FOSSIL FUELS VS RENEWABLE ENERGY

HOW IT WORKS

HAZARDOUS ASTEROIDS TO WATCH FOR

+ 5 COOL WAYS WE USE DRONES

Massive marble mausoleum

Giant molecule

Tower of trees

144 years to build

Golden-hearted skyscraper

+

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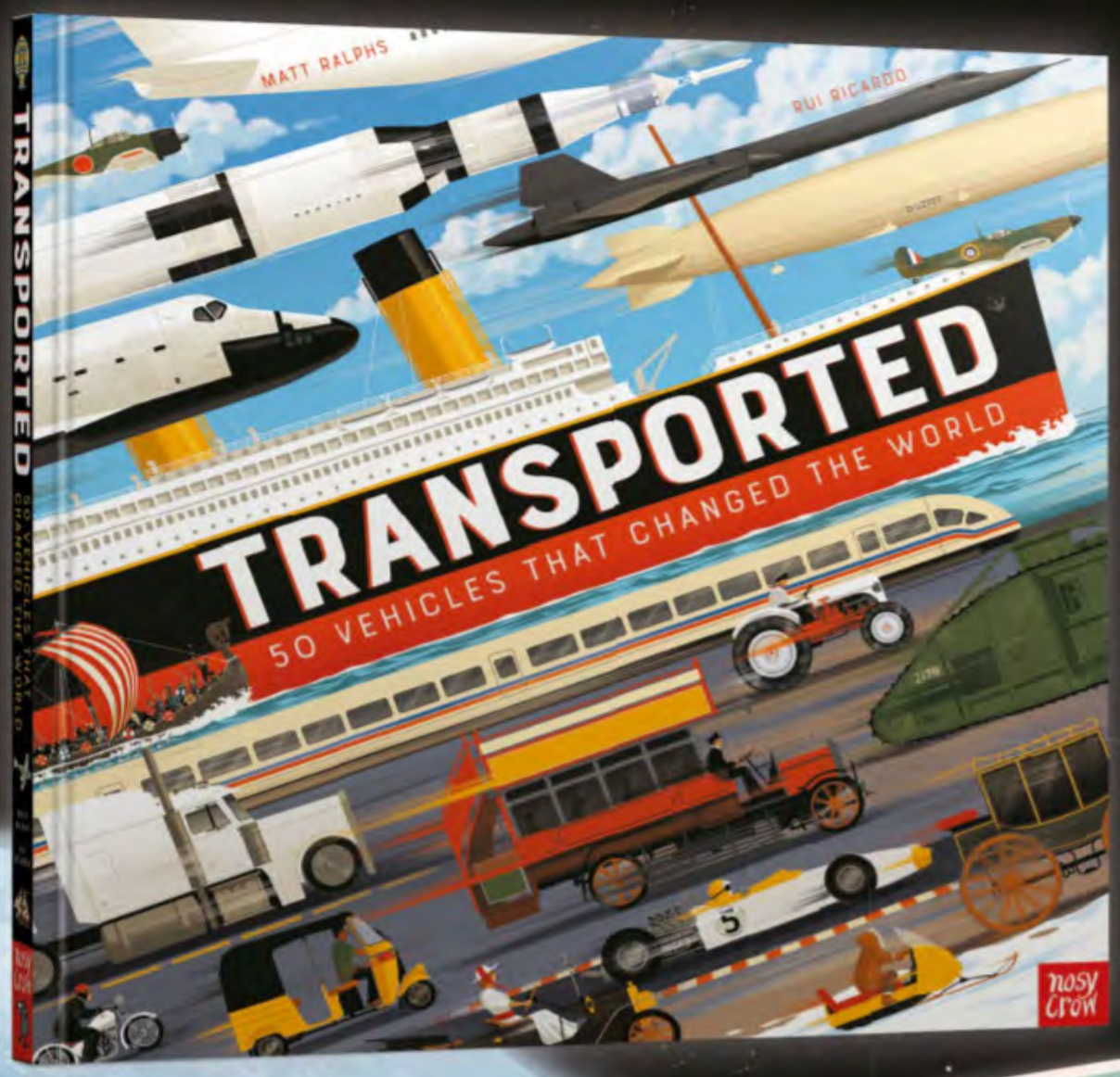

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WELCOME

Issue 168

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Seven modern wonders

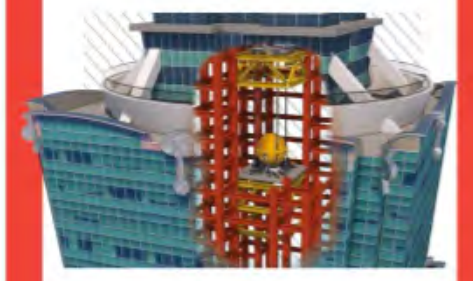
PAGE 26

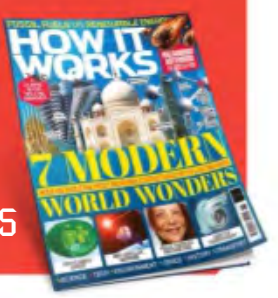
"This modern wonder has been a work in progress for over 140 years"

The photo above is of the Rhodian deer statues that flank the entrance to Mandraki harbour in Rhodes, Greece. But the picture is missing something: an iron-and-brass statue, 33 metres tall, of the Greek god Helios that was known as the Colossus of Rhodes. Some historians believe that this ancient world wonder stood sentinel over the entrance to the harbour for over 50 years before it collapsed in an earthquake in 226 BCE. We've built much bigger and more impressive constructions in the last 500 years, but will their legends stand the test of time like the Colossus? If you turn to page 26, you can decide for yourself whether the seven structures we've chosen are worthy of being wonders. Enjoy!

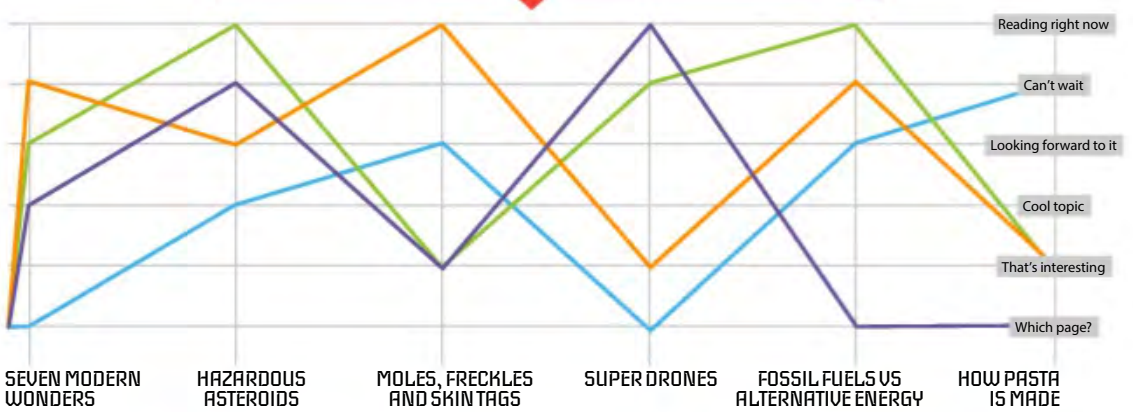
Ben Biggs
EDITOR

HIGHLIGHTS





WHAT WE'RE ANTICIPATING



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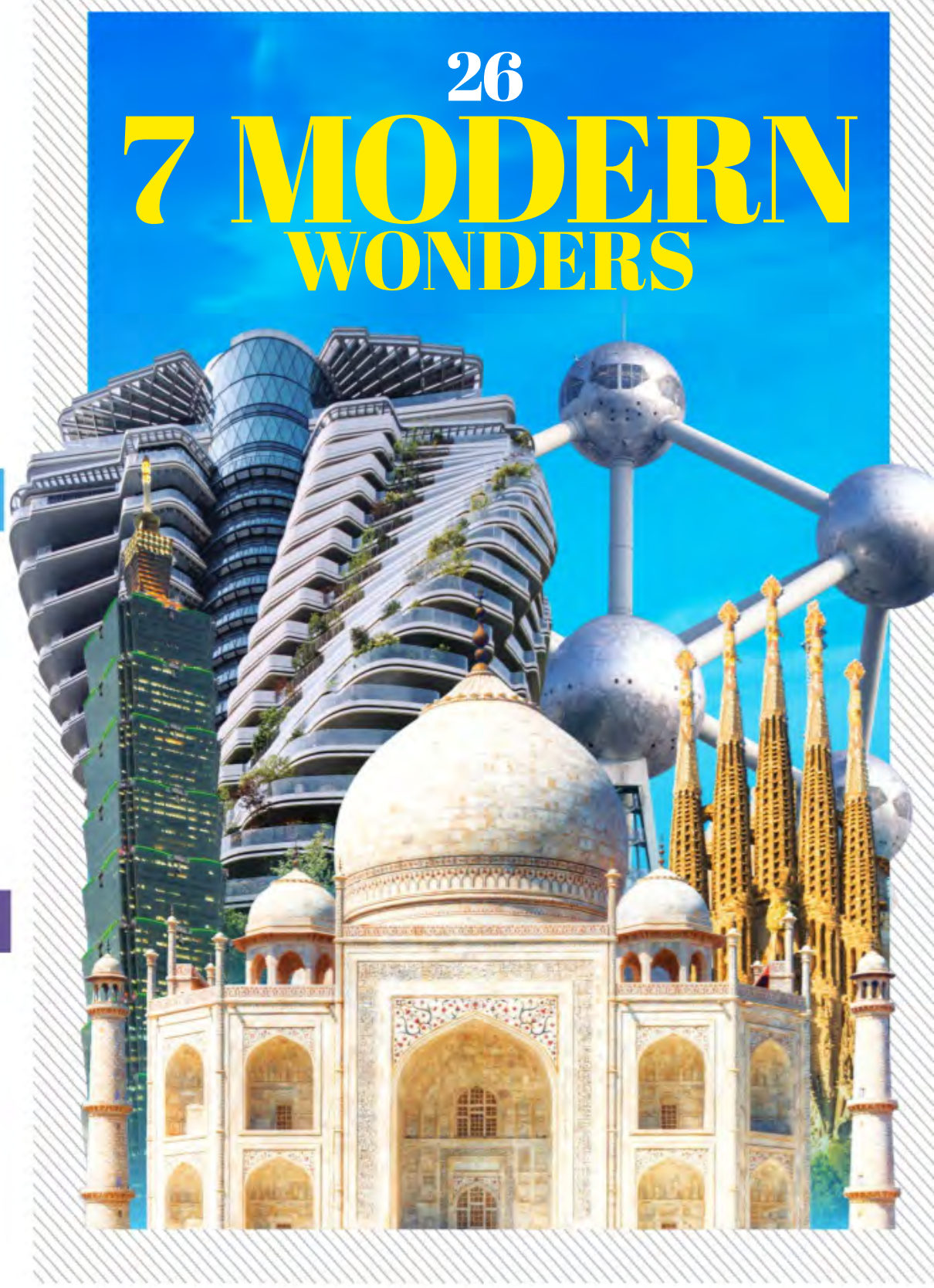

SPECIAL

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MEET THIS ISSUE'S EXPERTS

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

LAURA MEARS
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.

