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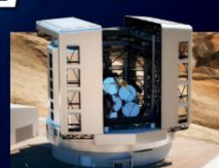
WHAT MIGHT THIS GIANT TELESCOPE SEE?

WELCOME

The magazine that feeds minds!

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"Crowds cheered as athletes battled it out to become the first Olympians"

Incredible Olympics, page 26

Can you imagine being at the first Olympic Games? Not the one from Greek legend – although watching the demigod Hercules destroy the competition with his superhuman strength would have been quite a sight to behold. No, the very first games nearly 3,000 years ago in ancient Greece. With just five events and one nation competing, it would have been a very different affair to Tokyo 2020, though still fascinating to see the origin of this international event. Today's top athletes might even seem superhuman compared to the first Olympic competitors, although no human Olympian is a patch on some of the animal athletes we're showcasing this issue. Enjoy!

Ben Editor

Meet the team...

Nikole
Production Editor
How is the human brain equipped to learn new things? Discover how your mind develops skills and knowledge on page 76.

Scott
Staff Writer
Which animal species would take home an Olympic gold medal? Meet the Olympians of the animal kingdom on page 40.

Baljeet
Research Editor
Though we still aren't sure what dark matter and dark energy are exactly, there are lots of theories. Find out more on page 52.

Duncan
Senior Art Editor
Next time you go to a live music concert, you'll notice how much goes on behind the scenes. Explore the tech on page 66.

Ailsa
Staff Writer
Today's trains bear little resemblance to the first steam engines. On page 58, see how technology will shape railways of the future.

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MEET THIS ISSUE'S EXPERTS…

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

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

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

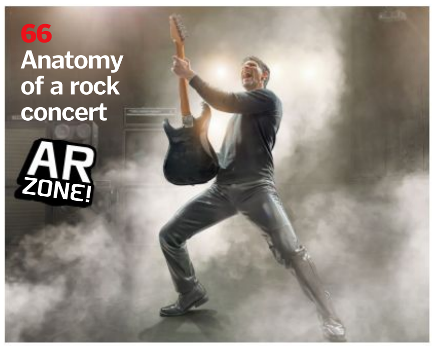
Jo Elphick
Jo is an academic lawyer and lecturer specialising in criminal law and forensics. She is also the author of a number of true crime books.

Amy Grisdale
Volunteer animal worker Amy has an enormous breadth of experience on animal conservation projects. She specialises in writing about environmental topics.

Laura Mears
Biologist Laura escaped the confines of the lab to the rigours of an office desk, as a keen science writer and full-time software engineer.

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

AR ZONE!



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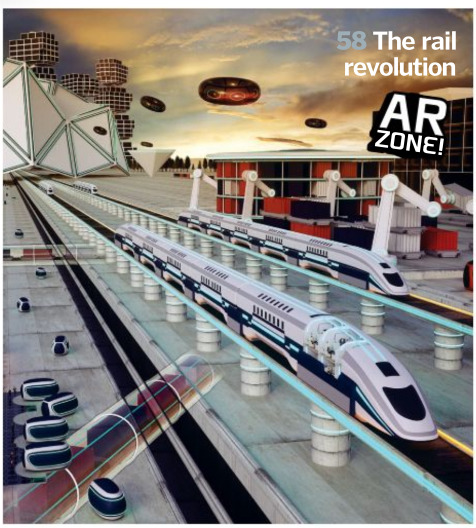

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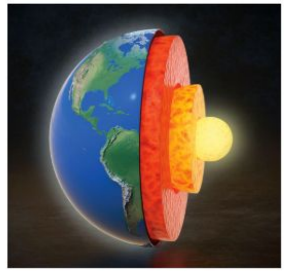
AR ZONE!

REGULARS



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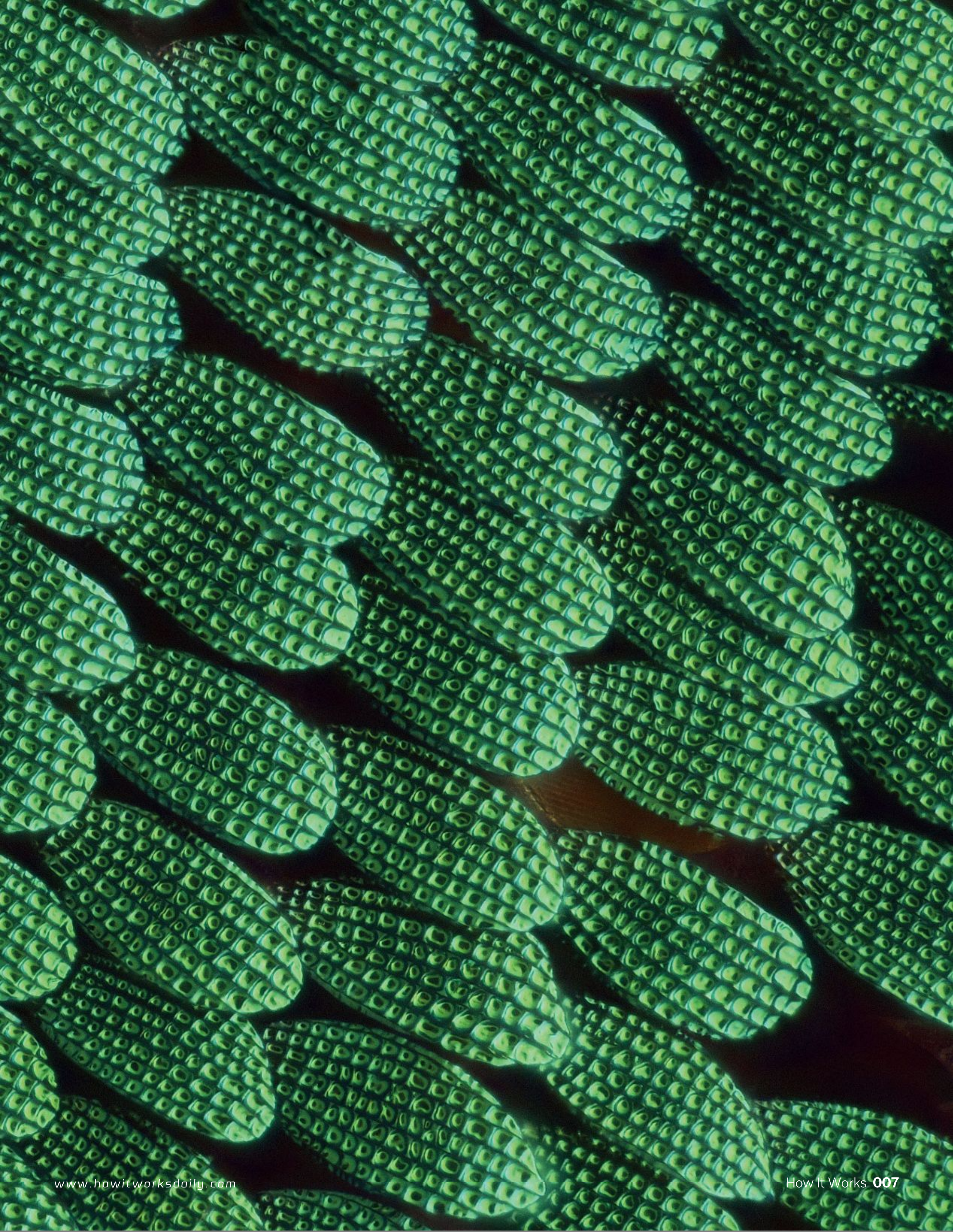
BUTTERFLY SKIN

The emerald swallowtail (*Papilio palinurus*) is native to Southeast Asia and gets its name from its vibrant wings. Depending on which angle you look at the insect, it will change colour, shifting between dark green, yellow and blue. This chameleon-like ability comes from the structure of its wings. Tiny microstructures called wing scales, revealed in this image, reflect blue and yellow light, often creating a green hue. However, due to the arrangement and structure of the scales, at different angles yellow and blue can be seen independently. It's believed the purpose of this colour-shifting biology may help this butterfly avoid predators.



BLACK HOLE POWER

Around 2.1 billion light years away from Earth lies an elliptical galaxy 1,000 times more massive than the Milky Way, called Hercules A. At the galaxy's core is a supermassive black hole ejecting spectacular jets of cosmic material millions of trillions of miles long. Hercules A is thought to be the brightest radio-emitting object in the constellation of Hercules, emitting almost a billion times more power in radio wavelengths than our Sun. This image was created in 2012 using imagery and information from both the Wide Field Camera 3 aboard Hubble and Very Large Array (VLA) radio telescope in New Mexico.

© Getty

FALLING FROM SPACE

On 23 April 2021, the burner from SpaceX's Falcon 9 rocket hurtled back towards Earth. The Falcon 9 was carrying the SpaceX Crew-2 mission astronauts – Shane Kimbrough, Megan McArthur, Akihiko Hoshide and Thomas Pesquet – to the International Space Station (ISS), the second crew SpaceX has launched. The crew were carried in the Endeavour capsule, the same capsule that was used in SpaceX's Crew Dragon debut in 2020. The launch took place at Complex 39A at the Kennedy Space Center in Florida. Not long after blastoff, the now-empty fuel burner used to propel the rocket into space fell back to Earth in this fiery spectacle.

FLYING THROUGH WATER

These birds are typically found along coastlines, soaring in the sky ready to dive down into the ocean below to catch fish. Like an avian spear, gannets tuck in their wings and feet, plunging into the water at speeds of 60 miles per hour. These expert divers can locate fish below the surface, plummeting head first into the water from heights of around 30 metres. To cushion the impact, these birds are equipped with a network of air sacs between their muscles and skin. In the UK alone there are 220,000 breeding nests, equating to around 60 to 70 per cent of the global population across large parts of Scottish, Welsh and northern English coastline.

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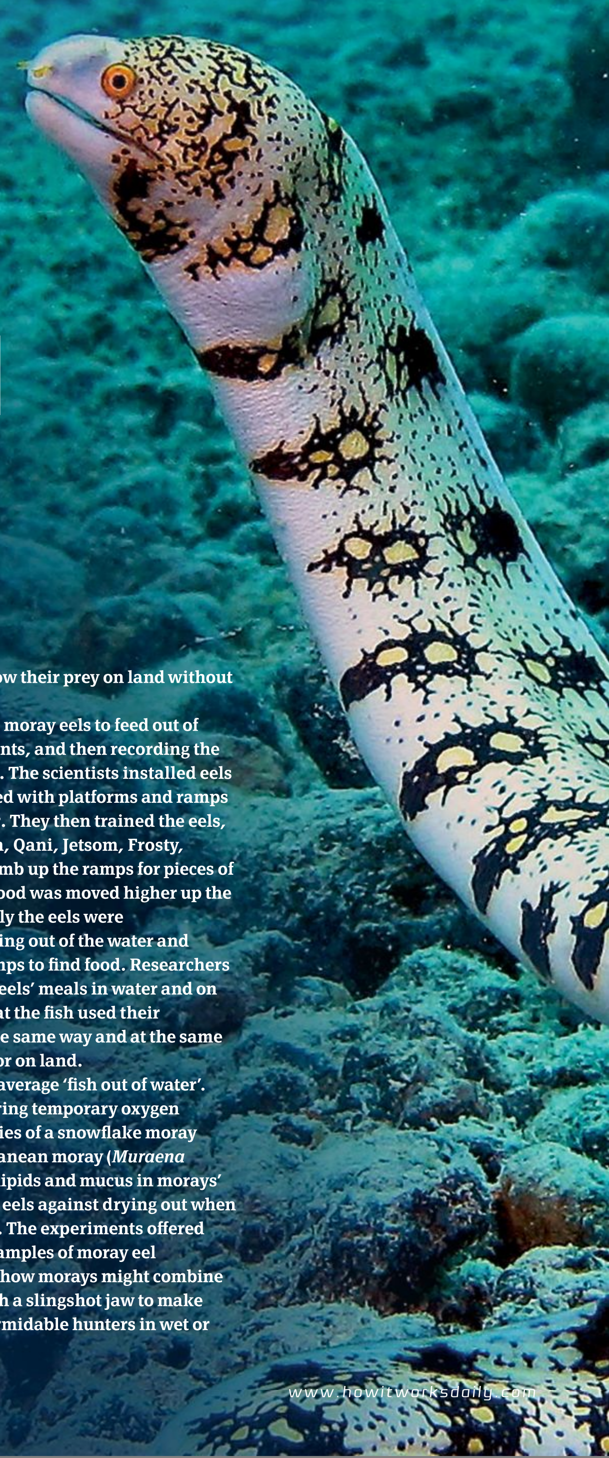
ANIMALS

Monster eels can swallow prey on land

Words by **Mindy Weisberger**



Moray eels have a second, hidden set of jaws that are the stuff of nightmares. This extra set can snap forwards in an instant to clamp into prey and drag the animal down into the eel's gullet. The terrifying slingshot jaws help a type of moray do something that's impossible for most fish: swallow their prey while on land. It's an unnerving sight, with video footage showing prey being yanked down the eel's throat as the moray's mouth gapes open.

Fish typically need moving water to carry food from their mouths into their bellies. But snowflake moray eels (*Echidna nebulosa*) can ambush crabs on land by wriggling from the sea to catch their prey during low tides, and researchers recently found that the recoil of the eels' secondary jaws was strong enough to help morays swallow their meal without having to retreat back into the ocean.

All bony fishes – those with skeletons made mostly of bone, rather than cartilage – have pharyngeal jaws in addition to their main jaws. Pharyngeal jaws lie behind the pharynx, or throat. They are smaller than the jaws in fishes' mouths, and are used for gripping and piercing or crushing food.

But unlike most fishes' pharyngeal jaws, those in moray eels "are highly mobile" and can spring past the throat and into the morays' mouths, said Rita Mehta, an associate professor in the department of ecology and evolutionary biology at the University of California Santa Cruz (UCSC).

Mehta and her team filmed eels as they munched on meals while out of the water. "Based on what we knew about the mechanics of the pharyngeal jaws, it made sense that if morays were able to capture prey in the intertidal or on land, they could also swallow their prey on land without relying on water".

Training snowflake moray eels to feed out of water in lab experiments, and then recording the results, took six years. The scientists installed eels in aquariums equipped with platforms and ramps that were above water. They then trained the eels, named Benjen, Marsh, Qani, Jetsom, Frosty, Flatsom and LB, to climb up the ramps for pieces of squid. Over time the food was moved higher up the ramps, until eventually the eels were independently wriggling out of the water and undulating up the ramps to find food. Researchers analysed 67 videos of eels' meals in water and on the ramps, finding that the fish used their pharyngeal jaws in the same way and at the same speed while in water or on land.

Morays aren't your average 'fish out of water'. They can function during temporary oxygen deprivation, and studies of a snowflake moray relative, the Mediterranean moray (*Muraena helena*), showed that lipids and mucus in morays' skin could protect the eels against drying out when they're exposed to air. The experiments offered previously unseen examples of moray eel behaviour, hinting at how morays might combine amphibious traits with a slingshot jaw to make them versatile and formidable hunters in wet or dry environments.

Snowflake morays were trained to eat outside of the water

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© NASA/JPL-Caltech/SwRI/MSSS

An image of Ganymede obtained by Juno's 7 June flyby

SPACE

Jupiter's largest moon is revealed in detail

Words by **Ben Turner**

Swooping low over Jupiter's largest moon Ganymede, NASA's Juno probe has snapped the first close-up photographs of the frozen giant in more than two decades – and they're breathtaking. Juno zoomed as close as 645 miles from the icy surface of the Solar System's largest moon on 7 June 2021, giving the spacecraft a 25-minute window to snap photos – long enough for five exposures – before it zipped away on its 33rd orbit of Jupiter.

Two photos from the flyby released by NASA, one of Ganymede's light, Sun-facing side and the other of its dark side, show an icy, inhospitable surface pockmarked with craters from asteroid impacts as well as long, narrow striations possibly caused by tectonic fault lines.

"This is the closest any spacecraft has come to this mammoth moon in a generation," said Juno principal investigator Scott Bolton, a physicist at the Southwest Research Institute in San Antonio. "We are going to take our time before we draw any scientific conclusions, but until then we can simply marvel at this celestial wonder."

NASA's Galileo captured the last photos of the enormous moon – which is the ninth-largest object in the Solar System – more than 20 years ago. Prior to this, the only other detailed close ups came from the Voyager missions in the late 1970s. First discovered by Galileo Galilei in 1610, Ganymede is one of the gas giant Jupiter's 79 known moons. At 3,270 miles wide, Ganymede is larger than the planet Mercury, and is the only moon in our Solar System with its own magnetic field.

"At 3,270 miles wide, Ganymede is larger than Mercury"

The Juno science team will now scour the new images for vital clues about the composition, ionosphere – the upper part of an atmosphere where atoms are ionised by solar radiation – magnetic field, radiation environment and ice shell of the Jovian moon, as well as investigating whether any areas of the moon have been altered since our last clear look. The level of detail offered by Juno's camera has enabled the team to take photos with a resolution of about 0.6 to 1.2 miles.

Launched just under a decade ago in August 2011, Juno has been orbiting Jupiter for five years, and the spacecraft is just a couple of weeks away from the end of its primary mission. NASA plans to keep the probe surveying the stormy surface of Jupiter until 2025, with passes over two of the gas giant's other large moons – frozen Europa and volcanic Io – lined up for 2023.

PLANET EARTH

Earth's core is growing 'lopsided'

Words by **Brandon Specktor**

There's a mystery brewing at the centre of the Earth. Scientists can only see it when they study seismic waves – subterranean tremors generated by earthquakes – passing through the planet's solid-iron inner core. For some reason, waves move through the core significantly faster when they're travelling between the North and South Poles than when they're travelling across the equator.

Researchers have known about this discrepancy, known as seismic anisotropy, for decades, but have been unable to come up with an explanation that's consistent with the available data. Now, using computer simulations of the core's growth over the last billion years, a recent study offers a solution that finally seems to fit: every year, little by little, Earth's inner core is growing in a 'lopsided' pattern, with new iron crystals forming faster on the east side of the core than on the west side.

"The movement of liquid iron in the outer core carries heat away from the inner core, causing it to freeze," says Daniel Frost, a seismologist at the University of California, Berkeley. "This means the outer core has been taking more heat from the east side [under Indonesia] than the west [under Brazil]."

To visualise this lopsided growth in the core, imagine a tree trunk with growth rings radiating out from a central point, Frost said, but "the centre of the rings is offset from the centre of the tree" so that rings are spaced farther apart on the east side of the tree and closer together on the west side. A cross section of Earth's inner core might look similar to that.

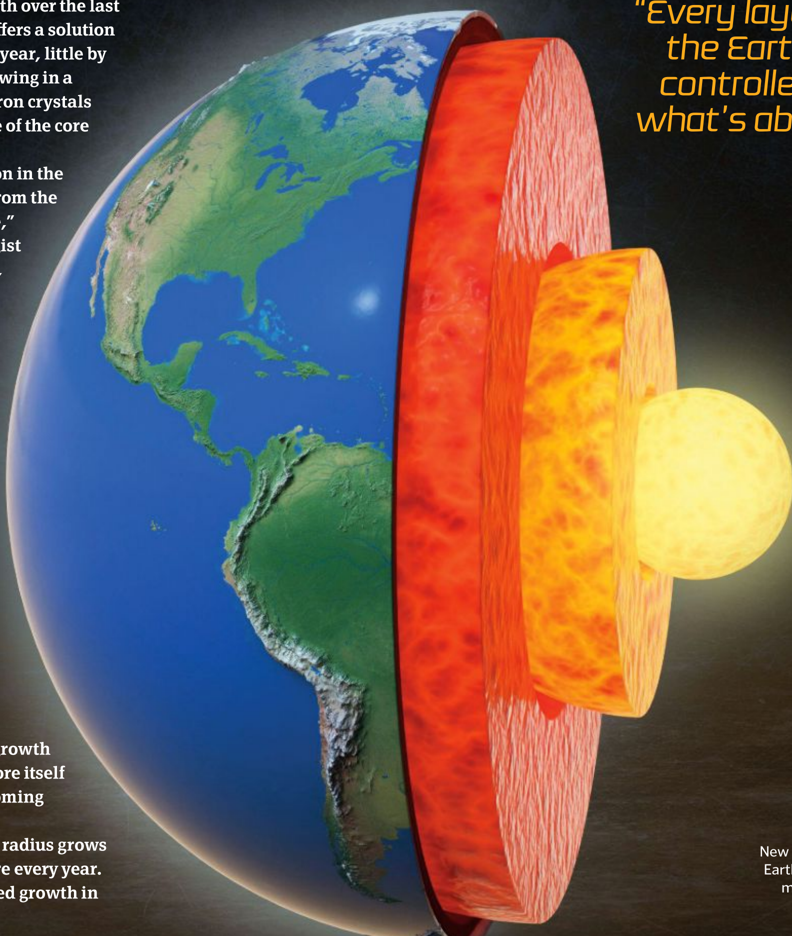
However, this asymmetric growth doesn't mean that the inner core itself is misshapen or at risk of becoming imbalanced.

On average, the inner core's radius grows evenly by about one millimetre every year. Gravity corrects for the lopsided growth in the east by pushing new crystals towards the west. There the crystals clump into lattice structures that stretch along the core's north-south axis. These crystal structures, aligned parallel with Earth's poles, are seismic superhighways that enable earthquake waves to travel more quickly in that direction.

But what's causing this imbalance in the inner core? That's hard to say without looking at all the other layers of our planet, Frost said. "Every layer in the Earth is controlled by what's above it, and influences what's below it," he said. "The inner core is slowly freezing out of the liquid outer core, like a snowball adding more layers. The outer core is then cooled by the mantle above it, so to ask the question of why the inner core is growing faster on one side than the other might be asking the question of why one side of the mantle is cooler than the other."

Tectonic plates could be partially to blame. As cold tectonic plates dive deep below the Earth's surface at subduction zones – places where one plate sinks below another – they cool the mantle below. However, whether mantle cooling could impact the inner core is still a subject of debate.

"Every layer in the Earth is controlled by what's above it"



New research suggests Earth's solid inner core may be growing in a 'lopsided' pattern

An artist's illustration of a woolly mammoth, which roamed Earth thousands of years ago

© Getty

ANIMALS

Gold miners discover three woolly mammoths

Words by **Owen Jarus**

Gold miners have discovered partial skeletons of three woolly mammoths, which may have been part of the same family, at Little Flake Mine near Dawson City, Yukon, in Canada. They turned over the bones to the Yukon government. "We seem to have one large full-grown mammoth, one younger adult and one juvenile," said Grant Zazula, the head palaeontologist for the Yukon government.

Some of the bones are still articulated (connected) with each other. The way the bones were found suggests "that these three mammoths were probably living together and died together very close to where the fossil bones were found," Zazula added. Even if they weren't family members, they may have been part of a larger herd, he said.

The miners found the skeletons near a layer of volcanic tephra that likely dates to around 29,000 years ago, when a volcano on the Aleutian Islands erupted. The mammoths likely lived around the time of the eruption. At that time, much of Canada was covered in glaciers, with the area around Dawson City being one of the few areas that was ice-free.

"The mining region in the interior of the Yukon was part of the unglaciated landscape called Beringia, which connected with Alaska and Siberia via the Bering land bridge," says Zazula. "The climate was incredibly cold and dry, and likely treeless, leading to the prevalence of grazing mammals."

From about 35,000 to 18,000 years ago, woolly mammoths (*Mammuthus primigenius*) crossed that land bridge into North America. The dry environment there helped to preserve the three mammoths. The climate was arid and the wind would have easily blown dust around. "This windblown silt, or loess, filled these valleys with sediment that rapidly covered the mammoths after they died," says Zazula. Because they were covered so quickly, the remains would have been less exposed to oxygen and to scavengers.

The "miners need to remove all this frozen silt to get to the gold-filled gravel in the valley bottoms, and when they do that, they often uncover the remains of ice-age animals" such as the three mammoths, said Zazula, who noted that more mammoths may be found at the mine site.

SPACE

Universe's largest spinning structures found

Words by **Charles Q. Choi**

Tendrils of galaxies up to hundreds of millions of light years long may be the largest spinning objects in the entire universe. Celestial bodies often spin, from planets to stars to galaxies. However, giant clusters of galaxies often spin very slowly – if at all. So many researchers thought that is where the spinning might end on a cosmic scale, according to Noam Libeskind, a cosmologist at the Leibniz Institute for Astrophysics Potsdam in Germany.

Previous research suggested that after the universe was born in the Big Bang about 13.8 billion years ago, much of the gas that makes up most of the known matter of the cosmos collapsed to form colossal sheets.

These sheets then broke apart to form the filaments of a vast cosmic web. Using data from the Sloan Digital Sky Survey, scientists examined more than 17,000 filaments, analysing the velocity at which the galaxies making up these giant tubes moved within each tendril. The researchers found that the way in which these galaxies moved suggested they were rotating around the central axis of each filament.

The fastest the researchers saw galaxies whirl around the hollow centres of these tendrils was about 223,700 miles per hour. The scientists noted they do not suggest that every single filament in the universe spins, but that spinning filaments do seem to exist.

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Artist's impression of a spinning cosmic filament

HEALTH

Chromosomes have extra mystery mass

Words by **Brandon Specktor**

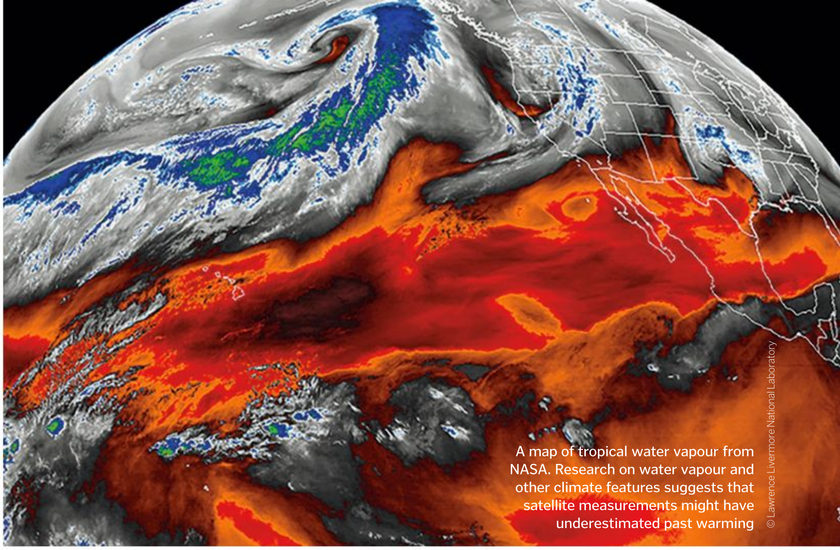
Using one of the UK's most powerful X-ray beams, researchers recently measured the mass of the 46 human chromosomes. Results were surprising: each chromosome was about 20 times heavier than the DNA contained inside, a much greater mass than the researchers anticipated. "Our measurement suggests the 46 chromosomes in each of our cells weigh 242 picograms [trillionths of a gram]," Ian Robinson, a professor of physics at University College London, said. "This is heavier than we would expect, and if replicated points to unexplained excess mass in chromosomes."

Each human cell normally contains 23 pairs of chromosomes. Within each chromosome is one DNA molecule and a plethora of proteins that serve a variety of functions, like compressing your two-metre strands of DNA into tiny bundles small enough to fit into individual cells.

The US government-run Human Genome Project revealed, among other things, the mass of DNA molecules. However, the weight of the chromosomes that house these molecules remained a mystery.

Understanding this could lead to further insights about the complex structure of chromosomes, which are studied extensively by medical labs for things like cancer diagnoses. The fact chromosomes weigh 20 times more than the DNA within them puzzled the team, and so far there's no good explanation. More research is definitely needed.

Turns out human chromosomes weigh about 20 times more than the DNA within them



A map of tropical water vapour from NASA. Research on water vapour and other climate features suggests that satellite measurements might have underestimated past warming

PLANET EARTH

Satellites may have underestimated global warming

Words by **Stephanie Pappas**

The global warming that has already taken place may be even worse than we thought. That's the takeaway from a new study that finds satellite measurements have likely been underestimating the warming of the lower levels of the atmosphere over the last 40 years.

Basic physics equations govern the relationship between temperature and moisture in the air, but many measurements of temperature and moisture used in climate models diverge from this relationship. That means that either satellite measurements of the troposphere have underestimated its temperature or overestimated its moisture, said Ben Santer, a climate scientist at Lawrence Livermore National Laboratory (LLNL) in California.

"It's currently difficult to determine which interpretation is more credible," Santer said. "But our analysis reveals that several observational datasets, particularly those with the smallest values of ocean surface warming and tropospheric warming, appear to be at odds with other independently measured complementary variables." Complementary variables are those with a physical relationship to each other – in other words, the measurements that show the least warming might also be the least reliable.

Santer and his team compared four different ratios of climate properties: the ratio of tropical sea surface temperature to tropical water vapour, the ratio of lower troposphere temperature to tropical water vapour, the ratio of mid- to upper-troposphere temperature to tropical water vapour and the ratio of mid- to upper-troposphere temperature to tropical sea surface temperature.

In models these ratios are strictly defined based on physical laws governing moisture and heat. It takes more energy to warm up moist air than dry air because water sucks up heat efficiently. Warmer air can also hold more moisture than cooler air, a phenomenon that is visible in morning dew – as the air cools overnight, it sheds water.

The researchers found that the satellite observations didn't stick to these supposedly well-defined rules. Instead they fell within a wide range depending on which dataset the researchers used. This might mean that some datasets – the ones that better mesh with the physical rules governing moisture and heat – are more accurate than others.

The datasets that best followed the rules for water vapour and temperature ratios tended to be those showing the most warming of the sea surface and troposphere. Likewise, the ones that best followed the rules for mid- to upper-troposphere temperatures and sea surface temperature ratios were those with higher measurements of sea surface temperature.

HEALTH

Mysterious protein changes the shape of human DNA

Words by **Cameron Duke**

The differences between human and mosquito DNA aren't limited to the arrangement of letters in the genetic code. If you were to slice open a human cell and a mosquito cell and peer into the nucleus of each, you'd see that their chromosomes are folded with a dramatically different type of genetic origami. Now researchers have figured out how to fold one type of DNA to take the shape of the other.

"In the human nucleus the chromosomes are bunched into tidy packages," said Claire Hoencamp, a doctoral candidate at the University of Amsterdam. "But in the mosquito nucleus the chromosomes are folded in the middle."

Hoencamp was studying condensin II, a protein involved in cell division. In one experiment she destroyed this protein in a human cell to observe its effect on the cell cycle. As if by elaborate choreography, the resulting cell's chromosomes would refold, but not like the DNA in a human nucleus.

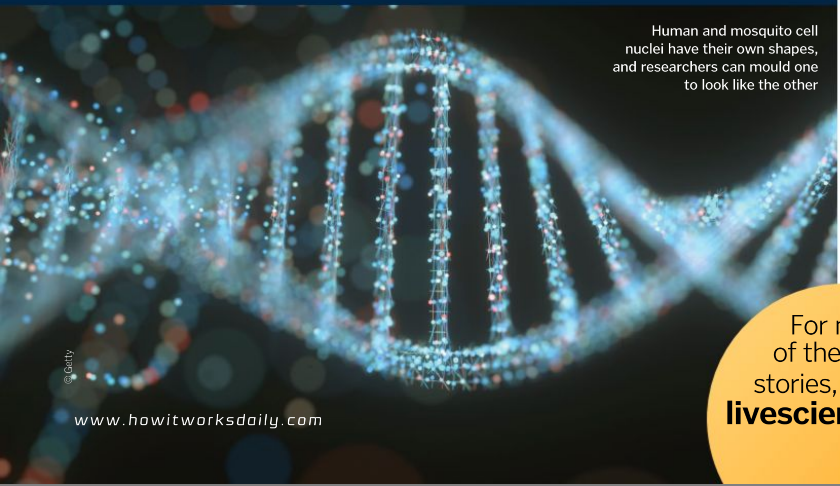
Meanwhile, Olga Dudchenko, a postdoctoral researcher at the Center for Genome Architecture in Texas, was classifying genomes based on the 3D structures their chromosomes form. As co-director of a multi-institutional project called DNA Zoo, she was seeing some distinct patterns. "We can classify things into two basic architectures," she said, referencing the tightly coiled and compartmentalised nature of the human genome versus the looser arrangement of the mosquito genome. No matter how many species she examined, chromosomes took on variations of two basic shapes. Her research suggested that some lineages would use one shape and evolve into the second and, in many cases, evolve back. However, she didn't know what force, if any, was driving these changes.

When presenting their research, the two teams realised they were approaching the same problem from different angles. Hoencamp had found a protein that folds chromosomes, and Dudchenko had spotted Hoencamp's experiment happening naturally across evolutionary timescales.

Due to COVID-19, the collaborators turned to computer simulations to better understand condensin II's role in nuclear organisation. With help from a laboratory at Rice University in Houston, they simulated the effects of condensin II on the millions to billions of letters in a genome, confirming what Hoencamp had found in her previous experiments.

Future research will aim to determine what evolutionary advantage, if any, one nucleus structure might have over the other. When the researchers examined gene expression, they found the folding structure of the chromosomes only mildly affected gene expression, or how much of each protein was made by different genes.

Given how little folding affected gene expression, it's not clear why a species would fold its DNA one way or the other. However, because both folding methods are found across the evolutionary tree, the subtle effects of each might have big implications.



Human and mosquito cell nuclei have their own shapes, and researchers can mould one to look like the other

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It's been discovered that electrons descend from space on Alfvén waves to create the aurora borealis

SPACE

Electrons 'surf' across space to create the northern lights

Words by **Brandon Specktor**

Physicists have definitive evidence that the aurora borealis is the result of electrons 'surfing' across the cosmos on powerful party waves. Scientists have known for a while that aurorae occur when energised particles from the Sun soar across space and crash into Earth's magnetosphere. Those energised particles ride our planet's magnetic field lines into the upper atmosphere, where they collide with oxygen and nitrogen molecules, releasing dazzlingly coloured light in the process. But there's still a big lingering question about the aurora process: How do those solar particles pick up enough speed and energy to crash into Earth's atmosphere with such force?

One popular explanation involves Alfvén waves, powerful geomagnetic waves that propagate through plasma, a charged gas that makes up the solar wind. These waves can pick up electrons in plasma and accelerate them to extremely high speeds without knocking them off course. Space-based instruments have detected Alfvén waves travelling towards Earth above aurorae, but scientists lacked a definitive way of proving these waves were accelerating electrons – until now.

