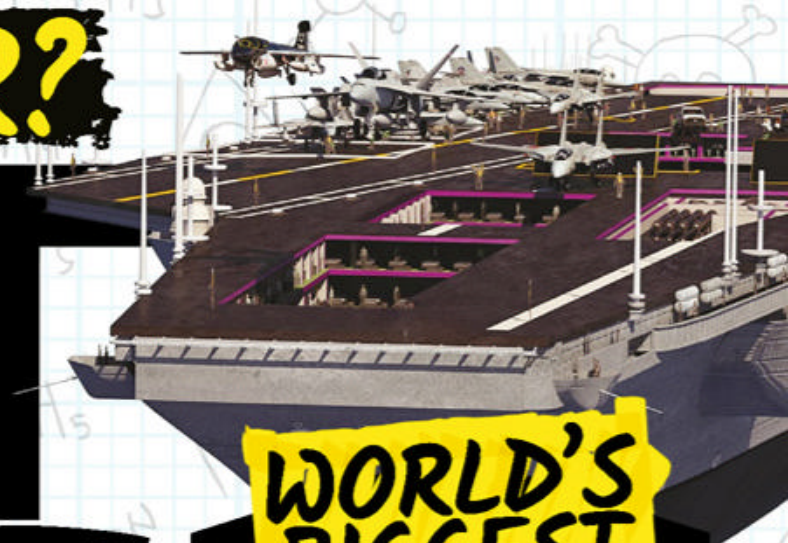
WHY DO CATS PURR?

HOW IT WORKS



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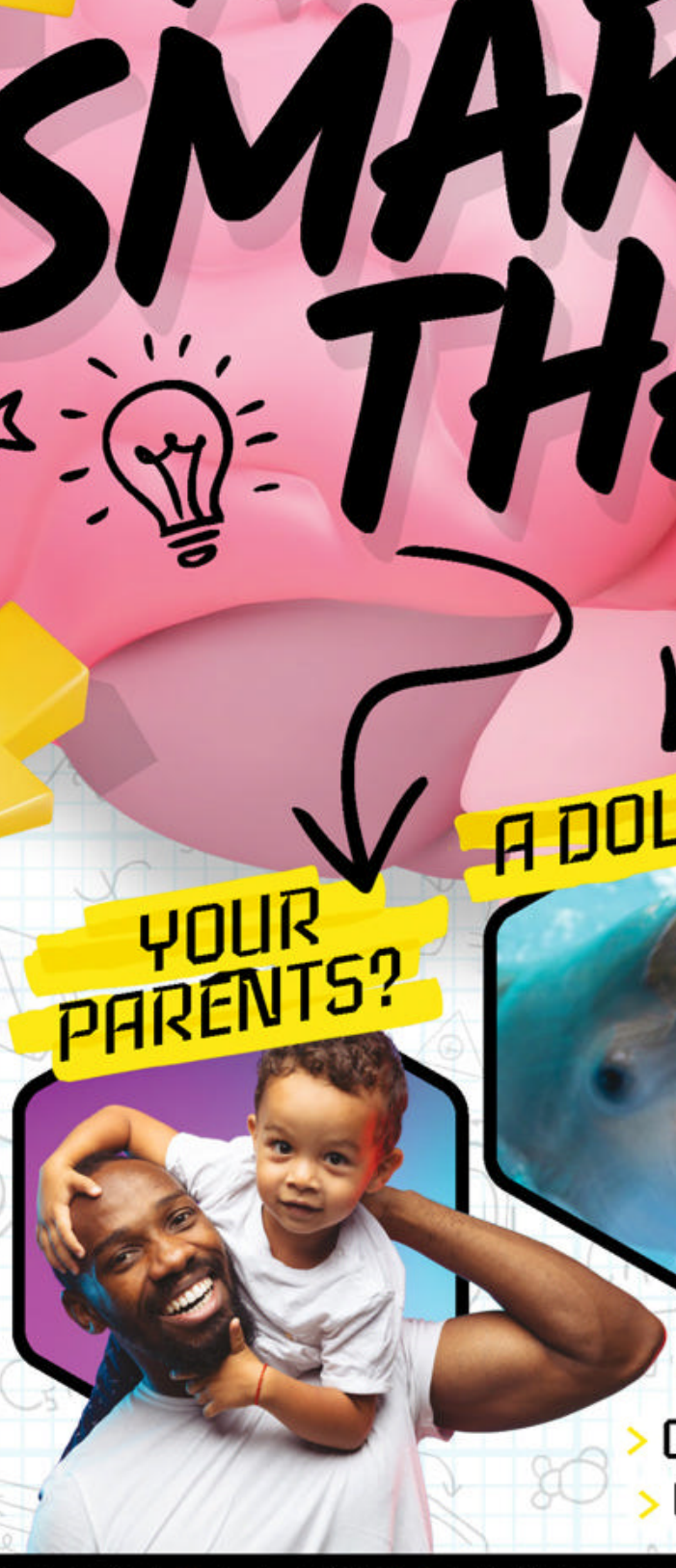
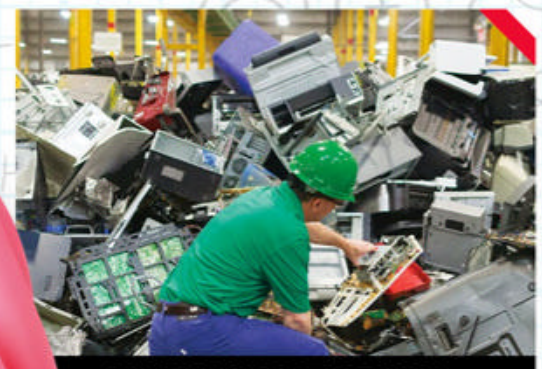
YOUR PARENTS?





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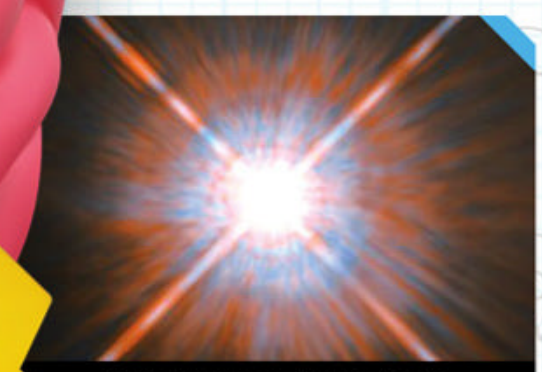

SEE THE BRIGHTEST STARS TONIGHT

WHY GOLF BALLS HAVE DIMPLES

LEGEND OF THE CHRISTMAS KRAMPUS

+

- HOW A COMPASS WORKS
- CHEESE MAKING EXPLAINED
- WHAT MAKES LIFE EVOLVE?

FUTURE
ISSUE 172

SCIENCE TECH ENVIRONMENT SPACE HISTORY TRANSPORT

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Issue 172

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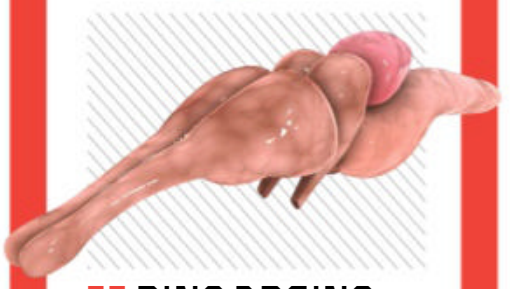
"Using fossilised *T. rex* skulls, researchers estimate that they had the largest brains of any dinosaur"

HIGHLIGHTS



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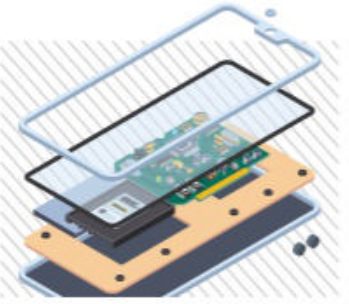

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The smartphone parts that can be recycled

Are you smarter than...?
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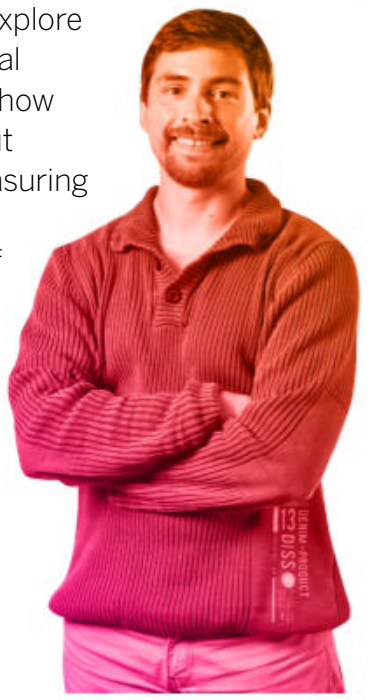
Just because they don't talk, get around on two legs or use a smartphone, doesn't necessarily make an animal much dumber than you. And just because someone is very old or very young, it doesn't mean they won't be able to outsmart you. In this issue, we explore the intelligence of different animal species, including humans, and how scientists have found a rough but reasonably accurate way of measuring brainpower in the animal kingdom, right back to the era of the dinosaurs. You'll be surprised at how brainy some animals are. You can also go head-to-head against How It Works in our intelligence test, to see how you fare against the team. Enjoy!



Ben Biggs
EDITOR

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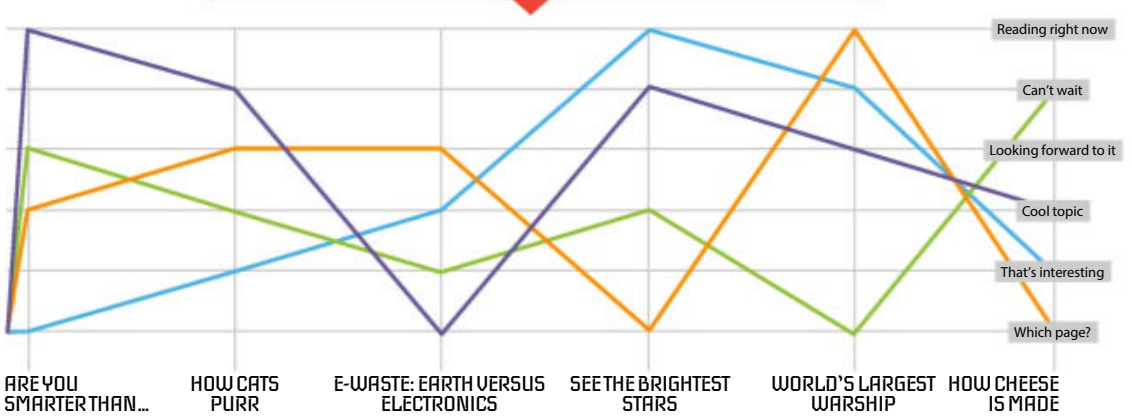

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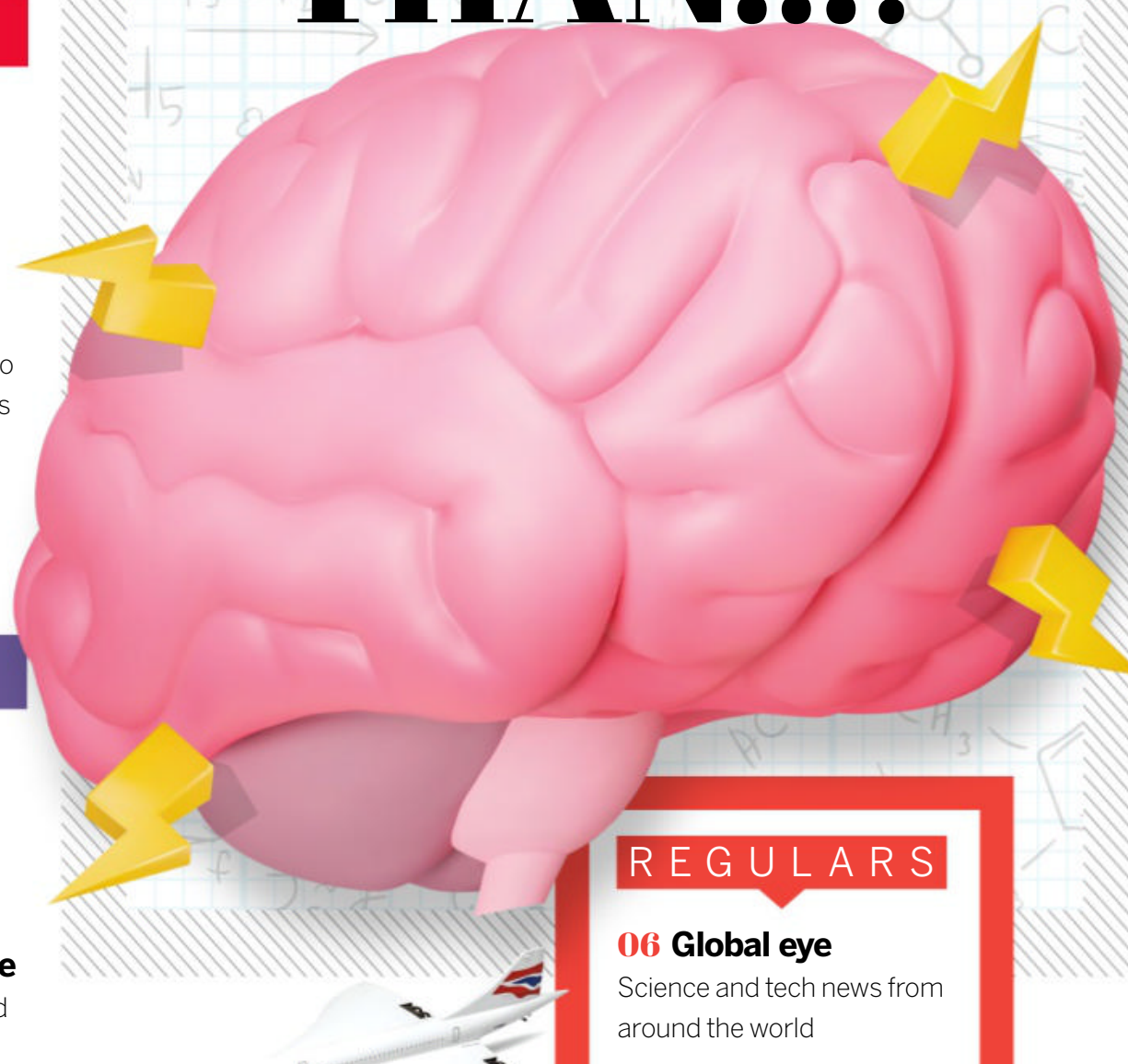

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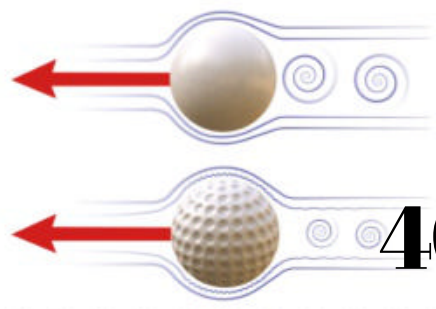

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1 OF 3 AIRFIX BUNDLES WORTH £100

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MEET THIS ISSUE'S EXPERTS

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

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


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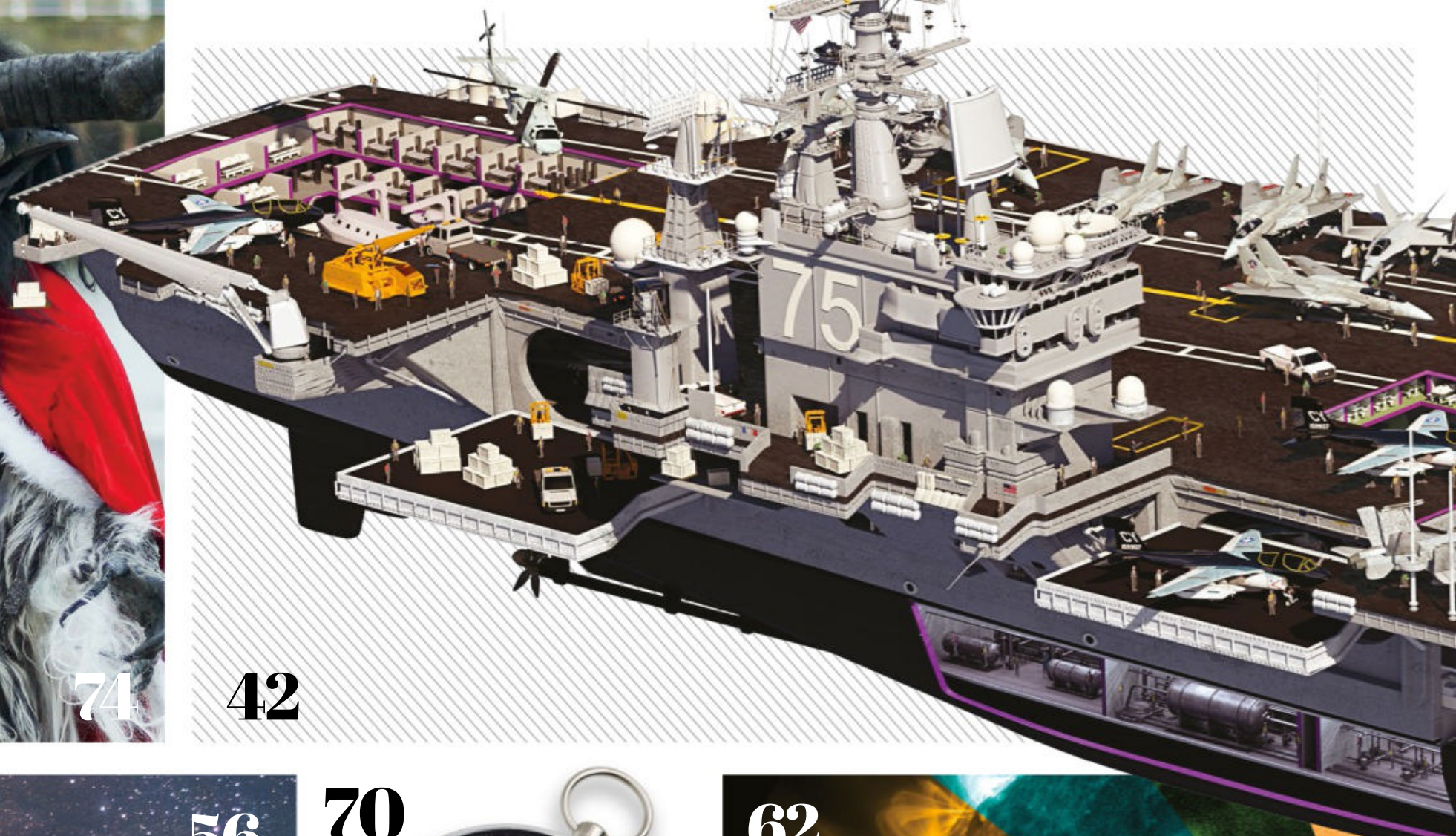
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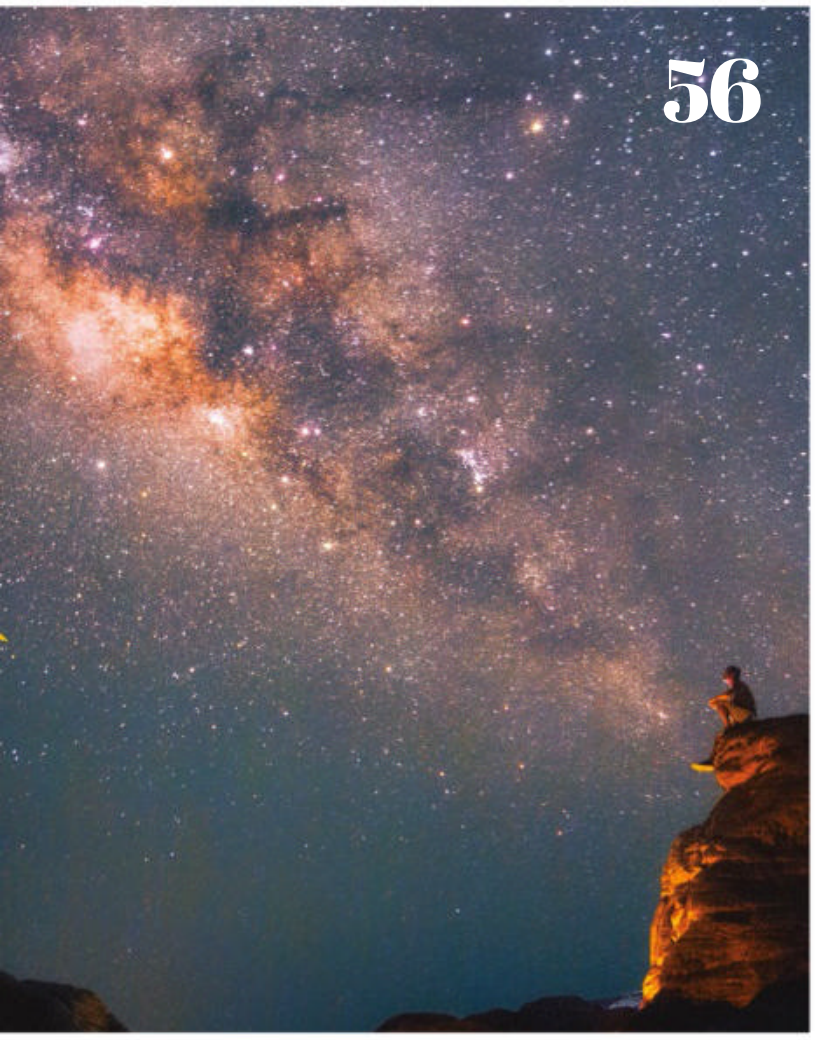
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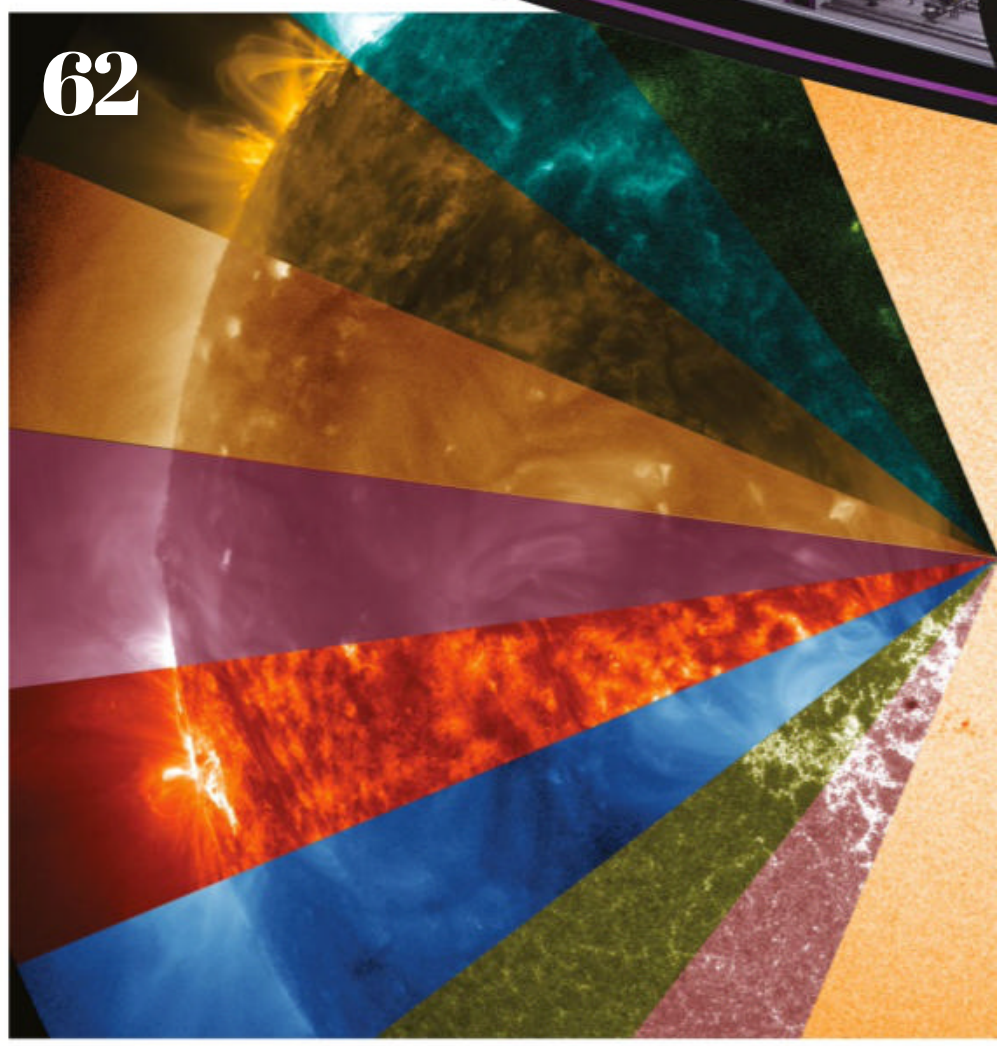
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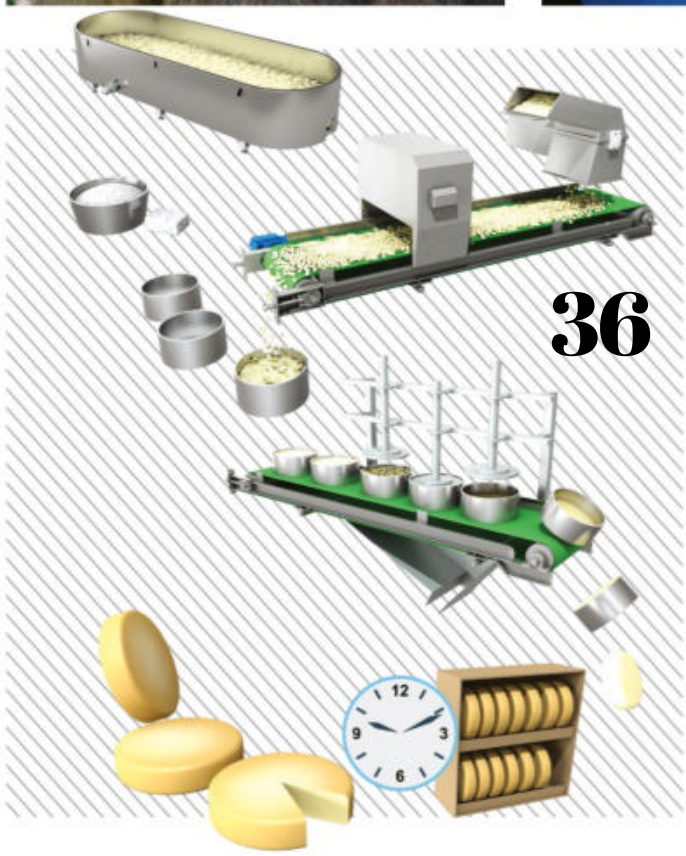
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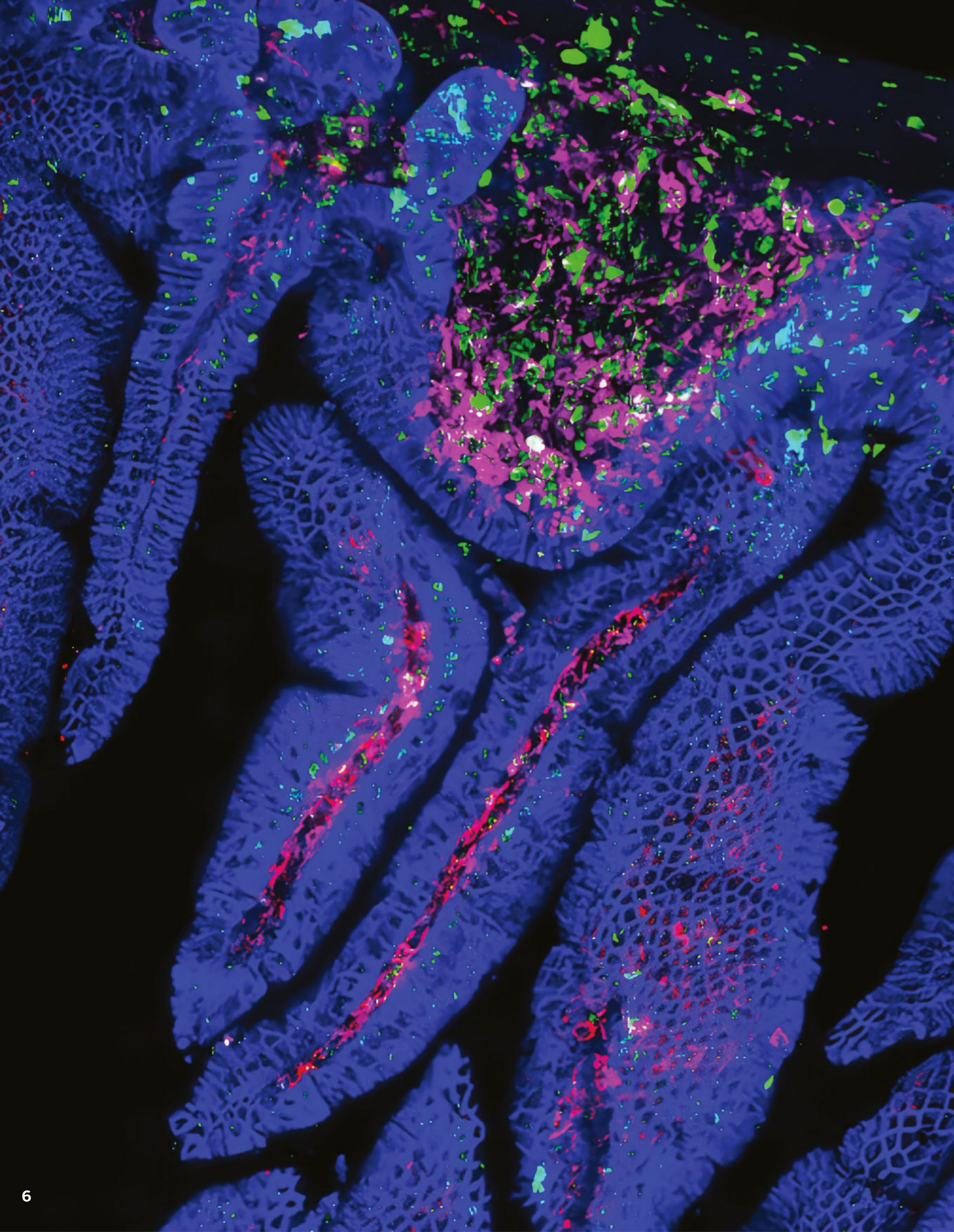


Intestines under a microscope

The small intestine is a tube-like organ forming a six-metre-long connection between the stomach and the large intestine, responsible for the absorption of nutrients such as carbohydrates and proteins. It's lined with countless finger-like structures called villi, seen here in blue. Villi structures maximise the surface area of the small intestine and increase rapid absorption.

Underwater moons

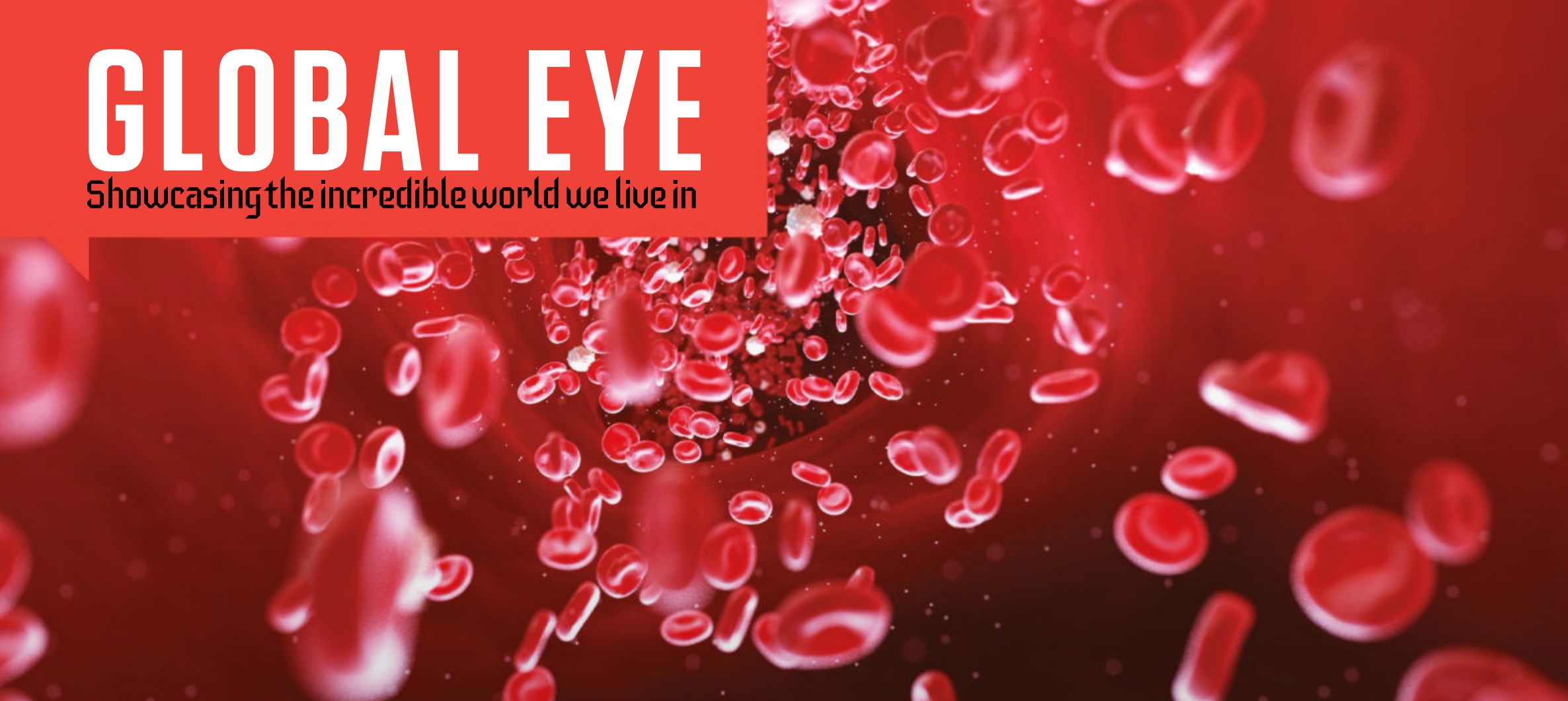
Aurelia limbata is found in the Northwest Atlantic, Northern Pacific and Arctic oceans. This moon jellyfish was found floating through the Sea of Okhotsk, near Russia's Kamchatka Peninsula. The fluffy, white structures are its oral lobes. These lobes are the site of its stinging cells, called nematocysts. These stinging cells will temporarily paralyse prey, giving the lobes the chance to capture and digest food.

Up, up and away

Every year, typically in spring or summer, hundreds of hot-air balloons gather in Cappadocia, Turkey, filling the sky with colourful patterns and prints. The backdrop for the festival are areas of Cappadocia's natural beauty, such as Göreme National Park. The balloons take off in the rocky Göreme valleys and rise thousands of metres into the air to witness the wonderful landscape below.

New view of creation

The James Webb Space Telescope is rapidly advancing the way we observe objects in the universe and updating our views of some iconic cosmic structures. Found in the Eagle Nebula, Webb captured a new image of the Pillars of Creation using its Near-Infrared Camera in October. The columns of cosmic dust and gas are in unprecedented detail, helping researchers update their models of how stars form within these cosmic clouds over millions of years.



HEALTH

Two people receive a world-first lab-grown blood transfusion

WORDS NICOLETTA LANESE

Two people in the UK are the first ever to receive transfusions of lab-grown red blood cells. The pair are healthy volunteers in the REcovery and survival of STem cell Originated REd cells (RESTORE) trial, a one-of-a-kind clinical trial taking place at Addenbrooke's Hospital in Cambridge. The trial will ultimately include at least ten participants, each of whom will receive a tiny transfusion of about one to two teaspoons worth of lab-grown red blood cells. The goal of the trial is to compare how well these lab-grown cells survive in the body compared with standard red blood cells from a donor. Each trial participant will receive two mini-transfusions – one with standard cells and one with lab-grown – spaced four months apart. The order of the transfusions will be randomised.

Scientists expect the lab-grown cells to survive longer than standard cells, mostly because standard blood transfusions contain cells of varying ages, while lab-grown cells can be made fresh. "If our trial, the first such in the world, is successful, it will mean that patients who currently require regular long-term blood transfusions will need fewer transfusions in future, helping transform their care," said Dr Cédric Ghevaert, a professor in transfusion medicine and consultant haematologist at the University of Cambridge. People who require regular blood transfusions, such as those with sickle cell anaemia, face a risk of iron overload, in which excess iron accumulates in the body and damages organs.

In addition, repeat transfusion patients can also develop antibodies that target specific proteins, or antigens, on the surface of red blood cells. These antigens distinguish the different blood groups, including the major groups A, B, AB and O, and the lesser-known minor groups that are challenging to match between blood donors and recipients. When transfusion patients develop antibodies against specific blood groups, this puts them at risk of life-threatening immune reactions and therefore limits the types of blood they can receive in the future. Ideally, the work will not only reduce the number of transfusions such patients need, but also allow medical researchers to grow rare blood cells in the lab. "The need for normal blood donations to provide the vast majority of blood will remain," Shah said. "But the potential for this work to benefit hard-to-transfuse patients is very significant."

For the new trial, scientists extracted stem cells from blood donated by adult volunteers and allowed those cells to mature in lab dishes. The stem cells were haematopoietic, meaning they could only mature into red blood cells, white blood cells and platelets. The team then ran the mature cells through a filter normally used to remove white blood cells from standard blood donations. Finally, they tagged the purified red blood cells with a radioactive marker so that they could track the cells in the body post-transfusion. So far, "no untoward side effects were reported" in the two trial participants. After the trial concludes, more research will still be needed before lab-grown blood cells can be widely used. "But this research marks a significant step in using lab-grown red blood cells to improve treatment for patients with rare blood types or people with complex transfusion needs."

Watermelons weren't always the sweet, juicy fruit we eat today

HISTORY

THE OLDEST KNOWN PLANT GENOME CAME FROM A STONE AGE WATERMELON

WORDS **JENNIFER NALEWICKI**

Scientists have sequenced the oldest plant genome on record, and it comes from watermelon seeds chomped on by Stone Age sheep herders in the Sahara. The 6,000-year-old watermelon seeds resurfaced in the 1990s during an archaeological dig of the cave site known as Uan Muhuggiag, located along a swath of the Sahara that's now Libya. Due to the cave's dry, salty air, the seeds, which may have fallen to the ground during a meal, were well preserved, enabling scientists from the Royal Botanic Gardens, Kew, to sequence their DNA. Examination of the genome also showed that the seeds were those of a wild watermelon, one of Africa's oldest crops, and probably contained a sickeningly bitter pulp. The discovery is important because it offers information about the domestication of the watermelon (*Citrullus lanatus*) that we enjoy today. It also offers insight into ancient people's diets and lifestyles.

Researchers also sequenced the genomes of dozens of watermelon species that are part of Kew Garden's extensive collections. The scientists discovered that the herders either intentionally collected or cultivated this bitter-fleshed watermelon, a finding that's consistent with teeth marks found on some of the oldest seeds collected in Sudan.

PLANET EARTH

'Artificial' photosynthesis could lead to new fuels

WORDS **STEPHANIE PAPPAS**

A method of artificial photosynthesis could get humans one step closer to using the machinery of plants to make fuels. The new system is ten times more efficient than previous synthetic photosynthesis methods. While natural photosynthesis allows plants to turn carbon dioxide (CO_2) and water into carbohydrates using the power of the Sun, the artificial method can turn CO_2 and water into energy-dense fuels like methane and ethanol. This could provide an alternative to fossil fuels. "The biggest challenge many people don't realise is that even nature has no solution for the amount of energy we use," said University of Chicago chemist Wenbin Lin. Natural photosynthesis, while sufficient for plants to feed themselves, falls short of providing the quantity of energy required to fuel our homes, cities and nations. "We will have to do better than nature, and that's scary," he said.

Researchers have been working to borrow the machinery of photosynthesis to create their own desired chemicals for years, but tweaking photosynthesis to serve human needs isn't easy. The process is complicated and involves two steps: breaking apart water and CO_2 and reconnecting the atoms into carbohydrates. Lin and his team had to create a system that would instead produce methane, or CH_4, one carbon surrounded by four hydrogen molecules. Though combusting this synthetic methane would still lead to greenhouse gas emissions, researchers are working on using artificial photosynthesis to make hydrogen fuels, which release only water vapour and warm air.

To do this, they began with a metal-organic framework, a web made of charged metal atoms linked by organic molecules. They submerged single layers of this metal-organic framework in a cobalt solution; this element is good at picking up electrons and moving them around during chemical reactions. Then the researchers did something that hadn't been tried before. They added amino acids, the molecular building blocks of proteins, to the mix. These amino acids boosted the efficiency of both sides of the reaction, breaking down CO_2 and water and rebuilding them as methane. The resulting system was ten times more efficient than previous artificial photosynthesis methods. However, that's still not efficient enough to make enough methane for human fuel use. "Where we are now, it would need to scale up by many orders of magnitude to make a sufficient amount of methane for our consumption," Lin said.

Did you know?

Leaves are green because of chlorophyll

A close-up of a chloroplast, the natural machinery that plants use to perform photosynthesis

The meteorite landed in a driveway in the town of Winchcombe in February 2021

SPACE

A 4.6-billion-year-old meteorite may reveal the origin of Earth's water

WORDS BEN TURNER

An ancient meteorite that crash-landed on a UK driveway may have solved the mystery of where Earth's water came from. The 4.6-billion-year-old space rock, which landed in front of a family home in the English town of Winchcombe in February 2021, contains water that closely resembles the chemical composition of water found on Earth, presenting a possible explanation for how our planet was seeded with the life-giving substance. When the rocky inner planets of the young Solar System first coalesced, clotting from clouds of gas and dust billowing near the Sun, they were too close to our star for oceans to form. Past a certain point called the frost line, no ice could escape evaporation, making the young Earth a barren and inhospitable landscape.

Did you know? Most meteoroids burn up in the atmosphere

Scientists think this changed after Earth cooled, when a barrage of icy asteroids from the outer Solar System brought frozen water to our planet to melt. Now, a new analysis of the Winchcombe meteorite has lent weight to this theory. "One of the biggest questions asked of the scientific community is, how did we get here?" said Luke Daly, a lecturer in planetary geoscience at the University of Glasgow. "This analysis on the Winchcombe meteorite gives insight into how Earth came to have water, the source of so much life. Researchers will continue to work on this specimen for years to come, unlocking more secrets into the origins of our Solar System."

The space rock, a rare carbon-rich type called a carbonaceous chondrite, was collected just a few hours after it smashed into the ground and so remains largely uncontaminated, making it "one of the most pristine meteorites available for analysis". It offers "a tantalising glimpse back through time to the original composition of the Solar System," said Ashley King, a research fellow at the Natural History Museum in London. To analyse the minerals and elements inside the rock, the researchers polished, heated and bombarded it with X-rays and lasers, revealing that it had come from an asteroid in orbit around Jupiter and that 11 per cent of the meteorite's mass was water. The hydrogen in the asteroid's water came in two forms – normal hydrogen and the hydrogen isotope known as deuterium, which goes to make up 'heavy water'. The scientists found that the ratio of hydrogen to deuterium matched the ratio found in water on Earth, strongly implying that the meteorite's water and our planet's water shared a point of origin. Amino acids, the building blocks for proteins and subsequent life, were also found inside the rock.

PLANET EARTH

THE PESKY 'LEAP SECOND' WILL BE ABOLISHED BY 2035

WORDS JENNIFER NALEWICKI

An international coalition of scientists and government agencies have voted to retire the dated timekeeping system, which will officially end in 2035. The decision was made on 18 November 2022 during a general conference in France held by the International Bureau of Weights and Measures (BIPM), the organisation responsible for global timekeeping. Similar to leap years, leap seconds are a measure of time added periodically to clocks to make up for the difference between astronomical time, or Earth's rotation, and Coordinated Universal Time (UTC), which is based on the atomic clock. "As Earth's rotation continues to slow down, it accumulates one minute of delay each century and one hour of delay over 5,000 years," said Patrizia Tavella, director of BIPM's time department. Thus, the leap second was invented.

First introduced in 1972, leap seconds have long been the bane of timekeepers' existence and have increasingly come under pressure for elimination as highly used technologies, such as satellite navigation, computer networks, telecommunication and aviation, increasingly demand extreme accuracy in time keeping. The addition of leap seconds has created its own host of issues and can result in technical difficulties that can affect everything from financial transactions to energy transmissions.

A close-up photo of Big Ben in London

SPACE

Mars may be ripping its largest moon apart

WORDS HARRY BAKER

Mars' largest moon Phobos shows signs of being ripped apart by the extreme gravitational forces exerted on it by the Red Planet. Researchers have revealed that the unusual grooves covering Phobos' surface, previously assumed to be scars from an ancient asteroid impact, are actually dust-filled canyons that are growing wider as the moon gets stretched out by gravitational forces. Phobos is around 17 miles across at its widest and orbits Mars at a distance of 3,728 miles, completing a full rotation three times every day. Unlike our Moon, Phobos' orbit around Mars isn't stable. The tiny satellite is trapped in a death spiral and is slowly falling towards the Martian surface at a rate of 1.8 metres every 100 years. But Phobos' most unusual feature is arguably its mysterious stripy surface. Parallel grooves, or surface striations, cover the moon. The most widely accepted theory suggests that the striations formed when an asteroid slammed into Phobos at some point in the past, leaving behind a six-mile-wide crater, known as Stickney, in the moon's flank.

A new study suggests that the grooves may be the result of the moon slowly being ripped apart by Mars' intense gravity as Phobos circles ever closer to the planet's surface. The thinking is that as one body, in this case Phobos, gets closer to a larger body, such as Mars, the smaller will begin to stretch out in a line towards the larger body. This is known as tidal force. In the case of Phobos, the tidal force exerted on the moon is predicted to increase as Phobos gets closer to the Martian surface, until finally the tidal force becomes greater than the gravity holding the satellite together. At that point, Phobos will be completely ripped apart and the debris will likely form a tiny ring around the planet, much like the rings of Saturn.