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.

Win!
ONE OF TWO AIRFIX MODEL BUNDLES, WORTH £100
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REGULARS

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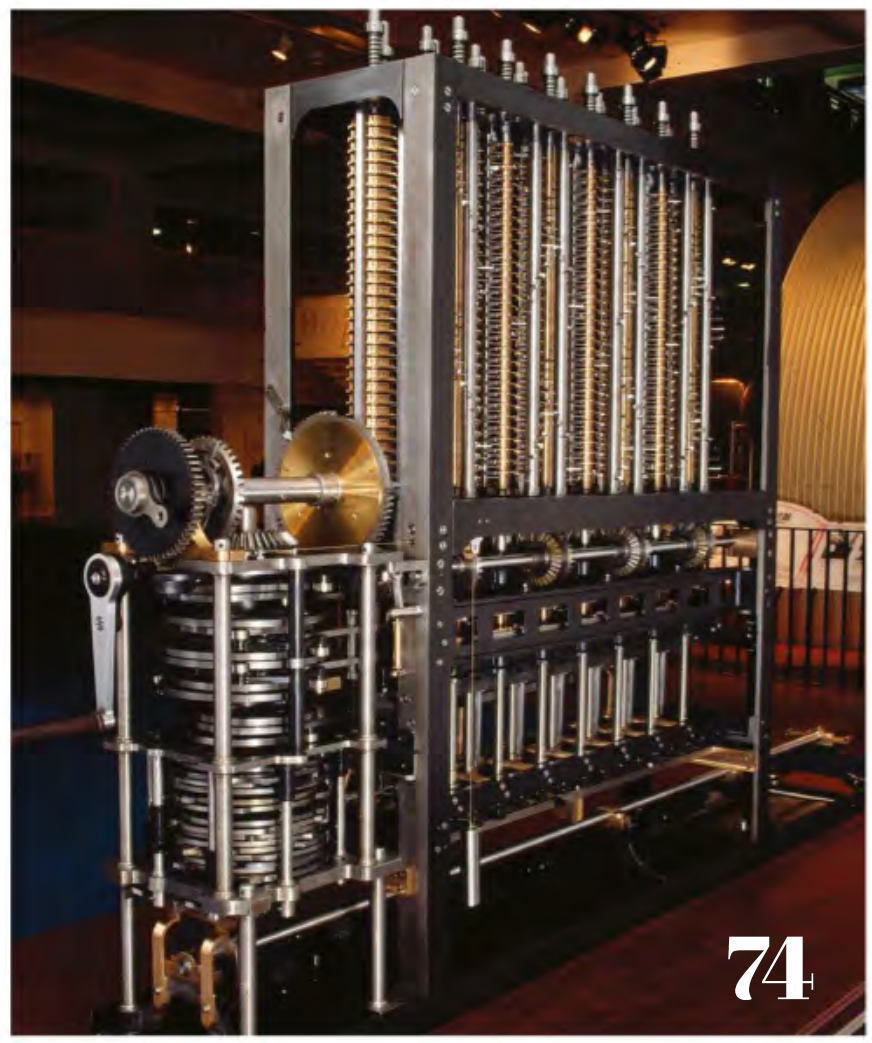

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Dental bacteria

Along with saliva, bacterial secretions form a sticky biofilm that accumulates as plaque. Bacteria are embedded between teeth and feed on the sugars that pass through our mouths. The bacteria release an acid that corrodes the enamel coating of our teeth. Without regular brushing and a proper oral hygiene routine, decay can set in as the enamel is dissolved, leading to gum disease.

Burning blue

Kawah Ijen spews sapphire lava when it erupts. The unusual nature of its eruptions are the result of large quantities of sulphur gas. When molten rock emerges from deep below Earth's crust at high pressures and temperatures, it's joined by sulphur gas that also rushes to the surface. When this sulphur gas, heated to around 600 degrees Celsius, reacts with atmospheric oxygen, it burns blue.

Vietnamese fishing

Fishermen follow near-shore currents to catch fish during the harvest season between May and September. Across the province of Phú Yên, fishermen flock to the waters around the island of Hon Yen to catch hundreds of thousands of kilograms of anchovies. Due to overfishing, anchovy hauls are on the decline, decreasing by 20 to 30 per cent over the past decade.

Cosmic Cliffs

The ‘Cosmic Cliffs’ of the Carina Nebula is one of the first five images to emerge from the James Webb Space Telescope. The celestial ‘mountains’ in this image are made up of hot, ionised gas and dust that has been sculpted by the ultraviolet radiation emitted by a young star at the centre of the nebula. Ultraviolet winds have created the appearance of mountain peaks and cavernous valleys.

Artist's interpretation of the quadruple star system HD 98800

SPACE

Unique triple star system likely ate a fourth star

WORDS HARRY BAKER

Astronomers have detected a triple star system that is unlike any seen before. The unusual trio of stars is much more massive and closely squeezed together than a typical triple system, which may be because the stellar triplets used to have a fourth sibling before one of the others gobbled it up. The tertiary star system is known as TIC 470710327 and was detected by researchers using data from NASA's Transiting Exoplanet Survey Satellite (TESS) observatory, currently orbiting Earth. The trio have a hierarchical structure, meaning a pair of binary stars circle one another at the centre of the system while a third star orbits the central pair.

Triple star systems are not that uncommon: as many as ten per cent of star systems in the universe could be tertiary. In September 2021, astronomers detected a single exoplanet orbiting a tertiary system for the first time, suggesting life could potentially exist in these systems if conditions are right. However, TIC 470710327 stands apart from all the other known tertiary systems because of its size and shape. The stars are much more massive than the typical stars found within a tertiary system, which also means the trio is much more compact because they all exert a stronger gravitational pull than normal. "As far as we know, it is the first of its kind ever detected," said Alejandro Vigna-Gómez, an astrophysicist at the Niels Bohr Institute at the University of Copenhagen in Denmark.

The binary pair of stars at the heart of TIC 470710327 have a combined mass of around 12 times the Sun's, and it takes just over one day for the two stars to orbit one another. The larger outer star is even more massive – weighing about as much as 16 Suns – and it orbits the binary pair once every 52 days.

The new system was originally found by a citizen scientist who was combing through the TESS database in search for abnormalities. The star system stood out to the amateur astronomer due to its high luminosity, a consequence of having three stars shining brightly rather than one. However, it wasn't until researchers later assessed the data that they realised it was a tertiary system. After discovering how massive the stars are, the team then began trying to figure out how the unusual system might have formed.

There are three potential explanations for how TIC 470710327 was created: the first possibility is that the large outer star formed first, and the smaller stars formed later. This is perhaps the most unlikely explanation, as the massive star would have ejected or absorbed the gas needed to form new stars. The second option is that the three stars all formed separately and gradually gravitated to each other until they started orbiting each other. This is also unlikely because the massive outer star would probably have ended up at the centre of the system.

The third explanation is that the system was originally made up of two binary pairs – the one at the centre of the system we see today and another pair orbiting where the more massive outer star currently sits. Researchers suspect that the outer binary pair then underwent a stellar merger to create a single, more massive star.

The WWII-era bomb was found on the banks of the River Po after a severe drought lowered water levels

HISTORY

INTACT WWII BOMB DISCOVERED IN ITALY'S RIVER PO

WORDS **BRANDON SPECKTOR**

Extreme drought brought on by record-high temperatures in Europe has revealed an unexploded, WWII-era bomb nestled along the banks of Italy's River Po. Fishermen discovered the American-made bomb on 25 July near the northern Italian village of Borgo Virgilio, near the city of Mantua. The bomb appears to have been submerged there for more than 70 years. However, water levels in the River Po – which stretches east-west across northern Italy and is the country's longest river – have diminished significantly this summer following multiple heat waves that hit many parts of Europe with record-high temperatures.

According to military experts, the bomb weighs nearly 450 kilograms. After evacuating the roughly 3,000 civilians who live in the village's vicinity, military experts cut the bomb's fuse and moved the device to a quarry about 30 miles away. Once safely there, the bomb was destroyed in a controlled detonation. There were no injuries or damages reported from the controlled explosion.

This summer has seen much of the Northern Hemisphere hit with extreme heat waves, predicted to become more and more common as a result of ongoing climate change. In late June, Rome reported its highest recorded temperature ever at 40.5 degrees Celsius.

SPACE

Chinese astronauts start testing new space station

WORDS **ANDREW JONES**

China's Shenzhou 14 mission astronauts are getting the country's new space station module ready to host crews over the next decade. The new module, called Wentian, was launched on 24 July and docked with the Tianhe core module hours later, expanding China's Tiangong space station to two modules.

Since then, the Shenzhou 14 crew – made up of Chen Dong, Cai Xuzhe and Liu Yang – have been busy getting Wentian into working order, testing out the module's six-metre robotic arm and installing a regenerative life-support system. Astronaut Cai has enjoyed more personal space recently by testing out Wentian's new sleeping quarters while his crewmates sleep back in Tianhe. The added crew facilities in Wentian allow the orbiting complex to temporarily accommodate six astronauts, meaning that the Shenzhou 14 and Shenzhou 15 crews will be able to conduct China's first crew handover later this year.