In a recent study, researchers used an instrument called the Large Plasma Device, a 20-metre-long vacuum chamber at UCLA that's capable of holding a magnetic field, to recreate Alfvén waves under conditions similar to those in the solar wind. The team measured the velocity of electrons moving through the plasma chamber, finding that a small number of electrons were indeed being accelerated to great speeds by the waves.

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SPACE

Astronomers map 100,000 star nurseries

Words by **Ben Turner**

Stellar nurseries, the cauldrons of gas and dust where stars are forged, are far more diverse than astronomers first thought. Astronomers at the Physics at High Angular Resolution in Nearby Galaxies (PHANGS) project have systematically charted more than 100,000 nurseries across 90 galaxies, finding that each one is far more unique than first thought.

Stars can take tens of millions of years to form, growing from billowing clouds of turbulent dust and gas into gently glowing protostars before finally materialising into gigantic orbs of fusion-powered plasma like our Sun.

But how quickly this process depletes a nursery's store of gas and dust – and how many stars are subsequently able to form in a given place – depends on a stellar nursery's location in a galaxy.

"We used to think that all stellar nurseries across every galaxy must look more or less the same, but this survey has revealed that this is not the case, and stellar nurseries change from place to place," said Adam Leroy, associate professor of astronomy at Ohio State University. "These nurseries are responsible for building galaxies and making planets, and they're an essential part in the story of how we got here."

The five-year survey, conducted across a section of the cosmos known as the nearby universe because of its proximity to our own galaxy, used the Atacama Large Millimeter/submillimeter Array (ALMA) radio telescope located in Chile's Atacama Desert. By conducting their survey in the radio part of the electromagnetic spectrum, rather than the optical part, the astronomers could focus on the faint glow from the dust and gas of the dark and dense molecular clouds, as opposed to the visible light from the young stars birthed by them. This allowed the researchers to study how a star's home cloud shapes its formation.

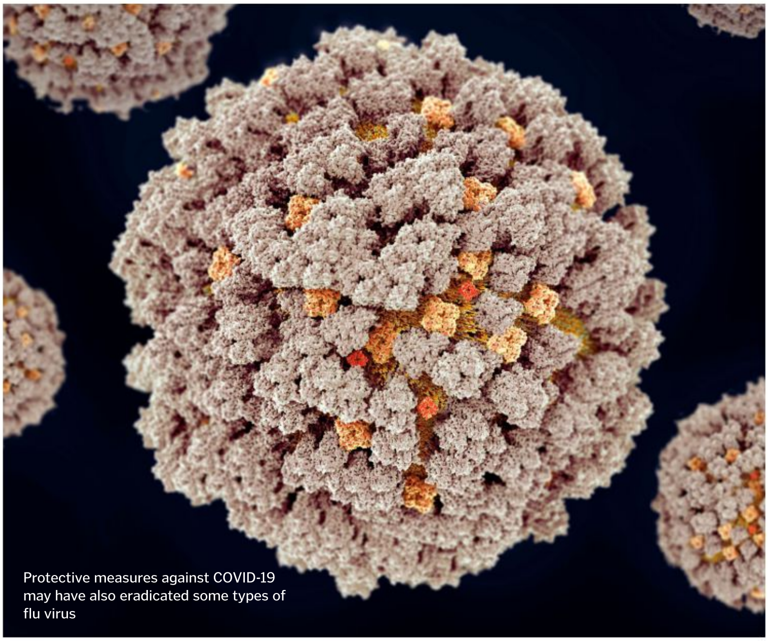
"To understand how stars form, we need to link the birth of a single star back to its place in the universe. It's like linking a person to their home, neighbourhood, city and region. If a galaxy represents a city, then the neighbourhood is the spiral arm, the house is the star-forming unit and nearby galaxies are neighbouring cities in the region," said PHANGS principal investigator Eva Schinnerer. "These observations have taught us that the 'neighbourhood' has small but pronounced effects on where and how many stars are born."

"Clouds in the dense central regions of galaxies tend to be more massive, denser and more turbulent than clouds that reside in the quiet outskirts of a galaxy," said Annie Hughes, an astronomer at L'Institut de Recherche en Astrophysique et Planétologie.

"The life cycle of clouds also depends on their environment. How fast a cloud forms stars and the process that ultimately destroys the cloud both seem to depend on where the cloud lives." Next, the researchers will try to figure out what this variation could mean for the formation of stars and planets, as well as for our own place in the universe.

NGC 4535, a barred spiral galaxy, was included in the survey

"Stellar nurseries change from place to place"



Protective measures against COVID-19 may have also eradicated some types of flu virus

© Getty

HEALTH

Two flu virus variants go extinct

Words by **Rachael Rettner**

There's been so little flu transmission during the COVID-19 pandemic that some types of flu virus may have gone extinct. During the COVID-19 pandemic, flu cases have dropped to historic lows, a phenomenon experts attribute to mask wearing and other precautions to combat the novel coronavirus.

Interestingly, two types of flu virus haven't shown up on anyone's radar for a year, meaning there have been no reported cases of these viruses anywhere in the world. Experts don't yet know if these types have gone extinct, but if so, officials could have an easier time picking the strains of flu virus included in the flu vaccine.

To explain which flu viruses may have gone extinct, it helps to understand how flu viruses are classified. Two families of flu virus cause seasonal flu: influenza A and influenza B. Influenza A viruses are divided into 'subtypes' based on two proteins on their surfaces known as haemagglutinin (H) and neuraminidase (N). Currently, H1N1 and H3N2 circulate in people, and each of these subtypes is further broken down into 'clades'. Influenza B viruses, on the other hand, don't have subtypes or clades, but are divided into two lineages known as B/Yamagata and B/Victoria.

One clade of H3N2, known as 3c3.A, hasn't been detected since March 2020. The same is true of the lineage B/Yamagata. "I think it has a decent chance that it's gone. But the world's a big place," Trevor Bedford, a computational biologist at the Fred Hutchinson Cancer Research Center in Seattle, said.

Florian Krammer, a virologist at the Icahn School of Medicine at Mount Sinai in New York, shared similar thoughts about the B/Yamagata lineage: "Just because nobody saw it doesn't mean it has disappeared completely – but it could have disappeared."

Less diversity among flu viruses would be a good thing. Each year, scientists make the flu vaccine months before flu season starts by seeing what strains are circulating in the world and then predicting which flu strains are likely to be the most common during the upcoming season. Lower flu virus diversity means a smaller pool of circulating viruses to choose from and a greater chance that the strains in the vaccine will match those in circulation.

HISTORY

7,000-year-old letter seal found in Israel

Words by **Yasemin Saplakoglu**

Archaeologists have found Israel's oldest known seal impression, a device that stamps a pattern onto soft material such as clay or wax in order to seal an object. The tiny clay impression dates back 7,000 years and was likely used to seal and sign deliveries, as well as to keep storerooms closed.

Researchers discovered the seal, along with nearly 150 others, during excavations that took place between 2004 and 2007 in Tel Tsaf, a prehistoric village in Israel's Beit She'an Valley. But while most of the other seals were just pieces of clay without any imprints, one had an impression with two distinct geometric shapes.

After conducting a thorough analysis, archaeologists identified this object as the oldest seal impression known in the region. Older seals dating back 8,500 years have been found in the region, but seal impressions had not. Prehistoric people used such sealings, or 'bulla', to sign and seal letters.

The ancient seal, which was found in great condition due to the dry climate of the area, is about a centimetre wide and has two different stamps on it. The two different stamp patterns suggest that the seal may have been used in a commercial activity that involved two people in the transaction.

© Vladimir Nichen

The newly found seal impression and a modern imprint of its pattern

WISH LIST

The latest **BBQ and grill** gadgets

FirePit+

Price: **£269.99 / $249.95**
uk.bioliteenergy.com / bioliteenergy.com

Barbecues no longer need to be bound to the backyard with the help of the FirePit+ by BioLite. This portable wood and charcoal-burning fire pit not only creates great campfires, but by using the BioLite cooking accessories this high-tech fire pit quickly transforms into a hibachi-style grill. Its patented airflow technology also means it can create smokeless fires in seconds. Using the companion app, you can control its integrated smart fan to regulate the fire's temperature and burn fuel more efficiently.

© Biolite

© GrillEye®

Ooni Fyra 12 Wood Pellet Pizza Oven

Price: **£249 / $299**
uk.ooni.com / ooni.com

Combining the convenience of a portable grill with the authentic taste of a stone pizza oven, the Ooni Fyra is a great addition to any barbecue. Using hardwood pellets, its innovative design allows it to reach temperatures of up to 500 degrees Celsius in just 15 minutes. This means you can have stone-baked pizza in only 60 seconds. The Ooni Fyra 12 weighs only ten kilograms and is collapsible, so it's perfect for transport to a campsite, beach or backyard.

©Ooni

GrillEye Max

Price: **€119.99 (approx. £102.75)**
www.grilleye.com

The GrillEye Max is a smart thermometer that keeps an eye on your food so you don't have to. Using up to eight thermometer probes, this compact device monitors the internal temperature of your meats with an accuracy within 0.1 degrees Celsius. With the companion GrillEye Hyperion app, you can watch as your meat reaches its desired temperature, and it will send an alert when it's ready to eat. It also comes with recording features, allowing you to store every cooking step you take to produce the best results for you.

Grillbot

Price: **$129.95 (approx. £93.50)**
www.grillbots.com

The Grillbot combines the independence of a Roomba with some elbow grease to create one of the first barbecue-cleaning robots. Using its three built-in electric motors, the Grillbot spins robust wire brushes to scrub away food debris from your grill. The device comes with three different timers and will automatically shut itself off.

© Grillbot

© Batesian

The Bartesian

Price: **$349.99 (approx. £251.70)**
www.bartesian.com

The Bartesian is a great gadget to accompany any barbecue. As your very own personal bartender, this innovative creation delivers premium cocktails at the touch of a button. Much like many of the coffee pod machines on the market, this device works using a flavoured capsule to create your favourite cocktails. Simply stock the Bartesian with four base spirits – such as vodka, rum, gin and whiskey – and then sit back and watch it pour one of 40 different cocktails.

© Bartesian

Sonos Roam

Price: **£159 / $169**
www.sonos.com

The Sonos Roam is a great gadget to bring music to any barbecue. This Bluetooth and WiFi-enabled speaker is durable and water-resistant, perfect for outdoor use. Its rechargeable batteries provide up to ten hours of playtime, and its also Alexa and Google Assistant-compatible for voice control of your music. Multiple Sonos Roam speakers can also connect, so you can have music flowing throughout your entire home or garden.

© Sonos

APPS & TOOLS

HowToBBQRight

Developer: **HowToBBQRight**
Price: **Free / Google Play / App Store**

This app provides all the latest recipes, tips and tricks from pitmaster Malcom Reed to help you make the most out of your barbecue and grill perfectly.

Veggie Alternatives

Developer: **AYUSH Apps**
Price: **Free / Google Play / App Store**

A great tool if you're looking for some vegetarian or vegan alternatives to include at your barbecue – there are over 300 animal-friendly substitutes.

Steak Timer

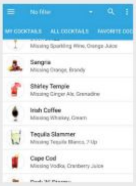
Developer: **SimpleInnovation**
Price: **Free / Google Play**

This helps you cook the perfect steak. Simply choose the steak's thickness and if it's chilled and the app will provide the optimal time and temperature for you.

My Cocktail Bar

Developer: **Roman Shuvaev**
Price: **Free / Google Play**

Can't decide what cocktails to serve at your barbecue? Simply choose what ingredients you have on hand and this app will help you decide what to make.



INCREDIBLE OLYMPICS

DISCOVER THE HISTORY, ATHLETICISM AND TECHNOLOGY THAT HAS CREATED THE BIGGEST SPORTING EVENT IN THE WORLD

Words by
Scott Dutfield

More than 2,700 years ago, crowds cheered as ancient Greek athletes battled it out to become the first Olympians. But the ancient games were a far cry from modern events. Lasting only five days, events were limited to boxing, wrestling, running, jumping, throwing and chariot racing, in which athletes typically competed in the nude. In Greek mythology, it was the son of Zeus, Heracles, who held the first Olympic Games to showcase his supernatural strength. However, it was a mere mortal who was first to claim the title of champion.

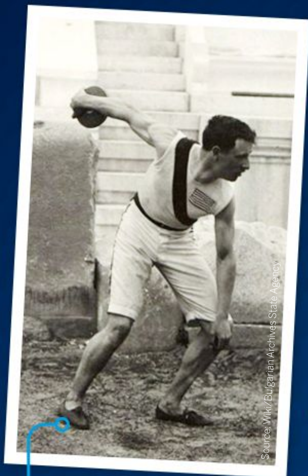
The original Olympic Games date back to 776 BCE and were held in Olympia, Greece. The first Olympic victor, a cook called Coroebus of Elis, won the first-ever Olympic event, a 192-metre foot race, or 'stadion'.

From then on, ancient Greeks convened every four years to showcase the next instalment of Olympians in an ever-growing number of disciplines. The reason the games are held in four-year intervals is because of the way the ancient Greeks measured time. Instead of the 12 months that make up the modern-day year, ancient Greek calendars were written in 'Olympiads' that equated to four years. The games were held at each new Olympiad, and even as calendars evolved, the tradition of waiting four years for the next event remained. The ancient games lasted through to 393 CE, and it wasn't until the late 1800s that the Olympics returned with a modern makeover.

The first modern Olympic Games was brought to life by Baron Pierre de Coubertin, a French sportsman who had a history of organising sporting conferences, ultimately founding the International Olympic Committee (IOC) to oversee the games. He was also the mind behind the creation of the five Olympic rings in 1913.

The modern-day games

12 OF THE GREATEST MOMENTS AND ACHIEVEMENTS FROM THE SUMMER OLYMPICS



Source: Wiki/Bulgarian Archives State Agency

Athens, Greece

1896

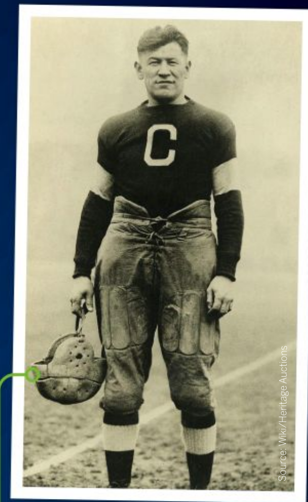
The first modern Olympic Games were not as grand compared to recent years, with only nine sporting events included. Harvard student James Connolly became the first modern-day Olympian, winning the triple-jump, then known as the 'hop, skip, jump'. However, what shocked many was another man's skill in a sport he'd never played before. Robert Garrett, a Princeton student, was asked to join the American athletes in Athens. The only problem was that Garrett had never thrown an ancient Greek discus, an event not played in the US. Nevertheless, through sheer natural skill and determination, Garrett not only competed but won the discus event, defeating Greek champion thrower Panagiotis Paraskevopoulos.

Paris, France

1900

Up until the start of the 20th century, only men were allowed to compete in the Olympic Games. At the 1900 event, 22 women out of a total of 997 athletes competed in five sporting events. One standout star of this year's games was Charlotte Cooper. Having won her first Wimbledon singles title in 1895, Cooper made easy work of the mixed doubles tournament along with her partner Reginald Doherty. The pair won big, and Cooper became the first woman to win a gold Olympic medal.

Source: Wiki/Olympics.org



Source: Wiki/Heritage Auctions

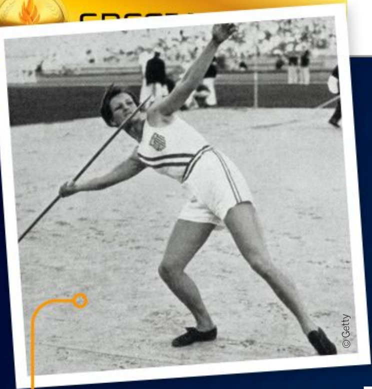
LET THE GAMES BEGIN — WOMEN ALLOWED — 1904 St Louis, US — 1908 London, UK — A STAR IS BORN — (cancelled due to WWI) 1916 Berlin, Germany — 1920 Antwerp, Belgium — 1924 Paris, France — 1928 Amsterdam, The Netherlands

Stockholm, Sweden

1912

Claiming gold for both the Olympic pentathlon and decathlon, which together were made up of 15 events, Jim Thorpe was hailed as being the world's greatest athlete. However, not long after King Gustaf V of Sweden put those medals around his neck, they were controversially stripped away from him. This was because at the time the Olympic rules stipulated that competitors had to be 'amateurs', unpaid for their sporting abilities. However, a few years prior to the 1912 games, Thorpe earned $25 a week playing minor league baseball, thus disqualifying his Olympic achievements.

> "The Olympics returned with a modern makeover"



© Getty

© Alamy

"Rather than having the shoes put his win in jeopardy, he decided to run barefoot"

Los Angeles, US

1932

It's hard enough to win a gold medal in just one Olympic event in a single sport, but Mildred Ella "Babe" Didrikson Zaharias did just that – and much more. At the 1932 games, the American athlete became the first person – male or female – to win individual Olympic medals in separate running, throwing and jumping events, taking home two gold medals for the 80-metre hurdle and javelin and a silver medal for the high jump.

Berlin, Germany

1936

Beamed out in black and white, the 1936 Olympic Games were the first to be broadcast on a television screen, even though it was reserved for those in the Olympic Village and 25 viewing rooms around Berlin and Potsdam. It wasn't until 1960 that the first live broadcast would reach homes across Europe.

London, UK

1948

Just two months after graduating high school, Bob Mathias travelled to London to compete in the Olympic decathlon. Mathias won the gold medal for the race, and at just 17 years old became the youngest person to ever win gold at an Olympic track-and-field event.

Rome, Italy

1960

Ethiopian marathon runner Abebe Bikila astounded spectators when he not only took home the gold medal for winning the race, but did so by running without shoes. Before the race began, Bikila was given shoes that didn't fit comfortably. Rather than having thr shoes put his win in jeopardy, he decided to run barefoot, something several other Olympians have done since.

JACK OF ALL TRADES – 1932 Los Angeles, US

TELEVISION DEBUT – 1936 Berlin, Germany

1940 (cancelled due to WWII) – Tokyo, Japan

1944 (cancelled due to WWII) – London, UK

TEENAGE TRIUMPH – 1948 London, UK

1952 – Helsinki, Finland

1956 – Melbourne, Australia

BAREFOOT BRILLIANCE – 1960 Rome, Italy

1964 – Tokyo, Japan

© Alamy

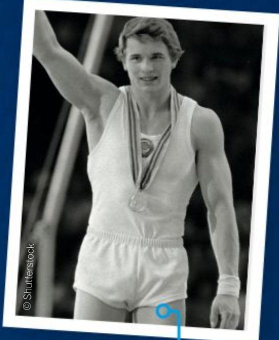
© Getty

© Getty

Moscow, Soviet Union

1980

Competing on home turf, Aleksandr Dityatin led the Soviet Union's gymnastics team to victory by not only qualifying for all six of the gymnastics apparatus events, but winning medals for each of them all in a single day. He was also the first male gymnast to receive a perfect score of ten for his long horse vault.



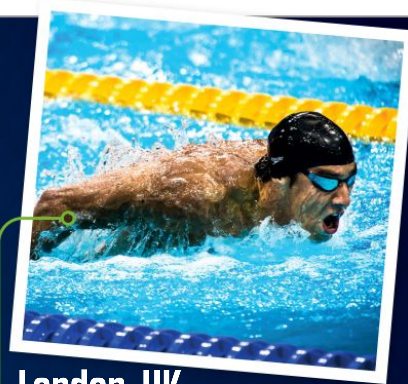
© Shutterstock

Beijing, China

2008

Usain Bolt dominated the racetrack at the 2008 Olympics, achieving a world record for the fastest 100-metre sprint. The Jamaican athlete sped across the finish line after just 9.69 seconds. The following year he topped himself again at the World Championships, finishing the race in 9.58 seconds.

© Getty



London, UK

2012

Until the 2012 Olympics, former Soviet gymnast Larisa Latynina held the record for the most medals won cumulatively, winning 18 by her last competition in 1964. However, American swimmer Michael Phelps snatched that title after winning the silver medal for the 200-metre butterfly and then the gold for the 4x200-metre freestyle relay in 2012, bringing his total medal collection to 20.

1968 – Mexico City, Mexico

RECORD MAKER

1976 – Montreal, Canada

GYMNASTICS GENIUS

1984 – Los Angeles, US

1988 – Seoul, South Korea

1992 – Barcelona, Spain

1996 – Atlanta, US

2000 – Sydney, Australia

2004 – Athens, Greece

SPRINTING TO SHOCKING SPEEDS

RECORD BREAKER

DEFENDING HER TITLE

Rio, Brazil

2016

Flyweight boxer Nicola Adams took home her second gold medal for Great Britain at the 2016 Olympics. As the first woman to ever win a gold medal for boxing, the 2016 Olympic Games saw her not only retain her boxing title, but she also became the first boxer to retain the gold medal in 92 years.

Munich, West Germany

1972

American swimmer Mark Spitz was the one to watch at the 1968 Olympic Games in Mexico City. However, his performance was lacking, and he only took two of the six gold medals he was predicted to win. But Spitz redeemed himself at the 1972 games, taking home seven gold medals, the most ever won at a single Olympic Games and a record he would hold until swimmer Michael Phelps won eight gold medals in Beijing in 2008.

© Alamy

The Olympic flame flew from Greece to Fukushima, and will tour each prefecture of Japan

© Getty

Source: Wiki/XXXX

The Japan National Stadium was completed in 2019 and can accommodate 60,000 spectators

Tokyo 2020

AFTER A YEAR'S DELAY, WHAT CAN WE EXPECT FROM THE LATEST SUMMER OLYMPICS?

The long-awaited Summer Olympic Games are set to descend upon Tokyo, Japan, from 23 July to 8 August. Thousands of athletes from around the world will make their way to the capital city with hopes of claiming the coveted gold, silver and bronze medals. Over the last 12 months there have been many false starts and delays for the 2020 games – with many doubts the event could even go ahead.

Measures have been put into place to tackle the spread of COVID-19, including ensuring around 80 per cent of athletes are vaccinated. The Japanese government and the IOC have also announced that international spectators will not be allowed to attend the Tokyo Olympics.

One of the biggest themes of this year's Olympic Games is sustainability and renewable energy. Working under the concept of "be better, together – for the planet and the people", Olympic organisers set out to implement sustainability initiatives to minimise the environmental impact of the games.

Historically the Olympic Games not only brings some of the world's greatest athletes together, but also contributes heavily to greenhouse emissions. The Tokyo Organising Committee for both the Olympic and Paralympic Games outlined a carbon-offset program to help make the games a 'zero-carbon' event. This environmental effort will include powering Olympic venues, media centres and athlete villages with renewable energy, such as solar panels, and also using 65 per cent recyclable materials at the event's food services.

One way organisers sought to reduce the games' environmental impact was to introduce a recycling program to source material for the Olympic medals. Starting in 2017, the Tokyo 2020 Medal Project called for donations of old small electronic devices, such as used mobile phones, from all over Japan. In the two years the project was open, 78,985 tonnes of devices were collected, which has provided 100 per cent of the metals needed to manufacture the 5,000 gold, silver and bronze medals that will be awarded to winners at the games.

The eco-friendly attitude of the games has also extended to the Olympic torch. Symbolising the connection between the games of ancient Greece and the modern era, the Olympic flame was first introduced at the 1928 Olympics in Amsterdam. Subsequently, at the 1936 Berlin Games, the Olympic Torch Relay introduced the concept of running the flame from the games' roots in Olympia to the host city. To light the torch, a parabolic (curved) mirror is used to reflect rays of the Sun's light into a single, concentrated focal point hot enough to ignite an Olympic flame.

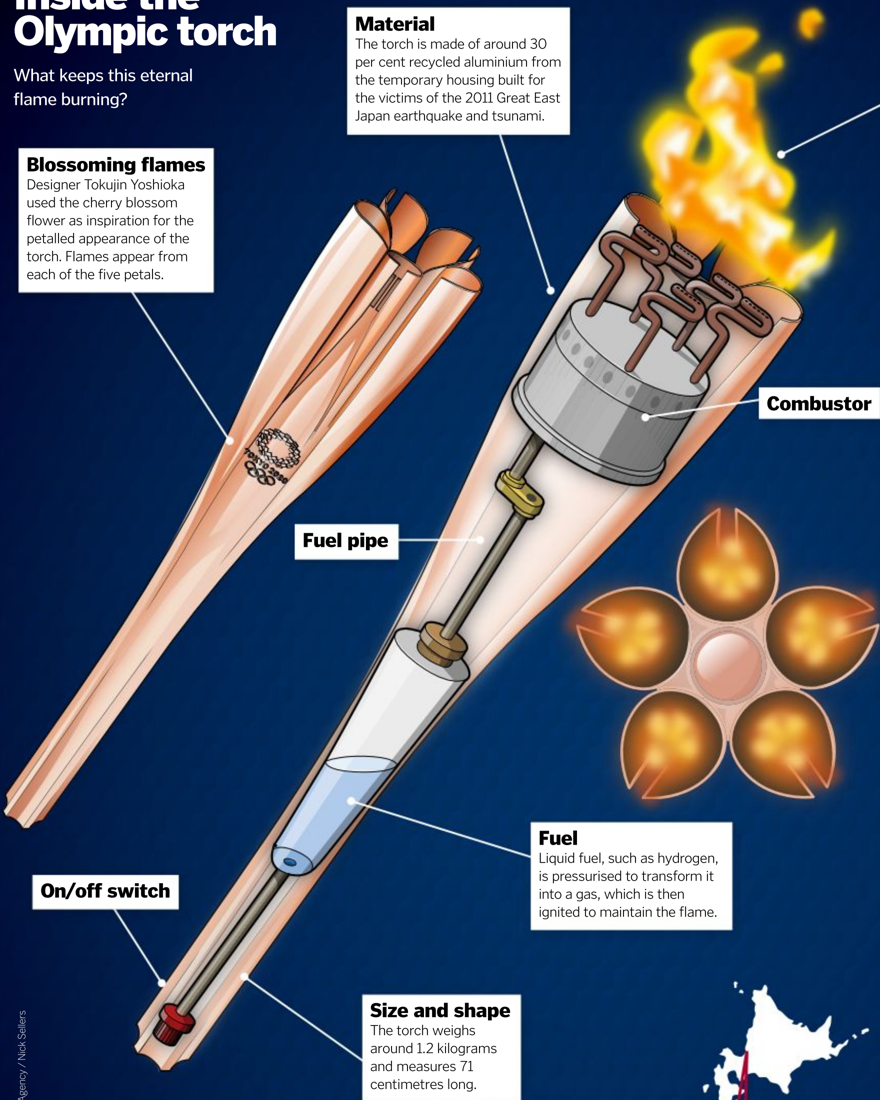
The Japanese rhythmic gymnastics team receiving gold medals at a Tokyo 2020 test event

© Getty

The latest relay began earlier this year in Fukushima on 25 March. For the following 121 days, the torch will make its journey through all 47 prefectures of Japan. Along the way through Fukushima, Aichi and parts of Tokyo, zero-emission hydrogen will be used as the flame's fuel source. Burning hydrogen emits no carbon dioxide into the atmosphere, and hydrogen fuel is rapidly growing in popularity as a more sustainable and renewable source of energy. Tech giant Toyota is aiming to deliver more than 500 hydrogen-fuelled vehicles to ferry athletes and officials to and from the Olympic events as a greener mode of transport.

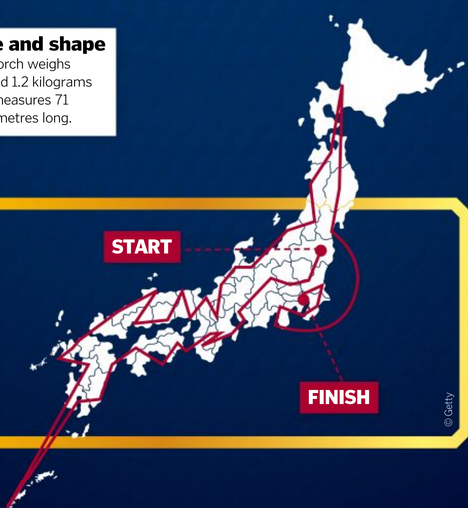
Inside the Olympic torch

What keeps this eternal flame burning?



OLYMPIC TORCH RELAY

Around 10,000 runners have been selected to jog around Japan to deliver the Olympic torch to the National Stadium. Each runner carries the torch for a distance of around 200 metres. The Olympic flame was flown in from Greece last year and delivered to Fukushima, where it ignited the 2020 torch.



NEW SPORTS AT THE TOKYO 2020 GAMES

1 Surfing
Crashing down on Tsurigasaki Beach are the best surfing athletes from around the world. The surfing events will take place over four days. However, due to the unpredictability of the waves, no exact date for these events has been given.

2 Skateboarding
Split into two categories, this year's skating Olympians compete in street and park skateboarding events. From zipping down handrails in the streets to powering through the hollowed-out courses at the Olympic park, athletes are judged on their originality, execution and tricks.

3 Sport climbing
20 athletes – both male and female – are taking part in this new event, which consists of three disciplines: speed, bouldering and lead climbing. After the events, each athlete is given a combined score from each discipline. Those with the lowest score progress to the final six and compete again for medal placement.

4 Karate
Six events make up this new Olympic sport, arranged by different weight divisions of the athletes: three categories for men and another three for women. Along with these combat events, two kata events showcase routines of punches and kicks.

5 Baseball/softball
These sports are no stranger to the Olympics, having been included in the games since the early 1900s. They were dropped after the 2008 Olympics but made their return this year, with the host nation among the favourites to win.

Q&A
Giarnni Regini-Moran


© Getty

Former junior gymnastics star Giarnni Regini-Moran makes his Summer Olympic debut for Great Britain this year. He won three gold medals at the 2014 Summer Youth Olympics in Nanjing, China, and a bronze medal on the vault at this year's European Championship. Giarnni reveals to How It Works what it takes to train for the Olympics and how the pandemic has played a role in preparation

WHAT DOES A TYPICAL DAY OF TRAINING LOOK LIKE FOR YOU?

When we're at the training camp we'll have breakfast at around 07:45 to 08:00, and then we'll get into the gym for 09:15 to 09:30, do our training and then finish around 13:00 for lunch. Then we will start back at 15:00 until about 17:00 or 17:30. We've been here [Lilleshall National Sports Centre] pretty much since January because we've had free Olympic trials, and now we've made it on the Olympic team we're continuing to stay here.

WHAT HAS BEEN THE BIGGEST TRAINING CHALLENGE FOR THIS YEAR'S GAMES?

Not knowing whether it's going to go ahead or not. You hear rumours that the Olympics may be cancelled, and you're still training so hard to try and chase your dream. In 2020 we were working so hard in January, and all of a sudden everything is cancelled. That's always been the hardest. We're training as if it's going ahead, but we could be doing all this work for nothing… the hardest part is trying to stay motivated.

HAS COVID AFFECTED HOW YOU TRAIN?

It's been difficult. Half the team got COVID in November, and as athletes we have to follow certain protocols. We had to do ten days of isolation and then another seven days of 'back to training', which is very minimal. Especially coming closer to the games, trying to avoid catching COVID, it's been tough. While the countries come out of a lockdown, we've almost got to go into one. It's been hard doing in-house competitions. Normally we'd be in arenas, there would be spectators, family, friends – having that real support behind you. But this time around everything's been done behind closed doors.


© Getty

Regini-Moran competing on the High Bar during the Men's Qualification of the FIG Artistic Gymnastics World Championships

Tokyo 2020 Robot Project

MEET THE MACHINES THAT ARE GIVING THIS YEARS' OLYMPICS AN UPGRADE


© Getty

Fetch and carry

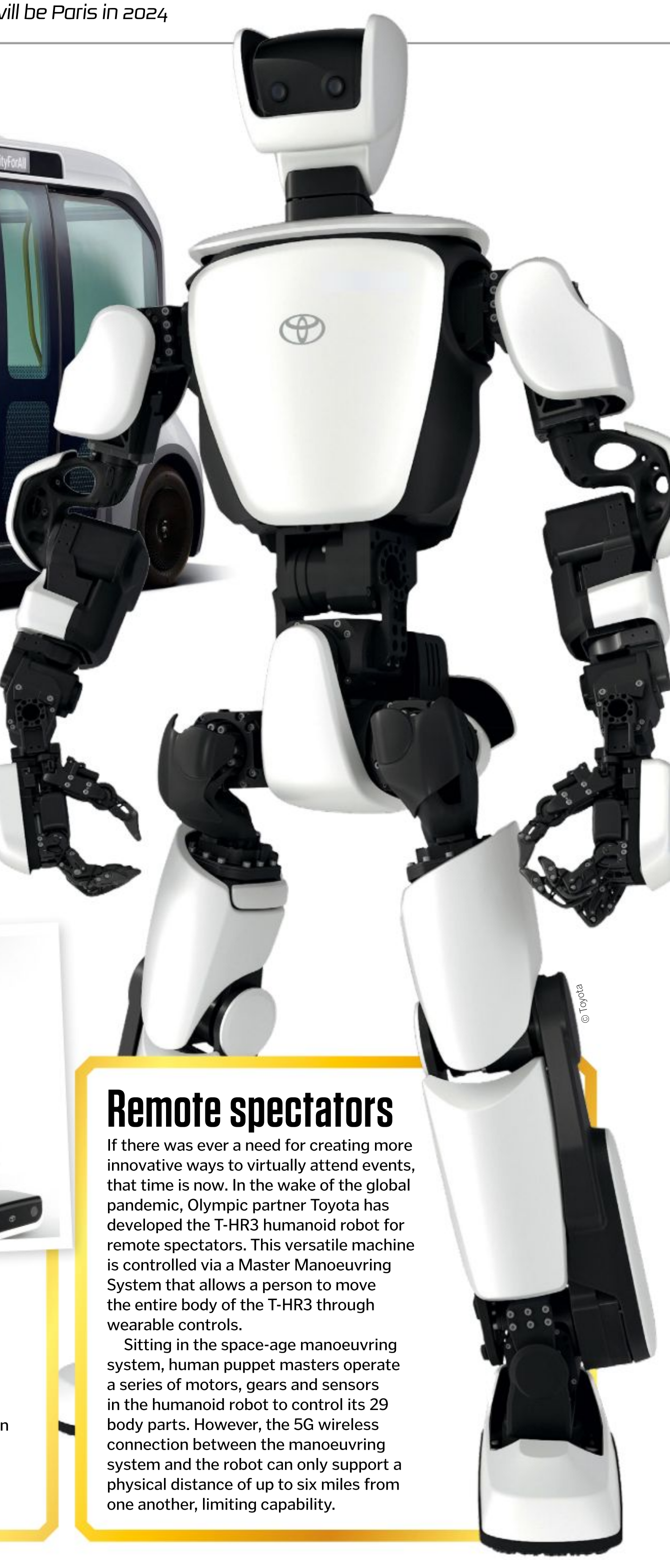
Meet the Field Support Robot (FSR). Its goal is to retrieve objects from throwing events, such as discuses and javelins. Much like a high-tech golf caddy, this robot has been created to autonomously follow a human member of staff who retrieves the objects, who can then place them in the FSR's built-in storage. The FSR works in a similar way to the many automatic vehicles seen in factories, using an AI-equipped camera to detect humans and the reflection of a laser beam to determine their distance. This robot utilises self-navigating technology to map routes along fields and pitches to avoid obstacles. This machine reduces the number of staff needed to collect objects and brings down the time it takes to collect them.

