed SpaceX mission to the ISS had the most online views of all launches, with 10.3 million people watching.

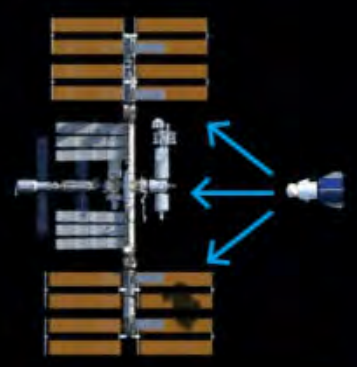
1 LIFT OFF

2 ORBIT ACTIVATION

3 PHASING BURNS



4 APPROACH INITIATION



5 PROXIMITY OPERATION

6 DOCKING AND PRESSURISATION

The Solar System's outer limits

Thanks to recent discoveries, we now have a clearer picture of what lies beyond Pluto

Words by **Andrew May**

For 60 years after its discovery in 1930, Pluto – together with its largest moon Charon, discovered in 1978 – marked the outermost limit of the Solar System. With an average distance from the Sun of 39 astronomical units (AU) – with one AU the distance from Earth to the Sun – that's pretty far out. But the 1990s saw the discovery of numerous other 'trans-Neptunian objects' beyond the orbit of Neptune, the most distant of the major planets, 30 AU from the Sun, with further discoveries coming in ever since.

Pluto actually resides in a relatively populous neighbourhood called the Kuiper Belt – a doughnut-shaped region extending from around 30 to 50 AU which contains hundreds of thousands of bodies larger than 62 miles in size.

Pluto is still the largest Kuiper Belt object (KBO) we know of. With a diameter of 1,473 miles, it has enough gravity to pull it into a spherical shape, classifying it as a 'dwarf planet' – a status it shares with other large KBOs such as Makemake and Haumea.

Smaller KBOs are more irregular-looking, resembling the asteroids found closer to the Sun. Unlike asteroids, however, which tend to be rocky in composition, KBOs are predominantly made of water ice and frozen methane and ammonia.

The region beyond the Kuiper Belt, called the 'scattered disc', contains icy bodies that have been scattered by Neptune's gravity into highly eccentric orbits. These may stray hundreds of AU from the Sun, rising far above the central plane, before their orbits take them back almost to the orbit of Neptune.

The largest scattered-disc object discovered so far, Eris, is similar in size to Pluto. In the course of its 557-year orbit, it roams all the way from inside Pluto's orbit to almost 100 AU from the Sun.

The outer Solar System

Trans-Neptunian space is filled with objects, including dwarf planets, which are fascinating worlds

Kuiper Belt
Stretching from around 30 to 50 AU, this is home to hundreds of thousands of small icy bodies.

Eris
Another dwarf planet and similar in size to Pluto, Eris is the largest known object in the scattered disc.


A close-up of Pluto, as seen by New Horizons in 2015

A brief history of distant worlds

In a sense KBOs have been known since antiquity – gravitational interactions can send them hurtling into the inner Solar System, where we see them as comets.

Astronomer Gerald Kuiper – after whom the belt is named – proposed such a scenario in the 1950s, but it wasn't until the 1990s that powerful telescopes began discovering KBOs in-situ in the outer Solar System. Astronomers were surprised to find that several of these were comparable in size to Pluto, which had hitherto been classified as a planet, playing a part in its demotion.

© NASA

Many comets, including Halley's Comet seen here, originate in the Kuiper Belt

New Horizons

The first and so far only spacecraft to explore the Kuiper Belt, NASA's New Horizons was launched in January 2006 and reached its first destination, the Pluto system, in July 2015. Passing within 7,767 miles of Pluto and 17,895 miles of Charon, the probe succeeded in capturing breathtaking images of both worlds. It also sent back masses of scientific data, including detailed maps of chemical composition and surface temperature.

Although Pluto was its main goal, New Horizons was designed to remain operational afterwards, using long-range sensors to investigate other KBOs. It had its second close encounter on 1 January 2019, this time with a recently discovered KBO just 21 miles across, which has since been named Arrokoth. Even that wasn't the end of the mission, and New Horizons is still going strong, passing the 50 AU milestone – 50 times farther from the Sun than Earth is – in April 2021.

5 FACTS ABOUT DISTANT OBJECTS

1 Total mass
Although there are hundreds of thousands of Kuiper Belt objects, NASA estimates their total mass to be no more than a tenth that of Earth's.

2 Planet 9?
Peculiarities in the orbits of some KBOs have led to speculation that there is another large planet way out beyond Neptune – but it isn't likely, and there are other explanations for this.

3 Seven light hours
At its current distance of 50 AU, it takes radio signals seven hours to reach New Horizons – and another seven for the answer to come back.

4 Farfarout
The most distant object discovered in the Solar System is a dwarf planet 132 AU from the Sun. First observed in 2018, it's been given the nickname Farfarout.

5 Oort Cloud
Hypothesised to exist far beyond the Kuiper Belt, the Oort Cloud is a roughly spherical shell of comet-like objects extending from around 2,000 to 100,000 AU from the Sun.

Pluto and Charon
The best-known dwarf planet in the Kuiper Belt, Pluto actually forms a binary system with its largest moon Charon.

Sedna
Also in the scattered disc, Sedna is currently 85 AU away, but its orbit extends to almost 1,000 AU.

Haumea
Part of the Kuiper Belt, dwarf planet Haumea has a distinctive oval shape, caused by its rapid rotation.

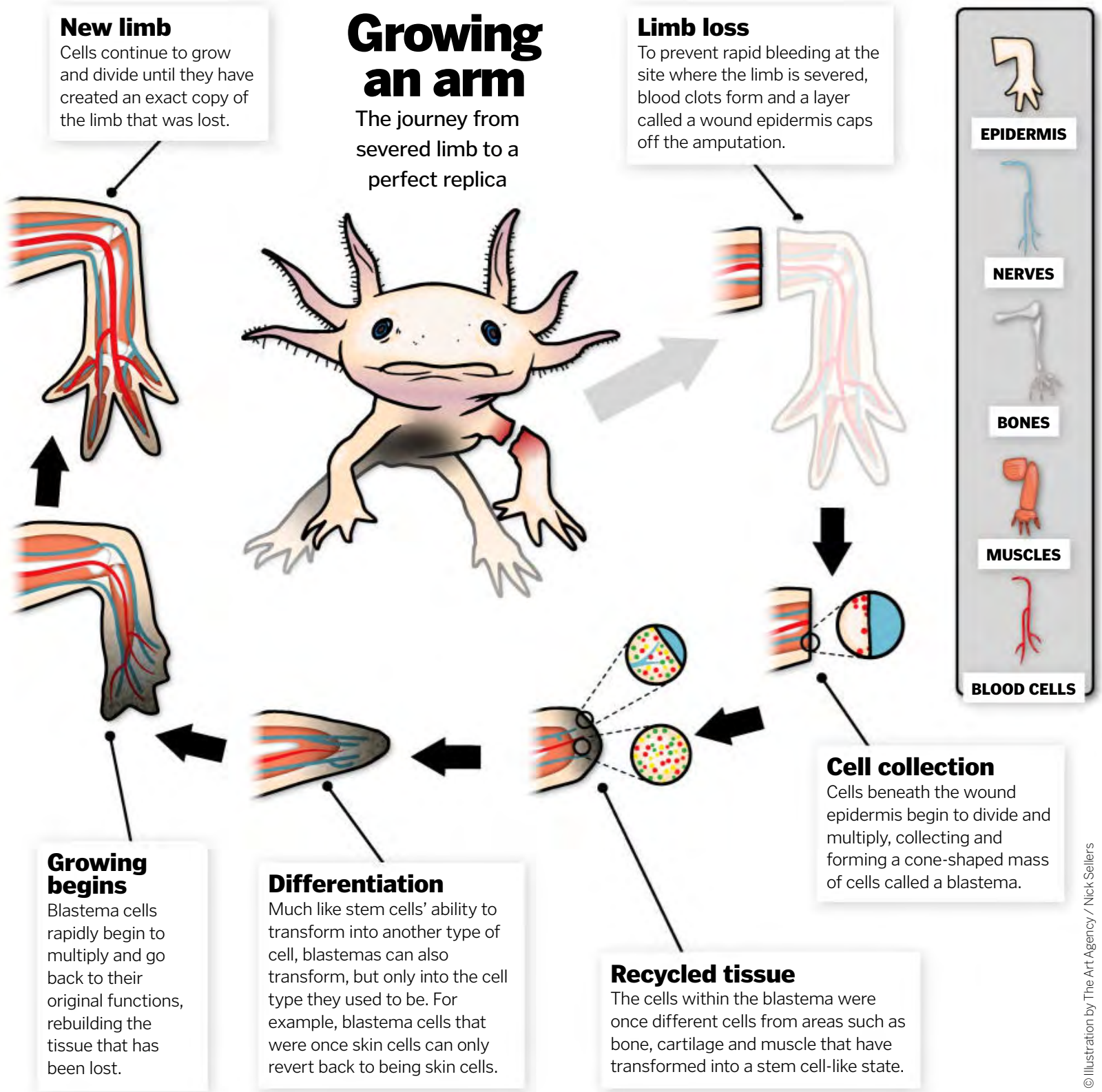
Scattered disc
Extending hundreds of AU beyond the Kuiper Belt, objects in this region generally move on more eccentric, highly inclined orbits.

"Pluto resides in a relatively populous neighbourhood"

ANIMAL SUPERPOWERS

SPECIES FROM AROUND THE WORLD ASSEMBLE! SHOWCASE YOUR SUPER ABILITIES

Words by
Scott Dutfield



The power of regeneration

Deadpool and Wolverine aren't the only ones with the ability to regrow their bodies: axolotls are real-life regenerators. Cellular regeneration occurs daily for most organisms, such as replenishing blood or skin cells. However, few can regenerate whole limbs, and it's rare to find an animal like the axolotl, which can go as far as regenerating its spinal cord and vital organs. After these salamanders lose limbs, in the days that follow their bodies have the ability to reorganise the cells at the site of the wound, beginning to regrow what's been lost.

The process involves cells called blastemas, which work in a similar way to pluripotent stem cells that can transform into different cell types. These cells are able to transform back into the building blocks of the axolotl's missing piece, including muscle tissue, bone, blood vessels and nerves.

As one of the few vertebrate species that can regenerate much more than lost limbs, axolotls have been the key focus for researchers exploring limb regeneration and even the ageing process in humans.

Looking at the axolotl genome – which is made up of 32 billion DNA base pairs compared to the mere 3 billion in humans – researchers are exploring the possibility of inducing regeneration in cells for tissue growth or cellular anti-ageing.


Axolotls are long-living salamanders and can survive for up to 15 years

5 FACTS ABOUT ANIMAL REGENERATORS

1 Starfish

Starfish are renowned for their ability to regenerate, and some species can regrow almost their entire body from a single severed limb. They can do this because their vital organs are located in their arms, but it can take around a year to regrow completely.

2 Tadpoles

During their metamorphosis from spawn to frog, at the tadpole stage of development these amphibians are able to regrow limbs, although they lose this ability when they transform into adult frogs.

3 Mexican tetra

These tiny fish have been found to possess the ability to regenerate their heart tissue. Researchers have discovered that this is because of a gene called LRRC10, which when turned off prevents the fish from regenerating.

4 Crabs

Crabs are known for throwing away their limbs in a fight or to evade predators. During their next exoskeleton moulting, crabs will regrow the limb within their existing shell until it is shed and the new limb is free for use.

5 Flatworm

Flatworms have evolved regenerative powers. These worms can reform their entire body from just 1/300th of their original body size.

Walking on water

Basilisk lizards are famous for their biblical ability to run on water. Using their powerful hind legs, lizards can dash over water for around 4.5 metres. This allows them to evade predators before sinking into the water and swimming away. What gives them this ability is their long toes, which unfurl scales when they come into contact with water. This increases the surface area of their feet. As the lizards rapidly pump their legs, they slap the water's surface and generate enough force to keep them upright.

Not only do these lizards generate enough force to stay upright, they can also create 'lateral reaction forces' to compensate for shifts in their body's movement as they run. This keeps the lizards above water and vertical.

© Alamy

© Getty

There are four species of basilisk lizard, which all live in Central and South America

Wood frogs are the only frogs that live north of the Arctic circle

© Getty

AR ZONE! SCAN HERE

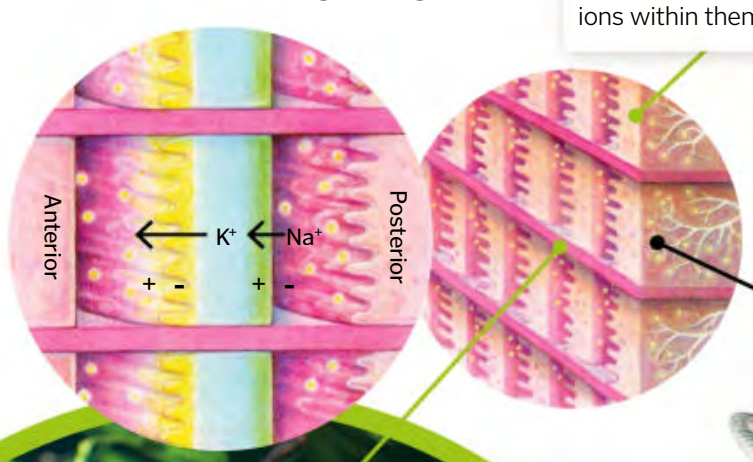
Shocking superpowers

All living creatures produce a small amount of electricity – at rest humans produce around 100 watts of power through our nervous system. Electric eels don't just generate electrical energy, but can emit shocks. Running along around 80 per cent of their body are a group of cells called electrocytes that transform eels' skin into a battery. The opposing sides of these cells are negatively and positively charged. When a burst of a neurotransmitter called acetylcholine is released within the cells, it connects the positive and negative charges of the opposing sides, collectively generating an electrical current. The entire body of an eel can generate the equivalent of up to 600 volts.

A quick zap from an electric eel is enough to deter most potential predators. But these eels also use their electric abilities to hunt. When in the vicinity of prey these eels emit an electrical pulse to immobilise them by activating the nerves in their muscles.

Generating electricity

How these eels create an electric shock when the signal is given



Electrocytes
These cells are the site of the electrical charge generation during changes in the positively charged ions within them.

Voltage
When nerve cells have sent the signal to open the gates, sodium ions flood the electrocytes and potassium ions leave, resulting in the generation of around 65 millivolts per cell.

Neurons
Nerve cells are responsible for releasing a neurotransmitter that opens gates in the membranes of the electrocytes to allow ions to move in and out, creating an electrical charge.

Electric organ
Running along the body length of the eel, the electric organ is composed of muscle-like cells called electrocytes.

Insulating tissue
Electrocytes are bound by connective tissue that assists in their function by allowing ions to pass in and out of them.

Electric eels live in streams and rivers and can grow up to 2.5 metres long

© Getty

© Illustration by The Art Agency / Sandra Doyle

Frozen frogs

Meet the frog with the power to survive freezing temperatures, thaw out and return to life. Species have evolved different methods of surviving the frigid conditions of winter. Some migrate towards the equator for a summer holiday, while others hibernate underground to escape the chilling temperatures at the surface. But in the case of wood frogs, they just freeze and wait for warmer weather. One species of wood frog, called *Rana sylvatica*, can tolerate freezing temperatures of -2.5 degrees Celsius. Scientists have discovered that these palm-sized amphibians go through daily freeze-thaw cycles, freezing at night when temperatures are at their lowest and thawing during the warmer daytime.

This antifreeze ability comes from how their bodies metabolise glucose. In a chilly scenario where any other animal would freeze to death, all the water content in the animals' cells moves out of their cells and becomes ice. This ultimately dehydrates the cells and causes the animal to die. However, wood frog biology is such that when the freezing process begins, their liver goes into overdrive and converts stored glycogen back into glucose and pumps the glucose into the thirsty cells. High levels of glucose in cells prevents further water from being lost as ice and keeps the frog 'candied' until the ice melts, and the glucose is then metabolised as energy or stored again as glycogen.

Fluorescent fireflies

Fireflies can often be seen twinkling around riverbanks and woodland as they illuminate their bodies with the help of some internal chemistry. A series of reactions involving oxygen, enzymes, adenosine triphosphate (ATP) and a luminescent chemical called luciferin are what give fireflies their illuminating powers. Fireflies can control this ability by regulating the amount of nitric oxide in their bodies. When this internal gas is produced, it allows oxygen to interact with the luciferin, resulting in a glow. When it isn't, oxygen and luciferin aren't able to mix.

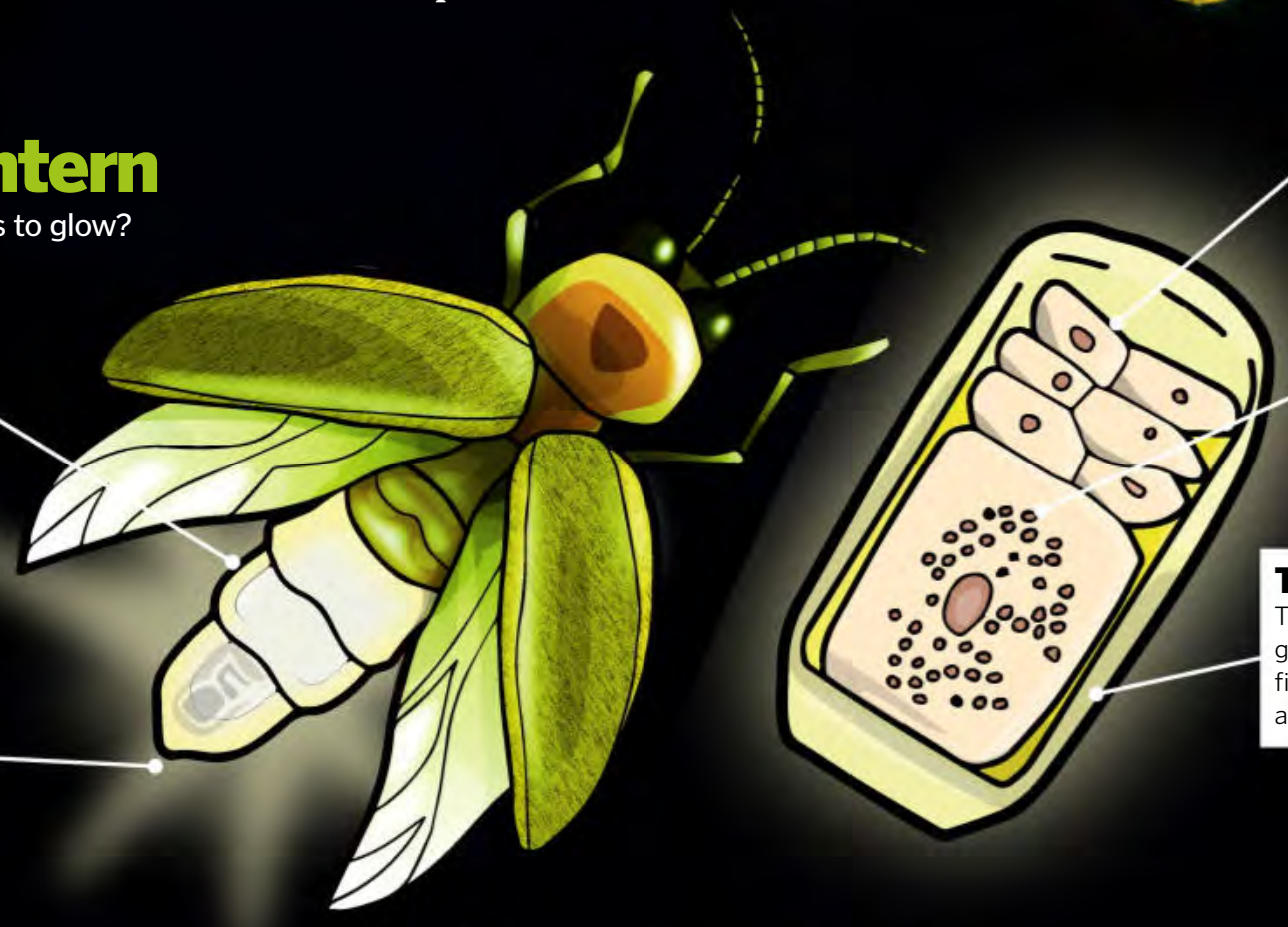
Typically things that emit light, such as light bulbs, also produce heat as a by-product, but this isn't the case for fireflies. If these small insects did simultaneously glow and get hotter they would certainly die. Therefore their glow is called 'cold light', as there is little energy lost as heat.

Fireflies use this glowing ability to communicate, particularly when trying to attract a mate. To prevent any cross-communication, each of the 2,000 firefly species have their own unique pattern of switching their glowing behinds on and off to attract members of the same species.

Fireflies use their biological lanterns as a mating strategy

Inside a firefly's lantern

What allows these insects to glow?



Colour
The photons emitted can create differing colours in fireflies: yellow, green, orange and even blue.