While prior research suggested tidal forces produced Phobos' tiger stripes, the theory has been largely dismissed due to the moon's powdery or 'fluffy' composition, making it too soft for such cracks to form. Researchers used computer simulations to test the idea that the moon's fluffy surface may rest atop a somewhat cohesive sublayer. The simulation found that a buried hard shell could have formed deep canyons that the surface dust could fall into, creating the grooves visible on the surface. At its current rate, Phobos will complete its death spiral and hit Mars in around 40 million years. But if tidal forces are already tearing the moon apart, then the satellite could be completely destroyed long before then.

Artist's impression of Phobos and Deimos orbiting Mars

GLOBAL EYE

HEALTH

ORGAN-ON-CHIP REPLICATES EARLY PREGNANCY

WORDS **JENNIFER NALEWICKI**

Scientists have designed a tiny 'organ-on-a-chip' that replicates early pregnancy, when the embryo implants in the lining of the uterus. The small device is made of clear silicone rubber and has two chambers: one to hold placental cells and one for tiny 3D blood vessels. A barrier runs between the two chambers and mimics the uterine tissue that would run beneath an embryo implanted in the womb. The team used the device to observe how trophoblasts, cells that help the embryo attach to the uterus and later form part of the placenta, migrate towards uterine blood vessels prior to the embryo's implantation.

Cells lining the blood vessels aid trophoblasts on their journey by switching on specific genes and secreting various proteins; with their new system, the researchers could watch this unfold. The research also revealed that certain immune cells may play a key role in preparing the uterus for implantation. "Our system was modelled to study interactions between the mother and the placental tissue of the baby," said Dr Monica Mainigi of the University of Pennsylvania. "Humans are fairly unique both in how the placenta attaches to the mother and in the interface between the maternal and placental cells. Now we've shown the relevance of this system, we can look at the individual cell types and get a much better understanding of what each individual cell type is doing.

This 'organ-on-a-chip' is about the size of a US quarter

ANIMALS

The Devils Hole pupfish is so inbred that it shouldn't be alive

WORDS **JOANNA THOMPSON**

The Devils Hole pupfish is small, blue and incredibly endangered. It also may be the most inbred creature on Earth. All 263 wild Devils Hole pupfish (*Cyprinodon diabolis*) live in one location: a three by six metre cavern in the middle of Devils Hole in Nevada, a detached part of Death Valley National Park and one of the hottest places in the world. Their cavern oasis, located just 15 metres below the desert floor, is at least 152 metres deep and stays at a balmy 33 degrees Celsius year-round. The species has lived there, isolated from all other pupfish, for at least 1,000 years, and possibly as long as 20,000 years.

Did you know? There are around 120 known species of pupfish

In a recent study, researchers have discovered that Devils Hole pupfish genomes are 58 per cent identical on average – "the equivalent of five to six generations of full sibling matings," said Christopher Martin, an evolutionary biologist at the University of California, Berkeley. That's enough to make the infamously inbred Habsburg dynasty look wildly diverse. Researchers sequenced the genomes of eight Devils Hole pupfish, as well as one preserved specimen from the 1980s. They found that the fish were missing some seemingly important genes. For example, they lacked a gene normally involved in producing sperm, one that causes infertility if knocked out in other species. "It's kind of surprising that they're even able to reproduce at all," said Martin.

The fish had also lost a gene that helps other types of pupfish survive in low-oxygen environments, a surprise given that the warm, stagnant pool they call home is very deoxygenated. At the moment it's unclear to what degree the absence of these genes is harming the pupfish's overall health. "The genome is a complex place," Martin said. He and his team plan to study the fishes' genetics in greater detail to determine what exactly each of their genes is doing and how they're compensating for genomic losses.

The intense inbreeding observed in the fish is likely due to their geographic isolation, coupled with multiple population bottlenecks in recent years. In the past two decades alone, the population nearly crashed twice, dipping to 38 individuals in 2006 and as low as 35 in 2013. This unique fish was one of the first species to be officially added to the Endangered Species Preservation Act in 1967, which was later folded into the Endangered Species Act of 1973. Since then, thanks to considerable conservation efforts, including the construction of a 379,000-litre replica of Devils Hole that houses a separate captive-bred pupfish population, the species has survived, though it has not always thrived.

New research reveals exactly how inbred the Devils Hole pupfish is

HISTORY

Ötzi the Iceman's corpse moved after death

WORDS **TOM METCALFE**

The ancient mummified body of Ötzi the Iceman was found decades ago by hikers in the high Alps, but how did it get there? A new study questions the prevailing story of Ötzi's death more than 5,000 years ago, suggesting that Ötzi did not die in the gully where he was found. His remains may have been carried there by the periodic thawing of the ice that surrounded his body, and researchers propose that other prehistoric people who died in icy, mountainous regions could have been preserved by the same process. "I think the possibility now is perhaps a bit larger" of finding another prehistoric body, said archaeologist Lars Pilø. "It's not so large that I can promise there will be a body in the next decade, but I think that there's definitely a chance."

The remains of Ötzi, who's named after the Ötztal Alps where he was found, were discovered on 19 September 1991 by German tourists in an Alpine pass between Italy and Austria. The hikers first thought they'd found the preserved body of a modern mountaineer, but investigations later determined that Ötzi died about 5,300 years ago. The generally accepted story of Ötzi's death comes from investigations by the late archaeologist Konrad Spindler of the University of Innsbruck in Austria. Spindler found that Ötzi had probably been murdered: an arrowhead was embedded in his shoulder, and a deep cut in his hand appeared to be a defensive wound suffered while warding off a blow. He also noted that Ötzi's backpack, bow and arrow quiver were damaged, which Spindler proposed was a sign of combat. But Pilø and his colleagues argue that the damage to Ötzi's equipment was probably caused by the pressure of the ice that surrounded them. "There's definitely been a conflict," he said. "But what we say is that the damage to the artefacts is more easily explained by natural processes."

The most significant proposal in the new study is that Ötzi didn't die at the bottom of the gully where he was found, but rather that his body was carried there as the ice thawed and refroze over several summers. Early investigations proposed that Ötzi was killed in the gully in the autumn and that his body was protected there from the crushing pressure of a glacier above. But analysis of the food in Ötzi's intestine suggests instead that he died in the spring or early summer, when the gully would have been filled with ice. Researchers propose that Ötzi died somewhere on the surface of a stationary ice patch, not a moving glacier, and that his remains and artefacts were carried into the gully by the periodic thawing and refreezing of the ice. That means the body and artefacts were exposed at times, and may have been submerged in melted ice water, but they nonetheless stood the test of time for thousands of years. It's likely that other long-dead bodies may have been preserved in the same way.

A reconstruction of Ötzi on display at the South Tyrol Museum of Archaeology in the city of Bolzano in South Tyrol, Italy

An illustration of a young planet forming from rocky asteroids. Some pieces careen off into the atmosphere of the local star

SPACE

Crushed-up planets around dead stars could rewrite history

WORDS BRANDON SPECKTOR

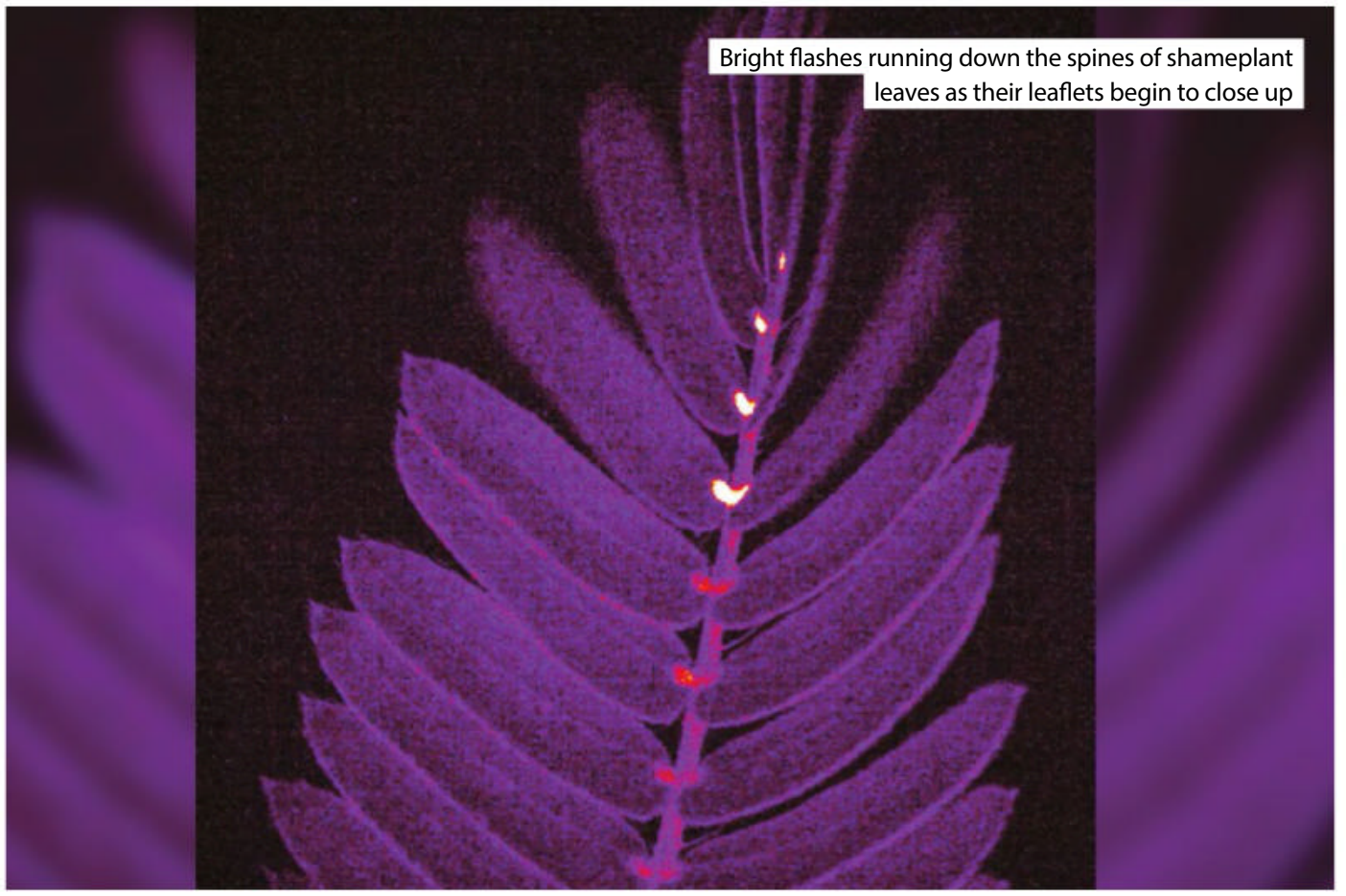
Planets may have begun forming in our Solar System when the Sun was still young, millions of years earlier than previously thought. Astronomers analysed the mixture of different elements in the atmospheres of more than 200 white dwarfs – the dead, dim husks of stars that were once as massive as our Sun or larger. They found clear evidence that these stars were polluted with heavy elements like iron, magnesium and calcium. White dwarfs typically have pristine atmospheres, and these elemental anomalies could only result from collisions with ancient asteroids called planetesimals, the rocky building blocks of early planets that burned up in the stars' atmospheres aeons ago.

This is not the first time that white dwarfs have been caught wearing the corpses of would-be planets in their atmospheres. However, the types of elements detected in these particular stars suggest that the burnt-up planetesimals once had iron cores, meaning they had gone through the long process of melting and hardening known as differentiation, the same process that gave Earth its rocky mantle and iron core billions of years ago. In order to have endured this long melting process, those iron-cored planetesimals must have formed within the first million years of their solar systems' lives, far earlier than most models of planet formation suggest. "The cause of the melting can only be attributed to very short-lived radioactive elements that existed in the earliest stages of the planetary system but decayed away in just a million years," said Amy Bonsor, an astronomer at Cambridge University. "In other words, if these asteroids were melted by something which only existed for a very brief time at the dawn of the planetary system, then the process of planet formation must kick off very quickly."

Today's leading theories of planet formation suggest that planets originate from icy discs of gas and dust that orbit young stars; over time, tiny particles in these discs stick together, forming ever-larger objects. Eventually, rocky planetesimals emerge. Some of these planetesimals continue to accrete matter from their surroundings, becoming planets, while others remain as asteroids, like the ones that apparently crashed into the white dwarfs in the new study. Most theories hold that planetesimals don't appear in a solar system until their host star has already reached its final size, many millions of years after the star's birth. But this new study suggests that cannot always be the case – in order for a dead star to contain the remains of iron-rich asteroids in its atmosphere, then that star and its planetesimals must grow up together. And that pushes back the start of planet formation by millions of years.

"Our study complements a growing consensus in the field that planet formation got going early, with the first bodies forming concurrently with the star," Bonsor said. This type of planet formation may be ubiquitous among solar systems, including our own. But that doesn't mean that Earth, or any other planet, is older than was previously thought; the study's findings only suggest that the physical process of planet formation begins much earlier than prevailing models have claimed.

Did you know?
Earth is estimated to be 4.5 billion years old



Bright flashes running down the spines of shameplant leaves as their leaflets begin to close up

PLANET EARTH

Fluorescent flashes reveal the secrets of the 'touch-me-not' plant

WORDS HARRY BAKER

Flashes of light shoot along the spines of fluorescent-stained leaves from the 'touch-me-not' plant as they fold up. The shameplant (*Mimosa pudica*), also known as the touch-me-not, is renowned for its ability to quickly curl up its leaves when they are touched by retracting the leaves' elongated, pine-like leaflets back towards its central spine. However, until now, the exact mechanisms behind this animal-like reflex have largely remained a mystery. A team of researchers created genetically altered fluorescent shameplants and filmed their leaves as they curled up. The resulting footage revealed that both chemical and electrical signals moved in unison through the leaves and triggered the leaflets to be pulled back. "Plants possess various communication systems that are normally hidden from view," said Masatsugu Toyota, a plant physiologist at Saitama University in Japan. The best way to figure out how they work is to make them visible,

Researchers discovered that parts of the leaves light up as action potentials, the electrical depolarisations of cell membranes, move through them. This is similar to how nerves work in animals, but without specialised cells to channel the electrical energy the signals travel more slowly through the plant's tissue. As cells depolarise, they release calcium ions that react with the fluorescent markers placed in mutated plants. The most noticeable flashes are those that consecutively light up along the centre of the leaves. These are given off by tiny organs called pulvini, which pull back the leaflets towards the leaves' spines using changes in water pressure. Fainter fluorescent signals also travel along the leaflets from where a stimulus is detected to the closest pulvinus before the folding organs start flashing. Once a pulvinus is activated, it sends a signal to the adjacent pulvini, which creates a bright domino effect along the spine.

Scientists already knew about pulvini, but until now they had no idea how quickly they contracted adjoining leaflets. The new videos show that the pulvini receive signals around 0.1 seconds before the leaflets contract, which is exceptionally fast for a plant. The new study also sheds light on why shameplants have evolved to close up their leaves. The leading theory is that the leaves close up to protect themselves from hungry insects. Researchers created additional genetic variants of shameplants which had no pulvini and therefore couldn't close up their leaves. The team then exposed the mutated and non-mutated plants to grasshoppers and found that the mutated plants had many more of their leaves eaten by the insects. Other potential reasons for the shameplants to close up their leaves include reducing water loss or preemptively hiding from insects, but there is less evidence to support these ideas.

ANIMALS

JUVENILE BIRD BREAKS THE RECORD FOR LONGEST NON-STOP FLIGHT

WORDS HARRY BAKER

A bird recently broke the world record for the longest continuous bird flight on its first long-haul journey across the Pacific after the youngster got mixed up and landed in the wrong place. The bar-tailed godwit (*Limosa lapponica*) flew 8,435 miles from Alaska to Tasmania. The youngster, around five months old, took off on 13 October 2022 and touched down on 25 October 2022 after flapping its wings non-stop for 11 days and one hour, or 265 continuous hours.

Most bar-tailed godwits finish their migrations in New Zealand or Australia. But satellite data reveals the youngster made a wrong turn late in the route on its approach to New Zealand; it flew between the two countries and ended up on the wrong side of Australia. Experts suspect this navigational mishap was caused, in part, because the bird had no idea where it was headed. Juvenile bar-tailed godwits make their maiden migration up to six weeks after their parents have already flown south for the winter, unusual for birds. The delayed departure enables youngsters to spend more time fattening up before they head out on their energy-sapping journey. Most juveniles manage to eventually meet up with the adults despite having never travelled to their final destination before.

An adult bar-tailed godwit flies across the Pacific on its annual migration

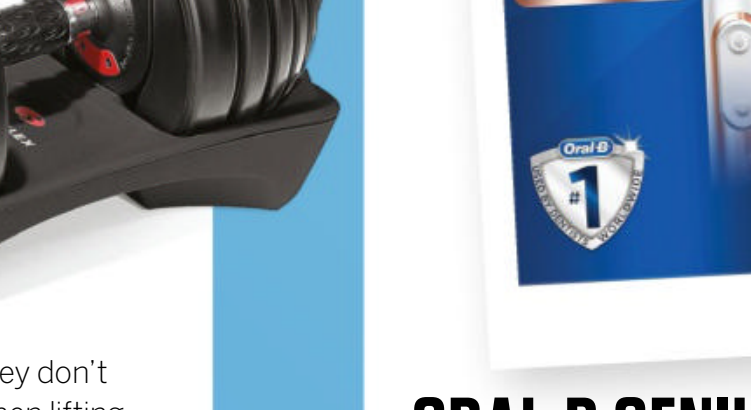
WISH LIST

The latest tech for HEALTH AND FITNESS

LAIRLUX EM 03 DEEP-TISSUE MASSAGE GUN

WWW.LAIRLUX.COM $89 (APPROX. £74.70)

The Lairlux EM 03 Deep Tissue Massage Gun uses 20 speed settings and six ergonomically designed attachments to deliver an effective full-body deep-tissue massage. This compact handheld device is no bigger than a travel hair dryer, yet packs some serious punch when it comes to drilling into hard-to-reach muscles and bonier body parts. This massage gun is lightweight in design and cost and comes neatly tucked away in a travel case with a charger, six individually shaped heads and a handy instruction manual for a quick lesson on performing a massage. If you're looking for a travel companion to keep your limbs loose on the go, the Lairlux EM 03 is up to the task. But if you're after a more industrial model, this won't be the massage gun for you.

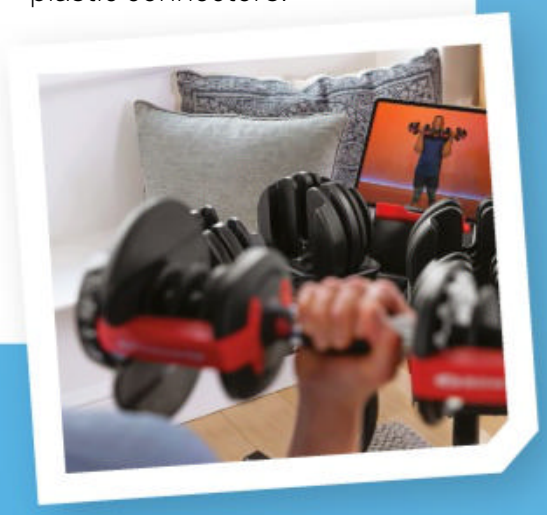


BOWFLEX SELECTTECH 552I

WWW.GLOBAL.BOWFLEX.COM

£325 / $375

A pair of Bowflex SelectTech 552i dumbbells replaces 15 standard sets and has an easy-to-use dial system for quick weight changes between 2.0 and 24.0 kilograms. This excellent range means that muscle strength can be built gradually and most stationary and motion exercises are possible, resulting in a whole-body workout. Weights on the 552i are switched with a smooth turn of the selector dial, removing the hassle of screwing on collars. Also, the metal plates are encased in moulding so they don't clang together when lifting. These dumbbells sit in a storage tray that neatly houses the weights not being used. You can pick up and port the whole carriage between workout spaces, but you'll need to avoid slamming them down because it can crack the plastic connectors.



ORAL-B GENIUS X

WWW.ORALB.CO.UK £156 / $199.99

The Oral-B Genius X is the ideal toothbrush for anyone wanting to improve and maintain good dental hygiene. An interactive app tracks and monitors your brushing habits and patterns using artificial intelligence, while extra features help users set oral hygiene goals with coaching tips. Featuring six cleaning modes, including tongue cleaning, sensitive, whitening, gum care and pro-cleaning, this toothbrush delivers on oral hygiene with a powerful oscillating-rotating brush head. Users who prefer a quieter brushing session may find the Oral-B Genius X a little noisy, given that it isn't a sonic toothbrush. Operating at around 70 decibels, it's similar to a dishwasher or washing machine. But for anyone who's been advised by their hygienist to improve their brushing technique, it could be a game changer.

LEVOIT CORE 400S AIR PURIFIER

WWW.LEVOIT.COM £219.99 / $219.99

The Levoit 400S is a sleek and stylish cylinder purifier, making it an easy addition to any room, whatever the décor. A colour-coded display gives users a great visual on air quality at any given moment. The air purifier is lightweight and features indented handles at either side, making it easy to move from room to room. A companion app gives useful data on air quality and allows users to schedule and time the air purifier to fit round a busy family schedule. Stylish, quietly powerful and with an intuitive, easy-to-use smart interface, the Levoit 400S is a great air purifier. It could be the ideal appliance for you if you're looking for an effective air purifier that's big on performance but doesn't blow the budget.

FITBIT SENSE

WWW.FITBIT.COM £219.99 / $224.95

The Fitbit Sense is one of the best models from Fitbit thanks to a combination of features and a sleek AMOLED display. While you won't get all the high-end features found on Garmin watches – no downloadable maps and the GPS functionality isn't as impressive – you do have some other extras, such as the EDA scanner. This measures 'stress' by reading how sweaty your hands are. If the model senses that you're feeling hassled, it will suggest meditation practices. The watch also comes with an ECG scanner, which offers some insight into your heart health, and will give you alerts if your heart rate is unusually high or low. Like a lot of other modern wearables, the Sense also has a Daily Readiness score that guides you on how much you should push yourself at the gym.

MOBVOI HOME TREADMILL

WWW.MOBVOI.COM £429.99 (APPROX. $512.50)

A decent treadmill will usually set you back by over £1,000, but this budget alternative from Mobvoi is surprisingly powerful for the price. It has a maximum speed of seven miles per hour, which is ideal if you want to do daily gentle jogs and runs. You can also add or remove the rails on either side of the machine, allowing you to slot it under a desk and use it as a walking treadmill. At this price, you won't get flashy extras like a dedicated digital running platform with upbeat classes displayed on a high-definition screen. But there's a handy slot for your tablet or phone at the front, allowing you to watch shows while you work out. You can navigate the different controls on the machine using either the LED dashboard or a handy remote. And because it's so compact, it easily slots underneath a sofa or bed for storage.

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SPECIAL

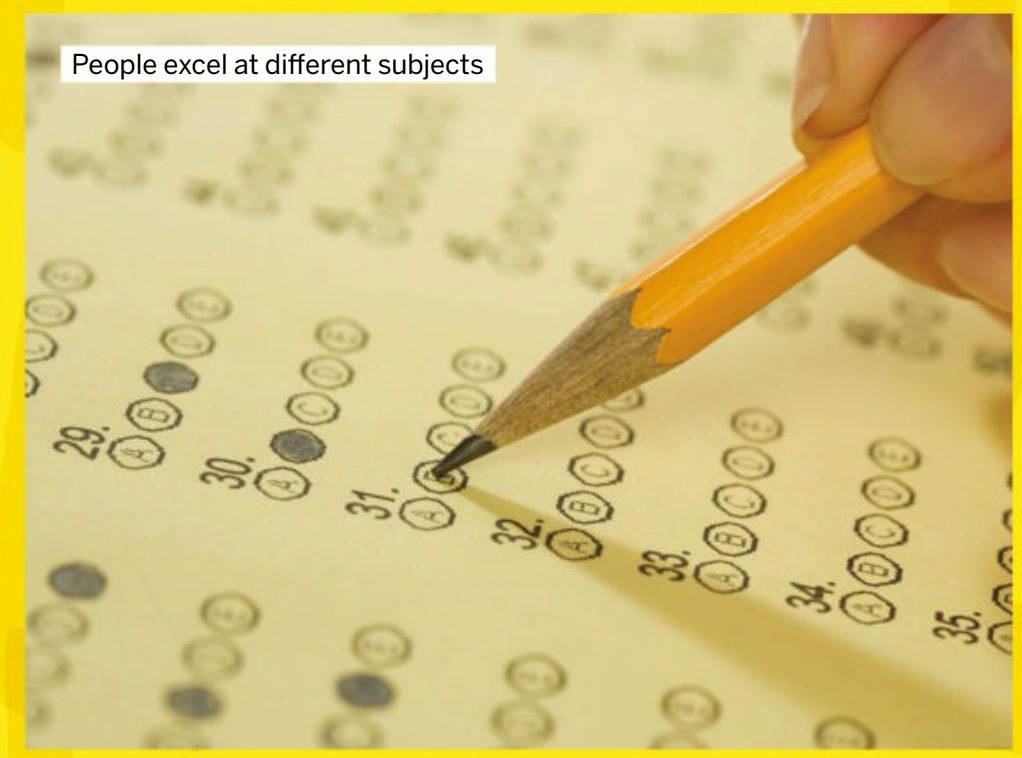
TEST YOUR INTELLIGENCE

ARE YOU SMARTER THAN...

How your intelligence compares to other clever members of the animal kingdom

WORDS **SCOTT DUTFIELD**

DID YOU KNOW? Electrical signals in the brain travel at 268 miles per hour



People excel at different subjects

What makes you smart? At its most fundamental level, intelligence is often defined as a person's ability to learn from an experience, understand their environment and complete tasks. The fundamentals of intelligence have been broken down and pored over for hundreds of years, from the emergence of general intelligence, or the g factor, in the late 1800s to more recent explanations of its niche branches. Psychologist and Harvard professor Howard Gardner estimates that intelligence can fall into one of eight different categories. Each category covers the different ways humans process information, including musical, linguistic, naturalistic, spatial and interpersonal intelligence. A person may have more intelligence in one of these categories but may struggle in others. Whether you're particularly adept at solving puzzles, retaining factual information or gauging emotion, all forms of intelligence come from the same place: the brain.

Within your skull is an organ that's so smart, it's the only organ in your body that perceives its own existence and has given itself a name. The average brain weighs around 14 kilograms, and it's made up of around 60 per cent fat. The rest consists of water, carbohydrates and proteins. To process thoughts and feelings and retain information and memories, the brain uses billions of cells called neurons. Neurons work together to form a vast network of active electrical impulses to keep your body ticking. Memories and cognitive abilities are held in the brain by forming connections of these neurons: the stronger the memory and the more information the neurons receive, the stronger the connection.

Did you know?

The human brain isn't fully formed until age 25

A BRIEF HISTORY OF TESTING INTELLIGENCE

BINET-SIMON SCALE

French psychologists Alfred Binet and Theodore Simon were asked by the French government in the early 1900s to develop a test for school pupils to evaluate intelligence based on different tasks, such as copying patterns, naming objects and putting things in the correct order. The Binet-Simon scale was quickly adopted by psychologists and educators to standardise the measurement of intelligence.

STANFORD-BINET SCALE

The Binet-Simon scale was adapted by Lewis Terman, an American psychologist at Stanford University, in 1916. Terman published *The Measurement of Intelligence*, which revised and broadened Binet and Simon's scale. The Stanford-Binet scale of intelligence quotient (IQ), as it became known, accounted for both a person's age, mental age and intelligence score to generate an overall IQ score.

WORLD WAR I ADMISSIONS

In 1917, American psychologist and chair of the Committee on the Psychological Examination of Recruits for the US Army, Robert Yerkes, developed new IQ tests to assess the suitability of potential recruits into the armed forces. During this time, Yerkes assessed over 2 million soldiers.

WECHSLER INTELLIGENCE SCALE

Developed by Romanian-American psychologist David Wechsler in 1941, the Wechsler scale applied a similar form of testing to the Stanford-Binet model, albeit longer and with fewer tasks. Rather than concluding with a single score, it calculated three: a person's verbal IQ, a performance IQ and finally a full-scale IQ.

ARE YOU SMARTER THAN YOUR PARENTS?

The ageing human brain is often associated with deterioration, memory loss and the development of neurological conditions such as dementia. While it's true that certain aspects of the human mind lessen in their functionality over time, intelligence doesn't necessarily decrease. A 2015 study by Harvard University revealed that different cognitive skills peak at different ages. Quick thinking and recalling information peak at 18 years old, whereas reading the emotions of others and event recall peak at 30. Other skills, such as basic maths and a broad vocabulary, don't peak until 50 years old. You might not be smarter than your parents in some aspects, but you are likely smarter than your distant relatives. Known as the Flynn effect, named after pioneering New Zealand intelligence researcher James Flynn, with every new generation, average IQ increases. It's estimated that with every decade, the average IQ score increases by three points. It remains unclear what the cause of this phenomenon is.

To measure the strength of these connections and gauge human intelligence, many scientists and psychologists have created different 'intelligence tests'. Some of the earliest examples of mental tests date back 3,000 years to ancient China. One of the most commonly known intelligence tests of the modern day is the intelligence quotient (IQ) test. First developed in the early 1900s, an IQ test measures five categories to evaluate a person's cognitive ability. These categories include fluid reasoning, or the ability to think logically; general knowledge; quantitative reasoning, which uses mathematics to solve problems; visual-spatial processing and working memory. All of these elements of intelligence are individually tested, scored and then combined to get an overall IQ score. The average IQ score sits between 90 and 109, with anyone scoring above 140 considered to have a high IQ.

Did you know?

The brain can store 2.5 million gigabytes of data

> **"One of the most commonly known intelligence tests of the modern day is the intelligence quotient test"**

Over the years, some studies have made a positive correlation between the volume of a brain and the IQ score of its owner. For example, Albert Einstein's parietal lobes have been a sounding board for a genius with a big brain – his parietal lobes were 15 per cent larger than the average person's. The somewhat simplistic theory behind this idea is that a bigger brain has more neurons, and therefore can process and retain more information. However, not all scientists are sold on this idea, especially when you consider intelligence in the animal kingdom and among those that don't even have a brain, such as starfish. When it comes to sizing up who's smarter than who in the animal kingdom, sheer brain mass might not actually matter, especially not when you compare it to the animal's body size.

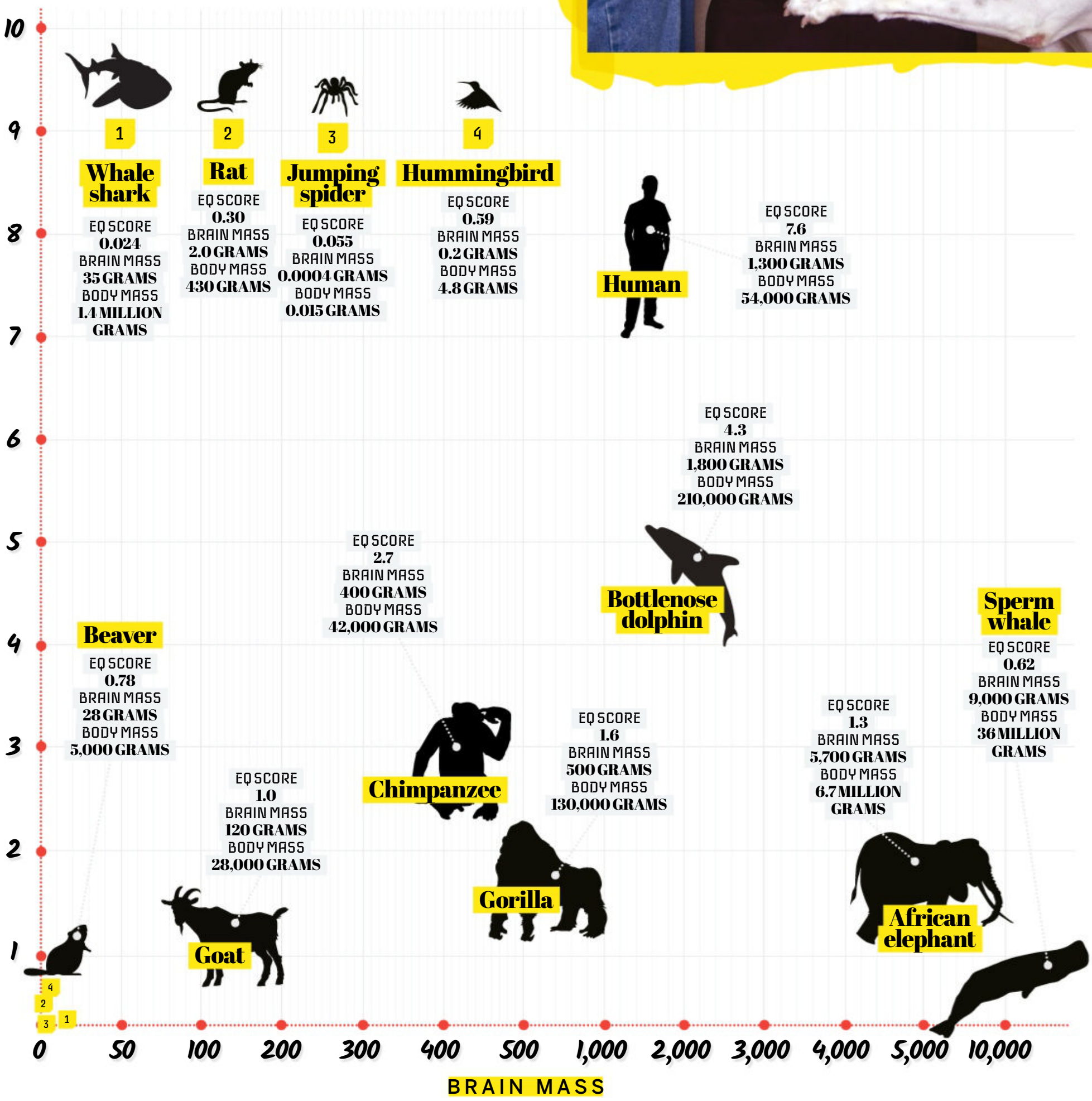
In 1973, psychologist Harry Jerison proposed a new metric to consider the relationship between the brain and body. Called the encephalisation quotient (EQ), Jerison said that calculating the ratio between an animal's body mass and brain volume could produce a comparative measurement of intelligence. Humans have an EQ score of between 7.4 and 7.8, which means human brain mass is over seven times greater than a typical mammal's. Much like any form of intelligence testing, EQ has faced criticisms and questions about its accuracy as a universal method to gauge an organism's overall intelligence.

Different types of intelligence peak at different ages

DID YOU KNOW? Although the brain only accounts for two per cent of your body weight, it uses 20 per cent of its overall energy

Animal intelligence

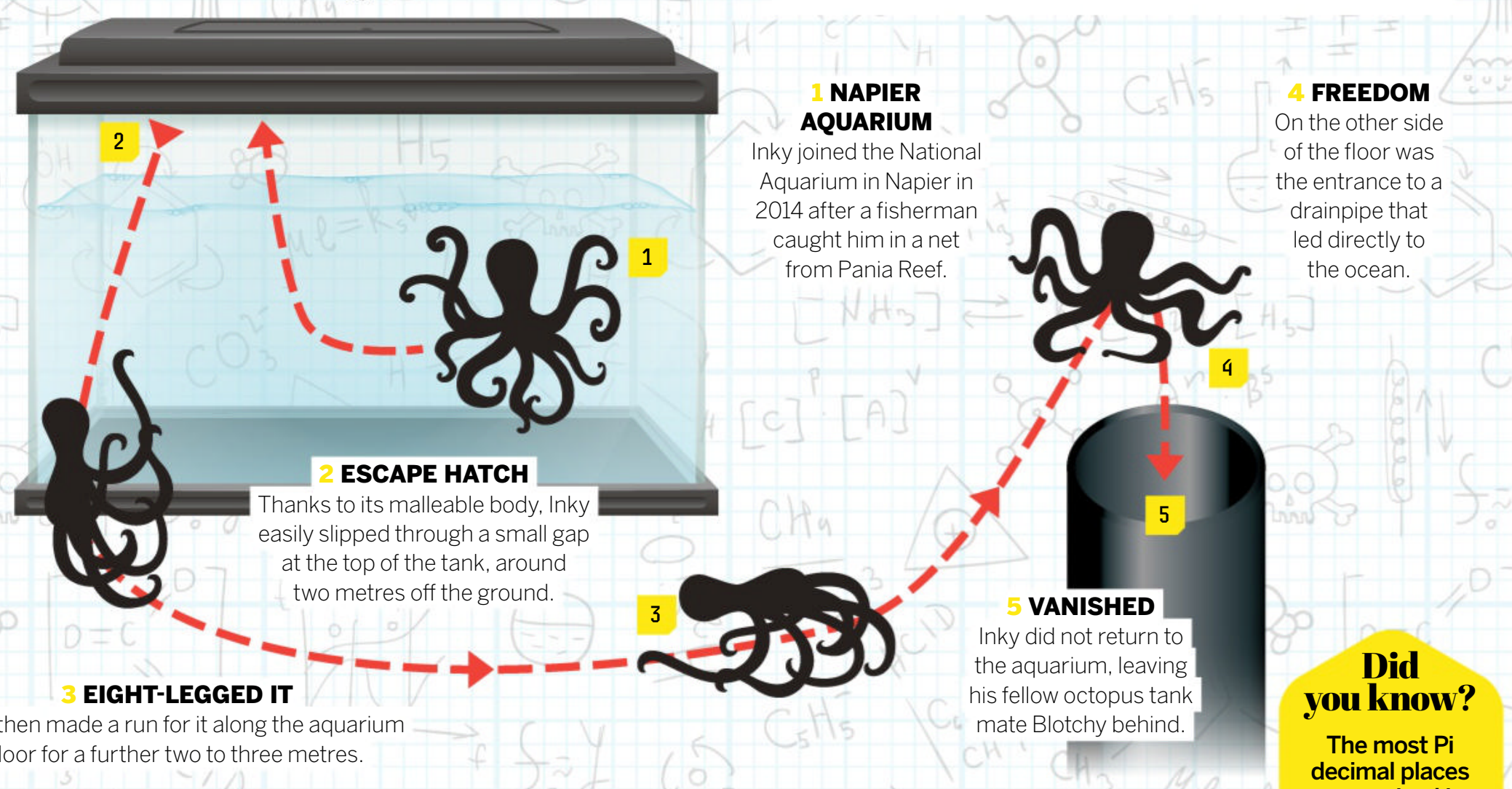
How EQ and brain size differ across the animal kingdom



Clever critters

INKY'S ESCAPE

How the Houdini of molluscs broke out of his glass box



1 NAPIER AQUARIUM
Inky joined the National Aquarium in Napier in 2014 after a fisherman caught him in a net from Pania Reef.

2 ESCAPE HATCH
Thanks to its malleable body, Inky easily slipped through a small gap at the top of the tank, around two metres off the ground.

3 EIGHT-LEGGED IT
Inky then made a run for it along the aquarium floor for a further two to three metres.

4 FREEDOM
On the other side of the floor was the entrance to a drainpipe that led directly to the ocean.

5 VANISHED
Inky did not return to the aquarium, leaving his fellow octopus tank mate Blotchy behind.

OCTOPUS ESCAPE ARTISTS

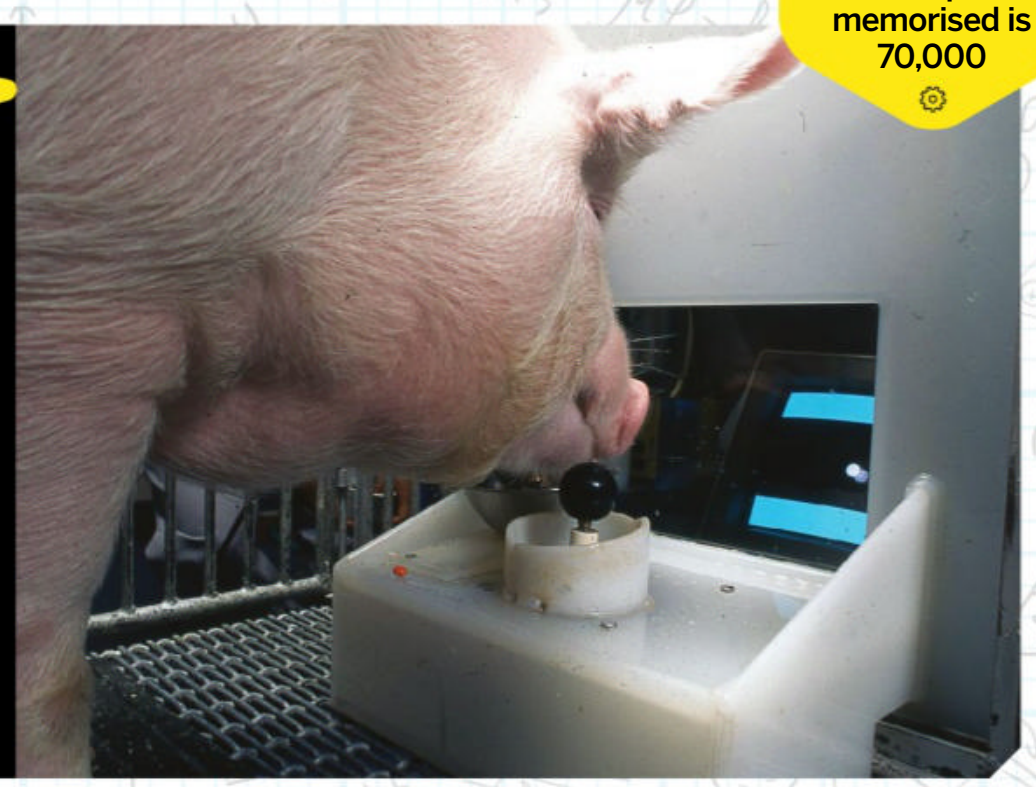
Octopuses, of which there are around 300 species, are brainboxes with a talent for escaping. Unlike other mollusc species, octopuses have a centralised brain similar to a human's. However, only a third of its overall neurons can be found in its brain. The rest can be found in the octopus' arms. Over the years, many octopuses in captivity have wreaked havoc on their keepers with their escape artist antics. In 2016, an octopus named Inky sprung itself from a New Zealand enclosure, *Finding Nemo*-style, and into a 50-metre drainpipe that led to the ocean. Similarly, in Bermuda an octopus temporarily escaped its tank to eat the crab inhabitants of the adjacent tanks before returning to its own enclosure.

Did you know?

The most Pi decimal places memorised is 70,000

PIGGY GAMERS

The intelligence of pigs has been well documented over the years. In puzzle-solving studies, researchers discovered that pigs can locate and flip containers holding tasty treats quicker than dogs and persist longer in the trials of unsolvable puzzles. Pig smarts have also been challenged in the gaming world. Researchers at Pennsylvania State University trained four pigs, called Hamlet, Omelette, Ebony and Ivory, to use arcade-like joystick games. The pigs used a joystick to move a cursor on a digital screen to hit walls, and some were better than others: Ivory hit one-wall targets 76 per cent of the time. However, Omelette and Hamlet only hit the targets less than half of the time. To keep the pigs engaged with the game, a food reward was dispensed after 'winning'. During this investigation the dispenser broke, but the pigs continued to play on without any rewards.



DID YOU KNOW? Researchers taught an African grey parrot called Alex a vocabulary of more than 100 words

CROW ENGINEERS


A New Caledonian crow using a twig to fish for grubs

Corvidae is a family that includes crows and ravens, which are among the cleverest birds on Earth. They are particularly good at solving puzzles and finding a solution to a problem, especially when food is involved. It's been well documented that crows, particularly New Caledonian crows (*Corvus moneduloides*), use small twigs to hook into holes in tree bark to fish out insect meals. Researchers at the University of Oxford have discovered that New Caledonian crows can construct tools to snatch food in hard-to-reach places. Researchers initially gave crows sticks long enough to dig out treats from a transparent puzzle box, which they completed easily. When researchers introduced items such as dismantled plastic syringes that alone were too short to reach the food, the crows quickly came up with a solution. By partially inserting the plunder of the syringe into the accompanying barrel, they created tools long enough to reach the food and move it out of the puzzle box.

CAN YOU OUTSMART A CHIMP?

As our closest evolutionary relative, chimpanzees are some of the smartest animals on Earth. Along with using tools and heightened emotional intelligence, these primates have remarkable memory and cognitive functions. Researchers at the Primate Research Institute at Kyoto University, Japan, conducted a landmark study that demonstrated the ability of chimpanzees to recognise and recall information. Ayumu, one of the test chimps, was shown numbers one to nine in random positions on a touchscreen. The goal of the task was to touch each of the numbers in ascending order. Once Ayumu hit one, the others became white boxes, forcing him to remember the order and positions of the other numbers on the screen. Remarkably, Ayumu and humans scored the same 80 per cent degree of accuracy in recalling their order and positions. The test became increasingly difficult, up to a numeral range of one to 19, and the two-digit structure of single numbers ultimately proved too difficult to recall for Ayumu.

SCAN HERE

or use the link to find out if you have a better memory than a chimpanzee

humanbenchmark.com/tests/chimp

5 ANIMAL TOOL USERS

1 SEA OTTERS
While floating on their backs, sea otters (*Enhydra lutris*) use stones to hammer at abalone shells and crack them open to eat the sea snails.

2 MACAQUES
Although flossing isn't the biggest concern among apes, researchers have found that some macaques use human hair as dental floss.

3 ORANGUTANS
As keen music makers, Bornean orangutans (*Pongo pygmaeus wurmbii*) gather leaves and twigs to form a musical instrument to alter their call and ward off predators.

4 ELEPHANTS
From fly swatters to weaponry, elephants have found many uses for tree branches. Observations of African elephants revealed that they use heavy pieces of wood to lower fences to climb over them.

5 SHRIKES
As fierce hunters, these cute, fluffy birds use sharp twigs and branches to spear their prey. Once they catch a mouse, snake or even another bird, shrikes impale them to create a macabre larder where they can feast on their prey over time.