Battling backache

To ease the strain of lifting boxes, transporting waste and unloading luggage, tech giant Panasonic has developed a power-assisted suit called the ATOUN Model Y. The carbon-fibre frame weighs around 4.5 kilograms, but can offer an additional lifting force of up to ten kilograms. Worn like a backpack, this device can pull the body up using a series of motors when lifting, lock in place during transport and support the body when lowering items.

© Getty

© Toyota


© Toyota

High-tech, low-emission cars

Continuing with efforts to deliver a zero-carbon event – or at least as close as possible – Olympic organisers have partnered with manufacturer Toyota to create several new vehicles to transport athletes between the Olympic Village and their events using renewable energy sources. The e-Palette is a battery-powered vehicle that uses LiDAR technology, similar to that used on large ocean vessels, to map out its surroundings and drive autonomously. Toyota has also created public transport fuelled by hydrogen with its Sora fuel cell-powered bus. Sora, an acronym for the water cycle – sky, ocean, river and air – can carry up to 78 passengers and transport them while releasing no carbon.


© Toyota

Robotic assistants

Meet the Human Support Robot (HSR) and Delivery Support Robot (DSR), both supporting the various activities of Olympic spectators. From guiding people to their seats to delivering food, these handy robots have been designed under the concept of providing support to everyone, including people with impairments.

Remote communication

Near life-size displays have been combined with a set of wheels to create the T-TR1. These machines allow remote spectators to have two-way communication with people at the events using a built-in 360-degree camera. It essentially uses the same connectivity technology as your phone when making a video call.

Remote spectators

If there was ever a need for creating more innovative ways to virtually attend events, that time is now. In the wake of the global pandemic, Olympic partner Toyota has developed the T-HR3 humanoid robot for remote spectators. This versatile machine is controlled via a Master Manoeuvring System that allows a person to move the entire body of the T-HR3 through wearable controls.

Sitting in the space-age manoeuvring system, human puppet masters operate a series of motors, gears and sensors in the humanoid robot to control its 29 body parts. However, the 5G wireless connection between the manoeuvring system and the robot can only support a physical distance of up to six miles from one another, limiting capability.

Tokyo 2020 Olympic Games in numbers

COST OF THE GAMES

2013 estimate:
£5.6 billion
($7.5 billion)

2021 estimate:
£18 billion
($26 billion)

DAYS OF SPORTING EVENTS

1964 Tokyo has hosted the Olympic Games twice. The first was 57 years ago

68,000 There are around 11,000 more seats at the Tokyo stadium than at the Rio 2016 Games' Estádio Olímpico Nilton Santos

528 The number of Japanese towns registered to welcome international competitors

THE YOUNGEST & OLDEST COMPETING ATHLETES

Youngest
Hend Zaza, Syria
12 years old
Table tennis

Oldest
Ni Xialian, Luxembourg
57 years old
Table Tennis

33 categories with 339 EVENTS

6,000
Around 4,000 fewer athletes are attending the opening ceremony than predicted

92.5% SILVER
for both gold and silver medals

6 GRAMS
First-place medals are plated with at least six grams of pure gold

60mm DIAMETER
3mm THICK

32kgs GOLD
3,500kgs SILVER
2,200kgs COPPER AND ZINC

4
THE NUMBER OF DEBUTING OLYMPIC SPORTS AT THE 2020 GAMES

42
The total number of venues in Japan hosting Olympic events

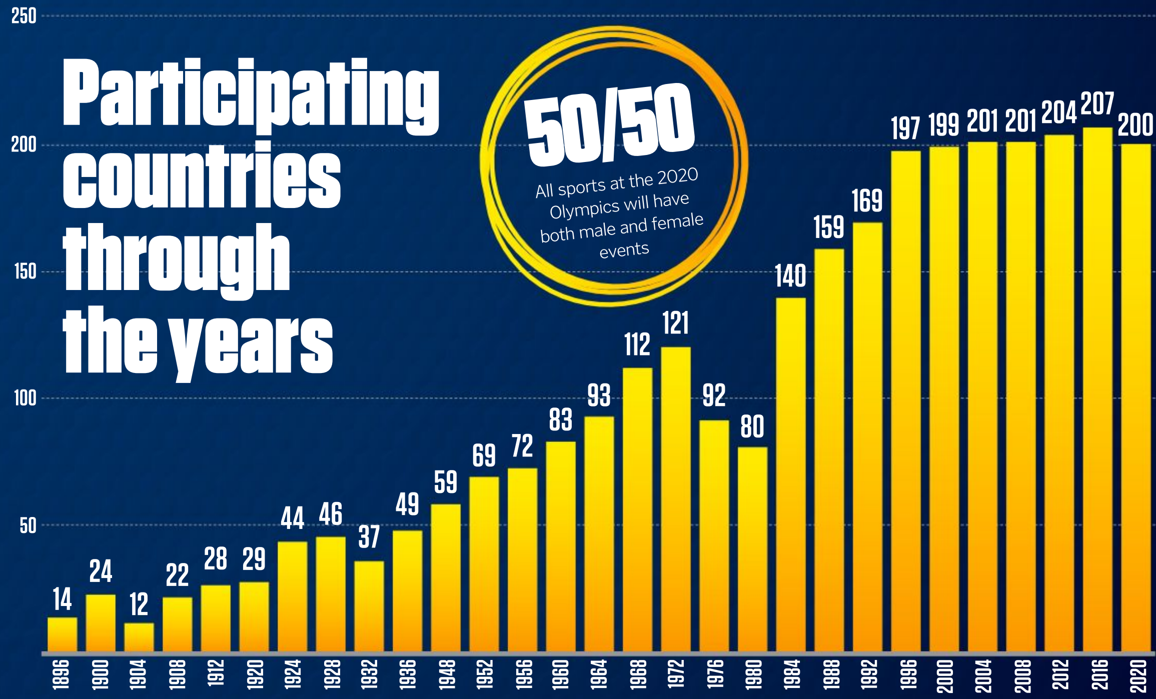
6,210,000
Millions of mobile phones were donated for medal-making materials, contributing to 78,985 tonnes of scrap

5,000 MEDALS WILL BE MADE FOR WINNING OLYMPIANS

47
The Olympic Stadium was constructed using timber from all 47 Japanese prefectures

Participating countries through the years

50/50
All sports at the 2020 Olympics will have both male and female events

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Inside 10 Downing Street

Take a tour of the UK prime minister's official abode

Words by **Ailsa Harvey**

Ever since Robert Walpole, the first person regarded as holding the power and position of a British prime minister, 10 Downing Street has been the prime minister's official residence. This came about when King George II offered Walpole the building as a gift in 1732. Walpole accepted it on the condition that it was not a gift solely to him, but to whoever held his position. To this day, the role of prime minister has come with this gift.

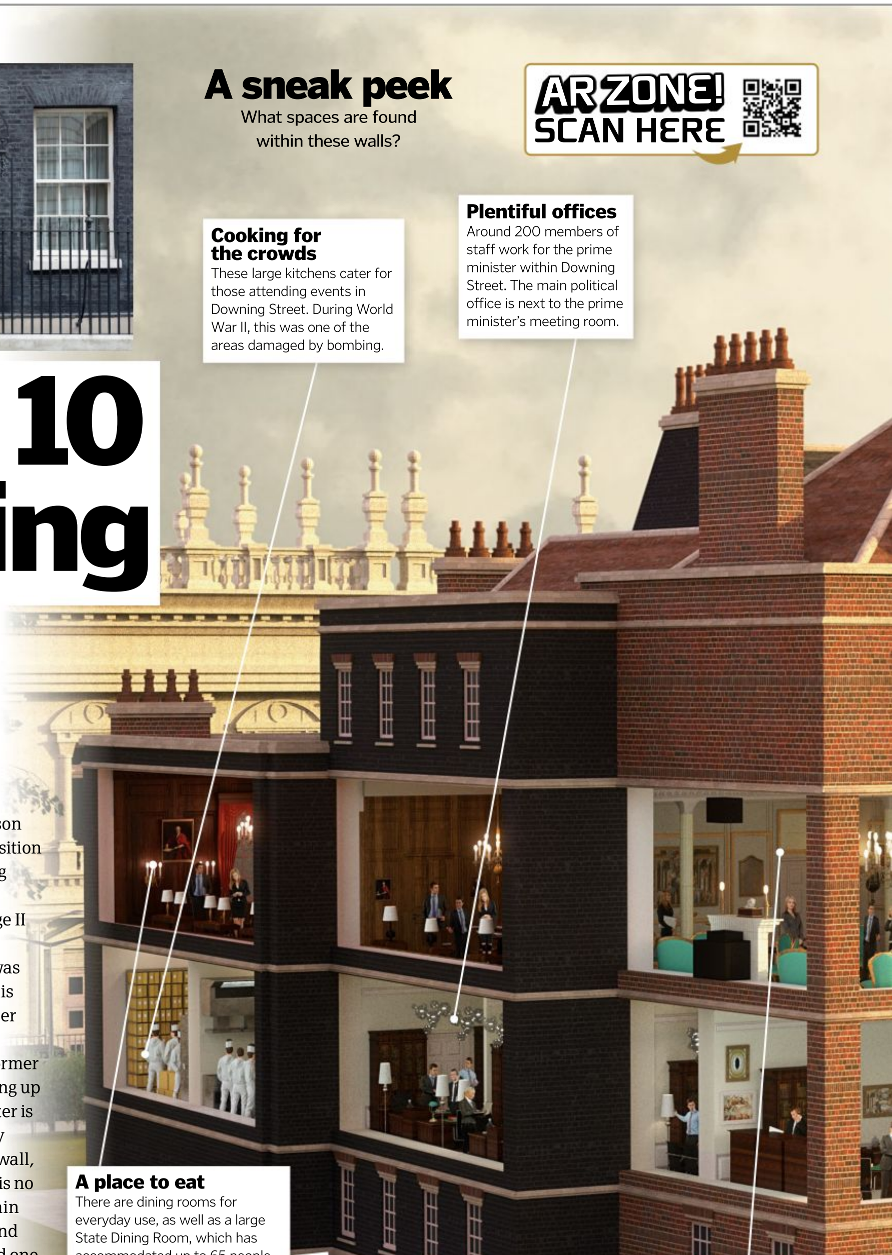
Signifying this tradition, the portraits of former prime ministers are placed on the wall leading up its grand staircase. The current prime minister is missing from this display, but as soon as they leave office the frames are shifted down the wall, and a new portrait is added at the top. There is no requirement for a prime minister to live within these walls, however. In fact, between 1735 and 1902, only 16 of the 32 leading statesmen – and one woman – stayed there. In more recent years many prime ministers, such as the UK's current leader Boris Johnson, chose to move into Number 11, where there is a more spacious flat.

Behind the famous, bomb-proof black door of 10 Downing Street is a mansion of around 100 rooms. The building's purpose isn't just to add comfort to the life of the prime minister, but to create a setting where some of the most important decisions can be made on behalf of the country.

A sneak peek

What spaces are found within these walls?

AR ZONE! SCAN HERE



Cooking for the crowds
These large kitchens cater for those attending events in Downing Street. During World War II, this was one of the areas damaged by bombing.

Plentiful offices
Around 200 members of staff work for the prime minister within Downing Street. The main political office is next to the prime minister's meeting room.

A place to eat
There are dining rooms for everyday use, as well as a large State Dining Room, which has accommodated up to 65 people.

Hosting grand receptions
This is the Pillared Room, which is used for the biggest receptions, including the signing of international agreements.


© Getty

The State Dining Room was designed in 1825 by Sir John Soane


© Getty

Guests are often shown the Pillared Room before they're seated to dine

The Blue, or Green, or Terracotta room

Its name frequently changes as the walls are painted new colours. This space was initially used for dining in.

© Alamy

Until 1940, the White Room was used by prime ministers for privacy

Not just Number 10

It might often be referred to as Number 10, but the prime minister's facilities actually cover more residences. The main building has been connected to the backward-facing Number 11, while Number 9 and Number 12 are also in use. 9 Downing Street is where press briefings take place. In the media room, the prime minister broadcasts to the country and the press. Number 12 is primarily used as offices for employees, and was traditionally home to the chief whip, who makes sure members of the political party attend and vote in parliament.

© Getty

A new media briefing room in Number 9 was unveiled in 2021

Luxurious living

On the top floor there is a large flat where the prime minister can choose to live.

Appointments with the chancellor

The chancellor has the option to live in Downing Street and is assigned this area to hold informal meetings.

The chancellor's workplace

This is where the chancellor works to track and control the country's finances.

The weekly gathering

Surrounded by sound-proof walls, the cabinet meets here on a weekly basis to discuss domestic and foreign affairs.

© Getty

The Cabinet Room in 1964

Enter the den

Important decisions are often made in the prime minister's meeting room, also referred to as the 'den'.

Areas for errands

At the back of the building are garden-facing rooms for Downing Street's secretaries. These secretaries attend to the prime minister's daily needs.

Illustrations by © Nicholas Forder

Dian Fossey, the world's leading gorilla expert

Fossey gained valuable insight into the world of gorillas through observation and habituation

The little blue cabin at Karisoke Research Center where Fossey lived while studying the mountain gorillas

A life's work

Fossey's life has been punctuated by some incredible zoological moments

1932
Fossey is born on 16 January in San Francisco, California, and grows up with her mother and stepfather.

1963
She travels to Africa and meets the 'gorillas of the misted mountains' for the first time.

Dian Fossey

This primatologist lived and died to protect mountain gorillas

Dian Fossey developed a love of animals at an early age, from learning to ride horses at six to working on a ranch in Montana at 19. However, when she decided to join the University of California as a pre-veterinary student, she found parts of the course too hard and changed direction, gaining a degree in occupational therapy. Initially she was content with working at a hospital in Kentucky, but when a friend showed her some photographs that she had taken while on holiday in Africa, Fossey realised that she too wanted to travel and see the world.

In 1963 she took out a bank loan and headed out on the adventure of a lifetime, journeying across Kenya, Zimbabwe, Tanzania – where she met future mentor Dr Louis Leakey – and finally Congo. When Fossey joined wildlife photographers Joan and Alan Root on an expedition up into the Virunga Mountains, she laid eyes on the magnificent mountain gorillas for the first time.

On returning to the US, Fossey published a number of articles about her first encounter with the gorillas, and with Leakey's support she secured funding for a return trip to Africa. Having set up camp in Kabara, Congo, she began observing the gorillas, learning to imitate their behaviour until eventually they accepted her. She could then follow the groups around, keeping detailed notes of their daily lives.

Due to a violent rebellion in Zaire (now Congo), Fossey was forced to flee her camp, but she refused to give up on her work. She travelled to Rwanda, where she could continue habituating with the gorillas, and set up the Karisoke Research Center. When a National Geographic Society photographer started taking photos of her working alongside the gorillas, Fossey became an overnight sensation. She soon used her newfound celebrity status to highlight the plight of these beautiful creatures at the hands of poachers.

> "Fossey became an overnight sensation. She soon used her newfound celebrity status to highlight the plight of these beautiful creatures at the hands of poachers"

She began chasing the poachers through the trees wearing terrifying masks and setting fire to their traps. She employed a group of park wardens to deter the hunters, but when her favourite gorilla 'Digit' was brutally slaughtered, Fossey became far more confrontational. Describing her methods as 'active conservation', she was able to draw attention to the precarious position of the mountain gorillas, but the poachers were infuriated by her meddling.

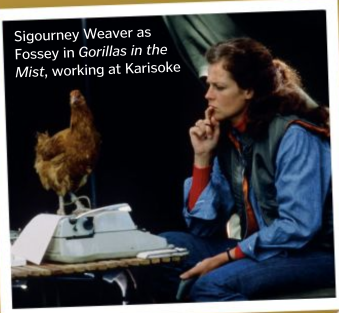
Just before her 54th birthday, Fossey was struck down with a machete in her cabin. Her murder still remains unsolved, but some believe she was killed by poachers. She left behind a wealth of fascinating data on mountain gorillas, paving the way for primatology students to follow their dreams.

THE BIG IDEA

In 1967, Fossey established the internationally renowned Karisoke Research Center

Nestled between Mount Karisimbi and Mount Bisoke in a Rwandan alpine meadow, Fossey set up a camp that would eventually become a world-famous centre for primatology studies. It was here that she successfully gained the trust of the shy mountain gorillas, and through sheer perseverance and determination she gathered vital data that would be used by future generations of zoologists, environmental campaigners and primatology students the world over.

Fossey perfected the process of 'habituation' – gaining the trust of the gorillas by mimicking their behaviour – and in doing so changed our perception of the mountain gorilla from vicious killer to gentle giant.



Sigourney Weaver as Fossey in *Gorillas in the Mist*, working at Karisoke

IN THEIR FOOTSTEPS

Mireya Mayor

In 2000, having been inspired by Fossey as a child, anthropologist Mireya Mayor helped discover the world's smallest primate, a tiny mouse lemur dubbed *Microcebus mittermeieri*. Her discovery has led to the creation of a national park in the heart of Madagascar, solely established to protect this rare and beautiful primate. Having received her PhD from Stony Brook University, Mayor has dedicated her life to studying wildlife in Africa and sharing her knowledge with audiences around the world.

Biruté Galdikas

Born in 1946, Galdikas is considered a leading authority on orangutans. Inspired by the photographs of Dian Fossey in *National Geographic*, Galdikas studied psychology and zoology before completing a master's in anthropology. She went on to pioneer the study of orangutans in their natural habitat of Borneo, and like her heroine Fossey, campaigns on behalf of primate conservation and the protection of the rainforest. In 1997 she received the Tyler Prize for Environmental Achievement.

1967 Fossey establishes the Karisoke Research Center in Rwanda.

1968 Photographer Bob Campbell of the National Geographic Society captures images of her work, making a star of the primatologist.

1974 She completes her PhD, having enrolled in the department of animal behaviour at Darwin College, Cambridge.

1978 Fossey establishes the Digit Fund, later known as the Dian Fossey Gorilla Fund International, or 'Fossey Fund'.

1980 She begins writing the manuscript for her bestselling book *Gorillas in the Mist* while staying in New York.

1985 Fossey's body is discovered in her cabin at Karisoke on 27 December, a few weeks before her 54th birthday.

ANIMAL OLYMPIANS

Animals aren't eligible to compete in the Tokyo Olympics, but could easily earn the top spot on the podium without a day of training

Words by **Amy Grisdale**

© Getty

SPRINTER

Cheetah

As far as we know, there has never been an animal on Earth as fast as a cheetah on land. That goes for everything living today and every species that's ever gone extinct. Early ancestors of the cheetah could only reach 20 miles an hour. During the process of evolution, the fastest cats were the most likely to survive because they'd have the best chances of catching prey. Because the ability to sprint fast is passed down from parent to cub, with each new generation the species started speeding up.

The drive behind the evolution of acceleration was food. But at the same time faster cheetahs were getting ahead in life, prey animals were getting a move on too. This increased the pressure on the predators. In those conditions, only those with extreme sprinting abilities can survive long enough to pass on their genes to the next generation, and world-champion sprinters were born.

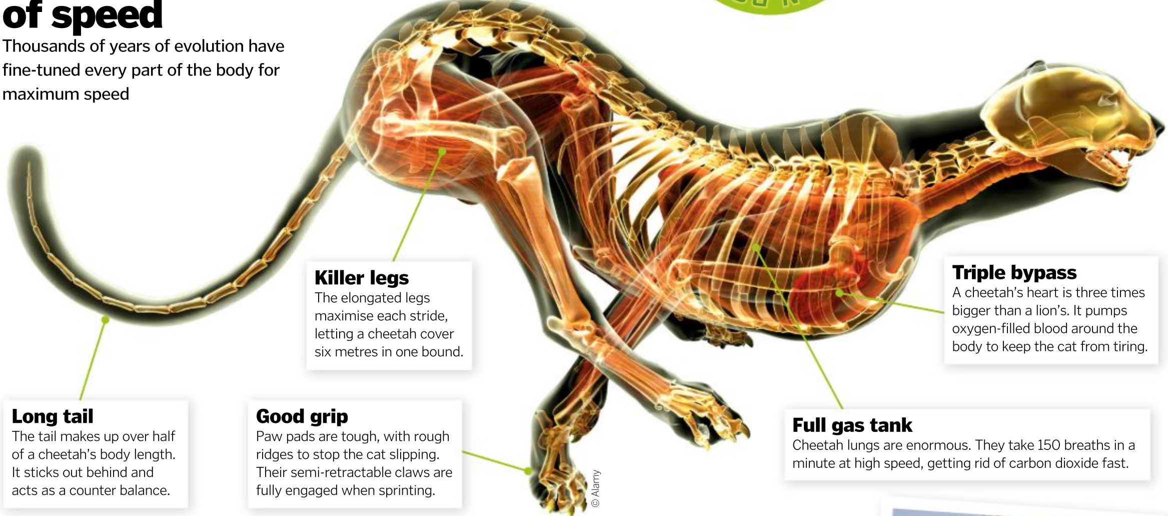

Speed is ideal when chasing down dinner

© Getty

ANIMAL RECORD
65 MILES PER HOUR
HUMAN RECORD
27.78 MILES PER HOUR

Built for bursts of speed

Thousands of years of evolution have fine-tuned every part of the body for maximum speed



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LONG-DISTANCE RUNNER

Wolf

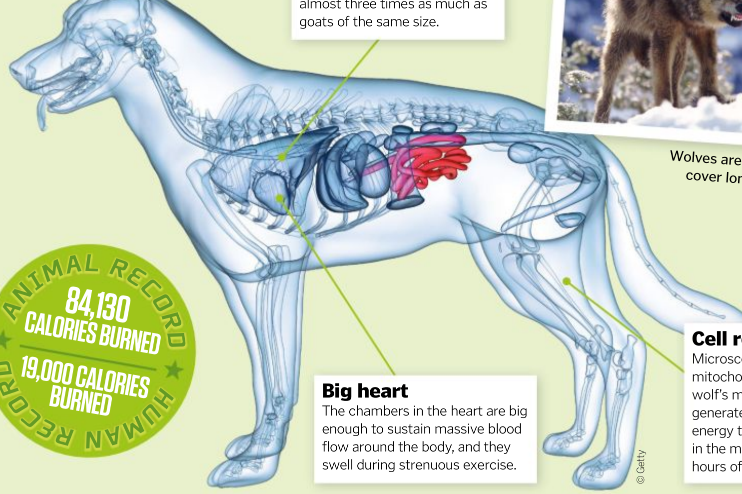
Simply put, wolves can burn many more calories than the fittest athletes on Earth. Wolves were tested racing 300 miles over three days to see how they matched up to the average Tour de France cyclist. The results showed wolves can generate four times as much energy than a human athlete at their physical peak.

The secret to a wolf's endurance is its lifestyle. These animals are on the move around the clock. They can run as fast as 38 miles per hour for short periods, but can comfortably trot around at five miles per hour all day long.

ANIMAL RECORD
84,130 CALORIES BURNED
HUMAN RECORD
19,000 CALORIES BURNED


Wolves are well built to cover long distances

© Getty



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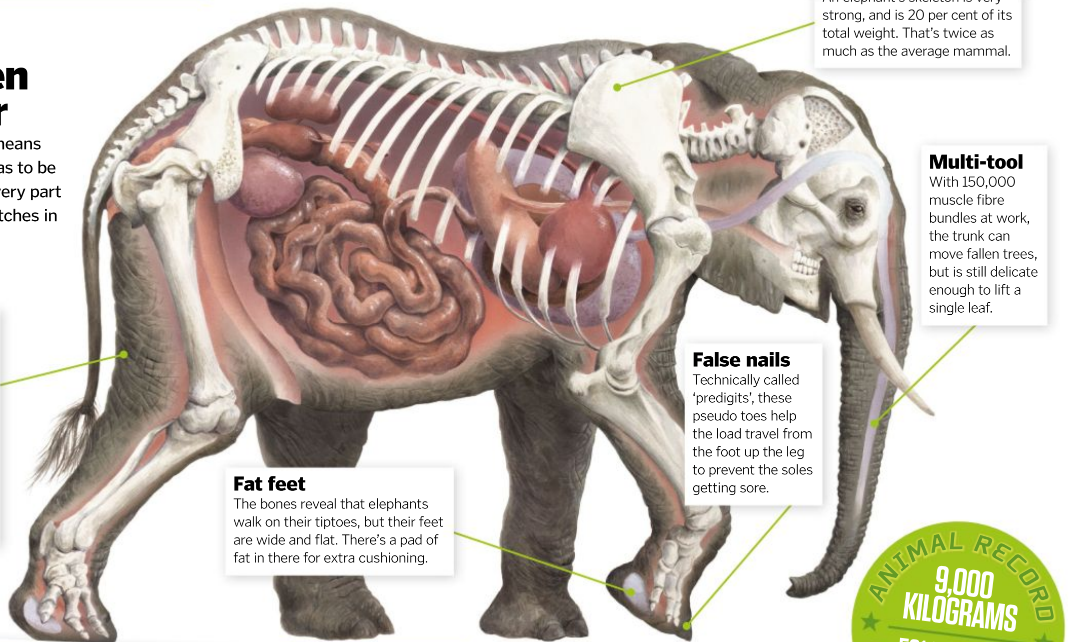
Hidden power

Being so big means an elephant has to be strong, and every part of the body pitches in with the load



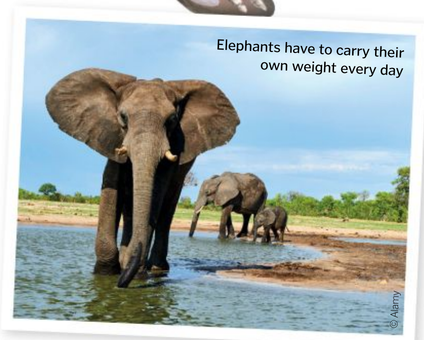
Big bones
An elephant's skeleton is very strong, and is 20 per cent of its total weight. That's twice as much as the average mammal.

Multi-tool
With 150,000 muscle fibre bundles at work, the trunk can move fallen trees, but is still delicate enough to lift a single leaf.

Precise position
The limbs are strategically placed in a near-vertical position from the body, like the legs on a coffee table, for strength and stability.

False nails
Technically called 'predigits', these pseudo toes help the load travel from the foot up the leg to prevent the soles getting sore.

Fat feet
The bones reveal that elephants walk on their tiptoes, but their feet are wide and flat. There's a pad of fat in there for extra cushioning.



Elephants have to carry their own weight every day

© Alamy

WEIGHTLIFTING

African elephant

ANIMAL RECORD
9,000 KILOGRAMS
501-KILOGRAM DEADLIFT
HUMAN RECORD

As the biggest terrestrial mammal living today, it's no surprise that elephants are heavyweight champions. An African elephant can lift more than 300 kilograms with its trunk alone. This unique appendage can also suck in water, blast out 110 decibels of sound and has a better scent-tracking ability than a bomb-sniffing dog.

The muscle-filled trunk is so strong that in experiments elephants involved have been known to accidentally break the equipment with their brute strength.

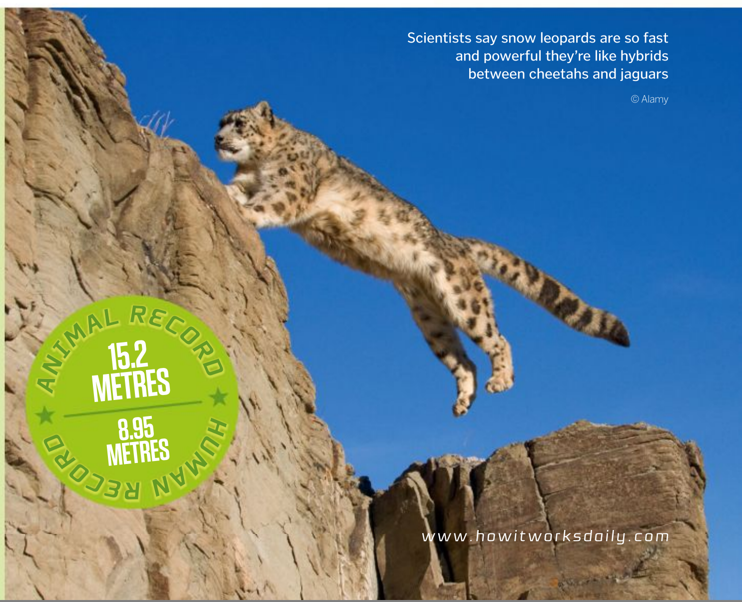
People have been marvelling at the amount of weight elephants can carry for thousands of years. They have been used for transportation and hauling for generations, although the practice seems to be falling from favour. Scientists now think that piling a lot of weight on an elephant's back can hurt their backbones, and even a single person riding an African elephant can cause damage.

LONG JUMP

Snow leopard

One of the world's most elusive big cats specialises in taking down wild sheep and goats high in mountain ranges. Snow leopards kill animals three times their size without any help and snack on hares and birds in between feasts. Snow leopards are masters of difficult terrain. Their bodies are built to climb, move through snow and chase prey at high speed, but their leaping ability is by far the most impressive. Aided by large pectoral muscles and a flexible clavicle, the front limbs swing wide and have enough grip to stick a landing.

They have adapted to jump long distances because of their preferred environment. Snow leopards found success living in clifftop caves and rocky outcrops where there was no competition. There also wasn't as much prey around, so the species started spreading out. Snow leopards claim huge territories, some as large as 80 square miles – that's three times the size of Manhattan.



Scientists say snow leopards are so fast and powerful they're like hybrids between cheetahs and jaguars

© Alamy

ANIMAL RECORD
15.2 METRES
8.95 METRES
HUMAN RECORD

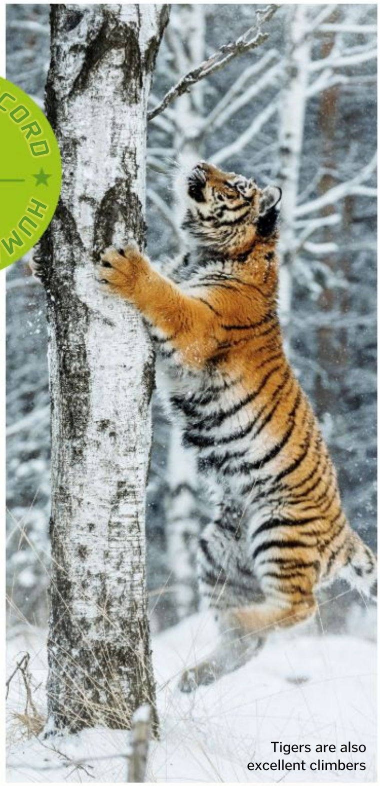
HIGH JUMP

Tiger

Weighing up to 310 kilograms, tigers are the heaviest big cat in existence. Because of their huge mass, they don't have the option to chase prey at high speeds like a cheetah. A tiger prefers to stalk prey, remaining hidden until it's close enough to leap out and catch the animal off guard. It waits until it's between six and nine metres away to strike. The fact that tigers do most of their hunting in the dead of night adds to the surprise factor.

They're solitary and free-roaming, so they're pounding the jungle pavement from dusk to dawn. Tigers need to hunt as much as possible to bring in enough energy to survive their nomadic lifestyle. Almost 75 per cent of a tiger's diet is made up of deer. These are easily startled and can escape in the blink of an eye if they feel threatened. A pouncing tiger only has one shot, and being able to ambush from above is its best chance of getting the kill.

ANIMAL RECORD
4.9 METRES
2.45 METRES
HUMAN RECORD

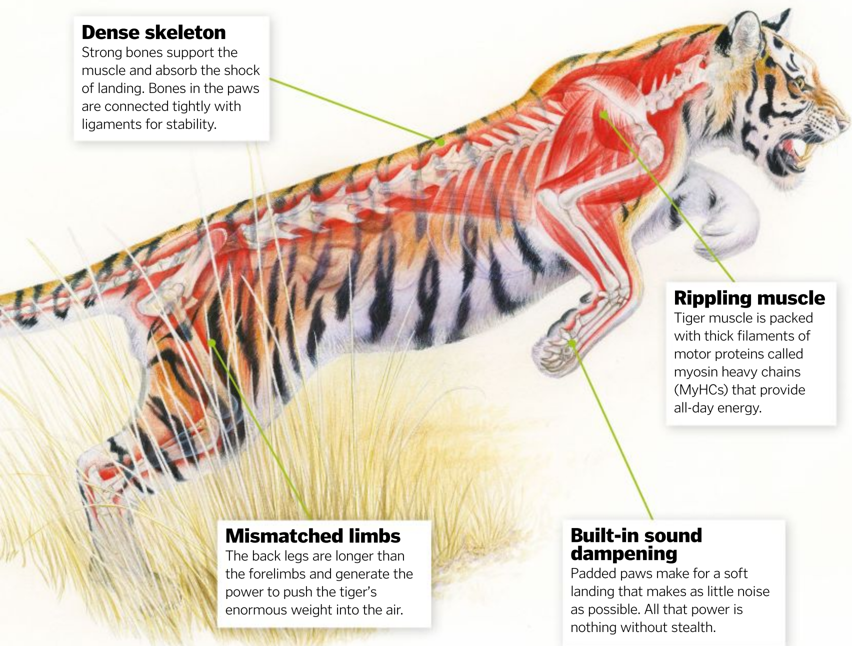


Tigers are also excellent climbers

© Alamy

Inside a champion jumper

The largest living cats rely on immense agility to survive, and their anatomy is key



Dense skeleton
Strong bones support the muscle and absorb the shock of landing. Bones in the paws are connected tightly with ligaments for stability.