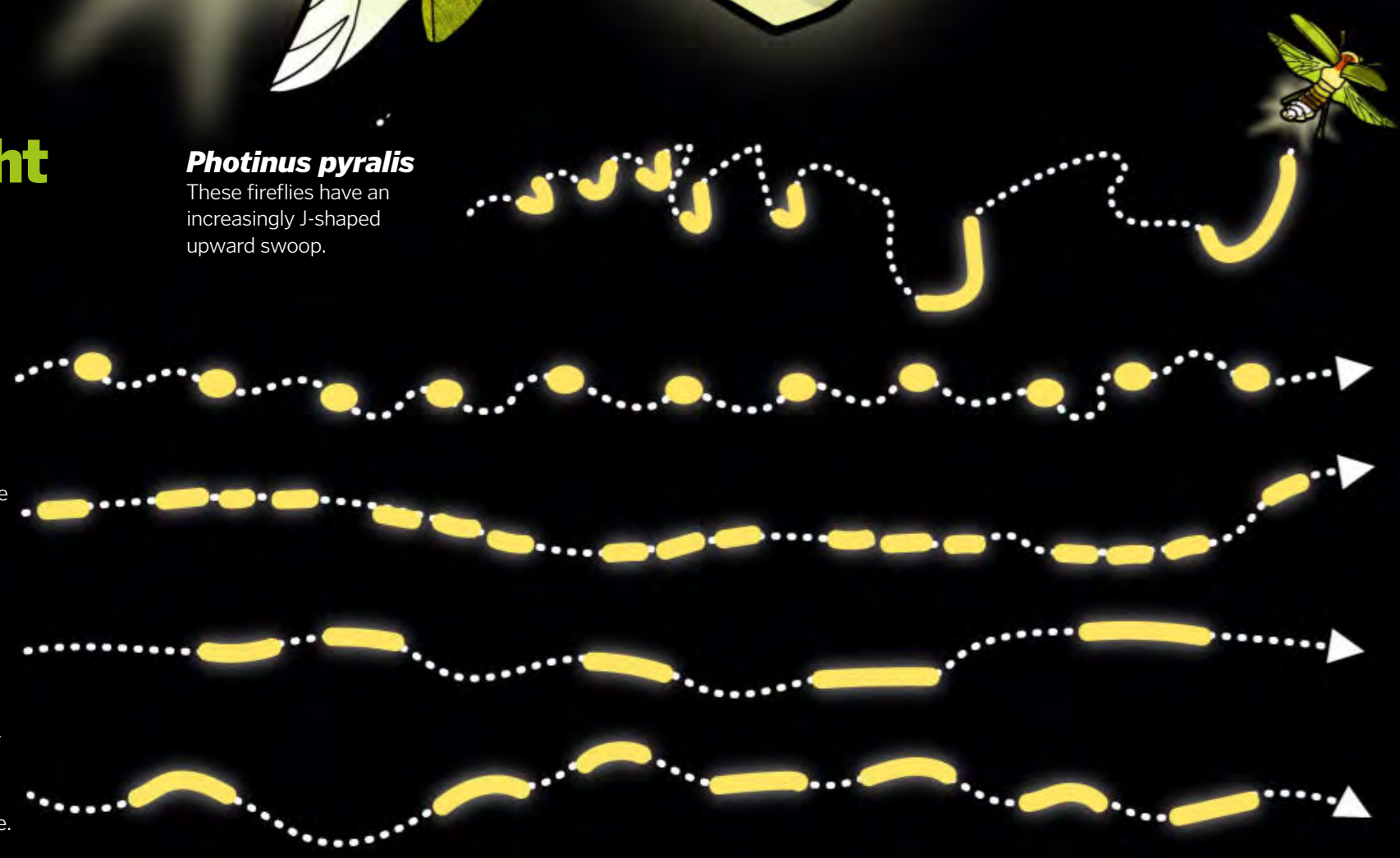
Bioluminescence
Reactions convert chemical energy into photons, which we see as light.

Reflector cells
Almost like mirrors bouncing off sunbeams, these cells reflect the bioluminescent light produced in the photocytes.

Light cells
Photocytes are where the glow is generated through the chemical reactions between oxygen and luciferin.

Transparent exoskeleton
There would be no point in being able to glow if the exoskeleton at the rear of the firefly was opaque. It is transparent to allow the light to emit beyond the body.

Firefly flight patterns



Photinus pyralis
These fireflies have an increasingly J-shaped upward swoop.

Photinus marginellus
These fireflies use short flashes of light to attract a female.

Photinus consimilis
Females of this species are more attracted to rapid flashing.

Photinus granulatus
These fireflies can be spotted glowing in longer one-second intervals.

Photinus collustrans
Females of this species await males to glow in regular arched intervals before selecting a mate.

Meet the mind-controllers

Mind control might sound like it's a talent reserved solely for the world of science fiction. However, long before Professor X broke into the minds of others, several species of parasites perfected the ability to remotely control their victims. One species of parasitic wasp in particular has become very talented in alternating the behaviour of ants.

During the life cycle of the *Ichneumon eumerus* wasp, females will inject larvae into the caterpillars of the mountain Alcon blue butterfly. The larvae then develop inside the caterpillar, internally feeding on it until they eventually leave their host. So where does mind control come in?

Mountain Alcon blue butterfly caterpillars attract red ants, which carry them to their nest and care for them. This is because these caterpillars emit a chemical that mimics that of ant larvae. In order for a parasitic wasp to inject its larvae into the caterpillar, it must tackle the problem of the protective ants, and does so by emitting a cocktail of chemicals that turns the ants on one another. These chemicals mimic the ants' alarm pheromones, making them hostile to one another so they begin fighting. While the ants are busy battling among themselves, the wasp can quickly enter the nest, parasitise the caterpillars and leave.

A female *Ichneumon eumerus* parasitic wasp looking for red ants
© Alamy

More mind-benders


© Alamy

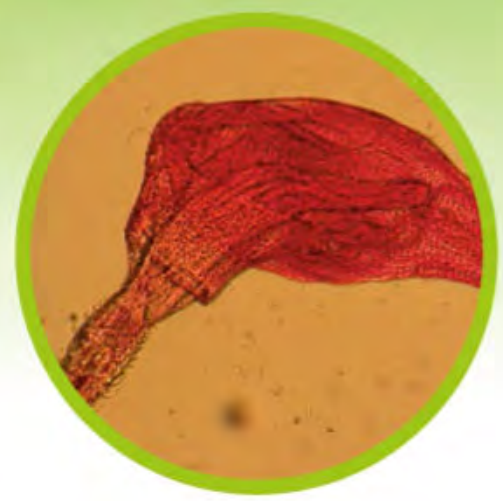
Emerald cockroach wasp

These vibrant insects inject a neurotoxic venom that places their cockroach prey into a zombie-like state. The wasps then lead the brainwashed cockroach, with a firm grip on its antennae, back to their nest to devour it.


Source: Wiki/José Lino-Neto

Glyptapanteles

This genus of parasitic wasps not only inject their eggs into the bodies of caterpillars, but use them as bodyguards. Once the larvae have developed in the caterpillars, most of them will emerge through the body without killing it. Others stay behind, which seems to cause the caterpillar to protect the external wasp larvae while they spin protective cocoons.


Source: Wiki/Dr. Neil Campbell/University of Aberdeen

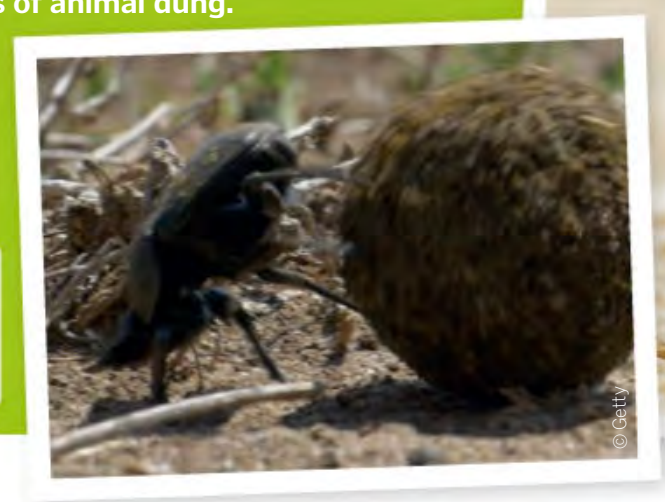
Spiny-headed worms

These sinister parasites have evolved a technique that alters the likelihood of survival for their host. Although it's not clear how, these parasites cause their hosts - which can be a range of different species - to move into vulnerable locations, near water or in the sunlight, where the worm's next host can spot the creature and eat them.

Dung beetle super strength

Relative to their size, dung beetles claim the 'world's strongest' title. There are around 6,000 species of dung beetle worldwide, and some are stronger than others. For example, the strongest species are male *Onthophagus taurus* beetles, which can pull 1,141 times their own body weight, equal to a human lifting around 81 tonnes. This strength allows these beetles to roll large balls of animal dung. These beetles will then go on to use the balled-up faecal waste in several ways, such as for food, as nesting materials, to regulate their body temperature and even as a tool for attracting females.

AR ZONE! SCAN HERE


© Getty


Not all species of dung beetle roll dung – some simply live in it where it's laid
© Getty

Walking on walls

Along with Spider-Man and his arachnid allies, geckos make easy work of scaling skyscrapers and hanging from ceilings. As a nifty way to escape predators or a cunning advantage over their prey, geckos are one of the few vertebrate species that can walk on walls and suspend themselves from a ceiling. This ability is thanks to the unique structure of their bulbous toes.

At the ends of gecko toes are thousands of microscopic hairs, known as setae, which themselves branch off into hundreds of bristles called spatulae. These tiny hairs enact something called Van der Waals force, an attractive force between the hairs and the wall's surface. It's this force that essentially acts as the glue that holds a gecko's body in place.

Geckos only need to enact this force with their toes to secure their relatively small size, less than 100 grams, to a surface. Humans would need adhesive gecko-like pads to cover 40 per cent of their body to stick like Spider-Man.

The design of gecko feet has inspired scientists to develop gravity-defying materials. In 2018 German scientists created a silicone material with adhesive properties similar to that of a gecko foot. This type of material has been used to create a strong adhesive tape that follows the 'gecko principle' without leaving a residue.

Toepad
Each one of the gecko's toepads consists of around half a million hair-like structures called setae, which are made from keratin.

© Getty

Gecko grip

How these wall-walkers stop themselves from losing their grip

© Alamy

Spatulae
At the ends of each of the setae are hundreds of further protrusions called spatulae.

Strong step
The combined force of the millions of spatulae on one foot can adhere to a surface with a force of around one kilogram.

Geckos are nocturnal and feed on insects, fruit and flower nectar

© Getty

Inside Etna

Italy is home to Europe's tallest active volcano, but what lies beneath the rock?

Words by **Ailsa Harvey**

On the east coast of Sicily lies an impressive 3,326-metre active volcano called Mount Etna. This volatile mountain has a reputation for spouting out scalding liquid rock on a regular basis. But even after decades of observation, Etna's actions can't be accurately predicted or controlled.

The first known eruption was recorded in 475 BCE, and it has sporadically been launching lava and ash onto the Italian island for thousands of years since. It's impossible to prevent Earth's natural movements that lead to these eruptions, but we have learned much about Etna's geology, which has helped the local population avoid disaster.

Ancient Greek legends say that a giant monster lives inside the volcano, trapped there by Zeus. It's said that every time he turns over, an eruption occurs. However, through the advancement of scientific research we know that these violent outbursts are caused by a build-up of pressure causing magma in the planet's mantle to spill onto the surface. Dormant volcanoes allow volcanologists to explore inside these once-volatile places and carry out in-depth studies that can help us predict volcanic eruptions. Despite transforming into a death trap multiple times a year, Mount Etna continues to draw in tourists, while the Sicilians who live in its shadow refuse to fear it.

Burning heart of the mountain

How past eruptions have built up Europe's tallest active volcano

Multiple vents
Mount Etna has a main summit vent and multiple flank vents, where lava can flow out from the sides.

Sedimentary rock
A thick layer of sedimentary rock lies beneath the volcano. This reaches up to 1,000 metres above sea level.

3 Trifoglietto
As the stratovolcanoes continued to grow, they eventually overlapped to form one large volcano called Trifoglietto.

Tectonic plate lines run through Sicily, with the African and Adriatic plates meeting underneath the City of Catania

1 Ancient shield volcano
The early shield volcano began erupting around 500,000 years ago. Shield volcanoes are relatively flat with gently sloping sides.

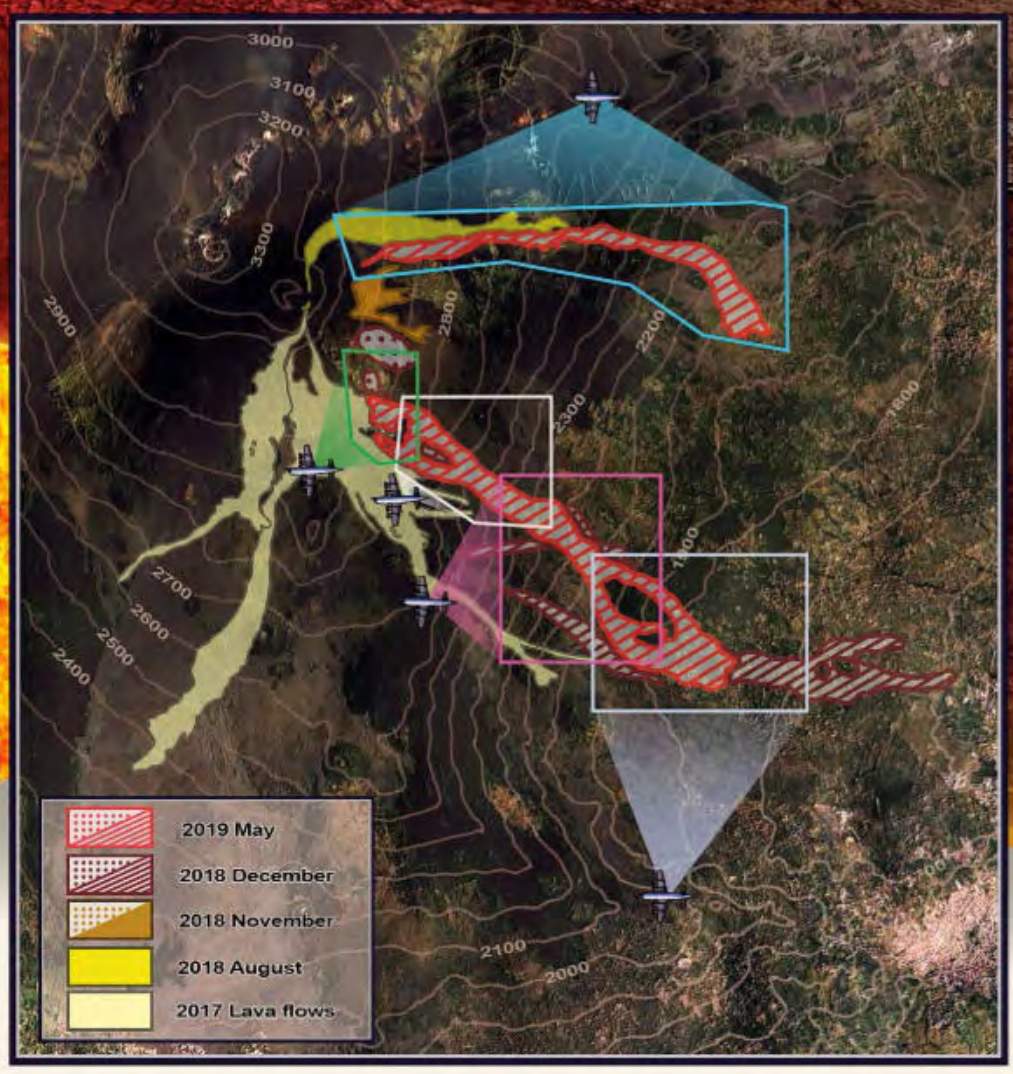
Magma chamber
The magma in Etna has a high silica content, making the lava flows more viscous and slow.

AR ZONE! SCAN HERE

5 Mongibello
Today's summit is locally named Mongibello. After the collapse of Ellittico, eruptions filled the caldera, and the volcano continued to grow to over 3,000 metres tall.

2 First stratovolcanoes
As the volcano erupted multiple times, it formed alternate layers of lava and ash. These rising mounds formed around 35,000 years ago.

4 Ellittico
Until 15,000 years ago the Ellittico volcano released acidic trachyte rock, adding material that was 400 metres higher than today's peak. It then collapsed, forming a two-mile-wide hollow.



© Illustration by Nicholas Forder

© Getty

Smoke continues to rise from Etna two days after its big eruption in 2018

Recent activity

Being one of the most active volcanoes in the world, it's unusual for a year to pass without Etna erupting multiple times. Mount Etna has been even more restless and unpredictable in recent years. 2021 kicked off with a fiery display from the volcano on 16 February. The first signs appeared at about 16:00 UTC in the form of a small lava flow from the southeast crater. Just over an hour later, violent bursts of lava streamed down its slopes. In the five weeks that followed there were 16 small eruptions from the volcano.

Since the eruption of December 2018, which triggered a magnitude 4.8 earthquake, the volcano has become much more active, even creating a new fissure for lava to exit from.

© Getty

The operations room at Etna's observatory has 24-hour surveillance

How is Etna monitored?

Catania is one of the cities that Mount Etna towers over. Those who live in the city are subject to constant reminders of the volcano's presence. Tracking and analysing Mount Etna takes place in Catania's National Institute of Geophysics and Volcanology (INGV) observatory, which is one of three surrounding Etna. The other two at Casa Etnea and Cantoniera are spread along the mountain's 93-mile circumference.

Working in the offices at INGV, around 100 scientists observe the actions of Mount Etna and search for explanations behind its every rumble and eruption. To do this they use data that is sent in real time from 150 monitoring stations around the volcano. They include gas-emission detectors, heat-sensor cameras and seismographs that detect tremors.

Deep-sea blobfish

Blobfish haven't got looks on their side, having been voted the world's ugliest creature

Words by **Lauren Eyles**

The smooth-head blobfish (*Psychrolutes marcidus*) wins the prize for having the most hideous face, looking like a grumpy, saggy old man. They are about 30 centimetres long and the most famous in the family *Psychrolutidae*, which contains around 30 different species. Fish in this family are also known as toadfish and fathead sculpins.

It's hard to believe that blobfish are a fairly normal-looking fish in their natural habitat, which is very deep. Here they look similar to tadpoles, with oversized heads and thin tails. For a deep-sea fish, they actually have quite a cute face, a bit like a pufferfish. It's no wonder they look so sorry for themselves though, as they are accidently caught by humans in deep-sea trawlers and brought to the surface. It's only then that their soft bodies collapse, and they look like one big wobbly, gruesome blob – that's where they get their name from.

Blobfish don't do much and are very lazy eaters. They don't actively hunt, but this is a brilliant tactic as they don't have the muscle power to help them swim fast. Most fish need a swim bladder to control their buoyancy, but not the blobfish. Their soft bodies give them the natural buoyancy they need to float above the seafloor in the hope that food passes their way.

They are a bit of a mystery to science, and not much is known about them – how many there are, how they reproduce and how long they live – as they are in a difficult-to-reach environment and are tricky to find.

"Blobfish are a fairly normal-looking fish in their natural habitat"

Sad-looking blob sculpins after being captured from their deep-sea world

© NOAA Psychrolutes

From fish to blob

Why do they look so different in and out of water? It's their deep-sea environment which gives them good reason to be ugly. A bit like a jellyfish, blobfish are made mostly of jelly. They have almost no muscle and very few bones; they need to be this way to survive the huge pressures of the deep. When underwater, the pressure forces their body into the right shape. They don't need muscle and bones to keep their form, so down in the depths they look like a normal fish. But when brought up from the depths, they look like one ugly mug. At the lower pressures of the surface, their unsupported jelly-like body collapses, and so does their fish-like face.

A colourful blob sculpin, part of the blobfish family, rests on a rock in the deep sea off Alaska

© Alamy

Challenges of the deep

Most animals can't survive beyond where there is sunlight, and those that do need special adaptations to live there. The blobfish and its relatives are no exception. Blobfish live up to 1,000 metres under the waves – as deep as the length of 20 Olympic-sized swimming pools. Here they feed on the bottom of the ocean in the twilight and midnight zones.

Other species can go even deeper into abyssal waters, which are some of the deepest and darkest locations on Earth. The pressure in these deep-sea zones is huge, over 100 times the pressure on land – you would be crushed if you went that deep. It's not only the crushing pressure they have to survive – the water is just above freezing, at about two to four degrees Celsius. The Sun can't reach these depths to allow sea plants to grow, and it remains very dark and very cold.

5 FACTS ABOUT FISHY FEATURES

1 More than one blobfish
Three types of blobfish can be found in the waters of Western Australia, Southern Australia, around the waters of Tasmania and north of New Zealand.

2 Energy saving
Very little energy is used in moving and eating, as they don't have the muscle to help them do this and need to save as much energy as possible.