SPECIAL

PARROTS HAVE SIMILAR BRAINS TO PEOPLE

If you've ever spent time with a parrot, you'll know they are intelligent birds. Many species have the ability to mimic speech and solve complex puzzles. They can even understand the concept of zero, much like humans. In fact, research has shown that parrots and humans share regions in their genomes that regulate the development of the brain. For humans that set of genes led to us growing bigger and more complex brains than our primate ancestors. Similarly for parrots, they possess some of the biggest brains among birds.

Scientists at the University of Alberta, Canada, have found similar neural circuitry in both parrot and primate brains. Two of the largest parts of the brain are the cortex and the cerebellum, which are both responsible for vital higher cognitive functions, including motor skills and information processing. There's a cerebral bridge between the two called the pontine nuclei that ferries information and plays a major part in the overall intelligence of primates. Parrots have a much smaller pontine nuclei than primates, but researchers found that these birds have a similar structure, called a medial spiriform nuclei, that appears to function in a similar way to primates' pontine nuclei. The researchers concluded that an enlarged spiriform nucleus enhances the connection between the cortex and the cerebellum, leading to higher cognitive functions.

Which is which: Monet or Picasso?

AVIAN ART DEALERS

Researchers at Keio University in Japan put pigeons to the test to see if they were able to make a distinction between the two artists' work. To do this, pigeons were trained to peck at an illuminated glass screen. The birds were divided into two groups, one of which was rewarded with hemp seeds when they saw Monet paintings behind the screen, while the other group was rewarded when Picasso's work appeared. By the end of the experiment, both groups could identify the work of their artist to an accuracy of over 90 per cent. Even when the paintings were shown in black and white, the birds still maintained this level of accuracy. This shows that the birds were able to recognise the style and structure of the artist's paintings, not just the colours.

THE CLEVEREST ANIMAL ON EARTH

Dolphins have been recognised as the smartest non-humans on Earth. Bottlenose dolphins have the biggest dolphin brains – they average around 1,600 grams, compared to an average 1,300-gram human brain. However, a dolphin's EQ score is the second largest, surpassed only by humans.

One of the most remarkable aspects of this animal's intelligence is self awareness. Researchers at the Rockefeller University, New York, tested the capacity for mirror self-recognition in bottlenose dolphins to gauge their self-awareness. Using a temporary non-toxic black ink marker, scientists either marked, pretended to mark or ignored their dolphin test subjects and placed mirrors in their swimming tank. What they discovered was that marked dolphins, and even those that thought they'd been marked, spent more time engaging in 'self-directed' behaviours in front of reflective surfaces. The study findings suggest that the dolphins used the mirrors and reflective surfaces to investigate the markings on their bodies. Dolphins aren't alone in their self-awareness. Elephants, orangutans and even ants can spot themselves in a mirror. However, combined with their big brains, a dolphin's social and communication skills put them at the top of the class.

"A dolphin's EQ score is the second largest, surpassed only by humans"

A bottlenose dolphin recognising its own reflection in a mirror

Was the T. rex dumb?

The biggest challenge in evaluating the intelligence of a dinosaur is that there are no living examples to examine. Scientists rely on fossil evidence and digital imaging to estimate the brain size of dinosaurs, such as the fierce *Tyrannosaurus rex*. Using fossilised *T. rex* skulls, researchers estimate that they had the largest brains of any dinosaur, with an enlarged cerebrum – which controls muscle and cognitive function – and enormous olfactory bulbs, which provide a sense of smell. It's estimated that its EQ score would make its intelligence similar to that of a chimpanzee.

Some researchers have suggested that tyrannosaurs evolved their smarts long before they became reptilian behemoths. The first tyrannosaurs, *Timurlengia*, lived around 170 million years ago and were small predators feeding in the shadows of much larger carnivores. Computerised tomography scans of a fossilised *Timurlengia* skull revealed that its brain was comparable in structure, such as a similar elongated cerebrum, to the evolved *T. rex*.

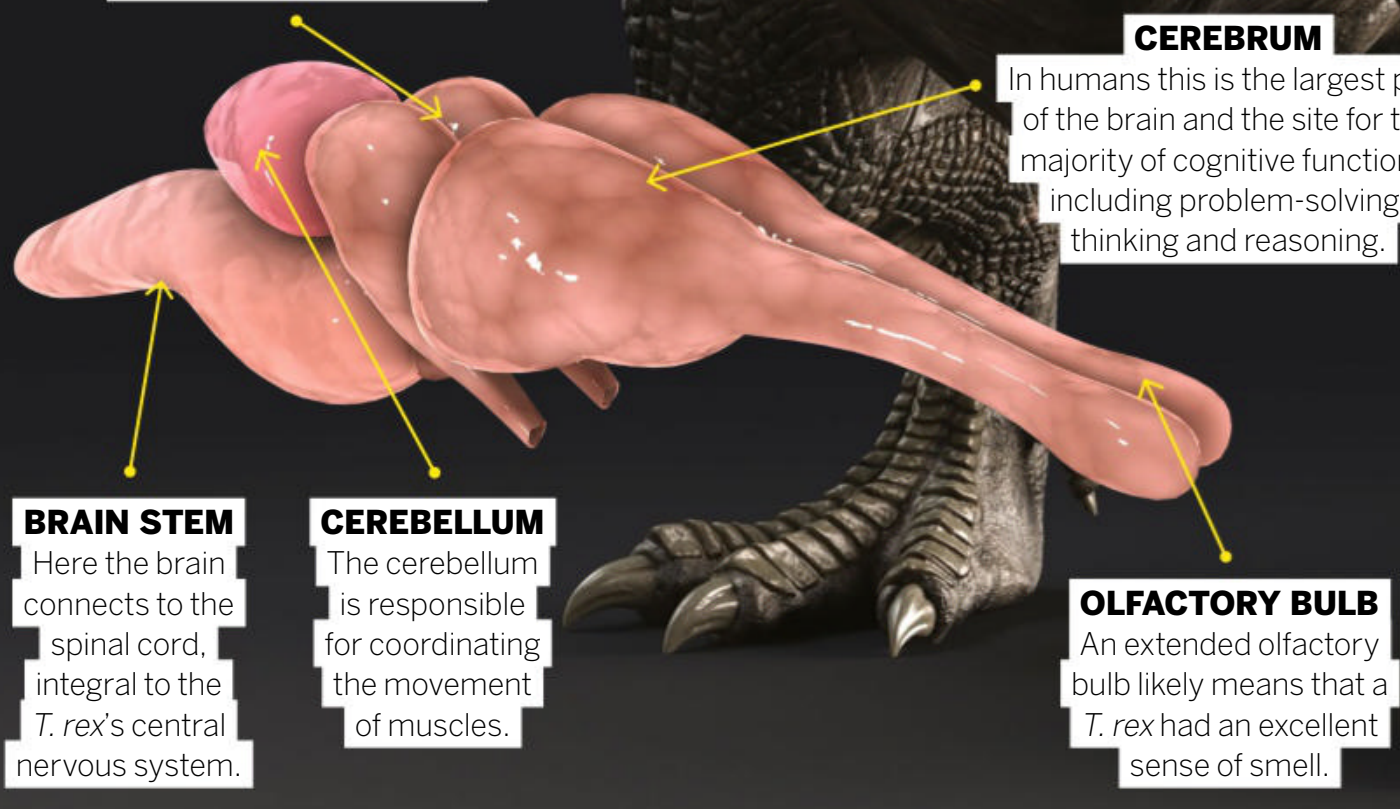
Did you know?

Pigs are thought to be as smart as a three-year-old child

INSIDE A *T. REX*'S SKULL

The brain behind the fiercest prehistoric predator

It's a common misconception that the *T. rex* was stupid



OPTICAL LOBE
Due to the large size of a *T. rex*'s optical lobe, they may have had great vision.

CEREBRUM
In humans this is the largest part of the brain and the site for the majority of cognitive functions, including problem-solving, thinking and reasoning.

BRAIN STEM
Here the brain connects to the spinal cord, integral to the *T. rex*'s central nervous system.

CEREBELLUM
The cerebellum is responsible for coordinating the movement of muscles.

OLFACTORY BULB
An extended olfactory bulb likely means that a *T. rex* had an excellent sense of smell.

Can you beat the How It Works team?

Put your IQ to the test with these perplexing puzzles and see how you compare against team How It Works. You've got 15 minutes, starting... now!

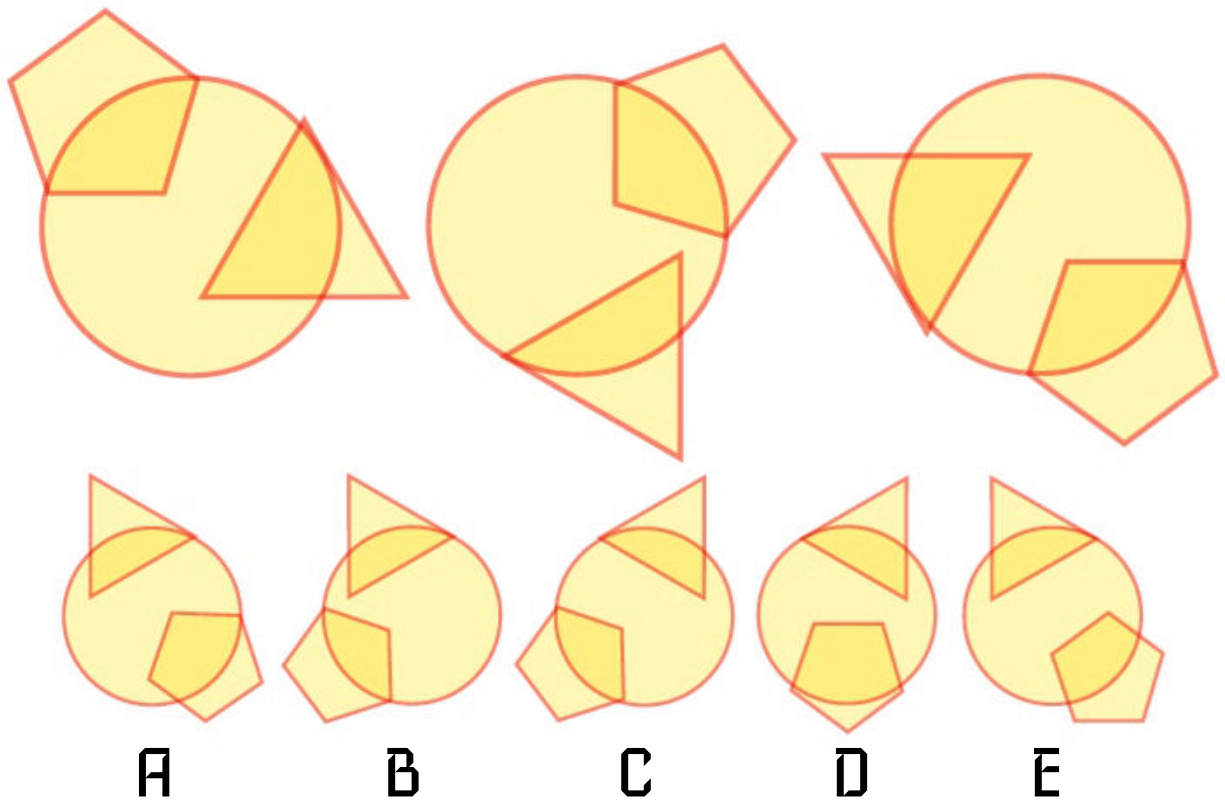
1

Fill in the missing plus, minus and multiplication signs to make the equation below correct, performing all calculations strictly in the order they appear on the page.

32 28 4 21 7 18 = 36

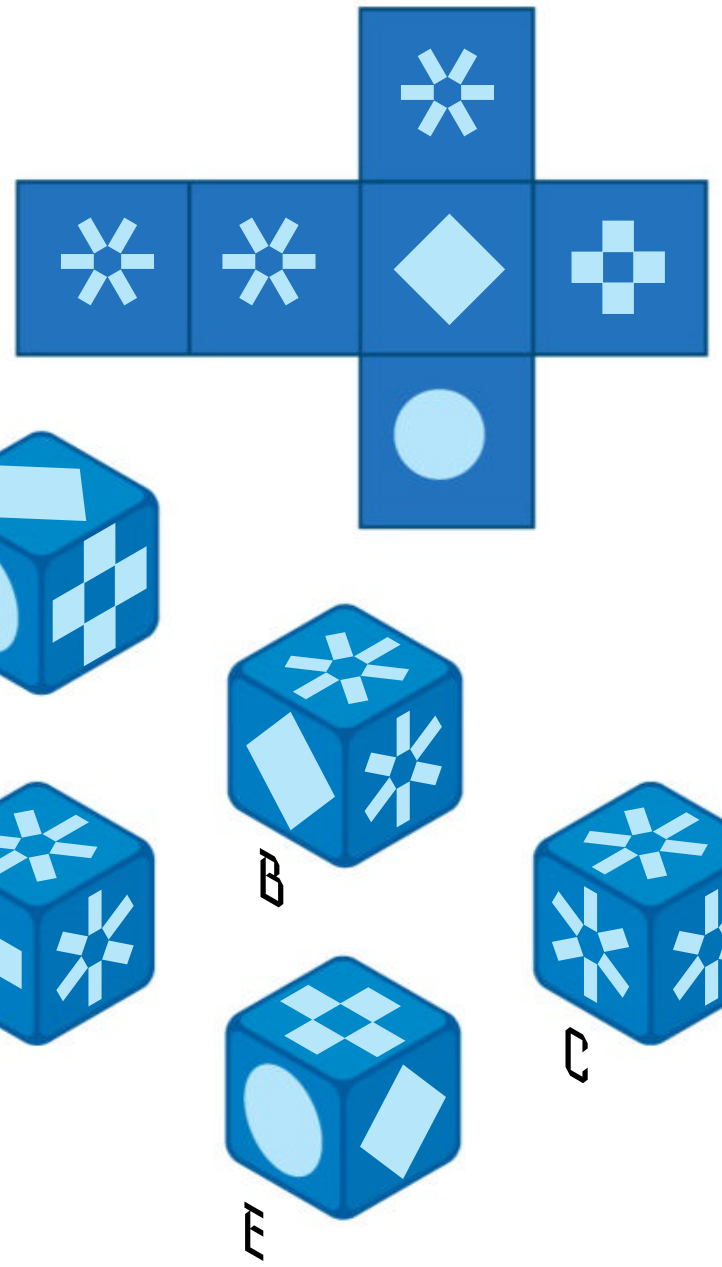
2

Which of the options A to E most accurately continues the sequence?



3

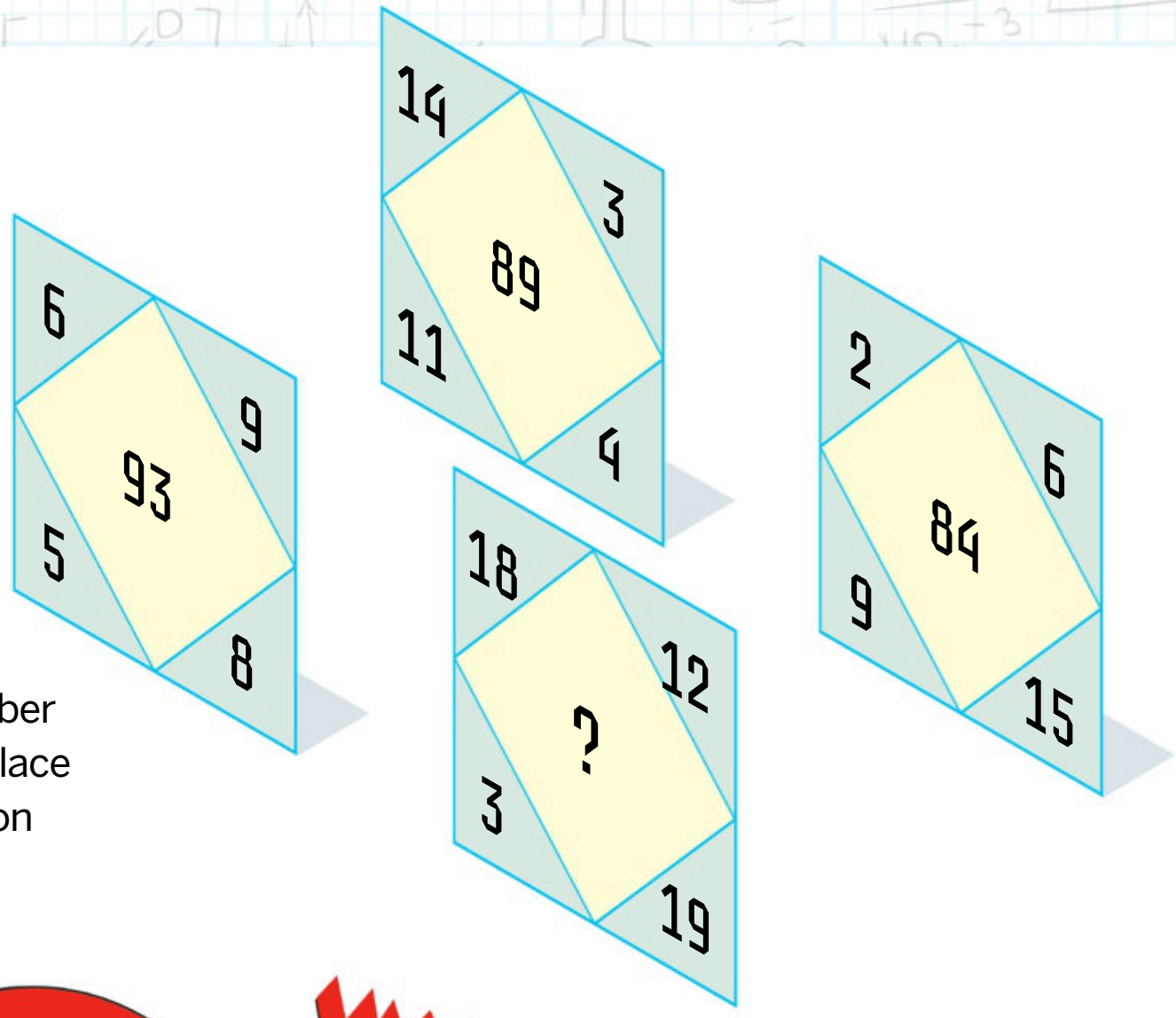
Which of the cubes A to E cannot be made using the layout shown?



(CUBES 180 DEGREES) PUZZLE 3: E PUZZLE 4: (18x19)+(3x12)=342+36=378 PUZZLE 5: B PUZZLE 6: 4:30+1:40=6:10

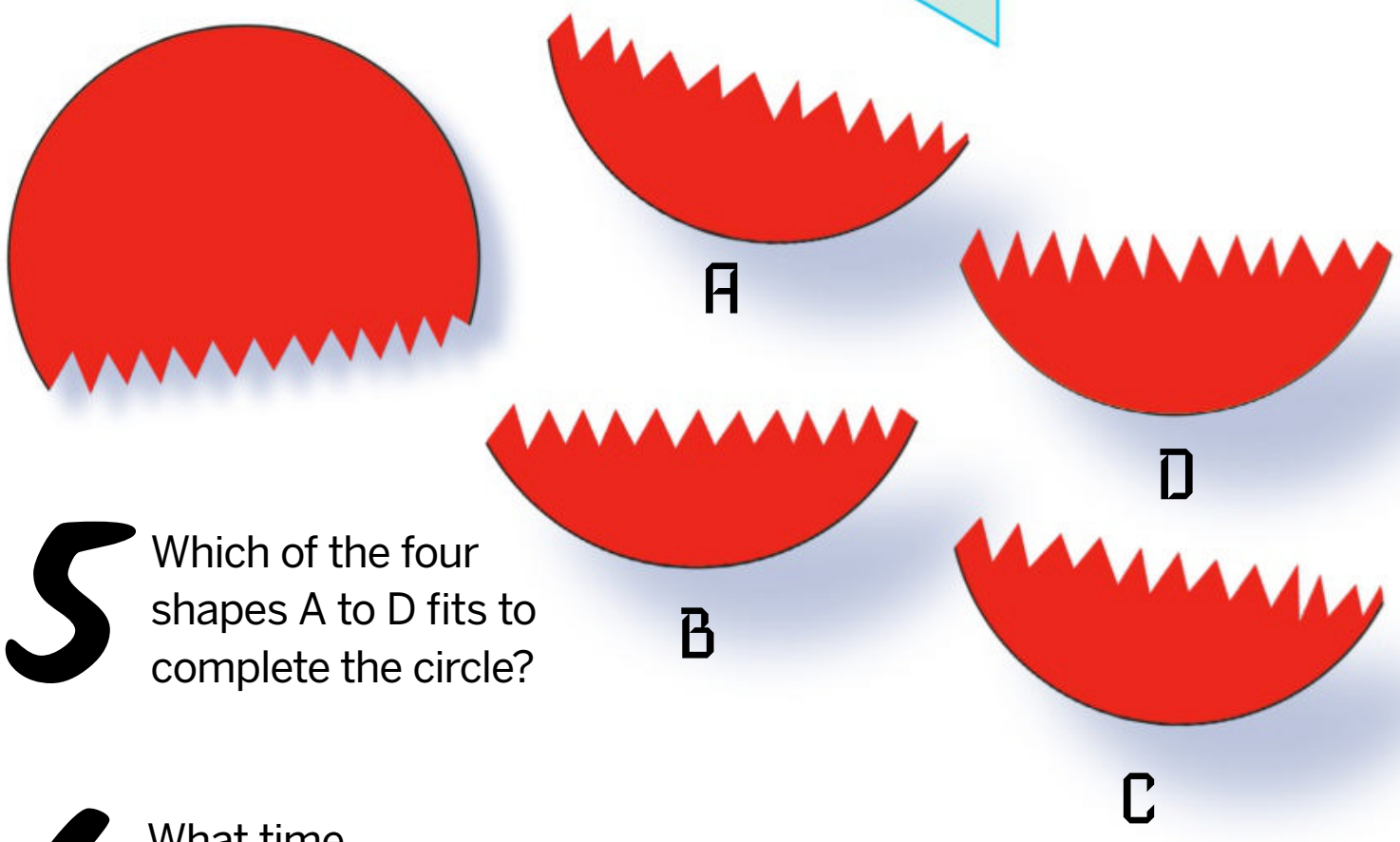
4

What number should replace the question mark?



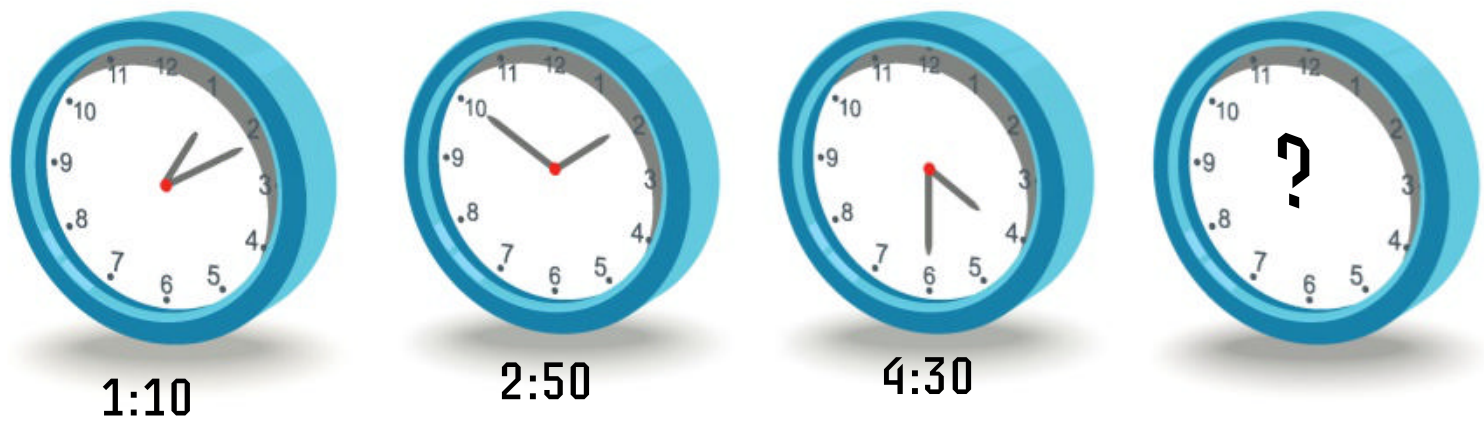
5

Which of the four shapes A to D fits to complete the circle?



6

What time should the final clock indicate?



Beat the team results

NIKOLE
Despite her modesty about taking this test, Production Editor Nikole topped the team. You'll do well to match her score.

6/6

DUNCAN
There must be something about dealing with pictures that gives Senior Art Editor Duncan the edge in this visual IQ test.

5/6

AILSA AND SCOTT
Writers Scott and Ailsa draw level with two-thirds accuracy. You can pat yourself on the back if you score four out of six too.

4/6

TIM
Shows that being the boss doesn't make you smarter than everyone. Except if you're the Editor-in-Chief bossing Editor Ben.

3/6

BEN
You'd think, being Editor and all, Ben would give himself a high score. Two out of six in this tough challenge isn't all that bad.

2/6

ANSWERS: PUZZLE 1: 32-28x4-21+7x18=36 PUZZLE 2: B (GROUP ROTATES 90 DEGREES CLOCKWISE, THEN TRIANGLE RO

HOW CHEESE IS MADE

From dairy farm to cheesemonger, explore the art of turning spoiled milk into a favourite foodstuff

WORDS **AILSA HARVEY**

Whether it's in the form of a French fondue, pizza topping, slice of grilled halloumi or sprinkling of feta, there's a type of cheese to complement most savoury foods. Humans have produced cheese for around 4,000 years, but its exact origin remains unknown. One common theory is that it was discovered accidentally when stomachs taken from butchered cattle were used to carry milk. Inside the stomach is an enzyme that causes milk to curdle, and when transporting milk for long periods, people discovered that their milk had solidified in the process. Upon tasting it, others wanted to recreate this newly discovered foodstuff's unique flavour. Over time, specific ingredients and controlled conditions provided the world with cheeses of different flavours, colours and textures.

Today, cheese is popular globally. In the US, for example, over one-third of all milk produced is used to make cheese. Part of what puts cheese in such high demand is its addictive chemistry. Cheese and other dairy products contain a chemical called casein, which stimulates the brain's opioid receptors to release the 'feel-good hormone' dopamine. This chemical is the brain's way of encouraging you to repeat a behaviour.

Much of the cheese selection on the shelves of a supermarket isn't classified as 100 per cent cheese because it's processed. Processed cheeses are products that combine natural cheese with other ingredients, such as preservatives, dyes and more dairy. This can extend shelf life, change its creaminess and ability to melt, as well as reducing the cost for the producer and consumer. However, these are often higher in salt and fat than naturally produced cheese.

SOFT VERSUS HARD

When it comes to buying cheese, one of the first things you might notice is that it is labelled as either a 'soft' or 'hard' cheese. This refers to its moisture content, with more moisture, called whey, resulting in a softer cheese. Hard cheeses have a whey content of 50 per cent or lower, while soft cheeses are higher than 50 per cent. All cheeses begin soft, but the longer the curd is heated at high temperatures, the more moisture is lost and the harder it becomes. Cheddar, parmesan and gouda are some of the most popular hard cheeses. Because bacteria favours a moist environment to grow in, hard cheese lasts around four times longer than soft cheese in the fridge. While hard cheese is a better source of calcium than soft cheese, the latter is particularly higher in vitamins B6 and B12.

Parmesan cheese usually takes between 24 and 36 months to mature

Did you know?

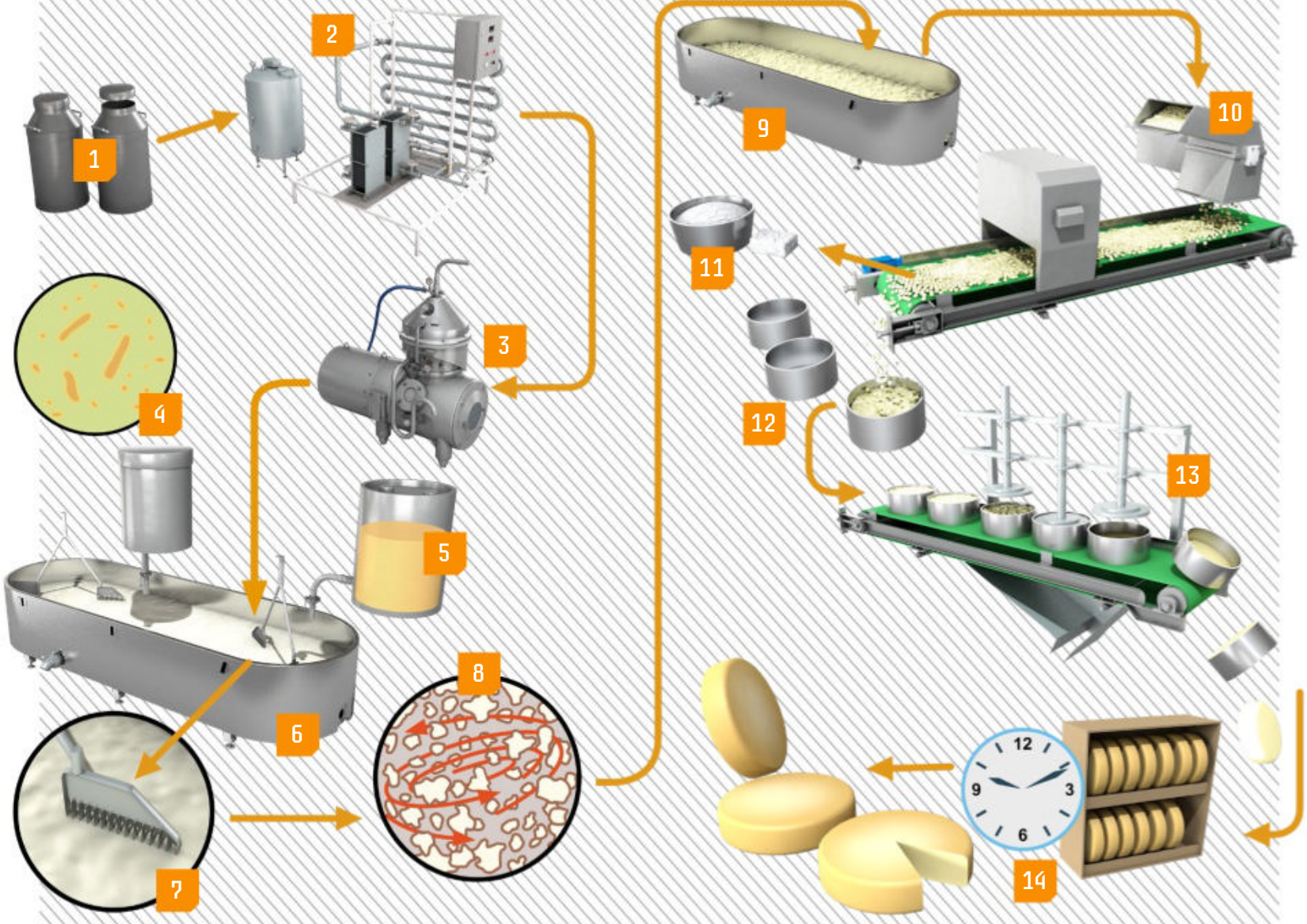
There are around 2,000 types of cheese

This machine is slicing through cheese curds

DID YOU KNOW? Cheese is made using ten times its final volume in milk

COW TO CURDS

A typical cheese goes through a complex process



1 CORE INGREDIENT
Cows, goats, buffalo or ewes are milked, depending on the cheese type.

2 PASTEURISATION
The milk is heat treated to destroy dangerous organisms.

3 SEPARATION
Milk is sent through a centrifugal machine to separate any unwanted particles and cells.

4 CULTURE ADDITION
Bacteria is added to the milk, changing the texture and taste.

5 ENZYME ADDITION
An enzyme called rennet is added to curdle the milk.

6 CURDLING PRODUCT
Tangled proteins called curds separate from the watery whey.

7 CUTTING THE CURD
When the curd becomes firm, it can be cut into small cubes.

8 COOKING
The mixture is heated to 38 degrees Celsius to increase bacterial activity and firm the curds.

9 WHEY DRAINING
The separated whey is drained, leaving curds that fuse together.

10 MILLING
A machine dices the curds into small pieces.

11 BRINING
Salt removes some of the moisture, stops the growth of harmful microorganisms and also adds to the final flavour.

12 MOULDING
Loose pieces are poured into moulds of the desired shape.

13 PRESSING
Hydraulic pressure is applied to compact the curd pieces together.

14 RIPENING
The pieces are stored in cool, dry conditions for months to several years, depending on the cheese type.

> "Processed cheeses are products that combine natural cheese with other ingredients"

5 UNIQUE CHEESES

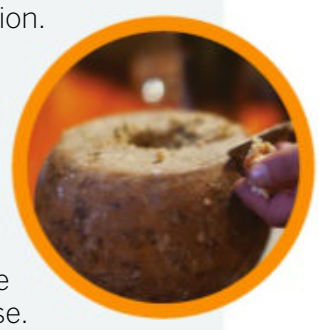
1 PASTA FILATA
This group of cheeses requires a stretching of the curd when heated. This gives the cheese an elastic-like consistency. Mozzarella is one type of pasta filata.

2 BLOOMY RIND
These often wheel-shaped cheeses are covered in a soft rind. This is mostly a combination of the white mould *Penicillium candidum* and fungus *Geotrichum candidum*, as found on camembert and brie.

3 BLUE CHEESE
The blue cheese mould, *Penicillium roqueforti*, gives this type its dark blue spots. The spores of the mould are added to the milk or the curd and grow rapidly due to the heating process.

4 WASHED RIND
During the periods these are left to mature, their rinds are regularly washed in salty water. This was done to keep the cheese clean and fresh, but the distinct flavour has led to continued production.

5 LIVE INSECT
Casu martzu is a type of cheese that's eaten while infested by maggots. Cheese skipper fly eggs are added to the cheese. When they hatch, they digest the proteins in the cheese and make it creamy.



SCIENCE

WHAT IS NITROUS OXIDE?

Discover the science of laughing gas

WORDS **AILSA HARVEY**

Nitrous oxide is commonly used as an anaesthetic in dental surgeries

Nitrous oxide (N_2O), also known as laughing gas and NOS, is a colourless gas at room temperature. The sedative and anti-anxiety side effects of this gas make it a useful tool for dentists and other medical professionals who carry out minor surgeries. A patient who is offered this gas will need to wear a mask over their nose and mouth throughout the entire procedure and will remain awake. While medical professionals know how to administer safe amounts of this gas, inhaling nitrous oxide can result in hallucinations and a feeling of dissociation with the body. Too much of the gas can cause people to become dizzy, pass out and even die. In low volumes and controlled concentrations, however, nitrous oxide is used as a painkiller and can cause people to laugh with euphoria – giving it the nickname 'laughing gas'.

Did you know?

NOS has been used as an anaesthetic since 1844

Naturally present in Earth's atmosphere, nitrous oxide is one of the ten primary greenhouse gases and is 300 times more harmful than carbon dioxide in terms of its contribution to global warming. Most of the gas in the atmosphere is released as a product of agriculture and will remain there for around 114 years before finally breaking down. The widespread use of certain fertilisers in modern farming has increased the volume of nitrous oxide in the atmosphere. These ammonium-based fertilisers improve the growth of crops, but the plants don't absorb all the fertiliser that's being sprayed onto them. As the fertiliser runs into the surrounding fields and streams, microbes in the soil convert the ammonia into nitrite, then nitrate and finally nitrous oxide gas.

A nitrous oxide molecule contains two nitrogen atoms and one oxygen atom

USES FOR NOS

1 **MEDICINE**
Anaesthesiologists give patients 70 per cent nitrous oxide and 30 per cent oxygen to breathe during surgeries.

2 **ROCKET MOTORS**
Nitrous oxide can be used in hybrid rockets. These use one solid rocket propellant and one gas. Another benefit of using the gas for rocket motors is that it's self-pressurising, meaning that its tank doesn't need to be repressurised as the fuel is used.

3 **INTERNAL COMBUSTION ENGINE**
When it burns in an engine, it splits into nitrogen and oxygen gas. Engines running on nitrous oxide produce more oxygen by volume for combustion and the gas easily liquefies under pressure.

4 **AEROSOL PROPELLANT**
Laughing gas is used in many food products as an aerosol propellant. This includes cooking spray and whipped cream, as nitrous oxide doesn't break down the fats in these products.

5 **RECREATION**
Selling large quantities of laughing gas is illegal in many countries. Despite the dangers, some people still inhale nitrous oxide recreationally.

DID YOU KNOW? After being used as an anaesthetic, the effects of nitrous oxide last three to five minutes

ANAESTHETIC PROPERTIES

How nitrous oxides acts on the nervous system to reduce pain

PRESYNAPTIC NEURON
This nerve cell transmits a pain signal across the junction between two nerve cells.

SYNAPTIC VESICLES
Neurotransmitters are held in these membranes. The vesicles release neurotransmitters when a chemical signal is detected.

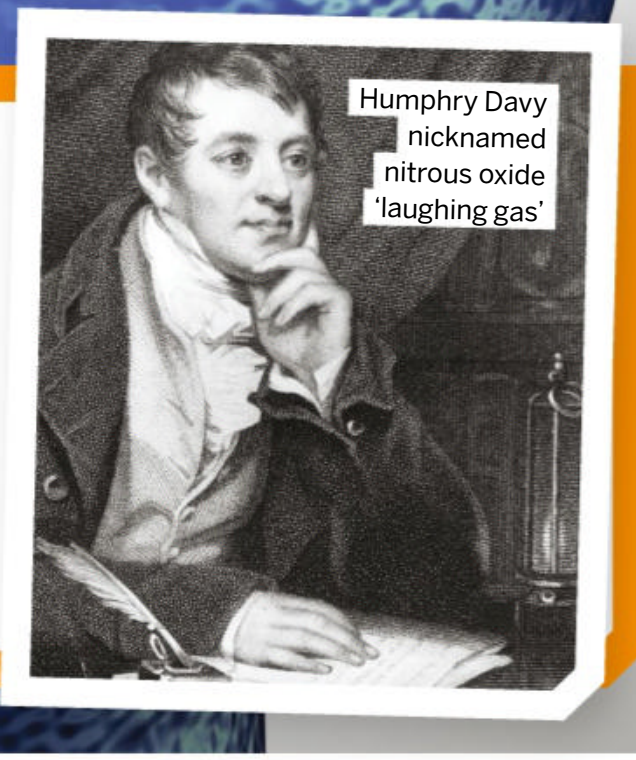
NEUROTRANSMITTERS
These are chemical messengers that alert the brain of damage to the body. When their path isn't blocked, neurotransmitters initiate the feeling of pain.

POSTSYNAPTIC NEURON
Normally, this neuron transmits pain signals away from the nerve junction to keep them travelling in one direction.

NEUROTRANSMITTER RECEPTORS
Nitrous oxide binds to ion channels between nerve cells. This temporarily blocks the pain signals travelling along the nerves.

LAUGHING GAS

Nitrous oxide was first discovered by British scientist Joseph Priestley in 1772. While experimenting with air, Priestley successfully isolated oxygen and nitrous oxide, which he initially named 'nitrous air'. But the intoxicating and painkilling effects of nitrous oxide would be explored a couple of decades later by another British scientist, Humphry Davy. Davy spent many days heating ammonium nitrate crystals before collecting and inhaling the nitrous oxide that was released. Upon inhaling the gas himself and administering it to his friends, Davy found that it worked as a sedative and also caused euphoria. Davy acknowledged that the painkilling quality could be useful during surgical operations, but initially his findings led to healthy people inhaling the psychoactive gas to entertain themselves at parties.



Humphry Davy nicknamed nitrous oxide 'laughing gas'

WHY DO GOLF BALLS HAVE DIMPLES?

The bumpy science that will get you closer to scoring under par

WORDS **SCOTT DUTFIELD**

A golf ball with dimples can travel almost twice as far as a smooth ball

Golf balls haven't always sported hundreds of tiny dimples. Originally, golf balls were smooth wooden balls, which evolved into feather-filled leather-sewn spheres called 'featherie' golf balls. Over time, golfers noticed that well-used balls travelled further than new ones. This was because with every strike of the golf club, balls were acquiring dinks and dents. In any other sport, old and damaged balls are quickly replaced, but it turned out that in golf, using battered balls can give golfers a great advantage.

Did you know?

The average golf ball dimple depth is 0.25 millimetres

Unknown to early golfers, each dent was interrupting the airflow around a travelling ball and reducing the amount of aerodynamic drag it experienced. Drag is a force that opposes motion and reduces an object's speed when it's moving through air or a fluid. When a golf ball is struck and sent flying through the air, it separates the airflow around it, causing a vacuumous zone of drag in the area behind the ball to form.

Dimples work to reduce the size of that zone, and therefore the amount of drag that slows the ball down. Less drag means the ball can fly further and faster before gravity takes hold and brings the ball back to the ground.

Having discovered the benefits of dimples, in the early 1900s golf ball manufacturers began making them standard. Modern golf balls are designed and manufactured to exploit the aerodynamic effects of dimples, varying their size, shape, distribution and patterns on the ball.

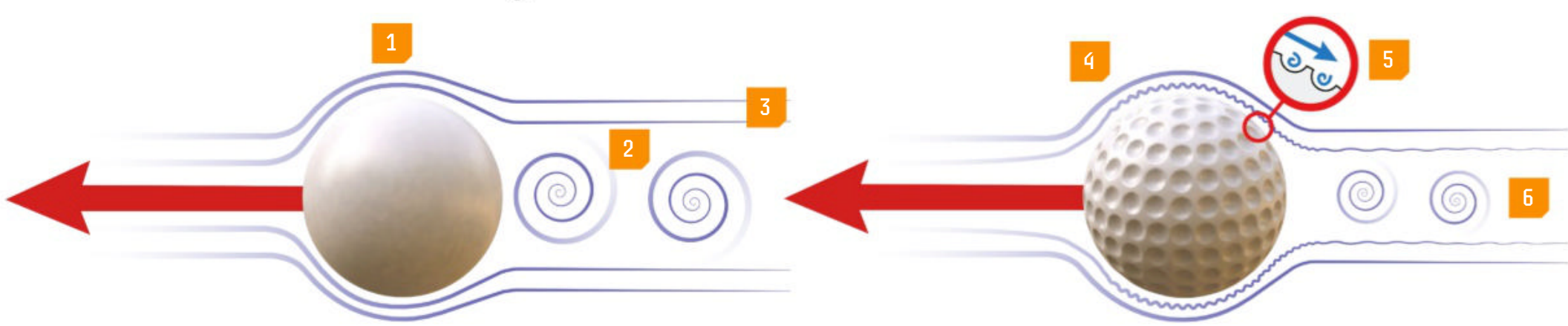
DIFFERENT DIMPLES

The dimpled surface of the golf ball has gone through many iterations. In 1848, the gutta-percha ball sported inverted dimples and was covered in a pattern of protruding squares to minimise drag. In 1899, American inventors Coburn Haskell and Bertram Work patented a gutta-percha golf ball with a rubber core. Their design lasted until the early 1900s, when more robust plastics were being developed. Manufacturers found that balls with concave dimples would fly better than a gutta-percha ball. Although it might be hard to differentiate between modern-day golf balls, the number of dimples and the shape of dimples can differ.

Golf ball dimples are created by filling moulds with plastic around rubber cores

GOLF BALL PHYSICS

How dimples help balls fly further



1 LAMINAR FLOW
The airflow around the ball is smooth and separates from it, creating a wide wake.

2 DRAG
As air flows over an object in flight, it separates, causing a low-pressure zone and drag.

3 WIDE WAKE
Smooth golf balls generate little turbulence and allow maximum air separation and drag.

4 TURBULATORS
Each golf ball dimple acts as a 'turbulator', disrupting the airflow around the surface of the ball.

5 TURBULENT FLOW
Each pocket of turbulence within the ball's dimples disrupts the laminar flow of air, causing it to reduce or delay its separation.

6 NARROW WAKE
Airflow separation is delayed by dimple turbulence, reducing the low pressure and drag behind the ball.

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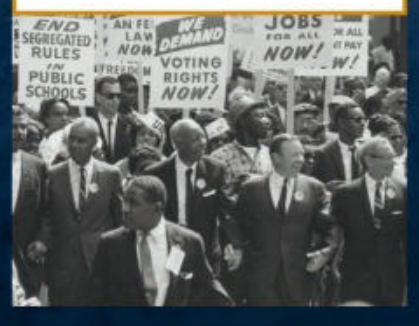		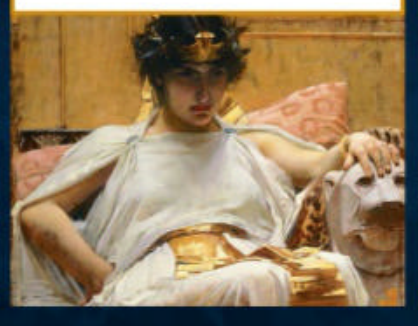		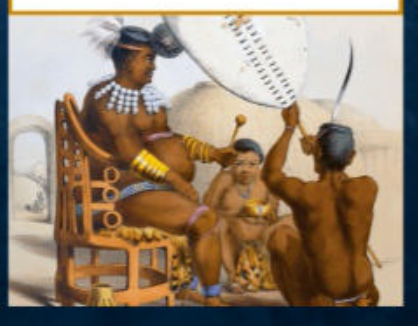

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INSIDE THE WORLD'S LARGEST WARSHIP

WORDS **AILSA HARVEY**

DID YOU KNOW? The carrier's homeport is Naval Station Norfolk in Virginia

Step aboard the USS Gerald R. Ford aircraft carrier and see how it compares to other giant warships

In order to protect a country at sea, a naval force doesn't rely solely on ships. Aircraft carriers are large warships that serve as a platform for military planes to take off from and land on, and they are so efficient that aircraft can be launched every 25 seconds from them. To be considered an aircraft carrier, all a ship needs is a runway on its upper deck. But as these vessels have evolved since the early 1900s, ships such as the Gerald R. Ford, the latest class in a long line of US Navy carriers, are decked out with an assembly of machine guns, missiles, submarines, fighter jets and helicopters. These assist the US Navy during rescue operations, weather observations, air-to-air combat and submarine and ocean surface attacks.