Rippling muscle
Tiger muscle is packed with thick filaments of motor proteins called myosin heavy chains (MyHCs) that provide all-day energy.

Mismatched limbs
The back legs are longer than the forelimbs and generate the power to push the tiger's enormous weight into the air.

Built-in sound dampening
Padded paws make for a soft landing that makes as little noise as possible. All that power is nothing without stealth.

Burly bodybuilders

HARPY EAGLE

EIGHT KILOGRAMS

Considered the world's most ferocious eagle, this bird can carry almost its entire body weight. They're famous for grabbing monkeys from treetops and flying away with a meal clutched in their talons. Females are bigger and stronger than males, who make up for it with speed and agility.

© Getty

GORILLA

2,000 KILOGRAMS

The inspiration for the legendary King Kong can lift ten times their own body weight. That works out as the combined weight of 30 people. Scientists estimate gorillas are six times stronger than a professional weightlifter. Even their jaw muscles are hefty, delivering a bite force higher than a lion or great white shark.

© Getty

AMERICAN FIELD ANT

25 GRAMS

It might not sound impressive until you know that these tiny ants, which only weigh a few milligrams, can lift 5,000 times their own mass. Scaled up to human size, that's the equivalent of being able to walk around with a blue whale balanced on each shoulder.

© Getty

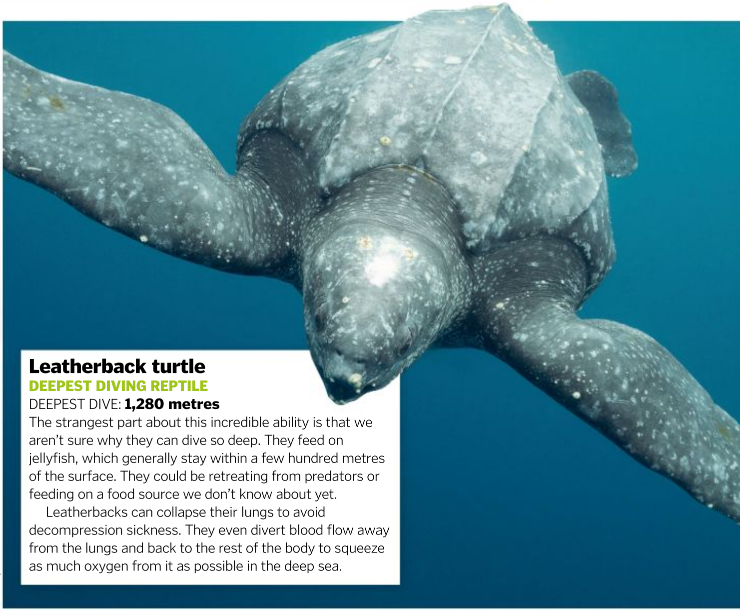
AQUATIC EVENTS

The animals of the ocean outstrip humans for every record imaginable

Human
DEEPEST DIVE: **332.35 metres**
FASTEST SWIM: **5.34 miles per hour**
LONGEST DISTANCE SWIM: **139.8 miles**

© Getty

Emperor penguin
DEEPEST DIVING BIRD
DEEPEST DIVE: **564 metres**



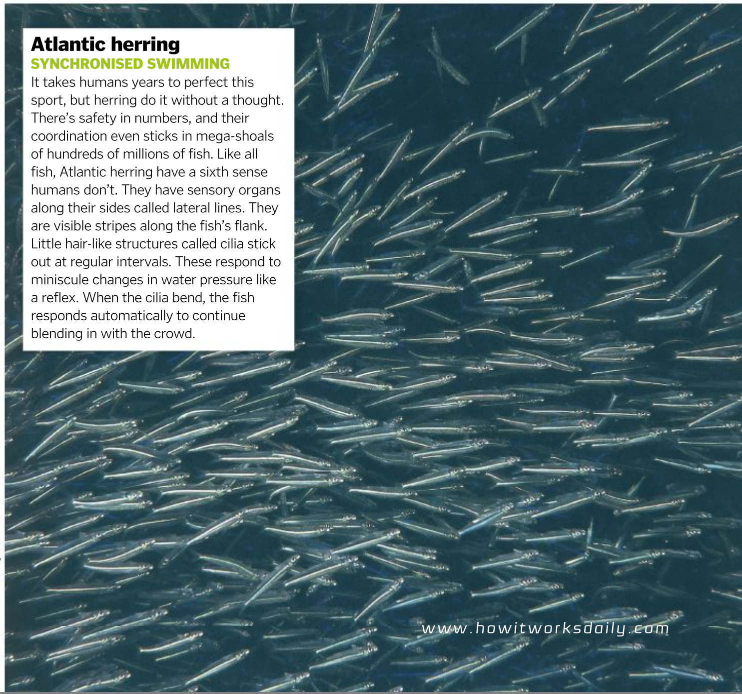
Leatherback turtle
DEEPEST DIVING REPTILE
DEEPEST DIVE: **1,280 metres**

The strangest part about this incredible ability is that we aren't sure why they can dive so deep. They feed on jellyfish, which generally stay within a few hundred metres of the surface. They could be retreating from predators or feeding on a food source we don't know about yet.

Leatherbacks can collapse their lungs to avoid decompression sickness. They even divert blood flow away from the lungs and back to the rest of the body to squeeze as much oxygen from it as possible in the deep sea.

© Alamy

Polar bear
LONGEST DISTANCE SWIMMING BEAR
LONGEST SWIM: **426 miles**



Atlantic herring
SYNCHRONISED SWIMMING

It takes humans years to perfect this sport, but herring do it without a thought. There's safety in numbers, and their coordination even sticks in mega-shoals of hundreds of millions of fish. Like all fish, Atlantic herring have a sixth sense humans don't. They have sensory organs along their sides called lateral lines. They are visible stripes along the fish's flank. Little hair-like structures called cilia stick out at regular intervals. These respond to miniscule changes in water pressure like a reflex. When the cilia bend, the fish responds automatically to continue blending in with the crowd.

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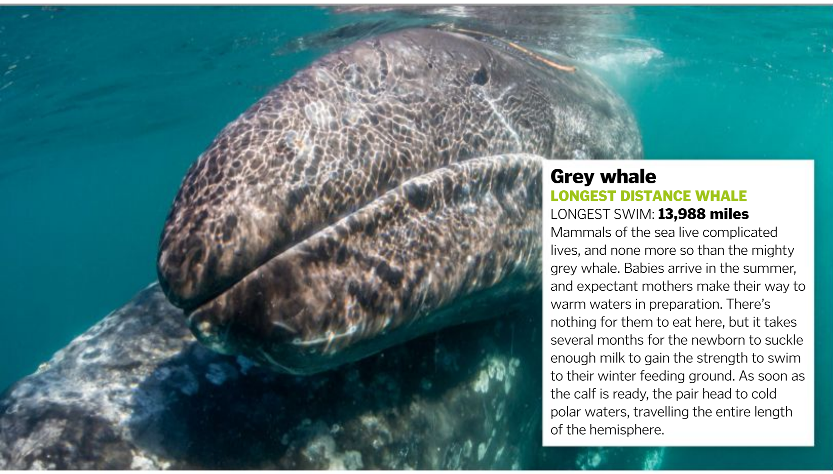
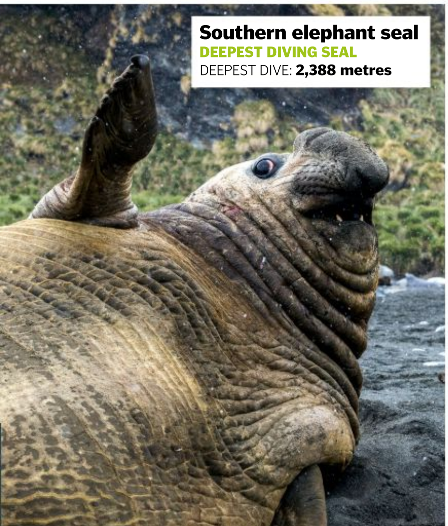


Grey whale
LONGEST DISTANCE WHALE

LONGEST SWIM: **13,988 miles**

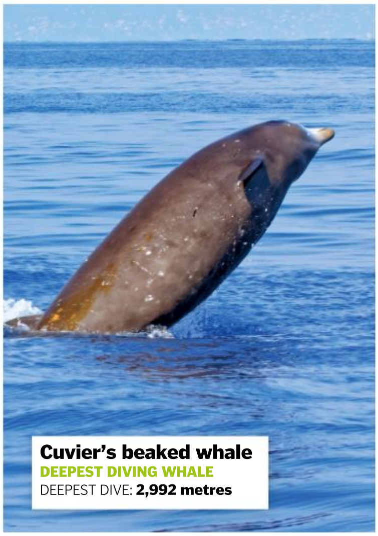
Mammals of the sea live complicated lives, and none more so than the mighty grey whale. Babies arrive in the summer, and expectant mothers make their way to warm waters in preparation. There's nothing for them to eat here, but it takes several months for the newborn to suckle enough milk to gain the strength to swim to their winter feeding ground. As soon as the calf is ready, the pair head to cold polar waters, travelling the entire length of the hemisphere.

© Getty



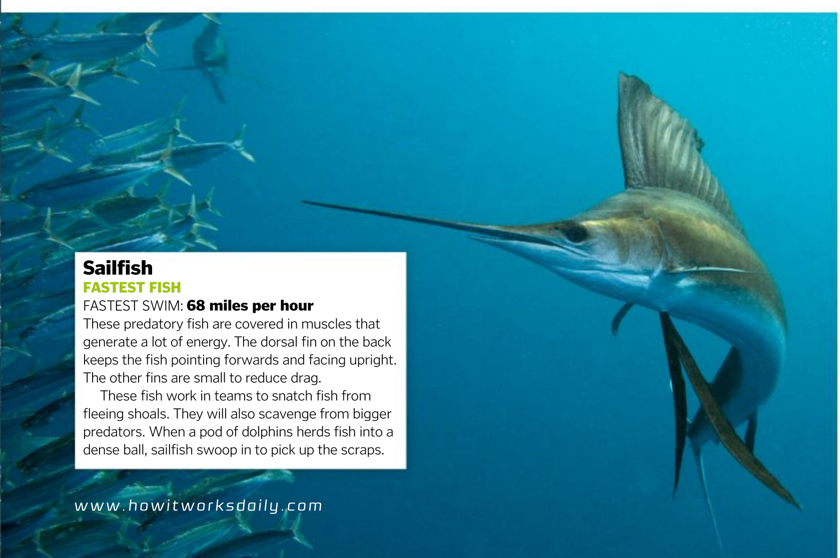
Southern elephant seal
DEEPEST DIVING SEAL

DEEPEST DIVE: **2,388 metres**



Cuvier's beaked whale
DEEPEST DIVING WHALE

DEEPEST DIVE: **2,992 metres**



Sailfish
FASTEST FISH

FASTEST SWIM: **68 miles per hour**

These predatory fish are covered in muscles that generate a lot of energy. The dorsal fin on the back keeps the fish pointing forwards and facing upright. The other fins are small to reduce drag.

These fish work in teams to snatch fish from fleeing shoals. They will also scavenge from bigger predators. When a pod of dolphins herds fish into a dense ball, sailfish swoop in to pick up the scraps.

© Getty

PEREGRINE FALCON
FASTEST SKYDIVE

© Getty

These hardy birds of prey reach 200 miles per hour when diving. The bird circles half a mile from the ground searching for signs of movement below with its excellent vision. These birds are the fastest of all land, sea and air animals on Earth today.

ARCTIC TERN
LONGEST FLIGHT

© Getty

Don't be fooled by the name. These birds are constantly flying around Earth. They fly from pole to pole and back every single year of their lives. This annual journey ranges from 44,000 to 59,000 miles, and the average Arctic tern will fly 1.5 million miles during its 30-year life span.

GOAT
FARMYARD SKATEBOARDING

© Getty

Happie the goat of Florida clocked in 36 metres on a skateboard in a time of 25 seconds in 2012. Goats are famous for their nimble feet and ability to navigate sheer cliffs with small ledges, which makes skateboarding their second-best sport after rock climbing.

MACAW
AVIAN BASKETBALL

© Alamy

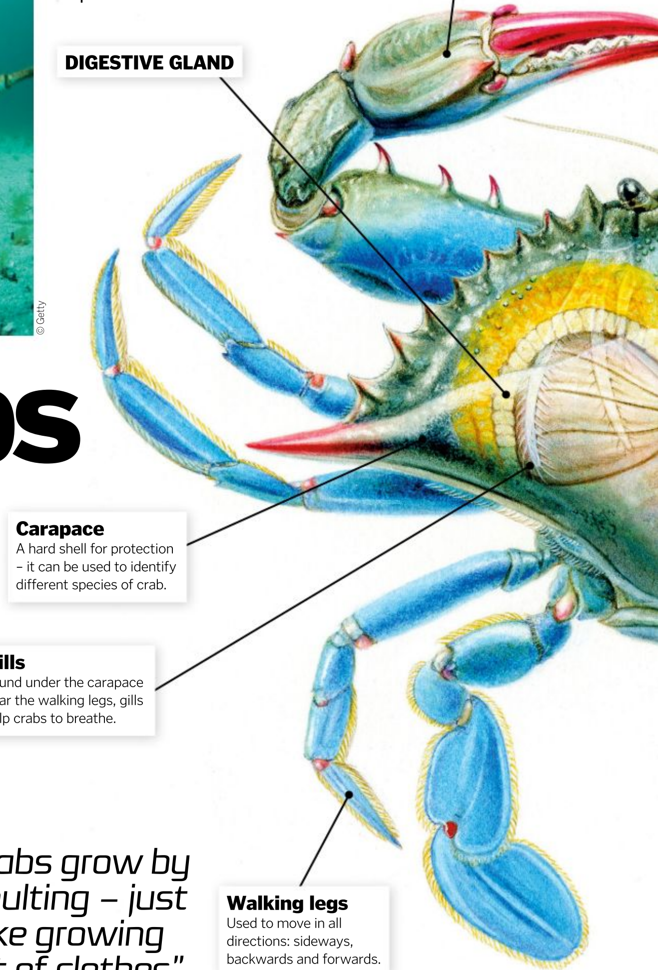
On 30 December 2011, Zac the macaw broke the world record for most basketball slam dunks in 60 seconds. He sank 22 shots with his sickle-shaped beak. These birds use their beaks like a third foot, letting it hold their entire body weight while grasping for food.

A spider crab high on its legs in the fighting pose

© Getty

Crab anatomy

Let's take a look at some features that help crabs survive



Why crabs are vital

These crustaceans are really fascinating, and have an important job in the ocean

Words by **Lauren Eyles**

There are over 4,000 different species of crab in the world, and some are pretty weird. The largest is the Japanese spider crab, which can reach the length of a car. The smallest is the pea crab, and as its name suggests, it's about the size of a pea – just a few millimetres wide. Not all crabs live in the ocean; there are some that live on land and in freshwater, only returning to the ocean on long migrations to mate.

Crabs are crustaceans, and belong to a group of animals called 'decapods', which means ten legs. They have eight on their sides used for walking and swimming, and a larger, stronger set at the front used for catching and crushing prey. They also use these oversized claws to help in fighting, as well as their hard exterior shell, the carapace, which protects their soft bodies inside.

Crabs grow by moulting – just like growing out of clothes, a crab has to do the same. They grow out of their shell and into a new, softer one. This happens when a new soft shell has developed underneath, and is also the time that most crabs are ready to mate.

It's really easy to tell male and female crabs apart, you just have to turn a crab over and look at its belly, or abdominal pouch: in males it's tall and triangular shaped, whereas in females it's a wide semi-circle, where she will carry hundreds of eggs after mating.

The best place to find crabs is on the seashore, where they are perfectly adapted to water changes from the tides. They have a busy and important role to play in keeping the ocean clean, and some people think they are very tasty too.

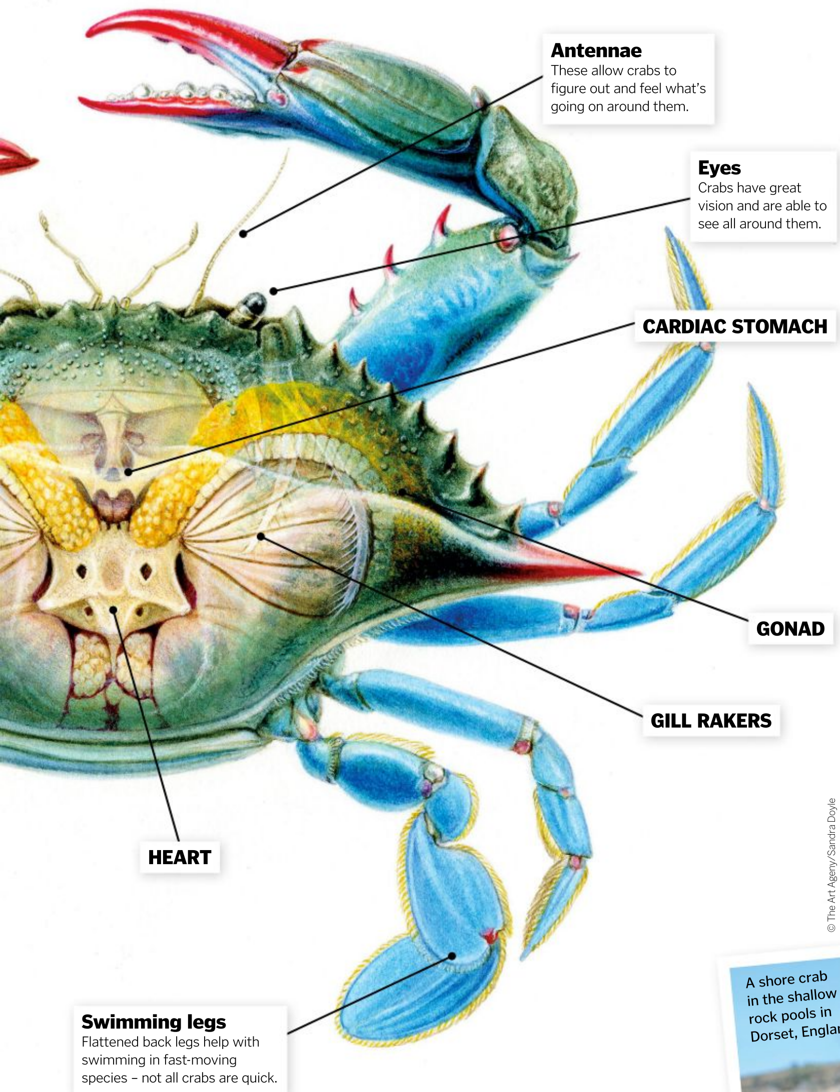
"Crabs grow by moulting – just like growing out of clothes"

Going nuts

There are always exceptions in the natural world, and the horseshoe crab is one of them. They aren't a crab at all, and look more like an armoured ray. They are more closely related to spiders than crabs. The coconut crab, or robber crab, is a really funny little character. They are the largest land crab in the world – so not that little at all. They're related to their much smaller cousin, the hermit crab, and like the horseshoe, aren't a true crab. Their name gives a little insight into their lifestyle; they are known for cracking into coconuts and scampering away with people's things.

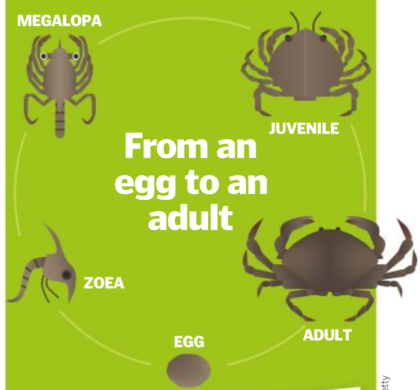
© Getty

A coconut crab showing just how big it can get, clinging to a tree

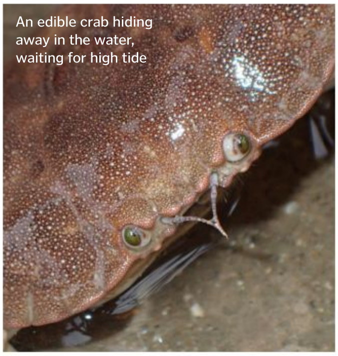


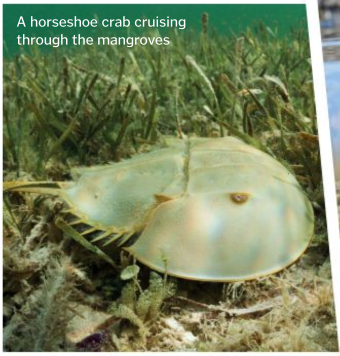
Life cycle

Different species of crab have unique strategies for attracting a mate, from chemical signals to waving their claws around. Once they find one, some come together in a preconception hug, and might wait in this position for a while before the female moults and they can get down to business. The female is pregnant for about one or two weeks. When ready, the larvae, or zoeae, are released by the female and become part of plankton – the tiny plants and animals in the water. Although they look strange and a bit like an alien, the little zoeae start to develop more crab-like features and eventually turn into what's called a megalopae. After this stage, the young crab looks like a miniature version of an adult and starts to grow bigger to begin the process all over again. How long crabs live varies massively, from as little as two years to a whopping 60.




A shore crab in the shallow rock pools in Dorset, England


An edible crab hiding away in the water, waiting for high tide


A horseshoe crab cruising through the mangroves

Earth's underground water stores

How water becomes trapped below ground, forming aquifers

Words by **Ailsa Harvey**

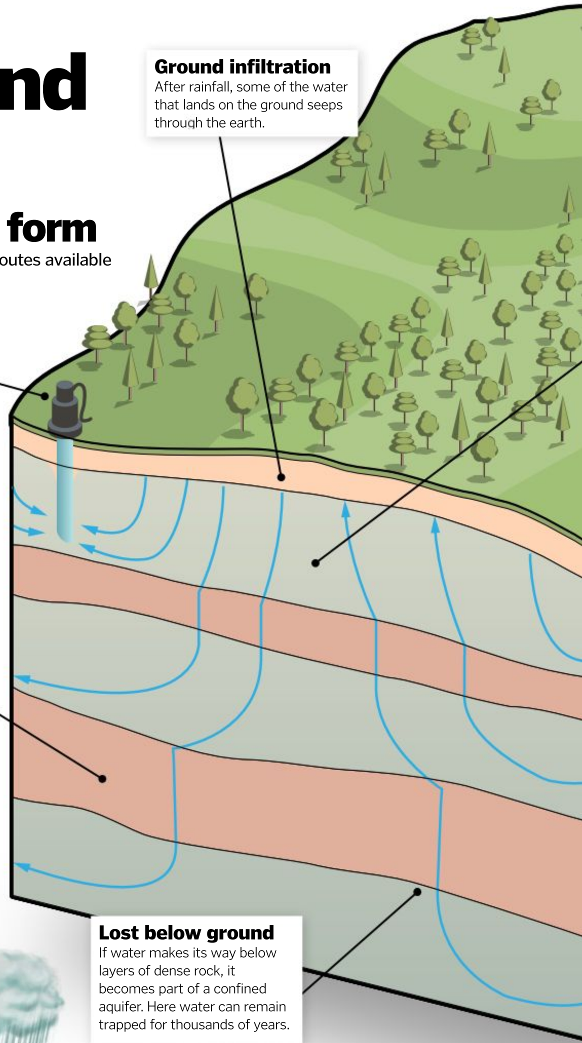
How much water is underground? If you were to extract it all and pour it across the planet's surface, it would cover Earth's entirety to a depth of 120 metres. When picturing this volume underground, you might mistakenly imagine it as a flowing body of water. In reality, bodies of groundwater, called aquifers, are soaked up by the solid ground. Just like when you dig in the sand at the beach and water appears to come from nowhere to occupy the space, water hides in small spaces in rocks and soil in a similar way.

Aquifers are a prime source of drinking water. Protected within rocks, groundwater is often an easier option for consumption, as it is usually less polluted than surface water. It can also exist in much larger volumes than the capacity available in human-made reservoirs.

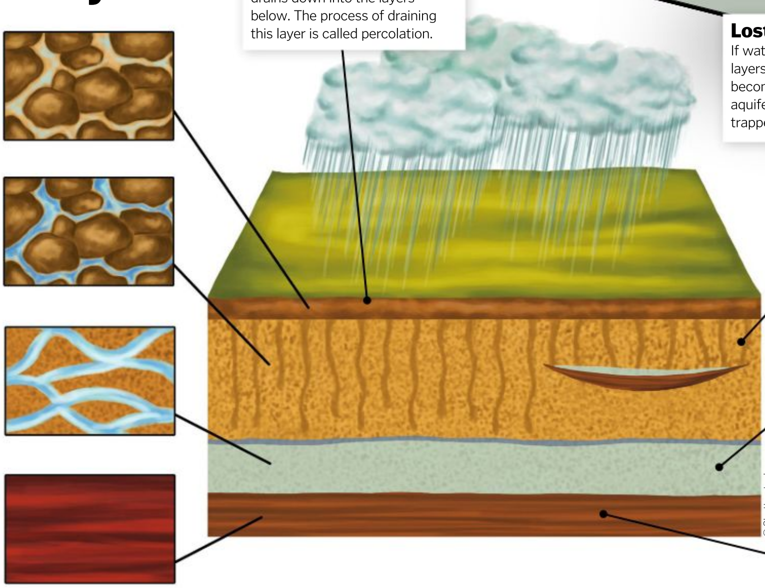
To retrieve water from aquifers, wells and boreholes are installed. These are drilled deep into the rock, to the most water-abundant depth, then water is pumped up to the surface. As long as it is monitored closely and its use is controlled, the aquifer won't be completely drained. As water between the rocks is removed, more will be drawn into the space as surface water replenishes it.

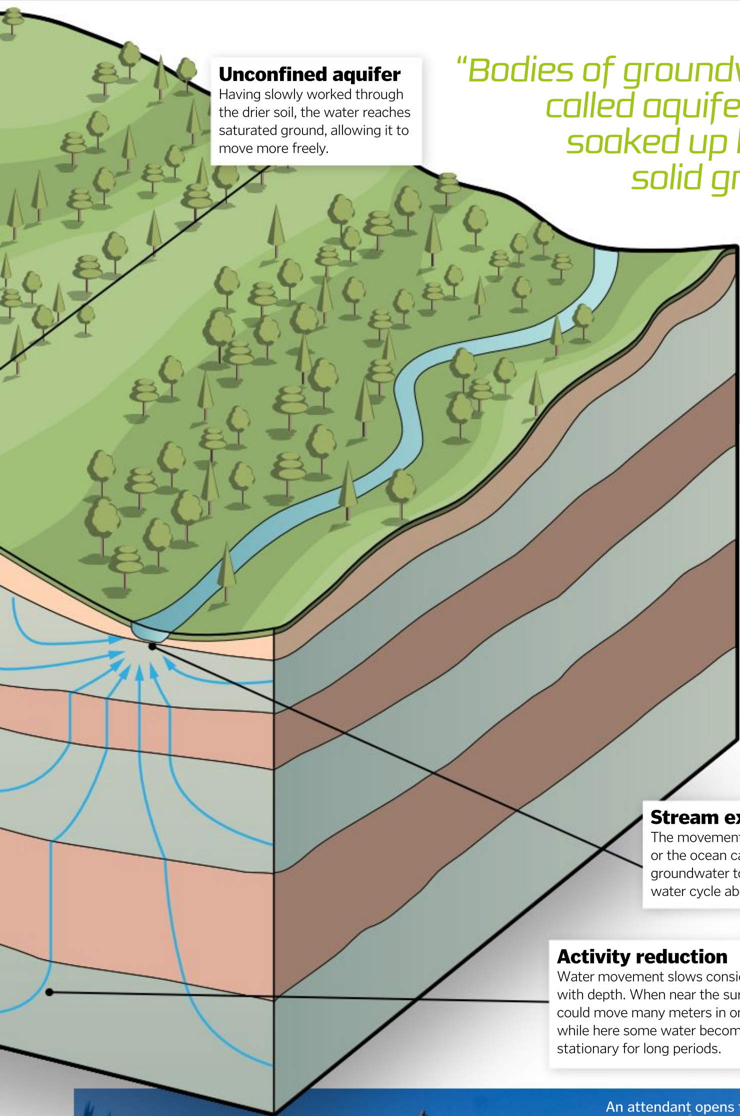
How aquifers form

Follow the multiple routes available to groundwater



Through the layers





© Ed Crooks

"Bodies of groundwater, called aquifers, are soaked up by the solid ground"


This groundwater drainage system is pictured newly installed

© Alamy


An attendant opens the valve on a borehole pump in Zimbabwe

© Getty

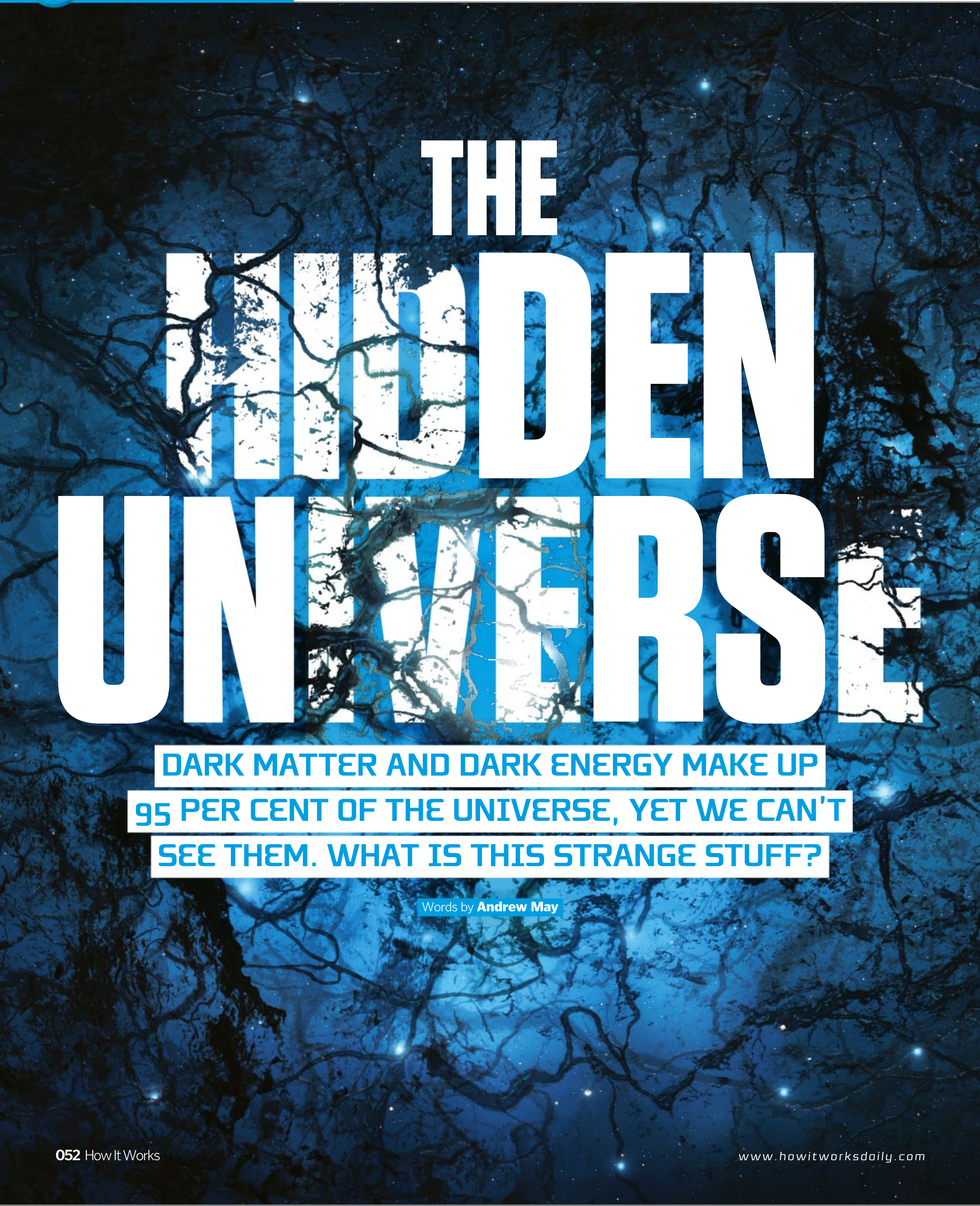
Detecting hidden sources

After particularly heavy and sustained rainfall, water can flood the ground. If you watch the pools and puddles closely, you can see them vanish before your eyes, draining away into the topsoil. The transition from rainwater to groundwater occurs beneath our feet and out of sight. For those attempting to source this water, how is an aquifer located?

The first place to look for aquifers is near a stream, lake or river. These are discharge areas where water can eventually be released from the ground. Next, you should head to an area where rainwater is likely to accumulate. You'll want to search at a low point in the landscape, rather than at the top of a hill. At a chosen spot, specialist equipment can fire signals into the ground and monitor changes in resistance. Ground-penetrating radars are machines that send electromagnetic waves into the ground to do this. The technology tells scientists how much space is between the rock in different areas, its density and relative water volume.


© Alamy

Ground-penetrating radars are used to detect irregularities underground



THE HIDDEN UNIVERSE

DARK MATTER AND DARK ENERGY MAKE UP 95 PER CENT OF THE UNIVERSE, YET WE CAN'T SEE THEM. WHAT IS THIS STRANGE STUFF?

Words by **Andrew May**

As telescopes became increasingly powerful during the 20th century, they started to reveal the true scale of the cosmos. Astronomers discovered that there were billions of other galaxies like our own, scattered throughout a vast, continuously expanding universe. At the same time, advances were made in theoretical cosmology, stemming from Einstein's theory of general relativity, which showed in precise detail how objects move under the influence of gravity. When those two developments – observational and theoretical – were put together, researchers came to a startling conclusion. By the end of the 20th century, it was clear that all those billions of visible galaxies were just a small fraction of everything there is.

The hidden 95 per cent of the universe goes by the names dark matter and dark energy – but these are two very different things. The word dark is appropriate in the sense that we are 'in the dark' about them – we can't observe them directly, and we don't know what they are. But it's misleading to think of them as being dark in colour. That's true of something like cosmic dust, which we can see quite easily if it gets between us and a bright object that it partially obscures, but dark matter and dark energy are completely transparent. Light across all wavelengths, and all other matter, simply passes through them as if they weren't there.