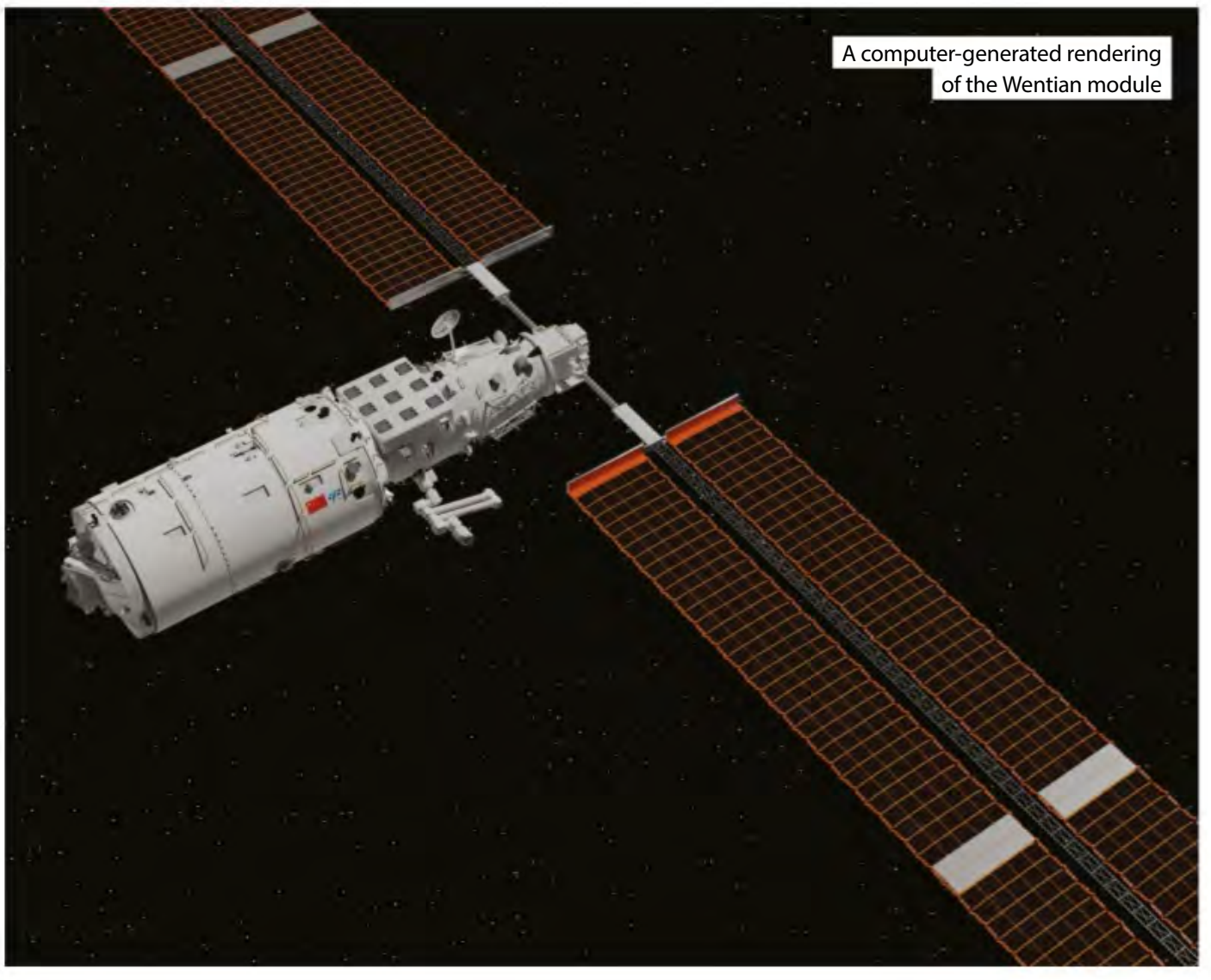
The robotic arm, a smaller but more dextrous version of the 10.2-metre arm launched with Tianhe, will be used for maintaining and repairing the exterior of the space station, but will also support spacewalks conducted by astronauts.

"Last week the astronauts used the in-orbit training software and training platform to test the small mechanical arm," Wang Chunhui, deputy chief designer of the astronaut system of the China Astronaut Research and Training Center, said. "During the spacewalk, we can see that the third astronaut is manipulating the mechanical arm in the cabin to support the work of the other two outside," Wang added.

Did you know?
Wentian means 'quest for the heavens'

Next up, the Shenzhou 14 astronauts will be testing the complex regenerative life-support system installed in early August. Wang stated that the system involves extensive plumbing operations, requiring a range of tests and adjustments and installation of instruments.

The crew are also expected to conduct a spacewalk using the Wentian hatch and host a livestreamed science lecture from the new module after testing is completed. Wentian also contains a range of science cabinets for carrying various experiments in low-Earth orbit.



A computer-generated rendering of the Wentian module

An impacted musket ball from the Fort Mercer trench excavation during the Red Bank Battlefield Archaeology Project

HISTORY

Revolutionary War mercenary grave unearthed in New Jersey

WORDS JENNIFER NALEWICKI

Researchers at a Revolutionary War battlefield in New Jersey have unearthed a mass grave holding the remains of around a dozen Hessian mercenaries who died during the Battle of Red Bank in October 1777. Volunteer diggers also unearthed a number of treasures, including weapons and a rare 1776 King George III gold guinea coin.

The burial site was discovered on 26 June when a volunteer amateur archaeologist uncovered a human femur during the excavation of a defensive trench at Fort Mercer, which is part of Red Bank Battlefield Park in Gloucester County, southern New Jersey. "One of our volunteers who was digging said, 'I think I have a bone,'" said Jennifer Janofsky, a humanities and social sciences professor and historian at Rowan University in New Jersey and the director of Red Bank Battlefield Museum. "I'll never forget that moment. It was stunning. It was overwhelming. It was sad."

All told, researchers unearthed the skeletal remains of about 13 Hessian soldiers, who were German soldiers hired to serve in the British Army. In addition to the human remains, the researchers also found five musket balls, pewter and brass buttons, grapeshot, lead canister shot, a knee buckle from a uniform that contained human blood stains and the gold guinea coin, equivalent to a soldier's pay for a month's work. The researchers from nearby Rowan University and officials from Gloucester County believe that there could be more remains at the site.

The Battle of Red Bank served as an attempt by the British Army and its Hessian mercenaries to overtake Fort Mercer, an American fort located along the shore of the Delaware River. They ultimately failed, and approximately 377 Hessian soldiers were killed or wounded during the fight, while the American forces only lost 14 troops. This imbalance deemed the battle the worst defeat the Hessians experienced during the Revolutionary War.

At present, all of the human remains that were uncovered in the Red Bank excavations are with the New Jersey State Police Forensic Unit and will undergo DNA extraction so that anthropologists can learn more about the soldiers. "We're hoping that, eventually, perhaps we can find some of these individuals," said Janofsky. "If we can extract their stories, and if we can tell their stories, it lets us put a name to a face. And that, to me, is a very powerful moment in public history."

Did you know?

The Revolutionary War lasted from 1775 to 1783

STRANGE NEWS

THE PENTAGON IS OPENING A UFO INVESTIGATION OFFICE

WORDS BRANDON SPECKTOR

The Pentagon, the headquarters of the US Department of Defense (DOD), will soon open an office focused exclusively on investigating UFO sightings. The new office, named the All-domain Anomaly Resolution Office (AARO), will serve as a central hub that collects, investigates and manages reports of UFO sightings across the DOD, which includes the Army, Navy and Air Force.

The US government has taken a renewed interest in UFOs over the past several years following the 2017 leak of three now-infamous video clips showing mysterious, wingless aircraft soaring at hypersonic speeds past some dumbfounded US Navy pilots. The US Navy officially confirmed and declassified the videos in April 2020, but has provided no explanation for what the mysterious objects might be.

In 2020, the US Senate Select Committee on Intelligence called for an inquiry into UFOs – or unidentified aerial phenomena (UAP), as the government prefers to call them – citing concerns that there was no unified approach for collecting and analysing reports of such sightings. In June 2021, the Pentagon released a report on over 140 UFO sightings by Navy pilots, concluding that there was no evidence of alien activity in any of these instances.

An aerial view of the Pentagon offices in Washington DC

PLANET EARTH

Massive magnet plans for deep-sea meteorite fishing

WORDS JAMIE CARTER

Astronomers are planning a fishing trip to land an extraterrestrial interloper on Earth: a small meteorite from another star system that crashed into the Pacific Ocean with energy equivalent to about 110 tonnes of TNT. The team, from Harvard University, hopes to find fragments of this interstellar rock, known as CNEOS 2014-01-08, which slammed into Earth on 8 January 2014.

"Finding such a fragment would represent the first contact humanity has ever had with material larger than dust from beyond the Solar System," said Amir Siraj, an astrophysicist at Harvard University. Siraj identified the object's interstellar origin in 2019 with 99.999 per cent confidence, but it wasn't until May 2022 that it was confirmed to Siraj by the US Space Command. "It struck the atmosphere about a hundred miles off the coast of Papua New Guinea in the middle of the night with about one per cent the energy of the Hiroshima bomb," Siraj said.

Measuring just 0.5 metres wide, CNEOS 2014-01-08 now appears to have been the first interstellar object ever discovered in our Solar System. CNEOS 2014-01-08 is thought to be from another star system because it was travelling at 37.2 miles per second relative to the Sun. That's too fast for it to be bound by the Sun's gravity. "At Earth's distance from the Sun, any object travelling faster than about 42 kilometres per second [26 miles per second] is on an unbounded, hyperbolic escape trajectory relative to the Sun," Siraj said. "This means that CNEOS 2014-01-08 was clearly exceeding the local speed limit for bound objects. It didn't cross paths with any other planets along the way, so it must have originated from outside of the Solar System."

Now Siraj and Harvard astrophysicist Avi Loeb are working on an expedition called the Galileo Project to lower a magnet similar in dimensions to a king size bed at 1.3 degrees south, 147.6 degrees east – the US Department of Defense's location of the meteorite's resting spot. That's about 186 miles north of Manus Island in the Bismarck Sea in the southwest Pacific Ocean.

CNEOS 2014-01-08 greatly exceeded the material strength of a typical iron meteorite, which should make it even easier to recover. Material strength refers to how easily something can resist being deformed or damaged by a load. "Most meteorites contain enough iron that they will stick to the type of magnet we plan on using for the ocean expedition," Siraj said. "Given its extremely high material strength, it's very likely that the fragments of CNEOS 2014-01-08 are ferromagnetic." Leaving from Papua New Guinea, the Galileo Project's ship would use a magnetic sled on a longline winch which will be towed along the seabed for one mile over ten days. It's hoped the magnet can recover tiny fragments of the meteorite, measuring as small as 0.1 millimetres across. However, it's unclear when the astronomers will be able to mount their expedition.

"The alternative way to study an interstellar object at close range is by launching a space mission to a future object passing through Earth's neighbourhood," said Siraj, who with Loeb is also working out the details of such a mission should another interstellar object like 'Oumuamua appear in the Solar System.

An illustration of an asteroid barrelling towards Earth

© Rowan University / Getty

GLOBAL EYE

ANIMALS

DEEP-SEA WORM LOOKS LIKE A LUMINOUS LUMP OF SPAGHETTI

WORDS **HARRY BAKER**

A bizarre seafloor creature covered with luminous orange spaghetti-like tentacles recently made its internet debut in newly released video footage. The unusual pom-pom-shaped creature is a type of segmented marine worm known as a polychaete and belongs to an appropriately named group: spaghetti worms. Researchers from the Monterey Bay Aquarium Research Institute (MBARI) captured footage of the pasta-mimicking worm in 2012 using a remotely operated vehicle (ROV) while they were exploring the Gulf of California off the coast of Mexico.