It was during World War II that the world's navies came to appreciate the advantages of aircraft carriers. Being able to transport aircraft closer to an overseas target made it possible to initiate devastating air operations. The Japanese Navy, for example, was able to attack Pearl Harbor, Hawaii, from the air in 1941. Because mainland Japan was 4,000 miles away from Pearl Harbor, without their aircraft carriers this attack wouldn't have been possible – Japan's Air Force would have run out of fuel long before reaching Hawaii.

Since World War II, aircraft carriers have increased substantially in size. The Gerald R. Ford-class carrier is owned by the US Navy, and when fully loaded weighs 100,000 tonnes. Being nuclear powered, this new class can theoretically operate at sea for around 20 years before needing to be refuelled. However, supplies for the thousands of crew members on board need to be taken into account, and most missions last for a few weeks or months. It's estimated that the Gerald R. Ford carrier has a total operational service time of 50 years.


Planes can be seen on deck

WHO WAS GERALD FORD?

The name of this class of aircraft carrier was chosen to honour the 38th US president and the work he undertook as part of the navy. Future president Gerald Ford signed up for the US Navy as a young man in 1941, after Pearl Harbor was attacked in World War II. Upon completing his training, Ford was sent on sea duty in May 1943 and became the assistant navigator on board the USS Monterey. Ford came close to becoming one of around 800 crew members who lost their lives during a typhoon on 18 December 1944, when the Monterey was severely damaged. After the Monterey was declared unfit for naval service, Ford continued working in the navy as an athletic officer.

On 3 October 1945, Ford was promoted to Lieutenant Commander. During his service in the navy, Ford led operations in the Gilbert Islands, Bismarck Archipelago, Marshall Islands, Hollandia, Mariana Islands, Caroline Islands, Western New Guinea and Leyte. After resigning from the navy in 1963, Ford became president of the US from 1974 to 1977. When the Gerald R. Ford-class carriers were announced, secretary of the navy Donald Winter expressed the navy's admiration for the former president. Winter said that he was "honoured to have the opportunity to name the first ship in the new class of aircraft carriers after this great sailor, this great man."


President-to-be Gerald Ford pictured on board the USS Monterey in 1935

NAVAL HEAVYWEIGHT

What rooms, weapons and mechanics make up this giant vessel?

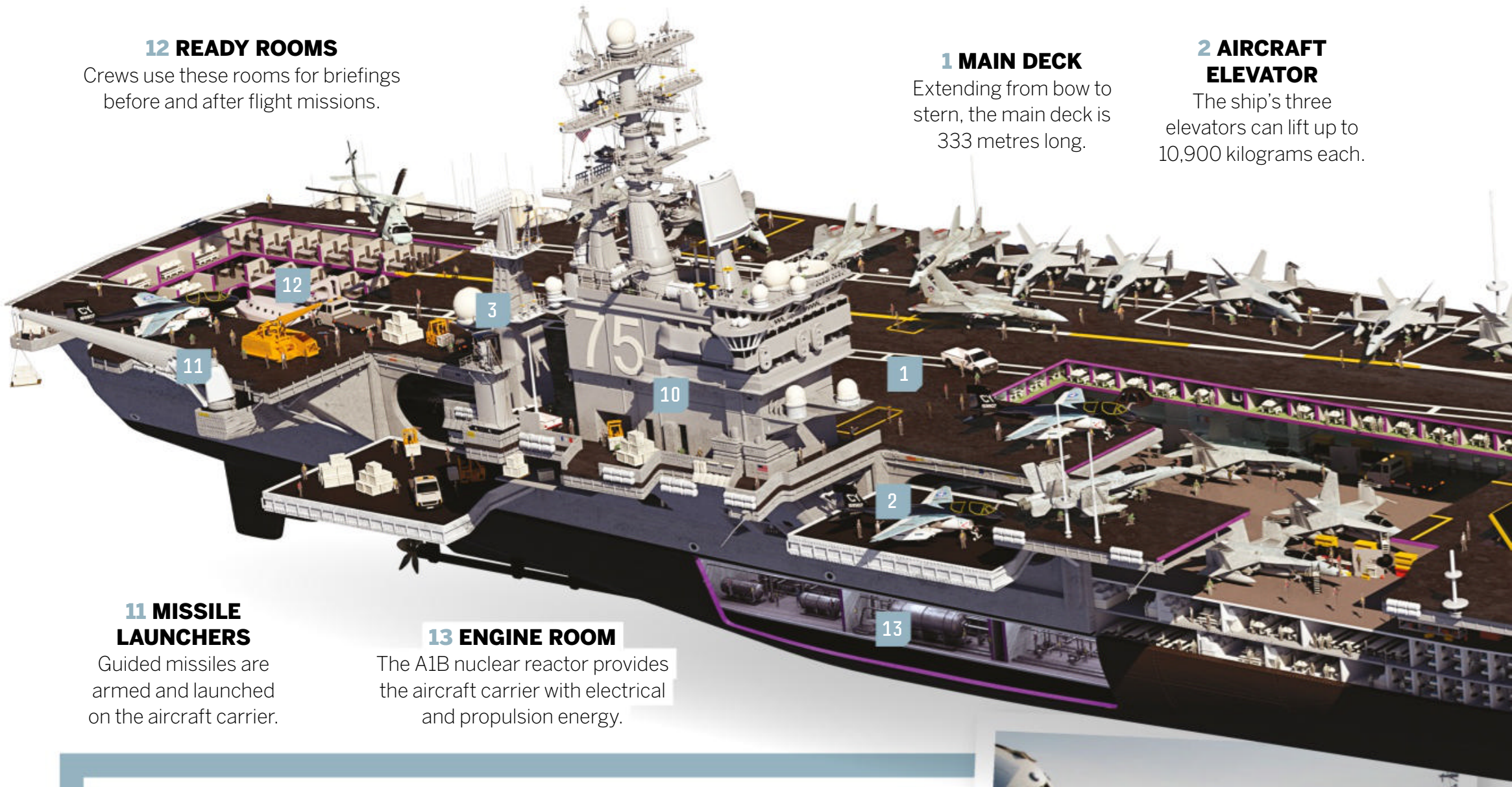
10 ISLAND
This is the ship's command centre for all activity taking place on the flight deck and the pilothouse for ship navigation.

3 DUAL-BAND RADAR
The air-search radar can search for objects at sea and in the sky using two bands. The S-band radar is less precise but works well in bad weather, while the X-band is more accurate.

12 READY ROOMS
Crews use these rooms for briefings before and after flight missions.

1 MAIN DECK
Extending from bow to stern, the main deck is 333 metres long.

2 AIRCRAFT ELEVATOR
The ship's three elevators can lift up to 10,900 kilograms each.



11 MISSILE LAUNCHERS
Guided missiles are armed and launched on the aircraft carrier.

13 ENGINE ROOM
The A1B nuclear reactor provides the aircraft carrier with electrical and propulsion energy.

MAIDEN VOYAGE

On 4 October 2022, the USS Gerald R. Ford departed for its first deployment. The ship left Norfolk on a mission to carry out training exercises and equipment demonstrations in the Atlantic Ocean. Alongside NATO allies Canada, Denmark, Finland, France, Germany, the Netherlands, Spain and Sweden, training included a total of nine countries, 20 ships and 60 aircraft. One of the desired outcomes of this deployment was to show strength in unity and improve relations among NATO navies. The aircraft carrier departed for two months, with much of the training involving air defence tactics and subsurface warfare. A primary focus of the initial sail was to practise coordinating vessels from different countries to work effectively as one group, ready for if a real threat were to emerge at sea.


Flight operations being observed on board the USS Gerald R. Ford

US NAVY AIRCRAFT CARRIER EVOLUTION


The USS Langley was the US Navy's first aircraft carrier.

1912

The Lexington-class was the first aircraft carrier to have a bulbous bow – one that protruded underwater.

1925


The USS Ranger was the only carrier in its class and was the first to be built from the keel – the ship's structural beam – up.

1933

Yorktown-class aircraft carriers were the first to have hydraulic catapults.

1936


Essex-class ships could hold up to 100 aircraft.

1942

DID YOU KNOW? The Gerald R. Ford aircraft carrier travels at 30 knots, equal to 35 miles per hour

USS Gerald R. Ford under construction in 2012

The commissioning ceremony in 2017 at Naval Station Norfolk

Flight deck and combat air-traffic control centre certification in 2020

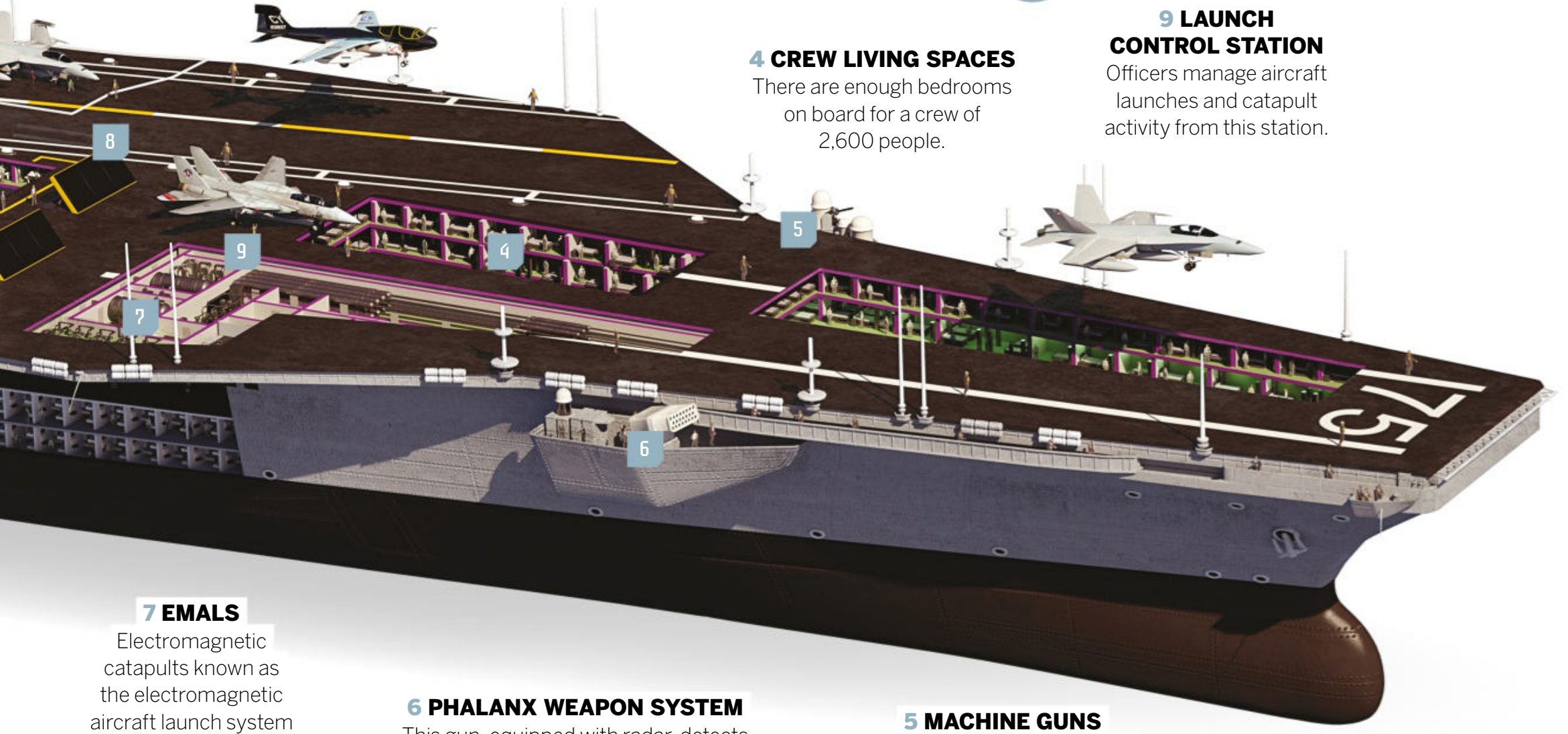
Did you know?

14 countries operate all of the world's aircraft carriers

8 JET BLAST DEFLECTORS
These shields protect the ship's equipment when aircraft are launched.

4 CREW LIVING SPACES
There are enough bedrooms on board for a crew of 2,600 people.

9 LAUNCH CONTROL STATION
Officers manage aircraft launches and catapult activity from this station.



7 EMALS
Electromagnetic catapults known as the electromagnetic aircraft launch system can launch the ship's 75 aircraft.

6 PHALANX WEAPON SYSTEM
This gun, equipped with radar, detects nearby threats and automatically fires at them for rapid defence.

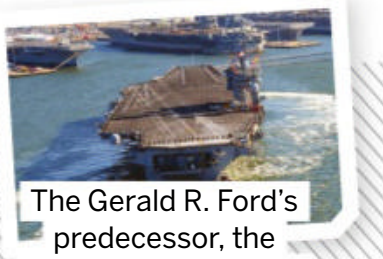
5 MACHINE GUNS
The four 50-calibre machine guns have a maximum effective range of 2,000 metres.

1945 The first armoured flight deck was constructed for Midway-class carriers.

1954 
Forrestal-class aircraft carriers were the first supercarriers. These are ships that displace at least 65,000 tons.

1960 The USS Enterprise was the first nuclear-powered aircraft carrier.

1967 
The USS John F. Kennedy was the last non-nuclear-powered aircraft carrier made.

1972 
The Gerald R. Ford's predecessor, the Nimitz-class, needed 600 more crew on board to operate effectively.

2013 Gerald R. Ford carriers convert steam into electricity using nuclear turbines.

INSIDE A COMBINE HARVESTER

This specialist machine is a farmer's go-to vehicle for harvesting crops

WORDS **AILSA HARVEY**

The hard outer shell, or chaff, is removed from the grain during winnowing

8 DRIVER'S CAB
A combine operator sits in this section to direct the vehicle towards the crops that need harvesting.

1 REEL
As this metal reel rotates, its jagged teeth cut the crops.

2 GRAIN CONVEYOR
The cut grain is carried upwards on a segmented belt towards the centre of the vehicle for further processing.

Wheat, barley, soy and rye are crops commonly grown by farmers, but the grains you buy in the shops and the products that contain them are only a small part of the plant grown. The edible parts of the plants are the seeds, and to collect them, three processes are required: reaping, threshing and winnowing. All three are usually carried out by combine harvesters.

These vehicles can often be seen on modern-day arable, or crop-growing, farms. The first process carried out by a combine is 'reaping', or the cutting of the crops. As the vehicle is driven over the field, sharp blades at the front cut the crop plants into smaller pieces so that they can be drawn into the machinery. Next, the cut crops enter a rotating drum for threshing – beating the plants so that the grains loosen and become separated. Finally, the combine winnows the grain, whereby a blast of air removes the chaff of the seeds.

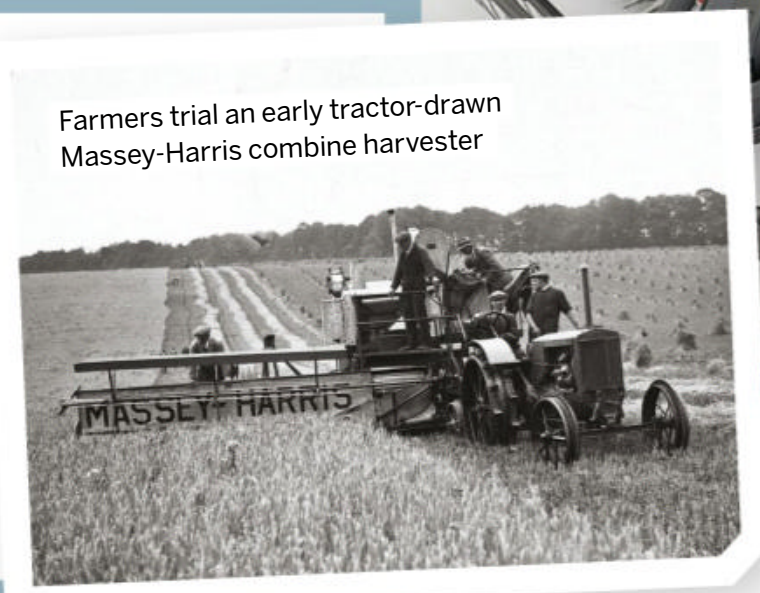
The chaff is the harder, external part, and can sometimes need additional force to encourage its separation. Incorporating these three core steps into one trip around the field, in a single vehicle, saves farmers a lot of time and money. Before the combine harvester was invented, much of this process was completed using handheld tools, making it significantly more time-consuming. The combine harvester's predecessor was a thresher, which could separate seeds from the straw, but relied on farmers to harvest the crops in advance.

Did you know?

Leftover straw is used to feed farm animals

WHO INVENTED IT?

The first patented combine looked vastly different to modern machines. It was designed by US inventor Hiram Moore, named a thresher and was drawn by horses. A thresher had a harvest rate of 20 acres per day, and since then modern vehicles have become more than twice as efficient. Up to 40 horses were needed to pull these early combine harvesters. In 1925, horses were replaced with tractors for the role of pulling combines. This milestone meant that farmers just needed to replace the hitch, which was the equipment connecting their combine to their horses. By replacing this with a tractor hitch, farmers could keep the same combine harvester and invest only in an accompanying tractor. The final significant milestone in the evolution of this farming vehicle was the first self-propelled combine harvester, invented by company Massey-Harris in 1939.



Farmers trial an early tractor-drawn Massey-Harris combine harvester

DID YOU KNOW? A combine harvester can be used to harvest around 80 different crop types

A VERSATILE VEHICLE

The mechanics of modern reaping, threshing and winnowing

7 GRAIN TANK
Once the grain is retrieved and cleaned, it's collected in this large tank.

9 UNLOADING AUGER
This drill-shaped component rotates to carry grain up and out of the tank.

6 SIEVE LAYERS
The grooves on these belts are tighter on the lower levels. They filter out and clean material from the grain, separating the largest down to the smallest pieces.

4 STRAW WALKER
After the grain is threshed from the crop, the waste straw is removed along a separate conveyor to exit at the back of the combine.

5 FAN
A central fan helps keep the air flowing from the front to the back of the vehicle, separating light objects from the grain and ejecting them.

3 STONE TRAP
At the top of the conveyor, only small pieces of grain fit into the rotating drum. Large objects like stones are collected here and filtered out.

SELF-DRIVING FUTURE

Autonomous farming may sound relatively futuristic, but self-steering GPS technology has been used since the mid-1990s. Following this invention, combine harvesters have become precision instruments that can treat field rows in straight lines and avoid missing any of the crop. Today combines are being developed that can autonomously navigate fields, as well as automatically adjust harvesting settings. This means that instead of an operator manually altering the settings based on the conditions they observe, cameras scan the field and monitor the condition of crops to maximise the quality of grain being harvested.


Autonomous harvesters use GPS to stay on track

DID YOU KNOW? The first multicellular organism evolved around 2 billion years ago

The forces of EVOLUTION

What's the big idea behind the theory of evolution, and why do species evolve?

WORDS **SCOTT DUTFIELD**

Since the first primordial organisms spawned in Earth's prehistoric oceans, life has been on a 4-billion-year journey to the modern day. Along the way, it's diversified and evolved to fill up almost every corner of the planet, both ocean and land. Evolution stems from environmental and biological events that lead to the morphological and behavioural changes of an animal over time. The theory of evolution was born from the mind of Charles Darwin, a British naturalist who dedicated his life to the study of advancing our understanding of animal biology. Following his journey to the Galápagos Islands on the HMS Beagle in the early 1800s, Darwin penned the beginnings of the theory of evolution by means of natural selection, later written in a book called *On the Origin of Species*.

One of the most famous Darwinian examples of evolution came from specimens of 14 finches Darwin collected from the Galápagos Islands. The Galápagos finches found across its many islands were different from one another, predominantly in the shape of their beaks. With the help of ornithologist John Gould, Darwin concluded that the birds were endemic to the Galápagos Islands and had morphologically changed to adapt to the different types of food available to them. Finches with pointed beaks were able to snatch insects more readily, while those with broader blunt beaks were better at cracking seeds or nuts. Over millennia, these birds have evolved to suit their environments and exploit the resources available to them.

Did you know?

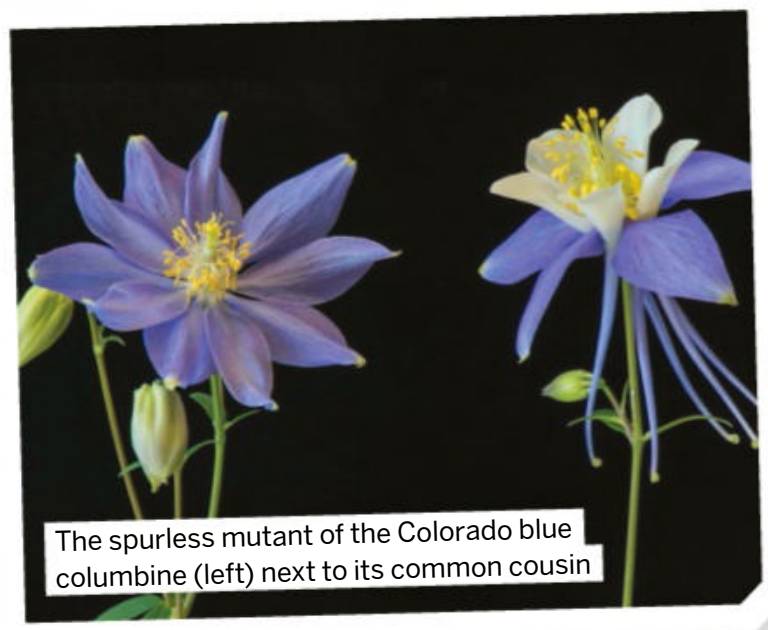
500 million years ago, plants colonised land

Although Darwin's theory of evolution tells us why animals evolve and some of the forces that cause it, Darwin's theories can't fully explain how evolution actually works. The missing piece of Darwin's evolutionary puzzle came from the work of biologist and monk Gregor Mendel. By the end of the 1860s, Mendel had completed a series of cross-breeding experiments using around 10,000 pea plants. What he discovered was evidence of the mechanisms of genetic heredity and the ability of organisms to pass on traits, such as petal colours, to their offspring. Mendel's work filled in the gaps in Darwin's theory and supported the process of natural selection.

HOPEFUL MONSTERS

It takes a million generations or more for a species to evolve lasting changes, but some species move quicker than others. Hopeful monsters are organisms with mutations that establish a new evolutionary lineage in a relatively short amount of time. Often, an event of radical genetic mutations would see a species face extinction, either due to its inability to function in its environment or low mating success. But for some hopeful monsters, rapid mutations can be beneficial to survival. Some research suggests that the concept of hopeful monsters might apply more to plants than animals.

Researchers at the University of California studying Colorado blue columbine (*Aquilegia coerulea*) discovered a population of their test plants that looked unlike the rest. A mutation in the plant's genome caused it to lose some of its petals and nectar spurs. After studying the behaviours of the plants' pollinators, researchers discovered that non-mutated plants were being damaged by insects and deer, but the spurless version remained undamaged and was preferred by pollinators, thus continuing the genetic lineage and changing the species.



The spurless mutant of the Colorado blue columbine (left) next to its common cousin

FOUR FORCES

Did you know?

The earliest mammals evolved around 230 million years ago

These environmental and biological factors can force a species to evolve

GENETIC DRIFT

Sometimes external forces can force the hand of evolution's seemingly gradual pace. Prehistoric mass extinction events are excellent examples of how one species' evolution can be accelerated. When a catastrophic event such as a volcanic eruption or climatic change occurs, many members of a species die, so only the genetic information of those that remain can be passed on to the next generation. This is known as the bottleneck effect, when a population decreases by as little as one generation and reduces the genetic variety of the population. Fewer variations in a population limits how a species evolves and even how it adapts to the environment.

1 A species evolves into a diverse population of genetic information, displaying variations in their morphology like colouration.

2 Mass extinction events can wipe out the majority of a species' population, leaving only a small population and a small gene pool to reproduce.

3 The genes in members of the species that survive this event are passed on to the next generation.

4 Over time, the impacted species will evolve using the limited genetic information and in a direction that might not have occurred without the mass extinction event.

NATURAL SELECTION

Also referred to as survival of the fittest, natural selection is one of the forces of evolution that results in animals best adapted to their environment. Arguably the most prolific force of evolution, natural selection requires an animal to morphologically or behaviourally adapt to its environment. Members of a species that don't adapt will likely die before they have the opportunity to pass on their ill-equipped genes. For example, during the Industrial Revolution tree trunks became darker through increasing air pollution. Over time, peppered moths became darker to blend in with the trees. The darker the moth, the better it blended in with the soot that covered the trees and the higher the chance of it avoiding predation.

Similarly, sexual selection is a key driving force in evolution. In choosing a potential mate, animals have certain criteria that their partners have to meet. For peacocks, the males with the biggest and most flamboyant plumage get the girls, passing on their genes to the next generation. Those with lacklustre plumage are unsuccessful at mating, so over time their genetic information is lost.

Camouflage helps with survival

THE FOUNDER EFFECT

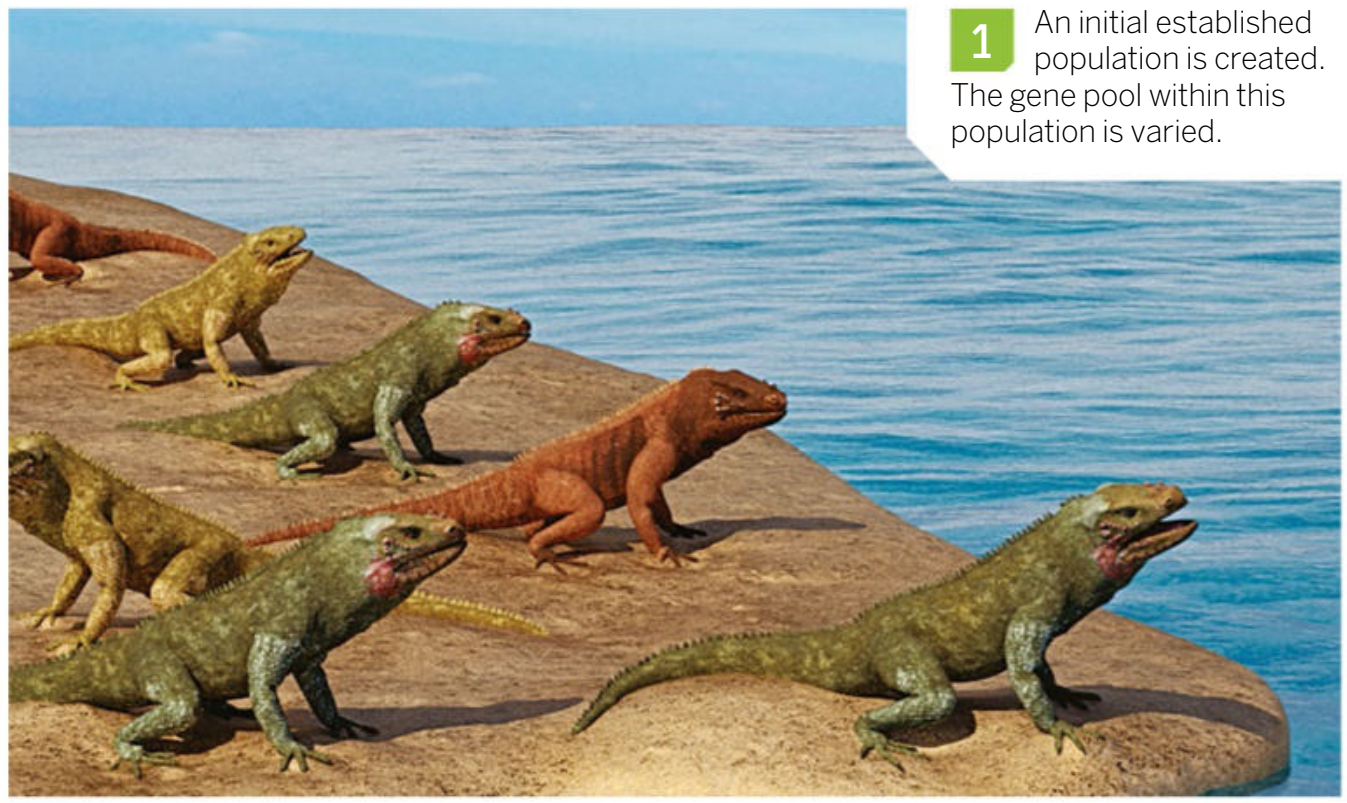
In a similar fashion to the bottleneck effect, the founder effect occurs when a new population is formed by chance. When a small number of individuals from a species find themselves displaced or separated from their original population, the following generations have a less varied genetic pool. Without new or varied genetic information, alterations or mutations to a species' genes are much more frequent. Similarly, in a process called gene flow, when a small population or individual member of a species migrates or moves out of one population and into another, the genetic information becomes mixed. Over time, this will cause the new combined population to evolve differently.

"The genetic information becomes mixed"

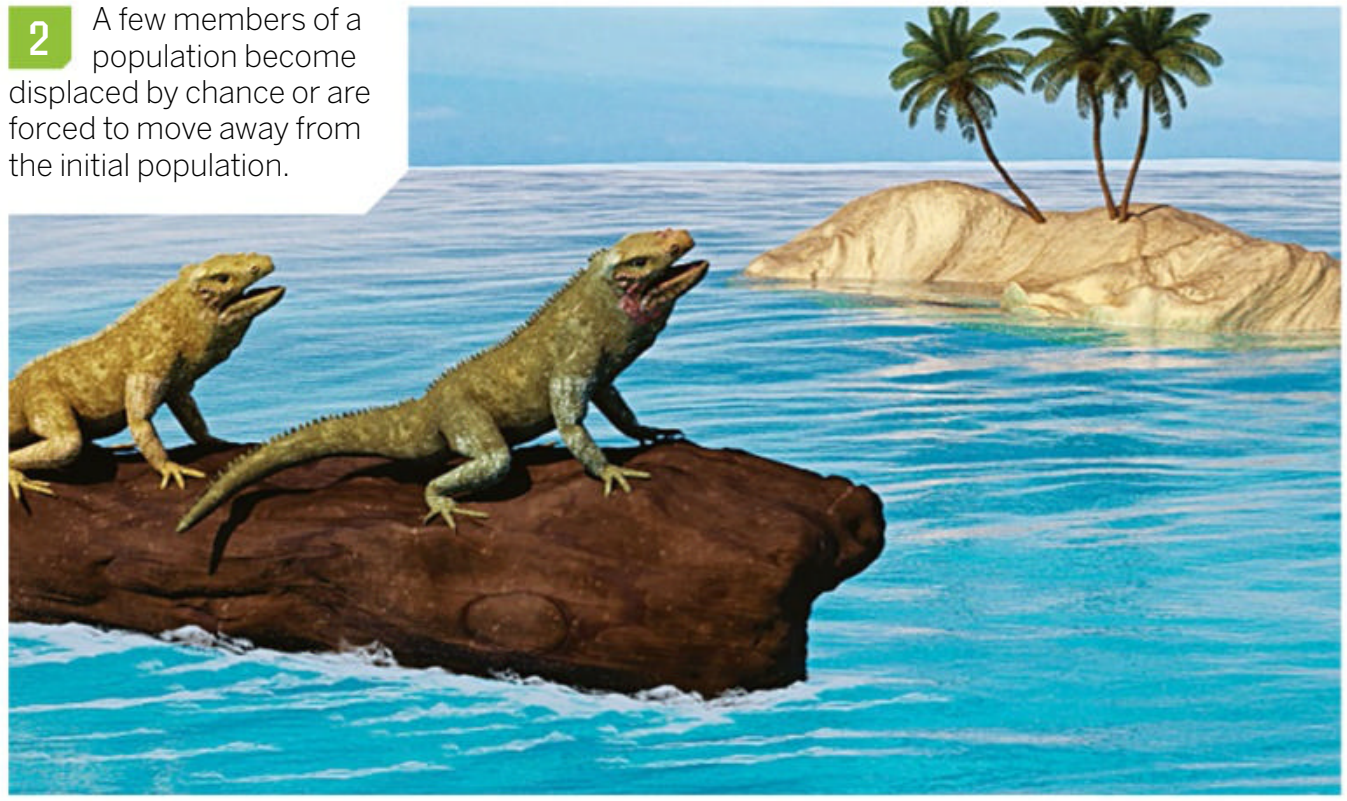
MUTATION

Genetic mutations can lead one species to become another species. Mutations can occur anywhere in an individual's genome – its complete set of genes and genetic material. From changing singular points in the genetic code to entire sections of DNA, mutations lead to changes in an organism's biology and physical appearance. The causes of a mutation are varied, but they commonly occur when DNA is either incorrectly copied and reproduced during the development of an organism or through external forces, such as radiation, that damage the structure of DNA.

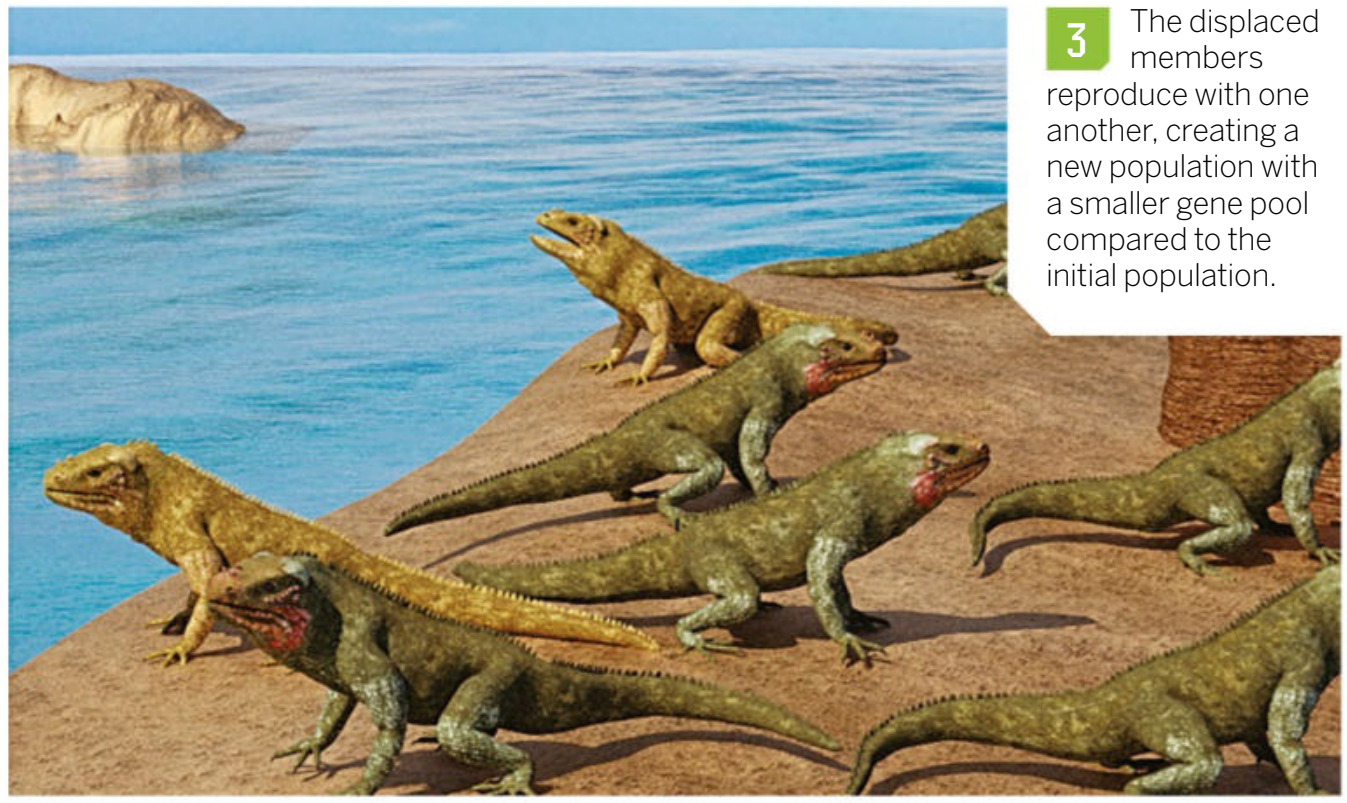
This kitten was born with an extra set of ears due to a genetic mutation



1 An initial established population is created. The gene pool within this population is varied.



2 A few members of a population become displaced by chance or are forced to move away from the initial population.

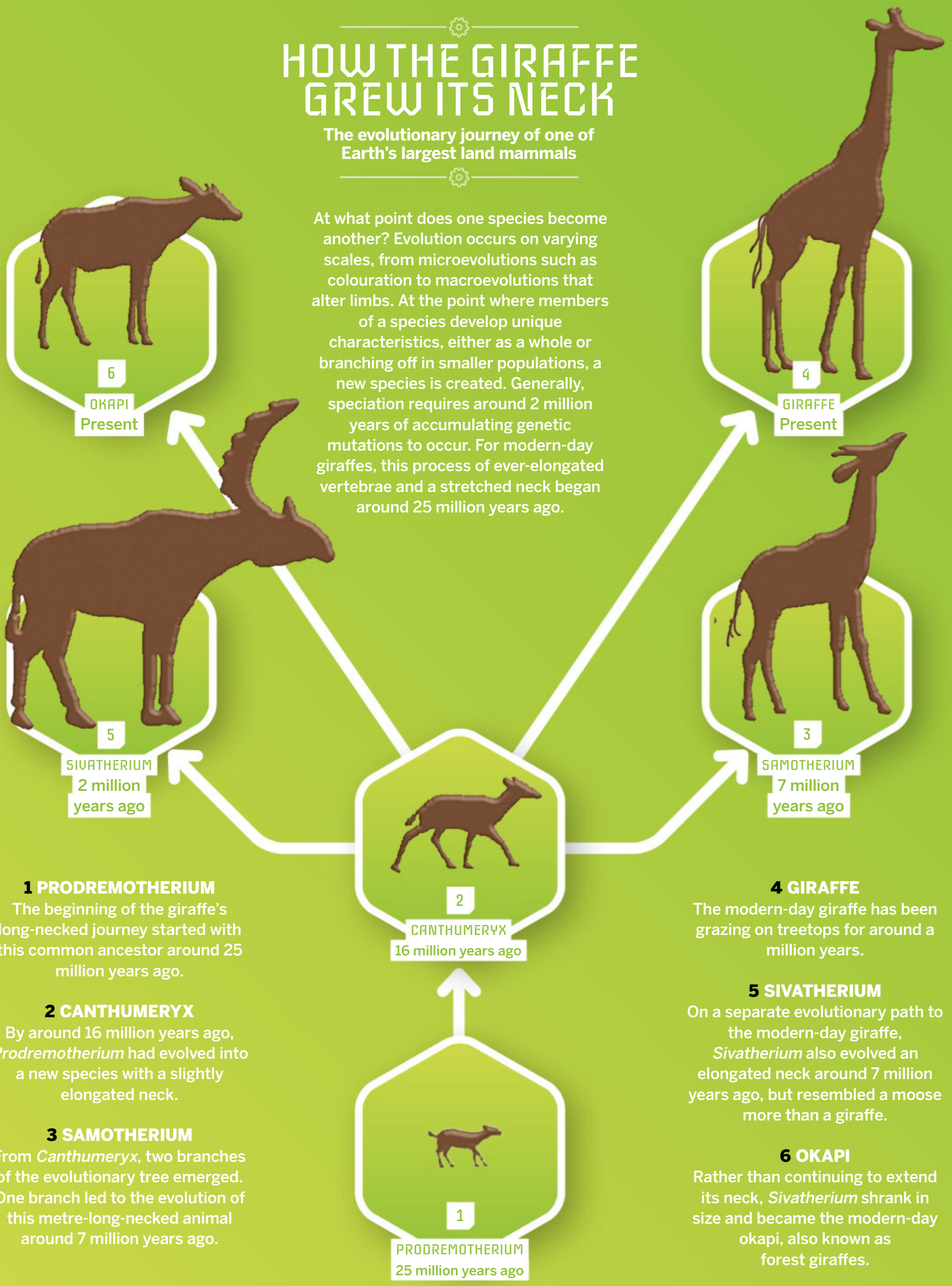


3 The displaced members reproduce with one another, creating a new population with a smaller gene pool compared to the initial population.

HOW THE GIRAFFE GREW ITS NECK

The evolutionary journey of one of Earth's largest land mammals

At what point does one species become another? Evolution occurs on varying scales, from microevolutions such as colouration to macroevolutions that alter limbs. At the point where members of a species develop unique characteristics, either as a whole or branching off in smaller populations, a new species is created. Generally, speciation requires around 2 million years of accumulating genetic mutations to occur. For modern-day giraffes, this process of ever-elongated vertebrae and a stretched neck began around 25 million years ago.



1 PRODREMOTHERIUM
The beginning of the giraffe's long-necked journey started with this common ancestor around 25 million years ago.

2 CANTHUMERYX
By around 16 million years ago, *Prodremotherium* had evolved into a new species with a slightly elongated neck.

3 SAMOTHERIUM
From *Canthumeryx*, two branches of the evolutionary tree emerged. One branch led to the evolution of this metre-long-necked animal around 7 million years ago.

4 GIRAFFE
The modern-day giraffe has been grazing on treetops for around a million years.

5 SIVATHERIUM
On a separate evolutionary path to the modern-day giraffe, *Sivatherium* also evolved an elongated neck around 7 million years ago, but resembled a moose more than a giraffe.

6 OKAPI
Rather than continuing to extend its neck, *Sivatherium* shrank in size and became the modern-day okapi, also known as forest giraffes.

Did you know?

2.8 million years ago, the first *Homo sapiens* evolved

HUMAN-DRIVEN EVOLUTION

The presence of people forced these animals to adapt and evolve

1 SEA-MONKEYS

These tiny crustaceans first became a popular low-maintenance pet in the 1950s. As a hybrid of brine shrimp (*Artemia salina*), Sea-Monkeys (*Artemia NYOS*) are small, aquatic, three-eyed invertebrates that use feathery gills on their legs to breathe. In the wild, brine shrimp have a relatively short life span of around six months. To make them into a commercial pet marketed as 'instant life', scientists created the hybrid from crustaceans that undergo a state of suspended animation called cryptobiosis. Sea-Monkeys were suspended as eggs in a dust-filled packet, ready to hatch when they met water.

2 UNDERGROUND MOSQUITOES

First spotted during World War II, a subspecies of mosquito can be found buzzing beneath the streets of London. In a classic case of the founder effect, it's thought that a small population of mosquitoes entered the city's subway train tunnels and became cut off from the outside world. Over time, reproductive isolation forced a new subspecies called *Culex pipiens molestus* to evolve. Along with clear genetic differences between the subspecies and its topside ancestors, some research suggests these mosquitoes don't hibernate in winter and are actively blood-sucking all year round.

3 SHORT-TUSKED ELEPHANTS

In the wild, African elephants use their elongated front teeth, called tusks, to dig up food, create walkways and battle against one another. Tusks are grown out of a robust material made from a combination of enamel and cementum, called ivory. Throughout history, the sale of elephant ivory has not only resulted in the decimation of African elephant populations on the continent, but also potentially impacted its evolution. Researchers at Princeton University have found that one-third of female African elephants in Mozambique's Gorongosa National Park born after 1992 were tuskless. After investigating their genetic make-up, researchers found that the genes that code for the production of tusk-building material had mutated, leading to this tuskless trait. The researchers estimate that 3,000 years of hunting large-tusked elephants has caused human-driven selection.

4 PIZZLY BEARS

Meet pizzly bears, the polar bear-grizzly bear hybrids that have been created by human-driven climate change. As the Arctic seas warm, polar ice thins and polar bears expand their hunting grounds, these furry giants are moving farther south. As they move down through Canada, polar bears have been mating more frequently with other bear species, including the grizzly bear. The resulting offspring is known as the pizzly bear, also known as grolars. Hybrids are typically sterile and can't reproduce – similar to mules, the hybrid of a horse and a donkey. However, research has shown that Pizzlies are able to reproduce in the wild.