Dark matter was discovered first – and the underlying theory is easier to understand. There's no need for relativity here, just Isaac Newton's basic theory of gravity. When you

A dense galaxy cluster interspersed with blue arcs, which are more distant, gravitationally lensed galaxies

have a large ensemble of stars in a galaxy – or galaxies in a galaxy cluster – despite all the complex physics that's going on inside them, gravity is the only thing that determines their motion. Just as a spacecraft can attain 'escape velocity' from Earth orbit if it's moving fast enough, there's a maximum speed that stars can travel at – determined by the total amount of gravitating matter in the galaxy – before they fly off at a tangent. It turns out that the stars in the outer parts of most galaxies are moving too fast, at least if the visible matter was the only thing holding them in. The concept of dark matter, which supplies the missing gravity but is undetectable by any other means, is the simplest way to explain the observations.

Astronomers see evidence for dark matter everywhere they look – here in our own galaxy, and in other neighbouring galaxies.

The constituents of the universe

From observations of stellar and galactic motions, astronomers know the universe must contain around five times as much dark matter as ordinary visible matter. Adding dark energy to the picture is a little harder. It isn't made up of material particles, as dark matter presumably is, so we can't simply characterise its contribution as so many kilograms per cubic metre. But thanks to Einstein's theory of relativity, we know that energy is equivalent to mass, and cosmological observations allow us to work out the amount of dark energy in a way that is directly comparable to the other two. The result, according to NASA's latest estimate, is that the universe is 68 per cent dark energy, 27 per cent dark matter and just five per cent ordinary matter.

Relative proportions of dark energy and matter – the latter split further into 'ordinary' and 'dark'

In contrast, dark energy only becomes apparent when we take a wider view of the universe as a whole. For a century now we've known that the universe has been expanding ever since the Big Bang. It's common sense to assume that this expansion is gradually getting slower over time, pulled back by the combined gravity of all the matter in the universe. But in the 1990s astronomers discovered that the exact opposite is true: the expansion rate is actually accelerating, not slowing down. Something is counteracting the effect of gravity, pushing galaxies apart faster and faster. That 'something' – and no one knows what it is yet – has been dubbed dark energy.

One thing both dark matter and dark energy have in common is an absence of direct evidence. They're assumed to exist because they're the simplest way to reconcile observations with theory. But it's possible that theory and observations are wrong, and we don't really need dark matter or dark energy after all. But the indirect evidence for them is mounting up all the time, so most astronomers believe they're here to stay.

Dark matter

It was in the 1930s that Fritz Zwicky first noticed a discrepancy between the visual appearance of galaxies and the speeds they were travelling at. When studying the Coma galaxy cluster, he realised that in order for it to be held together by gravity, it had to contain far more mass than he could see. He coined the term 'dark matter' for the unseen contribution.

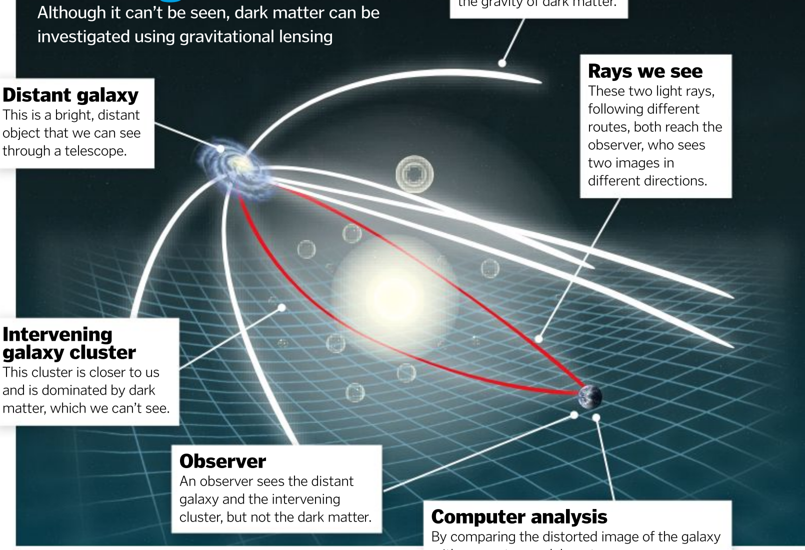
By the 1960s, spectroscopy had progressed to the point where high-resolution measurements could be made of stellar velocities inside a galaxy and plotted against radius. One of the great pioneers of these 'galactic rotation curves' was Vera Rubin. She discovered that the outer parts of most disc galaxies rotate much faster than would be expected from the gravitational effect of visible matter. The implication was that galaxies were embedded in a 'halo' of dark matter, the density of which dropped off more slowly with radius than that of the visible disc.

© ESO

Disc galaxies, like the Sculptor Galaxy shown here, are embedded in a halo of dark matter

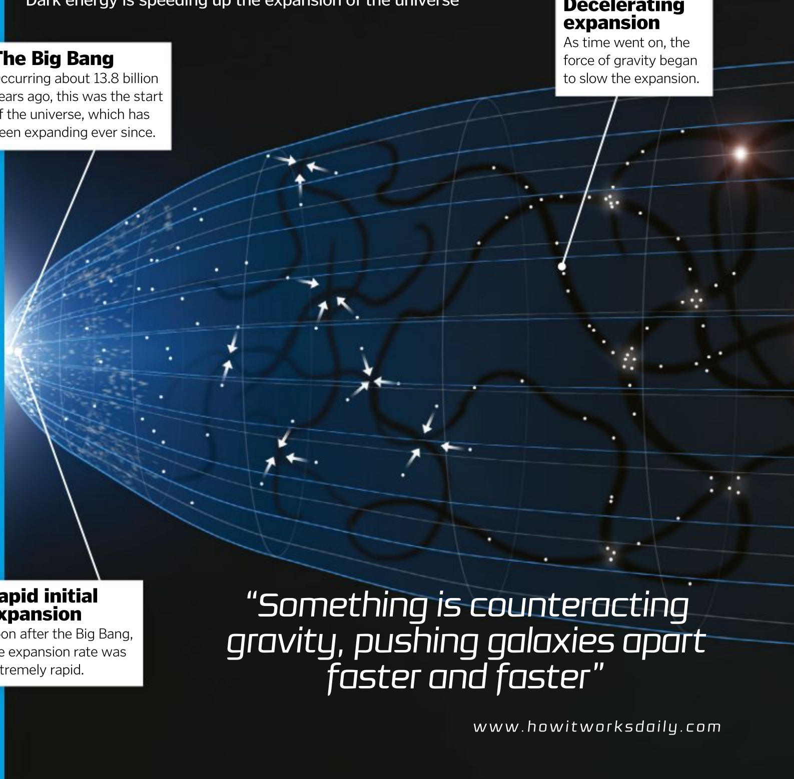
Probing dark matter

Although it can't be seen, dark matter can be investigated using gravitational lensing



The accelerating universe

Dark energy is speeding up the expansion of the universe



"Something is counteracting gravity, pushing galaxies apart faster and faster"

The Euclid mission

The European Space Agency's (ESA) Euclid space telescope, scheduled for launch next year, is designed to investigate both dark matter and dark energy. It will map gravitationally lensed galaxies, from which the distribution of intervening dark matter can be deduced. It will also study so-called 'baryonic acoustic oscillations', which are ancient patterns imprinted in the large-scale distribution of galaxies. Like explosive supernovae, these provide a standard ruler which allows astronomers to trace the expansion history of the universe – including the acceleration caused by dark energy. In a mission lasting six years, Euclid will survey galaxies in visible and infrared wavebands over an area of sky covering more than 35 per cent of the celestial sphere.


An artist's impression of the Euclid spacecraft in its operational configuration

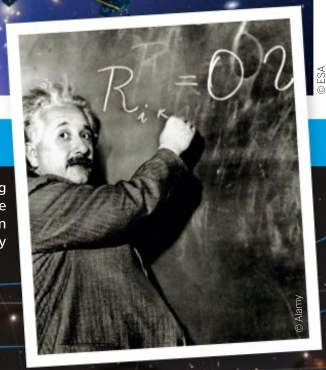
Dark energy

Astronomers accidentally discovered dark energy when they were looking for something else. They wanted to calculate the total mass of the universe by measuring the rate at which its gravitational pull slowed down the expansion rate. They attempted to do this by graphing recession speed versus distance for a special class of astronomical objects called Type Ia supernovae, but the result wasn't what they expected. The expansion of the universe isn't slowing down at all – in fact, it's speeding up.

It's as though the universe is filled with a mysterious something – dark energy – that counteracts the pull of gravity on the largest scales and pushes even harder in the opposite direction. This discovery was in a different league from dark matter, which may be a completely unknown substance, but at least obeys the laws of Newton and Einstein. Dark energy, with its strange, antigravity-like behaviour, doesn't even do that.

Or perhaps it does, if we look at an obscure factor in Einstein's equation called the cosmological constant. It has no counterpart in Newton's theory, and for years was assumed to be zero. But if it has a small positive value, it could explain dark energy as a fundamental property of space itself.


Brian Schmidt, Saul Perlmutter and Adam Riess, whose supernovae measurements showed that dark energy exists


Einstein included something similar to dark energy – the cosmological constant – in his theory of relativity

Dark energy kicks in
Around 5 billion years ago, dark energy started to affect expansion, which began to speed up again.
The present
The rate of expansion is still accelerating, so the universe is larger than it would have been without dark energy.
The future
Scientists think that dark energy will become increasingly dominant, with galaxies eventually becoming extremely far apart.

AR ZONE! SCAN HERE

Artist's rendering of the Giant Magellan Telescope as it will look when completed

© GMTO

The Giant Magellan Telescope will study exoplanets like Kepler-62e, seen here in an artist's concept

© NASA

Giant Magellan Telescope

This new ground-based observatory will be ten times as powerful as Hubble

Words by **Andrew May**

Work is underway on construction of a huge new telescope. When it becomes operational in 2029, it will view the universe with a clarity and sensitivity never seen before. Called the Giant Magellan Telescope (GMT) after the 16th-century explorer Ferdinand Magellan, it's a collaboration between a consortium of science institutions from the US, Australia, South Korea and Brazil.

In common with many of today's most powerful telescopes, the GMT won't use a single mirror to collect light from distant objects, but a whole array of them. Seven equally sized mirrors with an 8.4-metre diameter will give it a total effective aperture of 24.5 metres, ten times larger than the Hubble Space Telescope. As a result the GMT will be able to discern details ten times smaller than Hubble can, as well as imaging much fainter objects.

The new telescope is being built in the Atacama Desert in Chile, which has become a favoured location for astronomers. One reason is the exceptionally dry climate, giving as many as 300 clear nights per year. Another is the high altitude, 2,550 metres above sea level, which means there is less atmosphere for the telescope to peer through. In astronomical jargon, the 'seeing' – the lack of distortion due to atmospheric turbulence – is extremely good.

> "It will use a revolutionary new trick called adaptive optics"

Even so, the seeing isn't perfect, as it is for Hubble way above the atmosphere. This could pose a problem for a traditional telescope, but not the GMT. It will use a revolutionary new trick called adaptive optics to make its performance virtually as good as any space-based telescope. This involves using flexible secondary mirrors – controlled by hundreds of actuators – to constantly tweak the mirrors to counteract the effects of turbulence, transforming twinkling stars into sharp points of light as steady as anything Hubble sees.

Why build an enormous telescope?

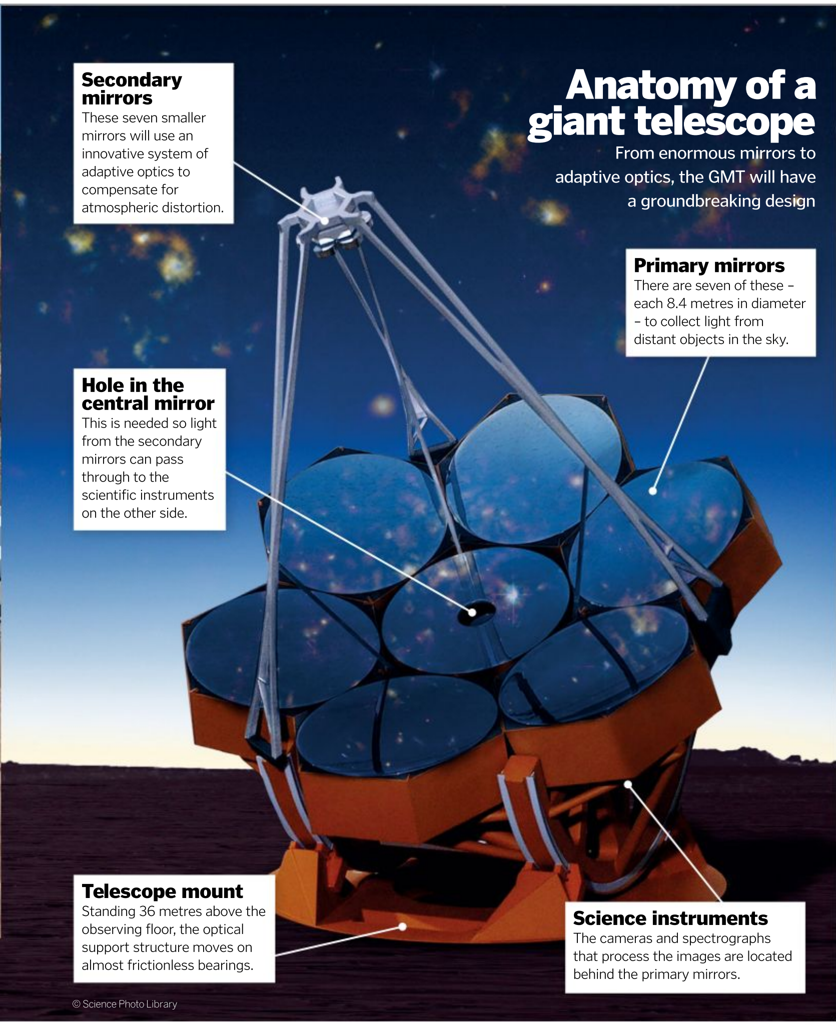
The size of an astronomical telescope is expressed in terms of its diameter – or aperture – and apertures are steadily getting bigger. There are two reasons for this: astronomers want to collect as much light as they can from faint sources, and the light-gathering power of a telescope increases with aperture. They also want to see objects with the highest possible resolution, which also improves with bigger apertures. Historically, increases in aperture have often led to new and unexpected discoveries, such as Lord Rosse's Leviathan of Parsonstown, which showed that other galaxies are vast star systems like our own.

© Wiki/ Working Men's Educational Union

Lord Rosse's 1.8-metre Leviathan, finished in 1845, was the ancestor of today's giant telescopes

Anatomy of a giant telescope

From enormous mirrors to adaptive optics, the GMT will have a groundbreaking design



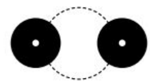
History of giant observatories

The Leviathan
Location: Birr Castle, Ireland
Aperture size: **1.83 metres**
Date of first light: **1845**

Hooker Telescope
Location: Mount Wilson, California
Aperture size: **2.5 metres**
Date of first light: **1917**

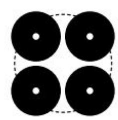
Hale Telescope
Location: Mount Palomar, California
Aperture size: **5.08 metres**
Date of first light: **1949**

Hubble Space Telescope
Location: Earth orbit
Aperture size: **2.4 metres**
Date of first light: **1990**

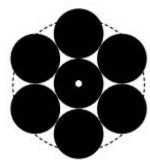


Large Binocular Telescope
Location: Mount Graham, Arizona
Aperture size: **11.8 metres (effective)**
Date of first light: **2005**

Gran Telescopio Canarias
Location: La Palma, Canary Islands
Aperture size: **10.4 metres**
Date of first light: **2007**



Very Large Telescope
Location: Atacama Desert, Chile
Aperture size: **16 metres (effective)**
Date of first light: **1998**

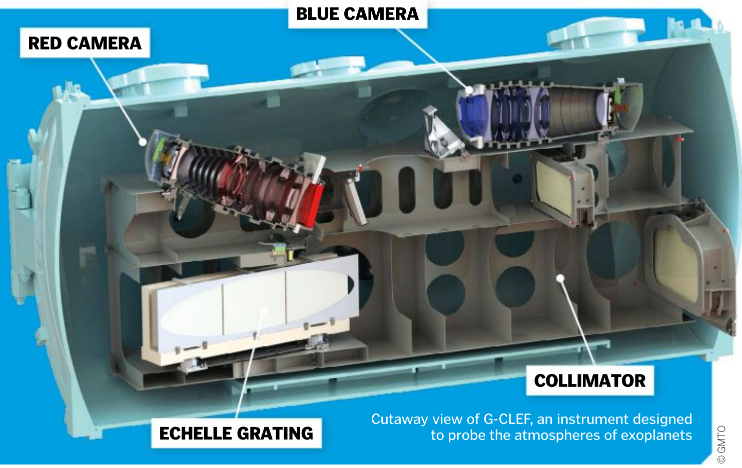


Giant Magellan Telescope
Location: Atacama Desert, Chile
Aperture size: **24.5 metres (effective)**
Date of first light: **2029**

Science goals

The light collected by the telescope will be channelled into an array of imagers and spectrographs for scientific analysis. The GMT's science goals cover a whole range of astronomical interests, from star formation and supernovae explosions to supermassive black holes and the tenuous gas filling intergalactic space. GMT data will also be used to shed light on the complex process of galaxy formation and examine the very first objects that formed in the universe.

Arguably most exciting of all, the GMT will play an important role in the search for exoplanets and life beyond Earth. Thanks to its unprecedented resolution and adaptive optics system, it will be able to produce direct images of planets in the habitable zones of other stars. Its spectroscopic capabilities, including the GMT-Consortium Large Earth Finder (G-CLEF) instrument, will also allow astronomers to analyse the atmospheres of exoplanets in search of key indicators of life.



Cutaway view of G-CLEF, an instrument designed to probe the atmospheres of exoplanets

THE RAIL REVOLUTION

DISCOVER THE INCREDIBLE TRAIN TECHNOLOGY OF TODAY, AND SEE WHAT THE FUTURE HOLDS

Words by **Ailsa Harvey**

When Richard Trevithick unveiled the first steam locomotive in 1804, the world's first railway journey became possible. This monumental breakthrough marked the beginning of centuries of rail travel, creating interconnected societies and an expanding market for businesses. Transport by rail remains the most efficient way to carry goods around the world, including fertiliser, grain, metals and chemicals, and when it comes to passenger transport, trains are frequently being updated for speed and comfort.

If someone had shown Trevithick the bullet trains of today, reaching speeds over 300 miles per hour, he might have failed to see any resemblance to his humble invention, which reached top speeds of five miles per hour. The typical experience of a train journey was one of unsteadiness, noise and unreliability, but as technology has progressed, journeys have become smoother and travel times shorter.

Currently, the fastest trains use magnetic levitation (maglev) technology. Using powerful electromagnets, these vehicles rise slightly above guideways, reducing friction and allowing passengers to soar over 370 miles in an hour. Early advances in rail technology may have occurred predominantly in the UK and US, but the modern-day rail revolution is being led by countries such as China and Japan. China is home to the world's biggest high-speed rail network, stretching around 24,850 miles – by 2035, China Railway hopes to extend this to 43,500 miles. Rail travel is one of the main modes of transport in the country, with around 4 billion passenger trips being made each year. As the country leads the world's railway development and continues to push the limits of trains' capabilities, how will the technology be upgraded for the next leg of the rail revolution?

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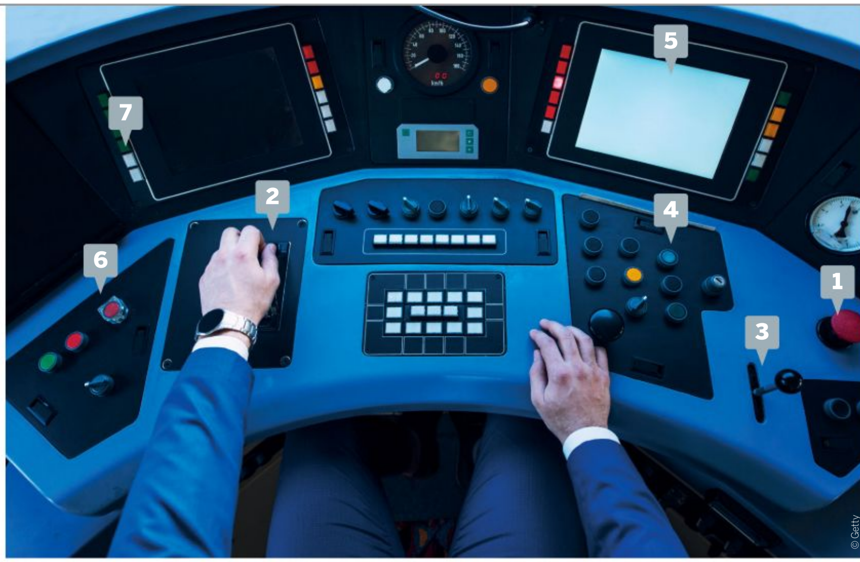
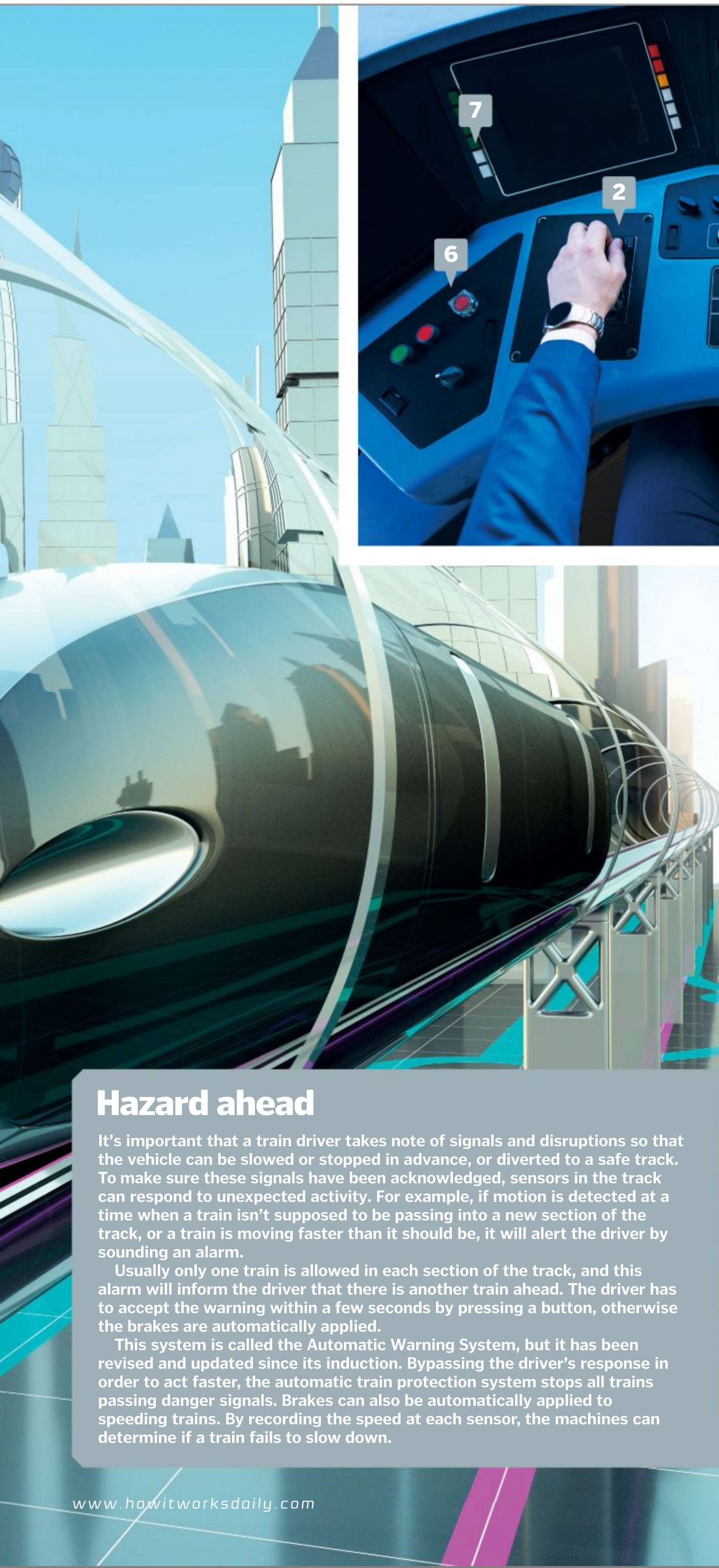




How to operate a train

Step inside the driver's cab and learn how these vehicles are kept in control

1 Emergency stop Positioned at the side to avoid accidental pushes, the emergency stop button is used to apply the maximum brake force instantly.

2 Power lever Sliding this lever controls the motor power of the train. By changing its position, the driver can accelerate and decelerate the vehicle.

3 Brake lever Pulling this lever releases compressed air onto the brake pads along the train. These brake pads push against the wheels to slow them down.

4 Operation buttons These buttons are used to open doors, sound the bell, communicate with other crew and passengers and control the lights.

5 In-car CCTV The driver can observe live footage inside the train on this screen. CCTV can also provide exterior images of the train, such as of the doors.

6 Vigilance push button A vigilance button or foot pedal tests that a driver is still conscious and responsive. If a lack of activity is detected for 30 seconds, a light tells the driver to push this button.

7 Radio control Drivers can receive information about changes to tracks and news from railway stations over the radio.

Hazard ahead

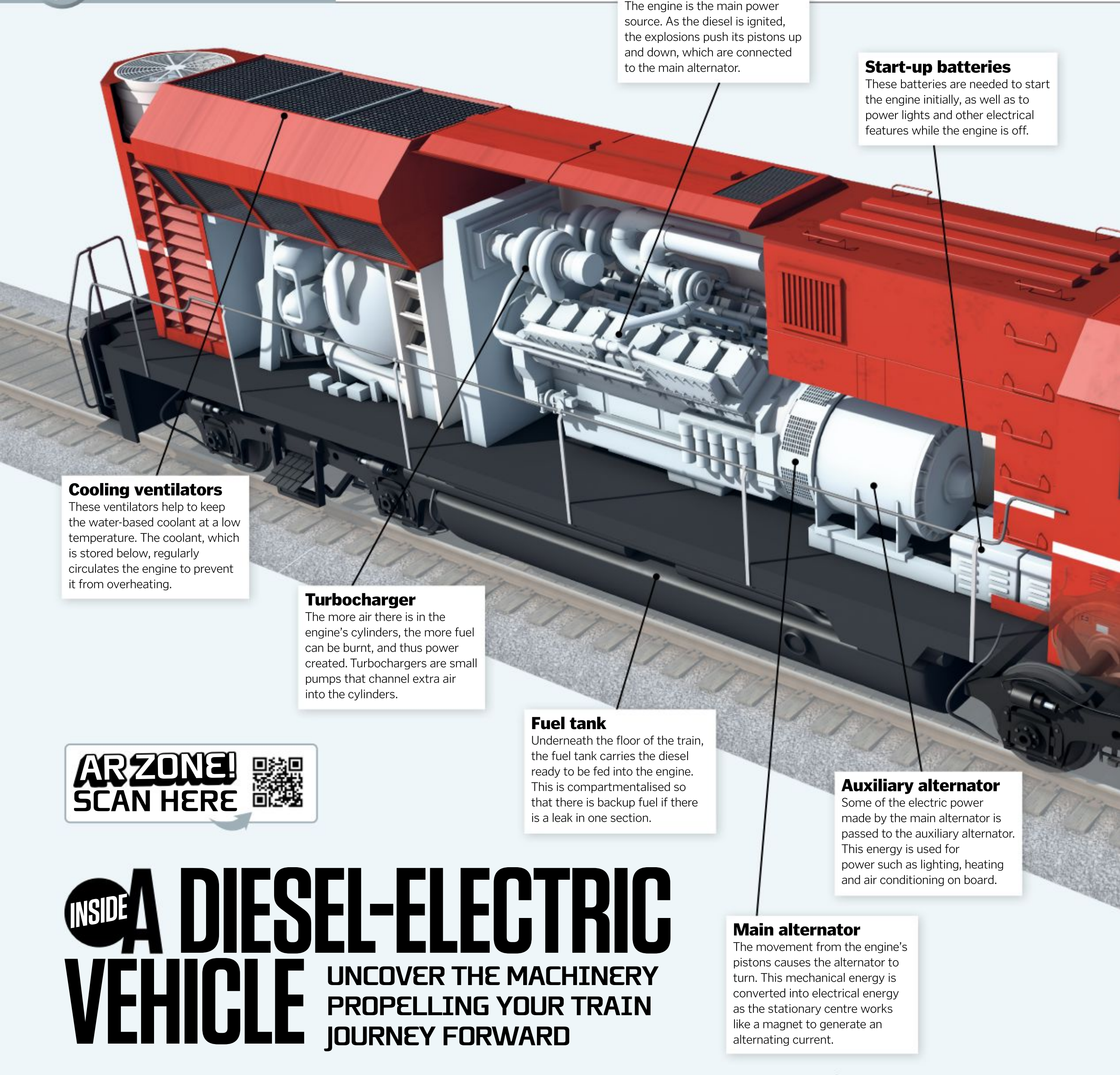
It's important that a train driver takes note of signals and disruptions so that the vehicle can be slowed or stopped in advance, or diverted to a safe track. To make sure these signals have been acknowledged, sensors in the track can respond to unexpected activity. For example, if motion is detected at a time when a train isn't supposed to be passing into a new section of the track, or a train is moving faster than it should be, it will alert the driver by sounding an alarm.

Usually only one train is allowed in each section of the track, and this alarm will inform the driver that there is another train ahead. The driver has to accept the warning within a few seconds by pressing a button, otherwise the brakes are automatically applied.

This system is called the Automatic Warning System, but it has been revised and updated since its induction. Bypassing the driver's response in order to act faster, the automatic train protection system stops all trains passing danger signals. Brakes can also be automatically applied to speeding trains. By recording the speed at each sensor, the machines can determine if a train fails to slow down.

Automatic warning systems can also alert people working on the tracks further down the line of an oncoming train

AR ZONE!



AR ZONE! SCAN HERE

INSIDE A DIESEL-ELECTRIC VEHICLE

UNCOVER THE MACHINERY PROPELLING YOUR TRAIN JOURNEY FORWARD

Understanding signalling

What do these colour combinations tell the driver?

Clear
Green means go! As long as the light is green, the train driver can happily continue on their journey with no known cautions ahead.

Caution ahead
Two yellow lights tell a driver they will need to stop soon. This is a warning that the next section of the track will show a yellow light.

Caution
A single yellow light indicates that the train needs to stop at the next section of the track. This gradual procession of yellow lights makes braking less sudden.

Danger
A red light means the train must come to an immediate stop. This usually means there's another train or obstacle on the next section of track.

Diverging route
If the white lights extending 45 degrees from the main signalling lights are lit, the train can proceed, but must swap onto the alternative line, branching in the direction of the signal.

Hazardous chemicals are transported in tanks along railroads that are no longer used by the public

Reductor gears
These control the power that's released to the wheels, based on the gears being used.

Main route
When the main light is green and the white lamps extending from the top of the main body are switched off, the train can proceed on the main route.

Multiple routes
When there are multiple lines branching from the main line, the lit-up arms reference which line to take, as their positions align with the tracks.

Railway timetables are usually changed in the summer and winter

How the timetable is organised

The first thing you probably do before arriving at a train station is to check the train timetable. You might simply glance at the information board inside the station, or maybe you plan your route weeks in advance. But how is the timing and frequency of each train plotted?

Firstly, each train operating company makes a bid for its ideal timetable in the area. These then need to be arranged, and compromises made to meet conflicting demands. Taking around 16 months, new timetables are made and revisited before any necessary changes to the track are added, and routes are eventually made public to passengers.

This is the role of a train planner, with the help of computer programming. An algorithm will use data such as passenger demand and train capacity to suggest the regularity and timing of different trains. This will ensure that there is enough time between each train and room at each platform for the designated vehicles. The timetable is checked over by a human train planner to reduce errors.

The L0 maglev train can reach speeds of 374 miles per hour

AR ZONE!

Railway drones
Across the world, railway lines cover over 248,000 miles. This makes the world more connected, but how can such large areas of train tracks be monitored for safety? Some railways use drones to examine high-voltage electrical lines, but in the future this technology could be more widespread. Serving as eyes in the sky, drones can analyse track conditions and provide security through efficient surveillance.

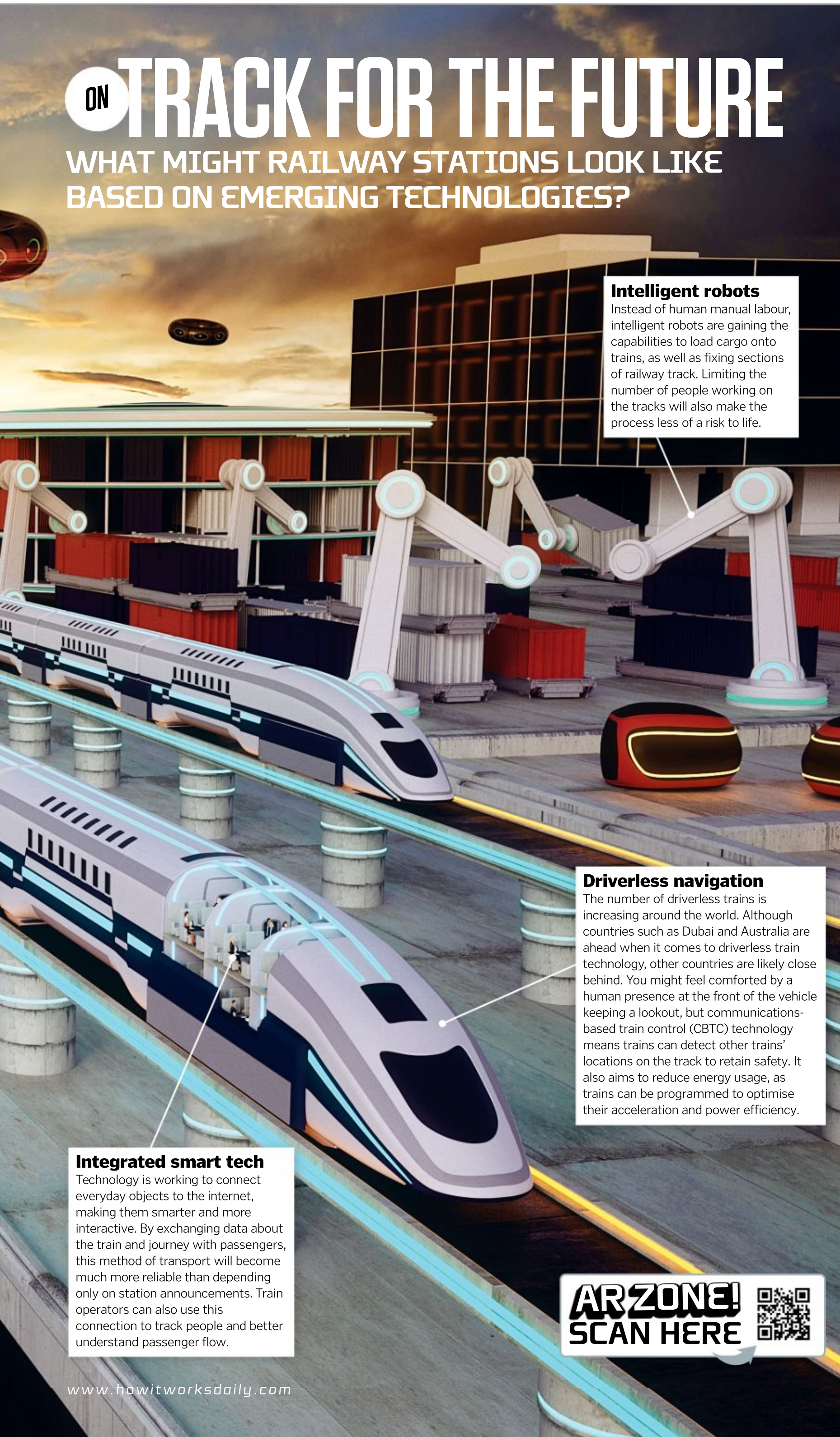
Energy-harvesting tracks
Every weekday in the UK alone, 24,000 trains trawl the tracks. They may have reputations for releasing pollutants, but what if these trains generated energy as they moved? Italian company Greenrail has created energy-producing sleepers. A sleeper is the rectangular section between tracks. As trains drive over these, the kinetic energy exerted on the sleepers due to the pressure of the trains' weight can be converted to electrical energy.