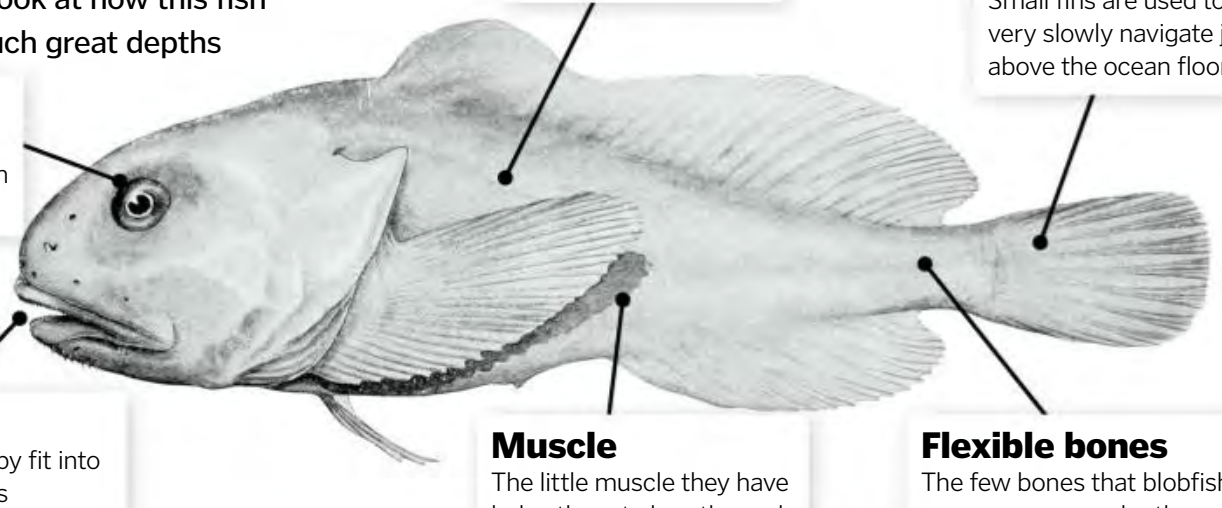
3 Could there be more?
The smooth-head blobfish was only discovered 18 years ago off New Zealand. There could be even more blobfish around the world that haven't been found yet.

4 No teeth
Blobfish don't have any teeth, so they can't crush the crabs and molluscs that they eat. Instead these prey are just sucked up into the blobfish's mouth as they float along.

5 Not a tasty dish
We are their biggest threat, but not intentionally, as there is no value in catching them to eat – they would taste disgusting!

Blobfish anatomy

Let's take a look at how this fish can live at such great depths



Soft body
A jelly-like body helps them to survive under extreme pressures.

Fins
Small fins are used to very slowly navigate just above the ocean floor.

Eyes
Blobfish have large, black eyes to help them see in full darkness.

Mouth
Small prey passing by fit into their mouth, such as molluscs, crabs and shellfish.

Muscle
The little muscle they have helps them to breathe and open their large mouth.

Flexible bones
The few bones that blobfish have can compress under the extreme pressure without breaking.

NINJA VS SAMURAI

How changes in Japanese society gave rise to warriors trained in specialised arts

Words by **Nikole Robinson**

© Getty

In 646, the Taika Reforms united Japan into a state ruled by an imperial government under an emperor. Land was redistributed, and heavy taxes were imposed. These taxes meant that many farmers had to sell their land and work under others, and as a result wealthy landowners gained more power, becoming lords who answered only to the emperor. To protect their wealth, they began to hire mercenaries and employ family members as guards, triggering the age of the samurai.

These early samurai – meaning 'one who serves' – would collect taxes, threaten those who wouldn't pay up and defend their lord from rivals who might look to expand and take over their assets. However, their importance in society didn't really take shape until the Heian period, between 794 and 1185, when imperial power began to decline. The emperor's influence was lost outside of the capital, and civil wars began to break out across the county. The warrior class now played a huge role in society, and local lords began to amass personal armies in the struggle for power.

While the two sons of Emperor Toba fought over what little imperial power remained in the latter half of the 12th century, two powerful samurai and their clans were fighting their own battles. Though Taira Kiyomori's clan would be victorious at first, seizing control of Japan and establishing the first samurai-led government, after his death the Minamoto clan would strike back in the Genpei War of 1180. After their victory, the head of the clan Minamoto Yoritomo established the Kamakura shogunate, turning Japan into a military dictatorship, but allowing the emperor to remain a figurehead.

Under military rule, samurai had more power than ever before, though they were still in service to their lords, who became known as daimyo. The new enemy became the Mongol Empire, a horde of nomadic tribes who had already conquered China. With the weather and seas on its side and samurai from all over the country fighting to repel the foreign forces, Japan

Master of arms

As samurai gained status it became customary to carry two swords in a practice called daisho: a smaller blade called a wakizashi was used in close combat or cramped spaces. When a longer reach was needed in combat, a samurai would use a long, straight-headed spear called a yari. These could puncture armour with a thrust, and were also used in mounted combat. Often fighting from horseback, the art of archery (kyujutsu) was another vital skill for any samurai, who used huge, two-metre asymmetrical bows (yumi). After the introduction of firearms to Japan, which they called tanegashima, it took a while for them to be widely adopted, with experienced archers still more deadly with bows than these advanced weapons. Once the design of guns had been improved, samurai began to use them as part of their arsenal.

© Wiki/Kusakabe Kimbei

Samurai would master fighting with yumi and ya (arrows), katana and yari

© Getty

Samurai swords were masterfully crafted by experienced blacksmiths

© Wiki/Akiyoshi Matsuoka

The woven basket of a komuso monk made a good face covering

kept the invaders at bay. However, the Kamakura shogunate was unable to offer much reward to the samurai leaders who had come to the country's defence, and soon its grip would begin to loosen.

In the 1400s the entire country was plunged into civil war once again, with the daimyo all vying for power using the strength of the samurai in their service. This 100-year conflict would be dubbed the Warring States period, and would see the status of the most powerful samurai equal that of nobles, with their standing able to pass down to their children.

During this brutal period, powerful daimyo would also employ more clandestine tactics, hiring shinobi warriors – better known as ninjas – for sneak attacks and sabotage. In stark contrast to the samurai and their newfound nobility and code of honour, ninjas were low-class citizens trained in specialised skills and stealth, making them the perfect spies. Because of their secretive nature, it's hard to say when exactly the art of ninjutsu began to develop and when ninjas were active in warfare, but many of them can be traced to the Iga and Koga regions of Japan.

The eventual reunification of Japan would start with the powerful daimyo Oda Nobunaga, whose army defeated other influential warlords and overthrew the Ashikaga shogunate. Seeing ninjas as a huge threat, he first defeated and scattered the Koga shinobi, then launched a massive offensive on the Iga clan. Decimating them in open combat, many remaining ninjas would end up in the service of Tokugawa Ieyasu, who would rule Japan as shogun from 1603.

After years of turmoil, Tokugawa ushered in a new era of peace and stability, and suddenly there was no place for the samurai or ninjas outside of the shogunate's service. Some samurai remained loyal to their lords, but rarely saw combat, while others were forced to hang up their swords and become farmers. Ninjas became more of a myth, with their exaggerated 'magical' abilities becoming legend.

AR ZONE!

Shielding the samurai

These highly decorated warriors wore heavy, plated armour and carried katanas

Menpo
Serving as protection for the face, the intricate and often demonic designs of these masks were also an intimidation tactic.

Kabuto
Protecting the head, helmets also showed off wealth and status. As samurai rose to power they became more elaborate, with maedate (front ornaments) becoming complex and ornate.

Do
Samurai armour was both sturdy and flexible. Made of metal, wood or leather plates stitched together, the wearer could move freely in battle.

Kote
Before the 12th century, only the left arm was covered to aid with archery. The style of these armoured sleeves varied greatly, as did their level of protection.

Katana
The iconic weapon of a samurai, a katana is a curved, single-edged blade with a long grip – they could be wielded with one or both hands.

Kusazuri
A four-piece, armour-plated skirt was attracted to a belt and laced to the do. This covered the thigh armour, called haidate.

Suneate
Made in the same style, colour and materials to match the kote, these were usually vertical armour plates with a cloth backing.

Waraji
Though the rest of their body was heavily guarded, samurai wore simple straw sandals on their feet over split-toe socks called tabi.

Way of the warrior

Samurai lived by a moral code called bushido

義

Justice (gi)
Sometimes called righteousness, the core of this virtue was doing the right thing, even when no one was watching, and treating all people fairly.

勇

Courage (yu)
A true warrior should be heroic, not only in combat when facing death, but in all aspects of life. A samurai would never run from battle or responsibilities.

仁

Compassion (jin)
A samurai used their strength to help others, using their power for the greater good rather than selfishness.

礼

Respect (rei)
Samurai showed respect by being polite and well-mannered to all people, including those beneath them in status.

誠

Honesty (makoto)
A samurai wouldn't lie, and needed to fulfil promises made. They were supposed to be sincere and dependable, and were therefore taken at their word.

名誉

Honour (meiyo)
Dishonour was worse than death for many samurai, who feared disgracing themselves and their families with actions that went against their virtues.

忠義

Loyalty (chugi)
Samurai needed to be counted on by the lords that they served and not betray them. They were also loyal to their families.

自制

Self-control (jisei)
A samurai was in control of what they said or did, always upholding their code of honour despite temptations and impulses.

A time of change

646
The Taika Reforms change the country to mimic Chinese culture and rule, allowing some landowners to become powerful lords.

1192
Minamoto Yoritomo becomes the first shogun of Japan, establishing the Kamakura shogunate.

Source: Wiki/Fujiwara no Takanobu

1274
Kublai Khan sends 600 ships carrying Mongol warriors to Japan. They are hit by typhoons and about 10,000 samurai called into service, who send the warriors packing.

1467-1615
The Sengoku or Warring States period. Japan is split into small regions. Daimyo fight each other for power and samurai and ninjas are active in their service.

1568
After unifying Japan and ending many conflicts, Oda Nobunaga instills Rokkaku Yoshikata as the new shogun.

Ninja strategies

Cunning and deception gave ninjas an advantage over their enemies

Assassination
Stealth allowed ninjas to get close to their targets without raising suspicion, and many daimyo feared a surprise attack. Castles used uguisu-bari flooring that would make a bird-like sound when stepped on.

Espionage
Blending in behind enemy lines, a ninja could learn about an enemy's plans or a castle's defences. Monks and priests were popular disguises for ninjas, though many simply dressed as commoners.

Arson
Gunpowder stores, armouries, warehouses and palaces were all prime targets – sometimes from afar by firing flaming arrows, or bo-hiya. Setting multiple fires would cause more chaos and confusion.

Deception and sabotage
A ninja hidden among the enemy could spread misinformation and pass on incorrect orders. They could also destroy or steal supplies, poison wells or ambush enemy soldiers.

Escape
Ninjas were so good at slipping away that it was said they could disappear through walls. They made use of nature, hiding high in trees or underwater, as well as using smoke bombs to obscure an enemy's vision while they ran or hid.

A ninja's arsenal

Specialised tools and weapons allowed ninjas to strike from the shadows

Kaginawa
Rope grappling hooks were used to scale walls, for example during castle sieges. Some ninjas used hooked rope ladders instead.

Masked identity
Allowing an assassin to remain anonymous, the head was wrapped in a zukin, while the face was covered by a piece of cloth called a fukumen.

Tanto
A short sword was easier to conceal, though some ninjas carried full swords, often choosing a disguise that would allow them to carry one without suspicion.

Tetsubishi
These small, spiked metal objects could be dropped to slow down pursuers and aid in escape. These would easily pierce straw waraji sandals.

Kusarigama
The weighted chain could be used a bit like a lasso, wrapping around an enemy's weapon or tying them up. The kama (sickle) could then be used to attack an incapacitated enemy.

Shinobi shozoku
A stereotypical ninja is shrouded in black robes. With most of their work done under cover of darkness, dark blue would actually have helped hide them more effectively.

Shuko and ashiko
With shuko worn on the hands and ashiko on the feet, spikes were driven into walls or trees to help climb them. They could also be used in hand-to-hand combat.

Shuriken
Designed in many shapes, the most commonly depicted is a star. These could be used as throwing weapons or as a small dagger in a pinch.

AR ZONE! SCAN HERE

Wiki/Utagawa Kuniyoshi

1591
Samurai are no longer allowed to farm their own land, and rice is provided by their daimyo as payment for their service.

1676
Fujibayashi Yasutake releases the Bansenshukai, a book on the ways and training of the Iga and Koga ninja clans.

1701-1702
The 47 ronin infamously avenge the death of their master Asano Naganori, after which they disband and commit seppuku, an honourable ritual death.

© Getty

1876
Samurai are banned from carrying daisho and are only permitted to carry short swords. With no real place for them in society, many enter military service.

Birth of the Euros

The 16th European Football Championship takes place in 2021, but how does it compare to the first?

Words by **Ailsa Harvey**

Football has existed for thousands of years, but the modern game we know today can be traced back to English playgrounds in the 1800s. As the sport grew in popularity, organisations such as The Football Association helped to create official rules, transforming the sport from an ancient pastime of kicking objects with our feet to a highly skilled and regulated game. By 1900, football had become Britain's national sport, and developments in transport and media meant that its popularity was spreading rapidly across the world.

In 1927, the administrator of the French Football Federation, Henri Delaunay, suggested that countries across Europe bring their passion for the sport together for an intracontinental competition. This vision would eventually become reality when it was organised in 1960 – unfortunately this was five years after Delaunay had passed away. To celebrate the man who first envisaged the Euros, the trophy awarded to the winning country was named after him.

Since its inception the tournament has been run by the Union of European Football Associations (UEFA) every four years, with the exception of 2020. As the COVID-19 pandemic prevented the tournament from going ahead, the matches were scheduled for June 2021 instead. However, in order to honour the 60-year anniversary of the European Football Championship, Euro 2020 will keep its original name. Other elements will also buck tradition: for the first time, instead of being held at one location, Euro 2020 will be hosted by 11 cities across Europe.

© Alamy

A 60-year championship

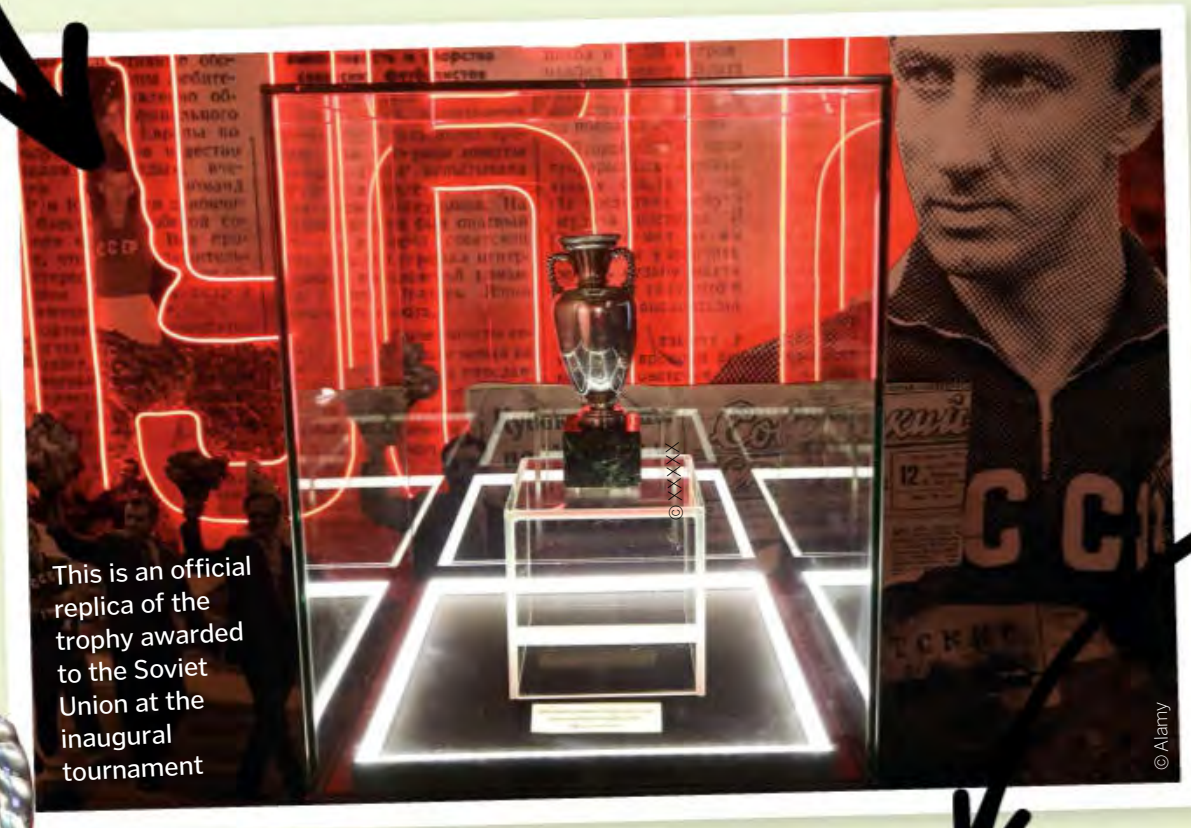
Take a look at how the tournament has evolved

1960
The Euros are born

At the very first European Cup, originally called the European Nations Cup, only the Soviet Union, Yugoslavia, Czechoslovakia and France compete in the finals. The competition needs 16 teams to enter for the qualifying tournament in order to go ahead: 17 sign up. Italy, England and World Cup winners West Germany show no interest.
Hosts: France
Number of teams: 4
Winners: Soviet Union

1964
Garnering interest

The number of countries participating in qualification matches grows from 17 to 29. More than 79,000 people turn up to watch the final between the tournament's first champions, the Soviet Union, and Spain. The score is 1-1 in just eight minutes, but the second and final goal that wins the match doesn't take place until the closing minutes.
Hosts: Spain
Number of teams: 4
Winners: Spain


This is an official replica of the trophy awarded to the Soviet Union at the inaugural tournament
© Alamy

2000
Co-hosting

Belgium and the Netherlands become the first countries to co-host the Euros. The two nations provide four stadiums each for the games to take place in. As part of the tournament rules, host countries automatically qualify for the tournament. Aside from the two hosts, 49 countries take part in qualification, and the final 16 teams compete in four groups.
Hosts: Belgium and the Netherlands
Number of teams: 16
Winners: France

1996
The golden goal

A 'golden goal' refers to a rule whereby the first goal scored during extra time decides the winners of the match. In 1996 the first golden goal of the European Championships occurs. German striker Oliver Bierhoff is brought on during the second half, and is the one to match the Czech Republic's 59th-minute goal. As extra time gets called, Bierhoff goes on to score the golden goal.
Hosts: England
Number of teams: 16
Winners: Germany


French players and staff celebrate winning the championship
© Getty

2004
Zero to hero

When Greece are declared the winners, some of the team's players fall to the ground in tears. This is the first European Championship for the entire team, and they were crowned the winners in their second participation of the tournament after a 24-year absence.
Hosts: Portugal
Number of teams: 16
Winners: Greece

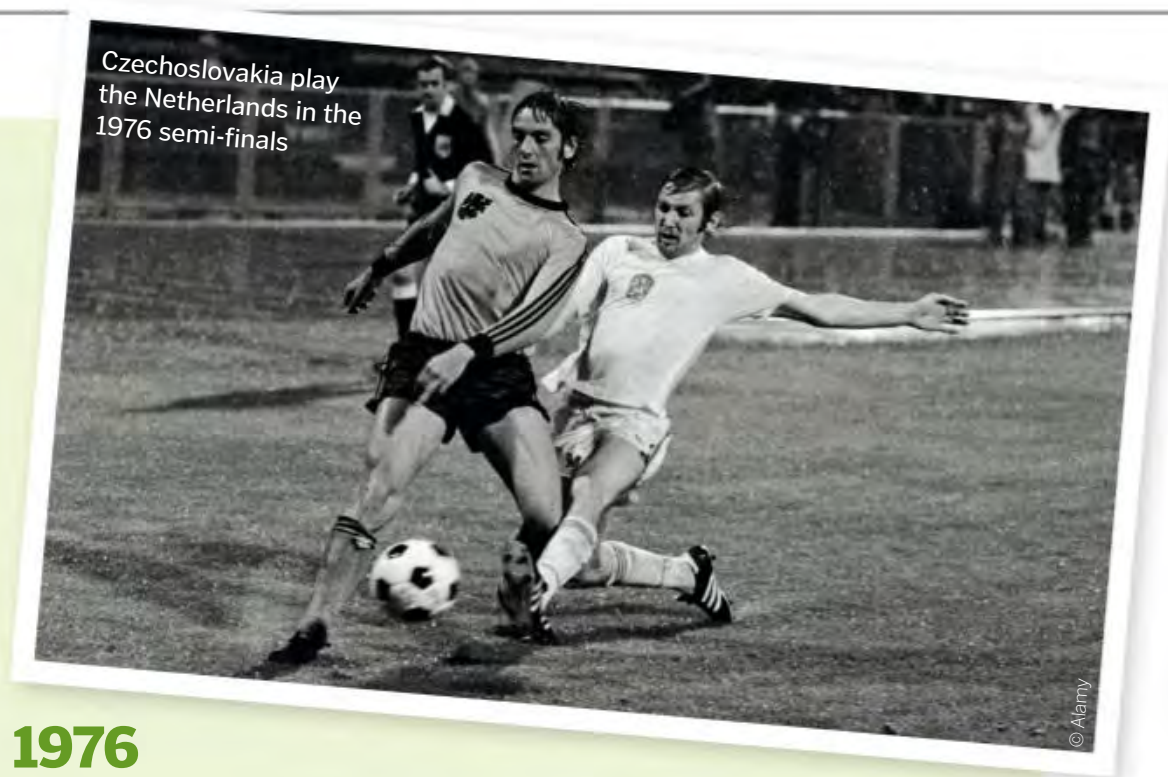

Italy and Yugoslavia play in the 1968 final

© Public Domain

1968
Coin-toss win
In the process of becoming the 1968 champions, Italy kick the Soviet Union out of the competition during the semi-finals, but neither side scores any goals. In the early years of the Euros, every team has a good chance of winning. After a 0-0 draw and extra time adding no numbers to the scoreboard, Italy are taken through to the final by a coin toss. In the final they draw again against Yugoslavia before winning 2-0 during the replay match.
Hosts: Italy
Number of teams: 4
Winners: Italy