HOW CATS PURR

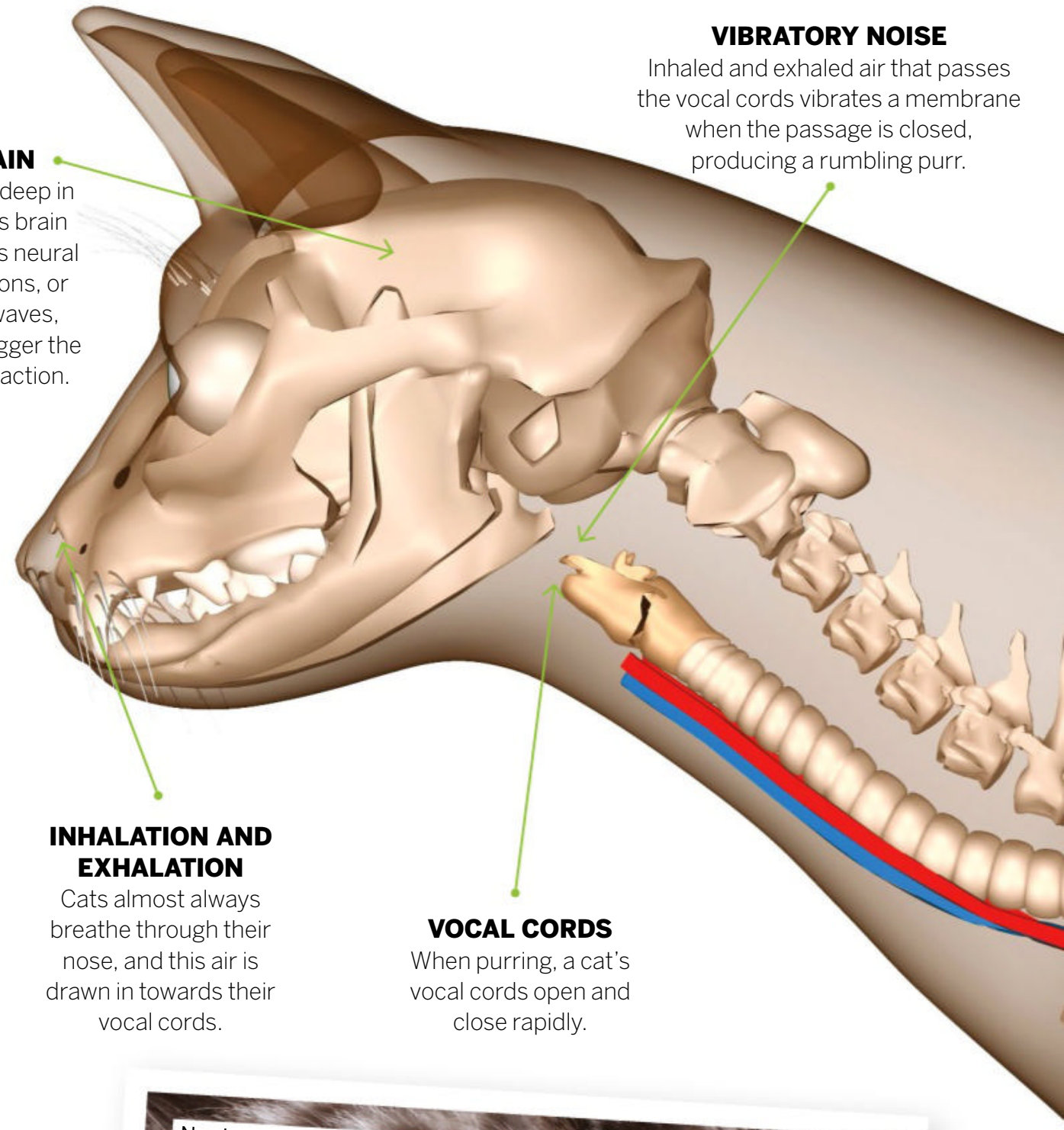
Discover the purpose of this distinctive feline sound and why a purring cat is not always a happy one

WORDS **AILSA HARVEY**

If you've ever spent time with cats, you'll be familiar with the echoing, low-pitched rumble they make. Called a purr, it's made without the animal opening its mouth, as it does to meow. This relaxing noise is generally associated with a happy cat, and the majority of the time this is true. But there are other circumstances when a cat will purr. Understanding the body language of a cat is one of the main ways to decipher what mood the animal is portraying when purring. If a cat is lying down with a stretched-out body and a closed mouth, the purr indicates contentment. However, if its body looks stiff, its eyes are wide open and ears pinned back, the purring is more likely to be a signal of worry or stress.

Purring is a sound made by both domestic and wild cats. Those in the wild that purr, such as mountain lions and bobcats, can't roar. For a cat to roar, its vocal cords need to be more flexible, while to produce the vibrations of a purr the vocal cords need to be stiffer. This means that roarers like lions and tigers are unable to purr.

The frequency of a cat's purr is between 25 and 140 Hertz and is believed by scientists to hold healing properties. A cat's bone tissue responds to purring frequencies between 25 and 50 Hertz, while soft tissue heals better in frequencies around 100 Hertz. Purring has evolved to benefit cats' health and social ability, but owning a cat and being in the presence of its purr can lower stress and blood pressure in humans, too.



BRAIN
An area deep in the cat's brain produces neural oscillations, or brain waves, which trigger the purring action.

VIBRATORY NOISE
Inhaled and exhaled air that passes the vocal cords vibrates a membrane when the passage is closed, producing a rumbling purr.

INHALATION AND EXHALATION
Cats almost always breathe through their nose, and this air is drawn in towards their vocal cords.

VOCAL CORDS
When purring, a cat's vocal cords open and close rapidly.

Newborn kittens get all their food from their mother

SURVIVAL SOUNDS

When a kitten is born, it's at its most vulnerable, and the ability to purr becomes essential to its survival. Kittens enter the world both deaf and blind for the first couple of weeks of their lives. Cats fully rely on their mothers before they become independent, and they use the sound of their mother's purring to guide them towards her. This is essential for finding warmth and their mother's milk. Kittens first learn to purr at three weeks old, before they can meow. Purring is key to survival because cats can communicate with their mother more subtly this way than meowing. Purring is a gentler, lower frequency noise that predators can't detect so easily.

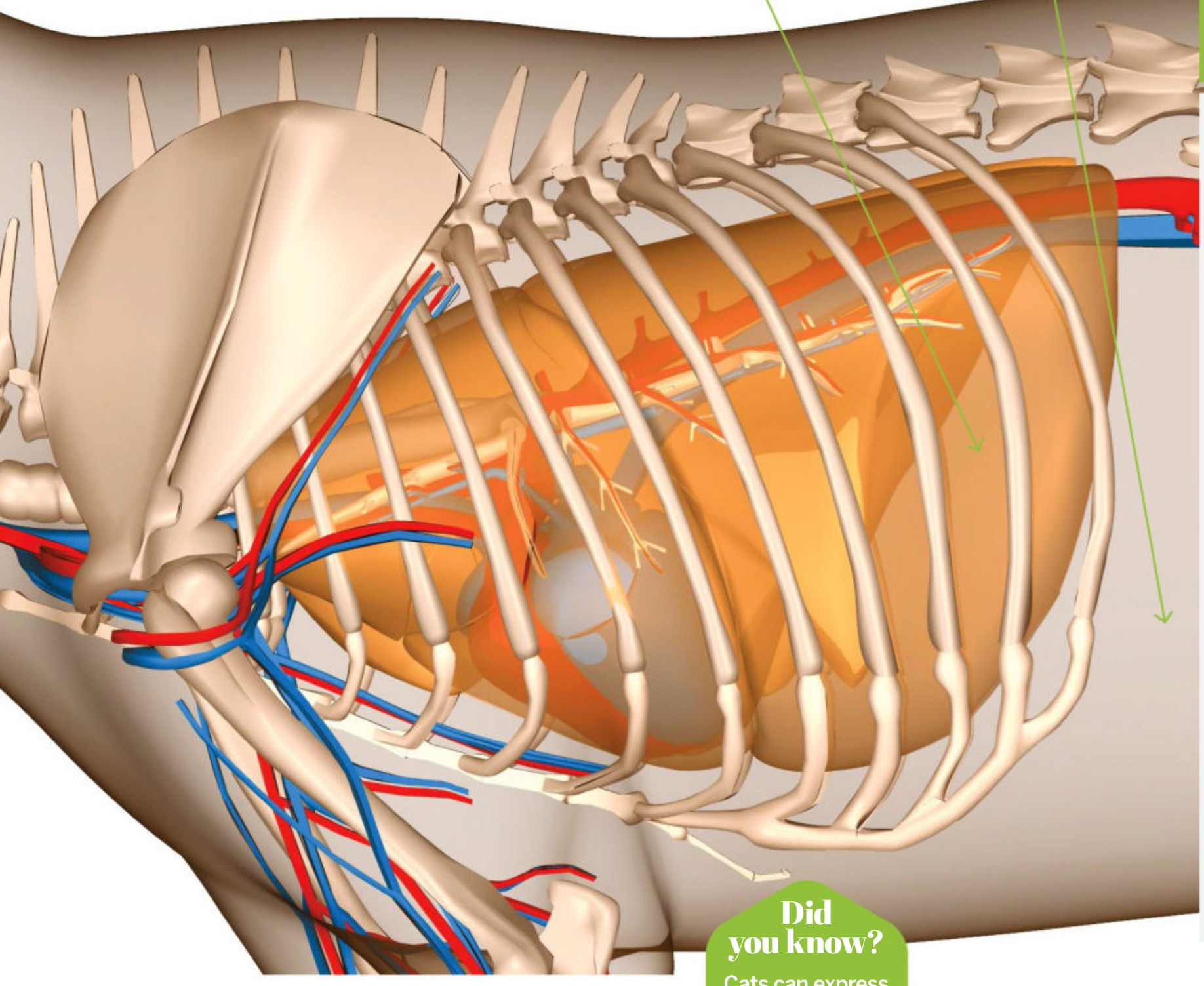
DID YOU KNOW? Rabbits and guinea pigs can purr, but cats are the only animals to purr by both inhaling and exhaling

HOW IS THE NOISE MADE?

The feline anatomy that creates this distinctive sound

DIAPHRAGM
The muscles at the base of the cat's chest vibrate 20 or 30 times a second when a cat purrs.

GOOD VIBRATIONS
A cat's whole body vibrates when it purrs, stimulating the muscles and helping bones grow.



5 REASONS FOR PURRING

1 HAPPINESS
When a purring cat looks relaxed, has its eyes closed and makes gentle noises, it's displaying happiness.

2 DISCOMFORT
Purring can benefit a cat when it's in pain. The soft vibrations help cats control their breathing and can reduce their pain.

3 STRESS
A cat may also purr as a defence mechanism during stressful situations. The light vibrations can help keep a cat calm.

4 PREGNANCY
Cats often become more affectionate and purr more when they are pregnant. Purring also helps cats limit any discomfort felt during pregnancy.

5 HUNGER
Domesticated cats have learned to combine their soft purrs with the higher pitched frequency that's similar to a crying human baby. This more demanding purr is to get human attention and let an owner know the cat is hungry.

Did you know?
Cats can express 100 different vocalisations

Purring can soothe a cat when it feels nervous or stressed

When cats hear the sound of running water, they stop purring

© Alamy / Getty

HOW TO FIND THE BRIGHTEST STARS

See some of the most notable stars in the night sky tonight

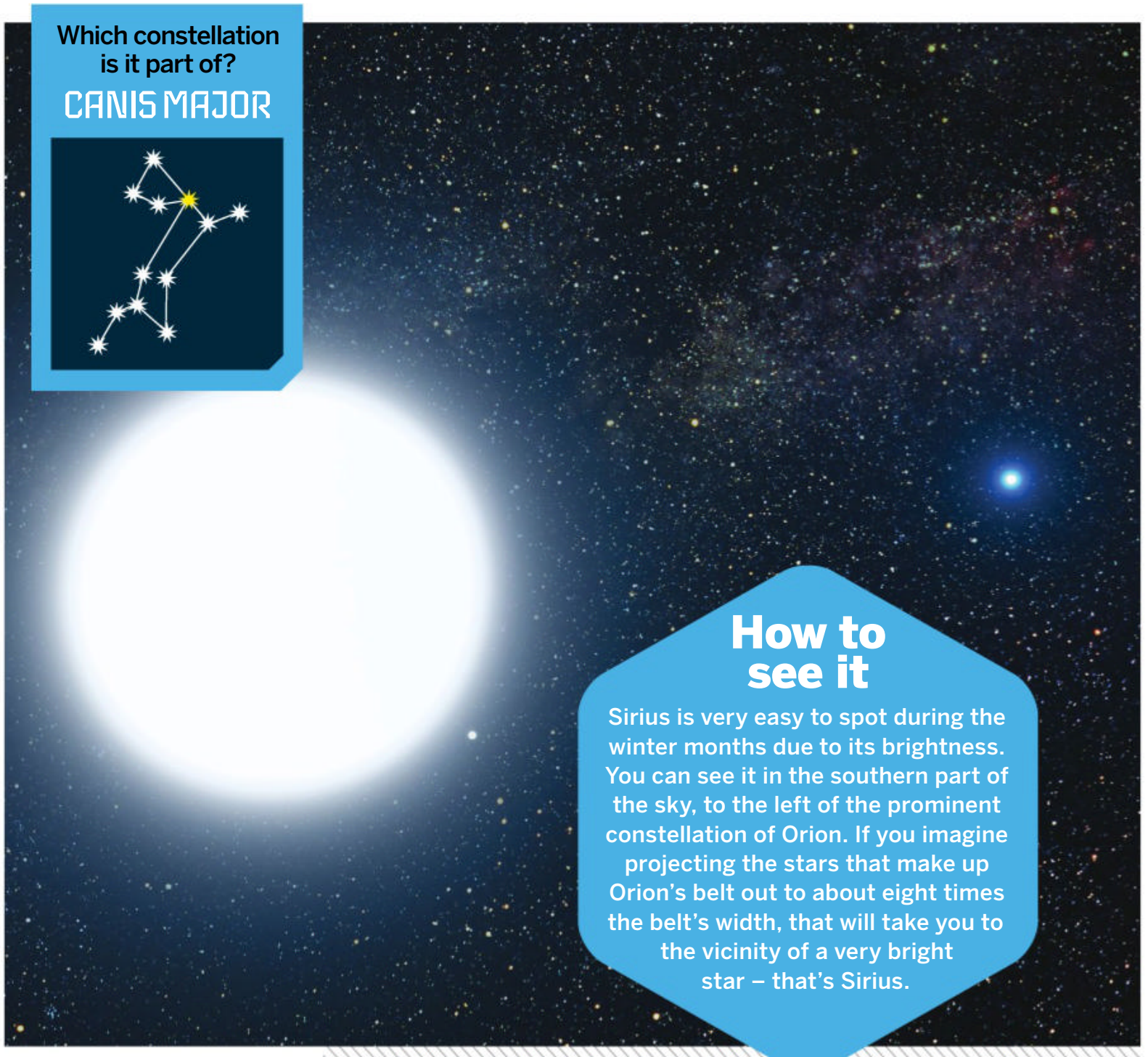
WORDS ANDREW MAY

If you live in a large town or city, even on a clear night you may only be able to see a few dozen stars against the light pollution in the sky. In a really dark location, you may see thousands of stars glittering above you. But even then, some stars will be noticeably brighter than others, and the brightest ones will be the same select few that city dwellers see. These brightest stars have been a familiar sight to humans since ancient times.

There are several reasons why some stars look brighter than others. Perhaps the most obvious is that they're all located at different distances from us. It's no surprise that, other things being equal, the nearer stars tend to look brighter than ones that are farther away. Our closest star – by a long way – is the Sun, and when it's in the sky it shines so brightly that we can't see the other stars at all. A second reason for the differences in brightness is that some stars are larger than others. Our Sun is in the prime of its life – referred to as the main sequence of stellar evolution – but stars that are further advanced in their life cycles can grow to giant proportions. Unsurprisingly, a giant star will be much brighter than a main sequence star seen at the same distance.

There's one other key factor that makes some stars brighter than others, and that's their temperature. Hot stars tend to produce more light than cooler ones. We can get a rough idea of a star's temperature based on its colour. Blue stars are the hottest, followed by white, yellow and orange, and red stars are the coolest. To put this sequence on a more scientific footing, astronomers refer to the spectral type of a star, designated by a letter followed by a digit between 0 and 9. The letters, from the blue end to the red end, run O, B, A, F, G, K, M, and the suffixed digits subdivide these into ten smaller steps. Our Sun, for example, is spectral type G2.

DID YOU KNOW? The current system of stellar classification was devised by Annie Jump Cannon early in the 20th century



SIRIUS

Magnitude: -1.46
Type: Main sequence, A0

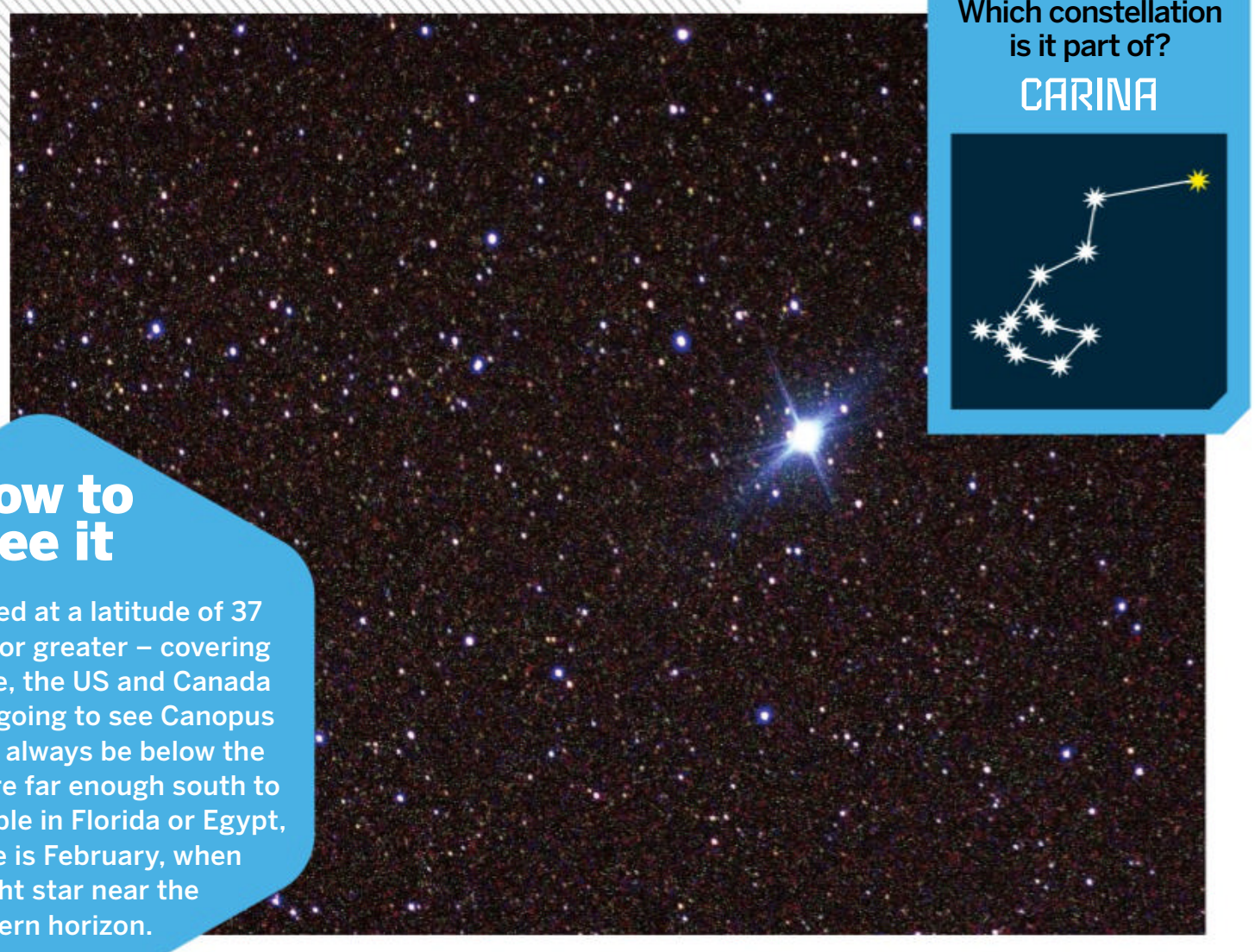
Sirius is the brightest star in the night sky. Sirius is a binary system, but the smaller of its two stars is much too dim to be seen with the naked eye. Called Sirius B, this faint star is a white dwarf in the final stage of stellar evolution. Requiring a powerful telescope, it wasn't discovered until 1862 – and even then astronomers weren't able to estimate its mass until it was observed by Hubble in 2005. That mass turned out to be just slightly less than that of our Sun, all crammed into a volume similar to the size of Earth.

It's the larger of the two stars, Sirius A, that makes it such a prominent sight in our skies. Some 10,000 times more luminous than its diminutive companion, this is a bright blue-white star around twice as massive as our Sun. Combined with a distance of just 8.7 light years, that's why it outshines all the other stars in the night sky. It was a familiar sight to the ancients, who knew it by various different names in different cultures. The one that's come down to us, Sirius, simply means 'glowing', which couldn't be more appropriate.

CANOPUS

Magnitude: -0.74
Type: Giant, A9

You've probably heard of Sirius, but the second-brightest star, Canopus, may be much less familiar, particularly for those living in northern latitudes. That's because it's essentially a Southern Hemisphere sight, but a very bright one. Given that Canopus has a similar spectral type as Sirius, you might imagine that it's a very similar star, but that's not the case. It's actually a giant star, ten times as massive as our Sun, or five times as massive as Sirius A. This gives it a much higher intrinsic luminosity than Sirius, which means in order to appear slightly less bright in our sky it has to be much farther away. Exactly how far away it is remained a mystery to astronomers until its distance was measured by the European Space Agency's Hipparcos satellite in the 1990s. It turned out to be 313 light years – 36 times farther away than Sirius.



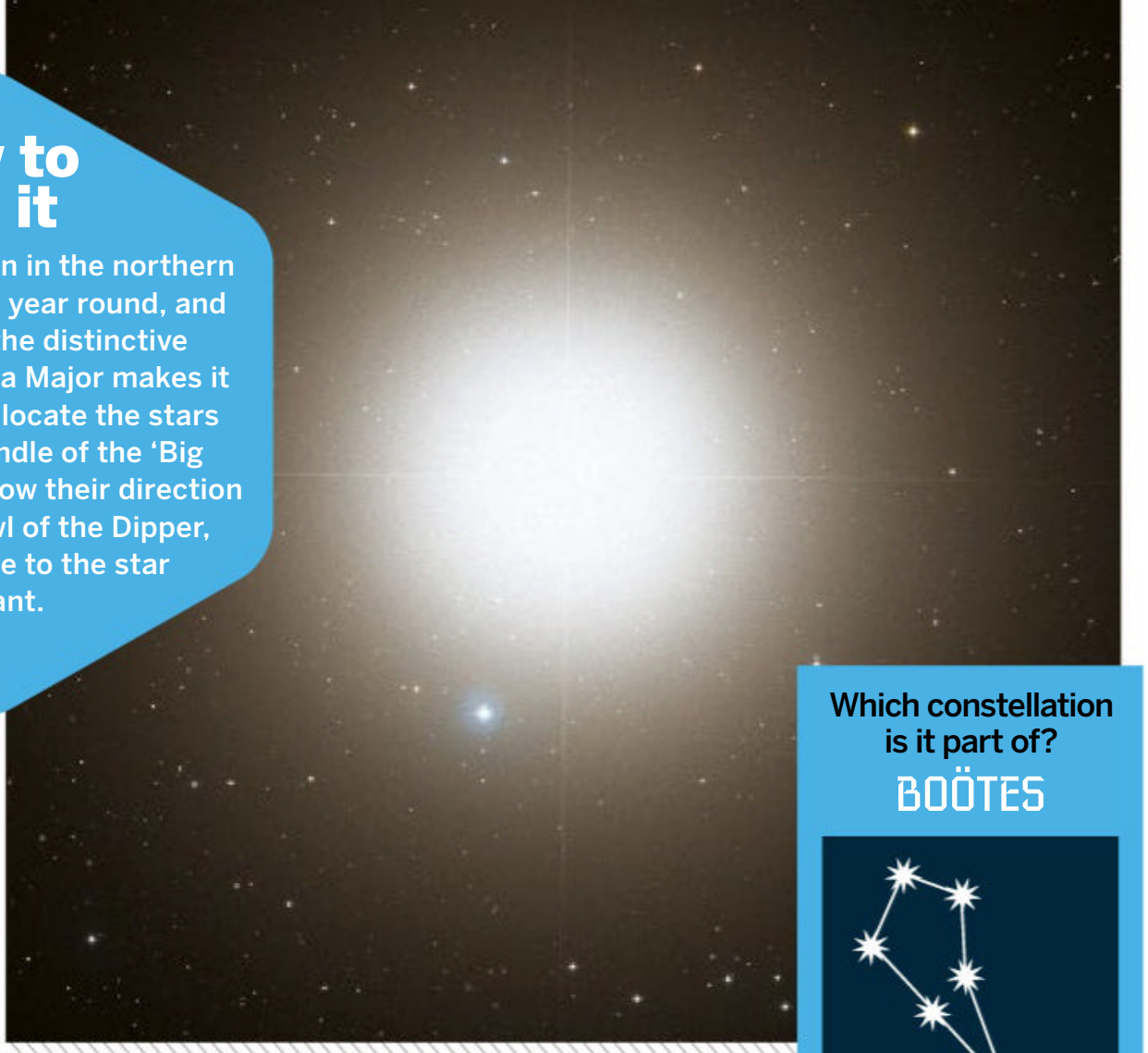
ARCTURUS

Magnitude: -0.04
Type: Red giant, K1

Arcturus is cooler than the Sun, in spectral class K rather than G, and has a mass that's only about one-and-a-half times as great. Yet it puts out far more energy, with an intrinsic luminosity 113 times greater than the Sun's. The reason is that it's in the red giant stage of its evolution, having swollen up to around 25 times the diameter of the Sun – a similar fate awaits the Sun itself in several billion years' time. This, coupled with the fact that Arcturus is only 37 light years away from us, makes it one of the brightest stars in the night sky. Unlike Canopus, Arcturus is far enough north that it features prominently in European mythology. The constellation it belongs to, Boötes, is named after a legendary herdsman supposedly in charge of the famous 'Great Bear' constellation of Ursa Major. In fact, the name Arcturus itself can be roughly translated as 'guardian of the bear'.

How to see it

Arcturus can be seen in the northern night sky the whole year round, and its proximity to the distinctive constellation of Ursa Major makes it easy to find. If you locate the stars making up the handle of the 'Big Dipper' and then follow their direction away from the bowl of the Dipper, you'll soon come to the star you want.

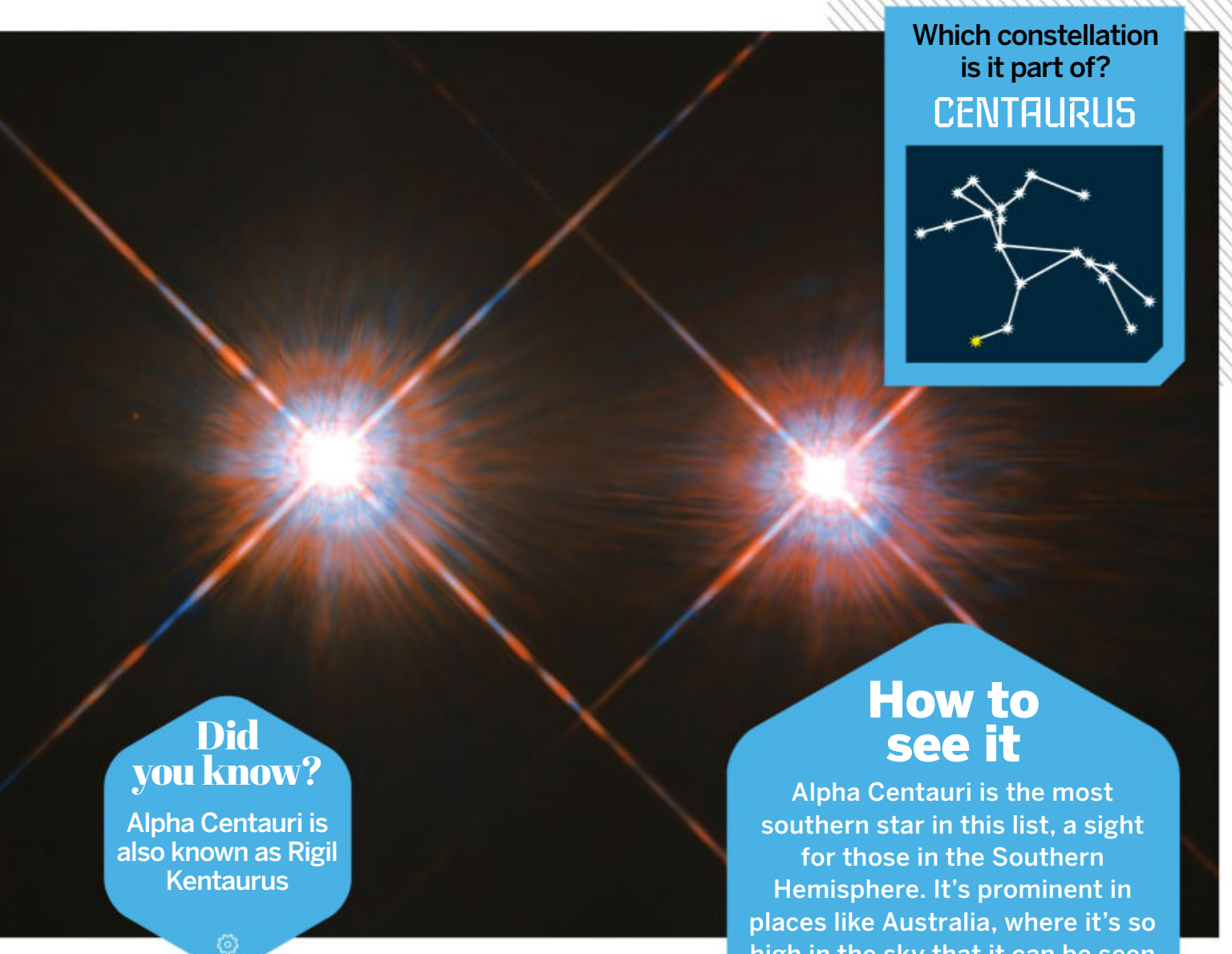


Which constellation is it part of?

BOÖTES

Which constellation is it part of?

CENTAURUS



Did you know?

Alpha Centauri is also known as Rigil Kentaurus

How to see it

Alpha Centauri is the most southern star in this list, a sight for those in the Southern Hemisphere. It's prominent in places like Australia, where it's so high in the sky that it can be seen year round, not too far from the distinctive Southern Cross.

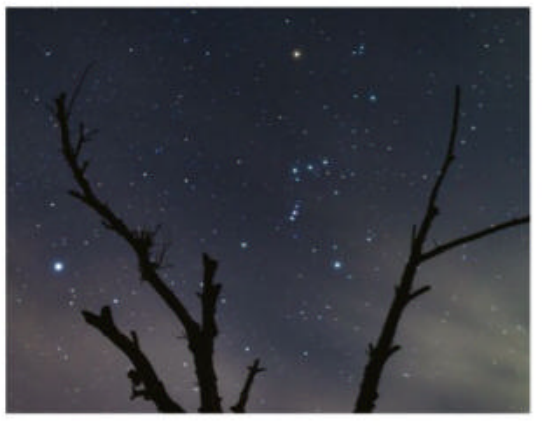
ALPHA CENTAURI

Magnitude: -0.27
Type: Main sequence, G2

Alpha Centauri is the closest star system to the Sun, a little more than four light years away. It actually consists of three separate stars. The brightest, Alpha Centauri A, is a G-type star similar in size, temperature and luminosity to our Sun. Its close companion, Alpha Centauri B, is a K-type star that's somewhat smaller, cooler and fainter. The third member of the system, Alpha Centauri C, is a much fainter red dwarf of spectral type M5. It's a fifth of a light year away from the pair, but it lies in our direction, which makes it the closest star to us after the Sun. Due to this proximity, it's commonly known by the name of Proxima Centauri. While its dimness makes Proxima a telescope-only object, Alpha Centauri A and B, seen together, make up one of the brightest stars in the sky.

STAR MAGNITUDES

The brightness of stars is usually expressed in terms of a magnitude value, and confusingly this number actually gets higher for fainter stars. The system originated in the ancient world, when people called the very brightest stars first magnitude, the next brightest second magnitude and so on. By the 19th century astronomers needed a more precise scale, so they defined magnitude +2.0 as 2.5 times fainter than magnitude +1.0, magnitude +3.0 as 2.5 times fainter than that and so on. This allowed the system to be extended to the fractional and negative numbers that we see today.

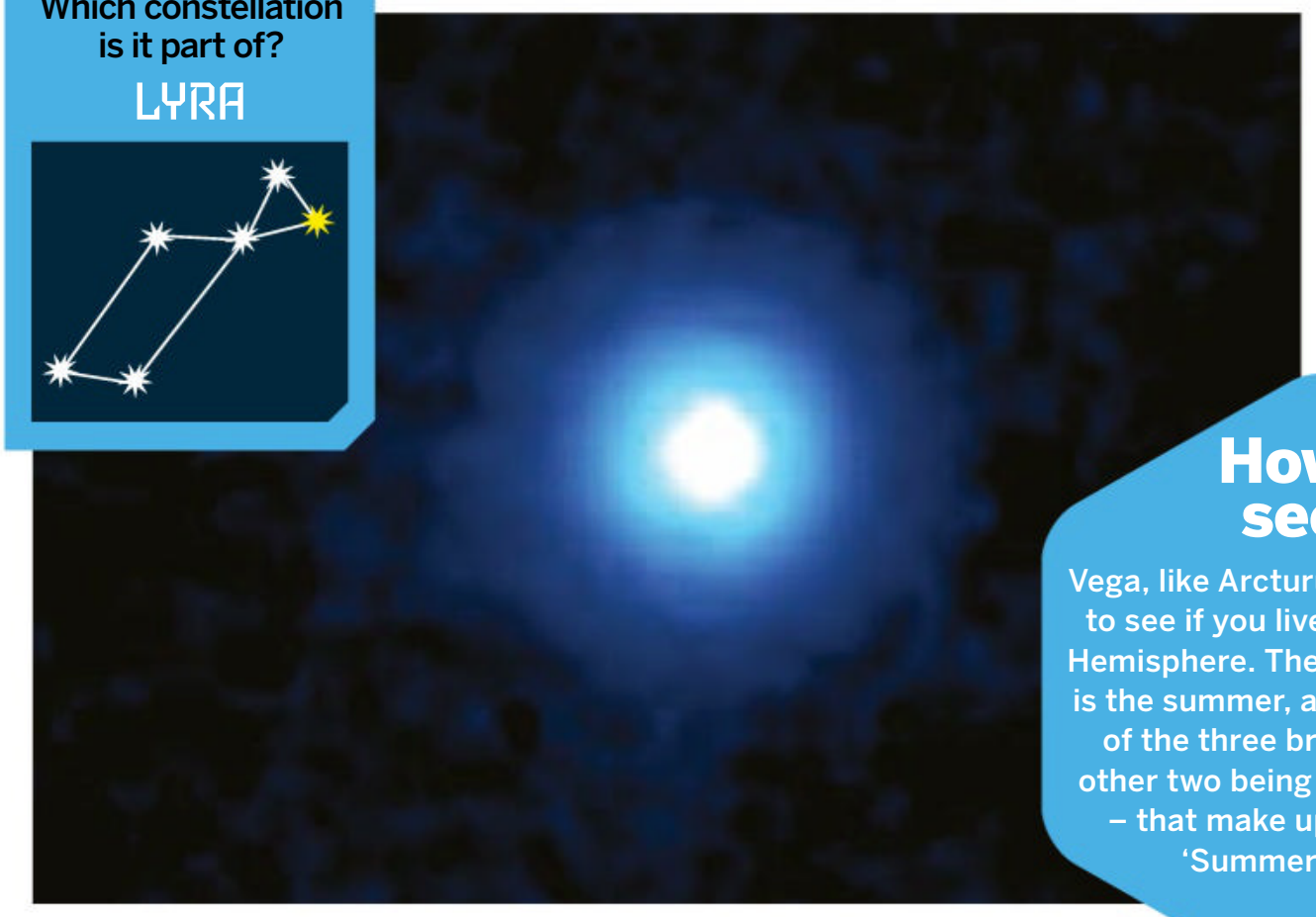


This photograph of the winter sky shows how stars come in a range of magnitudes

DID YOU KNOW? The fictional planet of Arrakis in the *Dune* franchise is supposed to orbit around the star Canopus

Which constellation is it part of?

LYRA



How to see it

Vega, like Arcturus, is an easy star to see if you live in the Northern Hemisphere. The best time of year is the summer, and in fact it's one of the three bright stars – the other two being Altair and Deneb – that make up the so-called 'Summer Triangle'.

VEGA

Magnitude: +0.03
Type: Main sequence, A0

Vega is a similar star to Sirius, with comparable mass, diameter and spectral type. However, it's around three times farther away, at a distance of 25 light years from us, so it doesn't look quite as bright in the sky. A couple of things make it a particularly interesting star for astronomers. For one thing, it's relatively young – only about 450 million years old, which is less than a tenth the age of our Sun. Observing it can tell us how stellar systems behave in the relatively early phases of their life. Another notable property of Vega is its rapid rotation rate; it only takes 12.5 hours to spin all the way through 360 degrees. That's so fast that the star is noticeably flattened at the poles, like an under-inflated ball that's been stepped on.

CAPELLA

Magnitude: +0.08
Type: Giant, G3

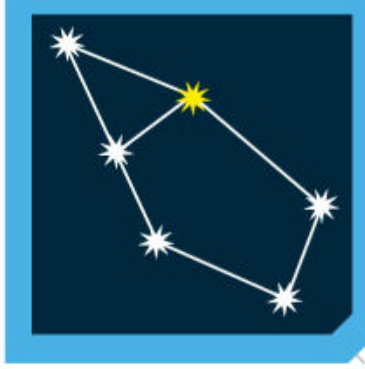
Capella has been known since ancient times, when for reasons that are now obscured it became associated with a little goat. Its formal name comes from the Latin word for a young female goat, and in English-speaking countries it's often known colloquially simply as 'the goat star'. When that name originated, long before the days of telescopes, it could only be seen as a bright, yellowish dot in the sky, so it was assumed to be a single star. Now, however, we know the situation is more complicated than that. Capella actually consists of four stars, arranged in two pairs. The two brightest stars are similar in spectral type to the Sun, but they're about ten times as big, while the other two are much smaller and dimmer red dwarfs. The whole system lies about 43 light years away.

How to see it

In the Northern Hemisphere, Capella is a prominent sight on winter evenings, though it can also be seen at other times of year. In colour and brightness it looks a little like the planet Mars, but its located in the northern part of the sky where Mars could never actually be seen.

Which constellation is it part of?

AURIGA



Which constellation is it part of?

ORION

RIGEL

Magnitude: +0.13
Type: Blue supergiant, B8

Of all the stars in this list, Rigel is the farthest away from us, at 863 light years. But it's still the seventh-brightest star in the night sky because its intrinsic luminosity is fantastically high – around 10,000 times that of our own Sun. Technically, it's a blue supergiant, which ticks all the boxes – blue meaning that it's very hot, and supergiant meaning that it's very big, almost 80 times the diameter of the Sun. Surprisingly, given its enormous size, Rigel is actually part of a multiple system. It has three smaller companions, dubbed Rigel Ba, Bb and C, although they're all too faint to see without a telescope.

How to see it

Rigel belongs to one of the most easily recognised constellations in the sky, Orion. It's a familiar sight in the Northern Hemisphere, where it dominates the southern sky on clear winter evenings. If you think of the constellation as a stick figure of a human, then Rigel is the bright star marking the figure's right leg.

Did you know?

Earth is 45 times older than Altair

PROCYON

Magnitude: +0.34
Type: Main sequence, F5

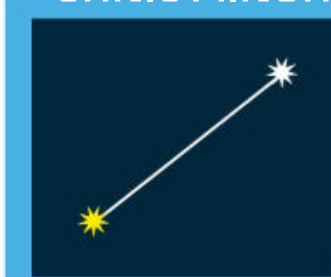
The brightest star in the night sky, Sirius, is often referred to as the 'Dog Star' as it's located in the constellation of Canis Major, or the 'Greater Dog'. But there's another somewhat fainter but still very bright star in the 'Lesser Dog' constellation of Canis Minor that rises in the sky shortly before Sirius. It's called Procyon, from a Greek phrase meaning 'before the dog'. Procyon resembles Sirius in having a similar mass – albeit a slightly cooler temperature – and a small, faint companion in the form of a white dwarf star. At around 11.5 light years away, it's a little farther than Sirius.

How to see it

The best time to see Procyon for observers in the Northern Hemisphere is in the evening during winter or early spring. At these times Procyon forms the prominent 'Winter Triangle' in the southern sky along with two other stars, Sirius and Betelgeuse.

Which constellation is it part of?

CANIS MINOR

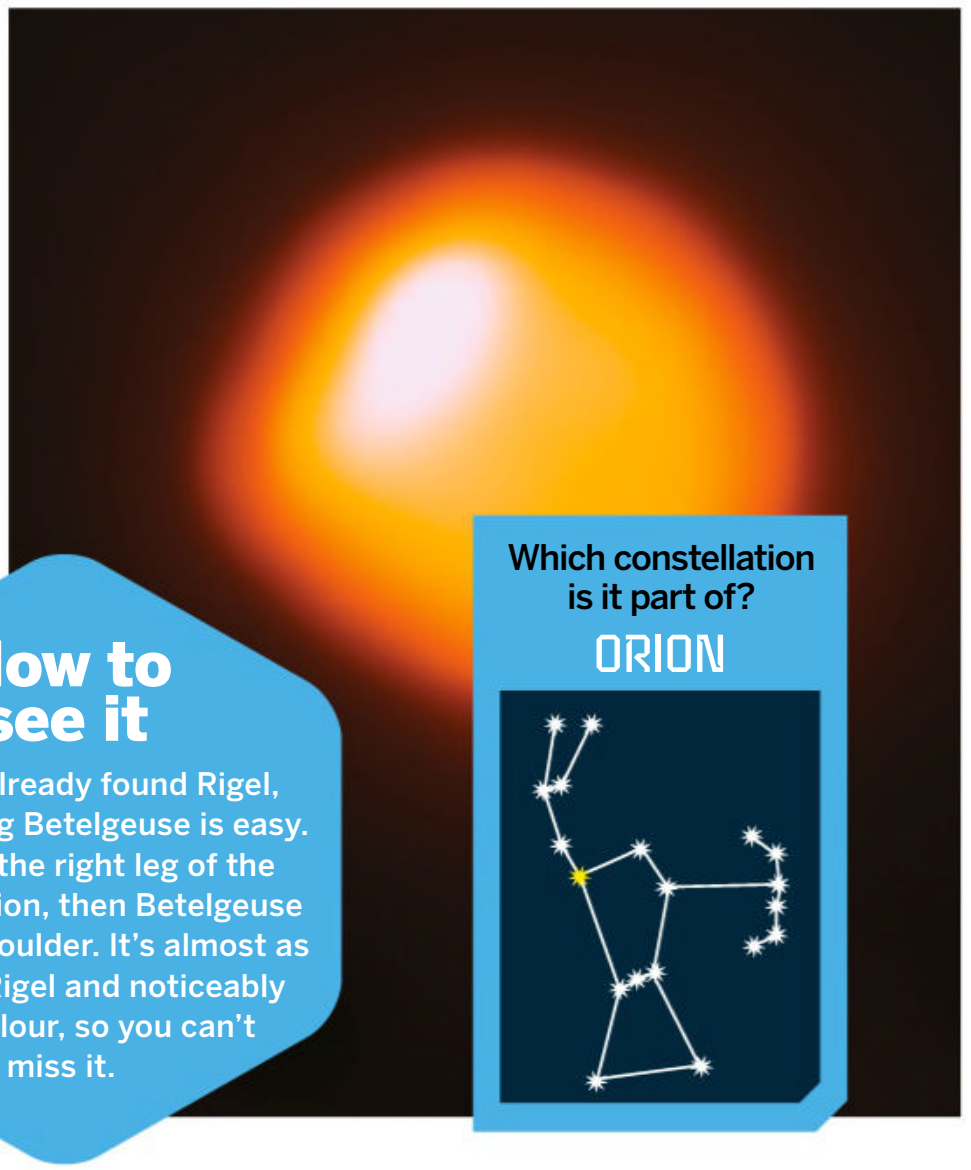


DID YOU KNOW? If Betelgeuse was located where the Sun is, it would engulf the orbits of Mercury, Venus, Earth and Mars

BETELGEUSE

Magnitude: +0.5
Type: Red supergiant, M1

Betelgeuse is in the same constellation as Rigel, and it's comparable to it in terms of mass – around 20 times that of our Sun. Yet the two differ in where they lie in the stellar life cycle. Rigel is a young blue supergiant, while Betelgeuse is an old red supergiant. This means it's cooler than Rigel, but still very big and bright – around 760 times the diameter of the Sun and more than 100,000 times its luminosity. Even at a distance of 550 light years, it's still one of the brightest stars in the sky. Betelgeuse is one of the most talked about of all stars because astronomers believe it's close to the most dramatic stage of its evolution, when it will blow itself apart in a supernova explosion. But don't get too excited – close in astronomical terms simply means within the next 100,000 years.

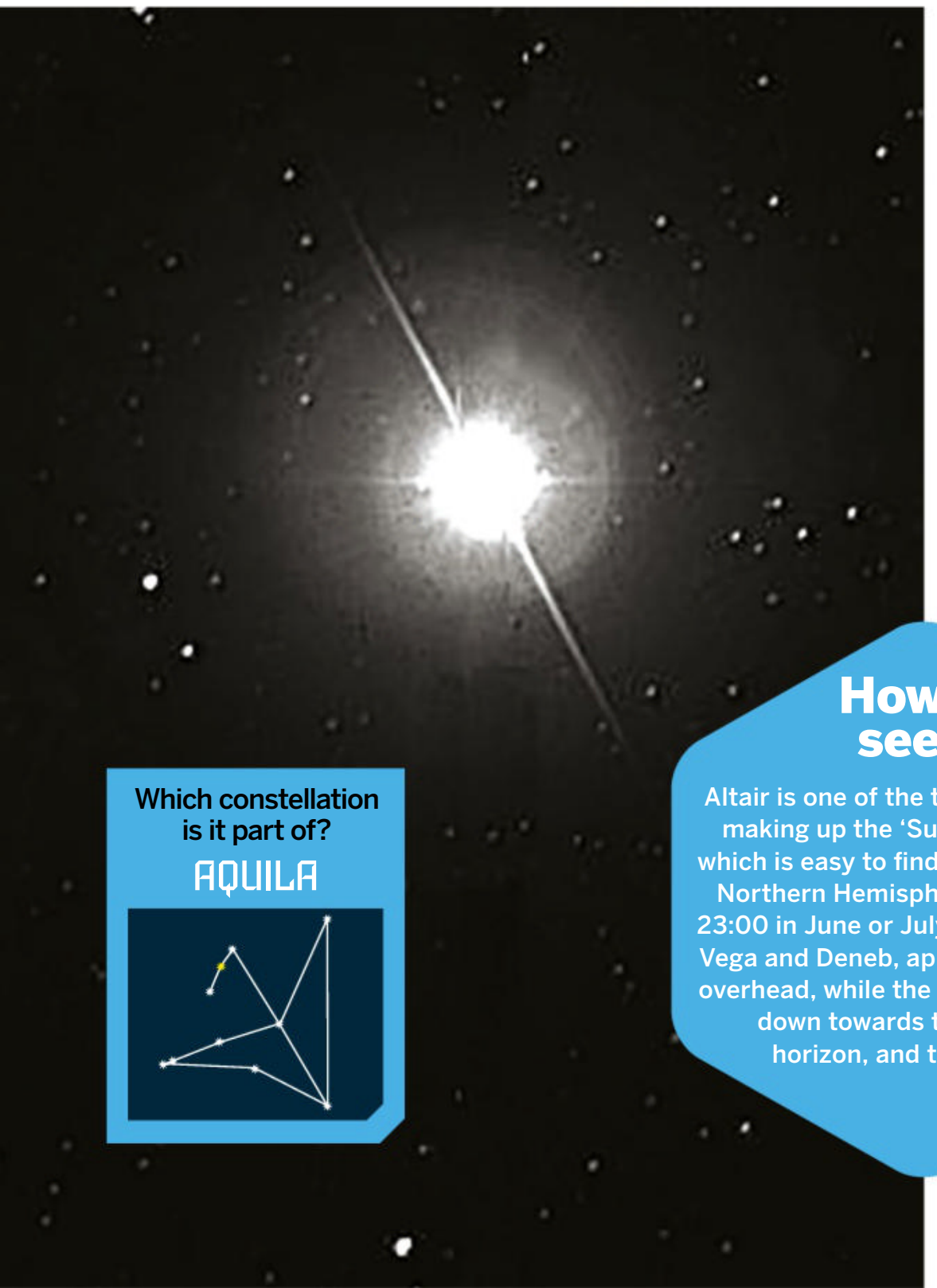


How to see it

If you've already found Rigel, then locating Betelgeuse is easy. If Rigel is the right leg of the figure of Orion, then Betelgeuse is his left shoulder. It's almost as bright as Rigel and noticeably red in colour, so you can't miss it.