This particular species of spaghetti worm has yet to be officially named, but it belongs to the genus *Biremis*. It has no eyes or gills and uses its colourful tentacles to catch tiny pieces of organic detritus, also known as marine snow, that it feeds on. Most spaghetti worms live in burrows or tunnels below the seafloor and only poke their noodle-like tentacles into the water to snatch up bits of food. But this *Biremis* worm spends its life above ground and has previously been observed swimming through the water or crawling along the seafloor to find locations where food is plentiful. It is unclear exactly how deep this worm can reside, but a majority of sightings have occurred below 2,000 metres beneath the surface.

MBARI's photo of the deep-sea spaghetti worm in question, with just the right amount of bolognese sauce

HEALTH

Man's raspy voice is fungus in his throat

WORDS **NICOLETTA LANESE**

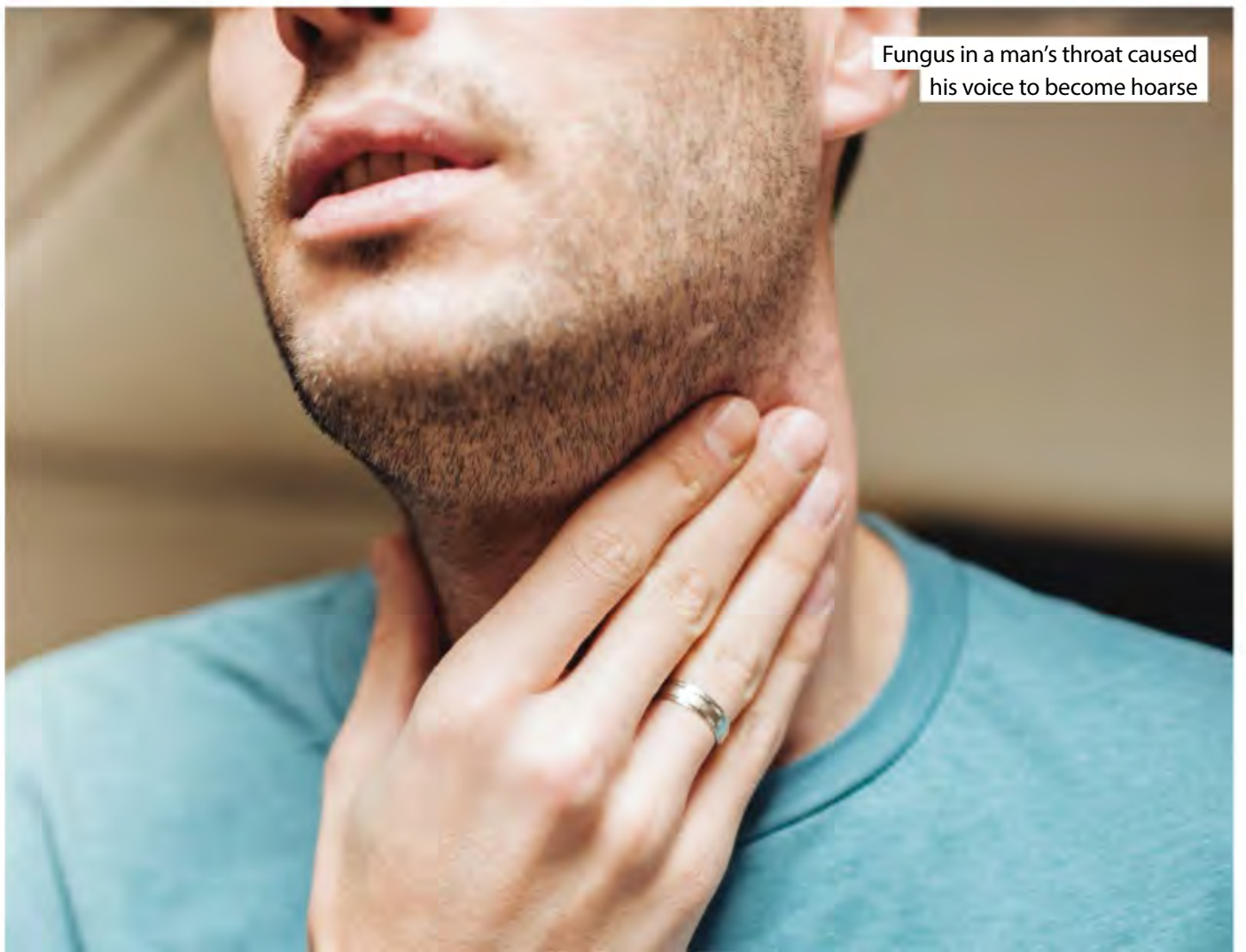
Over the course of a year, a man's voice grew progressively more hoarse and his speech became shrill and grating, but he didn't know why. Upon examining the man, doctors discovered the reason: fungus was growing in his throat. He appeared otherwise healthy when he went to a clinic in Pennsylvania that treats conditions of the head and neck. The man, in his 60s, said that he'd developed progressively worsening hoarseness and shortness of breath over the past 12 months. His physician had treated him with inhaled corticosteroids, a treatment for asthma, but his symptoms hadn't improved.

To examine the man's vocal folds and larynx, the hollow 'voice box' that holds the vocal folds, doctors used a high-speed imaging technique called videostroboscopy. This exam revealed severe swelling in the tissue lining the patient's throat, and this swelling had caused the airway to narrow. The doctors also performed a biopsy on tissue from the man's larynx and confirmed that the tissue was swollen, irregular and 'friable' to the touch, meaning it tore easily.

A close-up examination of the tissue revealed patches of dead laryngeal cells surrounded by clusters of immune cells, hinting that the cells had died off due to intense inflammation in the throat. The examination also revealed budding yeast cells, which the immune cells had surrounded and begun to engulf. A diagnostic test identified the yeast as *Blastomyces dermatitidis*, a fungus that causes an infection called blastomycosis. *B. dermatitidis* grows in outdoor environments, in moist soil and decomposing wood and leaves. People can develop blastomycosis after breathing in *B. dermatitidis* spores suspended in the air, although most people exposed to the fungus don't become ill.

Having a weakened immune system raises the risk of infection, and those who become sick develop symptoms between three weeks and three months after breathing in the fungal spores. Sometimes the infection can spread to the lungs, skin, bones or central nervous system, meaning the brain and spinal cord. In the man's case, the fungus grew only in his larynx, which is fairly unusual. "Laryngeal blastomycosis, first reported in 1918, is a rare extrapulmonary manifestation," his doctors noted.

Due to the significant obstruction of the man's airway, he underwent surgery to have a breathing tube placed in his windpipe and a feeding tube placed in his stomach. He received a long-term prescription for the antifungal drug itraconazole, and at a two-month follow-up appointment his hoarseness had improved considerably and he had his feeding tube removed. At a five-month follow-up, videostroboscopy revealed that the swelling in the man's throat had gone down and that his vocal folds had regained some mobility.



Fungus in a man's throat caused his voice to become hoarse

ANIMALS

Whale sharks are the world's biggest omnivores

WORDS **BEN TURNER**

Whale sharks are the biggest shark species in the world, and now scientists have found that the giant sharks are even more prodigious eating machines than thought. In addition to gulping down enormous mouthfuls of krill, whale sharks also swallow huge helpings of seaweed, enabling the aquatic giants to officially dethrone Kodiak bears as the world's largest omnivores.

Researchers made the discovery by analysing whale shark (*Rhincodon typus*) skin samples collected near Western Australia's Ningaloo Reef. These gargantuan sharks are the largest fish in the sea, weighing up to 36 tonnes and growing to about 12 metres long on average. Scientists thought that the gentle giants were primarily filter feeders, gaping their cavernous mouths wide to gulp in roughly 600 cubic metres of water every hour. By straining the water out through their gills, the sharks are left with mouthfuls of plankton, shrimp, tiny fish and crustaceans to swallow down. But the new discovery has given scientists important new information to chew on.

"This causes us to rethink everything we thought we knew about what whale sharks eat" and calls into question other aspects of the sharks' behaviour "out in the open ocean," said Mark Meekan, a fish biologist at the Australian Institute of Marine Science in Queensland. Meekan said that the discovery contradicts the common assumption that large land creatures are typically herbivores, but those that live in the sea occupy a different niche on the food chain, feeding on small shrimp and fish. "Turns out that maybe the system of evolution on land and in the water isn't that different after all," Meekan said.

For their study, the scientists collected the sharks' possible food sources, ranging from tiny crustaceans and plankton to large clumps of seaweed, and then chemically analysed the samples to reveal their amino and fatty acids. After cross-referencing these acids with those found in skin samples taken from whale sharks, the researchers identified high concentrations of sargassum – a type of brown seaweed made up of thousands of microscopic algae – in the sharks' diets.

The scientists think this omnivorous diet could be a result of the sharks evolving to digest accidentally swallowed seaweed, saving them the energy cost of spitting it back out. "We think that over evolutionary time, whale sharks have evolved the ability to digest some of this sargassum that's going into their guts," Meekan said. "The vision we have of whale sharks coming to Ningaloo just to feast on these little krill is only half the story. They're actually out there eating a fair amount of algae too."

Having a broader range of food sources might sound like good news for whale sharks, as it could help them withstand potential upheavals to their marine ecosystems brought about by climate change. However, it's possible that the sharks' propensity for swallowing most of what is swept into their mouths could make them far more likely to swallow copious amounts of ocean-borne plastics. Whale sharks can pass some plastics through the gut, but ingesting small or large plastic pieces could cause the sharks to vomit up their meals, and could reduce their gut capacity and interfere with digestion.