1972
Fallen favourites
After their win in Rome in 1968, Italy remain a strong team and the favourites to win at the 1972 championship. Unfortunately they don't make it past qualification, and Belgium, Hungary, the Soviet Union and West Germany are left to play for the cup. West Germany win their first-ever title in front of a crowd of over 43,000 people.
Hosts: Belgium
Number of teams: 4
Winners: West Germany

"Since its inception the tournament has been run by UEFA every four years"


Czechoslovakia play the Netherlands in the 1976 semi-finals

© Alamy

1976
New technique
Czech midfielder Antonín Panenka scores during a penalty shoot-out, not only setting up a win for his country, but also inventing an expression. Panenka stands before West German goalkeeper Sepp Maier as tensions rise. Will he shoot left or right? Instead the midfielder chooses to lightly touch the ball, causing it to loop over the goalkeeper's head. This technique is named the 'Panenka' and is successful when the keeper commits to a dive to either side of the net.
Hosts: Yugoslavia
Number of teams: 4
Winners: Czechoslovakia


Michel Platini (right) celebrates a goal against Portugal in 1984

©Getty

1980
Double up
In the sixth championship, the tournament size increases to eight teams. This involves having a group stage. The winners in the two groups compete against each other for the overall title, while the second-placed teams of each group play for third place.
Hosts: Italy
Number of teams: 8
Winners: West Germany

1984
Top scorer
Michel Platini, one of the most prominent football players of the early 1980s, becomes the top goal scorer of the 1984 tournament. This is the first official trophy that France wins for a team sport, and it is achieved within home stadiums.
Hosts: France
Number of teams: 8
Winners: France

1988
Spectacular strike
Regardless of being the favourites to win this championship, hosts West Germany are kicked out of the tournament during the semi-finals by the Dutch team. Marco van Basten of the Netherlands takes a risk to become a football hero. He is passed the ball while caught at an extremely tight angle to the goal. Instead of allowing the ball to leave the pitch for the corner, his spontaneous strike catches the inside of the net to become a famous winning goal.
Hosts: West Germany
Number of teams: 8
Winners: Netherlands

1992
Step-in win
Denmark initially don't even qualify for the 1992 Euros, but when they are called to say that Yugoslavia are no longer competing, the team rallies together. Despite their last-minute preparation, Denmark beat the reigning champions and make it to the final. There they secure a 2-0 win over Germany.
Hosts: Sweden
Number of teams: 8
Winners: Denmark


Denmark and Germany walk onto the pitch for the final (1992)

© Getty

2008
All-round winners
Spain becomes the second country to win all group-stage matches as well as the overall championship. While France achieved this first in 1984, there were half as many teams. Spain is also only the second team – since Germany's title in 1996 – to win the tournament undefeated.
Hosts: Austria and Switzerland
Number of teams: 16
Winners: Spain


The German team react to their loss in the 2008 final against Spain

© Getty

2012
Host dedication
Poland and Ukraine are elected as hosts for the first time, and they plan to impress. With half the stadiums in each country, five of them are built especially for the event. One of UEFA's conditions for hosting Euro 2012 is that new roads be built for the global visitors.
Hosts: Poland and Ukraine
Number of teams: 16
Winners: Spain

2016
Continuing popularity
In 2016 the number of teams that can qualify for the Euro finals increases to 24. 53 teams compete during the qualifiers to join France, who host for the third time. The country has ten stadiums in ten different cities for the championship. More qualifying spaces mean that more teams debut, including Iceland, Northern Ireland, Wales, Albania and Slovakia.
Hosts: France
Number of teams: 24
Winners: Portugal

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The origin of origami

What events shaped this ancient papercraft?


© Getty

Just as the process of creating an origami masterpiece comes with a series of subtle steps, the art form itself was a gradual evolution. The term 'origami' comes from the Japanese words 'ori', meaning 'folding', and 'kami', meaning 'paper'. This literal translation defines the art, which involves creating sculptures from single sheets of paper. No cuts are made, and no attachments are added. The shapes are made purely by folding.

Paper was first invented in China around 105 CE. Japan later adopted this material in the sixth century when Buddhist monks brought it over from China. Because paper deteriorates quickly over time, evidence to prove the earliest existence of origami has long decomposed. It's thought that the Japanese began using origami decorations shortly after paper reached the country, but it isn't known whether the idea came from art in China.

Today paper is cheaply available, but for the first thousand years that origami was crafted in Japan, the expense of the new product limited it to special occasions and formal ceremonies. It wasn't until the 1600s that the art form became a more common pastime.

Originally, origami artists were known to cut their creations to create more realistic features, but Japanese paper folding soon added styles from Europe. The European version of paper folding began with the use of napkins, which meant designs couldn't be cut. New techniques have also evolved during recent years. Origami artist Akira Yoshizawa is considered the master of modern origami. Before his death in 2005, he invented new techniques, such as wet-folding. This involves dampening the paper to allow curved shapes to be created.

Paper symbolism

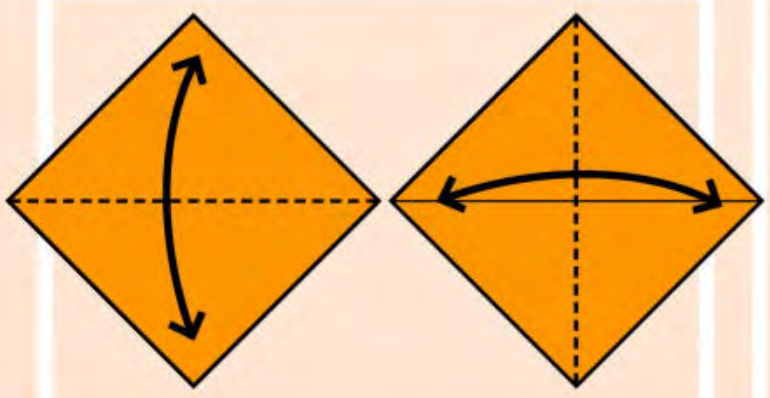
Stemming back to the earliest ceremonial uses of origami in Japan, different shapes can symbolise different qualities. In early Japanese weddings, origami butterflies were commonly displayed. The transition from caterpillar to butterfly was thought to represent the bride, becoming more mature, happy and carefree. Two origami butterflies were a symbol of a happy marriage. One of the most popular origami creatures today is the crane, a bird which according to Japanese folklore can live for a thousand years. This gave paper cranes connotations of good health and luck. One ancient legend says that anyone who folds a thousand paper cranes will be granted one wish.


© Alamy

Origami fish generally symbolise happiness, rabbits fertility and frogs good fortune

How to fold a fox

Make your own creature creation

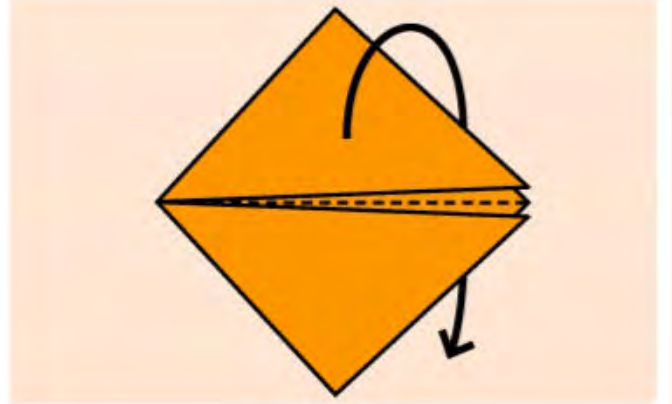


1 First folds

Take one corner of your paper square and fold it in half to the opposite corner, making a crease. Unfold it back into a square, then fold it in half again using the other two corners.

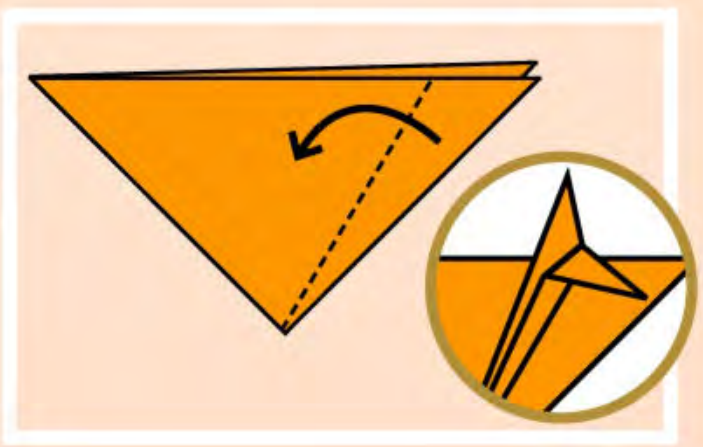
2 Folding in

With the crease horizontal, fold the top and bottom corners of the triangle into the centre. Use the crease to align the two folds in the middle.



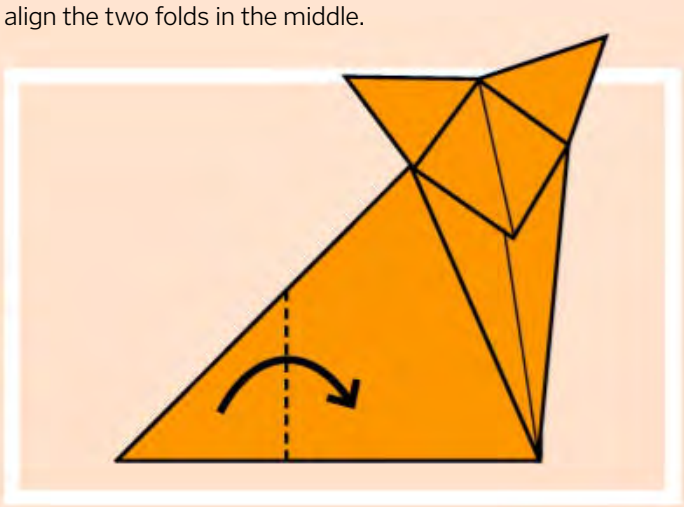
3 Small square

Now you have a small square, split into two triangles. Fold the corner of one triangle backwards to line up with the corner of the other.



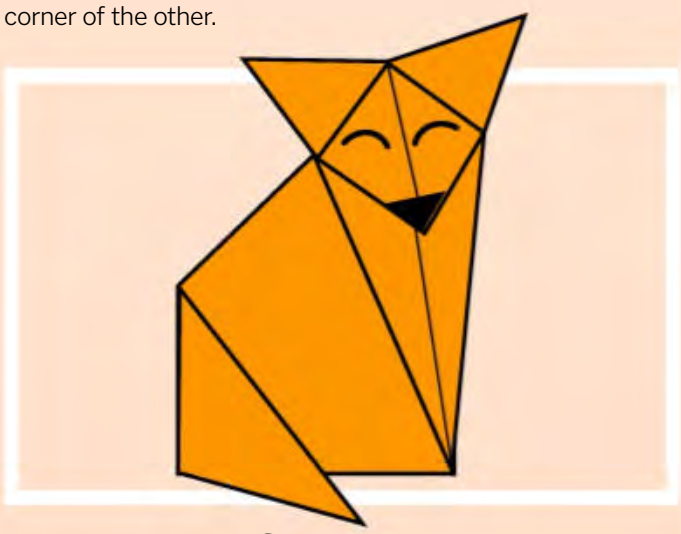
4 Making a face

Fold the corner, lifting only the top layer, at the angle shown by the dotted line. Lift the next layer from the same corner, open it up and flatten the top to make a diamond.



5 Bend the tail

Take the opposite corner and fold it forwards across the front of your design. This should make this corner look like the fox's tail.



6 Draw some features

Finish it off by drawing a fox's face onto the area you flattened out. Now you can stand your fox up straight to admire, using its tail to balance it.

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FUTURE

LIFESAVING VEHICLES

Words by **Ailsa Harvey**

When disaster strikes, these machines will race to your aid

Perhaps the most catastrophic element of an emergency scenario is its unanticipated nature. You don't expect to sustain an injury when you leave your house for a walk. You don't plan to return to see your house engulfed by flames. And you don't step into the sea thinking you'll get taken by the tide. So what can you do when you find yourself alone and in desperate need? Thankfully there are teams who are prepared for these events.

Each focused on a particular emergency, these squads are armed with vehicles to remove you from unforeseen dangers and save the day. Fire engines take their place in the station line, ready and waiting for the next alert, while ambulances store medical equipment for any possible encounter they could be faced with that day.

The technology incorporated into emergency trucks, helicopters, cars and boats makes them the most efficient at retrieving or

"Squads are armed with vehicles to remove you from dangers"

rescuing people in trouble. But it's modern communication technology that has largely enabled them to speedily assist us.

Originating in London in 1937, the UK's automatic emergency service number (999) is the world's oldest. Before this, police stations would be packed with people trying to report a crime. This created a disorderly service and left many missing out on help or not being seen quickly enough to make a difference.

As technology has advanced, rescue vehicles can be driven to the exact location that an emergency call was placed within minutes. For example, ambulance services aim to reach high-emergency situations in no longer than seven minutes. More people are using mobile phones to make these calls, which significantly increases a person's chance of survival.

The diversity of vehicles has also increased, with ambulances now able to save lives by travelling through the air and crossing water, as well as driving along roads. These are just some of the vehicles ensuring that no matter where an emergency presents itself, help will be sent to you.

© Alamy

Sometimes solo paramedics are dispatched on motorbikes for a speedy arrival at the scene

© Getty

5 RESCUE METHODS FOR DIFFICULT TERRAIN

Ski patrol

During an emergency on a snowy mountain, snowmobiles are the most efficient transport. These motorised vehicles are on skis so that the ski patrol team can speed over the soft surface.

© Alamy

Mountain emergency

Land Rovers are often used for mountain rescues. Four-wheel drive improves traction on the slopes, while the interior space allows a patient on a stretcher to fit inside next to a medic.

Source: Wiki/ Vauxford

Ice rescue

In colder areas of the globe, like Sweden, sheets of ice can cover large areas. Rescue hovercraft move quickly over a layer of air due to the smooth surface of ice creating less friction, reaching those who have fallen through in less time.

© Alamy

Navigating quicksand

Tracked vehicles and hovercraft are used by rescue teams to save people from quicksand. These vehicles are able to spread their weight across a large surface area to prevent sinking.

© Alamy

Saved from the waves

The speed and ease at which a jet ski can pick up surfers makes them lifesavers at big-wave events. Between waves, surfers can grab the back of jet skis, which can escape from waves over six metres high.

© Getty

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TYPES OF AMBULANCE

These vehicles vary based on the level of emergency

© Getty

Multiple-victim assistance ambulances are usually larger as they have more equipment to carry.

© Alamy

These ambulances transport patients when their case is not an emergency.

Patient transport service (PTS)

PTS vehicles are used solely for transport, and do not carry medicine or life-supporting equipment. They are only deployed for non-emergency transport of sick and injured patients. The vehicles' main priority is to bring patients to the hospital for an appointment.

Multiple-victim assistance unit (MVU)

Most ambulances can only cater for a couple of injured or ill patients. However, in some emergencies a larger group of people can become injured. At big gatherings or in the aftermath of a natural disaster, these larger vehicles can care for more victims. Often these vehicles will be sent to organised events as a precautionary measure.

© Getty

Mobile ICUs provide critical care during transit.

Mobile ICU

These ambulances contain some of the life-support machinery that can be found in the Intensive Care Unit at the hospital. Patients carried in these vehicles are at the highest risk and are supplied with life-saving drugs and hooked up to monitors and stabilisers during their transition to hospital.

Paramedic intercept

Sometimes a patient's condition can worsen, and the ambulance sent can no longer cover their needs. This is where paramedics can intervene. Upon a request for more supplies, paramedics can attend the scene, bringing equipment and expertise.

© Alamy

Paramedics usually attend a scene before ambulances arrive.

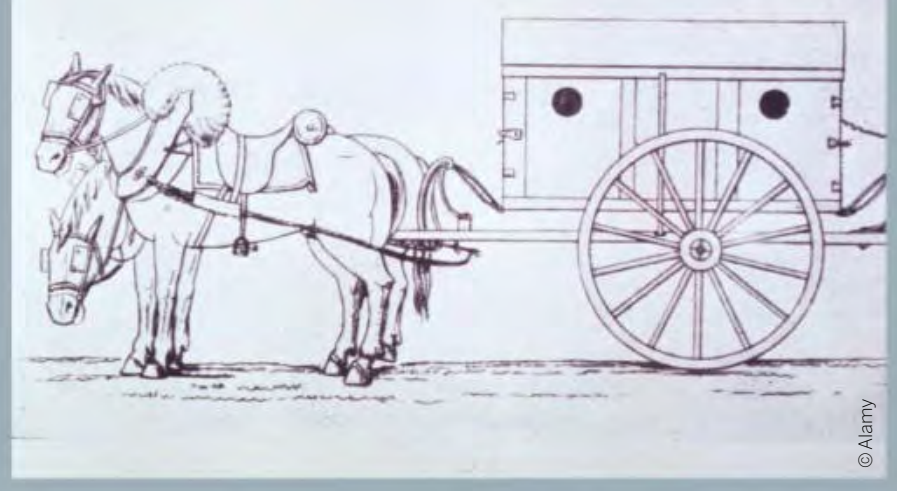
The history of 'mobile hospitals'

Today's ambulances are launched immediately following a call to the emergency services. They are equipped with machines and medicine to provide the best care. But before ambulances provided efficient transport to hospitals, the sick and injured often had to find their own way to one.

It was in the late-15th century that the term 'ambulance' was first used. Introduced by King Ferdinand II and Queen Isabella I of Spain, 'ambulancias' were field hospitals used to treat those wounded in battle. These were tents where soldiers were brought to be treated by medical practitioners.

300 years later, ambulances became mobile when a French surgeon named Dominique Jean Larrey designed a lightweight wagon. These could quickly transport soldiers across the battlefield to the tents, saving more lives. The first civilian ambulances provided horse-drawn transport in 1865, and the first motorised ambulances were used in World War I.

Larrey's mobile carriage of the late 1700s was dubbed a 'flying ambulance'



© Alamy

FIGHTING BLAZES

These trucks are well equipped to put out fires

Firefighters load equipment back onto the vehicles ready for the next dispatch

© Getty

Engine dispatch

A fire engine contains all the tools ready for an emergency. But in order for the vehicle to do its job, firefighters are trained to respond rapidly and dispatch fire engines as efficiently as possible. When a call is received, an alarm sounds throughout the fire station. The location of the call is relayed to the fire department. When using a landline, the exact address is recorded, but when using a mobile, it's the location of the nearest phone mast that is first received.

At the fire station, the type of emergency will be displayed on a screen alongside the incident location. Despite their title, firefighters are often called to emergencies other than fires. These include car crashes, floods and chemical spills.

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Inside a fire engine

What tools are used by firefighters?

Hose jets
These are used instead of the hose reel for more power and volume. Two firefighters are needed to control one.

Pike poles
This hooked tool can break walls to uncover fires. It can also be used to fetch items engulfed in flames.

Hose reel
For relatively small fires, these hoses are unravelled to the required length and used to direct water onto the flames.

Jaws of life
This hydraulic tool can cut through cars to free trapped people. It can pull two pieces apart or cut sections out.

Ventilation fan
These are placed in confined areas to suck out smoke. Fresh air is drawn in through gaps such as windows.

Breathing apparatus
Oxygen tanks are used for breathing when there is smoke or chemical fumes. These usually last for half an hour.

© Illustration by Adrian Mann

"Firefighters are often called to emergencies other than fires"

Upon arrival at the hospital, critical patients are taken straight to the emergency room.

© Getty

SEA RESCUE

Reaching safety
After being winched up to the helicopter, the rescue team will pull the saved individual into the aircraft.

Choice of approach
When the helicopter arrives at the scene, it will analyse the boat type, size and position.

Adaptable equipment
Depending on the condition of the casualties being lifted, air lifts can be carried out in harnesses, stretchers or baskets.

Rescue from water
If the person being airlifted is in the sea rather than on a boat, they are likely to be put into a metal basket.

Preparing for rescue
When radioing for help, the boat's crew will be briefed on what will happen. Loose items will need to be secured, as the helicopter will produce a downdraft.

Lifted from danger

How people are airlifted to safety from the sea

When the seas become ferocious, being caught in the waves can be life-threatening. For this reason, when people get into difficulties at sea, sending out more boats to save them isn't always the answer. This is when the rescue helicopters are sent in. Air-sea rescue is a vital way to evacuate people from the ocean while remaining in the air and away from the danger.

LIFE BOAT

How did simple rowboats become today's agile machines of the seas?

1785

The first lifeboats
Designed to be 'unsinkable', the first purpose-built lifeboat is invented by Lionel Lukin. He uses lightweight materials such as cork, with built-in pockets of air to keep it afloat and watertight compartments.

This depicts men bringing an early lifeboat to sea
Source: Wiki/Unknown Author

1890

Steam-powered
No longer relying on human strength to row, the Duke of Northumberland is the first lifeboat to use steam power. Burning coal on board is not easy, however, and this method is soon replaced.

1905

Motor lifeboats
Petrol engines are fitted to existing lifeboats and trialled in 1904 before they enter service the following year. They give the boats more power and makes them easier to control.

"Air-sea rescue is a vital way to evacuate people"

Onboard care
Stretchers are fitted onto the helicopter on a rail. These are locked into place to secure the casualty.

Constant monitoring
Serving as a portable ICU, medics on board can provide oxygen and various medicines to the patients.

Manoeuvrable equipment
Chairs can slide on the rails that stretch along the length of the helicopter. They also rotate to provide the medic with optimal patient access.