AR windows
What if the many hours of staring out the window could be more entertaining? Taking advantage of these large panels and the latest in augmented reality (AR) tech, train windows could soon become interactive. Japanese company Salad has invented such a product, letting passengers add digital features to the real landscape behind them. More useful functions to AR windows include displaying news, weather, the time and route information.

Underground freight
By 2050, freight activity could increase by 250 per cent. Building underground routes for non-human transportation will reduce congestion on the tracks.

ON TRACK FOR THE FUTURE

WHAT MIGHT RAILWAY STATIONS LOOK LIKE BASED ON EMERGING TECHNOLOGIES?



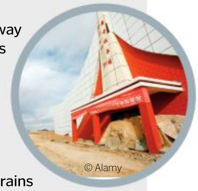
Intelligent robots
Instead of human manual labour, intelligent robots are gaining the capabilities to load cargo onto trains, as well as fixing sections of railway track. Limiting the number of people working on the tracks will also make the process less of a risk to life.

Driverless navigation
The number of driverless trains is increasing around the world. Although countries such as Dubai and Australia are ahead when it comes to driverless train technology, other countries are likely close behind. You might feel comforted by a human presence at the front of the vehicle keeping a lookout, but communications-based train control (CBTC) technology means trains can detect other trains' locations on the track to retain safety. It also aims to reduce energy usage, as trains can be programmed to optimise their acceleration and power efficiency.

Integrated smart tech
Technology is working to connect everyday objects to the internet, making them smarter and more interactive. By exchanging data about the train and journey with passengers, this method of transport will become much more reliable than depending only on station announcements. Train operators can also use this connection to track people and better understand passenger flow.

5 RAILWAY STATION RECORDS

1 Highest
Tanggula railway station in Tibet is situated 5,068 metres above sea level. Due to the low oxygen, the station is unstaffed, and although some trains stop there, passengers are usually required to stay on board.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2 Longest
A new platform at Shree Siddharoodha Swamiji railway station in the southern Indian city of Hubballi has become the world's longest. Measuring 1,505 metres in total, the platform has space for around 10,000 passengers a day.


Source: Wiki/ Deepak Patil

3 Biggest
When measuring by floor space, Nagoya Station in Japan takes the title of largest train station. It covers an area of 446,000 square metres and is the headquarters of Central Japan Railway Company.


© Getty

4 Busiest
Shinjuku Station in Tokyo, Japan, is the world's busiest, welcoming over 3.5 million people through its doors each day.


© Alamy

5 Oldest
Tanfield Railway in England is the world's oldest, having been in continuous use from 1725 to 1964. Today a vintage steam train takes tourists along the route between its four stations.


© Getty

What's inside a car seat?

More than just a place to park your bum, car seat technology improves a driver's comfort and safety

How do you hope to feel when you test drive a car, or place yourself in the passenger seat? The first thing many of us will automatically notice is comfort. As one of the most essential car features to consider when choosing a vehicle we hope to cover considerable mileage in, car seats have evolved to perfect our driving posture and support areas of the body under the most physical strain.

The choice of material used can greatly influence the sensation of a car journey. Seats typically contribute around six per cent of a car's mass. Manufacturers are constantly striving to use new lightweight materials that will assist in improving fuel efficiency. Opting for a selection of lightweight car seat materials, such as carbon fibre-reinforced plastics, magnesium and high-strength aluminium, reduces the weight of some car seats by 30 per cent, as opposed to constructing the majority of the seat's base in one heavier metal.

A vital aspect to consider in any element of a car's design is safety, and seat comfort can directly correlate with this. The aim for the driver is to be able to channel all their attention onto the road ahead. If your legs start to ache and your back begins to stiffen, it can be difficult to stop this impacting the quality of your driving. From controlling temperature to finding the most supportive materials, the technology behind car seats can be both a luxury and a lifesaver.

Beneath the chair

How do these components work to support your back?

Headrest
This part of the seat limits the movement of the head during a crash, preventing whiplash. Active headrests automatically move forwards in collisions to reduce the distance between head and seat.

Ventilation
Car seats are made using a permeable mesh of material to allow air to circulate. Some seats have air conditioning, which uses an internal fan to blow air through it.

Adding heat
Sometimes heated coils are found beneath the cover. As electricity flows through the chair, the coil resists the flow. The friction created by this is released as heat.

Lumbar support
Seats are usually curved to fit the shape of your lower back. This area can be adjusted to match the posture of the individual.

Side cushions
Supporting the back, the side sections curve forwards to hug the body and keep the person sitting straight.

Thigh support
The lower section of the seat is cushioned to support your legs, while also being raised to prevent you sliding forwards as you break.

Slide adjuster
To alter the seat's distance from the steering wheel, a lever releases the chair's attachment to this metal railing so the driver is able to slide forwards or backwards along it.

Buckle up into the seats of tomorrow

If you're a driver, you'll likely clock many hours sitting over the steering wheel. In the future, your seat will become as familiar with you as you will be with it. Biometric seats are in development, aiming to monitor a driver's stress during a journey. Extremely reactive sensors will track physiological activity like your body temperature, breathing and heart rate, as well as your body's movements in the seat, such as any shifting during an uncomfortable, long drive. With all this data, the smart seat will alert the driver if the information collected indicates that they are under too much pressure to safely drive.

When autonomous driving becomes widespread, engineers are planning to design these seats to detect whether the person seated is driving or being driven.

A biometric car seat can detect tiredness by monitoring heart rate and muscle activity

ANATOMY OF A ROCK CONCERT

Explore the advanced sound technology and special effects that keep live music audiences wanting more

Words by **Ailsa Harvey**

No recording can replace the experience of standing before your favourite band, surrounded by many thousands of like-minded fans as you shout back the lyrics in time with the performers. For many, the unique sound of a live gig helps them to connect with their idols. With less autotune and editing to hide behind, the authenticity of the raw music is often more appreciated. The songs will sound slightly different to the recordings you know inside out, as an irreplicable and unique version is created for those inside the venue.

You might have come to the event to see the band members, but there are many more elements required to build a rock concert. The stage before you isn't just an elevated platform for music to be performed on. It's also a carefully calculated piece of art, designed to encapsulate the crowd and complement the sound in new and exciting ways. Before the crowd arrives at a festival or event, the stage's technology is installed and tested. Many weeks before the event, the production manager works with lighting technicians to choreograph and manufacture lighting and visuals. The production manager relays to the technicians the colours and effects needed for the set, and it's the job of the lighting technician to carry out these transitions behind the scenes. This might involve keeping lights flashing in time with the melody, explosions of smoke or fire at the climax of a song or changing the colour schemes of lighting between songs.

The evolving technology that musicians use on stage enhances their performance and makes them more memorable for the audience. Even though the sound is being played live, bands have experimented with bringing the recording studio on stage in the form of loop pedals. By recording sections of vocals or instruments to be played continuously on a loop, they can layer their baselines and melodies to add more depth to their performance without having to increase the number of musicians.

© Getty

A band's equipment

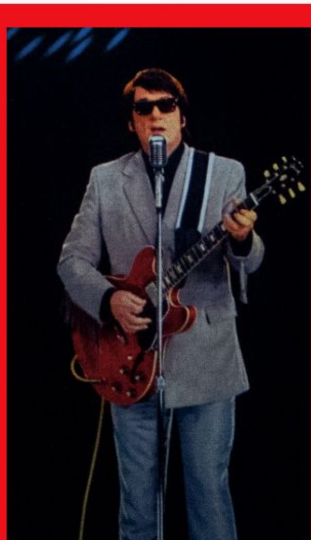
What instruments can you expect to see on stage?

© Shutterstock

A virtual experience

As immersive technologies improve their power to make virtual and augmented reality more believable, music concerts are becoming more diverse. Virtual-reality headsets are giving more fans the opportunity to buy 'front row' seats and the illusion of standing before a live performance without needing to leave the house. For those who are put off by standing around for hours or are uncomfortable in large crowds, this provides the opportunity to watch and listen in comfort and in their own space.

On other occasions, it might be the performer who is virtually at the venue. Hologram concerts are on the rise, allowing iconic deceased performers to appear to take to the stage once more. Using recordings of old performances, this allows their biggest fans to remember what it was like to experience them live, or attend one of their concerts if they were never able to. Technically these are not true holograms, however. A true hologram is a freestanding, three-dimensional structure which doesn't require a material to be projected onto. In these concerts the 'holograms' are light reflected onto a 2D glass pane, but are often still referred to as holograms as they create a similar effect.



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A hologram of deceased musician Roy Orbison played a concert in Madrid in February 2021

WELCOME TO THE STAGE

Take a tour of some of the technology enhancing live gigs

5 WAYS TO LIGHT THE SHOW

1 Spotlights
These focus strong light directly onto a performer. Often manually controlled, spotlights allow performers to remain visible to the audience and also work to add contrast when other lights are dimmed.

© Getty

2 Lasers and strobes
Flashing strobe lights and the flickering narrow beams of lasers can add a dramatic dynamic to a rock concert stage. Fog machines provide particles to scatter the light in, making the razor-sharp light visible.

© Getty

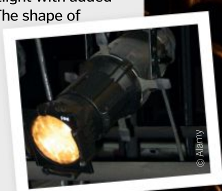
3 LEDs
These are popular, cheap lights that can project a range of colours onto a stage. They are also relatively energy-efficient, using less power and producing less heat than other lighting options.

© Getty

4 Floodlights
These lights are similar to spotlights but cover a larger area. When they illuminate the entire stage, it's called a wash.

© Getty

5 Ellipsoidal reflector spotlight (ERS)
The ERS is a spotlight with added special effects. The shape of the light can be changed and unlimited light patterns can be added to its projection.



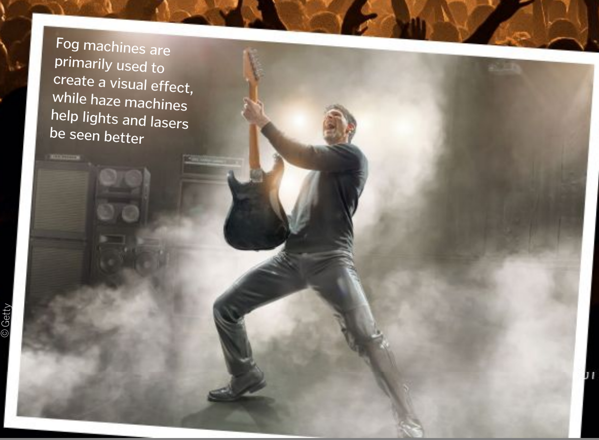
© Alamy

Haze
Haze machines vaporise water and glycerin-based fluids. As this vapour escapes the machine, it hits the cold air and condenses to form fog.

Motion graphic technology
The entire back wall of a stage is often a large digital screen. In some cases, a transfixing animation will move in time to the music, connecting the crowd's visual senses with the sound.

Pyrotechnic chemistry
Violent yet controlled fiery explosions are bound to turn any rock concert into an elaborate spectacle. Small amounts of a flammable material, such as powdered aluminium, are brought into contact with fuel and an oxidiser, such as nitrate, in a cigarette-sized tube to form this reaction.

Crowd syncing
The crowd can also be utilised for lighting effects. Many events involve wearing a wristband for access. These may have lights inside that can be programmed to flash in sync with the music.



Fog machines are primarily used to create a visual effect, while haze machines help lights and lasers be seen better

© Getty

© Getty

Truss
Made of metal triangles to distribute the weight, these structures are designed for lights and other equipment to be attached to. Sometimes the entire stage is constructed of trusses.

Sound system
The crowd has come to hear a band perform their music, and so sound quality is vital. The size and output of the speakers will vary based on the location.

Crowd control
Infrared cameras and other sensors can detect the most populated areas of a crowd so security can intervene before danger arises. Wearable tech such as radio-frequency identification tags in wristbands can convey data of a crowd's movements.

Inside an ERS light

The popular ellipsoidal reflector spotlight is incredibly versatile

Light source
Screwed into the back compartment is a lamp. This bright light has four filaments to increase efficiency.

Attachment area
This handle is where the ERS attaches to the top or side of the stage. Once secured, the angle can be adjusted.

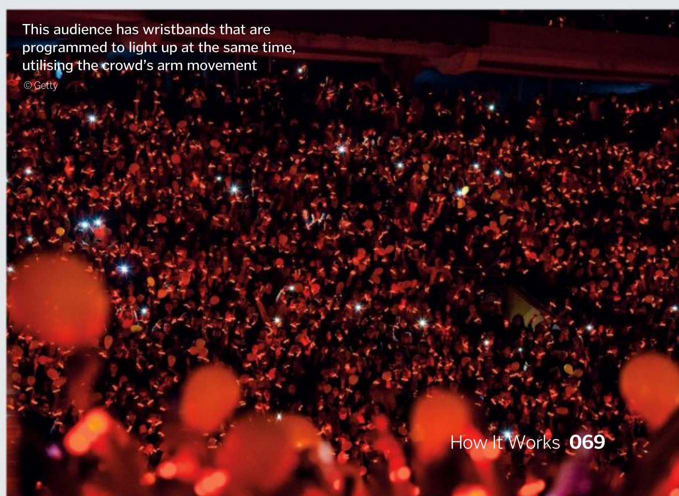
Shutter closure
Adjusting the shutters – by pulling them in or out – alters the size of the gap that the light can shine through, and therefore the light's width.

Focus adjustment
Depending on whether the concert requires defined light or a subtle, atmospheric hue, turning this bolt can make the light softer or sharper.

Shadow effects
Templates with a variety of patterns slide into this section. When the light shines through them from the back of the device towards the lenses at the front, the template creates shadows that project patterns onto the stage.

Adding colour
At the front of the light, a coloured gel can be placed into a slot. These are quick and easy to slide in and replace.

Illustration by © Adrian Mann



This audience has wristbands that are programmed to light up at the same time, utilising the crowd's arm movement

© Getty

AR ZONE!

How a fan oven works

How do these electronic devices cook food evenly?

Words by **Ailsa Harvey**

As you turn the dial to your desired temperature and set a timer, you don't have to give your food much thought during its time in the oven. The specifications are so controlled that you can relax away from the kitchen, safe in the knowledge that your meal will be cooked when you return. And the addition of a fan to these appliances has only enhanced our confidence in cooking.

The core function of an oven is to transfer heat energy to the food inside it. Before fans were incorporated into some of their designs, the main method of transferring this energy was to heat the still air, filling the oven and allowing this blanket of heat to be absorbed by the oven's contents. Although this method is quite effective, conventional ovens can result in food at the top of the oven being overcooked and food closer to the bottom being undercooked. This is because hot air rises, and while the oven door is closed, the same action is occurring inside. The main purpose of a fan is to better distribute this energy, preventing uneven heating.

Fan ovens don't enhance the cooking of all foods. Fairy cakes need still air as they rise. Too much movement can break apart their structure as they swell, resulting in flat bakes. Many fan ovens are designed with baking in mind, adding controls that manage the strength of the airflow.

Cooking with convection

How does this appliance create a controlled internal environment?

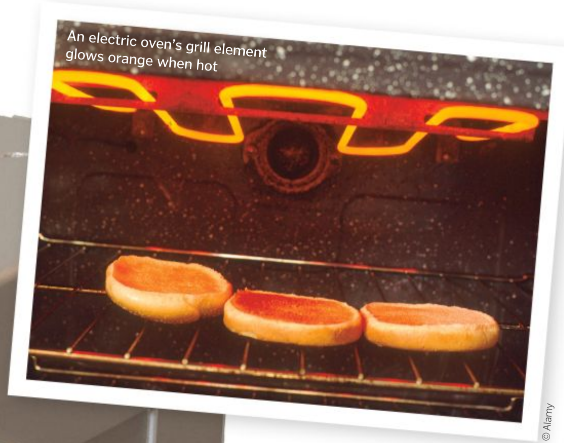
The fan usually sits right at the back of the oven

Oven evolution

Cooking hasn't always been as straightforward as flicking a switch. The earliest ovens consisted of simple metal cases that were heated by fires positioned below. During the Middle Ages, larger and more sophisticated brick ovens were being built, which featured chimneys to direct the smoke away, while metal containers were hung above the flames.

Later, around 1795, cast-iron stoves began surging in popularity due to their ability to heat different pots at different temperatures. Gas ovens first emerged in 1826, but this major step towards modern ovens was limited until the 1900s, when gas lines to houses became more common. Gas ovens allowed temperatures to be controlled more easily, but it was in the 1920s that electric ovens became more popular, despite being available since the 1890s. These electric ovens made cooking safer and just as easy – if not easier – while the first fan-assisted ovens became commercially available in 1945.

Thomas Ahearn patented the first electric oven



An electric oven's grill element glows orange when hot

> *"The purpose of a fan is to better distribute this energy"*

5 FACTS ABOUT USING ELECTRIC FAN OVENS

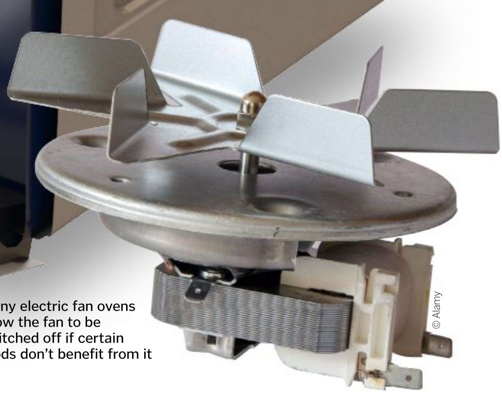
1 Consistency
The circulation of air allows all food surfaces to be heated equally, no matter which shelf they're on.

2 Speed
Moving air transfers heat more quickly than still air, as more hot air molecules can reach the food in a given time. This can cut cooking times by 25 per cent.

3 Quantity
When more food is placed in an oven, the heat is distributed around a larger mass, meaning cooking times can be longer. In a fan oven, the better distribution of heat inside can reduce this effect.

4 Eco-efficiency
Faster heat transfer reduces the time the oven has to be on, and it can cook at lower temperatures. When replacing a conventional oven with a fan oven, you reduce greenhouse gas emissions.

5 Safety
Ovens powered by electricity reduce the risk of fires. Additionally, it will eliminate the possibility of a gas leak from the appliance.



Many electric fan ovens allow the fan to be switched off if certain foods don't benefit from it

FLOATING RESEARCH LABORATORIES

Words by **Mark Smith**

THESE GROUNDBREAKING OCEAN-GOING VESSELS WERE DESIGNED TO UNCOVER THE MYSTERIES OF THE DEEP

Looking like something from a sci-fi movie, the SeaOrbiter was designed to tower above the waves as it made its way through some of the most unexplored parts of the world's oceans. Featuring its own underwater platform, sophisticated science labs and a sub-ocean 'garage' for submarines and divers, the breathtaking vessel has been described as the 'Starship Enterprise of the sea'. Work was due to begin on the ship in 2014, and it was designed to host a crew of up to 22 for long-term scientific missions lasting over six months. It was intended to roam the oceans and deploy submersible vessels at depths of up to 3.7 miles.

Its scale when seen on the horizon would have been immense. While modern ships usually sit flat to the surface and have most of their mass laid out horizontally, SeaOrbiter was to resemble a floating tower, casting an imposing figure on the horizon like a much larger version of the galleons of old. It would rise to a total height of 51 metres – the height of Nelson's Column in London – with over half submerged below the ocean.

Designed not just to roam the seas, but also to explore their depths, six of the SeaOrbiter's 12 decks were to sit below sea level, bringing the undersea realm to life and perfect for providing uninterrupted underwater observation for the scientists and explorers aboard. Its goal was simple – to pull back the curtain on one of nature's most unexplored habitats.

Despite covering 70 per cent of our planet, but with only five per cent explored and less than 20 per cent mapped, our oceans are still largely a mystery. What's more humans have explored less than one per cent of the deep ocean. In fact, we know less about the ocean floor than we do about the surfaces of the Moon and Mars. In addition to scientific study, it was to function as a global educational and communications platform, enabling scientists on board to share their findings with fellow experts and the public alike, right around the planet, as well as raise awareness of environmental issues.

The brainchild of French architect Jacques Rougerie ,who took his inspiration from Jules Verne, Jacques Piccard and Jacques-Yves Cousteau, work on the $50 (£35) million project has since stalled. Construction of the 1,000-tonne vessel had been due to start in 2014, but by May 2015 only the Eye of SeaOrbiter, the first part of the construction of the vessel, was successfully completed. Construction was made possible by a crowdfunding campaign.

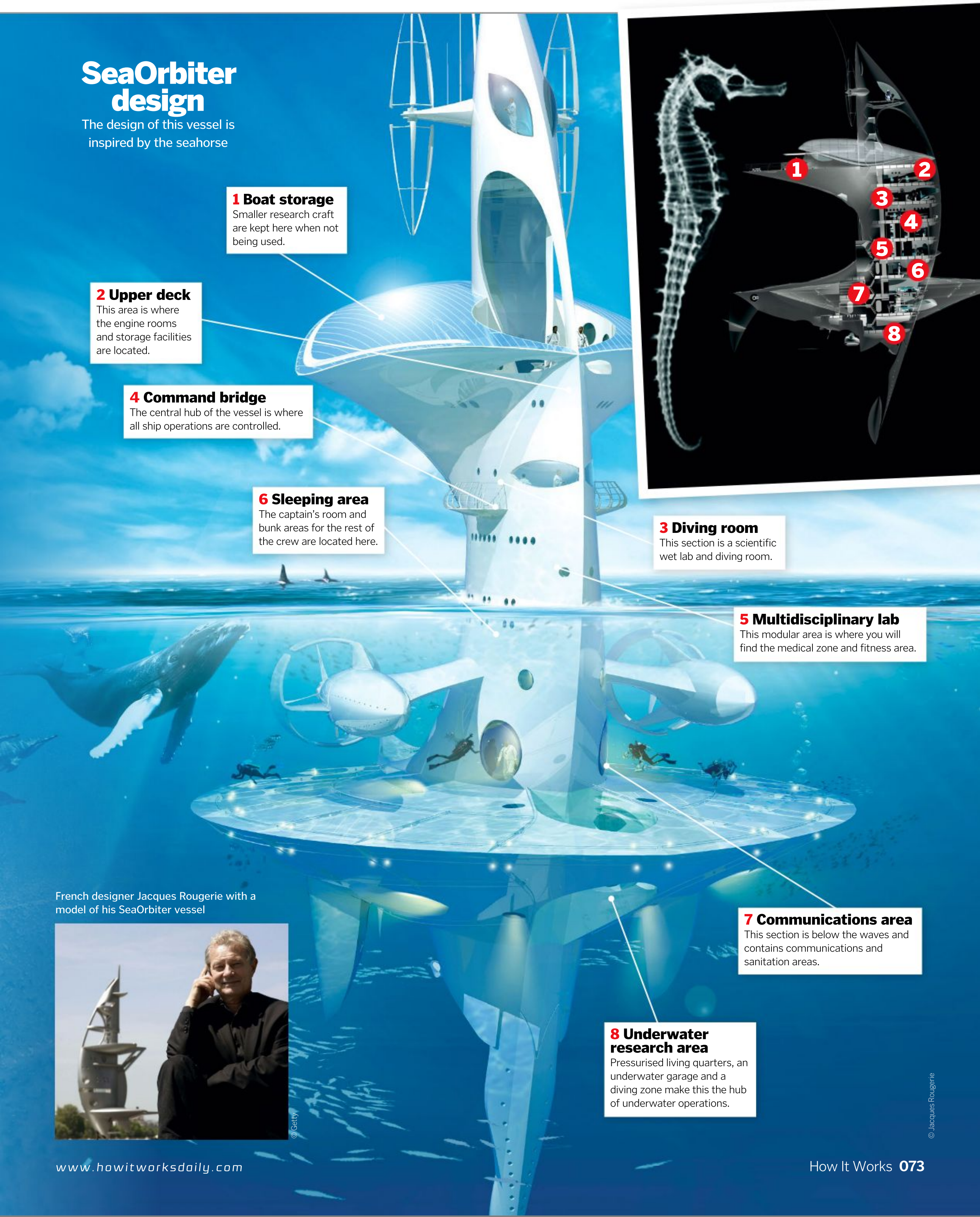
The seafaring City of Meriens was designed around one of the ocean's most recognisable creatures: the manta ray

City of Meriens

SeaOrbiter isn't the only groundbreaking design from the mind of Jacques Rougerie. The City of Meriens is designed to be nothing less than a floating city, measuring a gigantic 900 metres by 500 metres and housing up to 7,000 scientists and students from around the world.

Designed in the image of a giant manta ray, it will come equipped with labs, classrooms, lecture theatres, living quarters and areas for leisure activities and sports, making it a long-term place to live and work in order to facilitate research projects.

The design was picked for its ability to withstand harsh sea conditions, with most of its mass being below the water to help keep it steady. At its centre will be a large 'lagoon', where vessels such as the SeaOrbiter could dock. There are no plans to build the city yet, but if it ever takes to sea it would mark a new era in ocean research.



SeaOrbiter design

The design of this vessel is inspired by the seahorse

1 Boat storage
Smaller research craft are kept here when not being used.

2 Upper deck
This area is where the engine rooms and storage facilities are located.

4 Command bridge
The central hub of the vessel is where all ship operations are controlled.

6 Sleeping area
The captain's room and bunk areas for the rest of the crew are located here.

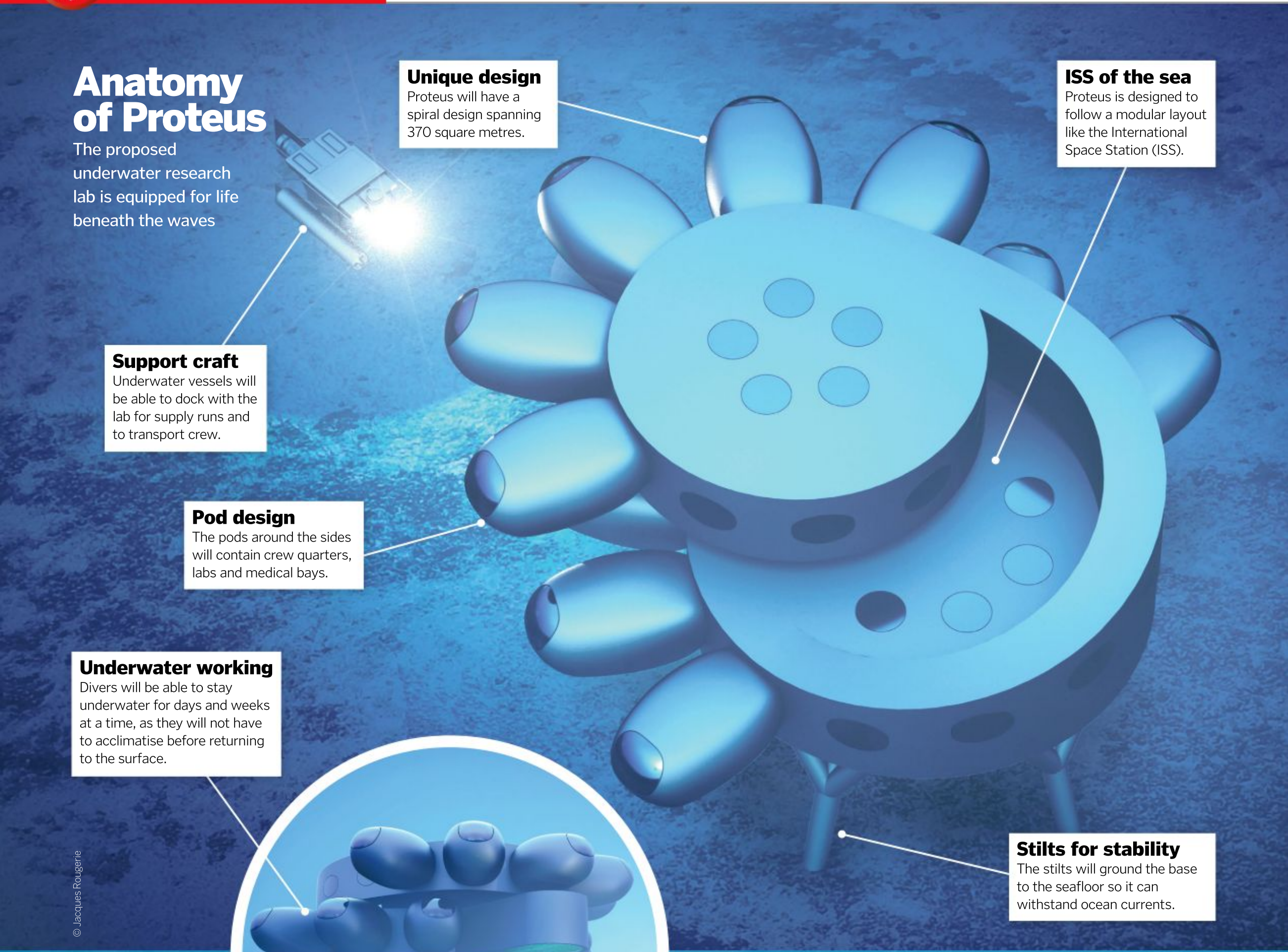
3 Diving room
This section is a scientific wet lab and diving room.

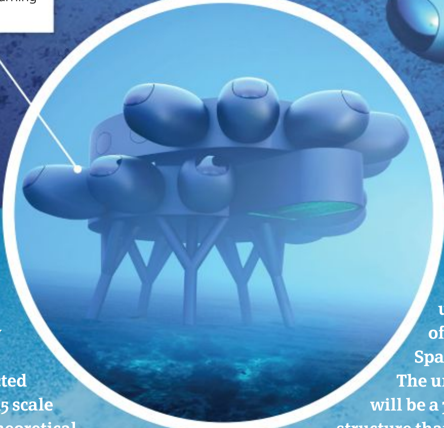
5 Multidisciplinary lab
This modular area is where you will find the medical zone and fitness area.

7 Communications area
This section is below the waves and contains communications and sanitation areas.

8 Underwater research area
Pressurised living quarters, an underwater garage and a diving zone make this the hub of underwater operations.

French designer Jacques Rougerie with a model of his SeaOrbiter vessel





Work on a smaller scale was also carried out. The Norwegian Marine Technology Research Institute MARINTEK conducted tank tests with a 1:15 scale model. Advanced theoretical studies and hydrodynamic tests were carried out to improve SeaOrbiter's seakeeping performance and to optimise its behaviour in waves and wind. But despite what appeared from the outside to be steady progress, as of today there is still no sign of any further work being carried out. While mystery may surround the apparent lack of further progress on the vessel, projects to uncover the secrets of our oceans have continued apace.

One such development is the Proteus project. Designed to be an underwater lab, the goal of its developers is for it to become an underwater version of the International Space Station (ISS).

The undersea laboratory will be a 370-square-metre structure that can be a home for up to 12 people at a time – but that could just be the start. Like the ISS, Proteus is designed to be modular in nature, so more pieces could be added as time goes by, making it even bigger.

Proteus will feature a two-storey circular structure fastened to the ocean floor on stilts, with protruding pods that house labs, living quarters, medical bays and a 'moon pool' – a hatch where divers can access the ocean floor. When constructed, it will sit on the seafloor about 18 metres below the surface off the island of Curaçao in the Caribbean Ocean. Once in place, it will allow scientists to dive and work for longer without having to return to the surface.

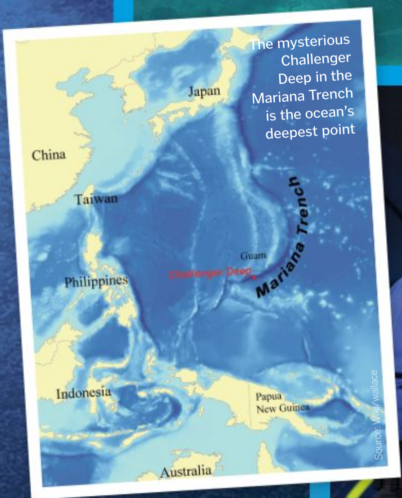
Power for the station is expected to come from solar energy and the movement of the ocean. It may also have what is thought to be the first underwater greenhouse in the world, enabling the lab's crew to grow some of their own food.

In some ways, working beneath the ocean is every bit as challenging as working in space. Diving takes a toll on the human body because when it is underwater, pressure causes nitrogen in the lungs to dissolve into the body. The longer a diver is underwater, the greater the build-up of nitrogen.