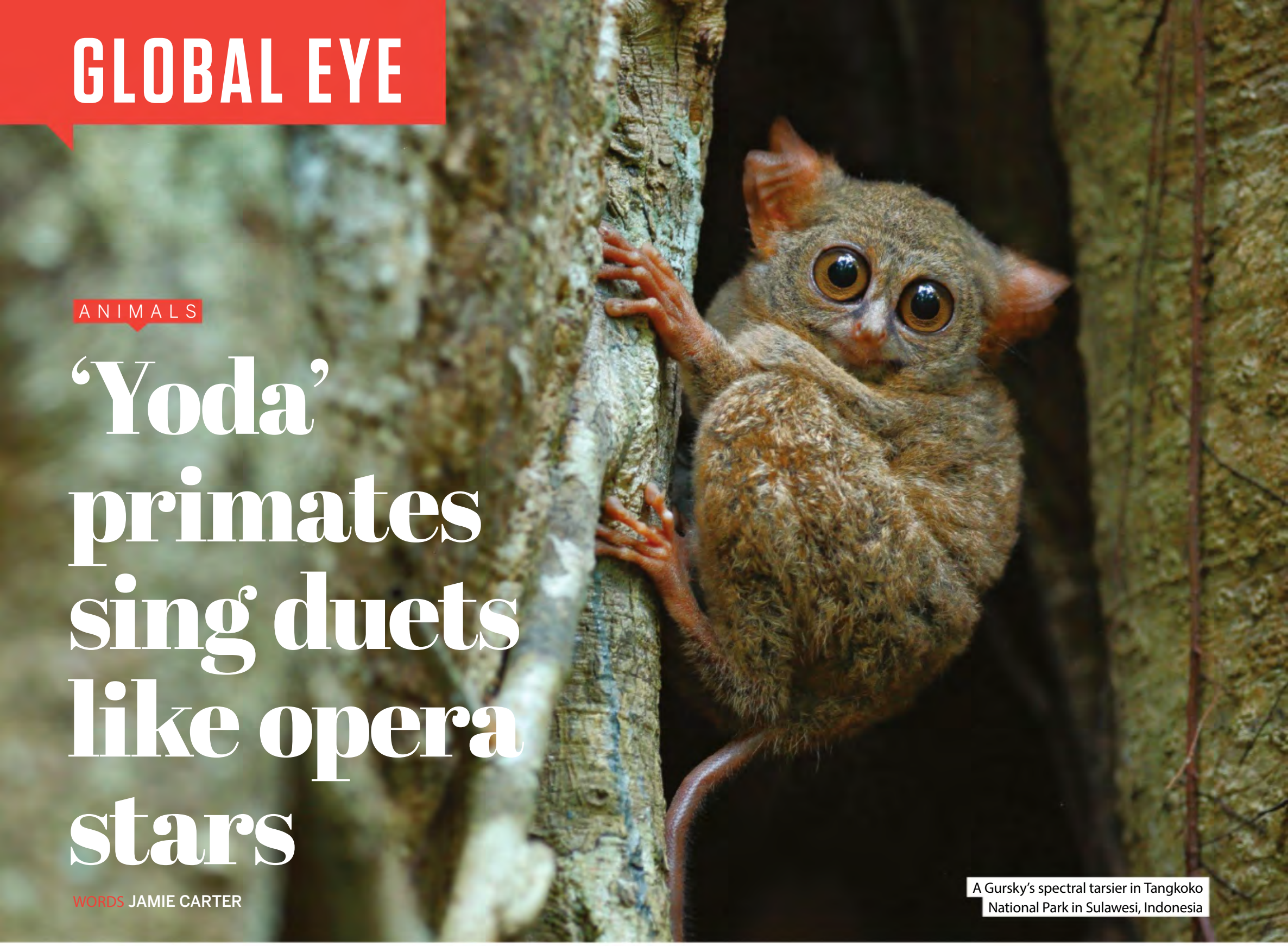
Did you know?
The biggest whale shark on record was 18.8 metres long

A whale shark opens its mouth to filter feed

ANIMALS

‘Yoda’ primates sing duets like opera stars

WORDS JAMIE CARTER



A Gursky’s spectral tarsier in Tangkoko National Park in Sulawesi, Indonesia

Tiny monkey-like creatures called tarsiers sing duets together in the style of opera singers – but those who fail to hit the high notes may also flop at attracting mates. With their large, pointed ears and expressive eyes, nocturnal tarsiers carry a striking resemblance to the diminutive Jedi master Yoda from the *Star Wars* films. But while Yoda never demonstrated any operatic ability, tarsiers are energetic singers who may exert themselves vocally as a form of sexual selection or to signal to each other that it’s time for all members of a troop to gather together to sleep.

To learn more about these vocal performances, scientists eavesdropped on tarsiers in Tangkoko National Park in Sulawesi, Indonesia, in July and August 2018, capturing 50 recordings of 14 pairs of Gursky’s spectral tarsiers (*Tarsius spectrumgurskyae*) singing their morning duets. Researchers from Universitas Sam Ratulangi in Sulawesi and Cornell University in Ithaca, New York, used machine learning to distinguish and classify notes and musical phrases in the tarsiers’ songs. The research suggests that these performances are so taxing that not all tarsiers can hit the fast and high notes and duet proficiently.

Measuring just 9 to 15 centimetres tall and weighing no more than 200 grams, Gursky’s spectral tarsiers live only on Sulawesi, an Indonesian island east of Borneo. They were described as a separate species from other tarsiers in 2017 and are classified as vulnerable by the International Union for the Conservation of Nature’s (IUCN) Red List of Threatened Species. About 13 species of tarsiers inhabit islands in Southeast Asia.

The researchers captured the tarsiers’ duets using a handheld digital recorder and autonomous recording devices that were installed in the tarsiers’ jungle habitats. When the scientists analysed the intricate duets, which were performed between male and female tarsiers, they found that the performances resembled coloratura – a singing style that produces many notes very rapidly and that’s used by opera singers during arias to showcase their control and virtuosity.

“The duets exhibit acoustic trade-offs in note rate and note bandwidth – the range of frequencies within a note,” said Isabel Comella, a researcher at the K. Lisa Yang Center for Conservation Bioacoustics. The tarsiers that sing more slowly do so with the widest range of frequencies within a note, while the tarsiers that repeat notes more quickly only appear capable of a narrower range of frequencies within a note. Only a minority manage both simultaneously.

Did you know?
Tarsiers eat insects, reptiles, frogs and even birds

The researchers hypothesise that rapidly singing notes containing a broad range of frequencies during a duet may be more physiologically and neurologically taxing for the singer, with only physically fit individuals able to do so.

Exactly why tarsiers duet in such a complex and physically taxing way is unknown, largely because the animals are rarely studied. Other primates are known to sing duets, including a type of lemur called the indri (*Indri indri*), titi monkeys in the *Callicebus* genus and eastern gray gibbons (*Hylobates funereus*). Prior studies into primate duets suggest that this behaviour may be used for finding or guarding a mate, defending territory or strengthening social bonds, though further research is required to determine exactly why tarsiers are performing these duets.

TECH

US Space Force tests robot patrol dogs

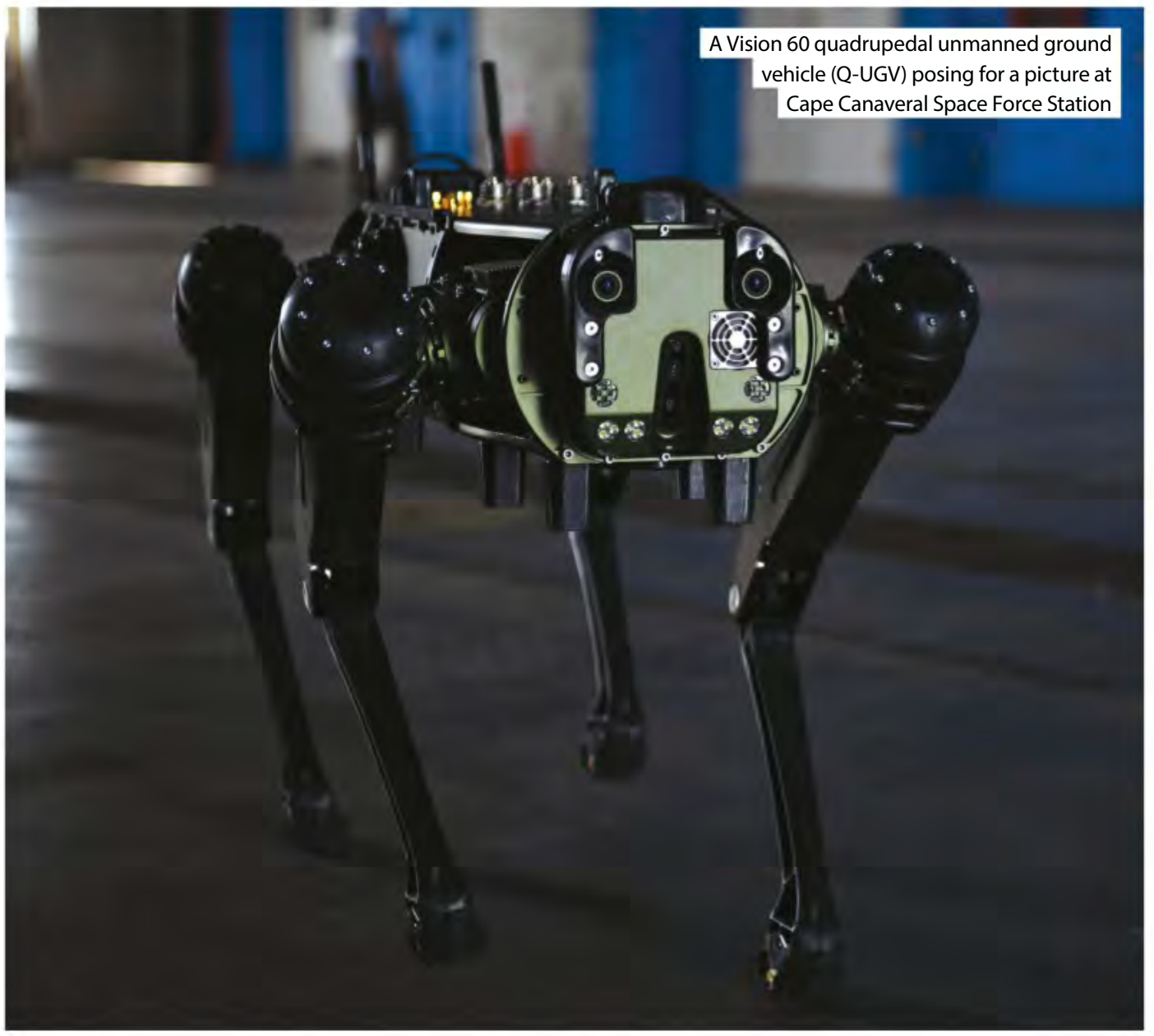
WORDS **BRETT TINGLEY**

Man's new best friend is coming to the Space Force. The agency has conducted a demonstration using dog-like quadrupedal unmanned ground vehicles (Q-UGVs) for security patrols and other repetitive tasks. The demonstration used at least two Vision 60 Q-UGVs, or 'robot dogs', built by Ghost Robotics and took place at Cape Canaveral Space Force Station. Space Launch Delta 45 will use the robot dogs for damage assessments and patrol to save significant man hours. The unit is responsible for all space launch operations from Kennedy Space Center and Cape Canaveral.