First rescue
If someone on the boat is injured, they will be the first to be rescued. One member of the rescue team will secure them to the winch.

© Illustration by Adrian Mann

AR ZONE! SCAN HERE

Deep Trekker's vehicles can capture footage in depths of up to 200 metres.

Underwater robots

Emergency searches aren't always deployed to save lives. Often search teams are looking for objects, sunken boats or victims of marine accidents. All of these underwater operations used to be carried out by professional divers, but technology now enables robots to do the initial search. This saves divers' energy and increases their safety until they are really needed.

These robots can be remotely operated from a ship above the water. Connected via cables, operators can command the machine as it trawls the seafloor. This vehicle is equipped with the tools it needs to see, feel and scan as it moves. Cameras allow the rescue team to see the robot's surroundings, while lights and a sonar system help it to view its surroundings clearly. The vehicles even come with a robotic arm to grab small objects and cut materials that may be obstructing the route.

Inflatables on beaches allow a fast response
© Getty

Inflatable design
Smaller, inflatable lifeboats are designed to rescue people closer to land. Easier to navigate in small spaces, this alternative is still used today.

1963

Mersey class
These lifeboats are designed to enter the ocean from the beach. Being lightweight with an aluminium hull, they can be transported on a carriage and launched from any point along the beaches.

1988

The Severn class is the largest RNLI lifeboat
© Getty

Severn class
These are the result of rigorous testing to make lifeboats faster. Lifeguards aim to reach farther out at sea while retaining optimum safety. The Severn class can travel at 29 miles per hour.

1996

Tamar class
This class manages the same high speeds as the Severn class, but improves on safety inside the boat. With added springs and suspension to the seats, the crew sustain fewer back injuries when being thrown around by the waves.

2005

Shannon class
These modern, all-weather lifeboats are powered by water jets rather than propellers. The boat is designed to last ten hours in extreme stormy conditions. If necessary, the crew can use its speed to beach the boat to be recovered later.

2013

Shannon class boats are over 13 metres long
© Alamy

Cars are packed full of safety features and undergo strict testing

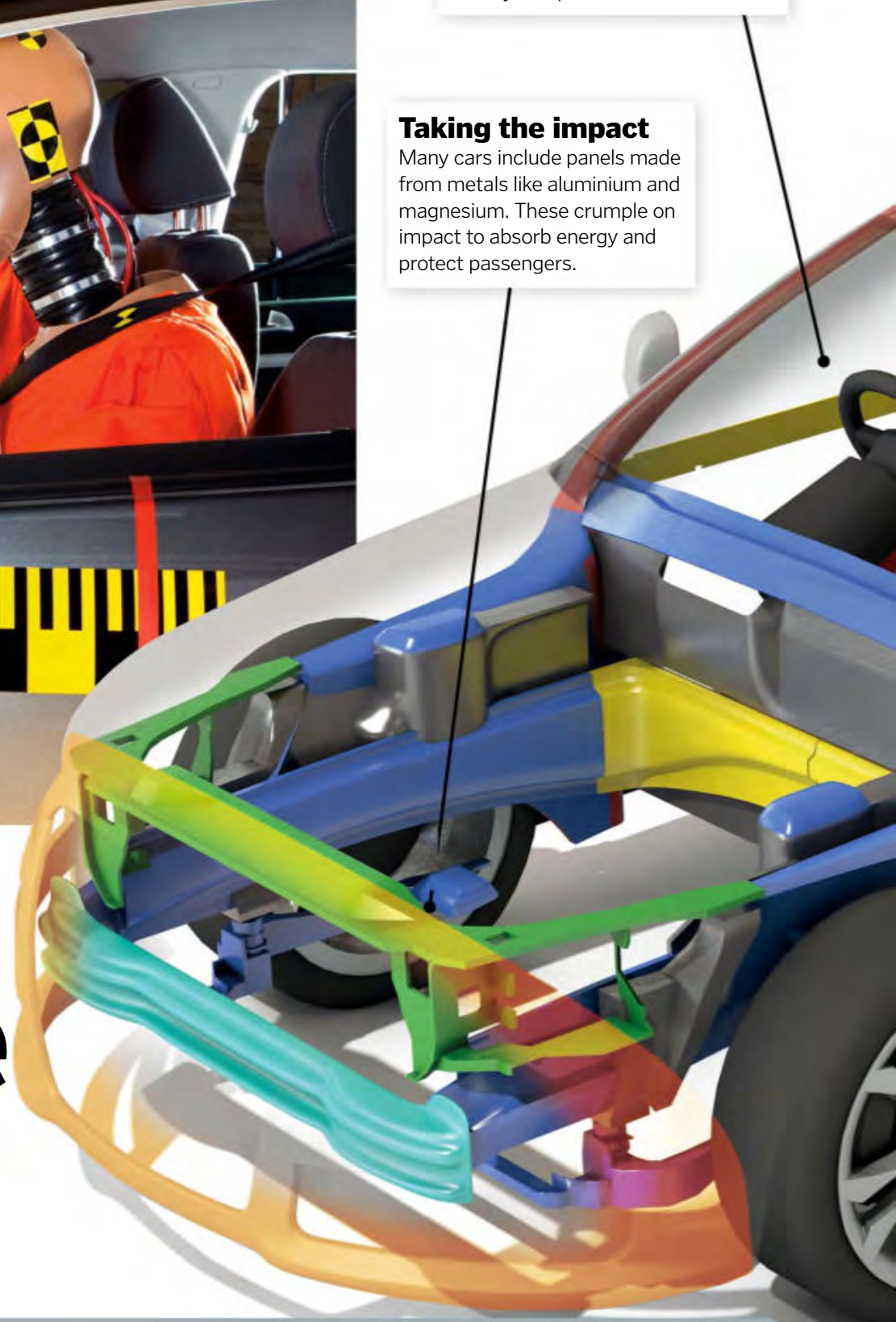
© Getty

Framed glass windows

Glass used in cars is designed to stay intact or fracture into rounded fragments so passengers aren't hurt by sharp shards.

Taking the impact

Many cars include panels made from metals like aluminium and magnesium. These crumple on impact to absorb energy and protect passengers.



How cars keep you safe

Delve beneath the bonnet to discover the impact manufacturers are making on car safety systems

Words by **Mike Jennings**

It's easy to forget when cars are integral to our everyday lives, but think about this for a second: they're metal boxes that can drive at excessive speeds to transport human bodies made of fragile flesh and bone. Safety is crucial. That means every part of a modern car is designed with protection in mind, from the engine to the bumpers and everything in between. And with safety so important, some parts of a car get more attention than you might initially expect. Let's look at the doors and side panels as an example.

These parts of a car are often closest to the driver and passengers, so they've got to be sturdy. To that end, car manufacturers have developed side-impact designs that include incredibly strong steel panels, extra metal inside the doors to brace against impacts and columns to help cars keep their shape during collisions.

A load of hot air

Airbags are one of the most common and crucial safety features found in modern cars, and they've been around for a long time – they were first fitted to cars in the 1970s. In modern cars, airbags are controlled by a little computer with an accelerometer that detects if there's a sudden change of speed. If a car decelerates quickly enough, the computer ignites a tiny propellant that generates nitrogen gas to expand into the airbag. This forces the bag out of its casing and into the car, where it cushions people from sudden dangerous collisions, and then the nitrogen gas escapes from the bag.

Airbags work because of incredibly fast chemical reactions, and they're used all over modern cars: they can usually be found in the steering wheel, the doors and side panels, towards the floor of the vehicle to protect people's knees and even in the roof.

© Getty

Airbags for use in automobiles were patented by John W. Hetrick in 1952

Safety first

Here are five key safety features that you'll find in most modern cars

Steered from danger
The metal that holds the steering wheel collapses in accidents so that drivers aren't thrust forward into a static column.

Pump the brakes
Computer-powered brake systems stop cars from skidding, meaning cars stop smoothly and safely instead.

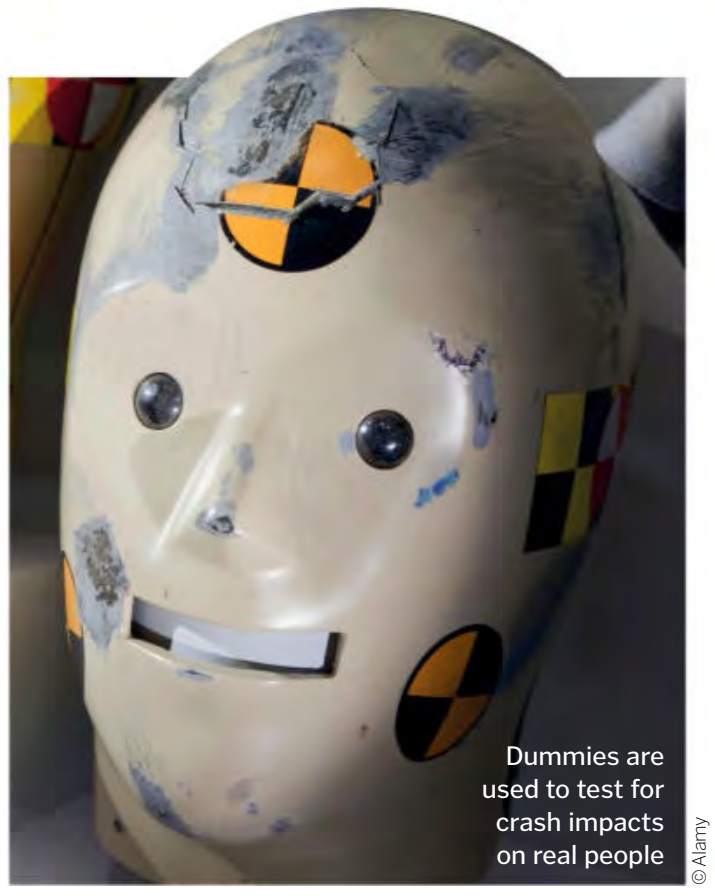
Strong steel
Side collisions can be more dangerous because passengers are nearer the impact, so modern cars use the strongest steel here.

© Illustration by Adrian Mann

The original Side Impact Protection System – or SIPS – was developed by Swedish car manufacturer Volvo and started appearing in its cars in the early 1990s. Volvo still includes SIPS technology in its cars, as does every other manufacturer with equivalent safety designs, albeit under different names.

Go beyond the sides of a car and you'll find an incredible array of safety features that protect every inch of a modern motor. Designers first started to incorporate basic impact protection into cars in the 1930s, and since then vehicles have become safer and far more sophisticated.

These days car safety features are organised into two camps: passive features like the car's frame, airbags and seat belts protect passengers after a collision, while active features like cameras, sensors and brakes work all the time to keep the car stable.



Dummies are used to test for crash impacts on real people

© Alamy

Roll cage

The roll cage is a giant, strong metal frame that surrounds the passenger compartment, which helps protect against impacts from any direction. If you'd like to see a roll cage in action, just look at GT and touring car racing. These speedy cars have big, tubular cages that are extremely obvious when you see in-car footage.

Not every road-going car has a roll cage built in though. While these cages do improve safety, they add weight and therefore hamper fuel efficiency. Manufacturers can make their vehicles safe using other methods, like stronger roof panels and other structural additions throughout the design.

© Getty

A sturdy metal roll cage is vital in many vehicles

Fascinating fastening

Seat belts are one of the oldest and most important safety features in cars. They were first introduced when a Californian doctor studied the links between seat belts and collision injuries, finding that seat belts made a huge difference. They work simply: the belt secures tightly into the buckle, and when a crash is detected in the car, the belt tightens so people aren't flung forward.

Older cars used seat belts that just stretched horizontally across passengers, but modern cars use three-point designs that also cover the chest area. That system does a better job of spreading energy out during impacts, which keeps people safer.

© Getty

Seat belts are simple, but they're life-saving safety devices

HOW ARE HOUSES BUILT?

FROM PLOT-PICKING PROTOCOLS TO FINALISING UNIQUE DESIGNS, FOLLOW THE PROCESSES THAT BUILD OUR HOMES

Words by **Ailsa Harvey**

The oldest known civilisations first cropped up over 5,000 years ago. As these communities began settling in one area, they gathered the materials around them to create long-lasting shelters. Millennia have passed, and today we use a growing abundance of materials, including bricks and cement, to build the best possible homes that stand the test of time. But what processes are used today to place a roof over our heads?

You can no longer gather the materials and build a house wherever you please. Before you can start any work that includes building new houses, making significant changes to your home or changing the primary use of a building, planning permission needs to be obtained. This prevents houses appearing without notice where they could invade the privacy of other home owners, drastically increase traffic or reduce habitats in protected areas. Requests are sent to local councils, often with the help of architects and planning consultants.

When building eventually commences, workers on construction sites analyse small details carefully. From the area of a plot to the measurements of a house's frame, greater accuracy improves building times and makes the environment safer for construction and living. Each person on site has been trained in specific roles, and as a team their specialised skills combine to produce the highest quality buildings. Each successful build is not merely another structure added to the landscape, but a personal space for someone to call home. Around 90 per cent of our time is now spent inside, and 70 per cent of this takes place within the walls of our own homes. Being used as areas to both work and wind down, we need houses to be built to the highest standards to keep us safe and comfortable every day.


A frame is built first to create the roof's shape

© Alamy

"Each person on site has been trained in specific roles"

Construction through the centuries

Ancient houses were built using more perishable materials than the sturdy stuff we use today. The ancient Egyptians, for example, began making flat-roofed homes with wood and Sun-dried clay bricks in 3100 BCE. Around 600 years later, people discovered that baking the bricks in fire made the clay stronger, while adding a silicate glaze made them more resistant to storms.

During the Middle Ages, in the 15th century, houses in Europe were built with stone or brick foundations. Whole tree trunks were used as corner posts and wooden beams joined them together to create support. The walls were typically filled with a clay mixture and straw, and most Tudor houses had a thatched roof. These consisted of layers of dry vegetation, such as straw and wheat, which drew water away from the layers beneath.

In the 1800s, during the Industrial Revolution, bricks began to be mass produced in factories instead of being made by hand. Brick became more affordable as a building material, and other strong materials, such as steel frames, became widespread.

There are still more than 60,000 thatched roofs in the UK today

© Getty

IMPORTANT ROLES

Many different people with specialised skills work together to construct a home

© Getty

Builder

Physically assembling the house mainly comes down to the builders. They also measure materials and carry out precise checks to keep brickwork and other structures straight and consistent.

© Getty

Architect

The unique design of each house is formulated by a qualified architect. Architects help create a look that their client desires, while also keeping plans safe and functional.

© Getty

Civil engineer

Site engineers oversee construction and advise plans based on their knowledge of mechanical function. This will include moderating drainage systems, driveway functionality and utility positioning.

© Getty

Plumber

Plumbers make sure heating and water systems are in place and functioning correctly to all appliances. They can also add waterproofing to the walls and roof of a home.

© Getty

Electrician

Making electrical installations during building is essential, ensuring that electricity can reach all rooms. Electricians also carry out risk assessments when wiring.

© Getty

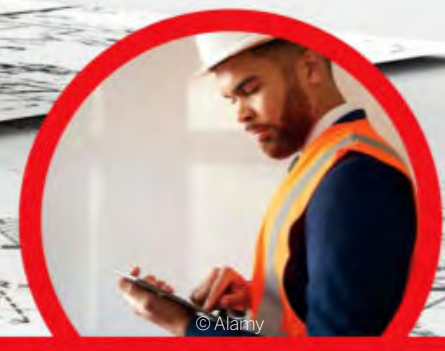
Interior construction

When the main body of the house is completed, people work on the internal construction and decoration, like plasterers, who apply plaster to smooth out walls and ceilings.

© Getty

Site manager

With everybody carrying out separate roles working together to form a complete house, it's down to a site manager to make sure each task is being completed on time.



© Alamy

Quantity surveyor

A quantity surveyor is responsible for tracking finances. This includes calculating the prices for different materials, valuing work once completed and sticking to an overall budget.

© Getty

AR ZONE!

THE BUILDING PROCESS

How materials are manipulated and combined to form strong, safe houses

Framing
A wooden skeleton is created to act as a vertical building guide. Pieces of the frame are securely attached using metal strapping.

Waterproofing
A weather-resistant membrane is built beneath the bricks. This waterproof membrane covers every outer area of the house, including the surfaces of the foundations.

Building exterior
Brick walls and other chosen materials are used to build the presentational exterior. This includes design features such as balconies.

Designing for power lines
Holes are knocked into the concrete for power lines to be fed through. Pipes are placed around the cables to protect them.

Watch a two-storey house being built in this two-minute video

© Getty

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Clearing space
Using bulldozers or other machines, the area is cleared of trees, rocks and debris.

Foundation excavation
A trench with a depth of at least one metre is measured and dug out in the area allocated to the house.

Bricklaying step by step

© Alamy

1 Start at the corners
Place the first bricks at each corner. After laying a few, you will be able to place down a line to see if they have been aligned straight.

2 Mix the mortar
To make the mortar, add five parts sand to one part cement and mix. Then add water to the centre until smooth but still compact.

3 Lay bedding mortar
Place a line of mortar along the string line. This base should be around two centimetres thick. Place the first brick onto the mortar.

4 Build brick pillars
Add more mortar to the end of the placed brick and press the next brick into contact to stick them together. Build the wall up at the pillars.

Steel frames can be used as a stronger and more durable alternative to wood

© Getty

"We need houses to be built to the highest standards"

Preparing utilities
The framework for electrical appliances, plumbing and sewerage can be added into the structure. This involves positioning wiring and pipes.

Designing interior
The interior walls, flooring and other permanent structures such as cabinets are the last to be fitted, and only once the outer structure is complete.

Installing footings
At the very bottom of the trench, concrete slabs are placed. These are called footings, which follow the floor plan to support the house's weight.

Filling the space
Starting at the corners, the bottom of the house's walls are built to just above ground level. Then the remaining trench is filled with a concrete mixture.

© Alamy

5 COMMON BUILDING MATERIALS

1 Wood
Wooden panels give houses a natural look and are relatively easy to cut and shape. This choice requires homeowners to regularly clean and maintain the panels.

© Getty

2 Synthetic stone
This material is made from a mixture of sand, cement and loose stone. It can cover the exterior of housing to look like almost any stone.

© Alamy

3 Stucco
This is a cement-based house siding which contains aggregate for a textured finish. Stucco is long-lasting in dry climates.

© Getty

4 Vinyl
These plastic panels are cheap and can be placed over any existing materials. They are quick to install and come in many different colours and textures.

© Alamy

5 Fibre cement
This combination of cellulose fibres, sand and cement is frost-free and fire resistant. The panels are easy to paint, allowing for a range of designs.

© Alamy

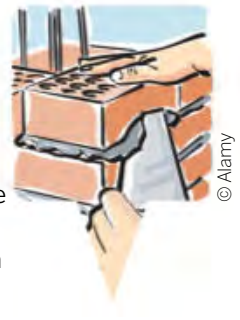
5 Cut to size
When an end requires a smaller brick, use a bolster chisel. Place the brick on its side to create neat, precise cuts.

6 Keep pillars high
Keep the pillar height at least one level higher for stability. Place the centre of each brick over the mortar bond of the bricks below.

© Alamy

7 Add soldier course
A soldier course is when end bricks are placed vertically along the top edge of a wall. This can keep the wall looking tidy.

8 Finishing touches
Use a rounded tool to scrape away any excess mortar. This will keep the sections between bricks looking smooth.



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What's inside a fridge?

How a cycle of evaporation and condensation keeps food cold

Words by **Scott Dutfield**

Keeping some foods cool is paramount in delaying the growth of harmful bacteria. Temperatures above four degrees Celsius are the optimal conditions for many bacteria and fungi to grow and spoil food. If food is stored below that temperature, its longevity can be increased.