Which constellation is it part of?

ORION



ALTAIR

Magnitude: 0.76
Type: Main sequence, A7

Altair lies in the constellation of Aquila, but is also part of the 'Summer Triangle' along with Vega. Altair is slightly cooler and smaller than Vega, but it's also slightly closer to us, so not much lower in apparent brightness. It exceeds Vega in one respect, in that it spins on its axis even more rapidly, completing a rotation in an even shorter time than the 12.5 hours that Vega takes. A 2019 study estimated the rotation period at less than eight hours, resulting in a flattening of Altair's shape by around 20 per cent.

How to see it

Altair is one of the three bright stars making up the 'Summer Triangle', which is easy to find in summer in the Northern Hemisphere. At 22:00 or 23:00 in June or July, two of its stars, Vega and Deneb, appear to be almost overhead, while the third is some way down towards the southern horizon, and that's Altair.

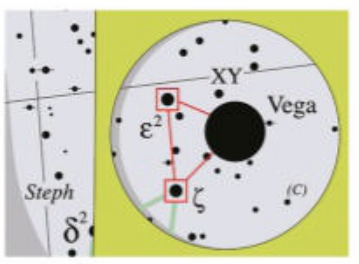
Which constellation is it part of?

AQUILA

HOW TO FIND STARS

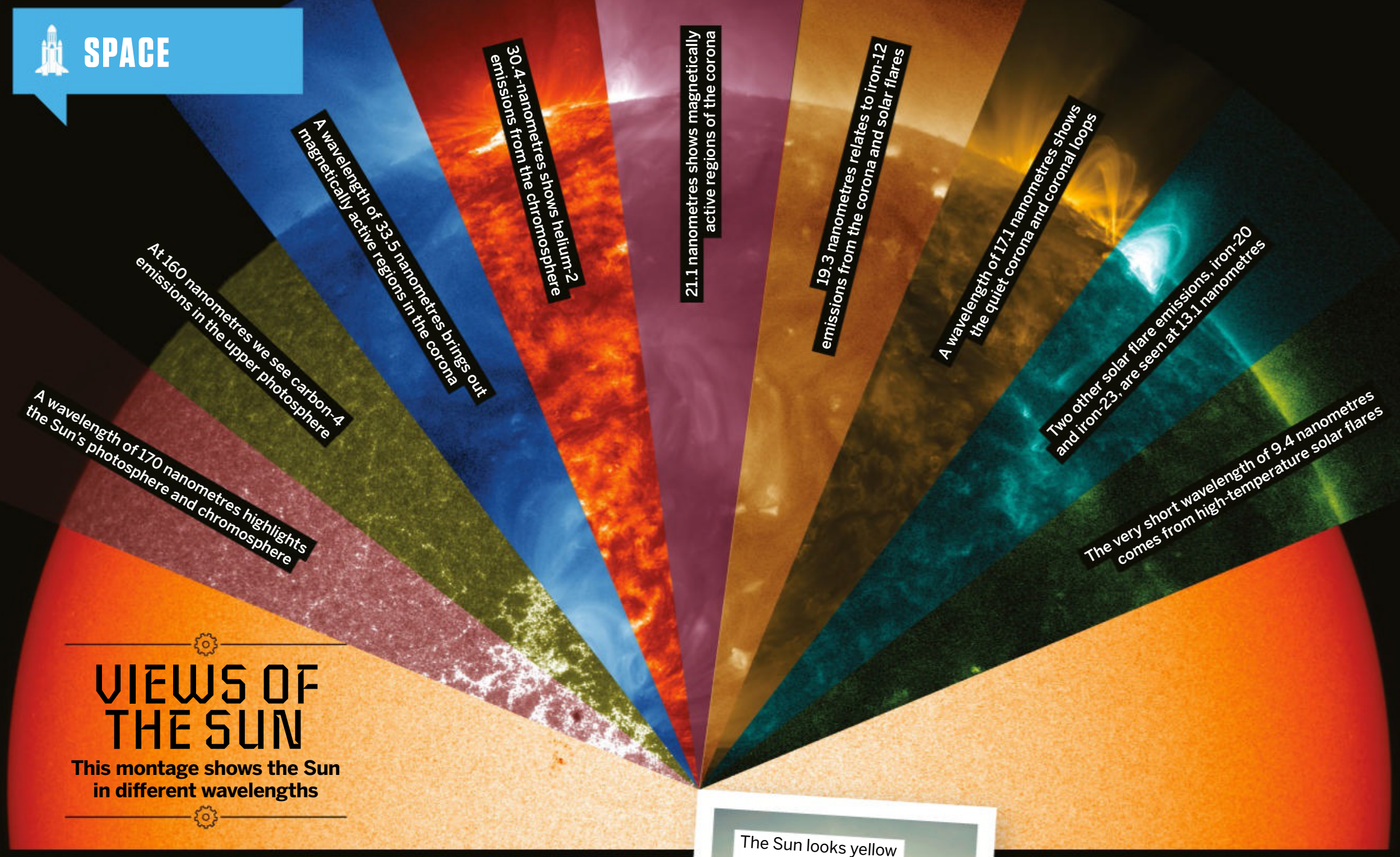
There are several different ways to find stars in the sky, some lazy, some fun

1 USE TECHNOLOGY
You can download a star-finding mobile app. Then you can just hold your phone up to the sky and it will tell you what you're looking at. Equally simple to use is a 'Go-To' telescope, which will automatically point at whatever star you tell it to once its aligned.



2 USE STAR CHARTS
A star chart is a map of the sky, but it's trickier to read than an ordinary map because the portion of the sky that's visible changes from month to month. And because you're looking upwards, east is on the left and west is on the right.

3 STAR-HOPPING
You start by identifying a few of the brightest stars and noting the patterns they make. Then, based either on a star chart or instructions you've read, you use those patterns as a guide to finding the particular star you're looking for.



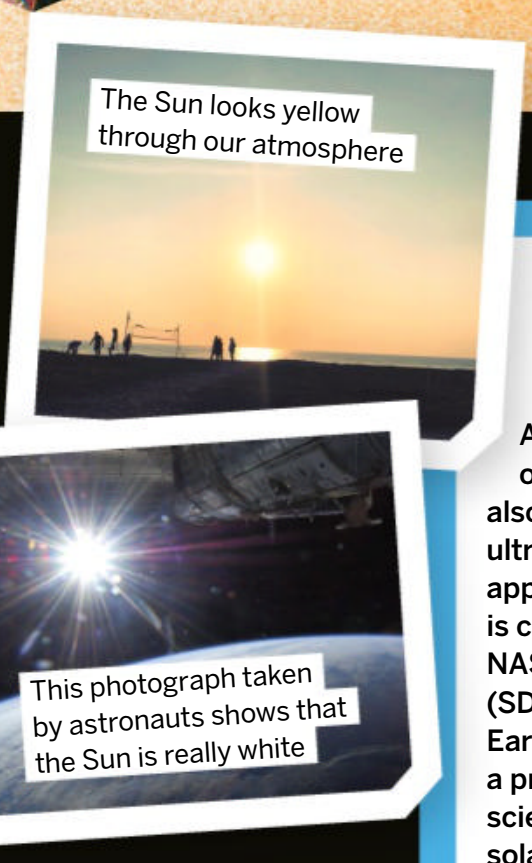
VIEWS OF THE SUN

This montage shows the Sun in different wavelengths

WHAT COLOUR IS THE SUN?

The answer depends on whether you're on Earth or in space

WORDS **ANDREW MAY**



The Sun is so bright that it's dangerous to stare straight at it. When we do glimpse it, either low in the sky or partially obscured by clouds, it generally looks yellow in colour, or even orange close to the horizon. But if we approach it more scientifically, it's not that simple. Sunlight is actually made up of all the colours of the rainbow – after all, rainbows are produced by sunlight. These colours represent different wavelengths of light, and the Sun emits roughly equal amounts of all of them. Combining all these colours together makes white light, which means the true colour of the Sun must also be white. In fact, in outer space, for example as seen from the International Space Station, the Sun really does appear pure white. So why does it look yellow from the surface of our planet?

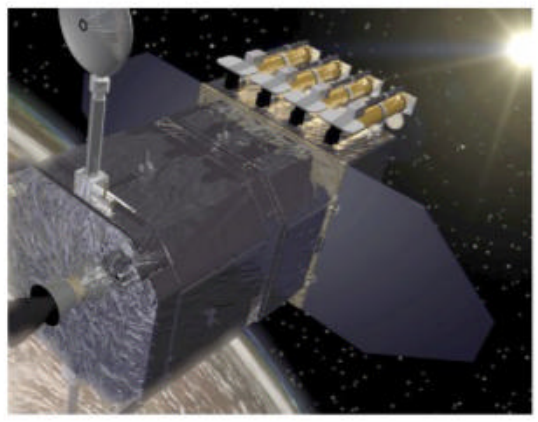
Did you know?

The Sun emits slightly more green light than yellow

The answer lies in what happens when this pure-white sunlight travels through the atmosphere. As it encounters air molecules, it's scattered off them, and some colours are scattered more than others. The blue end of the spectrum is scattered the most, so it gets bounced all over the sky before reaching our eyes, while red, orange and yellow light is scattered less. The end result is the familiar sight of a blue sky and yellow Sun.

SOLAR DYNAMICS OBSERVATORY

As well as the visible colours that our eyes are sensitive to, the Sun also emits radiation in infrared, ultraviolet and other bands. Its appearance at different wavelengths is constantly being monitored by NASA's Solar Dynamics Observatory (SDO), a satellite in geosynchronous Earth orbit. Launched in 2010, this has a practical purpose as well as a scientific one, because changes in solar conditions can have significant effects on life on Earth and our technological systems.



A NASA artist's impression of the SDO satellite observing the Sun

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E-WASTE

EARTH VS ELECTRONICS

How electronic waste is recycled and why it can be so harmful to our planet

WORDS **AILSA HARVEY**

More than 63 per cent of the world is now connected to the internet, and many workers require an electronic device to do their job. Even for activities that don't require an internet connection, such as blow-drying your hair, heating up your dinner or illuminating a room, there's always an electronic item waiting to be used.

Around 40 million tonnes of electronic waste, known as e-waste, is produced every year. This includes electrical or electronic equipment that has been discarded. But where does it all go? In the US alone, 100 million mobile phones, 41 million computers and over 20 million televisions are thrown into landfills in a year. Even for standard waste this is problematic, because any materials that are buried in the ground can't be easily retrieved and recycled. Recycling electronics can save energy and means that less of Earth's natural resources need to be mined. There are around 70 commonly used chemical elements that make up electronic devices, and many of these can be extracted from old electronics.

Failing to recycle e-waste is extremely detrimental to the environment due to the nature of the materials used in modern devices. Heavy metals and chemicals give electronics their fluorescence, conductivity and fire resistance. But while this improves a device's safety and user experience, these components become toxic if they're not disposed of properly. Your old phones, games consoles, kettles, microwaves and more can end up in landfills, leaking their harmful contents into the soil, water and air. Not only does this kill wildlife and destroy ecosystems, but the accumulation of toxins can impact human health too. As heavy metals and chemicals disperse into lakes and rivers, drinking water becomes contaminated. These toxins spread through the soil, impacting the health of crops and animals that people also rely on.

In some countries, e-waste isn't hidden out of sight in landfills but is incinerated in giant, open junkyards. Some countries ship waste electronics to other countries to deal with, and this often ends up in dumps across Africa and Asia. Workers in these scrapyards are exposed to polluted lands and chemical fumes.

Did you know?

5 billion mobile phones will be thrown away this year

The best solution to reducing the damaging and unsustainable side of e-waste production is to recycle electronic equipment. Rare earth metals, some plastics and chemicals can be recovered from e-waste and fed into the next generation of electronics in a process called urban mining. The steps to proper recycling of e-waste are extensive and need large investment, but as the technology improves, more and more countries around the world are turning to e-waste recycling.

DID YOU KNOW? E-waste takes up two per cent of landfill waste but 70 per cent of all toxic waste

TYPES OF HOUSEHOLD E-WASTE

How much do UK households throw away in a year?

183,704 TONNES

LARGE HOUSEHOLD APPLIANCES
Items such as washing machines and electric stoves make up the largest percentage of household e-waste.

54,199 TONNES

DISPLAY EQUIPMENT
Some old computer monitors contain cathode ray tubes, which have hazardous phosphor powder inside to create luminescence.

39,539 TONNES

CONSUMER EQUIPMENT
These are items people buy for personal use, such as headphones or televisions, and are often replaced despite working perfectly.

18,724 TONNES

ELECTRICAL AND ELECTRONIC TOOLS
Unlike consumer electronics, electrical tools such as multimeters have a low replacement rate.

2,328 TONNES

TOYS, LEISURE AND SPORTS EQUIPMENT
125,000 video game consoles were sold in the UK in August 2022. Many of these replaced existing consoles.

135,681 TONNES

COOLING APPLIANCES
Air conditioners, drinking fountains, dehumidifiers, refrigerators, freezers and other cooling appliances contain refrigerants.

48,563 TONNES

TELECOMMUNICATION AND IT EQUIPMENT
Telecommunication equipment transfers voice, data, text, sound and video. This e-waste includes mobile phones, antennae, cables, satellites and routers.

36,703 TONNES

SMALL HOUSEHOLD APPLIANCES
Toasters, hair dryers and coffee machines easily fit in bins, but taking the time to recycle them at specialist plants helps reduce the volume of harmful materials in landfills.

5,369 TONNES

GAS AND LED LIGHTS
LED lights contain rare earth metals such as lutetium, cerium or europium and precious metals like gold and silver.

141 TONNES

MONITORING AND CONTROL INSTRUMENTS
Heat and smoke alarms are just one type of monitoring and control equipment that make up e-waste. It's recommended that these be replaced every ten years for safety.

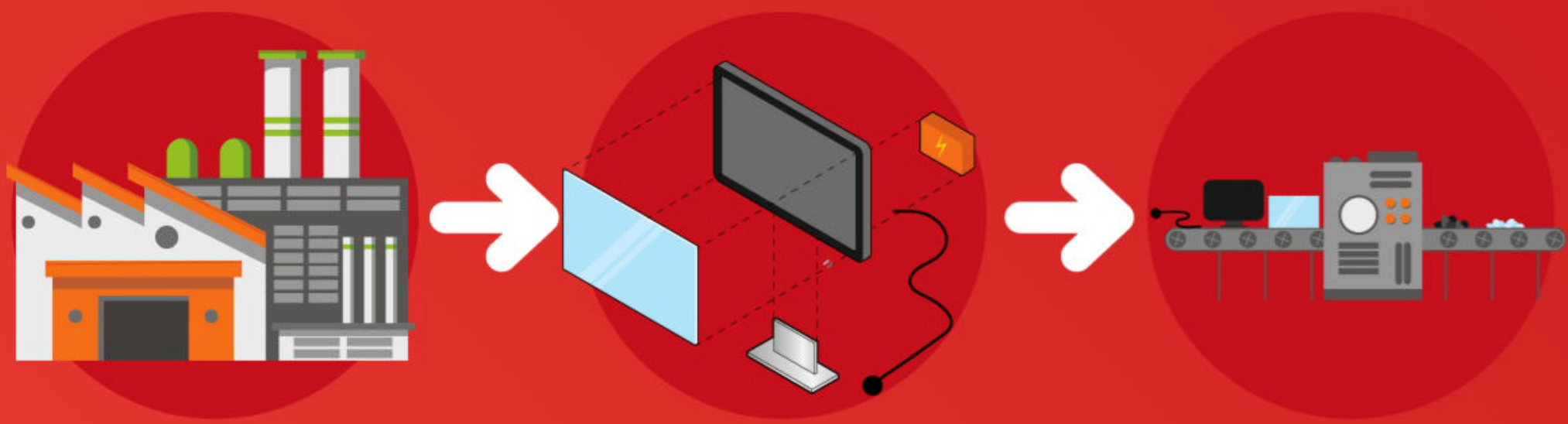
HOW IS E-WASTE RECYCLED?

Electronic recycling plants dismantle products to reuse their core materials

1 ORGANISED COLLECTION
When any electronic product breaks, loses efficiency or is no longer needed, it needs to be taken to a specialised electronic collection site.

2 ITEMISATION
Collection sites have different boxes so that you can dispose of your items by type.

3 TRANSPORTATION
Categorised electronics are taken to recycling plants. Items such as rechargeable lithium batteries are carefully packaged to prevent fires.



4 DELIVERY
There are specialised plants that can handle cathode ray tubes from computer monitors, mercury, circuit boards and batteries.

5 CAREFUL DISASSEMBLY
Electronics are broken down into their core materials, such as glass screens, plastic covers, metal wires and batteries.

6 BATTERY AND CARTRIDGE REMOVAL
These components can't be shredded, as their materials can explode when mixed together.

7 SHREDDING
Machines break the electronics into smaller pieces just a few centimetres wide so that their core materials can be separated.

8 MATERIAL SEPARATION
Metals such as iron and steel are separated using a giant magnet, while glass and plastics are separated from each other in water.

9 CERTIFICATION
A certificate of destruction shows customers that their electronic waste was recycled safely and effectively.

DID YOU KNOW? For every million laptops recycled, enough energy is saved to power 3,600 homes for a year

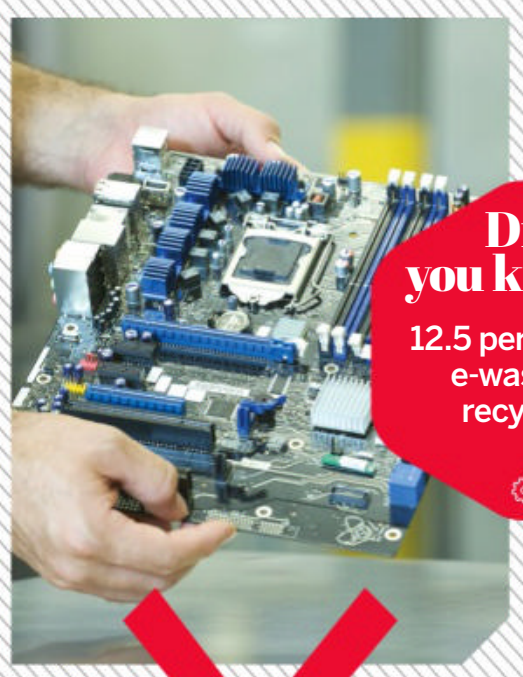
WHAT CAN E-WASTE BE RECYCLED INTO?

LAWN MOWERS TO MUSIC

The strong plastic acrylonitrile butadiene styrene (ABS), which is used to make hover lawn mowers, can be recycled to make car bumpers, musical instruments and pipe fittings.

GAMES TO ACCESSORIES

The circuit boards inside games consoles are made of gold, silver, palladium and other precious metals. By recycling e-waste, in their next form these metals can be used to make jewellery.

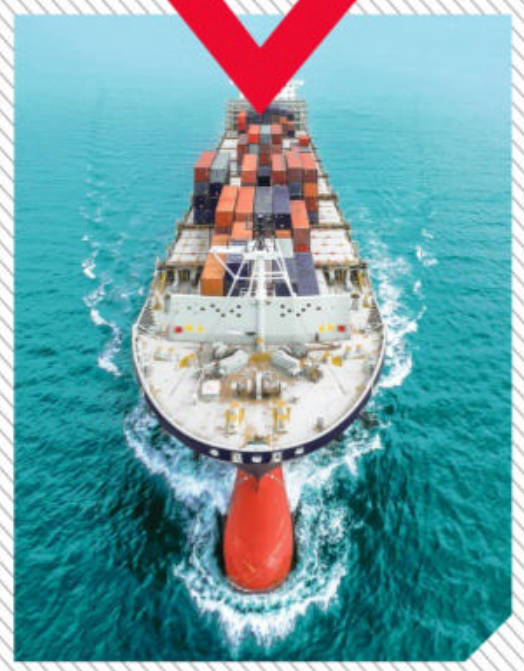


Did you know?

12.5 per cent of e-waste is recycled

SMARTPHONES TO SHIPS

The zinc in the electronics of smartphones can be dismantled and used to build ships. Zinc prevents ships from rusting as it corrodes 100 times slower than other metals.



5 TOXIC MATERIALS IN ELECTRONICS

1 BERYLLIUM
This metal exists in televisions, smartphone connectors, computer chips and thermostats, released in significant amounts as beryllium oxide. When this comes into contact with human skin and lungs, it can cause irritation and lung cancer.

2 CADMIUM
Cadmium is a protective metal coating often used as an outer layer on batteries and switches. It's highly toxic and contact with it can cause damage to the kidneys, lungs and bones.

3 MERCURY
This element is a component of liquid-crystal display (LCD) screens. Because mercury exposure can damage the nervous system, e-waste with mercury in it should be taken to a hazardous waste centre.

4 LEAD
Lead has a low melting point, so it is used as solder to connect components together in electronics. It's toxic to humans when ingested, as well as causing reproductive failure in plants and animals when released into the environment.

5 ANTIMONY
This silvery metalloid is toxic to humans and can irritate the eyes and skin in particular. It is present in laptop batteries, circuit boards and infrared detectors.

THE SHORT LIFE OF YOUR ELECTRONICS

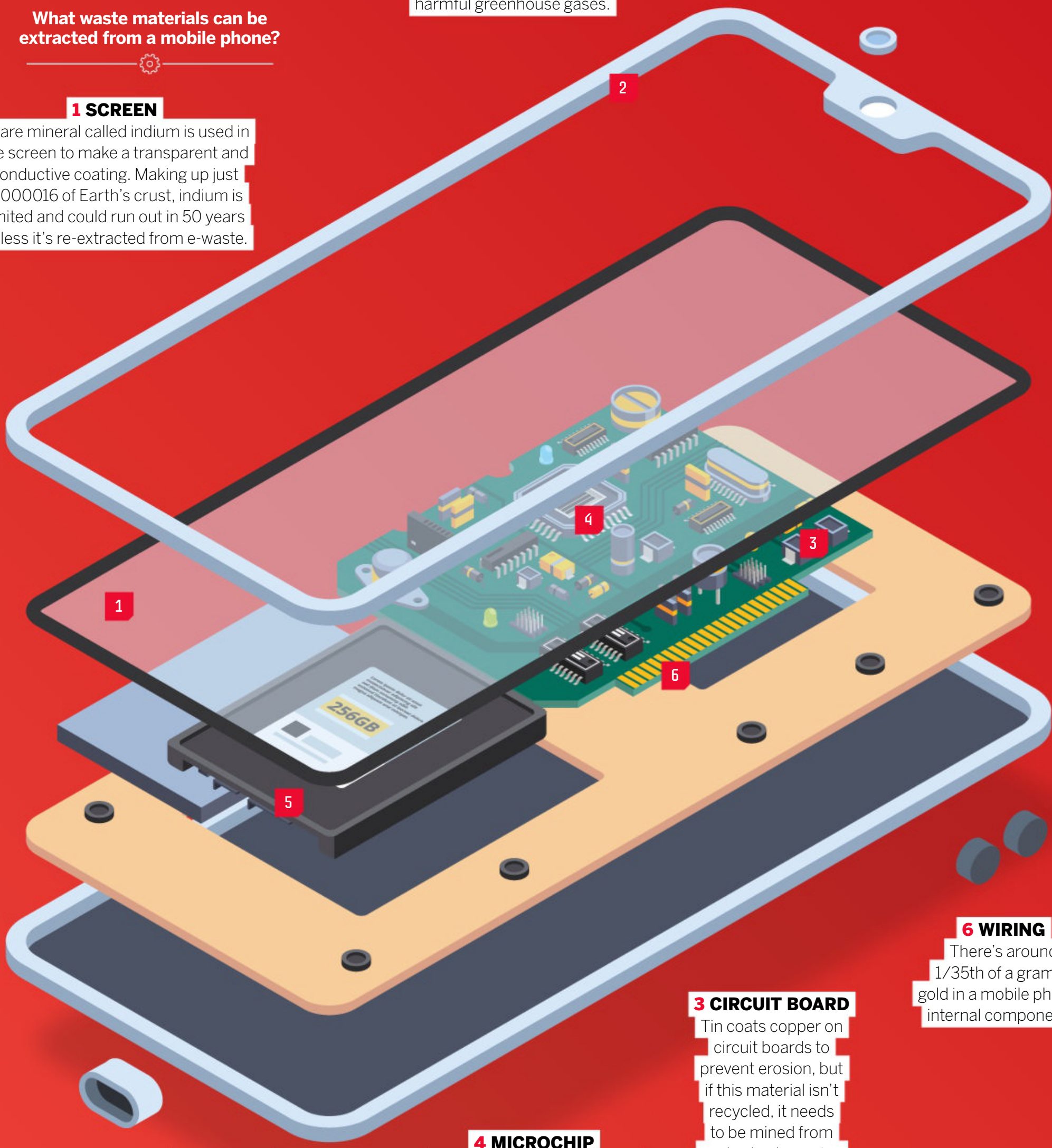
Even if you have taken good care of your mobile phone or other electronic device, you will still notice that it deteriorates over the years. This is because electronics become less efficient the more they are used. Although this can't be prevented, some phone manufacturers purposely aim to increase the deterioration rate of their devices to encourage customers to replace their phone with a newer model. Currently, the average smartphone is replaced after just two-and-a-half years of being used. The three biggest contributing factors to reducing a smartphone's life span are damage, reduced battery life and general usage.

SMARTPHONE BREAKDOWN

What waste materials can be extracted from a mobile phone?

1 SCREEN
A rare mineral called indium is used in the screen to make a transparent and conductive coating. Making up just 0.000016 of Earth's crust, indium is limited and could run out in 50 years unless it's re-extracted from e-waste.

2 CASING
Aluminium in smartphone casings is made from aluminium oxide. The production of this metal releases harmful greenhouse gases.



3 CIRCUIT BOARD
Tin coats copper on circuit boards to prevent erosion, but if this material isn't recycled, it needs to be mined from seabeds, damaging marine life.

4 MICROCHIP
Silicon, gallium, arsenic and antimony are needed to make microchips. In e-waste, less than one per cent of gallium is recycled.

5 BATTERY
The demand for lithium used in smartphone batteries is expected to double by 2030.

6 WIRING
There's around 1/35th of a gram of gold in a mobile phone's internal components.

DID YOU KNOW? There's around 250 kilograms of silver and 24 kilograms of gold in a million mobile phones

THE JOURNEY OF E-WASTE

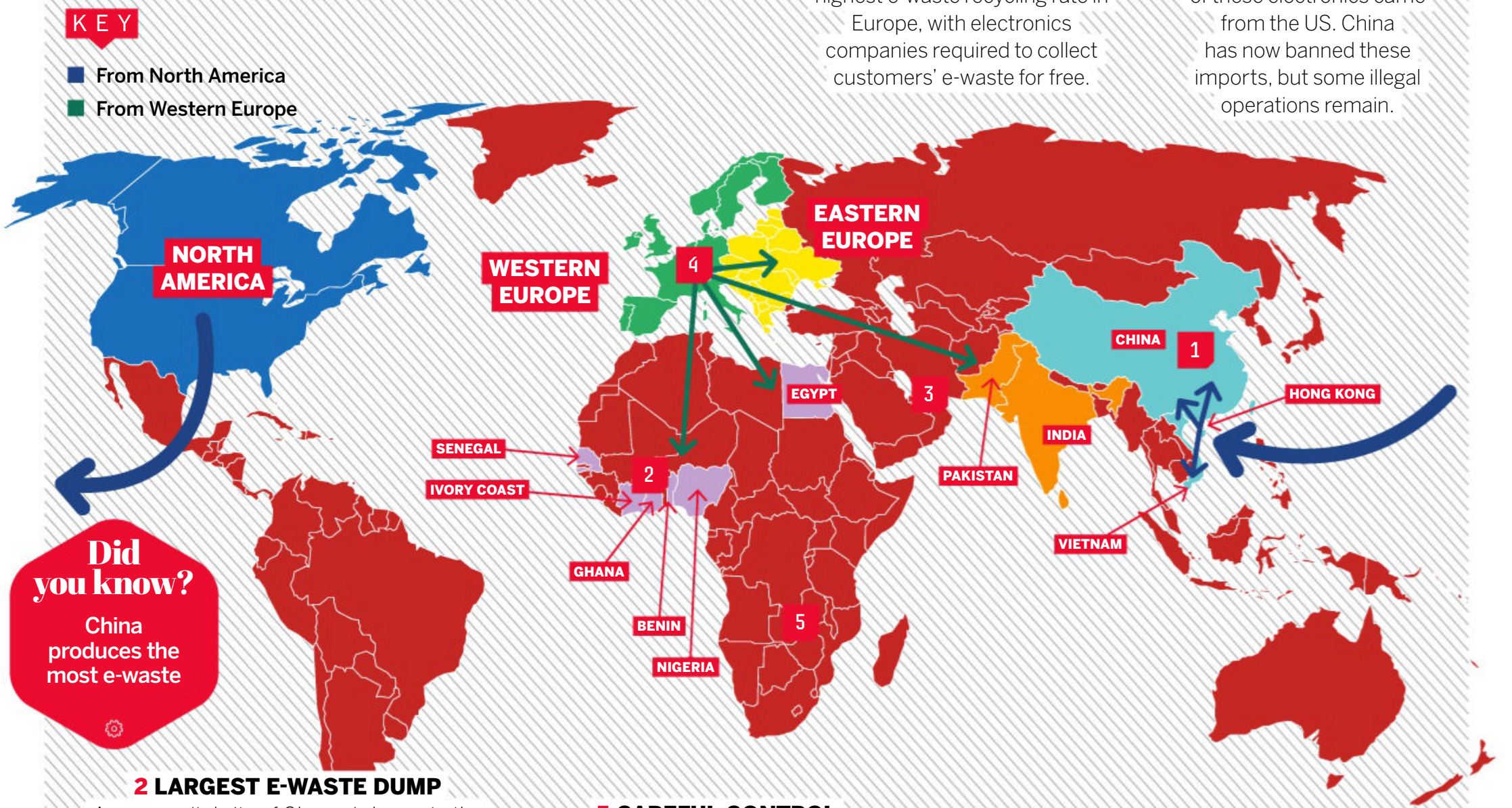
The countries that produce and process the most e-waste

4 HIGHEST ACTIVITY

Europe has the highest e-waste generation rate per person, but also the highest collection and processing rate. Croatia has the highest e-waste recycling rate in Europe, with electronics companies required to collect customers' e-waste for free.

1 CHINA E-WASTE BAN

China used to receive huge imports of e-waste to process from other countries. A high percentage of these electronics came from the US. China has now banned these imports, but some illegal operations remain.



2 LARGEST E-WASTE DUMP

Accra, capital city of Ghana, is home to the world's largest e-waste dump, where ships have sailed to import e-waste since 2000. This site is called Agbogbloshie, and the soil, water and air around it are gravely contaminated by toxins. Workers here burn the plastic sheaths on electric wires to recover and sell the metals inside.

5 CAREFUL CONTROL

Electronic items entering Zambia must meet strict safety standards. Careful tracking of these items helps the government predict e-waste statistics and better monitor environmental impact.

3 LARGEST RECYCLING PLANT

At 26,000 square metres, the Dubai Industrial Park e-waste recycling plant operates using the most advanced recycling technology. It can process 100,000 tonnes of e-waste per year.

HOW CAN YOU REDUCE YOUR E-WASTE?

If you want to minimise how much e-waste you produce personally, the most effective way would be to stop using electronic devices completely. However, today that might not seem like a practical solution. There are ways you can reduce your e-waste without giving up electronic devices. Firstly, not all new electronics are practical. Before buying, you should consider whether your purchase is actually necessary. It may be that you can combine more than one function into one device.

If you do buy a new electronic device, taking care of it will reduce your electronic turnover rate. Handle your phone and other electronics carefully and buy protective accessories such as a phone case to limit damage to your device during an accident. Keep an eye on the battery life of your electronics. This means not charging them all night so that they become overcharged and not letting the battery drain regularly.

Finally, when you no longer need an appliance or device, or it stops working, think about the next action you take. If it is broken, it might be cheaper and easier just to get it fixed before you look for an e-waste recycling bin or facility. If it still works, consider donating it to a social program so that a device's life is maximised by those who most need it.

Donating your electronics is a much less wasteful way of disposing of useful devices

HOW DOES A COMPASS WORK?

The compass has revolutionised how we find our way, making it possible to reach a destination when other means of navigation aren't possible

WORDS **MARK SMITH**

The compass has revolutionised exploration and navigation

From great explorers sailing the seas to hikers trying to find their way home after a trek through their local hills, it's impossible to overstate just how revolutionary the humble compass has been for navigation. A compass is simply a device that indicates direction, and the earliest ones harnessed the power of one of the most powerful forces in nature: magnetism.

The original compass design used a magnetised needle that rotated until it lined up with Earth's magnetic field, with the ends pointing north and south. The part that pointed north would be coloured or marked in some way so whoever was using it didn't get confused.

The first compass designs just consisted of one of these magnetised needles attached to cork or wood, which was then floated in a bowl of water. When the needle settled, the marked end would point north and other directions could be worked out from there. Being able to use a compass revolutionised map reading, making it possible to follow a map's directions when other means of navigation such as the Sun, stars or landmarks were not visible.

A digital compass works in a similar way to a traditional one. Because there's no shaky needle, they're the preferred option of serious hikers and the military. Instead of using magnetic pulses to find the right direction, which themselves can be unreliable, a digital compass finds direction by using the north pole as a guide. To help, it usually has some kind of global positioning system (GPS) features built in. GPS uses a network of satellites to pinpoint the user's location.

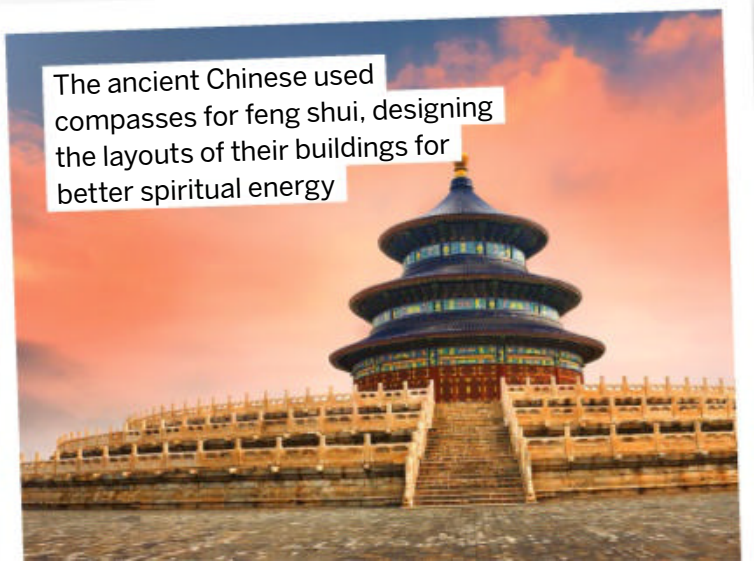
They're found in smartphones, tablets and the built-in navigation systems of many modern vehicles. Despite these types of advancements, the humble compass is still widely used. Aircraft and ships still use them and they're a handy backup to the more sophisticated devices used by many adventurers today.

Did you know?

The magnetic north pole shifts position by about 40 miles a year

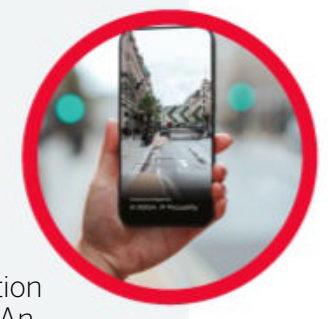
WHO INVENTED THE COMPASS?

Mystery still surrounds exactly when the compass was invented, but there are a few clues. The ancient Greeks understood the concept of magnetism around 2,000 years ago. But many historians think it was actually the Chinese who were the first to develop a practical working compass that could be harnessed for navigation. Chinese scientists may have developed navigational compasses as early as the 11th or 12th century. Western Europeans then followed in their footsteps at the end of the 12th century. But by the 15th century, scientists realised something strange was afoot – the 'north' indicated by a compass wasn't the same as Earth's true geographic north. This discrepancy is called 'variation' or 'magnetic declination', and varies depending on where you are in the world, with the problem being greater the closer you get to Earth's poles. Once they realised the problem, navigators had to start adjusting their compass readings to account for this variation, otherwise they could end up miles off course.


The ancient Chinese used compasses for feng shui, designing the layouts of their buildings for better spiritual energy

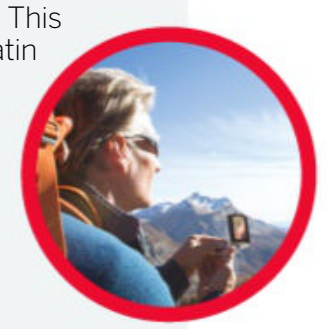
TYPES OF COMPASS

1 SMARTPHONE COMPASS
A smartphone contains a sensor called a magnetometer that's used to measure the strength and direction of magnetic fields. An app on your phone can harness it for use as a compass.



2 MARINE COMPASS
Compasses on ships are often mounted on stands in a binnacle, a type of protective housing. This derives from the Latin word habitaculum, meaning 'little dwelling place'.

3 SOLAR COMPASS
A solar compass uses the Sun to navigate, with the angle of the Sun indicating direction.



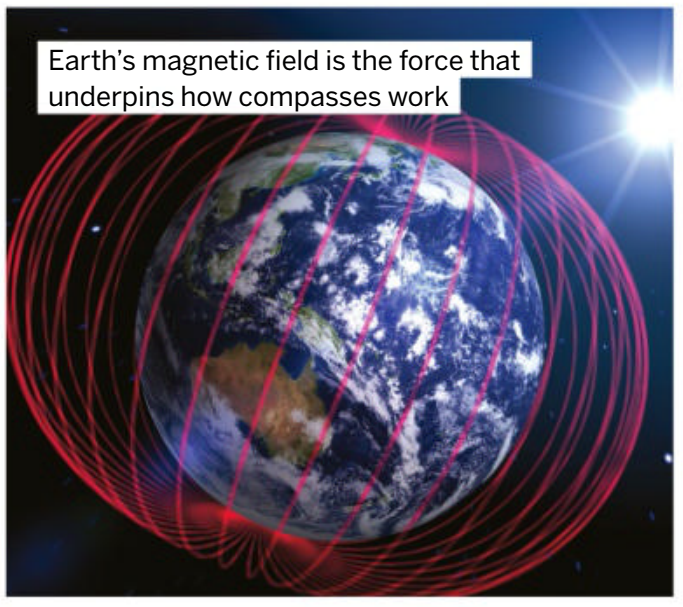
4 GYROCOMPASS
Invented in the early 20th century, this uses a spinning gyroscope to follow Earth's axis of rotation to point to true north.

DID YOU KNOW? Many birds have an innate compass in their brain and can follow Earth's magnetic field when they fly

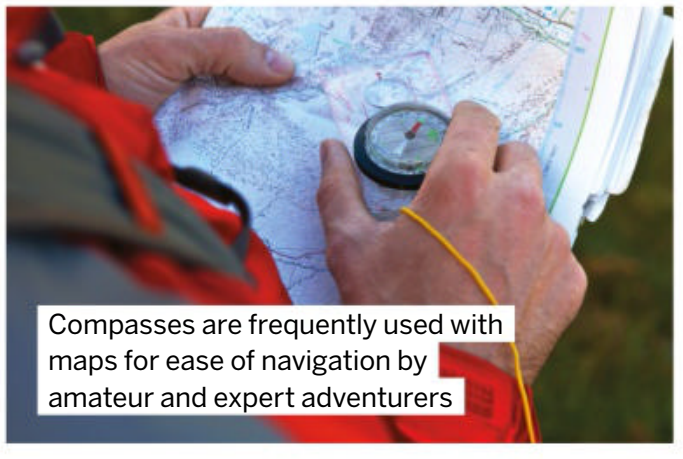
SURVIVAL SITUATION

If you ever find yourself stranded in the wilderness without your smartphone, fear not – you can make your own compass to help navigate to safety. First you're going to need a compass needle. For this you can use something made from iron or steel such as a paper clip or safety pin. Magnetise it by tapping it on a steel or iron object at least 50 times. Failing that, you can just rub it against your hair, silk or animal fur. Find north by using the stars, the Sun or a landmark and mark the piece of your needle that points north. Then you need to put it on something that will float, like a leaf. Place the leaf in water and the needle will now point north.

Placing a magnetised pin on a leaf in water can give you a rudimentary compass



Earth's magnetic field is the force that underpins how compasses work



Compasses are frequently used with maps for ease of navigation by amateur and expert adventurers

INSIDE A MARINE COMPASS

The nautical compass must see off a number of challenges, meaning it must be built for the elements

COMPASS DOME
The clear polymer dome protects the inner workings of the compass, magnifying it to make it easier to read.

NIGHT-LIGHTING SYSTEMS
Secure LED lights allow the compass to be seen easily at night.

GIMBAL SYSTEM
Boats move around a lot in stormy weather, so the gimbal system is required to keep the compass stable while the vessel pitches and rolls.

FLUID BAFFLE AND ROLLER DIAPHRAGM
This lets fluid expand and contract inside the compass with changes to temperature and pressure without forming bubbles, which could give a false reading

CORRECTOR MAGNETS
These magnets help compensate for 'deviation', which is when local magnetic fields interfere with the readings for true north.

COMPASS BOWLS AND HOUSINGS
This is designed to provide protection and support to the internal compass components. It's usually made from brass or high-strength-glass reinforced polymers.

HOW HOLOGRAMS ARE PRINTED

Credit cards, bank notes and more: the many uses for applying 3D images to a 2D surface

WORDS **SCOTT DUTFIELD**

Printed holograms are created through a photographic principle called holography, whereby the contours of a three-dimensional object are captured in a two-dimensional image. The history of holograms dates back to 1948, when Hungarian-British engineer Dennis Gabor first conceptualised what's now referred to as holography. Using an electron microscope and interacting waves of light, Gabor captured the point where the phase of two light waves aligned, creating the illusion of depth in an image.

But the invention of the laser in the 1960s allowed scientists to really explore the possibilities of making holograms. In 1962, Russian scientist Yuri Denisyuk introduced single-beam reflection holography, also known as Denisyuk holography. Denisyuk used laser beams – a more focused form of light than other light sources – and mirrors to bounce light over an object and capture how it interacted with the object on a photographic plate. The resulting holographic image showed how light was reflected off the object from all different angles and in different colours. These printed holograms aren't a mere optical illusion; they have many practical uses. For example, banknotes around the world include a holographic image as an anti-counterfeit measure.

Did you know?

Dennis Gabor won the Nobel Prize In Physics in 1971

Holograms have evolved further since laser-printed images, and the technology has become even more sophisticated. One of the most realistic 'holograms' has been created by a company called Light Field Lab. Using its technology, called 'SolidLight', Light Field Lab has demonstrated the real-world applications of holograms.

The SolidLight system sends light through a series of layers in a polymer that makes up a modular panel called a Phaseguide. This focuses the light into a point in mid-air in the form of a holographic image or SolidLight object. These objects appear off-screen and in open space, as though you're looking at them with augmented-reality glasses.

DIGITAL MODELS INTO HOLOGRAMS

A company called Voxon Photonics has created a holographic projector that creates holograms from digital models. Much like a 3D printer, a Voxon display slices up the information about the appearance of an object or design and divides it into hundreds of layers. Each one of those layers is then projected onto a screen that's moving forwards and backwards at high speed. Each layer is stacked on top of the other until the hologram is complete. Voxon's displays can project over half a billion points of light every second into a physical space.