Images from the demonstration show personnel operating the robots with a hand controller inside a hangar. The Ghost Robotics Vision 60 Q-UGVs can be equipped with a wide variety of optical and acoustic sensors, enabling them to serve as automated 'eyes and ears' around sensitive installations such as a Space Force base. The robots can be operated either autonomously or by a human controller and can even respond to voice commands.

The dog-like robots can also serve as miniaturised communications nodes, carrying antennae to quickly extend networks beyond existing infrastructure or in locations where no such infrastructure exists. The robots have been previously tested by the US Air Force for perimeter defence tasks and as part of a large test of the service's Advanced Battle Management System data-sharing network. In a 2020 test, robot dogs at Nellis Air Force Base in Nevada provided real-time strike targeting data to US Air Force operators in Florida using Starlink satellite links.

The Ghost Robotics Q-UGVs are designed to withstand water and weather and were recently demonstrated with a tail-like payload enabling them to travel underwater. Aside from their military applications, the robot dogs are also being eyed for uses in emergency management, public safety and industrial inspection.



A Vision 60 quadrupedal unmanned ground vehicle (Q-UGV) posing for a picture at Cape Canaveral Space Force Station

Overhead footage of the massive sinkhole, located in a rural area in Chile

PLANET EARTH

ENORMOUS SINKHOLE OPENS IN CHILE

WORDS **BRANDON SPECKTOR**

An enormous sinkhole has opened up on a plot of mining land in Chile. The 32-metre hole appeared on 30 July in a rural area outside the town of Tierra Amarilla, about 500 miles north of the capital, Santiago. The hole appears to be about 200 metres deep, with a reservoir of water sloshing around the bottom. The hole opened on the site of Alcaparrosa Mine. No injuries or damage have been reported. Geologists are investigating the hole and have placed a 100-metre security perimeter around the site.

Sinkholes form over areas where water gathers underground without external drainage, causing the water to carve out subterranean caverns. Sinkholes also form regularly near old and active mines, where large amounts of rock and ore have been extracted. Sinkholes often form gradually over many years but can also open quite suddenly, taking cars, homes and streets down with them.

Cristóbal Zúñiga, the mayor of Tierra Amarilla, told a local radio station that the Alcaparrosa mining operation has already taken a toll on his community. According to Zúñiga, tremors and daily blasting from the mine "have destroyed our houses and our streets, and today destroyed the ground. Today it happened in a space that's an agricultural property, but our greatest fear now is that this could happen in a populated place, on a street, in a school."

WISH LIST

The latest tech for PHOTOGRAPHY

DJI OM 4 SE

STORE.DJI.COM £85 / $119

The DJI OM 4 SE is one of the best photography gimbals for tackling a shaky hand thanks to its excellent stabilising motor. This gimbal comes with a handy magnetic phone clamp or magnetic ring holder which allows you to attach your smartphone instantly. It's also compact for easy storage. One of the most commendable qualities of the DJI OM 4 SE is the amount of photography-assisting features, including face-tracking technology, creative filming templates, dynamic zoom and gesture controls. The DJI OM 4 SE also offers a second pair of hands when it comes to snapping amazing panoramic pictures at the touch of a button.

LOUPEDECK+

WWW.LOUPEDECK.COM £229 / $279

If you want a new and more ergonomic way to edit your photographs, the Loupedeck+ might be just what you're looking for. Intended to replace the complex menus and panels in editing software such as Adobe Lightroom and Photoshop, each of the buttons, dials and wheels on the Loupedeck+ corresponds with editing features. Its user-friendly design means that beginner and expert photographers alike can edit images in minutes. This console has a combination of eight dedicated buttons for functions such as saturation or tint. However, users are able to assign 16 presets to apply different editing features instantly with the press of a button.

MOMENT ANAMORPHIC LENS – BLUE OR GOLD FLARE

WWW.SHOPMOMENT.COM

$149.99 (APPROX. £125)

There are plenty of smartphone lenses on the market, but the Moment Anamorphic Lens with either Blue or Gold Flare gives any photographer snapshots with cinematic finesse. The anamorphic lenses transform your smartphone camera into a 16:9 widescreen film camera and provide iconic flares thanks to either a blue or gold coating. The Blue Flare lens can add distinct science-fiction inspired flares, while the Gold Flare lens adds a vintage style to your footage.

The lenses are compatible with a wide range of Android and iPhone devices, including the latest iPhone 13. They're easy to install, too: simply click the accompanying Moment smartphone case over your phone's camera and you're good to go.

SHIFTCAM PROGRIP

WWW.SHIFTCAM.COM

FROM £119.99 / $119.99

A lot of today's advanced smartphone cameras can easily rival some high-end cameras for their photographic abilities. However, what smartphones lack as a camera is ergonomic design. That is until you add the ShiftCam ProGrip, the accessory that makes your smartphone feel like a DSLR camera. With the signature curve, thumb rest and shutter button of a DSLR, you can quickly slide on the ProGrip and start shooting like a professional. Along with being a great ergonomic addition to your smartphone, it's also a wirelessly charging battery pack so that your camera is always ready for the next shot. ShiftCam has a range of modular additions that can build upon the ProGrip, including an LED light, ProLens and hand strap.

DJI MINI 3 PRO

WWW.DJI.COM £709 / $759

It's one of the more expensive ways to take a picture, but the DJI Mini 3 Pro is a photographer in the sky that can snap some incredible shots. Lightweight and compact, this mini drone is only 249 grams in weight and can fit easily inside your backpack for photography on the go. The Mini 3 Pro can take 4K video footage at 60 frames per second and offers intelligent features such as active tracking, true vertical shooting and timelapses. The drone can stay airborne for up to 34 minutes and can transmit footage from distances up to seven miles away. It also comes equipped with tri-directional obstacle sensing and advanced piloting assistance so that it can avoid potential obstacles in real time.

KODAK PRINTOMATIC

WWW.KODAK.COM £49.99 / $49.99

The Printomatic camera by Kodak is a compact camera that instantly and automatically prints high-quality images with ease. Unlike some instant-printing devices, the Printomatic doesn't use any ink or toners to print its images, instead using Kodak Zink photo paper. All of the images this camera prints are in vibrant full colour and are tear and water resistant. One handy feature of this camera is its ability to capture new images while the previous shot is printing, meaning you don't have to miss a moment. There's also space for a micro SD card to be inserted into the camera so that you can store images if you want to upload them online later.

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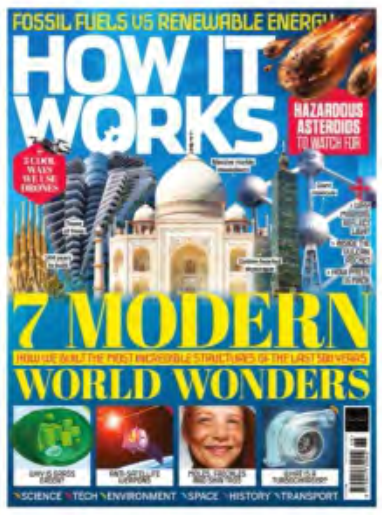

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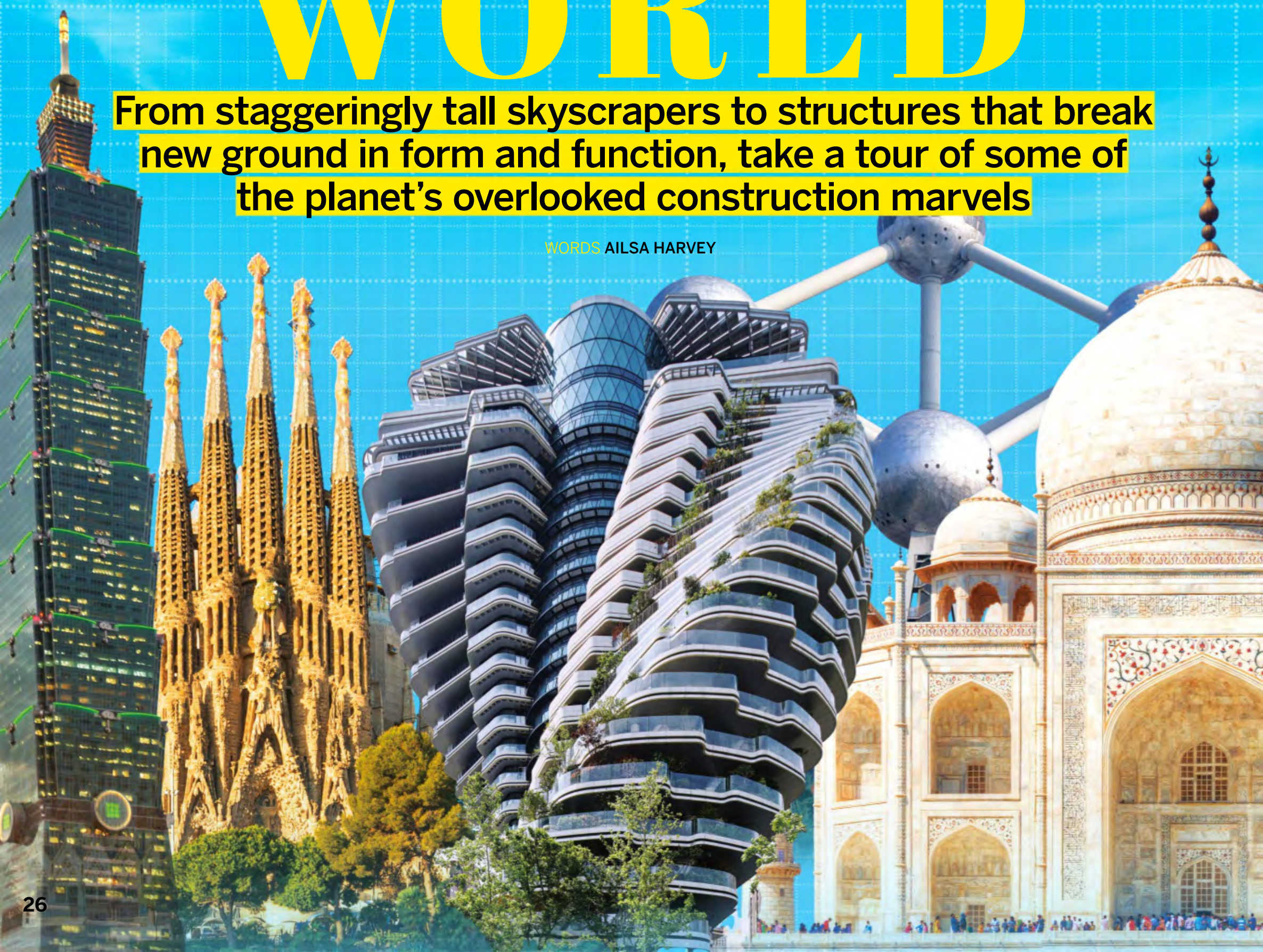
SPECIAL