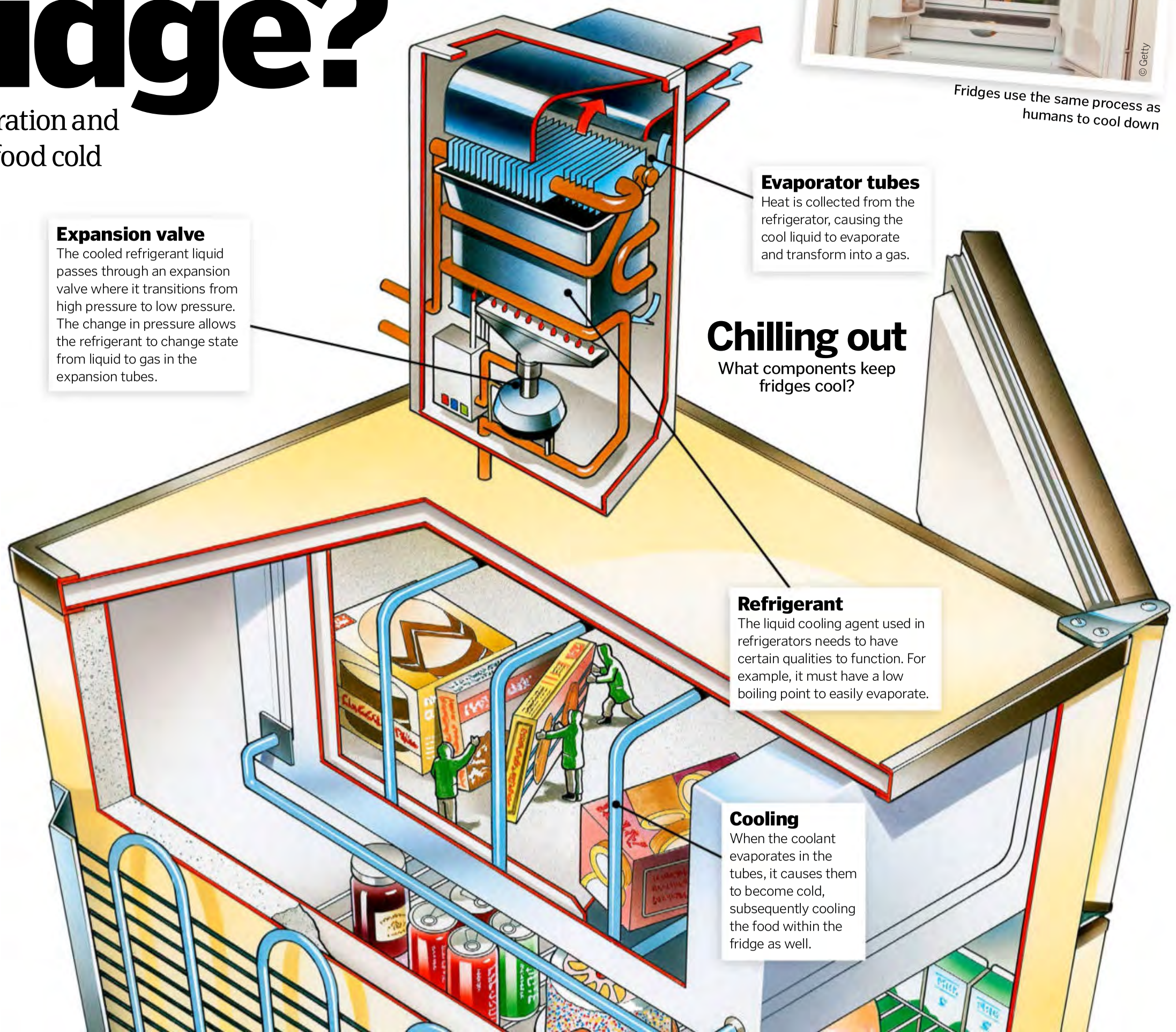
Across thousands of years, humankind has developed different methods of refrigeration to battle bacteria and store food safely. The ancient Greeks dug snow pits to store food, and during the 18th century Europeans used salted ice as a natural freezer. However, it wasn't until the early 1800s that refrigerators similar in design to today's kitchen essentials were developed.

Modern-day refrigerators rely on a process called evaporative cooling to function. Evaporative cooling depends on the change of a liquid's molecular state into a gas via evaporation. This process can remove heat from a surface and lower the surrounding temperature. In human biology, this is the natural cooling process of sweating. Once sweat has formed on the skin, body heat

Fridges use the same process as humans to cool down

Chilling out

What components keep fridges cool?



Expansion valve
The cooled refrigerant liquid passes through an expansion valve where it transitions from high pressure to low pressure. The change in pressure allows the refrigerant to change state from liquid to gas in the expansion tubes.

Evaporator tubes
Heat is collected from the refrigerator, causing the cool liquid to evaporate and transform into a gas.

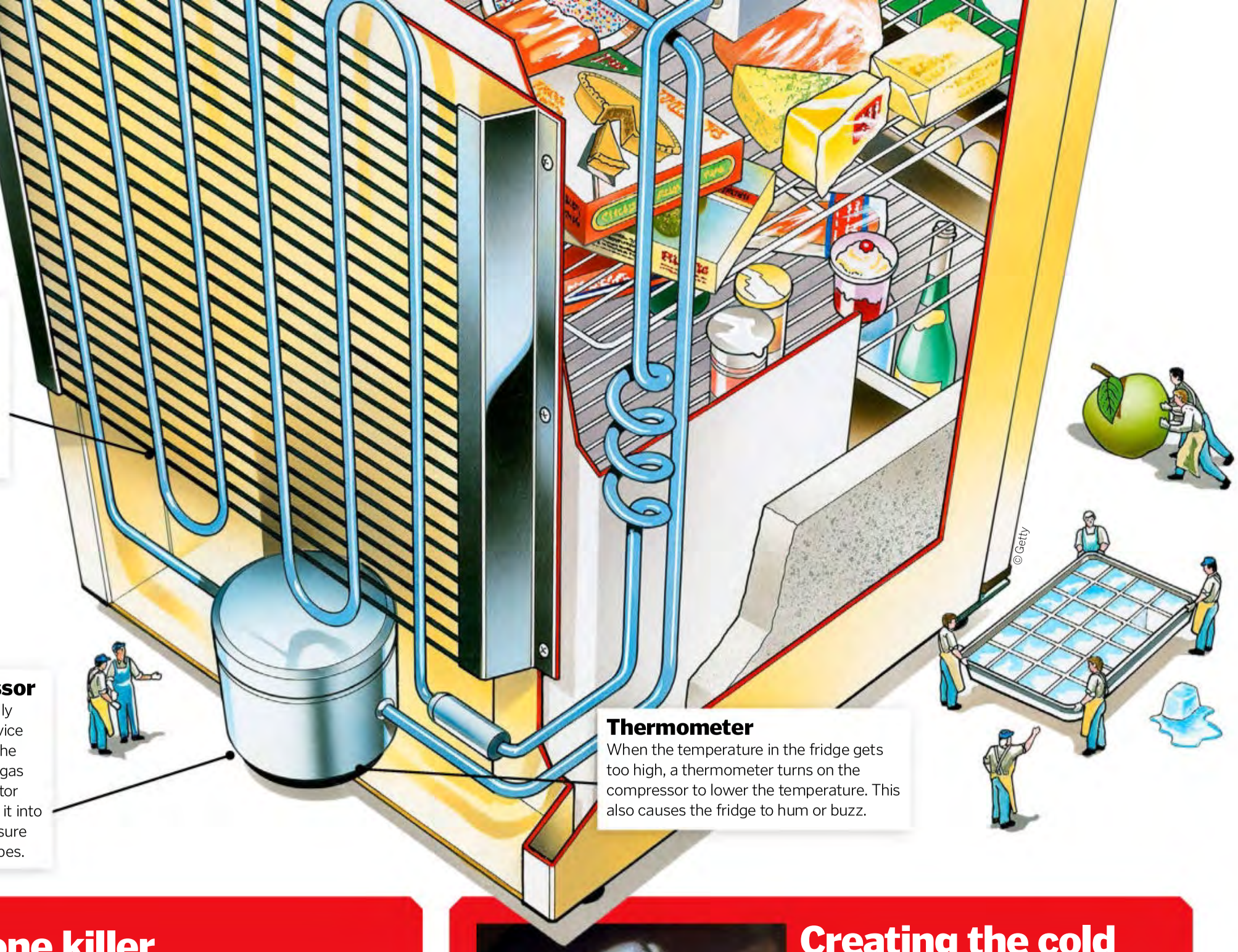
Refrigerant
The liquid cooling agent used in refrigerators needs to have certain qualities to function. For example, it must have a low boiling point to easily evaporate.

Cooling
When the coolant evaporates in the tubes, it causes them to become cold, subsequently cooling the food within the fridge as well.

evaporates the liquid into a vapour, taking the heat from the skin with it and leaving a cooling sensation behind. Similarly, applying rubbing alcohol to the skin results in a quick chill because the low boiling point of alcohol makes it evaporate faster.

In place of skin, refrigerators have an internal network of pipes that run a liquid coolant called a refrigerant. The refrigerant is heated and evaporates, then the vapour is funnelled to external coils at the back of the machine where the heat is released, leaving the internal pipes nice and cool.

Evaporative cooling is the predominant method used in refrigerators, though researchers are developing innovative ways to keep our food cool, including the investigation of molecules called neopentyl glycol crystals as an alternative. When these crystals are held under pressure using magnets, they become cold very quickly.



Condenser tubes
At the rear of the refrigerator, a series of condensation coils facilitate the hot gas collected from inside the fridge to release the heat into the ambient air and condense back into liquid.

Compressor
This electrically controlled device compresses the low-pressure gas from evaporator tubes, driving it into the high-pressure condenser tubes.

Thermometer
When the temperature in the fridge gets too high, a thermometer turns on the compressor to lower the temperature. This also causes the fridge to hum or buzz.

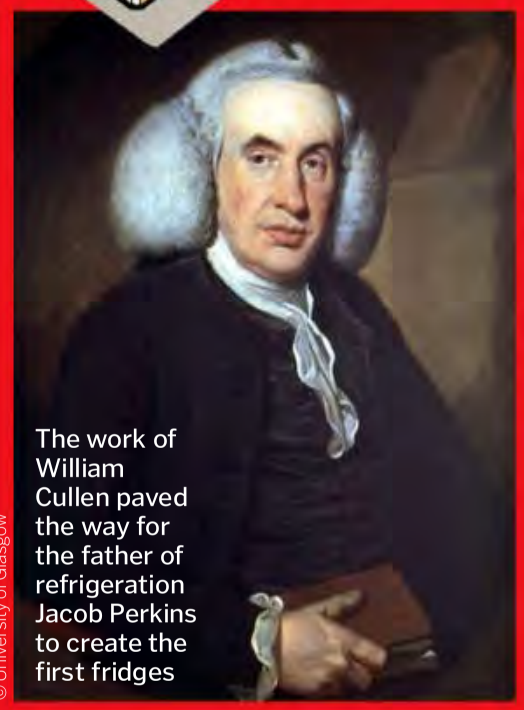
© Getty

Ozone killer

In the 1920s, early versions of the modern-day fridge used refrigerants called chlorofluorocarbons (CFCs). These compounds offered a safer alternative to the flammable and toxic chemicals that had been previously used. Although safer in terms of preserving human health, their environmental impacts were catastrophic. Upon release from damaged or discarded refrigerators, CFCs have a nasty tendency to react with oxygen molecules in the ozone and cause holes in it. The ozone is crucial in protecting life on Earth from deadly ultraviolet radiation from the Sun. Having discovered the environmental cost of using CFCs, from 1974 large parts of the world began banning their use. Currently 197 countries hold the ban. Refrigerator engineers turned to a less damaging compound called hydrofluorocarbons (HFCs), which remain in common use in fridge production.

The ozone hole above the South Pole on 7 October 2008
©KNMI/ESA

Creating the cold



The work of William Cullen paved the way for the father of refrigeration Jacob Perkins to create the first fridges
© University of Glasgow

The modern-day refrigerator resulted from the collaborative effort of scientific minds over many years, starting with Scottish inventor William Cullen. In 1748, Cullen demonstrated the basis for the first artificial method of refrigeration at the University of Glasgow. Cullen used a pump, vacuum and a volatile compound called diethyl ether, which when heated evaporated, creating a cooling effect on the apparatus. Later, in 1835, American inventor Jacob Perkins invented the first refrigerator to use a vapour compression cycle. It was informed by Cullen's work with the design assistance of another inventor, Oliver Evans. This system used compressed vapours from liquid ammonia as the refrigerant.

DID YOU KNOW? *A refrigerator uses around ten per cent of the total electricity consumed in an average household*

BRAIN DUMP

Because enquiring minds need to know...

MEET THE EXPERTS

Who's answering your questions this month?


JO ELPHICK


LAUREN EYLES


ANDY EXTANCE


ANDREW MAY

Research suggests that Neanderthal craniums were sometimes larger than that of *Homo sapiens*

DID YOU KNOW?

Neanderthal brains were much bigger than ours

HISTORY

Why couldn't Neanderthals evolve into a wiser human?

Emma

Although people think Neanderthals were unintelligent, they created and used tools, although they weren't as smart as the *Homo sapiens* that walk the Earth today.

Neanderthals went extinct in Europe 40,000 years ago, likely due to the changing climate. While *Homo sapiens* ate a variety of foods, Neanderthals feasted on woolly mammoths. When they moved to warmer climates, they were left without food. As they interbred with humans, their DNA mixed with ours. It could be argued that Neanderthal DNA did evolve into wiser humans by becoming part of the human race that we recognise today. JE

© Getty

WANT ANSWERS? Send your questions to...

How It Works magazine @HowItWorksmag @howitworks@futurenet.com

SCIENCE

What is body odour?

Azeem Patel

The smells of different parts of our body are caused by many different chemicals, often containing the element sulphur. These chemicals are usually made by bacteria. In our armpits there are roughly a million bacteria per square centimetre. They take normal molecules in sweat and turn them into smelly ones. **AE**

DID YOU KNOW?

Bacteria turn unsmelly chemicals in sweat into smelly ones

© Getty

TRANSPORT

Can the police commandeer any vehicle whenever they like?

Jamie Poster

Police have the right to commandeer a private vehicle in a number of countries, including the US and UK. They can even insist that you stay in the vehicle and help apprehend a criminal. This old law is known as 'posse comitatus', and is still used today when necessary. **JE**

© Getty

© Getty

TRANSPORT

Is there a speed limit for aircraft?

Alex Read

Absolutely. Aircraft are limited to 250 knots when travelling below 3,050 metres above sea level. At 915 metres or close to an airport, they must reduce their speed to 200 knots. **JE**

© Getty

There are many different types of plant milk available today

SCIENCE

How do they make milk out of oats, almonds or soy beans?

Sean Curtis

In each case the milk-maker puts protein and other healthy nutrients from the plant ingredients into water. This often means soaking the ingredient for up to 12 hours. After that they can be ground into a smooth paste. Or instead of soaking the ingredient, the milk-maker just grinds it up while dry, into a powdery flour. Either the paste or the flour can then be mixed with water. Sometimes the milk is strained, separating the liquid from fine gritty bits. Usually milk-makers add other ingredients, like gums to thicken the milk and vitamins to make it healthier. **AE**

BRAIN DUMP

The radio telescope array used by Australian astronomers to discover odd radio circles

© CSIRO (Commonwealth Scientific and Industrial Research Organisation, Australia)

SPACE

Is there an observable object in the universe that is a complete mystery to science?

Sophie Mueller

When astronomers observe a new type of object, no matter how strange, theories to explain it usually emerge within a few years, so the best place to look for a complete mystery is in a brand-new discovery. A current contender is a class of objects dubbed 'odd radio circles', or ORCs. These are large, highly circular objects, seen at radio wavelengths, which are brighter at the edge than the centre. They were discovered by Australian astronomers in late 2019, and to date – with at least five such objects known – no one has a convincing explanation of what they are. **AM**

SCIENCE

How do we create sparkling water?

Arthur Chayun

It's made from ordinary still water by injecting carbon dioxide into it to create the bubbles. Another term for it is carbonated water, and it can also occur naturally. **AM**

© Alamy

© Getty

SCIENCE

Why does household dust build up even when the doors and windows are closed?

Daniella Appleton

Household dust is made of many things, including our dead skin, hair and threads from our clothes. As these things fall off us, dust piles up on furniture and floors. **AE**

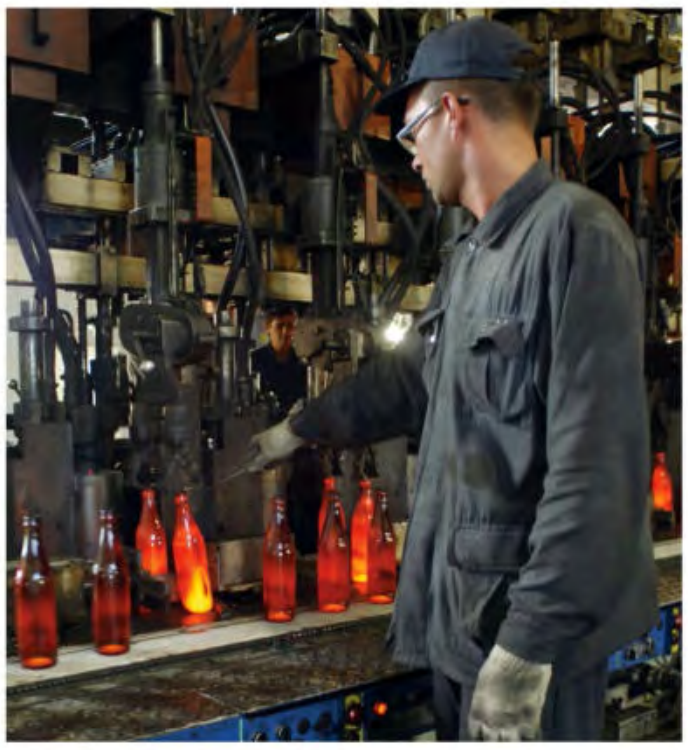
© Getty

TRANSPORT

Why don't they make cars out of plastic?

Sam Humphrey

Cars bodies and engines are mostly made of metals like steel and aluminium. These metals are strong enough not to break in a crash, but most plastics aren't. A petrol car engine made out of steel is powered by regular explosions. A plastic engine would break apart and burn. However, about half the parts used in cars are now made of plastic. A lot of plastic parts are inside the car, like the dashboard. **AE**



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TECHNOLOGY

How does bottle mass production work?

Alan Jones

The process still involves glassblowing, but not with human lungs. Instead, compressed air is used to blow molten glass into a line of moulds in a machine such as the one seen here, which allows dozens of bottles to be made at the same time. **AM**

© Getty

HISTORY

Did Italians invent spaghetti before the Chinese invented noodles?

Louise Maxwell

The legend that explorer Marco Polo brought noodles back to Italy from China, instigating the invention of spaghetti, is almost certainly a myth. Food historians believe that the two foods developed in parallel from entirely separate sources. Early pasta was used by the Greeks in 1000 BCE, while the earliest known noodles, discovered by archeologists in 2005, were made 4,000 years ago in China. Although the two foods developed separately, noodles most likely came first. **JE**

Everyone loves spaghetti and noodles, but which came first?

SCIENCE

Why can't we see in more colours?

Francesca Lennon

The basic answer is that it's because of the 'cone' cells in our eyes that detect coloured light. They're only able to detect some of the possible colours of light. Some insects and animals can detect more colours, like ultraviolet light. But in another way this is a hard question that even the smartest people struggle with. Do we see as many shades of green as you? Right now we just don't know for sure. AE

How many shades of green do you see? Does another person say the same thing?

© Getty

BRAIN DUMP

SPACE

What is the Oort Cloud? How is it different from the Kuiper Belt?

Kristina Bowler

Both the Oort Cloud and the Kuiper Belt are regions of the outer Solar System, and both can occasionally send comets plunging into the inner Solar System. The Kuiper Belt is a doughnut-shaped ring just beyond the orbit of Neptune, while the Oort Cloud is a thick, spherical shell hundreds of times farther away. And while we can see objects in the Kuiper Belt – including Pluto – the Oort Cloud is too far away to observe directly. AM

DID YOU KNOW?

The Oort Cloud may extend halfway to the next star

Exploded diagram showing our planetary system (top), the Kuiper Belt (middle) and the Oort Cloud (bottom)

© Getty

TRANSPORT

How do they paint cars to look so shiny?

Habib Kerr

When cars look shiny, it's because of the paint ingredients. Metallic paints contain shiny aluminium particles, and pearlescent paints give cars a shimmering shine. That's thanks to tiny crystals of rocky ceramic materials such as mica and titania. To stop them fading they have a protective see-through coat on top. **AE**

© Getty

ENVIRONMENT

What will happen to all the face masks that are dropped on the ground?

Matthew Garner

Disposable face masks on the street damage the environment and wildlife. These surgical masks are made from thermoplastic polypropylene, and many will end up in rubbish dumps, eventually finding their way into oceans via rivers or sewers. Once there, the plastics they contain could remain in the water for up to 450 years, breaking down into harmful microplastics that can be ingested by marine life and then travelling up the food chain to humans. **LE**

© Alamy

ENVIRONMENT

Is the keratin in my nails exactly the same as the keratin in rhino horns?

Wendy Key

The material keratin is actually a type of molecule called a protein. We humans have it in our hair and nails. The reason these two materials are so different is thanks to how proteins are made. They are put together from building blocks called amino acids. Rhino horns are made of keratin with slightly more of some amino acids containing the element sulphur, so it's not quite the same as human keratin. Sadly people hunt and kill rhinos because they think rhino horns have medical benefits – but these rhino hunters might as well chew their own fingernails. **AE**

Rhino horns are made of keratin, like human hair and nails

© Getty

© Alamy

SCIENCE

What is the memory metal in glasses made of?

Holly Watkins

There are a lot of shape-memory alloys, but a common one is nitinol, a mixture of nickel and titanium. When heated up, nitinol always returns to its original shape. **AE**

The paper industry uses vast amounts of wood, clearing huge areas of forest

© Getty

ENVIRONMENT

Is recycling actually beneficial for the environment?

Vanessa Chen

Yes! There are many ways recycling is beneficial to the environment: it helps reduce the demand for natural materials such as wood for paper products, so fewer trees have to be cut down to supply the paper industry. Oil is used to create new plastics, and the less we depend on this fossil fuel, the better. The production of both wood and oil as raw products can negatively affect many ecosystems. Recycling also reduces the need for other harmful waste disposal practices, such as landfill sites or incinerators, both of which contribute to greenhouse emissions. **LE**

BOOK REVIEWS

The latest releases for curious minds

Grow, Forage and Make

FUN THINGS TO DO WITH PLANTS

- Author: **Alys Fowler**
- Illustrator: **Heidi Griffiths**
- Publisher: **Bloomsbury**
- Price: **£9.99 / $15.49**
- Release: **Out now**

Any botanist or green-fingered gardener will tell you that the fruit and vegetables readily available in the supermarket are only a fraction of the edible plants that you can grow in your garden, or forage for in the wild. Nasturtiums, for example, are a common species of pretty flowers that come in various shades of yellow and red, and are completely edible: root, leaves, flower – the lot. They have a nice, peppery flavour that works well in salads, and you'll sometimes see celebrity chefs use them on the television.