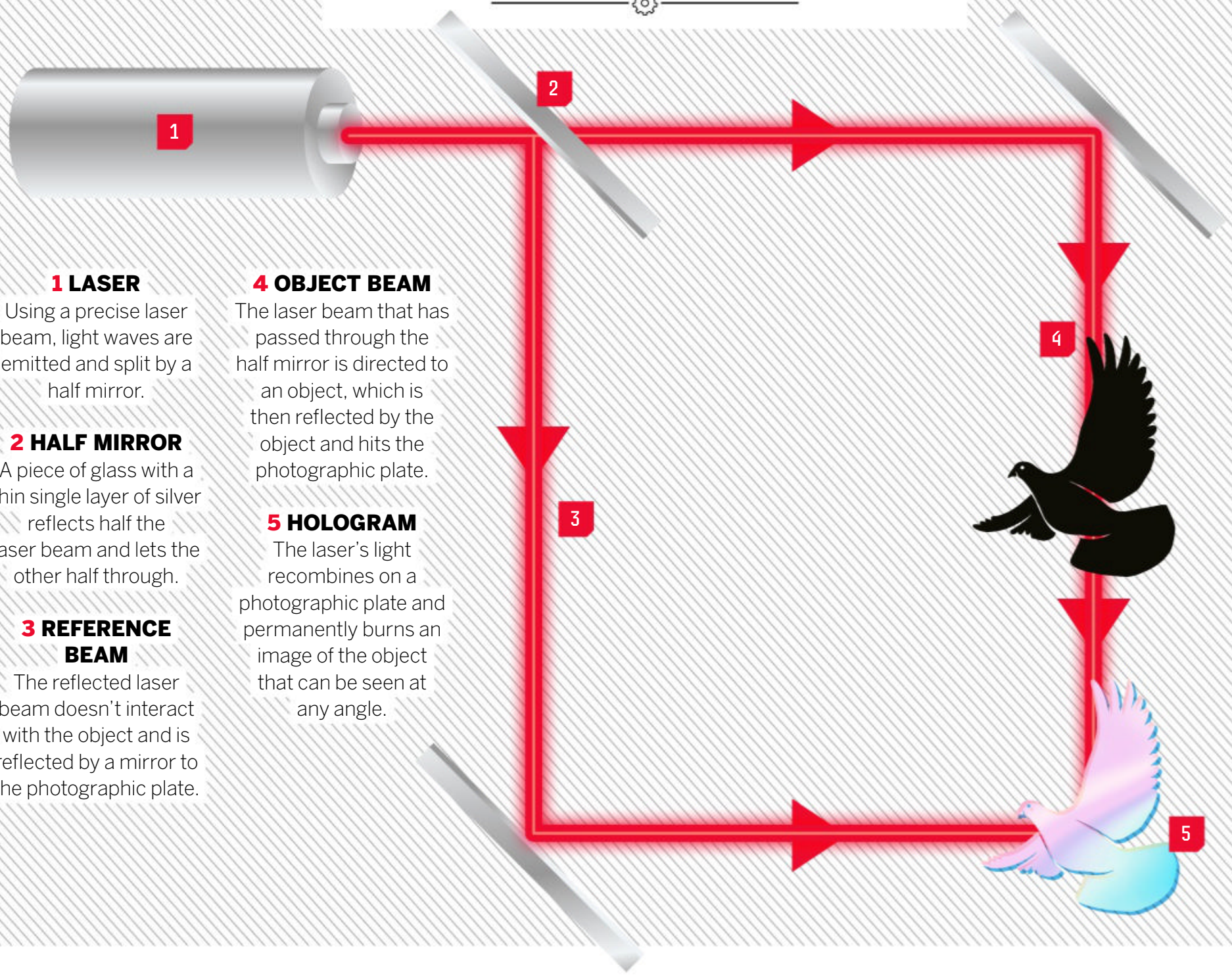
When you look at a Voxon display, you aren't able to see the individual layers and the fast-moving screen thanks to an optical illusion called persistence of vision. This illusion occurs when you look at an object and quickly move your head; you can temporarily see the object before it fades from view. When looking at the Voxon display, your brain experiences this optical illusion and blends the layers to form the final hologram.

An example of a Voxon Photonics layered created from a 3D digital model

DID YOU KNOW? Holograms have appeared on banknotes for over 30 years across 97 currencies

PRINTING HOLOGRAMS

How the first laser holograms were created



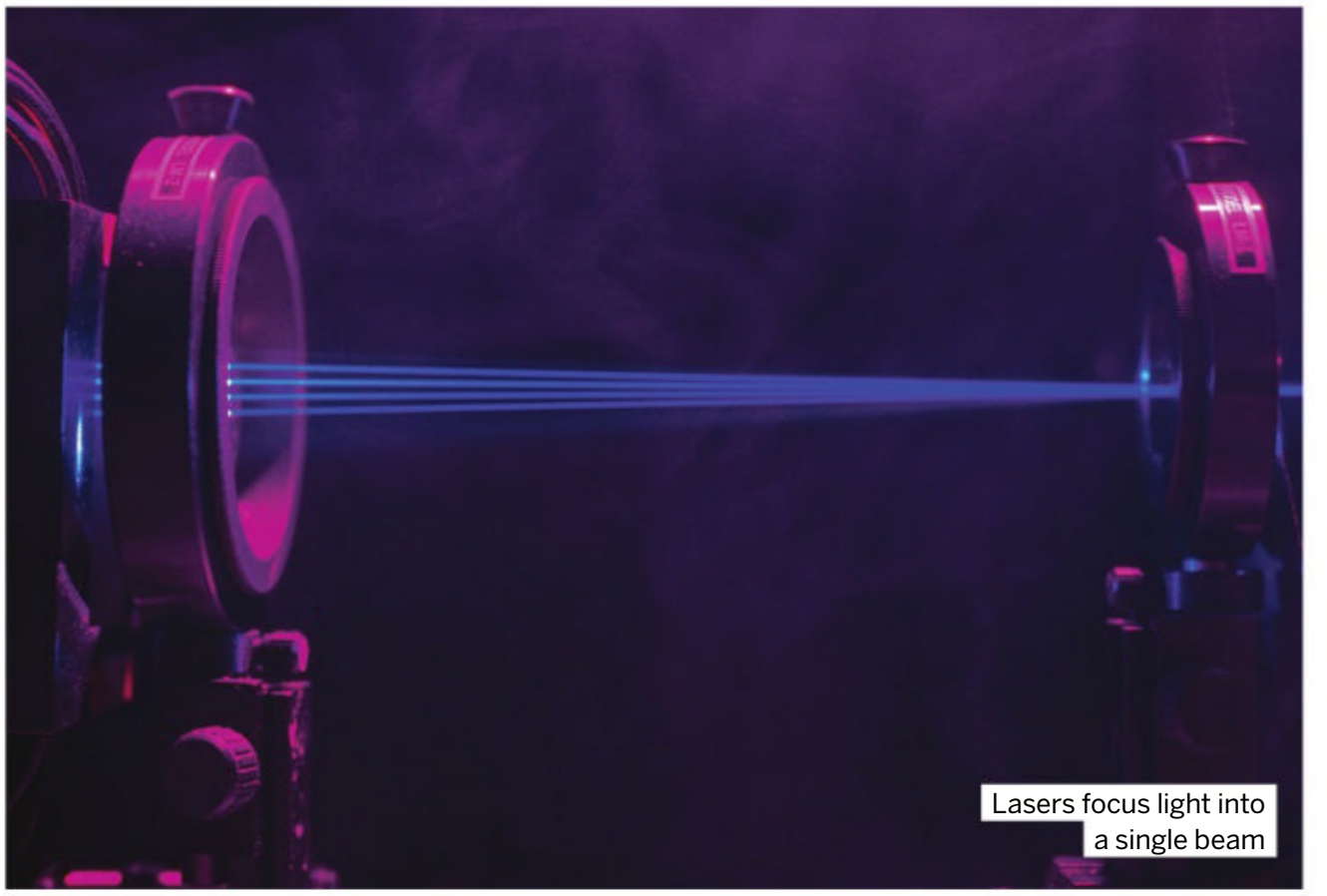
1 LASER
Using a precise laser beam, light waves are emitted and split by a half mirror.

2 HALF MIRROR
A piece of glass with a thin single layer of silver reflects half the laser beam and lets the other half through.

3 REFERENCE BEAM
The reflected laser beam doesn't interact with the object and is reflected by a mirror to the photographic plate.

4 OBJECT BEAM
The laser beam that has passed through the half mirror is directed to an object, which is then reflected by the object and hits the photographic plate.

5 HOLOGRAM
The laser's light recombines on a photographic plate and permanently burns an image of the object that can be seen at any angle.



Lasers focus light into a single beam

KRAMPUS

YOU'D BETTER WATCH OUT

WORDS CALLUM MCKELVIE

Scared? You should be! We delve into the mysterious origins of one of the strangest characters of Christmas folklore

You try to run, but your little legs won't quite go as fast as you need them to. Tears stain your cheeks as you desperately look for your parents. All around you the flames dance as sinister horned shapes run between them. You tried so hard to be good this year, you really did. You did all your homework, ate all your greens and even helped with the chores. None of that matters now, though. You had hoped for a gift from Saint Nicholas this Christmas, but now you're being hunted... hunted by Krampus, for this is his night.

The Krampus Runs of the Alpine regions of Europe have become legendary – a popular alternative Christmas attraction for tourists with an interest in a more satanic side to Santa. Taking place several weeks before Christmas Day, parents take their children to a parade that sees kindly Saint Nick accompanied by an altogether more demonic creature. If you've been good, Saint Nicholas might reward you with a gift – but if you've been naughty, Krampus will track you down. Once a subject of obscure folklore, Krampus has become a modern phenomenon, having made the transition from Europe to the United States. He was the subject of the 2015 movie *Krampus*, ten direct-to-DVD films and has appeared in episodes of TV shows such as *Supernatural* and *Inside No. 9*. Yet this transition has sidelined him mostly as a cult figure, a modern horror icon with comic books and action figures. Of Krampus' folkloric

Below: At Christmas, the Krampus Runs see people dressing up as the twisted figure

DID YOU KNOW? Saint Nicholas and Krampus are said to visit children together on the night of 5 December

This creepy illustration shows a family visited by Saint Nicholas as Krampus sneaks in to spoil the festive fun

origins, only vague hints and whispers remain. Yet in Europe, Krampus is alive and well, still haunting the nightmares of naughty children who fear Krampusnacht, the Night of the Krampus, most of all.

But just who or what is Krampus? In contemporary American tellings he's presented as something of an anti-Santa, but traditionally he's one of a band of 'helpers' who work alongside the saint. In this instance he's very much the yin to Santa's yang. Whereas Saint Nicholas brings gifts and goodies for the children who've spent the year obeying their parents, Krampus brings beatings... or possibly something even worse, with some early stories describing how he would drag naughty children straight to hell. Monte Beauchamp, who helped bring the character into the American public consciousness when he published a book of Krampus postcards in the early 1990s, explained in a 2012 interview that: "He is Saint Nikolaus' companion. In America, Santa Claus has elves, whereas in Europe, Saint Nikolaus – from which Santa was derived – has Krampus. Saint Nikolaus would bring treats and small gifts for the children who'd been good all year, and those that had behaved badly were visited by Krampus."

"The Krampus Runs of the Alpine regions of Europe have become legendary – a popular alternative Christmas attraction for tourists"

Indeed, the figure is part of a long European tradition in which Saint Nicholas and his numerous 'helpers' appear at festivals and parades. The majority of these occur on 6 December, known as the Feast of Saint Nicholas, the 4th-century bishop of Myra and the original 'Santa Claus'. The patron saint of children, these events quickly became focused on fun and frivolity, with men dressing up as Saint Nicholas and his many helpers, including Krampus. In Munich, this event is thought to have begun in the 16th century when schoolmasters, choir masters and teachers would dress up as the beast and cause well-meaning chaos. At the same time, there are stories of boys in a Jesuit school receiving a visitor dressed as Saint Nicholas who would distribute treats, possibly the origin of our modern-day 'store Santas'.

However, whereas we have a very clear genesis for the kindly Saint Nicholas, the origins of Krampus, somewhat befitting of a mythical figure, remain shrouded in mystery. As a result, folklorists remain unable to agree on any exact starting point for the creature. Numerous sources suggest that he may have pre-Christian origins, noting the similarity between the appearance of Krampus and the Horned God of some pagan religions, later used as a deity in some forms of Wicca. However, this seems to have very little grounding in fact. As proposed by classicist Spencer Alexander McDaniel, it's more than likely that this idea originated with Maurice Bruce in his 1958 article entitled *Krampus in Styria* and tied to Margaret Murray's now-outdated theories regarding pre-Christian witchcraft. In 1921 Murray published *The Witch Cult in Western Europe*, in which she hypothesised that witches belonged to a goddess-worshipping fertility cult that was active throughout much of the Middle Ages and operated secretly in Christian Europe. This theory took off and became popular in the public consciousness. But writing in *The Witchcraft Reader*, Jacqueline Simpson stated: "Among scholars, her reputation is deservedly low; her theory that witches were members of a huge secret society preserving a prehistoric fertility cult through the centuries is now seen

MARI LWYD

It's not just continental Europe that's visited by supernatural apparitions on the eve of Christmas, as in the United Kingdom we too have our fair share of peculiar creatures who walk the streets. In Wales, one of the strangest traditions involves a skeletal horse puppet called Mari Lwyd, who travels from house to house challenging individuals to a rhyming battle.

Mari is usually represented as having lights or baubles for eyes, a mane of colourful streamers and a white cloak falling from her skull. The spooky horse parades around the village before venturing to the local public house. What figures march alongside Mari vary. Illustrations from the 1800s depict individuals in their best clothes, and the photo here from the Edwardian era shows a man in top hat and smart attire. Some versions feature her accompanied by a Punch and Judy who, similar to some Morris dancers, have been known to wear blackened faces.

The origins of Mari are shrouded in mystery. Like her devilish Austrian counterpart Krampus, many believe her to be of pagan origin, but some scholars think that there may be a link to the Nativity. An obscure story related to the birth of Christ involves a horse being sent out of the stable so that Mary would be able to give birth to Jesus. The horse then wandered the land looking for somewhere to have her foal.

At Christmas the streets of Wales are haunted by a ghostly, skeletal horse

DID YOU KNOW? The name derives from the German word Krampen, meaning 'claw'

A 1935 photograph showing Saint Nicholas and several Krampuses in Matrei in Osttirol, Tyrol

to be based on deeply flawed methods and illogical arguments."

In his article, Bruce similarly makes jumps of logic, assuming that the birch rods carried by Krampus, as shown in many of the illustrations, "may have a connection with the initiation rites of certain witch covens". More likely, the rods were featured in illustrations as an indication of the beatings that Krampus was said to deliver to the naughty children he took to his lair. However, the pagan concept of Ruten – a brandished bunch of birch sticks – has more recently been cited as a possibly symbolic origin.

While Krampus' origins may be a mystery, he's just one of a long line of other similar and sinister figures who haunt the night of Saint Nicholas, depending on where in the world you might be. Other examples include France's Père Fouettard, translating as 'the Whipping Father'. Fouettard's origin story, which dates back to 1150, is particularly gruesome. Supposedly a butcher, Fouettard is said to have captured three young boys on their way to a religious boarding school. Robbing them of their money, he proceeded to cut their throats and, obviously being familiar with the old adage 'waste not want not', salted the meat ready for that night's dinner. However, Saint Nicholas appeared at his door, which perhaps led to Fouettard being an innkeeper in some variations of the story. Seeking to appease his guest, Fouettard offered him a cut of his best meat. However, perhaps spying a stray piece of homework among his prime cut, Saint Nicholas became suspicious. Ruining dinner, he resurrected the boys, returning them to their parents. As punishment, Fouettard became 'Father Whipper'. Now he serves much the same function as Krampus, delivering punishment to naughty children.

Perhaps the most controversial of all these figures is the Netherlands' Zwarte Piet, or 'Black Pete'. Supposedly of Moorish descent, he would arrive by boat every year with Sinterklaas, the Dutch Santa, and kidnap bad children, taking them back to Spain. Now the figure remains controversial due to festivals that involve adults wearing blackface, and numerous protests have been held to oppose them.

However, it's Krampus who endures the most. This is due no doubt to the Krampuslauf, translating literally as the 'Krampus Run', the event that's held on the Feast of Saint Nicholas, which continues to this day. The traditions within the runs vary from county to county and from town to town, but the core remains the same. Adults dress up in Krampus costumes, usually consisting of full–body suits and elaborate masks, and cause chaos. In recent years the runs have attracted much attention due to the large amount of alcohol involved, which has caused some of the Krampuses to get a little too enthusiastic.

But for any attendee not wishing to get too physically involved, there's still much to enjoy.

The elaborate masks – referred to as 'Larven', coming from the Latin 'larva' and simultaneously meaning both 'mask' and 'ghost' – attract a lot of attention and are prized by their owners. Compared to those worn today, the earliest known examples were incredibly simplistic, sometimes consisting of a face covering made of cloth or a simple carved mask. Now the masks are intricately hand-carved by 'Larvenschnitzers' – mask carvers who usually prefer traditional methods over modern tools.

While there's a smattering of earlier examples, the craft as it exists today truly began in the 1930s when an unemployed sculptor, Sepp Lang, first turned his hand to carving a Krampus mask, and it's to him that much of the contemporary style of masks is attributed. Lang reinterpreted the creature and took little inspiration from the designs featured on postcards or in books, instead crafting beautiful works with large and ornate horns and oversized gaping jaws. Sometimes Lang's creations weren't even designed to be worn, but were crafted for an ever-growing tourist market, which kept him in a steady income. Now, Krampus mask makers create more and more elaborate designs and costumes, and a lucrative collectors' market has emerged for masks carved in the traditional style, with some professional carvers making around 100 masks a year.

Yet despite having an eager collectors' market and thriving tourist industry built around the runs, Krampus doesn't have a monopoly on them. Tyrol and Salzburg in Austria

Krampus meets his match – this baby isn't the least bit scared of the evil ghoul

Krampus on the loose in Austria during a typically anarchic Krampus Run

KRAMPUS ON THE COAST

Since Krampus' recent rise in popularity, numerous Krampus Runs have begun to take place in towns and cities where the mysterious creature was hitherto unknown. One of the most surprising of these is a run that takes place in the town of Whitby in the north of England. Beginning in 2015, the event bases itself on the traditional Austrian and European runs and usually takes place around 7 December. The free event has previously taken over the east side of Whitby, turning this area into 'Krampus Town'. The event has also sought to weave in local folklore alongside the European figure, with some costumes using articles found on the beach. Usually run as a fundraiser for numerous local charities, the event has seen a steady rise in popularity since its beginnings.

A traditional Larvenschnitzer working on a Krampus mask

"We have a clear genesis for Saint Nicholas, but the origins of Krampus, somewhat befitting of a mythical figure, remain shrouded in mystery"

also have another tradition involving devils and demons that occurs around the winter solstice. This too is believed to have pre-Christian pagan origins, although the connection is slightly more believable. This festival centres around the goddess Frau Perchta, a half-goat, half-woman goddess who represents the duality between good and evil. In the winter months she is said to hike across the mountains with a gang of evil spirits, visiting towns as she goes. These 'Perchten' runs are designed to chase out evil spirits and banish them and feature both ugly and beautiful Perchten, representing the dual nature of the goddess. The beautiful Perchten are represented by men carrying large figures on their shoulders, which can be as tall as two metres. These figures bow at the spectators and dance, but the ugly Perchten are altogether more terrifying and, like Krampus, get up to all sorts of mischief. Some of these costumes were originally made from sheep's pelts, whereas today's versions are intricately woven from corn leaves from northern Italy.

These costumes are topped with a traditional hand–carved mask that can weigh around 30 kilograms. The suit is then ordained with bells, chains and drums, and all together the costumes can weigh up to 100 kilograms.

Krampus has also shown his versatility in adapting to new mediums, regularly being reinterpreted and revitalising interest in the creature. One such example occurred with the birth of mass-print media and the rise of the Christmas card across Europe.

In the so-called 'Golden Age of Postcards', which began in the late 1890s, Krampus was a regular fixture on many designs. With the earliest known example appearing in 1893, the creature soon cemented his place in European Christmas mythology and was regularly depicted alongside Saint Nicholas or alone. Some of the most striking examples utilised a process called chromolithography and were made by the famous Wiener Werkstätte, which was founded in 1903 by architect Josef Hoffmann, graphic designer and painter Koloman Moser and patron Fritz Waerndorfer. Wiener Werkstätte's striking designs created a stunning 'Art Nouveau' Krampus.

Many of the main postcard publishing houses were destroyed along with their work during the World Wars, and as such, any surviving cards are now highly prized by collectors. One such enthusiast, Monte Beauchamp, brought them back into the public consciousness when he published *Krampus: The Devil Of Christmas* in 2010, depicting some of the best examples of pre-World War I Krampus postcards.

Of course, as might be expected of a demonic figure, Krampus has many enemies. Chief among them is the Catholic Church. Numerous sources state that during the time of the Spanish Inquisition the Church banned dressing up as a devilish figure, bringing a halt to the Krampus Runs. The figure's supposed pagan origins doubtless came into question as well, along with the chains that he is often pictured carrying, which were believed by some to indicate the bonds of the devil.

Centuries later during World War II, Krampus found himself with a new enemy: the Nazis. For

DID YOU KNOW? Krampus is a half-goat, half-demon monster

reasons that are somewhat hard to pinpoint, Krampus and his various traditions were considered to be the creation of the fascists' enemies, most explicitly the Social Democrats. The implication appears to be that he was designed to demoralise the German population, and the result was that Krampus in any form was banned. The runs were halted and depicting him on postcards or in costumes was strictly forbidden. For a party that was obsessed with Teutonic ritual and Germanic tradition, the Nazis were rather picky when it came to Christmas.

Today, Krampus' lair isn't in the depths of the Earth – it's in movies, books and comics. In 2015, Universal Pictures released *Krampus*, directed by Michael Dougherty. He may have seemed the perfect choice after directing the ultimate Halloween film *Trick 'r Treat* in 2007, which drew somewhat on that holiday's folklore and customs, but unfortunately the same approach was not brought to Krampus. While still an entertaining horror comedy with shades of *Gremlins*, the film faltered when it came to the folkloric origins of Krampus. To begin with, the film's creature looks little like the Krampus of legend, instead acting more like Santa Claus' evil twin brother, squeezing down chimneys, having elvish helpers and so on.

Indeed, Al Ridenour, author of *The Krampus and the Old, Dark Christmas: Roots and Rebirth of the Folkloric Devil* states that the film visualises Krampus as "an oversized hunchbacked being in a red fur-trimmed robe, white bearded and with a ghoulish but human face resembling a rather exhausted Santa Claus". Perhaps most distressingly, the film paints Krampus as a creature of Germanic origin, and while Ridenour is keen to remind us that he does have provenance there, this is confined to the south – Krampus' real home is in Austria and Bavaria. And the less is said about straight-to-DVD efforts such as *Krampus: The Reckoning* the better.

As Krampus becomes more and more popularised, the hope of more scholarly research into his origins is increasingly likely. For a creature whose folkloric tradition casts a large shadow over Austria and Europe's Yuletide celebrations, it seems bizarre that there is still so much that remains a mystery about him. Yet, of course, the obvious answer is maybe that's just the way Krampus likes it – after all, the unknown is always much more terrifying. So as you're putting away your copy of **How It Works** or perhaps flicking through to the next article, just ask yourself – have you been nice or naughty this year?

KRAMPUS CARDS

Five Krampus postcards that were produced at the turn of the century

A particularly terrifying example from Vienna's Wiener Werkstätte showing a giant Krampus

A 1911 card showing Saint Nicholas holding Krampus, who grins evilly

A 1915 Krampus postcard with a propaganda angle. It states: I'll get all the Serbs right away

This postcard from 1911 shows Krampus with an elongated tongue, which he uses to ensnare his victims

In this 1908 example, the depiction of Krampus is very close to traditional imagery of the Christian devil

ALFRED RUSSEL WALLACE

How this Welsh naturalist helped Charles Darwin formulate his theory of evolution

WORDS **AILSA HARVEY**

Two centuries ago, the codiscoverer of the theory of evolution was born. Alfred Russel Wallace was not just a naturalist, but a keen explorer, geographer and anthropologist. One of Wallace's first jobs involved mapping the lands of Bedfordshire and Wales. As a surveyor, Wallace had to make accurate measurements of farmland so that landowners could be taxed to fund their local churches. Wallace wrote essays about the social and economic struggles of working-class farmers during his time surveying, but his true interests lay elsewhere. He loved to study the natural world in his free time.

His first trip to study natural specimens took place in 1848, when he travelled to Brazil to search for valuable biological items. Over the following years, Wallace's expeditions led him to multiple areas of the Amazon basin. As a self-employed naturalist, Wallace was free to follow his own interests. He made observations about the languages and cultures of people he encountered, as well as biological analyses of the butterflies, birds, insects and plants in each area he visited.

After visiting Brazil, he travelled to the island of Sulawesi in Indonesia. Some of the animal species that were isolated there had never migrated to any other area on Earth. In Sulawesi, Wallace studied the traits of one particular bird, the maleo, finding that its behaviour and characteristics were matched closely to the environment of the island. For example, the birds had learned how to use the geothermal hot springs of the island to keep their unhatched eggs warm. To do so they had adapted to dig into the ground and learned over time how to find locations where temperatures were ideal for incubating their young.

Another important observation made by Wallace, which was key in piecing together the theory of evolution, was observing similar species and making links between them. After observing the maleo, Wallace studied related species in nearby Australia. However, he

Above: Wallace illustrated many of the species he observed

Right inset: Only some of Wallace's notes and sketches survived when his ship sank after leaving South America

5 THINGS TO KNOW ABOUT ALFRED RUSSEL WALLACE

1 FAMILY BUSINESS
Wallace took over his brother William's business as a surveyor in 1845 after William died.

2 SOCIAL ACTIVIST
Wallace fought for women's right to vote.

3 NEW FINDS
Of the 125,000 specimens that Wallace collected in his life, 5,000 were the first to be documented.

4 SHARED THEORY
Wallace looked up to Darwin and had previously read much of his work.

5 AUTHOR
Throughout his scientific studies, Wallace published 20 books about varying subjects.

Did you know?

Wallace is related to Scotland's William Wallace

The BIG idea

Wallace was friends with Darwin, dedicating his book *The Malay Archipelago* to him

WALLACE AND DARWIN

Although Charles Darwin received almost full credit for his theory of evolution, it was also the work of Alfred Wallace. Wallace was studying the specimens of Southeast Asia and writing his observations at the same time Darwin was composing his famous theory. Many of the specimens that Wallace found were sent to Darwin to help him, as Wallace was aware that they were conducting similar research. In addition, Wallace informed Darwin of his own findings that species evolve by developing beneficial adaptations. He noted that these mutations allowed the species to survive and altered their traits in successive generations. This discovery was very similar to the conclusion Darwin was coming to himself. As Darwin compiled and published his findings first, Wallace received minimal credit for his contributions.

DID YOU KNOW? Wallace was one of the first scientists to write about the harmful impact humans have on the planet

couldn't find any related species in Borneo or Asia. In his research, he drew a line between Borneo and Indonesia to separate the differing biological regions of Asia and Australia. Named after the scientist, this line is called the 'Wallace Line' and marks the area where two continental shelves meet.

Through his documented discoveries, it's clear that Wallace was in tune with Earth and nature, but what he is less known for is his passion for otherworldly science. During the latter years of his life, Wallace wrote books about astronomy, including whether or not life could exist on other planets. One of his books, entitled *Is Mars Habitable?*, was published in 1907 and focuses on many of the issues scientists are still debating today.

A LIFE'S WORK

Expeditions, publications and awards

1823
On 8 January, Wallace was born in Llanbadoc, Wales.

1841
Wallace moved to Neath, conducting lectures at the Mechanic's Institute.

1844
He met naturalist Henry Walter Bates, the first person to observe mimicry in animals.

1847
Wallace published his notes on the insect *Trichius fasciatus*.

1848
Wallace and Bates travelled to the Amazon, undergoing four years of specimen collecting.

1854-1862
Wallace collected specimens from the Malay Archipelago, Indonesia.

1858
Wallace and Darwin's work on natural selection was first presented on 1 July.

1870
His essays in *Contributions to the Theory of Natural Selection* were published.

1881
Wallace was named the first president of the Land Nationalisation Society.

1908
Wallace was awarded the Darwin-Wallace Medal of the Linnean Society of London.

1913
On 7 November, Wallace died in Dorset, England.

Win!

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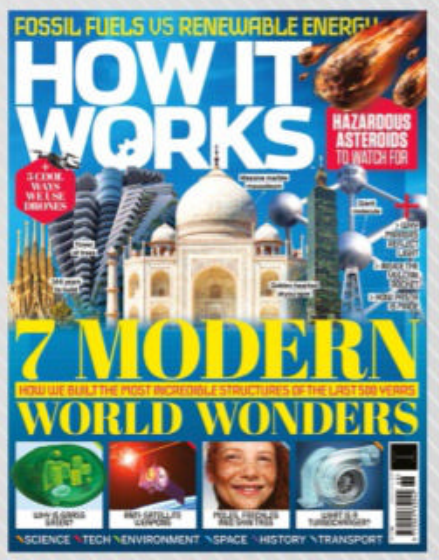

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OFFER EXPIRES **28 FEB 2023**

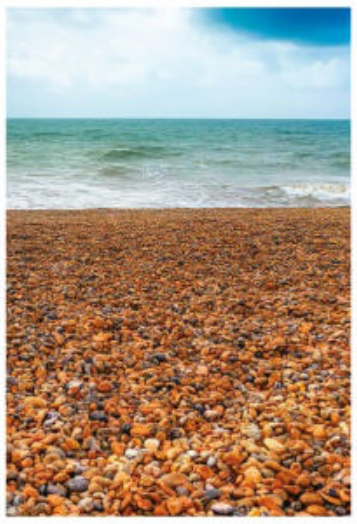
BRAINDUMP

Amazing answers to your curious questions

Which is hotter: the centre of the Earth or surface of the Sun?

Nick McDonald

The temperature at Earth's core and at the surface of the Sun are very similar. We can estimate the Sun's surface temperature by studying the colour of the surface, together with the continuous spectrum emitted by the Sun. When a piece of metal is heated it starts glowing red, then changes progressively to bluish-white as it gets hotter. Similarly, the colour of the Sun's surface is an indicator of temperature. Using this information, we can get a reasonable estimate for the surface temperature of around 5,778 Kelvin, or 5,505 degrees Celsius. The core of the Earth is mainly composed of an alloy of the metals iron and nickel under very high pressure. Scientists can examine the properties of materials such as iron under pressure in the laboratory. Using such methods, we can calculate that the temperature at the core is about 5,700 Kelvin, or 5,430 degrees Celsius.



WHY DO SOME BEACHES HAVE SAND, WHILE OTHERS HAVE PEBBLES?

Joe Saint

There are many factors that determine what kind of beach occurs on any part of the coast. The shape of the coastline, the local geology and the prevailing weather conditions are all significant factors. The size of particles that make up a beach are often a reflection of the energy of the waves that hit the shore. In low-energy environments such as shallow bays or estuaries, we often see very fine particles such as silt or mud deposited. Higher energy beaches are often characterised by larger particles, such as pebbles or even boulders. The famous pebble beaches along the south coast of England are often composed of flint derived from the chalk cliffs that are found locally. The chalk is dissolved in the seawater, leaving the flint behind. This, combined with the steeply sloping shoreline, creates pebbly beaches.

WHEN WAS THE FIRST FORMULA ONE CAR BUILT AND HOW FAST WAS IT?

David Merchant

Many cars were built to compete in the Formula One World Championship, but the first one to win it was the Alfa Romeo 158, also known as the Alfetta, meaning 'little Alfa' in Italian, in 1950. It was driven by Italian Giuseppe Farina during 1950, in which he won three races out of seven. One of the most successful racing cars ever produced, the 158 and its derivative, the 159, took 47 wins from 54 Grands Prix entered. In the hands of drivers such as Giuseppe Farina, Juan Manuel Fangio and Luigi Fagioli, it dominated the first two seasons of the Formula One World Championship. It was capable of driving at 180 miles per hour.

Did you know?
The 1946 Turin Grand Prix was the first F1 race

WHY WERE SOME SWORDS CONSTRUCTED WITH A CURVED BLADE?

Danielle Thorpe

Such swords, or sabres, were used to slash or cut an opponent rather than stab them. It might be argued that the curve of the blade enabled large sweeping attacks, especially from horseback, with contact with the target being maintained along the entire length of the blade. However, a more important consideration for swordsmiths and potential owners was probably the dashing appearance of such swords when most swords were strictly straight. They suggested a certain amount of panache and swagger.

What is nectar and why is it sweet?

John Furlong

Nectar is a sugar-rich liquid produced predominantly by flowers in purpose-built glands referred to as nectaries. It's a largely watery solution of the sugars sucrose, fructose and glucose, but it also consists of a wide variety of plant-specific proteins, salts, acids and essential oils. This variety stems from the nature of the plant species itself, as well as the soil and air conditions. Nectar is produced by a plant to attract insects, which both benefit from its life-sustaining contents and aid the pollination of the plant's species.

BRAINDUMP

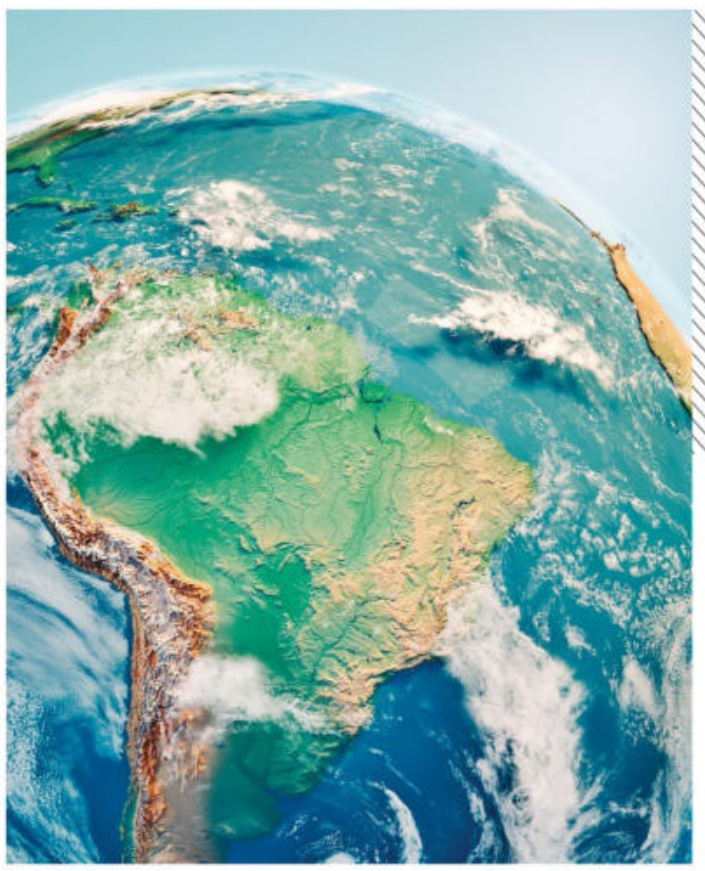
HOW DO WE KNOW LIONS AND MANY OTHER MAMMALS ARE COLOUR BLIND?

Sophie Newton

Mammals have special cells that respond to light that are arranged in a layer called the retina at the backs of their eyes. Two types of cell respond to light: rods detect light but not colour, whereas we have three kinds of cone cells that contain different pigments that respond to red, green and blue light. By stimulating differing combinations of these cones, we can see many different colours. Other animals, including rodents, may have more kinds of cones that detect other colours, including ultraviolet. We can find out which pigments mammals have in their eyes by the different wavelengths of light they absorb, or we can look at their DNA to see which genes are present, which are code for the different pigments. Many carnivores and ungulates have only two pigments, so we know they're colour blind.

Did you know?

The mantis shrimp sees the most colours



What stops Earth's water supply evaporating off the planet?

John Daley

Earth inhabits a special area called the 'Goldilocks' zone – not too cold, not too hot, but just right. This means the temperature at the surface of the planet is ideal for the existence of liquid water. When water does evaporate in hotter regions, it rises as vapour into the atmosphere. Earth retains its atmosphere due to the relationship between the thermal energy of the particles in the air, including water vapour, and the strength of its gravitational field. Essentially, water vapour molecules cannot travel at anywhere near the escape velocity required to enter space.

HOW DO WIDE-ANGLE LENSES GENERATE LARGE PANORAMAS?

Mohammed Al-Judah

The simplest type of camera is a pinhole camera, which has no lens. It's just a box with a piece of film at the back and a tiny hole at the front. The angle between the edges of the film and the pinhole determines the camera's angle of view. If the film is close to the pinhole, you get a wide-angle image. Modern cameras replace the pinhole with a lens and the film with a digital detector. Different lenses are distinguished by their focal length, equivalent to the distance between the film and pinhole. A wide-angle lens has a focal length less than half as long as a standard lens. A lens that images an angle of 180 degrees is called a fisheye lens, because this is what a fish sees if it looks up at the air from the bottom of its pond. Try it from the bottom of a swimming pool.

HOW DOES A SPIDER MAKE A WEB AND WHY DOESN'T IT GET STUCK IN ITS OWN CREATION?

@ladylightning

In making a web, the spider starts by drawing a thread of silk out of its spinneret. The strand trails down until it catches on vegetation. The spider pulls it in and attaches the other end. Like the spokes of a wheel, radial threads are attached from the centre to the surroundings. The spider then goes around the 'wheel' attaching silk to the radial lines until the web is complete. It doesn't cut threads with mandibles, but dissolves them using saliva and recycles excess silk by eating it. Some of the threads are coated in droplets of adhesive. It doesn't get caught in its own web because it avoids the sticky threads. It also has body oils and special hairs on the legs that prevent it from becoming stuck.

Finally, the chemical nature of the adhesive is such that by pulling very gently, a trapped leg will go through it. Only if it is pulled too quickly or jerkily does the adhesive harden to trap the body, just right for catching flying insects.

Was the *T. rex* the biggest dinosaur ever?

Toby Cameroon

At 13 metres long and weighing up to nine tonnes – heavier than one-and-a-half African elephants – *Tyrannosaurus rex* was one of the largest meat-eating dinosaurs to have lived. *Spinosaurus aegyptiacus* was even longer at up to 18 metres, and was possibly twice as heavy. However, the largest dinosaurs were herbivores, not carnivores. One of the largest dinosaurs we know about from fossils was the long-necked sauropod *Argentinosaurus huinculensis*, which could possibly grow up to 30 metres long and weighed over 90 tonnes, almost as much as 17 African elephants. Another sauropod dinosaur called *Amphicoelias altus* may have been larger, but the fossilised bones of this creature are lost. Working out the size of dinosaurs is very difficult because we very rarely find complete skeletons. Normally we only have a few bones available to estimate overall size and weight, so there may be many different estimates.

What are the giant stone heads on Easter Island?

Sean Stamp

The giant stone heads on Easter Island were probably built by Polynesians who arrived on the island from the Marquesas Islands between 300 and 1200 CE. The heads are not actually heads at all, but heads and torsos, with many of them buried by shifting sand and soil. The statues are called 'moai' and were carved by the populous between 1250 and 1500. They represent the living faces of deified ancestors, watching over the island and its people. There are 887 statues surviving on the island, a World Heritage Site due to cultural significance to an extinct culture. The statues' building and transportation around the island is considered by historians to be a remarkable feat, with some of the larger statues weighing up to 86 tonnes.

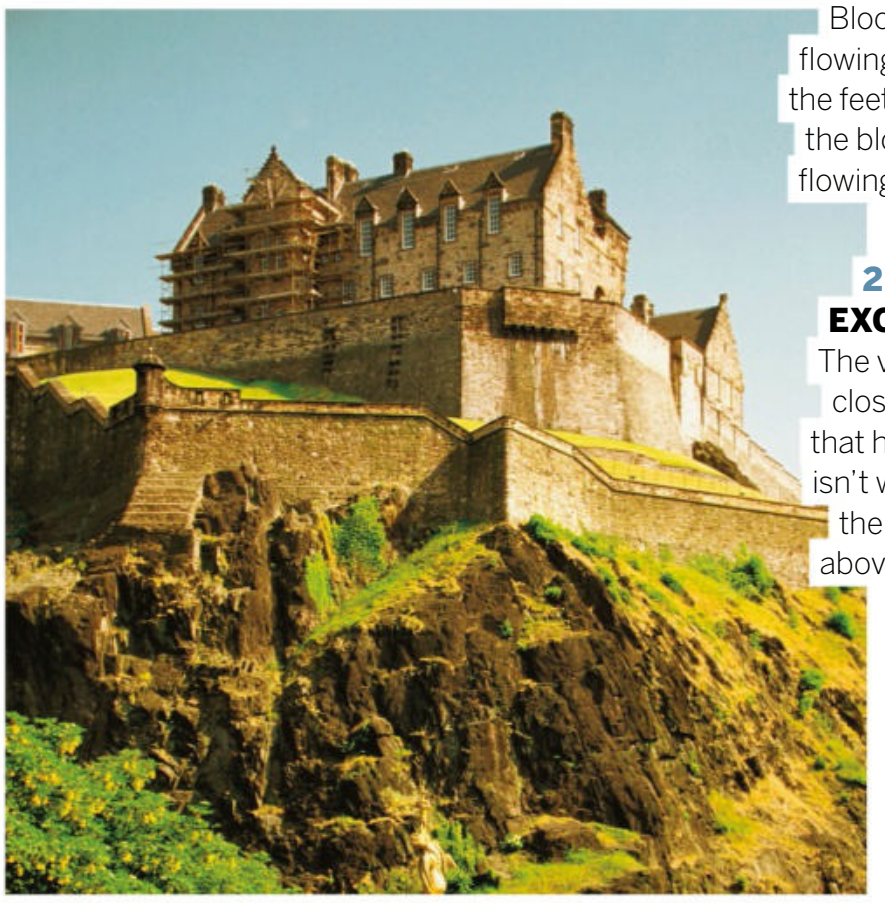
Did you know?

Easter Island is also called Rapa Nui

WHO BUILT EDINBURGH CASTLE, AND WHY?

Hannah Simpson

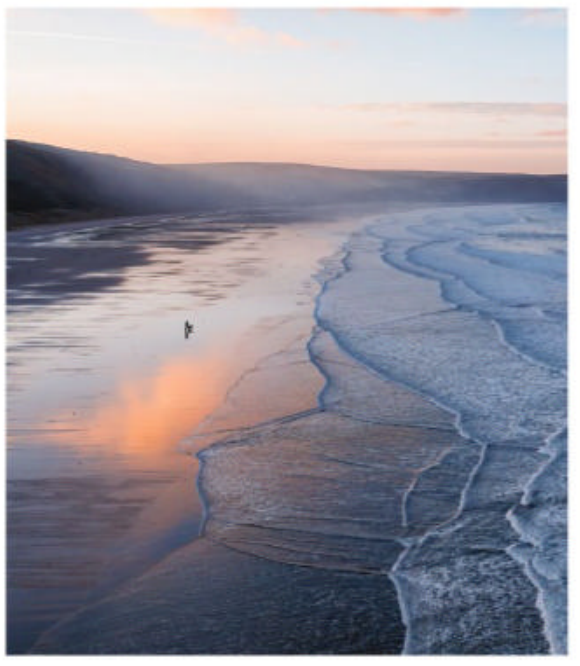
Occupation of Edinburgh Castle rock is known to go back to about 1000 BCE, and possibly earlier. In the late-6th century CE, it was a stronghold of the local British people known as the 'Votadini' or 'Gododdin'. By the 11th century it was a fortress of the kings of the Scots, and in the Medieval period it developed into a royal residence and arsenal with workshops and a foundry for making cannons. It remained an important strongpoint with a garrison into the 19th century. The oldest building that can be viewed today is the little chapel, named after Saint Margaret, who died 1093, but built after her death by one of her sons, probably King David I. The castle rock was valued for its defensibility, and the castle was a place of prestige, commanding the surrounding countryside and the burgh of Edinburgh.



WHERE DOES WATER GO WHEN THE TIDE GOES OUT?

Brian Day

The gravitational field of the Moon, though weak compared to Earth, has a strong influence on our planet. One very obvious effect is the occurrence of tides in the oceans and seas on Earth. As the Moon orbits Earth, its gravity will pull on the surface of the planet. The effect on the solid rocks of Earth is too small to see, but the effect on the surface water is significant, creating a bulge at the point opposite the Moon, or a high tide. As the Moon moves around Earth, the bulge will follow and the tide will fall. In creating this bulge, water is drawn from other parts of the ocean, causing a low tide. When the Moon is closer to Earth, exceptionally high and low tides can occur.



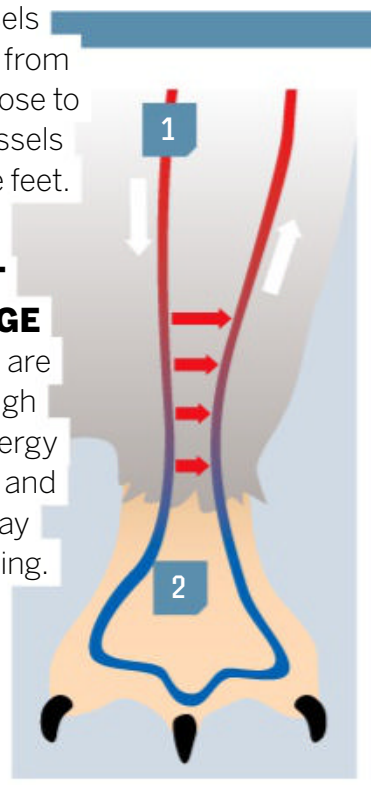
Are there any anatomical differences between a crocodile and an alligator?

Patrick Kepel

There are many differences between the crocodile and the alligator. However, the three main ones are its family type, jaw shape and teeth placement. There are three families of crocodilians: the *Alligatoridae*, *Crocodylidae* and *Gavialidae*. Crocodiles are part of *Crocodylidae*, while alligators are *Alligatoridae*. Second, alligator jaws are U-shaped and larger like a shovel, while crocodile jaws are V-shaped with a narrow snout. An alligator's upper jaw is larger than its lower, completely overlapping it. Crocodiles, on the other hand, have equal-sized upper and lower jaws.

1 BLOOD FLOW
Blood vessels flowing away from the feet run close to the blood vessels flowing to the feet.

2 HEAT EXCHANGE
The vessels are close enough that heat energy isn't wasted and the feet stay above freezing.



WHY DON'T PENGUINS' FEET FREEZE?

Leanne Ryan

Penguin's feet don't freeze, but they are often very cold. Penguins need bare feet so they can walk without slipping and to help steer them when swimming. Penguins often avoid their feet getting too cold by hunching down so that their belly feathers cover their feet or by rocking back onto their heels and tail to lift their feet off the ice. They also have countercurrent heat exchangers that regulate their foot temperature to keep them at least just above freezing. If their feet were too warm, they would waste lots of energy. Blood vessels running away from the feet run close to those running to them so that just the right amount of heat can be transferred between them to keep their feet warm enough. If they get too cold, the amount of warm blood flowing to the feet can also be increased by increasing the diameters of the arteries running to the feet.