7 MODERN WONDERS OF THE WORLD

From staggeringly tall skyscrapers to structures that break new ground in form and function, take a tour of some of the planet's overlooked construction marvels

WORDS **AILSA HARVEY**



DID YOU KNOW? An elevator carries visitors to the top of the Atomium in just 23 seconds

MOLECULE MAGNIFIED 165 BILLION TIMES

WONDER: The Atomium
LOCATION: Brussels, Belgium


Three-metre tubes connect the atoms

1

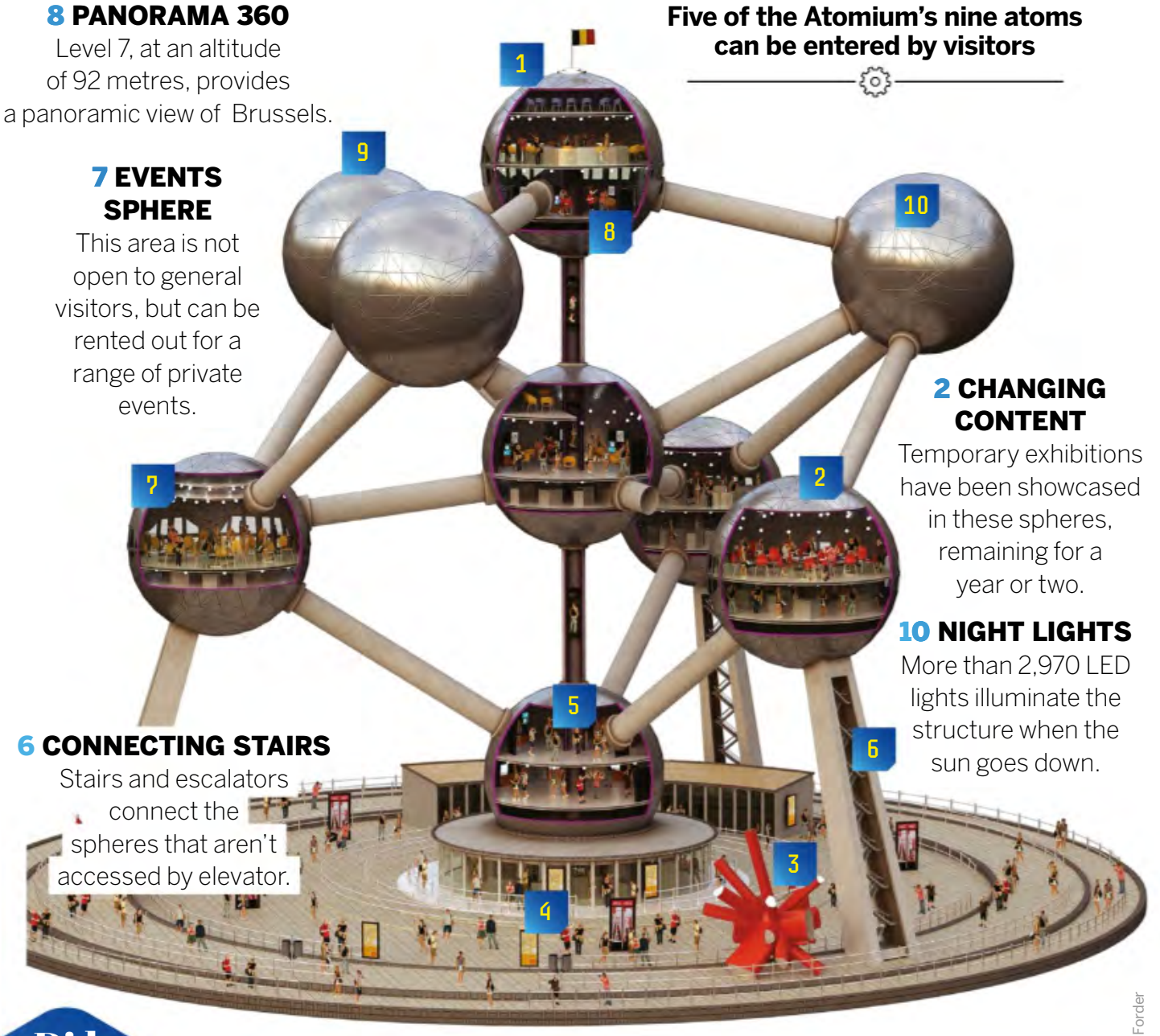
This iconic 102-metre structure and its giant reflective spheres dominate the surrounding park. However, the design inspiration for this modern edifice includes elements so small they are invisible to the naked eye. The Atomium, designed by architects André and Jean Polak and engineer André Waterkeyn and built in 1958 for the World's Fair, represents a molecule of solidified iron magnified 165 billion times. Each of the nine spheres, representing atoms, are 18 metres in diameter and are evenly spaced 30 metres away from each other.

The steel sculpture has become a famous attraction in Belgium, but it was only designed to be a temporary feature. For the short-term fair, the spheres were built using aluminium sheets, but were renovated in 2004 using longer lasting stainless steel. The World's Fair was the first in a series to be held following World War II and was an international exhibition to showcase national achievements. The Atomium structure remained permanently as a reminder of how science, and something as small as an atom, can hold a great impact on the planet. Post-war there was widespread belief that science could be used to improve lives instead of destroying them, and this structure serves as a reminder of the peaceful applications of the atom. The war had led to the development of nuclear weapons, with atomic bombs proving the large-scale and catastrophic impact of atoms. But nuclear technology can also be used to serve humanity through new systems and cures. The Atomium symbolised, and continues to symbolise, peace.

Today the Atomium is one of Brussels' most popular tourist attractions, welcoming 600,000 people a year. Visitors can marvel at the external structure or venture inside some of the spheres to experience panoramic views of the surrounding landscape, navigating between the atoms through giant tubes.

INSIDE THE CUBIC CRYSTAL

Five of the Atomium's nine atoms can be entered by visitors



9 PRACTICAL ATOMS
Four spheres can't be accessed for safety reasons.

1 FOOD WITH A VIEW
Level 8, in the top sphere, is the site of a 100-metre-high restaurant.

8 PANORAMA 360
Level 7, at an altitude of 92 metres, provides a panoramic view of Brussels.

7 EVENTS SPHERE
This area is not open to general visitors, but can be rented out for a range of private events.

2 CHANGING CONTENT
Temporary exhibitions have been showcased in these spheres, remaining for a year or two.

10 NIGHT LIGHTS
More than 2,970 LED lights illuminate the structure when the sun goes down.

6 CONNECTING STAIRS
Stairs and escalators connect the spheres that aren't accessed by elevator.

5 FIRST EXHIBITION
This permanent exhibition features the history and purpose of the Atomium itself.

4 ASCENDING THE ATOMS
A central elevator carries visitors straight to the top sphere.

3 ROCKGROWTH 808
A nine-metre-tall red steel sculpture. Its mirrored arms reflect light from the Atomium to represent the power of atomic-force microscopes.

Did you know?
'Atomium' is a combination of words 'atom' and 'aluminium'

TOWER'S GIANT GOLDEN HEART

WONDER: **Taipei 101**
LOCATION: **Taipei, Taiwan**

2

Building a 101-storey tower block might seem brave in an area with high seismic activity. However, Taipei 101 – which held the title of the world's tallest building between 2004 and 2009 – has built-in earthquake and typhoon resistance. At its tallest point, Taipei 101 reaches 508 metres, and at its base 380 concrete-filled steel piles are buried tightly in the soil up to 80 metres deep. This provides structural stability during the events of an earthquake or strong typhoon winds. But by far the most mesmerising safety feature hangs at the top of the structure – a giant golden ball. Called a mass tuned damper, this 660-tonne suspended steel ball dampens any vibrations that are caused by earthquakes or strong winds and steadies the swaying building as the floor and air around it moves. The damper, which is the world's largest, is visible to visitors from viewing platforms within the building. Entering above the 87th floor will make any person feel small in the presence of the tower's golden heart.

ENSURING STABILITY

How does the golden damper keep this building steady above the Pacific Ring of Fire fault lines?

6 POSITIONING
The mass damper is located at the top of the building where there is the most displacement during an earthquake or strong winds.

5 MASS BLOCK
The 660,000-kilogram sphere moves in the opposite direction to the building, reducing sway by 40 per cent.

2 CABLES
The mass damper is suspended by strong 42-metre-long cables.

1 METAL FRAMES
Frames contain the mass damper for safety, but provide room for swinging.

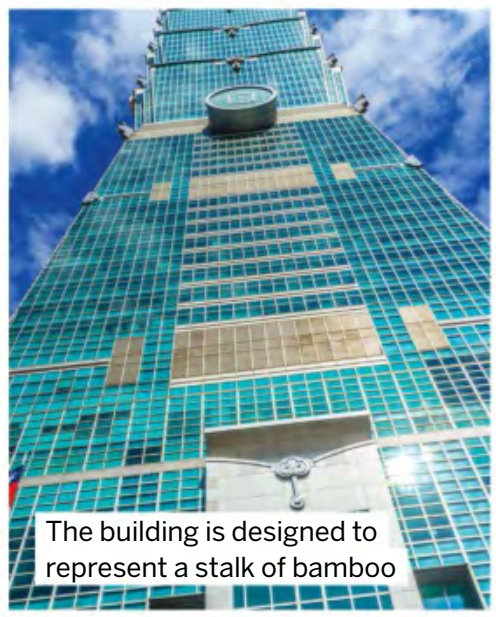
7 VIEWING PLATFORMS
Between floors 87 and 91, visitors can view the large ball.

3 HYDRAULIC PUMPS
These components turn kinetic energy into heat, serving as shock absorbers.

4 CLAMPING
The ball is secured so that it can move up to 1.5 metres in any direction.

LUCKY EIGHT

The number eight is lucky in Chinese culture, and this is just one element of local culture that's reflected in the building's design. There are eight clearly differentiated sections of the tower, each with eight storeys. In Chinese the word eight is pronounced 'ba', similar to the character 'fa', which means 'well-off'. This has led to the number being associated with wealth in Chinese culture. On the side of the building, each section also features a large, traditional Chinese symbol that can be seen from the ground.