If you're not much for growing your own food then that fact might come as a surprise to you, and there's more of this kind of revelation in Alys Fowler's *Grow, Forage and Make*. It's very much a hands-on guide to using the garden not just as a vegetable plot, but for wildlife spotting, cultivating eco-friendly habitats and even making your own paper.

Each turn of the page introduces new ideas for making use of the space that's literally on your doorstep, with how-to guides on foraging for roots, making gardening implements, encouraging beneficial insects and, of course, growing a variety of tasty crops. There's even a handful of art projects that use garden plants, and not just your garden-variety flower pressing.

> *There's even a handful of art projects that use garden plants*

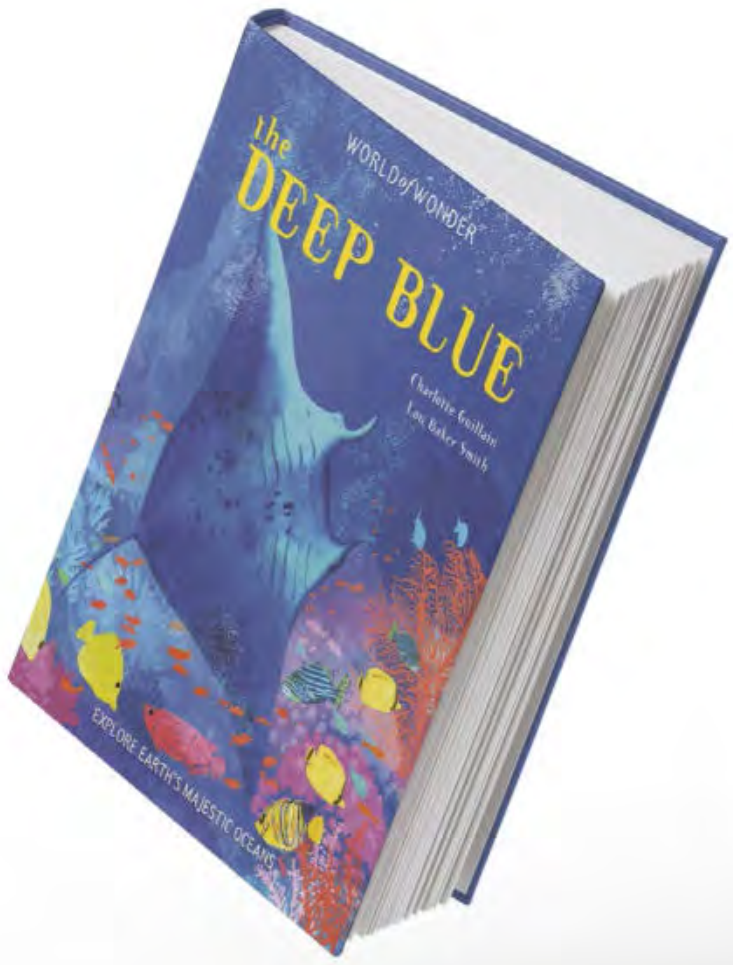
These projects and activities are in a similar format to our own How To's in the back pages of **How It Works**, except the illustrations here are even more attractive than they are functional. Artist Heidi Griffiths has paid as much attention to the incidental details – ivy emerging from the corners and insects buzzing about the pages – as she does to illustrating each step of each project's instructions. It gives the whole book a suitably organic feel and gives younger readers something to seek out each time they dive into a new activity. This is an ideal home-learning tool for any household with a garden, plot or allotment, and there's plenty in *Grow, Forage and Make* for adults as well.

Ancient World Magnified

COMES WITH A 3X MAGNIFYING GLASS

- Author: **David Long**
- Illustrator: **Andy Rowland**
- Publisher: **Wide Eyed Editions**
- Price: **£16.99 / $24.99**
- Release: **Out now**

What would a combination of a *Where's Wally* book and a children's encyclopedia of ancient civilisations look like? This brilliantly interactive book imparts knowledge about the past without you even realising. From early Mesopotamia to the Aztecs, *Ancient World Magnified* takes the reader on a journey through humankind's ancient origins, exploring how civilisations changed and evolved over thousands of years. Along the way and at each point in history, the book prompts the reader to look closely at the highly detailed illustrated spreads to spot ten items, such as Mayan maize, Roman sewers and Greek sails. With more than 200 items in total, this book is not only informative, but great fun. Make sure to use the magnifying glass, as some items are much harder to spot than others.



The Deep Blue

EXPLORE EARTH'S MAJESTIC OCEANS

- Author: **Charlotte Guillain**
- Illustrator: **Lou Baker Smith**
- Publisher: **QED Publishing**
- Price: **£12.99 / $18.95**
- Release: **Out now**

You can practically hear the crashing of ocean waves and the squawks of seabirds through author Charlotte Guillain's writing style. Her descriptive tone makes quick work of transporting the reader to one of the many marine locations around the world. From shallow coastal shores and underwater forests to the nightmarish twilight zone of the deep ocean, Guillain leaves no watery stone unturned in this immersive book. Accompanied by beautiful illustrations depicting the diverse life that populates Earth's oceans, it offers an insight into how our oceans work and their importance, giving a glimpse into some of the many ecosystems that are sustained by them.

This is a great book, along with others in the World of Wonder series, for inspiring a younger generation to discover more about our planet and the life that inhabits it.

Guillain leaves no watery stone unturned in this immersive book

Volcano, Where Fire and Water Meet

THE STORY AND SCIENCE OF VOLCANOES

- Author: **Mary Cerullo**
- Publisher: **Capstone Editions**
- Price: **£13.67 / $19.26**
- Release: **1 August 2021**

This book doesn't just cover the basic science of volcanoes, but presents it alongside the story of Kilauea. Retelling the dramatic history of one of Hawaii's most active volcanoes, the author engages the reader by incorporating the human impact alongside the geography. With informative diagrams, explosive imagery and ancient tales, this book is ideal for children between 10 and 12 years old. Explore what lurks beneath these mountains, the most explosive spots around the globe, how they ended up at their location and much more. Distinguishing *Volcano, Where Fire and Water Meet* are the diagrams that can be used to help children understand Hawaiian culture and folklore. Which gods made volcanoes their home? How did these legends arise, and how are volcanologists learning to predict the activity of volcanoes? While this book combines storytelling and science, it also reveals a link between the two, with life thriving where fire and water meet.

Video Games: A Graphic History

THE JOURNEY TO 21ST-CENTURY GAMING

- Author: **Sean Tulien**
- Publisher: **Graphic Universe**
- Price: **£20.44 / $27.99**
- Release: **3 August 2021**

A perfect book for any young gamer, this comic-style read turns a historical timeline into a captivating story. The vibrant cartoons fit its theme, combining colours and characters that any gamer would appreciate. From the first-ever console, designed by an engineer in New Hampshire, to the complex graphics of today's games, discover how the rise in televisions and competitive inventors helped to spread video game's popularity. The story isn't a predictable one: as gaming came to a standstill in the early 1980s, this book explains how one company brought it back into our lives. 'Console wars' have been a regular occurrence through the history of gaming, and the statistics of their success are delivered in compact infographics, allowing the reader to easily comprehend and compare them. As you flick through the pages, you watch decades of entertainment evolve before your eyes, and can appreciate the technology of today even more.

BRAIN GYM

GIVE YOUR BRAIN A PUZZLE WORKOUT

QUICKFIRE QUESTIONS

Q1 How old was the world's oldest human when they died?
- 145 years and 26 days
- 104 years and 211 days
- 116 years and 80 days
- 122 years and 164 days

Q2 Viruses aren't affected by antibiotics because they:
- Don't have cell walls
- Move inside cells
- Use cells to reproduce
- All of the above

Q3 What is the name of the huge, icy cloud that surrounds the planets?
- Cumulonimbus
- Oort Cloud
- Kuiper Belt
- Asteroid belt

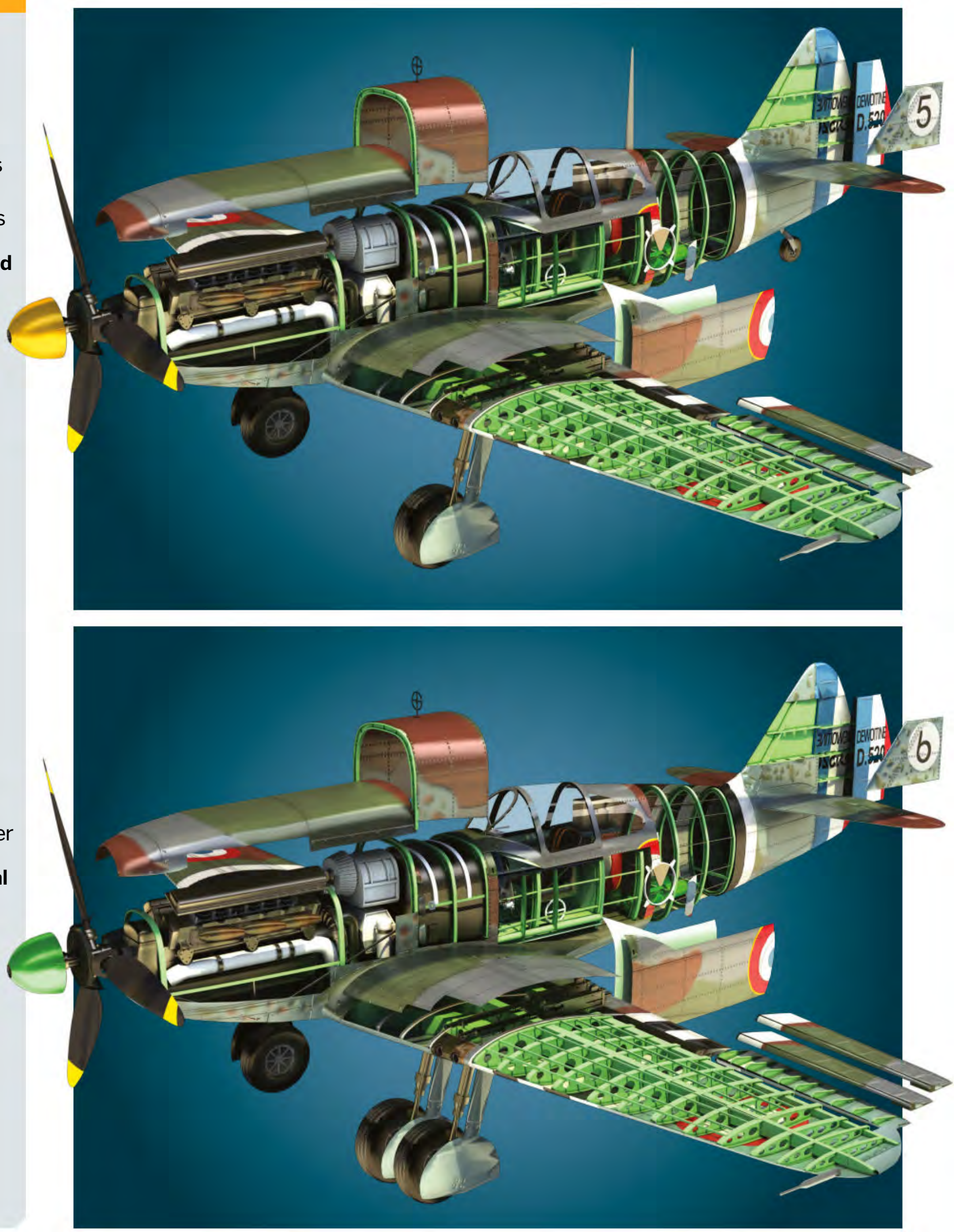
Q4 Why do octopuses have blue blood?
- It's low in oxygen
- Because of the blue crustaceans they eat
- Their blood contains copper, not iron
- For camouflage in water

Q5 Which of these animal names isn't real?
- Chicken turtle
- Colon rectum beetle
- Boops boops fish
- Red devil deer

Q6 When was the first turbojet aircraft made?
- 1929
- 1939
- 1949
- 1959

Spot the difference

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



Sudoku

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

EASY

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

DIFFICULT

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

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What is it?

Hint: Breakfast, anyone?

A .....

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

Wordsearch

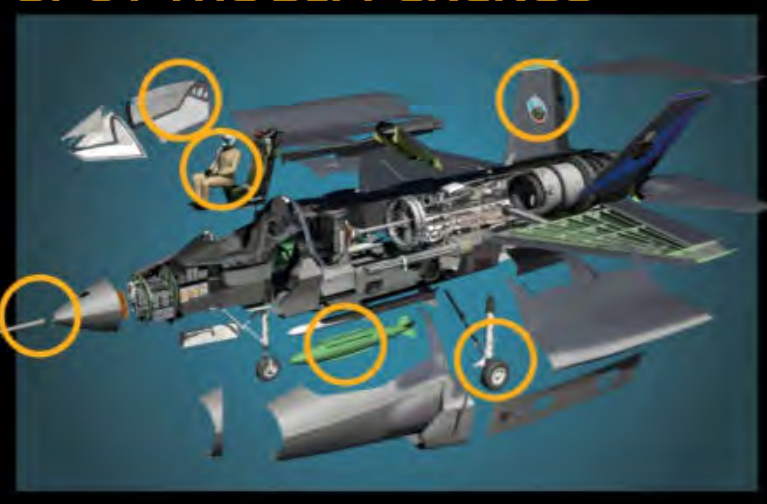
FIND THE FOLLOWING WORDS...

LAVA
DNA
ACID
PLUTO
SAMURAI
EURO
BUILDING
SPACE
MOLECULE
IMPACT
SUPER
COSMETIC

Check your answers

Find the solutions to last issue's puzzle pages

SPOT THE DIFFERENCE



QUICKFIRE QUESTIONS

Q1 6.7 metres
Q2 1928
Q3 It is scattered easily
Q4 425M years ago
Q5 2
Q6 Minotaur

WHAT IS IT? ...FABRIC (CLOTHES)

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Get in touch
Send your ideas to...
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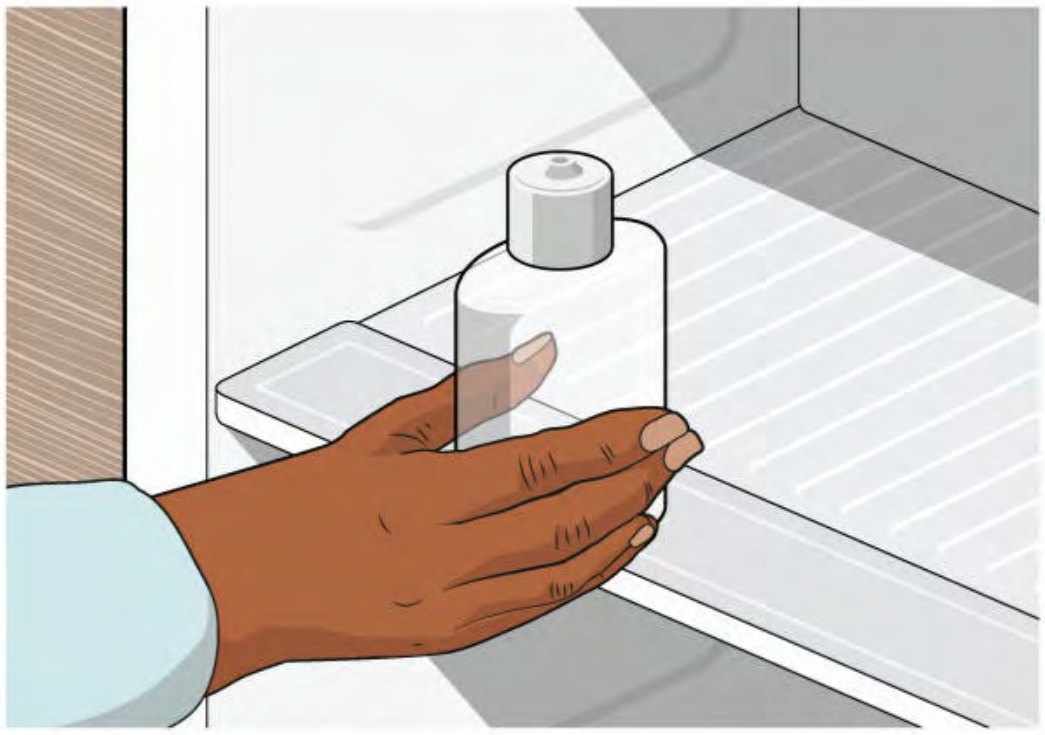
DON'T DO IT ALONE
IF YOU'RE UNDER 18, MAKE SURE YOU HAVE AN ADULT WITH YOU

How to extract banana DNA

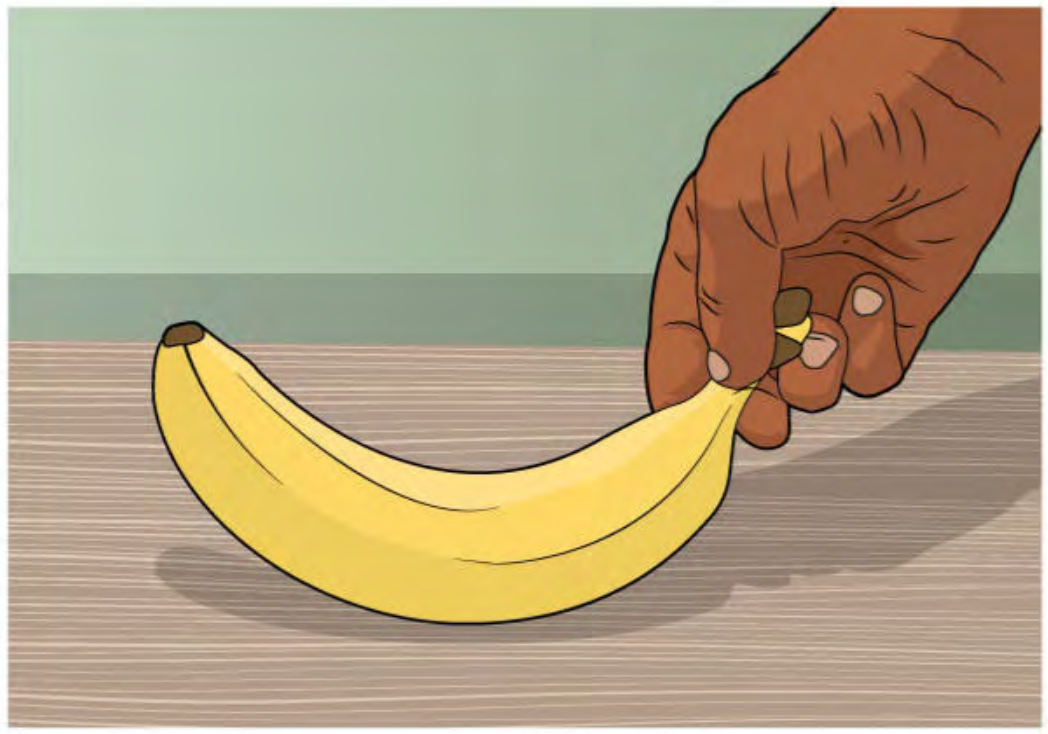
Break apart this fruit's cells to view its genetic material

YOU WILL NEED:
- A ripe banana
- Isopropyl alcohol (90 per cent)
- Measuring cup
- A teaspoon of salt
- Washing up liquid
- Coffee filter
- Narrow glass
- Spoon
- Elastic band



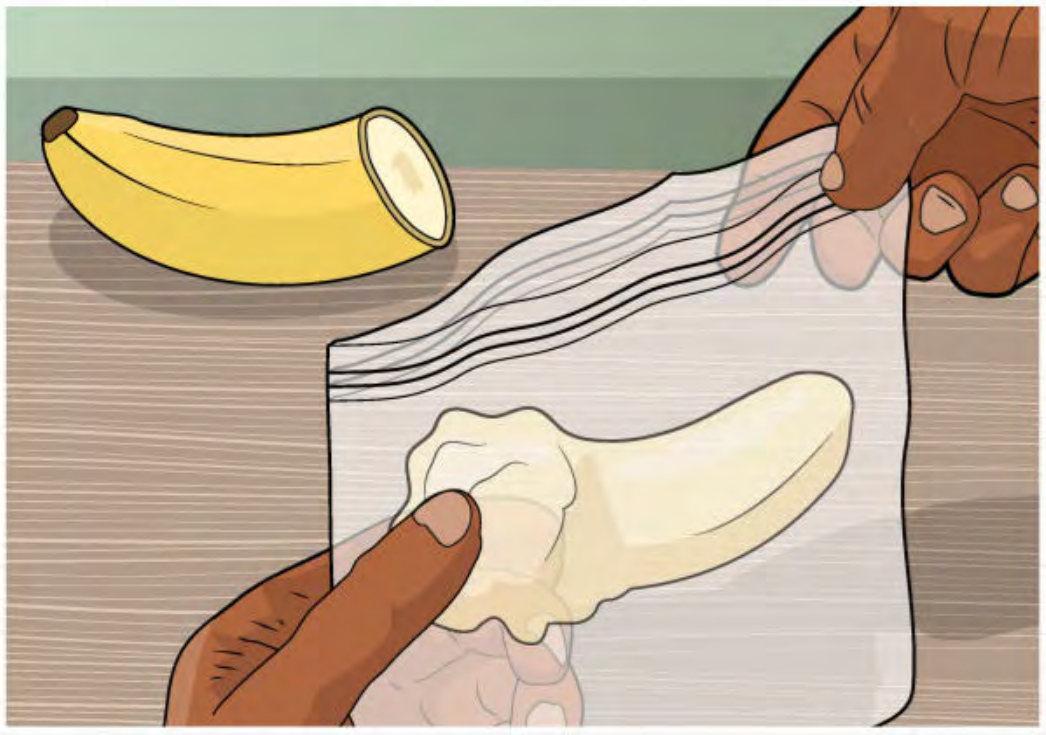
1 Cool the isopropyl

The first thing you need to do is place your bottle of isopropyl alcohol into the freezer. The alcohol won't freeze like water, but it needs to be as cold as possible for this experiment.