If a diver comes back to the surface too quickly, the nitrogen can form bubbles in their blood, which can make them extremely ill and confused, known as 'the bends'. To stop it happening, divers have to slowly come back to the surface while they gradually

The Aquarius Reef Base is an underwater facility off the coast of Florida

Source: NASA



The mysterious Challenger Deep in the Mariana Trench is the ocean's deepest point

Source: Wiki/wallace

Fabien Cousteau, grandson of Jacques Cousteau and the man behind Proteus

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acclimatise. The process can take hours, meaning all of that potential research time is lost. This is what makes an underwater research hub so potentially groundbreaking. If divers were able to stay underwater for long periods of time on a facility like Proteus, they could undertake dives night and day. This would have huge benefits for their ability to explore the deep.

The man behind the Proteus project, conservationist, aquanaut and filmmaker Fabien Cousteau, is the grandson of legendary ocean explorer Jacques Cousteau, one of the famous 'musketeers of the sea', who was also an inspiration to the architects of the SeaOrbiter.

The structure itself was designed by industrial designer Yves Béhar. Together they hope to raise the $135 (£95) million needed to turn their dream into reality. If successful, it will be operational by 2023. Cousteau says that once it is up and running, as well as studying the ocean it will also allow scientists to research new ways of growing food, creating energy and even carrying out medical research.

If it is a success, Cousteau says there could one day be a whole network of underwater habitats in different oceans around the world. They would be able to warn of tsunamis and hurricanes, and also allow for pioneering research into things like robotics, sustainability and energy. While it may be trailblazing in both scope and ambition, Proteus will not be the first underwater lab. Another facility called Aquarius has been operational since 1986.

Positioned off the coast of Florida, Cousteau previously set a record for living underwater when he worked there for 31 days in 2014. The 37-square-metre base can only accommodate six people, while the Proteus lab will be ten times bigger at 370 square metres, and can house double that number.

Q&A

SeaOrbiter designer Jacques Rougerie is a French architect and oceanographer who specialises in underwater habitats. How it Works speaks to him about SeaOrbiter's future and his thoughts on the future of ocean exploration

What is happening with SeaOrbiter at the moment? Has the project stalled?
The SeaOrbiter project is in no way stopped, especially since it is increasingly anchored in major current issues on climate and ocean biodiversity. It is more relevant than ever. However, the international situation due to the coronavirus has slowed down the search for funding. But more than ever we are determined to carry out this project on an international level.

Where did you get design inspiration for SeaOrbiter?
SeaOrbiter is the synthesis of 30 years' of experiences related to the realisation and the experimentation of underwater habitats that we have carried out, such as the underwater houses Galathée, Hippocampe or Aquabulle, or the semi-submersible vessels with transparent hulls like Aquascope and Aquaspace that we have also made.

Given the specificity of the SeaOrbiter program to maintain crews for long periods of time under the drifting sea, we started with a concept of biomimetic architecture: this vessel is vertical, like a hippocampus [part of the brain associated with learning and memory].

How does SeaOrbiter compare to your other ocean projects? Which is your favourite?
The different submarines or underwater research boats around the world are not able to do what SeaOrbiter does: an international base that allows a crew to constantly observe and listen under the sea and which is able to exit directly underwater at any time.

What do you think of other sea projects currently being undertaken, such as the Proteus underwater lab?
I happen to work as an architect in collaboration with Fabien Cousteau on Proteus, which is a magnificent project for an international fixed submarine station. It is a research base with versatile programs to develop a [ocean-friendly] Blue Society on the scale of *The Blue Planet*.

HOW WE LEARN

Forget artificial intelligence, the human brain is the original neural network

Words by **Laura Mears**

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The brain is a collection of an estimated 86 billion neurons, connected together in a communications network more complex than the internet. Neurons pass messages like telephone wires, shooting electrical impulses at speeds of up to 180 miles per hour. They exchange signals using packets of chemicals called neurotransmitters, which can either tell the next neuron to pass the message along or to stay quiet. The connections between neurons are the basis of memory, and making them is how we learn.

The theory of human learning is founded on the idea that one brain cell can't learn on its own – it's the connections between brain cells that make learning possible. In the late 1940s, psychologist Donald Hebb explained that "nerves that fire together wire together". This essentially means that when brain cells are repeatedly activated at the same time, they become physically and chemically linked. Learning a new skill is all about strengthening the connections between the brain cells that send the signals to perform that skill.

This concept is called 'Hebbian learning', and at a cellular level, it looks a bit like this: when one brain cell sends a message to another brain cell, the second cell has to decide whether to pass the message along. At first it's not always clear if the message is important, but if the cell sends the same message again and again and again, something starts to change. The first cell starts producing more neurotransmitters so that it can send a bigger signal, and the second cell makes more receptors so that it can detect the signal more easily. Together these changes strengthen the connection between the cells, ensuring that the message always gets through.

"The theory of human learning is founded on the idea one brain cell can't learn on its own"

In the real brain, the situation is a bit more complicated. It's rare that communication happens only between two cells. In reality, each

© Getty

Everything you know is stored in the connections between your brain cells

Artificial neural networks

AI works in almost the same way as the human brain. Instead of thousands of brain cells, machine learning algorithms have thousands of nodes. Just like a neuron, each node receives incoming signals and has to decide whether to pass them on to the next node. To make this choice, it gives each signal a weight, which determines how important it is. A higher weight means a higher chance the signal will be passed on. To begin with all the weights are set at random, so the algorithm is essentially guessing what to do with each signal. To learn, it makes tiny changes to the weights, and then sees whether its guess is better or worse than before. This trial and error tunes the network, strengthening good connections and weakening bad ones – just like human learning.

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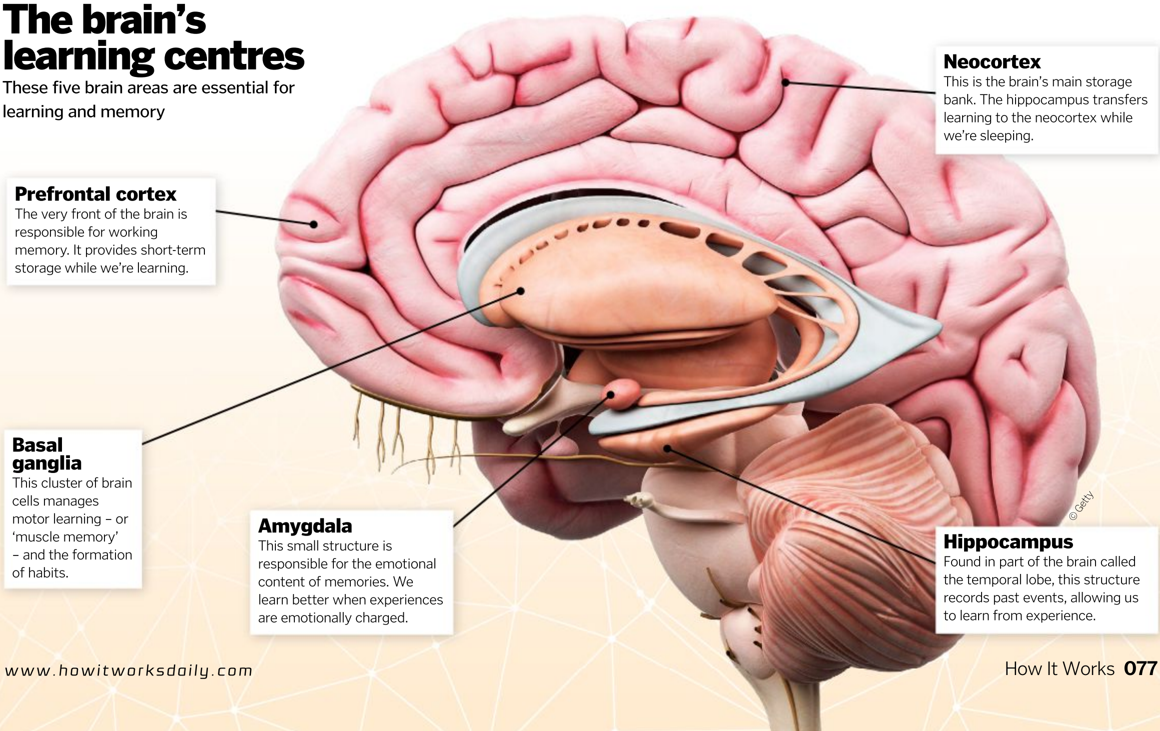
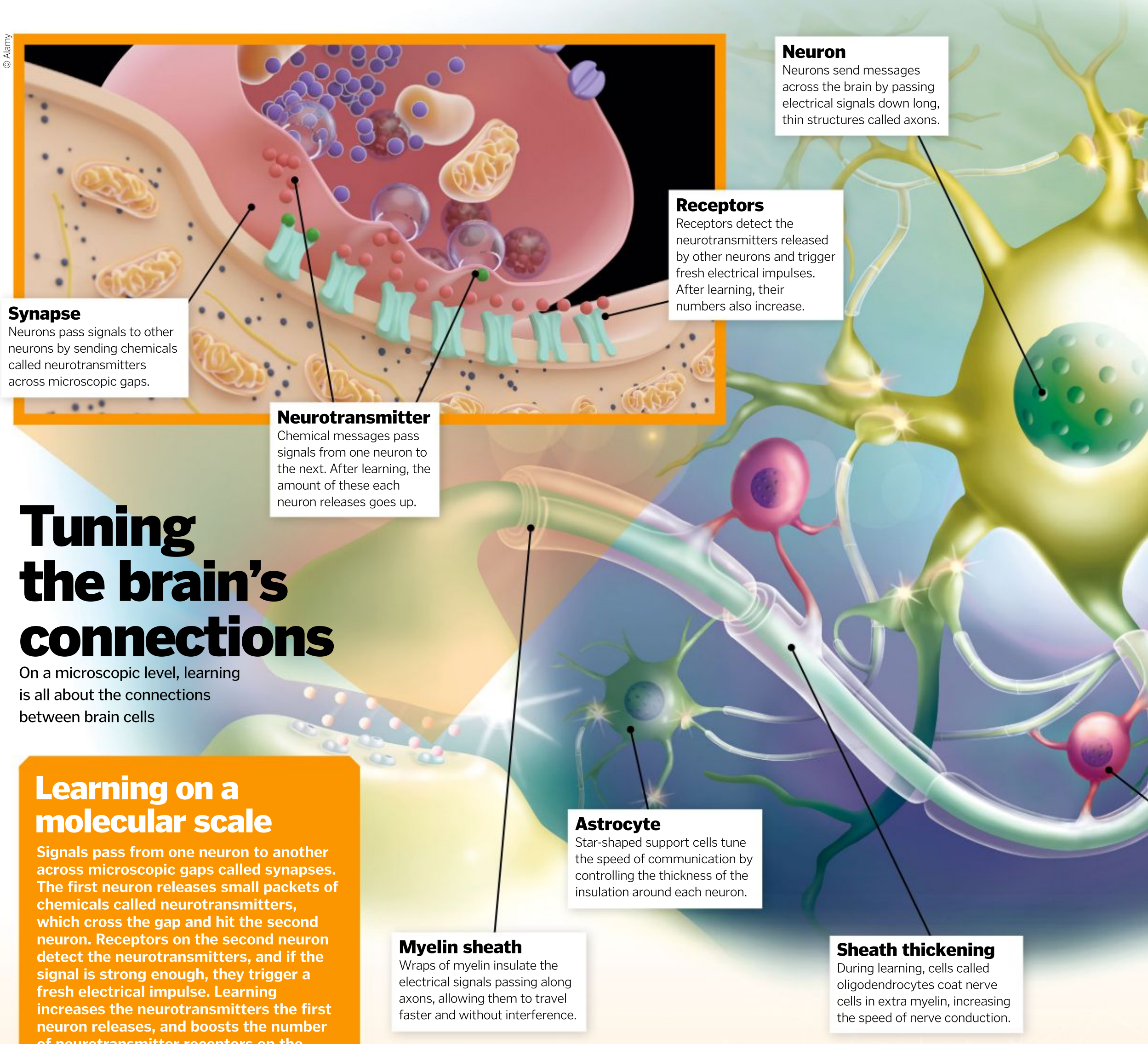
The most intelligent computer algorithms are modelled on the human brain

The brain's learning centres

These five brain areas are essential for learning and memory



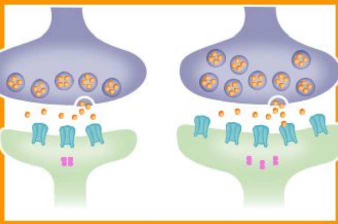


Tuning the brain's connections

On a microscopic level, learning is all about the connections between brain cells

Learning on a molecular scale

Signals pass from one neuron to another across microscopic gaps called synapses. The first neuron releases small packets of chemicals called neurotransmitters, which cross the gap and hit the second neuron. Receptors on the second neuron detect the neurotransmitters, and if the signal is strong enough, they trigger a fresh electrical impulse. Learning increases the neurotransmitters the first neuron releases, and boosts the number of neurotransmitter receptors on the the second neuron. These changes strengthen the connection between the two cells, making it easier for them to exchange signals in the future.

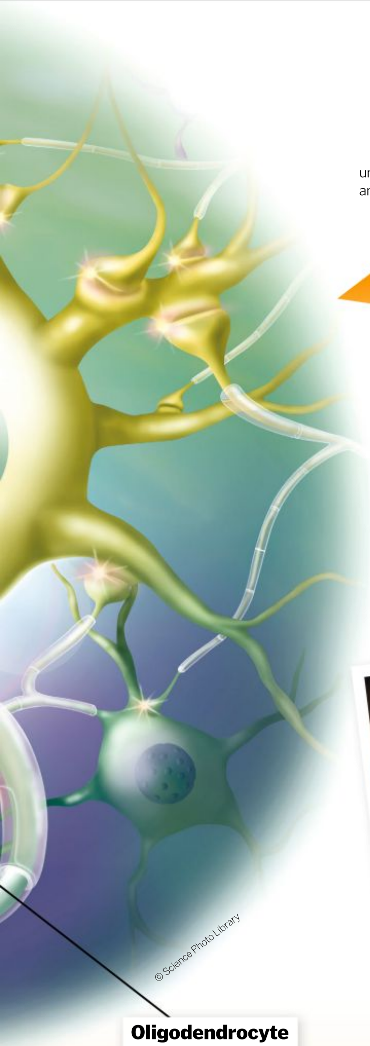


neuron makes up to 1,000 connections to others, and signals can arrive all at once. Each neuron has to weigh up every message it receives and decide whether to pass it along. Learning is the process of balancing those decisions. One of the easiest ways to see this in action is to look at organisms with simpler nervous systems than our own.

> "Each neuron makes up to 1,000 connections to others"

Sea slugs have an organ called a siphon, which they use for moving, feeding and breathing. It's quite delicate, so if they sense danger they quickly pull it away. This reflex normally doesn't happen if they feel a really gentle touch on their siphon. But they can learn to withdraw from this non-threatening situation if the connections between their neurons are altered.

Researchers at the University of California attached electrodes to sea slug neurons. They chose one neuron from the siphon and another from the tail, both of which pass messages to a third neuron that controls siphon movement. Before the experiment, the movement neuron



From zero to hero

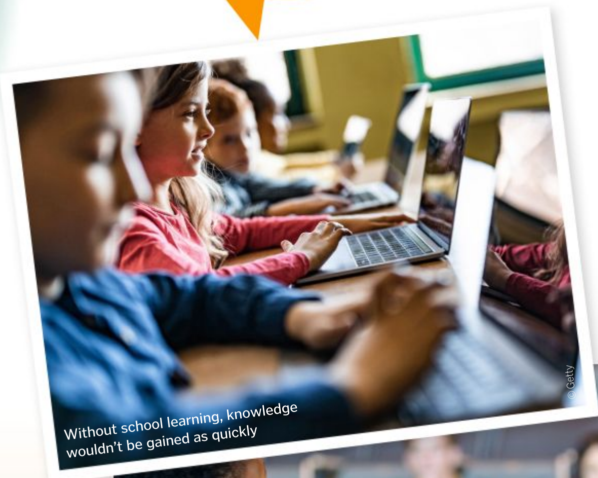
Invented by Noel Burch in the 1970s, the four stages of competence explain how we think and learn

1 Unconscious incompetence
The learner is completely unaware that they lack the skill, and may even be overconfident in their ability.

2 Conscious incompetence
The learner becomes aware that there is a gap in their understanding. This can either be motivating or demoralising.

3 Conscious competence
The learner practises the skill and starts to learn, but they need to concentrate hard to be successful.

4 Unconscious competence
The learner masters the skill. They are now so good at it that they can do it without thinking.



Without school learning, knowledge wouldn't be gained as quickly

5 FACTS ABOUT YOUR NEURONS

1 They have three parts
The cell body houses genetic code and protein factories. Dendrites receive incoming signals, and the axon passes electrical messages to other cells.

2 There are three types
Sensory neurons detect touch, taste, light, sound and smell. Motor neurons send signals to the muscles and interneurons connect other neurons together.

3 They don't live forever
Like us, nerve cells in the brain and body get old and die. Loss of neurons contributes to diseases such as Alzheimer's, Parkinson's and Huntington's.

4 They need support
Neurons rely on other cells to do their job properly. Astrocytes maintain chemical balance, oligodendrocytes insulate electrical signals and microglia guard against infection.

5 They can regenerate
Researchers once thought brain cell regeneration was impossible. Now we know that even in adults there are stem cells capable of creating new neurons.

didn't really respond to messages from the siphon neuron.

To change this, the researchers passed electrical impulses along the siphon neuron to simulate a gentle touch. At the same time they passed strong electrical impulses along the tail neuron to simulate a danger signal. This taught the synapse that the gentle touch signal meant that danger might soon be coming. During the experiment, the connection between the siphon neuron and the movement neuron strengthened so much that eventually a light touch on its own was enough to trigger the withdrawal reflex without any danger signal from the tail at all.

Adults find it easier to learn skills related to skills they have already mastered

Human, machine and evolutionary learning

Dr Richard Watson is an associate professor at the University of Southampton. He works at the interface between computer science and theoretical evolutionary biology

Just because we're made out of different stuff doesn't mean that humans learn in a different way to computers. Dr Watson's work on expanding the theory of evolution has given him great insight into the way animals, machines and even evolution itself learns and adapts – and he has come to some quite staggering conclusions.

Can you explain how learning works?
One of the key insights of neural models of brain learning is that intelligence is not in the neurons – it's in the organisation of the connections between them. The way that they learn is by changing the strengths of these connections.

There's one particular model of how connections change which is sufficient to do some really interesting behaviours, and that is Hebbian learning. It says that if two neurons fire at the same time, or in quick succession, then the strength of the connection between them is increased. But if one fires without the other, the connection is decreased.

That's such a simple rule, but it's capable of many interesting behaviours: forming an associative memory – storing multiple patterns that describe what things naturally 'go together' – generalising from past data to new situations and improving its ability to solve problems with experience.

Is that the same as the way AI learns?
Artificial neural networks also learn by changing the strength of the connections between neurons. The way that they change the strength of the connections is not the same in the details, but it's similar in essence.

In machine learning you often have an idea of what the output is supposed to be. If it's a picture of a cat, you want it to say 'cat'. If a network's output is a little bit wrong, you adjust the connections in the direction that makes it a little bit less wrong. Hebb's rule reinforces what your response was already, whereas this rule makes

© Sarah Rush

Watson participated in the world's largest project to update our understanding of evolution

your response more like what the answer 'should' be – but they both work by modifying connection strengths.

Your work suggests that evolution can learn too. What does that mean?
The kind of learning where you learn by changing the strengths of connections, natural selection can do that too. Evolution works by making small random changes. If the change produces an improvement then it's kept, and if it makes things worse then it's not. That sounds a bit like trial-and-error learning: you try stuff at random and do more of the behaviours that work and less of the behaviours that don't. That kind of equivalence between learning and evolution has been noted many times.

A further level of equivalence is a connection between evolution and the kind of connection-based learning that I mentioned already. If you produce an organism with not just a set of genes, but a network of genes, then the effect of natural selection acting on the connections between the genes acts in the same way that Hebb's rule did in the previous examples. It strengthens the connections between genes that are expressed at the same time, and it weakens the connections between genes where one is expressed and the other is not.

It means that evolution by natural selection can do the same kind of tricks that neural networks can do. It can evolve a network that holds an associative memory of multiple patterns it's been exposed to in the past. It can improve its ability to solve problems with experience in the same way that a neural network can. And it can generalise; evolution isn't supposed to be able to anticipate which phenotypes will be well adapted for a new environment. A neural network can do that: you train it on past data and you show it a situation it hasn't seen before, and it produces an output suitable for that new situation. And that's not magic – it's called generalisation. The idea that evolution can do that too expands our understanding of how evolution works.

What do the links between human learning, AI and evolution tell us?
These principles of learning can also operate in other kinds of networks that are not brains and not networks within organisms. Networks such as the networks of friendships between people in a society.

Artificial neural networks also learn by changing the strength of the connections

An AI cat at the China International Big Data Industry Expo in 2021. This robot learns in a similar way to the girl next to it

© Getty

Suppose that I'm doing some behaviour and you're doing some behaviour. When I behave the same as you, we strengthen our friendship. And when I do the opposite of what you're doing, we weaken our friendship. If friendships change in that way, then that means that social networks can do the same kind of learning that neural networks and gene networks can do.

It means that human organisations and human society can learn in a way that's greater than the sum of the parts – a way that's not just about getting smarter because the people in the system get smarter, but about intelligence that's held in the relationships between people.

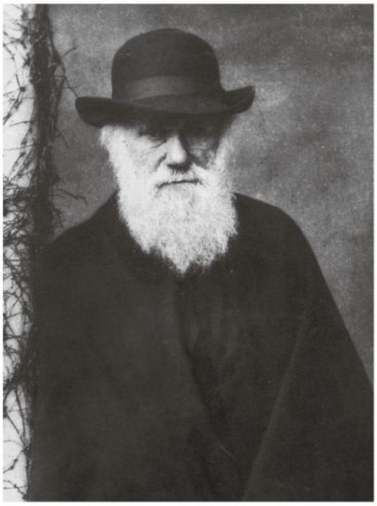
What do you think that means for the future?

The conventional scientific view suggests that survival of the fittest is how nature works. If you interfere with competition, you'll make the system worse, not better. This supports a worldview that says that life is about competition, selfishness and individualism.

But there's a different worldview that says we're all part of a larger web of living things in relationships with one another. That worldview is more to do with cooperation and connectedness, not winning.

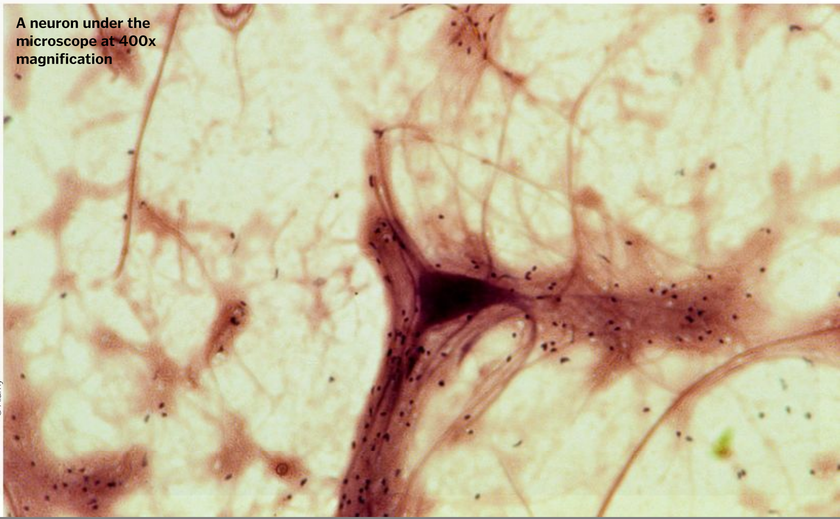
If it's the case that selection changes relationships in a way that produces intelligence at the system level, then it's not just everyone against everyone fighting for themselves. Although they might not know what their role is in the system, they are part of a larger system, and the organisation of that system is not arbitrary. The organisation of that system is shaped by the past experience of the system and has knowledge in it which is valuable, knowledge which enables the system to adapt to future circumstances.

This gives some scientific basis to the ancient worldview that we're part of a harmonious web of life with relationships that deserve respect. That's where the systemic intelligence resides – not in us as individuals, but in the connections between us and with other living things. This is a more humble view where treating other people and the biosphere as resources to be exploited is not natural, not healthy and not inevitable.



© Getty

Charles Darwin laid the foundations for evolutionary theory, which Watson is expanding on with evolutionary learning



A neuron under the microscope at 400x magnification

© Alamy

BRAIN DUMP

Because enquiring minds need to know…

MEET THE EXPERTS

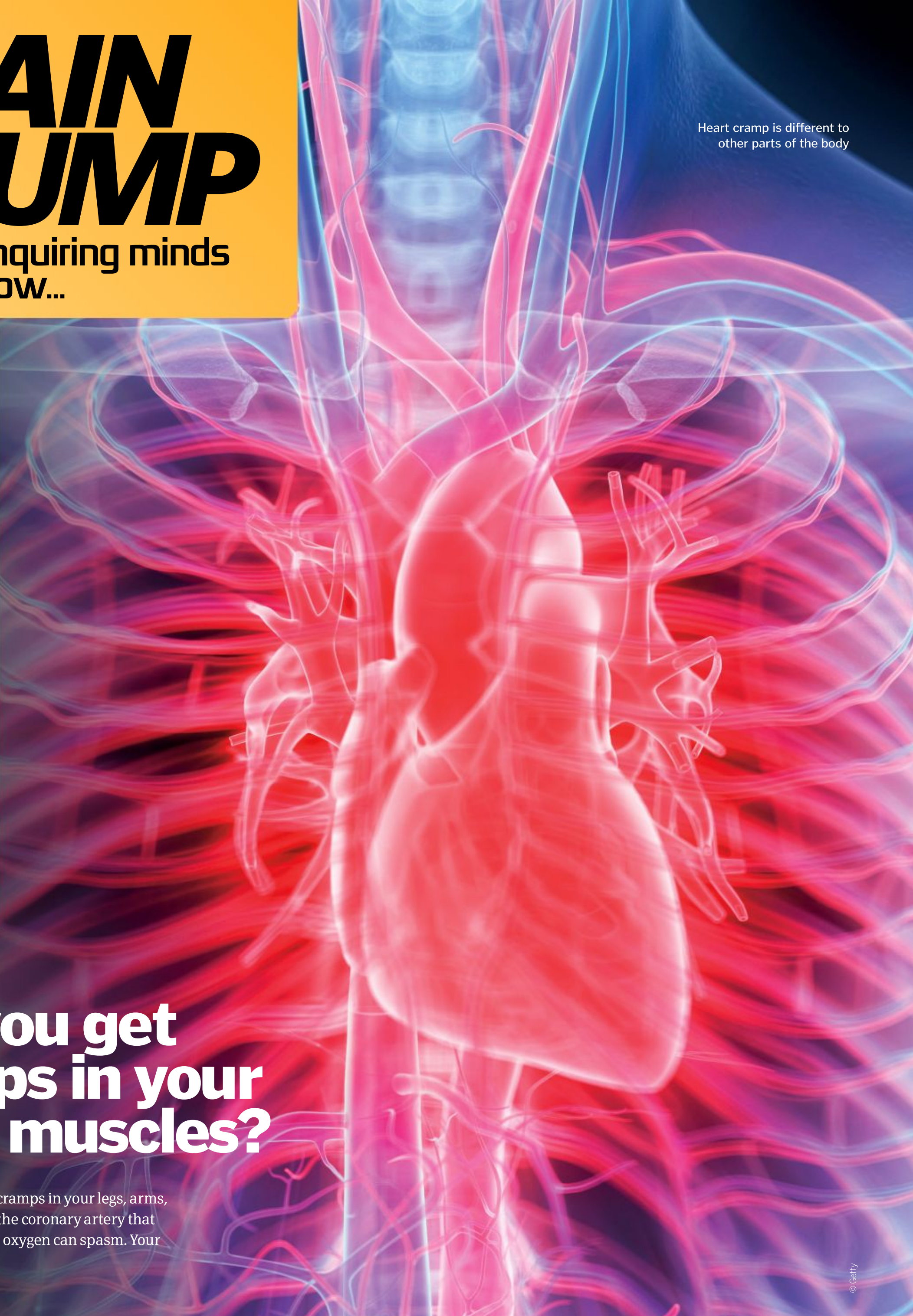
Who's answering your questions this month?

JO ELPHICK

AMY GRISDALE

ANDY EXTANCE

ANDREW MAY



Heart cramp is different to other parts of the body

© Getty

SCIENCE

Can you get cramps in your heart muscles?

Ed Howell

■ Not the way you get cramps in your legs, arms, hands or stomach. But the coronary artery that supplies the heart with oxygen can spasm. Your ribs can cramp too. **AE**

WANT ANSWERS? Send your questions to… How It Works magazine @HowItWorksmag howitworks@futurenet.com

HISTORY

Why did America test so many nuclear bombs?

Josh Ramis

The US tested over 1,000 nuclear bombs between 1951 and 1992, both atmospheric and underground. The purpose of these tests was to determine the effects of a nuclear attack on the physical environment and any human-made structures, as well as studying the effects of nuclear fallout. As the Soviet Union began building up its own atomic weapon arsenal after World War II, America became intent on developing the largest number of nuclear arms to reinforce US power and control. **JE**

A beautiful but deadly mushroom cloud towering above Bikini Atoll

ENVIRONMENT

Why do badgers have black and white faces?

Suzannah Wilson

There are two theories about badgers' appearance. They might be warning stripes to let predators know not to mess with a badger because they'll put up a fight. Scientists call this aposematism, and it's the reason toxic frogs are so vividly coloured. The alternative idea is that variations in the stripes help badgers recognise one another. **AG**

DID YOU KNOW?

The first US atomic bomb used in war was called 'Little Boy'

ENVIRONMENT

Do birds have knees?

Colin Powers

Yes, but not where you might think. The bend we see in a bird's leg may look like a knee bending backwards, but it's actually the ankle. Bird knees are inside the body, hidden by skin and feathers. The long foot begins at the ankle joint, but it isn't all used to stay in contact with the ground. All a bird's weight is carried by its toes. **AG**

Humans have mostly the same bones as many animals, just in a different configuration

TECHNOLOGY

When will we stop using physical money?

Alison Crowley

Despite today's contactless payment technology and chip-and-pin devices, we may never lose hard cash. Physical money is stable, unlike Bitcoin. It's also untraceable, which might occasionally prove useful. Notes and coins are globally reliable and ultimately convenient. The internet may crash, but you can still pay with cash. **JE**

BRAIN DUMP

ENVIRONMENT

Why is the desert in Australia so red?

Fu Wei

Two main factors give the deserts of Australia, which cover nearly 20 per cent of the country, their characteristic tinge: the hot and dry conditions are perfect for oxidisation, in which the iron-rich rocks react with the air to form large amounts of ferrous oxide. The red colour you see in the desert sand is rust. Australia has largely been unaffected by the ice ages in Earth's recent history, so this rust has had the chance to pile up over millions of years. **AE**

The Simpson Desert in South Australia's Northern Territory has large tracts of orange-coloured sand

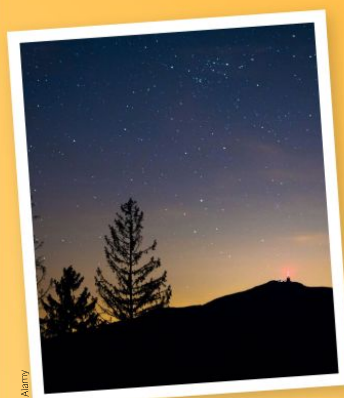
© Getty

SCIENCE

Why has no one made strong alcoholic ice cream?

Isla-Rose Gray

It's because the alcohol in drinks, technically called ethanol, freezes at a much lower temperature than water: -114 degrees Celsius. If you add too much ethanol to ice cream, it won't freeze. You can't get away with more than a few spoonfuls of strong spirits, and even that makes it much softer. **AE**



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ENVIRONMENT

Does starlight still hit Earth during the day?

Kallum Rogers

Yes, the stars are just as bright during the day as they are at night. But they are much fainter than the Sun shining in the daytime sky, so we can't see them until after sunset. **AM**

© Getty

ENVIRONMENT

Do all animals have hearts?

Matthew Foster

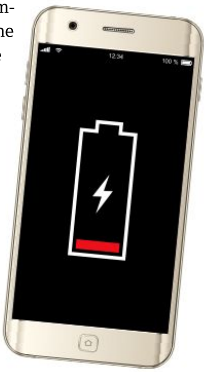
Jellyfish and corals don't have hearts – or a circulatory system of any kind. They absorb all the nutrients they need from the surrounding water. Starfish and sea urchins don't have hearts either, but pump food-filled sea water directly into their bodies. **AG**

TECHNOLOGY

Can batteries discharge themselves over time without being put in a device?

Ferne Robson

Yes, it's called self-discharge. Lithium-ion batteries lose about two per cent of their charge per month if left charged. This is because batteries are electrochemical, rather than purely electronic devices. That's reflected in their names. In lithium-ion batteries, ions of the element lithium move between electrodes, releasing electrical energy as they do so. They do this quickly on demand when we use our gadgets. But it can also happen when the battery is left alone. **AE**



If you leave a device switched off for a long time, it can self-discharge

© Getty

© Alamy

SCIENCE

Why do muscles go soft if they're not exercised for a while?

Anne Mikayla

When you exercise a muscle rigorously, your muscles achieve what is known among bodybuilders as 'the pump': your heart pumps extra blood to the muscle, giving the muscle tissue the extra nutrients and oxygen it needs to perform. The increased blood flow causes the muscle to swell up and become much harder than before, like a football that has been fully pumped up. 'The pump' only lasts for around 20 minutes after a workout, but if you don't exercise that muscle again for a long time then it will atrophy. This is when the muscle shrinks, loses strength and becomes softer, and is common in older bodybuilders who have stopped lifting heavy weights. **AE**

Bodybuilders have to train hard and frequently or their muscles quickly lose mass and become softer

HISTORY

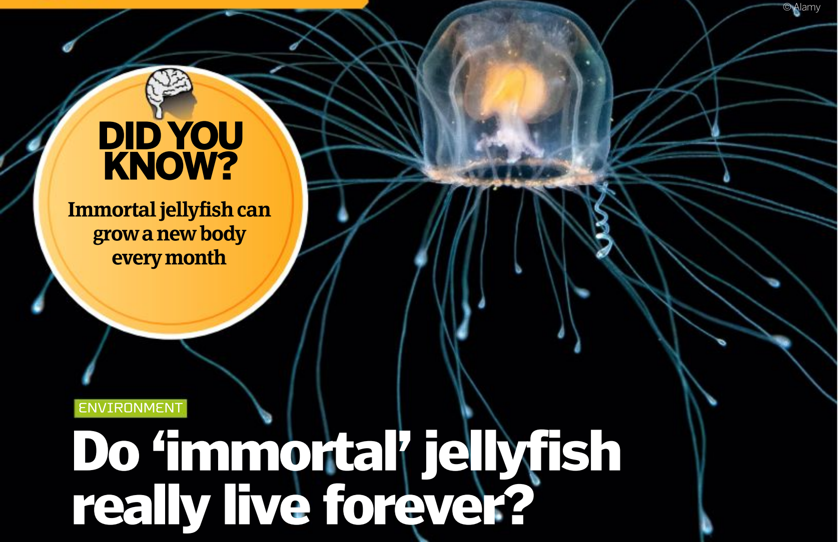
Why does Britain's queen have two birthdays?