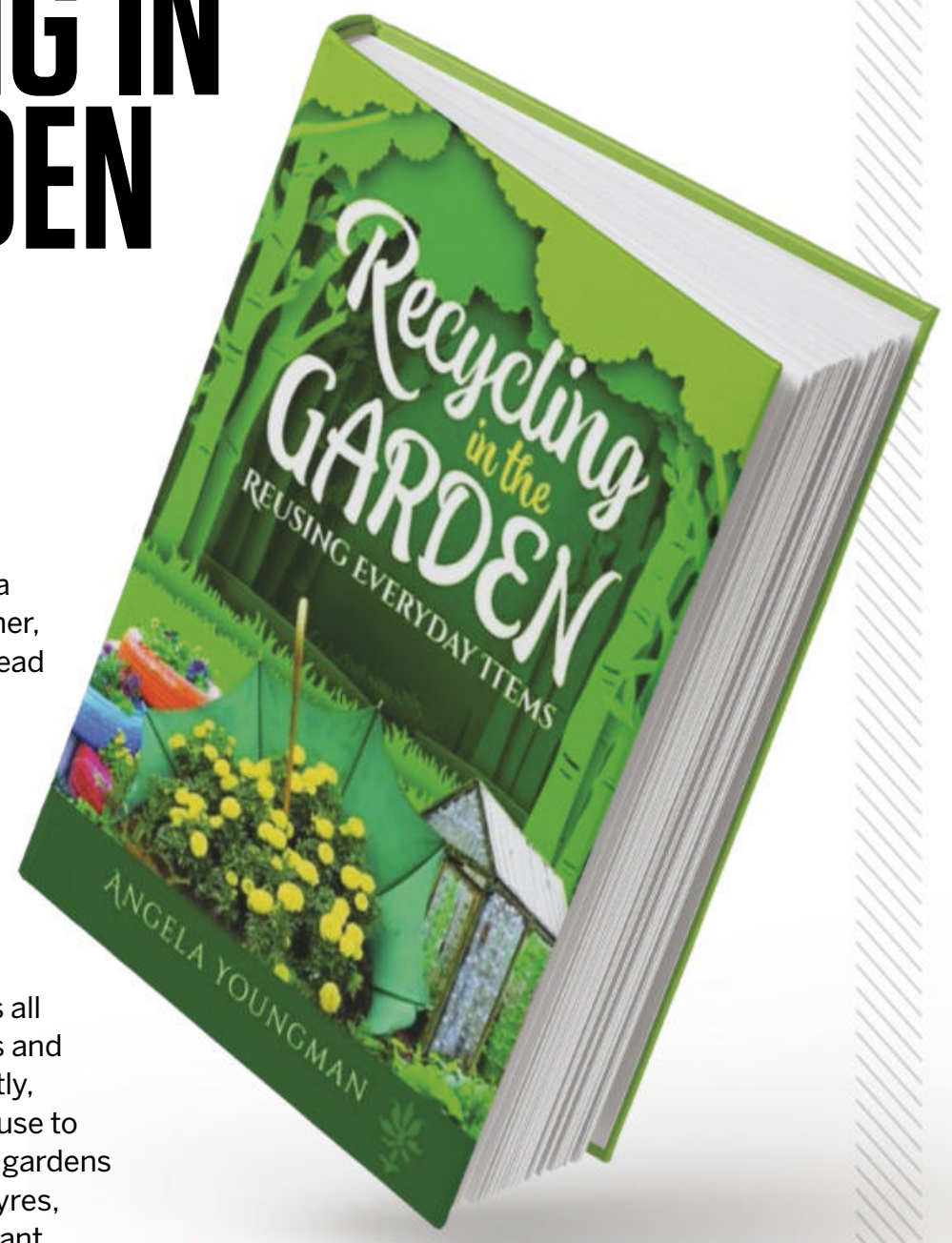
THE LIBRARY

The latest book releases for curious minds

RECYCLING IN THE GARDEN

GREEN-FINGERED AND ECO-FRIENDLY

AUTHOR **ANGELA YOUNGMAN**
PUBLISHER **PEN AND SWORD**
PRICE **£16.99 / $26.95**
RELEASE **OUT NOW**



Journalist and author Angela Youngman is a keen gardener, but she's not trying to go head to head with the likes of Monty Don or Alan Titchmarsh. She's not jostling for a place alongside Charlie Dimmock either, even though there's something about Dimmock's horticultural legend that has the same rustic charm as *Recycling in the Garden*. Youngman is going for green-fingered, green-themed frugality: she's all about making the most of the leftovers and waste of our modern society. Apparently, there's a lot of everyday waste we can use to decorate outdoor spaces and help our gardens flourish, including footpaths made of tyres, pottery garden mosaics, tree stump plant beds, energy and water recycling, composting and much more.

Hailing from rural Norfolk, Youngman draws some inspiration from British wartime austerity, when there was no question about vegetable plots and recycling, they were simply a part of life. In that era, everyone had a garden of some kind, and whether you were landed gentry with acres of country estate or lived in an inner-city terrace with a tiny plot, everyone was collecting rainwater and using animal – even human – waste to fertilise their gardens. Youngman doesn't go as far as encouraging the reader to turn away from their wasteful water closets and start compost toileting, but an ambitious home eco-warrior could aim for this level of self-sustainability.

For us, the most fascinating part of *Recycling in the Garden* was the creative ways in which rubbish we wouldn't normally think twice about throwing away was reused in the garden. Plastic bottle greenhouses, for example, might look like a strange addition to an allotment, but they're just as effective as the glass variety, will save you a good deal of money and are an interesting talking point, too. An old chest of drawers as a planter, empty wine bottles as path edging and burst double-glazed windows as cold frames for delicate plants are among other recycled gardening solutions. On their own they might look odd, but could make an attractive theme for a recycled garden project.

"Youngman is going for green-fingered, green-themed frugality"

Youngman has taken plenty of photos of the projects that she has been involved with, which is important because *Recycling in the Garden* is intended to both make you think about what you're throwing away, as well as inspiring you to make the most of whatever green patch of garden you have.

HEDY LAMARR

THE GIRL INVENTOR WHO HELPED DEFEAT THE NAZIS

AUTHOR **MARIA ISABEL SANCHEZ VEGARA**
ILLUSTRATOR **MAGGIE COLE**
PUBLISHER **FRANCES LINCOLN**
PRICE **£9.99 / $15.99**
RELEASE **5 JANUARY**

Meet Hedy Lamarr, the Austrian-born American film star of Hollywood's Golden Age and the pioneer behind Wi-Fi, GPS and Bluetooth communications technology. Even as a child Hedy had an eye for invention, designing a dog collar that glowed in the dark. However, in adulthood Hedy's journey took two paths – one into the glitz and glamour of filmmaking and the other to answer the call of the US military during World War II by creating a radio-signalling device to fight the Nazis. Little did Hedy know that her work would one day be the basis for the internet technology used around the world. This endearing children's book from the critically acclaimed Little People, Big Dreams series tells Hedy's story of perseverance, ambition and success in small snippets. It highlights some of the key moments of her life with charming illustrations to bring her story to life.

WHEN DINOSAURS CONQUERED THE SKIES

THE INCREDIBLE STORY OF BIRD EVOLUTION

AUTHOR **JINGMAI O'CONNOR**
ILLUSTRATOR **MARIA BRZOZOWSKA**
PUBLISHER **AURUM PRESS**
PRICE **£12.99 / $19.99**
RELEASE **OUT NOW**

Discover the world of prehistoric birds and how they dominated the skies in this wonderful book. It begins with a gentle introduction to how the science works and the early theories of evolution before taking the reader on a fast-paced journey from the ground to the prehistoric skies and unearthing all the feathered beasts that made this evolutionary trip.

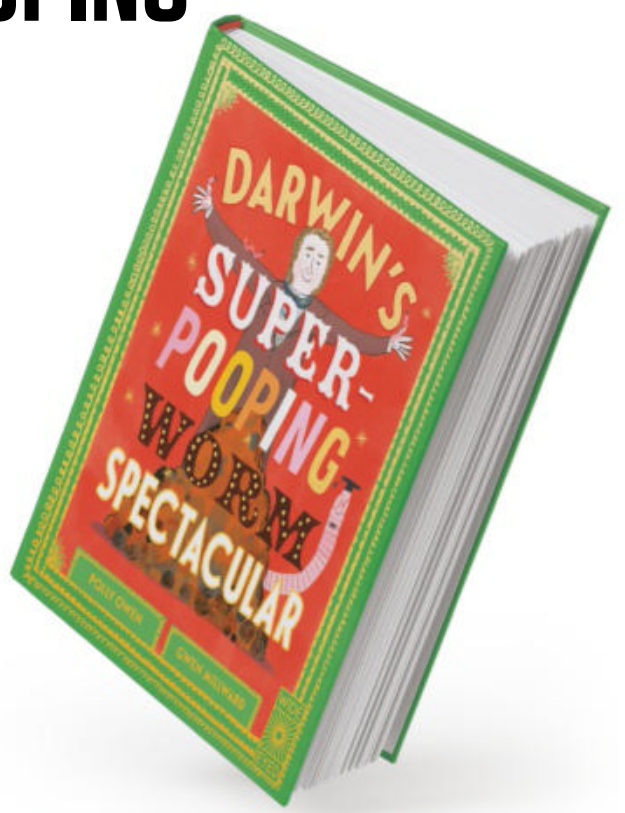
When Dinosaurs Conquered the Skies is exceptional in the way it's taken millions of years of evolutionary history and condensed it into a series of answers to the most common questions budding palaeontologists ask. From building the fossil timeline of birds to revealing their eating habits, the anatomy of feathers and when the first birds took flight, this book has all you need to know and more. It's beautifully illustrated with vibrant and amusing depictions of dinosaurs and their feathered cousins throughout time.

DARWIN'S SUPER-POOPING WORM SPECTACULAR

FINDING THE HIDDEN POWERS OF THE EARTHWORM

AUTHOR **POLLY OWEN**
ILLUSTRATOR **GWEN MILLWARD**
PUBLISHER **WIDE EYED EDITIONS**
PRICE **£12.99 / $19.99**
RELEASE **5 JANUARY**

Charles Darwin is well known for his research on the theory of evolution. But following on from this, he spent 40 years experimenting with earthworms. After becoming fascinated with their behaviour, Darwin carried out a series of tests to explore what these animals could and couldn't do. Darwin figured out that worms are both deaf and blind after simulating day and night with a lamp and even playing the bassoon for the creatures. While he gained some useful knowledge of how they navigated the earth, people thought Darwin was wasting his time with his worm obsession. That was until he discovered the power of worm poop. Just by digesting food, earthworms help farmers grow the food we rely on, shape ecosystems and even helped Darwin fill in some of the gaps in his theory of evolution.



This story of perseverance and passion reveals some of the lesser known facts about Darwin's work and character. Suitable for children between the ages of six and nine, this story is presented to be both amusing for young readers and factually interesting. The captivating comic illustrations turn each worm experiment into an engaging display, while some of the friendly faced worms even take on the role of narrator. This is an ideal choice to inform and entertain young readers.

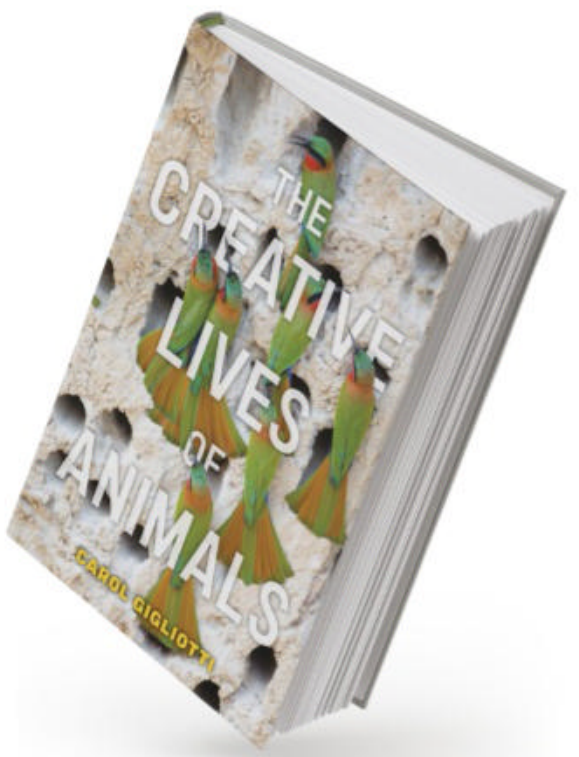
THE CREATIVE LIVES OF ANIMALS

REMARKABLE WAYS THAT ANIMALS THRIVE

AUTHOR **CAROL GIGLIOTTI**
PUBLISHER **NEW YORK UNIVERSITY PRESS**
PRICE **£25.99 / $30**
RELEASE **OUT NOW**

The Creative Lives of Animals opens the reader's mind to the diverse, intelligent, abstract and creative behaviours of the planet's millions of species. From the unique ways that animals have learned to communicate to the intricate and decorative homes of animals like the bowerbird and beaver, when observed closely the animal kingdom is full of displays of creativity. Some animals utilise the materials in their natural habitats to build, while others manipulate the threads and other substances they excrete from their own bodies.

Just as humans can be creative through art and music, so can many animals. Songbirds learn new tunes to communicate and dolphins give each other names; we are really only just beginning to understand the extent of animal capabilities. Gigliotti defines animal creativity as being unique to each species. Instead of comparing animals to humans, Gigliotti analyses the creativity of animals in species-specific ways. In doing so, this book allows the reader to better understand how different animal populations shape the world. *The Creative Lives of Animals* is backed by in-depth research so that even those who regard themselves as animal experts are sure to learn from it.



BRAIN GYM

Give your brain a puzzle workout

Sudoku

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

EASY

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

MEDIUM

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

HARD

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

Word search

Find the following words

BRAIN
SMART
CHEESE
GOLF
NITROUS
AIRCRAFT
EVOLVE
PURR
STAR
WASTE
SUN
KRAMPUS

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

What is it?

Hint: Flower power insect

A

Spot the difference

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

QUICKFIRE QUESTIONS

Q1 What did Scotland's James IV famously pay people for?

- To make him laugh
- To extract their teeth
- To rub his feet
- To fight to the death

Q2 What is a morning star?

- A Solar System planet
- A newspaper
- A medieval weapon
- A TV presenter

Q3 What happens when water freezes into ice?

- It expands
- It contracts
- It evaporates
- It ignites

Q4 What's the heating power of the average human?

- 80 Watts
- 150 Watts
- 1,000 Watts
- 1,600 Watts

Q5 What percentage of animals have no bones?

- 10 per cent
- 30 per cent
- 55 per cent
- 95 per cent

Q6 Which is true about the far side of the Moon?

- It's always dark
- It's made of cheese
- We can't see it on Earth
- We've never landed there

Answers

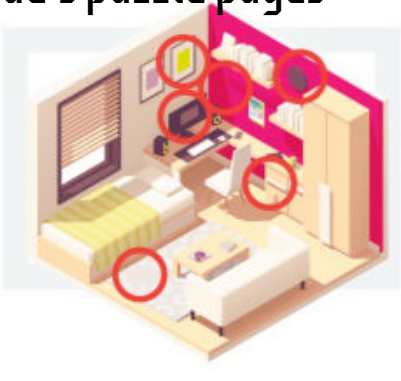
Find the solutions to last issue's puzzle pages

Q1 HIPPOCRATES
Q2 SATURN
Q3 C
Q4 VALLEY OF THE KINGS
Q5 EAR
Q6 20,000

What is it?

COFFEE BEANS

Spot the difference



HOW TO...

Practical projects to try at home

MAKE A HOLOGRAM

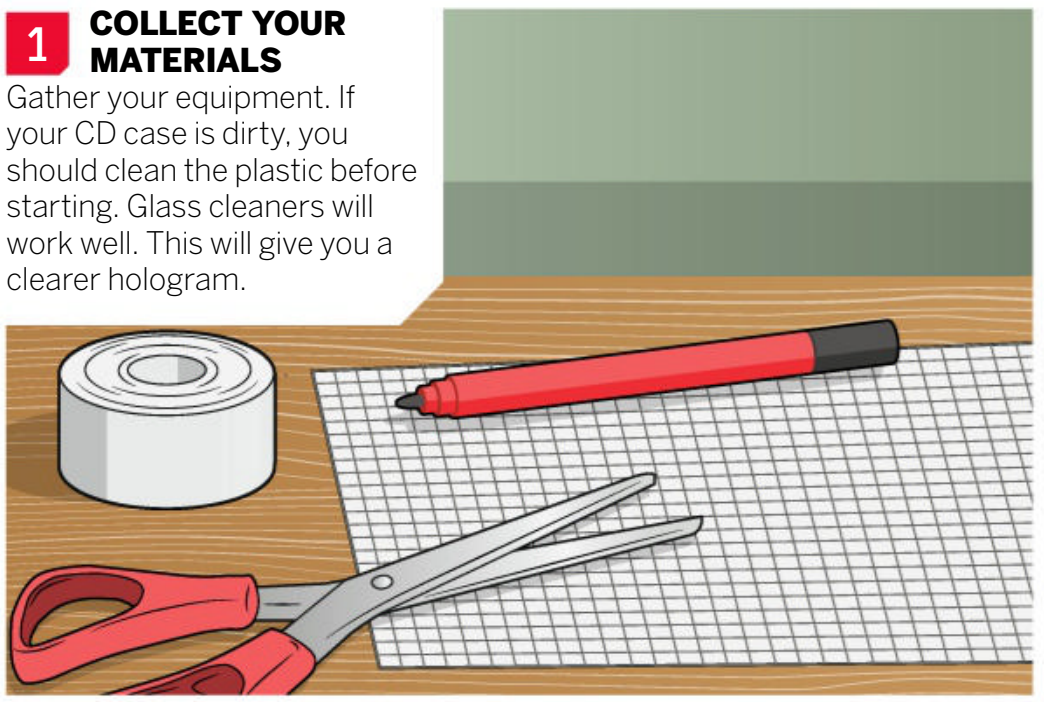
Watch as 3D objects are projected from your smartphone's screen in this simple project

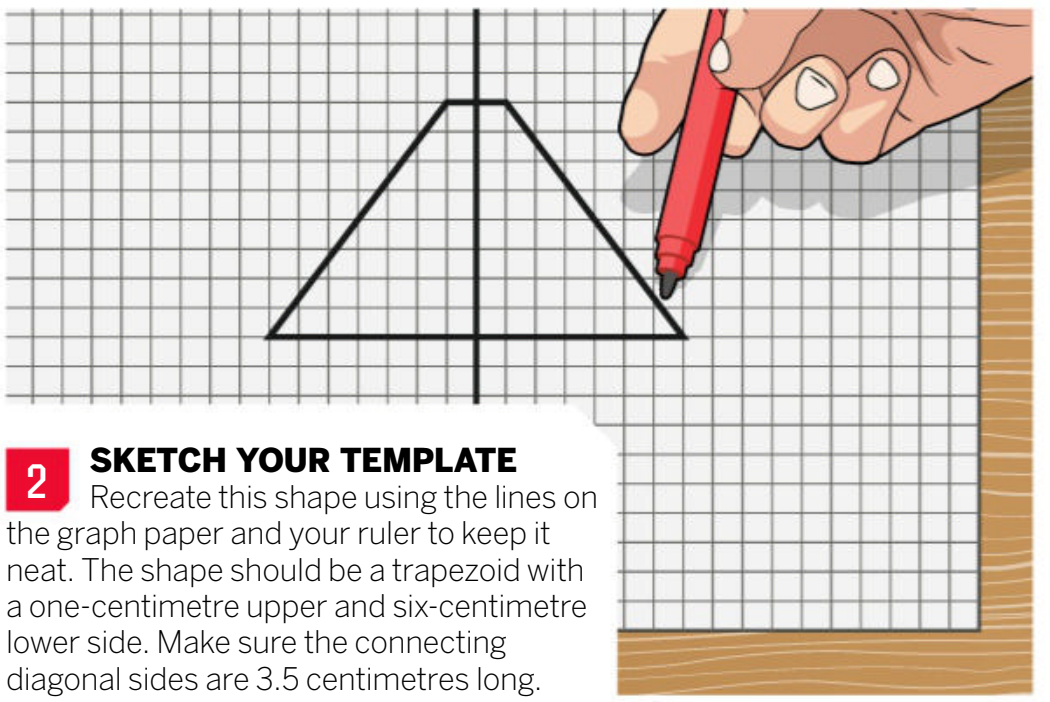
KIT LIST

- Plastic CD case
- Graph paper
- Cellotape
- Smartphone
- Pen
- Ruler
- Scissors

1 COLLECT YOUR MATERIALS

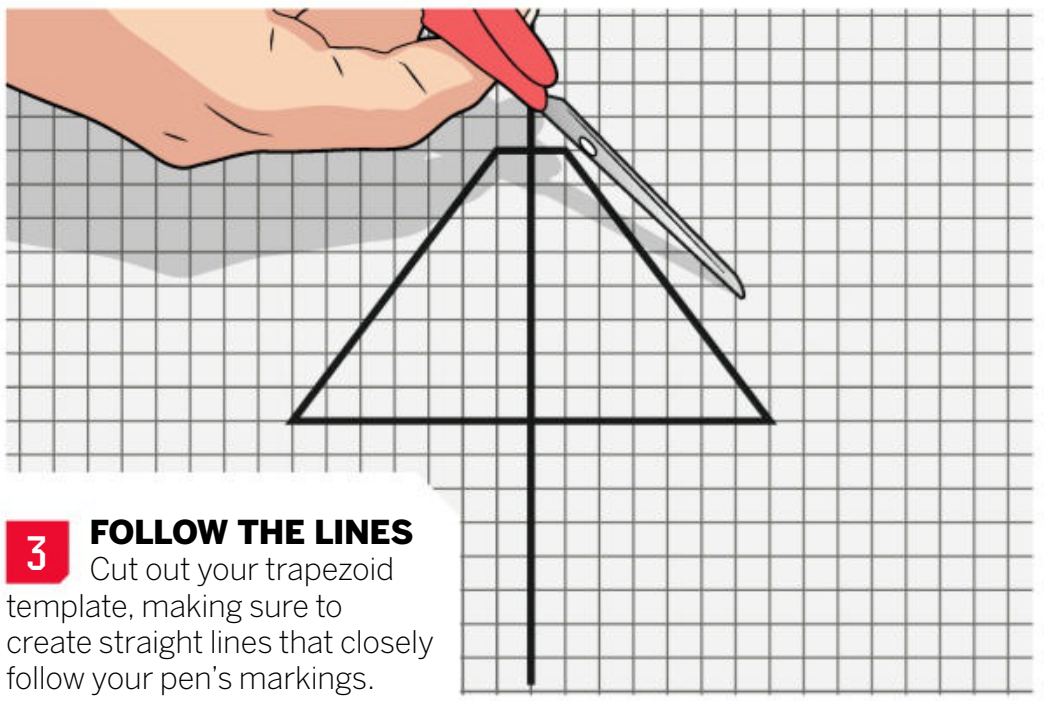
Gather your equipment. If your CD case is dirty, you should clean the plastic before starting. Glass cleaners will work well. This will give you a clearer hologram.





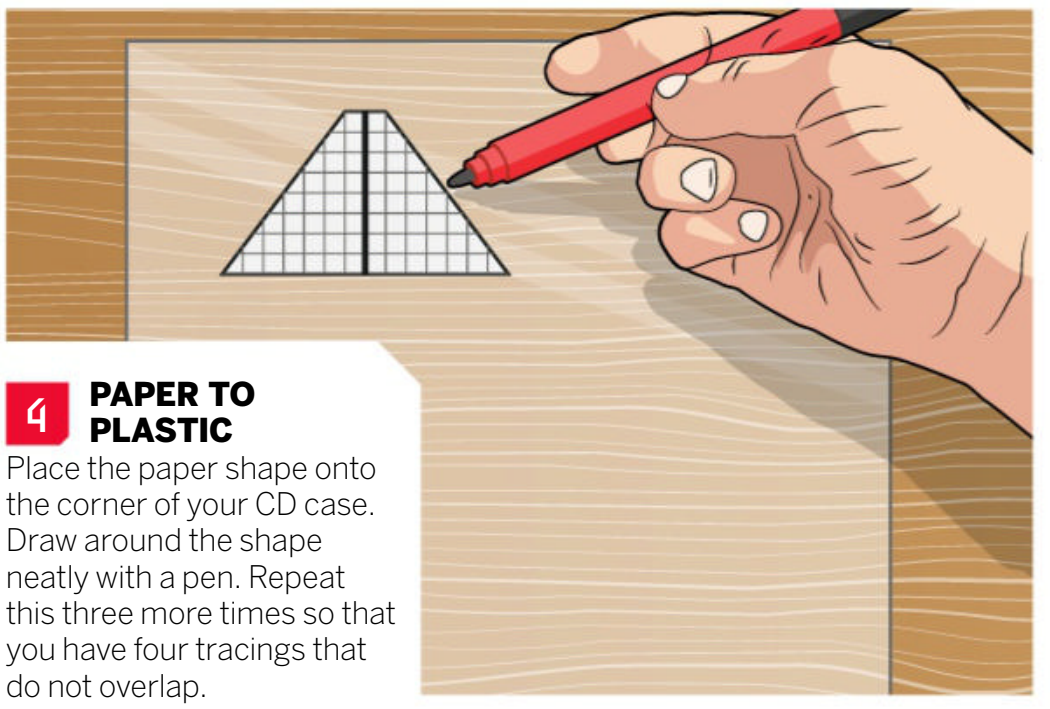
2 SKETCH YOUR TEMPLATE

Recreate this shape using the lines on the graph paper and your ruler to keep it neat. The shape should be a trapezoid with a one-centimetre upper and six-centimetre lower side. Make sure the connecting diagonal sides are 3.5 centimetres long.



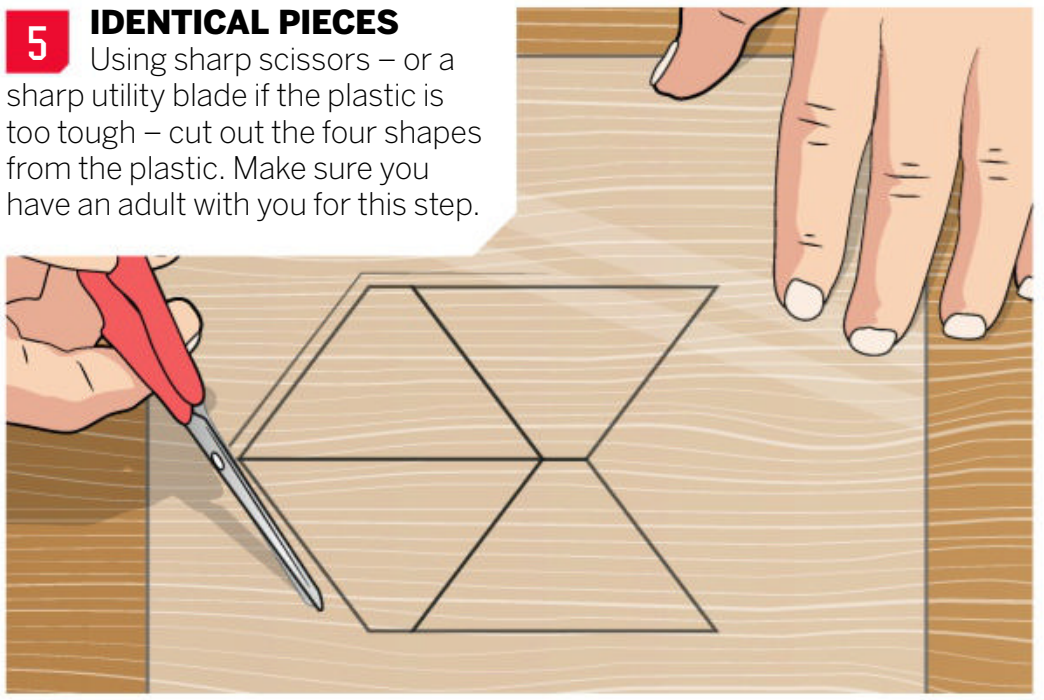
3 FOLLOW THE LINES

Cut out your trapezoid template, making sure to create straight lines that closely follow your pen's markings.



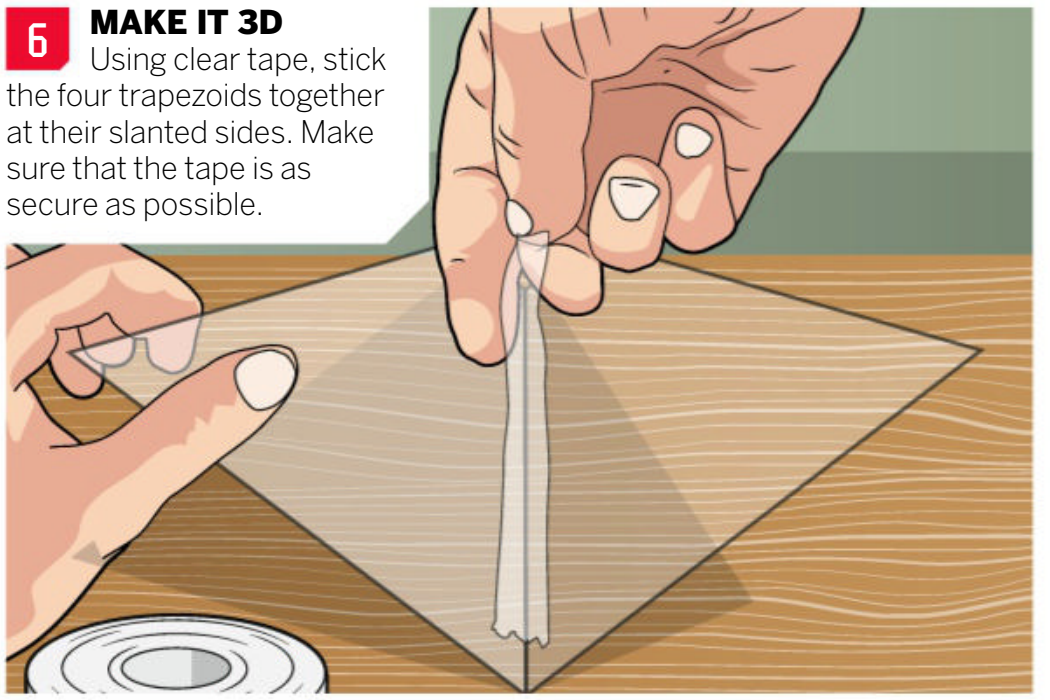
4 PAPER TO PLASTIC

Place the paper shape onto the corner of your CD case. Draw around the shape neatly with a pen. Repeat this three more times so that you have four tracings that do not overlap.



5 IDENTICAL PIECES

Using sharp scissors – or a sharp utility blade if the plastic is too tough – cut out the four shapes from the plastic. Make sure you have an adult with you for this step.

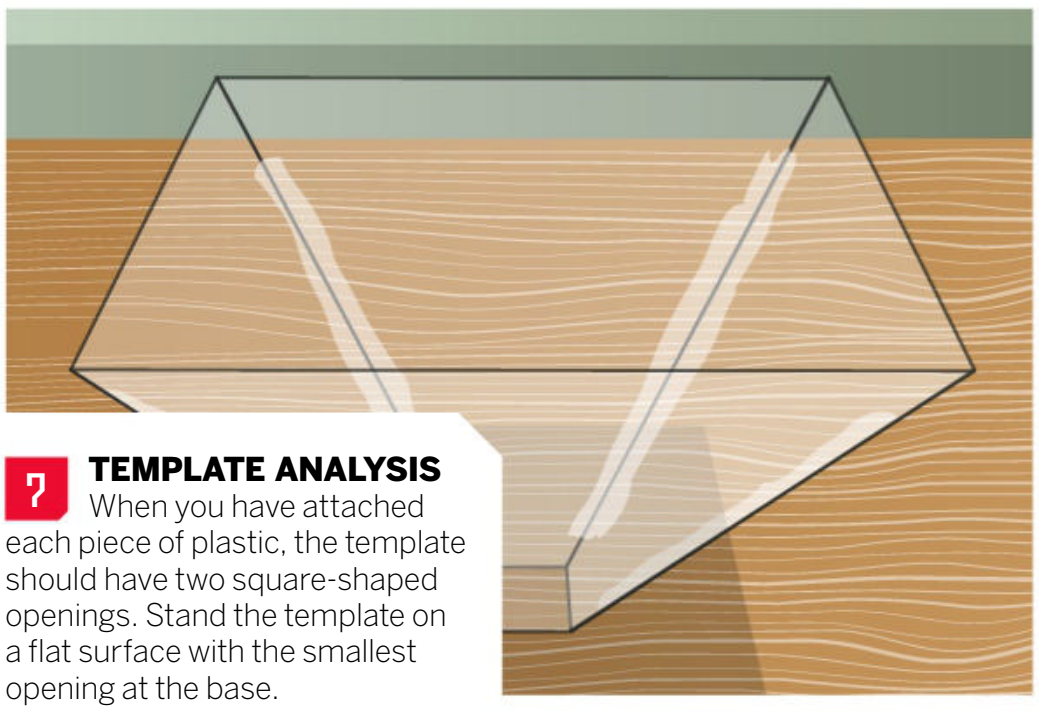


6 MAKE IT 3D

Using clear tape, stick the four trapezoids together at their slanted sides. Make sure that the tape is as secure as possible.

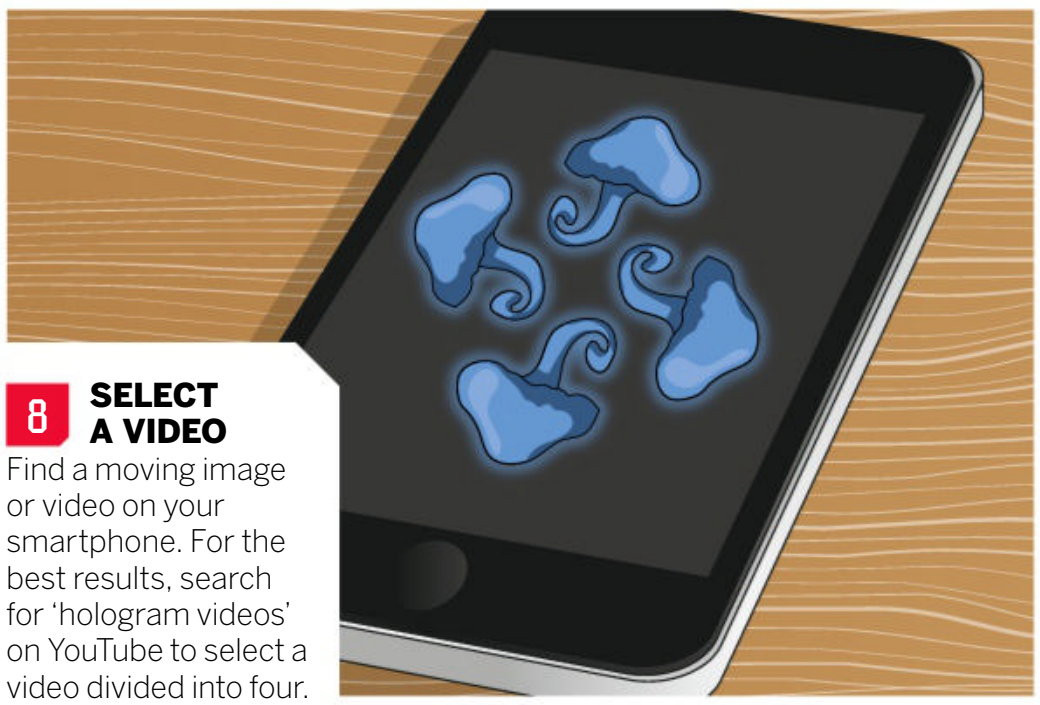
DON'T DO IT ALONE!

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



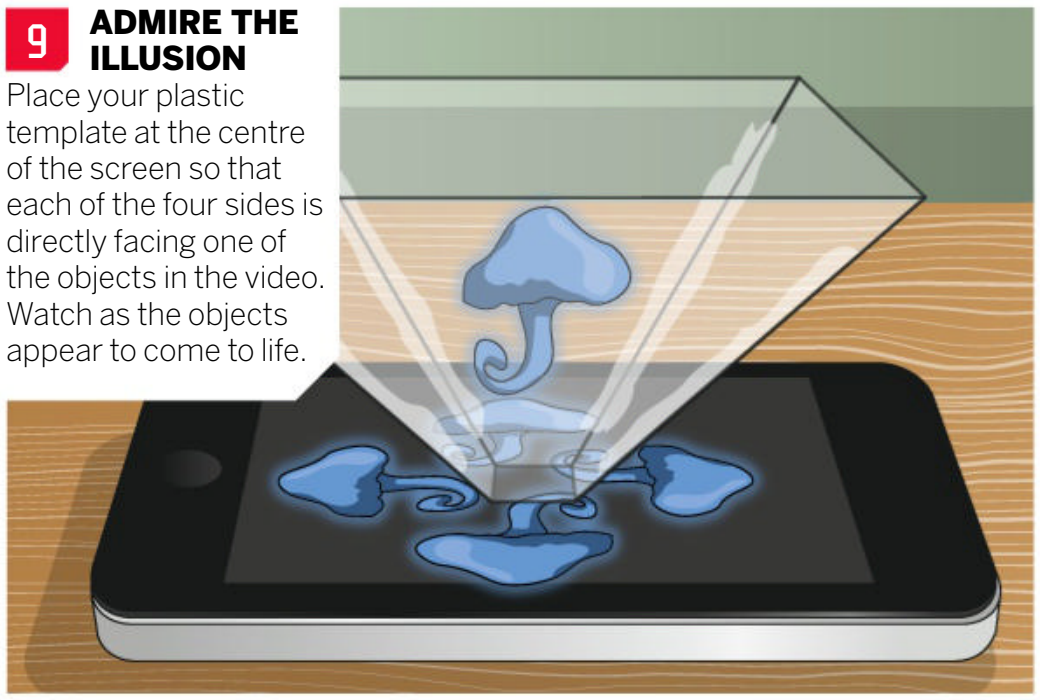
7 TEMPLATE ANALYSIS

When you have attached each piece of plastic, the template should have two square-shaped openings. Stand the template on a flat surface with the smallest opening at the base.



8 SELECT A VIDEO

Find a moving image or video on your smartphone. For the best results, search for 'hologram videos' on YouTube to select a video divided into four.



9 ADMIRE THE ILLUSION

Place your plastic template at the centre of the screen so that each of the four sides is directly facing one of the objects in the video. Watch as the objects appear to come to life.

SUMMARY

The four identical videos displayed on the smartphone need to be lined up with the template for this illusion to be effective. This ensures that all of the light emitted is reflected by the plastic to display a complete and realistic image. The clear plastic is positioned at 45 degrees to the screen so that it reflects each of the four images up into the centre. Here the light from all four comes together at the same point, giving the illusion that the image is floating. When the four perspectives are placed together, the two-dimensional video appears to be three-dimensional as your brain is processing all of these perspectives at the same time. In these specially made hologram videos, four angles of an object or person are often featured, making the hologram more realistic when adjusting your view to different sides of the phone.

Had a go? Let us know!

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

INBOX
Speak your mind

ATOMS VERSUS CARDS

Dear **HIW**,
I was on holiday with a friend and got into a heated discussion. He claimed that there are more possible ways to shuffle a pack of cards than there are atoms in the Earth. Is this true? Can you explain to me how this is possible as I just can't believe it.
Ben Chapman

Thanks for your letter, Ben. We hate to tell you, but in this instance your friend was correct. This is a difficult fact to get your head around as the huge numbers are very hard to imagine. In a deck of 52 cards, there are $8x10^{67}$ different order arrangements possible. Meanwhile, our planet contains around $1.3x10^{50}$ atoms. If you take just one number in a pack of cards, there are four suits available. These alone could be arranged in 24 different ways. There are four options for the first card in any ordering, three for the second, two for the third and one for the last card. To work out how many ways they can be arranged, the equation is 4x3x2x1. 24 possibilities for four cards seems very insignificant when compared to the huge number of atoms. But this is just to show how probability works. As the number of cards grows up to 52, this number increases exponentially. The solution to the equation 52x51x50x49... reaches the 68-digit number.


The extreme difficulty of predicting the order of cards in a standard deck is what makes card games so entertaining

LETTER of the MONTH

WIN!
AN AMAZING PRIZE FOR LETTER OF THE MONTH
RECYCLING IN THE GARDEN
Turn unwanted items into useful features such as footpaths made from tyres, garden forks into table lamps, broken pottery to mosaics and tree roots into lush garden stumperies

CAT REVENGE

Dear **HIW**,
Did you know that cats take revenge on humans that upset them? I have experienced this behaviour on three different occasions. On one occasion I roughly pushed my neighbour's cat off my porch chair. The next day I found that the cat had come back and left a poop on the chair. Then there was the time when I chased the same cat off my pathway. Again it left a poop on the path the next day. Another time a cat was taking an unhealthy interest watching a budgie in a cage. When I moved the cage out of the cat's reach, it reacted by jumping up angrily onto me as if to say this was my bird, and you had no right to interfere!
Stephen


Cats don't have the same emotional responses as us

Grudges held by people are fuelled by long-term emotional resentment, but a cat's reactions hold different purposes. There's no evidence to suggest that going to the toilet anywhere outside the litter box is an indication of a cat's anger. However, it has been linked to territorial behaviour. In the places where you have shown the cat that the area belongs to you, the cat might be trying to portray the same message. While these events may seem like acts of anger towards you, they are unlikely to be personal.

DRAIN HACKS

Dear **HIW**,
I have a shower drain that keeps overflowing. Drain unblockers refuse to work. Do you know a science hack?
Charles Fredricksen

At How It Works, we do know some science hacks for daily life. In fact, you can read about some in issue 164. For blocked drains, one of the best hacks involves baking soda and vinegar. First, you need to pour boiling water down the drain. Then add one cup of baking soda followed by a solution of one cup of vinegar and one cup of water. After ten minutes, pour more boiling water down the drain and much of the clog should have disappeared. This hack works as the acidic vinegar reacts with the baking soda to create a bubbling effect, breaking up and loosening any clogs.


Baking soda and vinegar work as a natural drain unblocker

NEXT ISSUE
ISSUE 173
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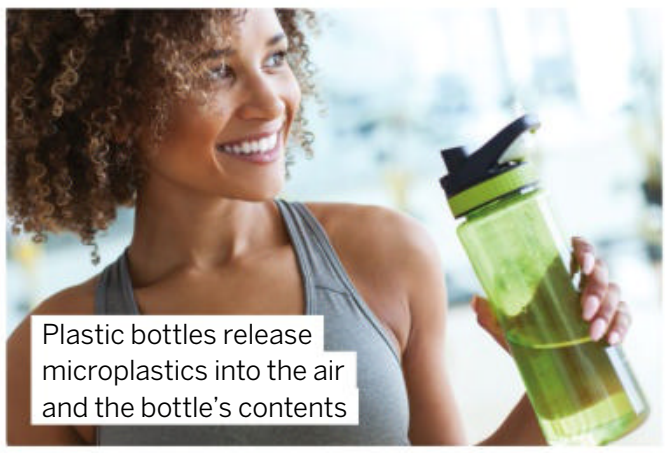
Next-day orders usually have a cut-off time to make sure there's enough time to complete the delivery

DELIVERY DILEMMA

Dear **HIW**,
Does next-day delivery make general delivery times slower? Do they push back the loading of items into lorries that haven't paid for next-day to make room for the priority parcels?
Gareth Schmidtke

Next-day delivery does have a higher priority among shipping companies than other standard deliveries. But there's still a window of time that customers are given as a guide as to when to expect their parcel. To remain highly regarded and to avoid customer complaints, companies stick to their guidelines to make sure deliveries are made promptly where possible. Larger companies usually have a separate carrier for priority deliveries so that when these requests are higher in number, standard deliveries aren't slowed.



Plastic bottles release microplastics into the air and the bottle's contents

HEALTHY DRINKING

Dear **HIW**,
After reading about microplastics in **How It Works**, it got me wondering whether I should replace my water bottle. It is a plastic reusable sports bottle. Could I ingest small amounts of plastic by using it?
Holly Manson

Unfortunately, the answer to this question is yes. But everybody is drinking small amounts of microplastics. Microplastics are so widespread in the environment that they are impossible to completely avoid. Tap water also has a very small percentage of plastic in it, but drinking water in reusable plastic bottles can increase how much plastic you ingest.

WE ASKED YOU

This month on social media, we asked you: If you could choose the next stage in human evolution, what would it be?

@JEANMCDOUGALL8333
Super intelligence

@LOUISTYNDALL
Kindness

@RAK.MALIGE
Cyberpunk theme for sure

@SONEW.O_O
Superman

@GRANT_SHELDON
Horses' running ability

@DUTRZ
Bigger and better lungs so that we can spend long periods of time underwater

@MERLE.HAHA
Peace

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FAST FACTS

Amazing trivia that will blow your mind

8,849 METRES

Bees can fly higher than Mount Everest

31,760

Tomato plants have 7,000 more genes than humans

ANTARCTICA IS LOSING SO MUCH ICE, IT'S AFFECTING GRAVITY IN THE REGION

171 MILLION CUBIC MILES

The Pacific Ocean has twice as much water in it than the Atlantic

2060

The year that physicist Isaac Newton believed the world would end

9%

Ice takes up a significant percentage of extra volume than the water that created it

SIX MINUTES

Brain cells react remarkably quickly to alcohol

48.6

Humans average nearly 50 individual thoughts per minute

Ten-year-old Clara Lazen discovered a new molecule in 2012

GENIUS THEORETICAL PHYSICIST STEPHEN HAWKING NEVER WON A NOBEL PRIZE, DESPITE HIS SCIENTIFIC ACCOMPLISHMENTS

576 MEGAPIXELS

Our brains can process images larger than most digital cameras can

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