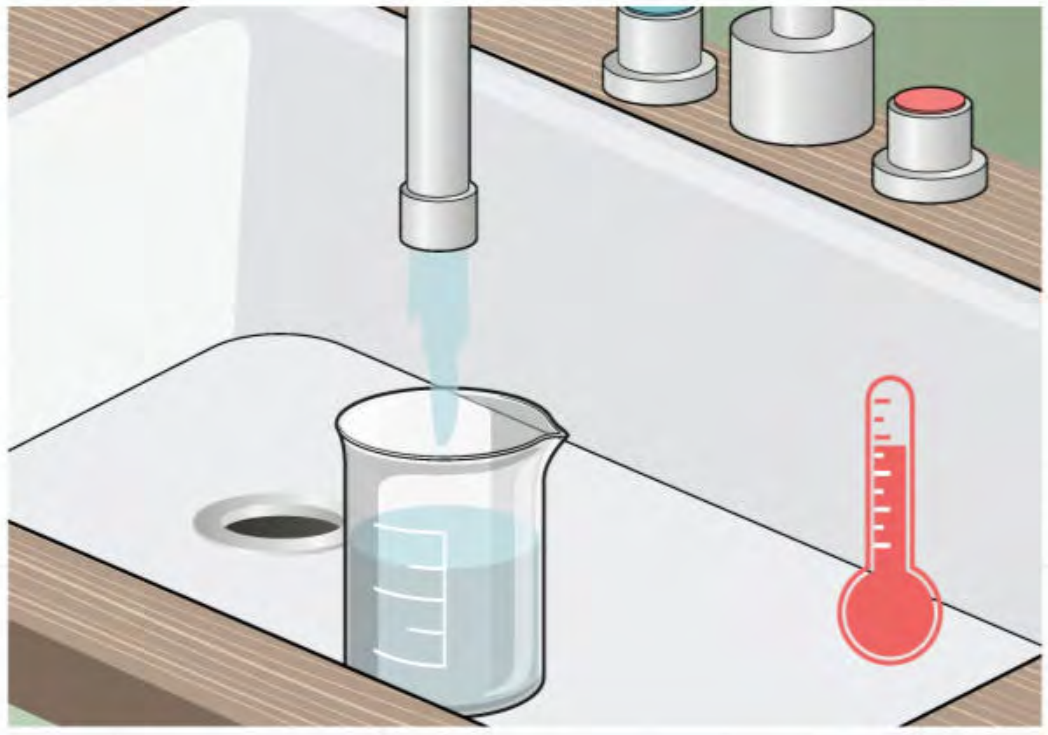
2 Ripen to perfection

Find the softest, ripest banana you can. The outside of the skin should be dark yellow or brown with black spots. If you don't want to wait for one to ripen, you can put it in a blender to make it soft enough.



3 Mash the banana

Peel the banana and cut it in half. Seal half into your plastic bag, removing the air from the bag before shutting it. Now thoroughly mash the banana with your hands to remove all lumps.

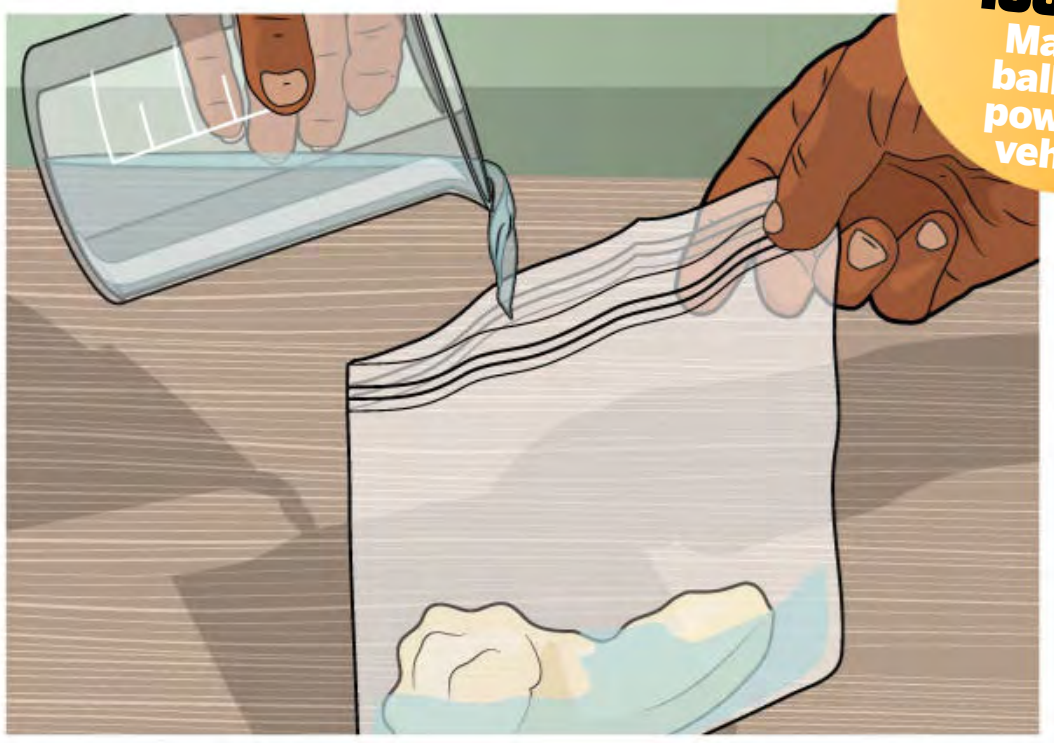


4 Make a salt bath

Carefully pour 120 millilitres of steaming-hot water into your measuring cup. Add one teaspoon of salt to the water and mix it in until it has completely dissolved.

NEXT ISSUE...

Make a balloon-powered vehicle

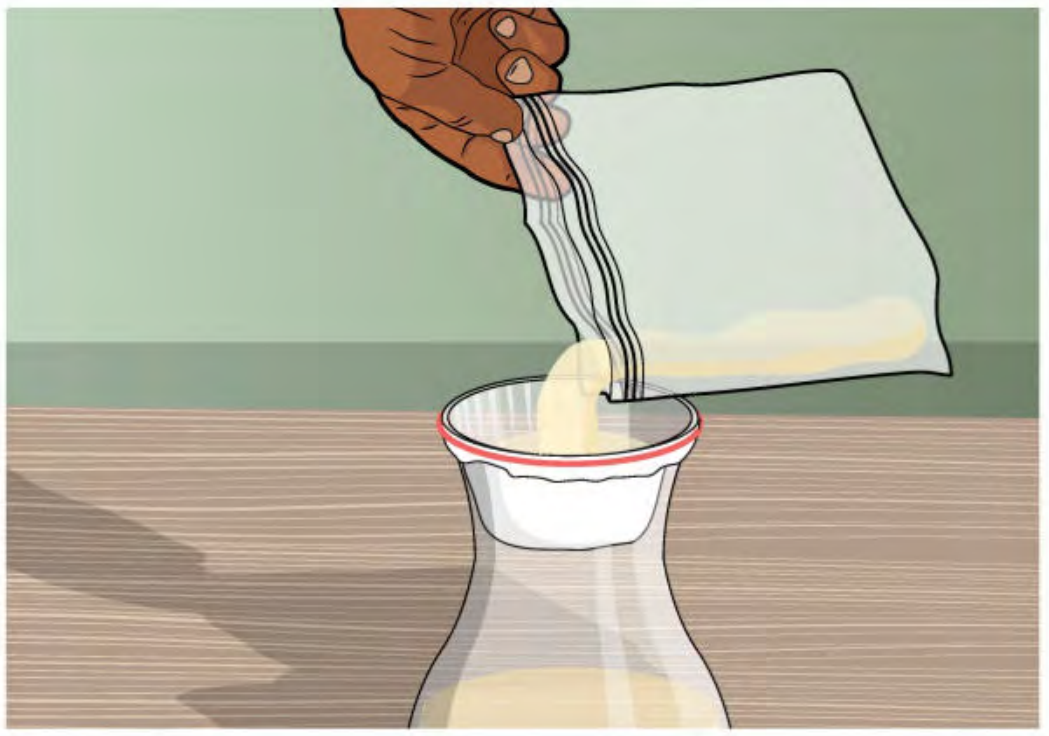


5 Add the water

Pour the salty water into the bag with the banana. When the water is cool enough to handle, continue to mix the banana and water with your hands for 45 seconds. You can also shake the bag to combine them.

6 A splash of soap

Next add about half a teaspoon of washing up liquid into the bag. To mix this in you will need to move your hands gently. The aim is to spread the soap around without creating too many bubbles.



7 Filter the DNA

Attach a coffee filter to the top of a tall glass using an elastic band. Slowly pour the contents of the bag into the filter, bit by bit. Liquid should begin to drip from the filter. It might take a few minutes for all the liquid to drain through into the glass.

8 Slowly pour in the alcohol

When all the liquid has been collected, take off the filter. Take your isopropyl alcohol from the freezer and pour it slowly down the side of the glass while holding it at a 45-degree angle. Stop when you can see a two to five centimetre layer of alcohol on the liquid mixture.

9 Eight-minute wait

Leave the glass standing for at least eight minutes. During this time the alcohol and salt will work together to make the DNA visible. These molecules will clump together to form solid, white pieces in the glass. What you're looking at is banana DNA.

HAD A GO? LET US KNOW!

If you've tried out any of our experiments – or conducted some of your own – then let us know! Share your photos or videos with us on social media.

SUMMARY

The three main events in this experiment are the dismantling of the banana's cells, the solidification of the DNA molecules and the way they combine to form larger, visible clumps. The salt has a positive electrical charge, which combines with the negatively charged DNA, causing the molecules to collect together. Without this the molecules would be dispersed and would remain too small for the eye to see.

Being made of lipids, the cell membranes are broken down by the washing up liquid. This is because soap works to separate fats in the membrane. At this point the DNA is dissolved into the mixture. Finally, by adding the isopropyl alcohol, the molecules can no longer remain dissolved. This solution solidifies the DNA, suspending it in the glass.

INBOX

Speak your mind...

Get in touch

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

How It Works magazine @HowItWorksmag

howitworks@futurenet.com howitworksmag

© Getty

The transmission of COVID-19 is less likely outdoors

Seasonal illness

Hi **HIW,**

Are illnesses like the flu more prevalent in winter because the bug survives better in colder temperatures? Why doesn't this apply to COVID-19, which seems to thrive in summer?

Stephen Conn

Flu is definitely more prevalent in winter, and scientists think this could be to do with cold temperatures. Cold air is less able to carry water vapour. This causes the water to fall as rain, leaving the air drier than it is in summer. In this dry air, the flu virus is better able to live and spread. COVID-19 has proved to be almost entirely dictated by human behaviour. Many of the trends in cases have been due to when restrictions have been in place. It's thought that COVID follows a similar trend to the flu virus, and spikes in cases during winter support this. While the weather plays some part in reducing the virus' spread, summer means many of us spend more time outdoors, so COVID is still able to survive.

LETTER OF THE MONTH

Mastering ginger beer

Dear **HIW,**

Over the lockdown I have made a ginger beer plant. I was wondering how to stop it turning to vinegar, and which bacteria I have picked up. Thank you for taking the time to read this.

Ajax King

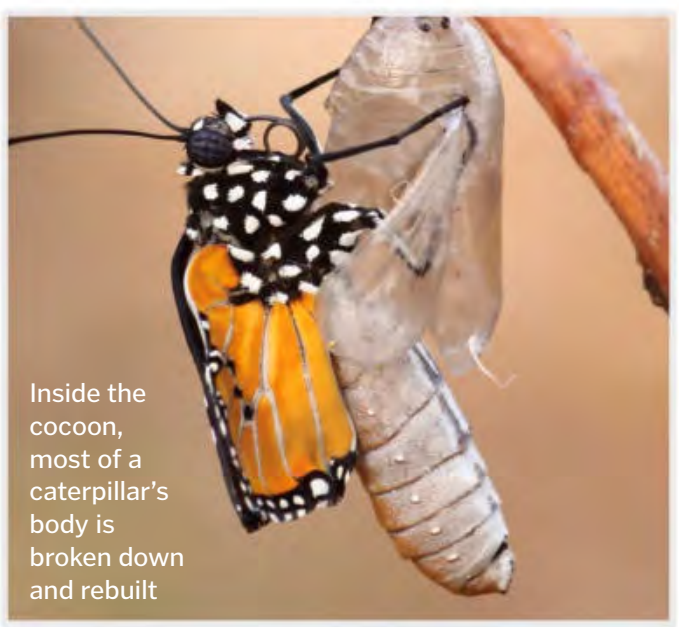
It's very common to face these issues when making a ginger beer plant, as it's notoriously difficult to perfect. Despite its name, a ginger beer won't look much like a plant. It is actually a group of small grains, produced during the fermentation of ginger root and sugar water. This produces the yeast *Saccharomyces florentinus*, giving ginger beer its signature flavour.

Often other organisms make their way into the mix, and can ruin the taste. As you rightly point out, bacteria is what gives the drink a more vinegary smell and taste. The bacteria responsible is called acetobacter, or acetic acid bacteria. It consumes sugars and releases acetic acid, which makes up vinegar.

Ginger is fermented in lemon juice and sugar water to make ginger beer

© Alamy

The best way to prevent this happening is to limit the amount of air that comes into contact with the contents of the container. Keep your container covered and work quickly when transferring your ginger beer plant. You should also keep your container away from any open windows. Finally, make sure all your equipment is clean and sterile before beginning the process. These measures can make it much less likely that your ginger beer will turn to vinegar, but unfortunately sometimes it's a matter of luck! We hope this is helpful and that your next try is a success.



Inside the cocoon, most of a caterpillar's body is broken down and rebuilt

© Getty

Caterpillar memories

Hi **HIW,**

When a butterfly emerges from its cocoon, does it remember its caterpillar life? We recently had an experience with caterpillars that turned into beautiful butterflies.

Arthur Alaphilippe, 12 years old

It's impossible to know for sure exactly what goes on inside the mind of a butterfly, but what we do know about their memory is pretty impressive. Some scientists carried out an experiment in which they trained caterpillars to dislike the smell of a chemical called ethyl acetate. They gave them mild electric shocks so that they would associate discomfort with the smell.

Incredibly, when they emerged from their cocoons, most of them continued to avoid the chemical. This showed that the nervous system remained intact during their transformation. While the butterflies you observed might not remember much from their caterpillar lives, there are definitely parts that will stay with them!

Triggering allergies

Hi **HIW,**

How do food allergies work?

Keith Canford

© Getty

Peanuts are one of the most fatal and common food allergies

Your immune system can sometimes become overactive, triggering an unnecessary response to non-toxic substances, such as specific foods. Proteins called antibodies are sent to attach to these cells, acting as a signal to identify the threat. During this process, histamine is produced. This is the chemical responsible for the pain and discomfort you feel during an allergic reaction. Indications that you're suffering from a food allergy can include having an itchy mouth and throat, swelling in the face and mouth, being sick, itchy ears and rashes. The most serious food allergies cause anaphylaxis, which involves a series of symptoms including low pulse and shock, and can be life-threatening.

Life-saving tech

Dear **HIW,**

I've recently bought a new car, and I wondered how the brakes are so effective at slowing speed.

Sharon Henderson

To slow down the vehicle, brakes use friction. Pressing the brakes against moving wheels, the kinetic energy is turned into heat energy. When all the energy from movement is transformed into heat, the car is brought to a standstill. As you put your foot on the brake pedal, the force used is boosted by a vacuum engine, which helps to stop the car more quickly. Pistons are moved by this force along the cylinder that contains them, which creates an opening to the brake fluid canister. The pressurised brake fluid is released until it hits the brake pad, pushing it against the revolving rotor and allowing friction to come into play.

Brake technology gives drivers greater control over their cars

© Alamy

What's happening on... social media?

This month on Instagram, we asked you: Given the opportunity, would you go on the next trip to space?

@sammy.glanfield

Yes! It would be a lifetime memory. I've always wanted to fly, and floating is very close!

@vanessa.__.chen

It would be extraordinary to visit space as only around 600 people have. It would also be very fun to experiment with gravity – you could float around in the rocket. The view would also be very beautiful and a once-in-a-lifetime chance.

@scimaxfacts

I would visit space. This is because it would be awesome to be in low gravity!

@sparkellium

I'd rather see a young scientist go in my place to help protect our unique, fragile planet.

@caroljsheldon

No! Scared in case I wouldn't get back.

NEXT ISSUE...

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FAST FACTS

Amazing trivia to blow your mind

1205

ENGLAND WAS SO COLD IN THIS YEAR THAT WINE FROZE AND WAS SOLD BY WEIGHT, NOT VOLUME

$15 MILLION

NASA'S APOLLO-ERA SPACESUITS COST A FORTUNE TO MAKE

1,400%

BY BLOWING OUT CANDLES ON A CAKE, YOU INCREASE ITS BACTERIA COUNT 14 TIMES

1,825 MILLIMETRES

THE MOST RAIN IN 24 HOURS WAS RECORDED FALLING ON THE ISLAND OF RÉUNION IN 1966

50%

MOSQUITOS HAVE CAUSED HALF OF ALL DEATHS IN HUMAN HISTORY

WHEN LIGHTNING HITS A BEACH, IT FUSES THE SAND INTO A GLASS TUBE

CHICKENS HAVE A VOCABULARY OF OVER 200 CLUCKING SOUNDS

15 MILES PER HOUR

WOODPECKERS HIT THEIR HEADS INTO TREES FASTER THAN THE AVERAGE SPEED OF A PUSHBIKE

40 MINS

SLOTHS CAN HOLD THEIR BREATH FOR NEARLY AN HOUR

12 MINS

PLASTIC BAGS ARE USED FOR A VERY SHORT TIME, BUT TAKE 1,000 YEARS TO BREAK DOWN

ELEPHANTS HEAR BETTER WHEN THEY HAVE ONE FOOT OFF THE GROUND

AIRFIX

QUICK BUILD

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

J6044
BUGATTI CHIRON

Bugatti Chiron
Build an Iconic Model

The Bugatti Chiron is a mid-engine two-seater sports car designed and developed in Germany by Bugatti Engineering GmbH and manufactured in Molsheim, France by French automobile manufacturer Bugatti Automobiles S.A.S.. The successor to the Bugatti Veyron, the Chiron was first shown at the Geneva Motor Show on 1 March 2016 and is based on the Bugatti Vision Gran Turismo concept car. The CHIRON is the fastest, most powerful, and exclusive production super sports car in BUGATTI's history.

Named after the Monegasque driver Louis Chiron, the car also shares the name with the 1999 Bugatti 18/3 Chiron concept car. Like its predecessor, the Veyron, the Chiron utilises a carbon fibre body structure, independent suspension and a Haldex All-wheel drive system. The carbon fibre body has a stiffness of 50,000 Nm per degree.

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

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Coastal Gun Battles

BY MID 1942 great swathes of Asia and the Pacific came under the conquest of Japan and its Imperial Army and Navy.

In just six months the Japanese won a spectacular series of victories that crushed their western opponents and left the victors with massive amounts of captured weaponry at their disposal.

Some of the most useful were the ***'Coastal Guns'*** that had once been part of massive artillery batteries defending *Singapore* at the southern tip of British Malaya and *Saigon* and *Haiphong* in French Indochina.

To help defend their newly-won empire the Japanese dismantled and relocated many of these coastal guns onto captured Pacific islands that were to form a defensive chain against the inevitable American counter offensive that was already on the way.

Another figure, **JN069** the *Japanese Officer with binos* makes a perfect gun crew commander.

ALSO AVAILABLE

Four more *Imperial Japanese Army* soldiers on guard duty will also be released...

JN071 shows a *standing machine gunner.* **JN072** *Soldier on Guard Duty* with his long *'Arisaka'* rifle and bayonet plus **JN073** *Standing at Ease Soldier.*

The K&C's final release is **JN074** the *Japanese Dispatch Rider* with his motorcycle.

All of these figures and the gun itself play their part in continuing to tell the dramtic story of the war in the Pacific during WW2.

GUN & GUNNERS

Among the most useful of these coastal artillery pieces were the formerly-*French 155mm guns* that had once protected the sea approaches to both *Saigon* and *Haiphong.*

Originally installed in the years after WW1, the Germans also made use of these same French coastal guns in their *'Atlantic Wall'* fortifications in Western Europe.

JN067 ***The Japanese Coastal Gun*** shows a 155mm gun in action together with its concrete base. Each gun can elevate and rotate 360˚ and comes with a breech block that can open and close.

To man the gun we have **JN068** the *4 x figure guncrew* set and **JN070** the *standing NCO with sword.*

TO FIND OUT MORE

For more details about all of these K&C 1:30 scale, all-metal, hand-painted figures and mixed media fighting vehicles simply contact Britain's biggest and most extensive *King & Country* Dealer.

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JN068
Japanese Coastal Gun Crew Set
(4 x figure set)

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