Chloe Brandon

She enjoys her actual birthday on 21 April, and a second 'official' birthday in June when the weather is warmer so that her subjects can watch the Trooping of the Colour parade in good weather. **JE**

© Getty

BRAIN DUMP



There are only two animals known to science that can revert back to being babies, and they're both jellyfish

© Alamy

DID YOU KNOW?

Immortal jellyfish can grow a new body every month

ENVIRONMENT

Do 'immortal' jellyfish really live forever?

Sid Blair

■ It's technically possible for these animals to live forever, but only in perfect lab conditions. Once the jellyfish has sustained an injury or can't find enough food to survive, it shrinks back down to its juvenile form. It reabsorbs its tentacles and sinks to the seafloor as a polyp. It begins maturing and eventually becomes an adult again. This process is called transdifferentiation, and it's extremely rare. If there were no predators in the ocean the immortal jellyfish would really live up to its name, but jellyfish of all growth stages are eaten by fish, turtles and sea slugs. The adults only have a weak sting, and the polyps are defenceless blobs ready for the taking. **AG**

King Kullen supermarkets are still 'piling it high and selling it low' today

© Getty

HISTORY

When were supermarkets invented?

Anthony Edwards

■ The first supermarket appeared in New York on 4 August 1930, named 'King Kullen' after its creator Michael J. Cullen. The store was an instant hit, providing self-service, individual product departments and discount pricing. It also had a car park, which meant families could load up their weekly shopping in one go without having to travel to different stores. The supermarket's motto – 'Pile it high. Sell it low' – became the blueprint for all supermarkets that followed. Cullen also started the concept of 'chain stores'. By the time of his death there were 17 King Kullens in operation. **JE**

© Alamy

SCIENCE

Why doesn't injecting deadly Botox for beauty treatment harm the patient?

Cathy Torres

■ Botulinum toxin kills by paralysing muscles, including the crucial ones that work the lungs. But when it's used in medical procedures under the name Botox, the dose is much too small to be dangerous. The paralysing effects remain localised, for example in the muscles that cause facial wrinkles. **AM**

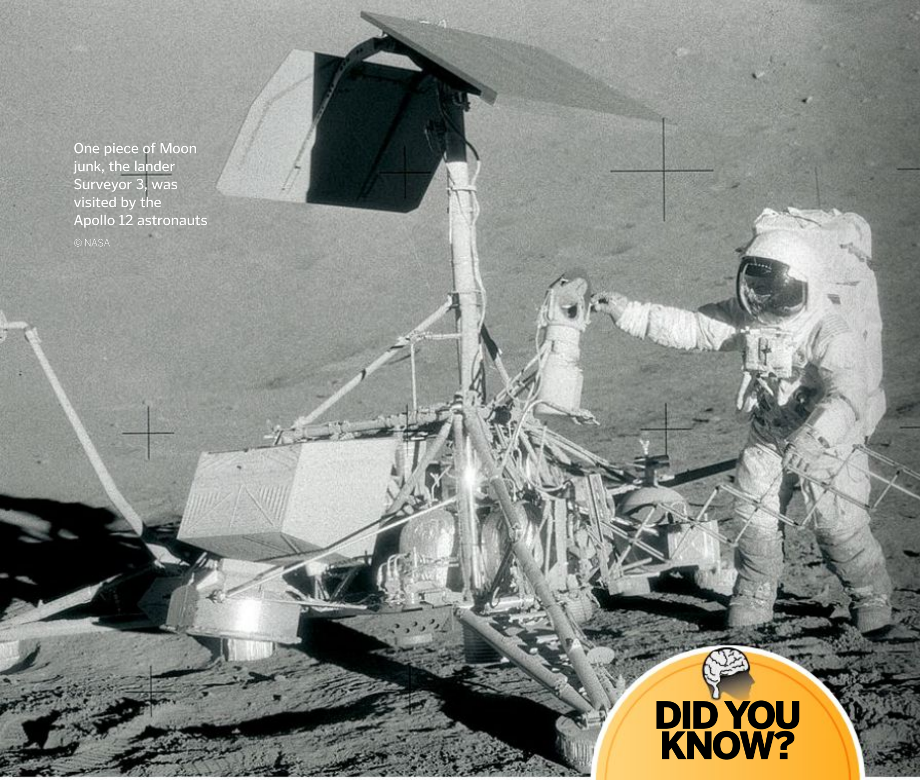
© Alamy

TRANSPORT

Why did the Victorians make penny-farthing bikes with a ridiculously huge wheel?

Letitia Jordan

■ Two features of modern bicycles – the chain drive and pneumatic tyres – only emerged in the 1880s. Before this, with solid wheel rims, bikes were uncomfortable 'bone-shakers', while their speed was limited by the lack of gearing between pedals and wheel. The penny-farthing was an attempt to get around these problems. The large wheel meant the bike travelled faster for a given rate of pedalling, while its springy, extra-long spokes provided a degree of comfort. **AM**



One piece of Moon junk, the lander Surveyor 3, was visited by the Apollo 12 astronauts

SPACE

What space junk has been left on the Moon?

Stuart Powell

Since the first lunar probe in 1959, the Moon has seen more than 180 tonnes of 'space junk' arrive from Earth. The bulk of this consists of space vehicles, over 70 in all, that either soft landed or crashed. The latter weren't always accidents; this includes orbiters and rocket stages that were deliberately crashed after achieving their purpose. The Apollo astronauts also left their share of junk behind, discarding unwanted items like tools, boots and cameras to save weight on the journey home. To top it all off, there are 96 small plastic bags filled with human waste. **AM**

DID YOU KNOW?

Avocados are extremely calorific, but are very good for you

SCIENCE

What makes high-GI foods more quickly digested and absorbed?

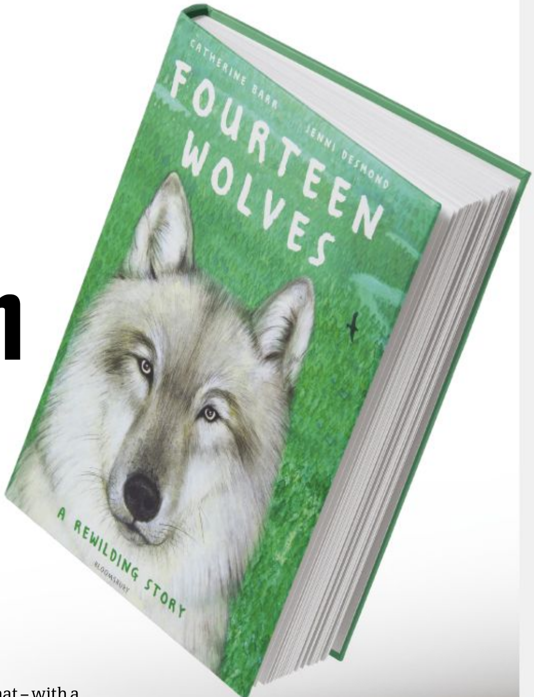
Sarah A (@masarahrit)

A food's glycemic index (GI) rates how fast it raises glucose levels in your blood. Many things affect this. Sometimes food breaks down into small particles that are easier to absorb. If food contains glucose as an ingredient, that easily gets into blood. But food often contains starch instead, which is a long, chain-shaped molecule. The links in that chain can be sugars like glucose. These chains break down in different parts of our guts, releasing glucose more slowly. Foods also contain fibre, containing complex chains made of sugars like glucose that break down even more slowly in our guts. **AE**

Food contains sugar in simple glucose form and more complex forms like starch and fibre

BOOK REVIEWS

The latest releases for curious minds



Fourteen Wolves

A REWILDING STORY

- Author: **Catherine Barr**
- Illustrator: **Jenni Desmond**
- Publisher: **Bloomsbury**
- Price: **£12.99 / $21.59**
- Release: **Out now**

This is a story – a true one at that – with a simple but profound lesson in how humans can drastically affect the ecological balance of a wilderness. Over the course of the 20th century, the wolves of Yellowstone National Park in the US were systematically hunted and driven from their native lands, until there were none left.

Incredibly, the removal of this one species, an apex predator, had a direct and diabolical effect on this national park. The population of elk boomed without the wolves to keep them in check, and these huge, roaming herds of grazers ate all the young saplings and shrubs so that new tree growth disappeared. Without trees, birds began to leave Yellowstone, beaver populations shrank and thousands of other species that directly or indirectly depended on wolves in some way were diminished. Even the rivers changed their course – without roots to anchor them, river banks collapsed and fish stocks dwindled.

Then, in 1995, the wolves were reintroduced to Yellowstone from Canada. They bred: three packs became six, six became twelve and so on. The elk population was brought under control once more, trees were given a chance to grow again and balance was restored. It was good news for everyone – even the elk.

Delivered with simple but particularly powerful language

Fourteen Wolves is the illustrated story of the first wolves that were brought back to the stunning Yellowstone wilderness that spans nearly 3,500 square miles. Author Catherine Barr delivers this tale with simple but particularly powerful language, following the footsteps of the 14 wolves in their first year and beyond.

It's coupled with Jenni Desmond's vivid illustrations that perfectly capture scenes from the wild and bring the animals to life. And it ends with a lesson that can be applied to any species: all animals are connected to each other and the land they inhabit. No species exists in a bubble – not even humans. Remove one from its natural habitat and, like a giant game of taxonomical Jenga, you could bring the whole ecosystem tumbling down.

The Atlas of a Changing Climate

OUR EVOLVING PLANET VISUALISED WITH MORE THAN 100 MAPS, CHARTS AND INFOGRAPHICS

- Author: **Brian Buma**
- Publisher: **Timber Press**
- Price: **£26.99 / £35**
- Release: **9 November**

This is very much a 'does what it says on the tin' kind of reference book. Across nearly 300 pages, National Geographic explorer Brian Buma takes the reader on a journey through the Earth's atmosphere, water, land, cities and wildlife, discovering how it's changed over time. What stands out the most, unsurprisingly, are the impactful and varied pieces of photography, illustrative maps and diagrams that any visual learner will relish.

Although this book is heavy in its scientific content, it's also written in a compelling way that would quench the thirst for knowledge of anyone wanting to learn more about our planet. It's a fascinating and enlightening read about the state of planet Earth and stimulates the mind to consider what the future will hold.

The Book of Amazing Trees

FROM THE BEAUTIFUL BEECH TO THE REGAL REDWOOD

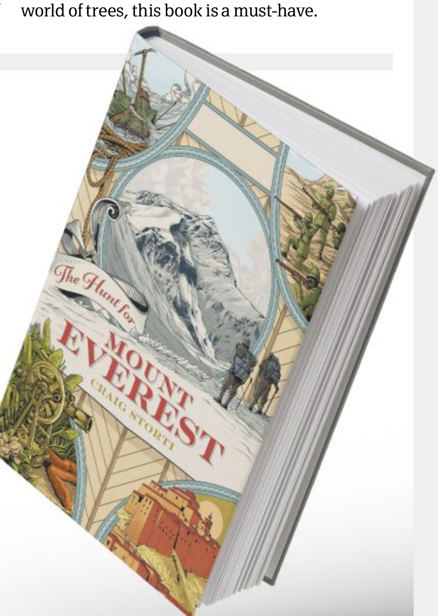
- Author: **Nathalie Tordjman**
- Illustrators: **Isabelle Simler, Julien Norwood**
- Publisher: **Princeton Architectural Press**
- Price: **£14.99 / $19.95**
- Release: **30 September**

As the follow up to *The Book of Tiny Creatures*, author Nathalie Tordjman has once again created a fun and informative encyclopedic guide, but this time for trees. This book is certainly aimed at a younger audience, combining bite-sized nuggets of information about a whole host of tree species with fun activities and beautifully illustrated guides.

Tordjman has filled its pages with a breadth of scientific information, including the principles of photosynthesis and germination and a tree's life cycle, along with fun facts and even a few quizzes. If you've got budding botanists at home who want to learn more about the wonderful world of trees, this book is a must-have.

The Hunt for Mount Everest

RELIVING THE 71-YEAR QUEST



- Author: **Craig Storti**
- Publisher: **John Murray**
- Price: **£20 / $24.95**
- Release: **Out Now**

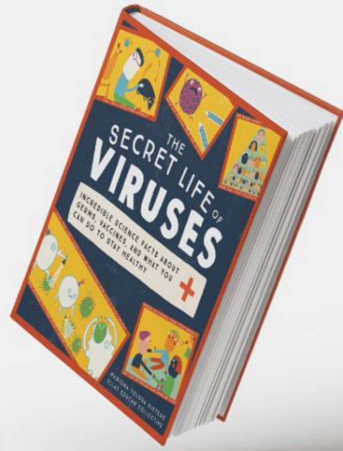
Everest hasn't always been a mountain populated with climbers from around the world. The height of the planet's tallest peak was first measured in 1850 from a nearby ground station, but the first ascent attempts to its peak were only made 100 years ago in 1921. Author Craig Storti has brought together his thorough research into detailed accounts by Everest's first climbers to tell the captivating tale of events before this time. After starting the story with the measurements of the mountain range, this book ends where many other Everest stories begin.

Even if you think you know the history of the world's tallest mountain well, you can pick up this book and become mesmerised by the peculiar personalities, political limitations and animal appearances that played their part in bringing climbers to Everest.

> *The first ascent attempts were only made 100 years ago*

The Secret Life of Viruses

INCREDIBLE SCIENCE FACTS ABOUT GERMS, VACCINES AND WHAT YOU CAN DO TO STAY HEALTHY



- Author: **Mariona Tolosa Sisteré and Ellas Educan Collective**
- Publisher: **Sourcebooks Explore**
- Price: **£12.76 / $17.99**
- Release: **3 August**

Young readers may be familiar with mask-wearing and social distancing today, but how much is known about the science of these microorganisms? Through the medium of clever cartoon-style illustrations, this visually informative book personifies viruses into characters that young readers can get to know and understand. While suitable for younger children, *The Secret Life of Viruses* doesn't hold back on the science.

Instead it expertly explains viral structure, reproduction and activity in a way that can be easily imagined and comprehended by a child. For those who have questions about pandemics, COVID-19 and viruses in general, this book is perfect for widening understanding in a friendly way and without causing worry. Among the final pages, a fun and interactive 'true or false' section can test the reader on fascinating facts from the book, helping children to remain engaged.

BRAIN GYM
GIVE YOUR BRAIN A PUZZLE WORKOUT

QUICKFIRE QUESTIONS

Q1 When was the Bank of England founded?
- ◯ 1098
- ◯ 1694
- ◯ 1835
- ◯ 1993

Q2 What did the world's heaviest pumpkin weigh?
- ◯ 159.05 kilograms
- ◯ 392.11 kilograms
- ◯ 836.20 kilograms
- ◯ 1,190.49 kilograms

Q3 How many neurons in an adult human's brain?
- ◯ 86,000
- ◯ 86 million
- ◯ 86 billion
- ◯ 86 trillion

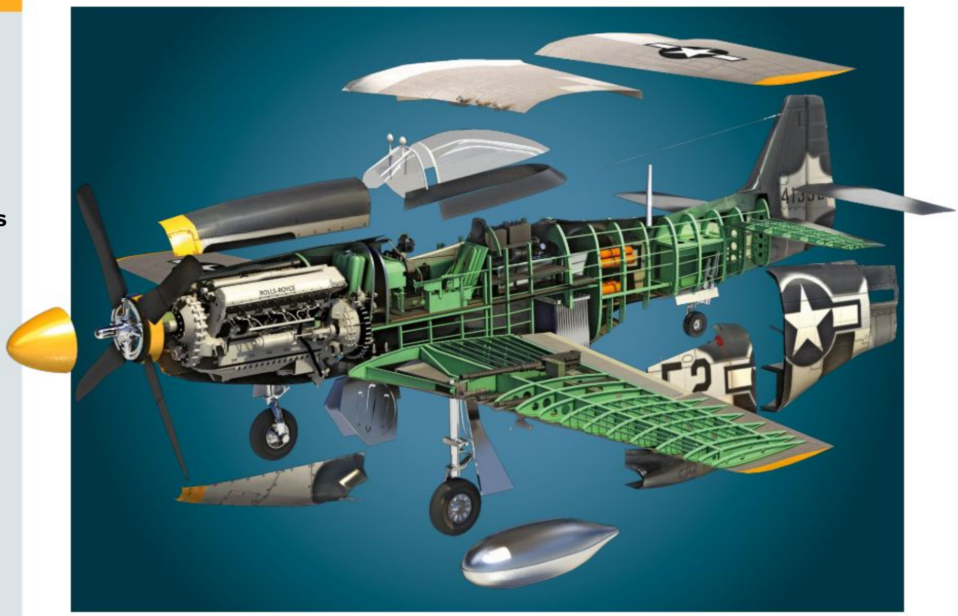
Q4 Approximately how far is the Voyager 1 probe from Earth, currently?
- ◯ 14,000 miles
- ◯ 14 million miles
- ◯ 14 billion miles
- ◯ 14 trillion miles

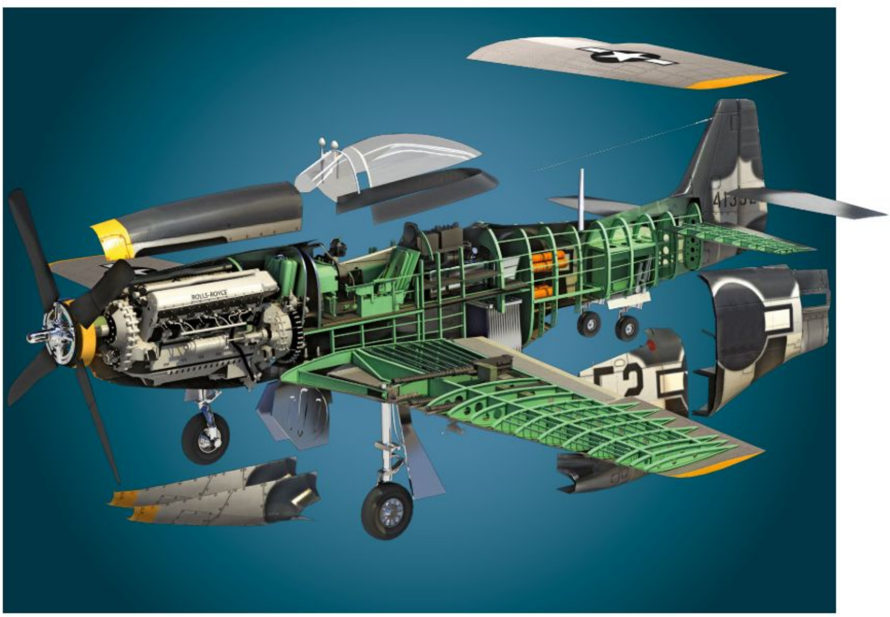
Q5 What speed did the first steam train average in 1804?
- ◯ 4 miles per hour
- ◯ 10 miles per hour
- ◯ 20 miles per hour
- ◯ 30 miles per hour

Q6 The world record for the loudest drummer is, at 137.2 decibels, as loud as:
- ◯ A vacuum cleaner
- ◯ A thunderclap
- ◯ Aeroplane take-off
- ◯ A rocket launching

Spot the difference

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





Sudoku

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

EASY

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

DIFFICULT

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

© Getty

What is it?

Hint: These usually form as a result of an overproduction of melanin...

A ....

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

Wordsearch

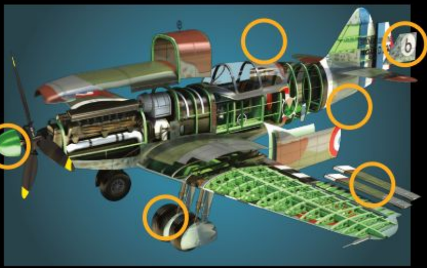
FIND THE FOLLOWING WORDS...

FACILITY
MEDAL
ATHLETE
DOWNING
CRAB
AQUIFER
ENERGY
DIESEL
ROCK
BRAIN
OVEN
SEAT

Check your answers

Find the solutions to last issue's puzzle pages

SPOT THE DIFFERENCE



QUICKFIRE QUESTIONS

Q1 122 years, 164 days
Q2 All of the above
Q3 Oort Cloud
Q4 Copper blood
Q5 Red devil deer
Q6 1939

WHAT IS IT? ...CORN FLAKES

© Getty

HOW TO...

Practical projects to try at home

Get in touch
Send your ideas to...
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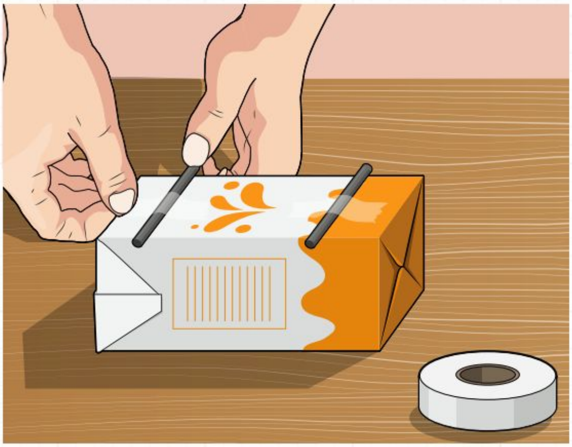
Make a balloon-powered car

Watch as the air from your lungs propels your vehicle across the room

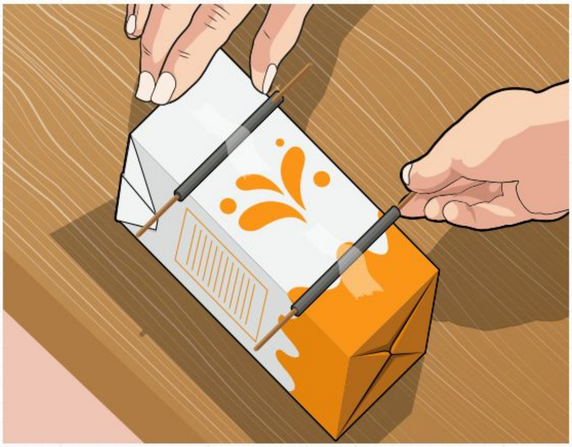
YOU WILL NEED:
- Drink carton
- Four plastic bottle tops
- Two wooden skewers
- Two straws
- Balloon
- Tape
- Glue
- Scissors

1 Choose the body
Place the drink carton in front of you. We are using a cardboard drink carton as the car's body here, but feel free to experiment with different materials, such as bottles, to see how they compare.

2 Cut to size
Hold your straws across the width of the carton and cut them both to size. The straws should extend beyond the carton a little bit on each side.

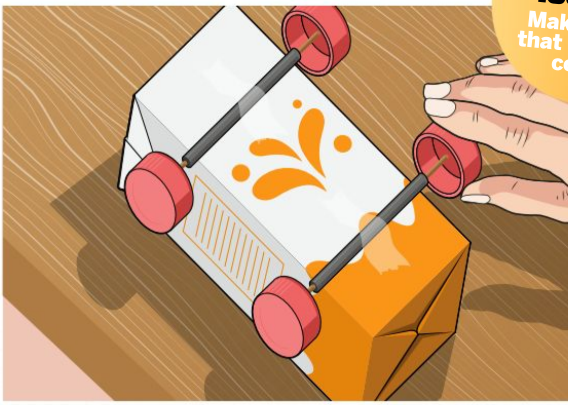


3 Stick down the straws
Secure the straws, using tape, onto the base of your carton. These should be parallel to each other, as they will hold the wheel axles.



4 Insert the axles
Cut two pieces of wooden skewer so that they are a centimetre or two longer than the straws. Insert one into each straw.

NEXT ISSUE...
Make water that changes colour

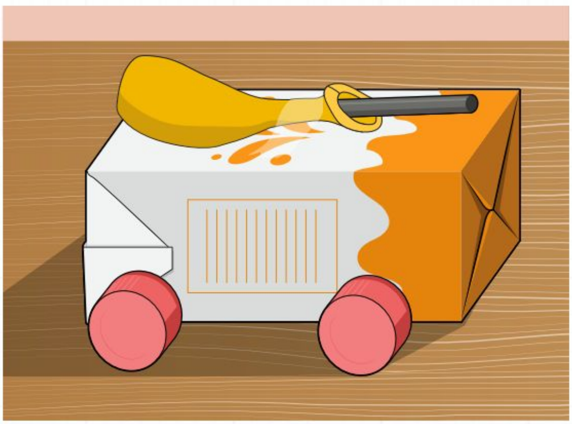


5 Secure the wheels

Using glue, attach each of the four skewer ends to the centre points of each of your four bottle caps. If necessary, you can make small holes in the caps' centres to attach these securely.

6 Prepare the engine

For this car, the power will come from your balloon. Place a straw inside the balloon, and cut it so only a couple of centimetres stick out from the opening. Tape the balloon tight around the straw so that air can't escape around the straw's sides.



7 Attach the balloon

Using tape, secure the balloon to the top of the car, with the straw facing the back. Make sure you add tape to both the balloon and the straw to keep the two from coming apart as the car moves.

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

8 Ready, steady, go!

Blow air through the straw and into the balloon. When your engine is as full as you would like, stop blowing and quickly place your finger over the hole at the end of the straw. Put the car on a flat surface, and when you're ready to launch, release your finger.

SUMMARY

As air in the inflated balloon is released, the potential energy stored inside is converted into kinetic energy, driving your car forward. This is due to Newton's third law of motion, which says that every action has an equal and opposite reaction. As you force air into the balloon, you create a higher pressure inside it than outside. When released, this air rushes out towards the area of lower pressure, exerting an equal force on the car. The straw inside the balloon not only makes it easier to blow, but also channels the released air in one direction. This controlled airflow causes the car to travel in a straight line. A more inflated balloon will result in more energy being released and a higher speed. Why not design multiple cars with your friends and host a race to see who wins?

INBOX

Speak your mind...

Get in touch

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

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© Getty

The European Football Championship is usually held every four years

Football facts

Hi **HIW,**

I have been watching the Euros recently. I think lots of people enjoy the simplicity of the sport, but has the game changed much since it was invented?

Rory O'Gorman

Football was invented over 100 years ago, and the sport is constantly adapting its rules. When the game began, rules were less official, so they could vary based on location. Many games allowed players to carry the ball in their hands, which goes against the fundamental rules of today. It was also common for players to kick others during an attack on the goal.

In 1863, the first official rules were made and written down. During games at this time, there was no crossbar on goals – this meant goals were accepted at any height.

A referee makes key decisions during the game. This role didn't exist when football was invented, appearing in 1871, and their use of penalty cards was made part of the Football Association's official laws in 1992.

WIN! FOURTEEN WOLVES

With evocative storytelling and atmospherically beautiful illustrations, *Fourteen Wolves* introduces readers to one of the world's most successful conservation projects. This is the incredible true story of how reintroducing wolves into Yellowstone Park saved its crumbling ecosystem.

LETTER OF THE MONTH

Science of sore heads

Dear **How It Works,**

I have headaches a lot of the time, and I was wondering what causes them. I know it can be a lack of sleep, or stress, but I was wondering what the scientific explanation was. What does being stressed do to the brain to make it hurt, and what is the pain?

Nestor

Thank you for your question, Nestor. Headaches can be a horrible experience, and have a variety of causes. Most of the time, what feels like pain in the brain isn't caused by the brain at all. There are many nerves in the muscles and blood vessels in your head, neck and face that relay pain. Stress, enlarged blood vessels and muscle tension can all be responsible for bringing on these headaches. As these nerves start to send signals to the brain, it can give the sensation that the pain is occurring further inside the head.

You've acknowledged stress as being a primary cause of many headaches, which is accurate. Stress is a prime cause of tension headaches. This pain is a result of physical stress, as muscles in your head or neck tighten for significant periods. Other times, stress causes your body's 'fight or flight' response to kick in. This releases chemicals that alter the size of blood vessels. When this occurs in your head, it is felt as a headache.

Migraines are another common type of headache that can be brought on by stress, as well as bright light, lack of sleep and skipping meals. This type of headache can feel like an intense throbbing pain, and is often caused by the brain's overreaction to a sensory trigger. The increase in electrical activity in the brain actually affects how much blood flows to it, putting strain on nerves and creating pain.

Cluster headaches are much rarer and usually occur on one side of the head, around the eye. These types of headaches can feel much more intense than the average headache and are caused by the blood vessels that carry blood to your brain widening.

While headaches are common and can occur for so many reasons, from tiredness to sustaining a head injury, if you feel like you are having headaches regularly and are unsure of the cause, it's always a good idea to go to the doctor and get it checked out.

© Getty

One of the main causes of headaches is stress

Weight limits for takeoff vary based on a plane's size

© Getty

Luggage limits

Hi **HIW,**

Now that some flights are back up and running, I was keen to book a holiday. I noticed the maximum luggage weights, and I want to know how much weight affects flight. If everyone went over the weight limit, what would happen to the plane?

Peter Greenwood

It might seem like a nuisance to have to weigh your suitcases and limit your holiday packing, but it's for a good reason. Strict control makes sure handling of the aircraft can still be carried out properly. The pilot needs to know how heavy the aircraft is and how this weight is balanced to manage plane orientation and navigation. Airlines use average weights for people and limit luggage to narrow the possible range of the accumulative weight. Lighter planes are able to accelerate quicker and perform steeper climbs. If everyone's luggage was excessively over the limit, the plane might not be able to take off at all, as it would be prevented from climbing higher!

The lost walrus


Wally is believed to be a relatively young walrus

Hi **HIW,**

I don't know where Wally the walrus is now, but I found the news of his travels really interesting. How did he travel so far away from his natural habitat, and do walruses do this often?

Roshni S

Thanks for your question, Roshni. We have also been following news of Wally closely. Wally the walrus managed to travel over 1,850 miles away from the Arctic Circle, and has since been sighted in Ireland, Tenby in Wales, Cornwall in England and Les Sables-d'Olonne in western France. Scientists think Wally travelled on part of a drifting iceberg. There have been three other walrus sightings since 1999, but those are just ones that have been witnessed and recorded. In fact, there are an estimated 20,000 walruses in the North Atlantic. Walruses may be more inclined to travel away from the arctic climate as global warming alters their habitat.

Animal individuals

Hi **HIW,**

Most people can recognise each other. I also think animals of the same species can distinguish between each other. Why can't I easily recognise individuals of another species, such as sparrows feeding in a group?

Stephen Conn

As you have noticed, the brain is fine-tuned to recognise differences between human features almost instantly. This is because we are highly social animals and have evolved parts of the brain to decipher different features for us. Each neuron that is activated during facial recognition responds to a specific dimension of a feature on the human face. Your brain compares each face to an 'average human face'. In other animals, the face is significantly different. It takes more mental effort to spot differences between these animals because your brain will see them as entirely different.


Most animals are better at recognising their own species

What's happening on...

social media?

This month on social media, we asked you: If you could add a new sport to the Olympics and Paralympics, what would it be?

@definitely.notmax
I would add walking for the people who aren't so sporty!

@scimaxfacts
*I would add an Olympic sport being **How It Works** reading!*

@cathode149
Just full-on false naval battles like the Romans used to

@joxley7
Foot golf and mixed martial arts

@max.fx.shorts
Definitely golf, as I am surprised that they still haven't added it after so many years!

@hani_hopwood
Scuba diving

@louistyndall
Racketlon!

NEXT ISSUE...

Issue 154 on sale **5 AUG 2021**

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

Editorial
Editor **Ben Biggs**
Senior Art Editor **Duncan Crook**
Research Editor **Baljeet Panesar**
Production Editor **Nikole Robinson**
Staff Writer **Scott Dutfield**
Staff Writer **Ailsa Harvey**
Editor-in-Chief **Gemma Lavender**

Contributors
Lauren Eyles, Andrew May, Andy Extance, Jo Elphick, Laura Mears, Mike Jennings

Cover images
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Photography
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Advertising
Media packs are available on request
UK Commercial Director **Clare Dove**
clare.dove@futurenet.com
Senior Advertising Manager **Amanda Burns**
amanda.burns@futurenet.com
0330 390 6036
Account Manager **Garry Brookes**
garry.brookes@futurenet.com
+44 020 3970 4176

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FAST FACTS

Amazing trivia to blow your mind

112,000 MILES

IN YOUR LIFETIME, YOU WALK THE EQUIVALENT OF 4.5 TIMES AROUND THE EQUATOR

46 LITRES

YOU PRODUCE ENOUGH SALIVA IN A MONTH TO FILL 23 POP BOTTLES

3 TRILLION

THERE ARE MORE TREES ON EARTH THAN STARS IN OUR GALAXY

3,000

QUEEN ELIZABETH I HAD A HUGE SELECTION OF DRESSES

20%

A SURPRISINGLY SMALL AMOUNT OF THE SAHARA DESERT IS COVERED IN SAND

MAMMOTHS ROAMED EARTH WHEN THE PYRAMIDS WERE BUILT

MOZART, THE COMPOSER, KEPT A DIARY OF HIS FARTS

2 MILLION YEARS

THE SOIL IN YOUR GARDEN IS TRULY ANCIENT

1,131

THE US HAS COLLECTED MORE OLYMPIC GOLD MEDALS THAN ANY OTHER COUNTRY

440 TONNES

CHINA MINES A HUGE AMOUNT OF GOLD EVERY YEAR

HALF OF THE ELEMENTS IN THE PERIODIC TABLE CAN BE FOUND IN AN iPHONE

SUPERMARINE SPITFIRE Mk.Vc

1:72

AIRFIX

starter SET

SET INCLUDES:
• POLY CEMENT • PAINT BRUSH • 4 ACRYLIC PAINTS

A55001
SUPERMARINE SPITFIRE Mk.Vc

9042

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

Length 131mm Wingspan 157mm Pieces 26

Use your smartphone to find out more!

0006