The building is designed to represent a stalk of bamboo

DID YOU KNOW? 2,995 tonnes of CO_2 emissions are saved per year by the energy efficiency practices of Taipei 101

Each palm tree branch has a sandy beach perimeter

RECLAIMED ARCHIPELAGO

WONDER: **Palm Jumeirah**
LOCATION: **Dubai, UAE**

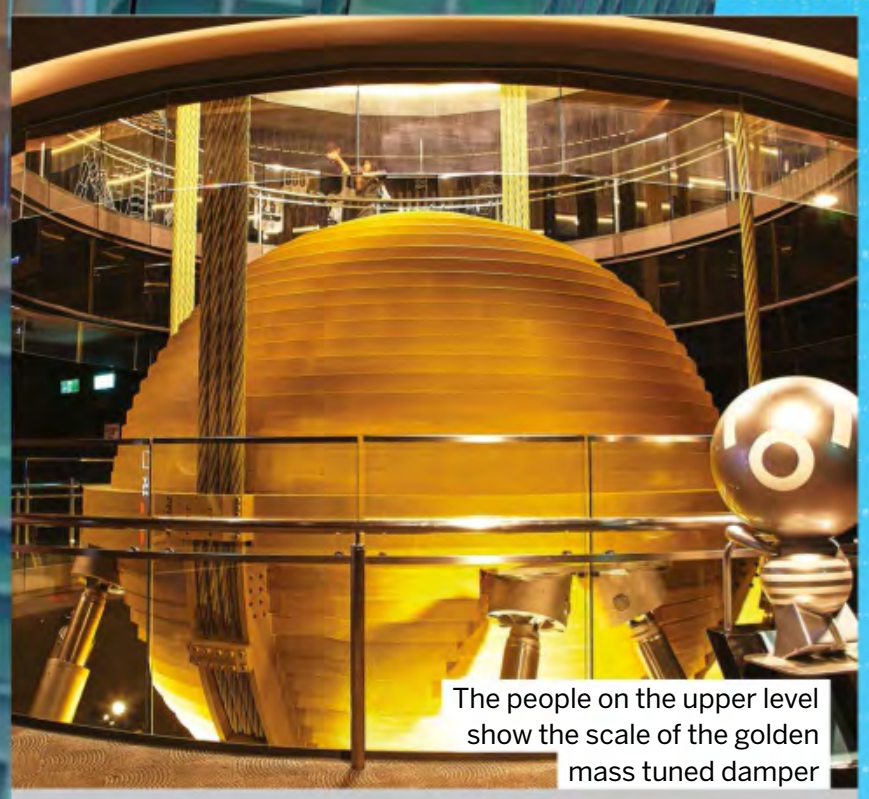
Did you know?

GPS was used to accurately plan the archipelago's shape

3

Branching from Dubai's shoreline into its turquoise waters, the Palm Jumeirah islands represent the shape of a palm tree within an incomplete circle. This artwork isn't a formation of nature, but part of an artificial archipelago known as the Palm Islands. The foundations for these islands came from the surrounding sand and rock. First, 7 million tonnes of rock was exported to the site from the nearby Hajar Mountains to form a strong base from giant rock slabs. Next, a huge 92 million cubic metres of sand was dredged from the bottom of the ocean of the Persian Gulf and sprayed into place to form the island's unique shape. The result of this six-year effort was an extra 50 miles of coastline added to Dubai.

On the trunk of the island are mostly apartments and shops, while hotels and resorts surround them on the outer crescent. The crescent is divided into three sections in order for the circulation of seawater not to be disrupted. Only a few years after the island was completed, by 2017 more than 10,000 people called Palm Jumeirah home. There are two additional palm islands – Palm Deira and Palm Jebel Ali – but Palm Jumeirah remains the only finished project of the three.



The people on the upper level show the scale of the golden mass tuned damper

ECO-FRIENDLY ARCOLOGY

WONDER: The Agora Garden
LOCATION: Taipei, Taiwan

4

A DNA molecule is a source of life. It carries all the information for the development and proper function of living organisms. It's apt that this molecule is the inspiration for the shape of the Agora Garden. This is a residential tower designed to restore life to our planet through eco-friendly technology and carbon-reducing lifestyles. Designed by Belgian architect Vincent Callebaut and completed in 2018, this 93-metre-tall building combines urban life with natural habitats so that the two can not just coexist, but support each other. The height of the tower limits the occupied ground space, while plenty of plants serve as a carbon-absorbing city ecosystem for wildlife. Residents of this tower block have balconies packed with plants, including vegetable gardens and fruit trees. This encourages residents to grow their own food, and all their biodegradable waste is composted.

With a luxury swimming pool, gym facilities and a rooftop clubhouse, this modern tower demonstrates how achieving low energy consumption and following a climate-conscious way of life doesn't necessarily require a simple lifestyle. In his design proposal, architect Callebaut made his goals clear: "In the heart of Taipei, after having built the city on the landscape, after having then built the city on the city, it is now time for the landscape to rebuild itself on the city."

6 SKY GARDEN
Rainwater is filtered and purified here to be used within the building.

5 PHOTOVOLTAIC ROOF
At a height of 100 metres, this 1,000 square metre platform uses sunlight to produce electricity for residents.

The Agora Garden is locally known as Tao Zhu Yin Yuan

7 LIGHT DISTRIBUTION
A circular central lightwell allows daylight to reach lower levels of the building.

4 CAR ELEVATOR
Four high-speed elevators and one car elevator carry people and their vehicles to every level.

1 FIXED CENTRE
The structure is a cross between a single tower and twin towers.

2 GREEN MOUNTAIN
An area of around 6,000 square metres is covered by plants, making the total green coverage of the building's floor space 246 per cent.

3 OPEN-AIR GARDENS
The 21 floors twist around the central column by 90 degrees, providing open-air space above every balcony.

CARBON-ABSORBING ARCHITECTURE

Many features of this luxurious twisted tower help make it a self-contained ecosystem

DID YOU KNOW? The Agora Garden can absorb 130 tonnes of carbon emissions

MASSIVE MARBLE MAUSOLEUM

WONDER: **Taj Mahal**
LOCATION: **Agra, India**

Cars cannot drive within a 500-metre radius of the Taj Mahal to limit pollutants

FINIAL
The central bronze spire is a crescent Moon shape, with the pointed edges facing heavenward. Until the 1800s the finial was made of gold.

5

Shah Jahan, the fifth emperor of the Mughal Empire which ruled much of South Asia between the 16th and 19th centuries, had many wives. But it was his third wife, Persian princess Mumtaz Mahal, who was his favourite. Following her death, the emperor built the Taj Mahal for her to be her final resting place on the southern bank of the Yamuna river. The total build included the work of 22,000 labourers and continued for 22 years. Since it was declared complete in 1653, the Taj Mahal's sheer size, impressive symmetry and spectacular detail have mesmerised visitors.

BENEATH THE DOME

Inside the Mughal emperor's mighty and symbolic legacy

MINARET
Calls to prayer are recited from these four pillars, called minarets. The caller climbs spiral stairs to project sound from the top.

CENTRAL DOME
The double-layered main dome is around 35 metres tall and symbolises unity.

CHATTRI
The bases of these domes are open, serving as gateways for sunlight into the building.

CENOTAPH
The main central room displays empty tombs to replicate those below ground.

ARCHWAY
The Taj Mahal entrances are framed with interlaced floral patterns and Quran inscriptions.

PRECIOUS STONES
43 types of precious stones from across India were used for decoration, including sapphires, bloodstones and topaz.

TOMBS
The graves of Shah Jahan and Mumtaz Mahal are one level below ground.

Did you know?
The Taj Mahal combines Islamic, Persian and Indian styles

WHAT IS MAKRANA MARBLE?

The light colouring of the Taj Mahal comes from white Makrana marble, the primary material mined for construction. As is traditional in Mughal architecture, red stone is the material of choice for military buildings and white marble for sacred places. The exterior buildings, such as the entrance gate, were built using red sandstone, while the majority of the Taj Mahal comprises pure white marble. Makrana marble comes from Makrana in Rajasthan and is about 99 per cent pure calcium carbonate. Being mostly calcium carbonate with traces of impurities, the material is the most water-resistant rock in India. As demonstrated by the Taj Mahal's appearance today, this material still retains its pale colouring and shine.

Makrana is the oldest marble quarry in India

60-STOREY DAM

WONDER: Hoover Dam
LOCATION: Arizona-Nevada border

The dam is named after US President Herbert Hoover, who provided funds for construction

6

Even without knowing the history behind the Hoover Dam's origins, the size of this giant water levee is enough to inspire awe. Even today, building a dam the height of a 60-storey building across one of North America's biggest rivers would be technically challenging. And when the Hoover Dam was being constructed between 1930 and 1936, it was the largest dam ever built.

The Colorado River, which stretches 1,400 miles from Colorado's Rocky Mountains to the Gulf of California, was once faster flowing, more direct and very unpredictable. It caused sudden flooding and regularly left the surrounding lands in drought. To convert the river into a reliable water source for the drier southwest region of the US, the Hoover Dam was built.

Did you know?

The Hoover Dam was originally called the Boulder Dam

Construction commenced during the Great Depression, resulting in thousands of people travelling many miles to the Hoover Dam looking for employment. Workers scaled the rocky canyon, inserting dynamite into the rock by hand to break away the foundations. Despite the treacherous working conditions, which caused around 100 men to fall to their deaths, the Colorado River was eventually tamed by the dam. Today this dam is one of the world's largest hydroelectric power plants.

5 IMPACTS OF THE DAM

1 FARMLAND IRRIGATION
The dam holds enough water to irrigate 2 million acres of land.

2 WATER CONTROL
Water can be contained or released to prevent floods and droughts.

3 HYDROELECTRIC POWER
1.3 million people use electricity from the dam each year.

4 ALTERED ECOSYSTEMS
As water is used and stored by the dam, water levels in the Colorado River have lowered. Local plant life has reduced to benefit areas further away.

5 CITY GROWTH
Branching out the Colorado River has resulted in the development of cities such as Los Angeles and Las Vegas.

HYDROELECTRIC HOOVER DAM

How does this historic construction function?

1 DAM
Over 3,300,000 cubic metres of concrete makes up the dam.

2 INTAKE TOWERS
These four concrete structures control the water supply that reaches the power plant turbines.

3 SPILLWAY INLET
To prevent flooding, any overflowing water enters spillways eight metres below the dam's top.

4 PENSTOCKS
Water travels through steel pipes known as penstocks to the powerhouse.

5 POWERHOUSE
Water passes through turbines at speeds of 85 miles per hour. A generator turns this kinetic energy into electricity.

6 VALVE HOUSES
These components are built about 55 metres above the river level to monitor the release of water through outlets.

DID YOU KNOW? Gaudi built a school at La Sagrada Familia for the builders' children

4.5 million people visit the building each year, despite it still being incomplete

A CATHEDRAL THAT'S TAKEN OVER 140 YEARS TO BUILD

WONDER: **La Sagrada Familia**
LOCATION: **Barcelona, Spain**

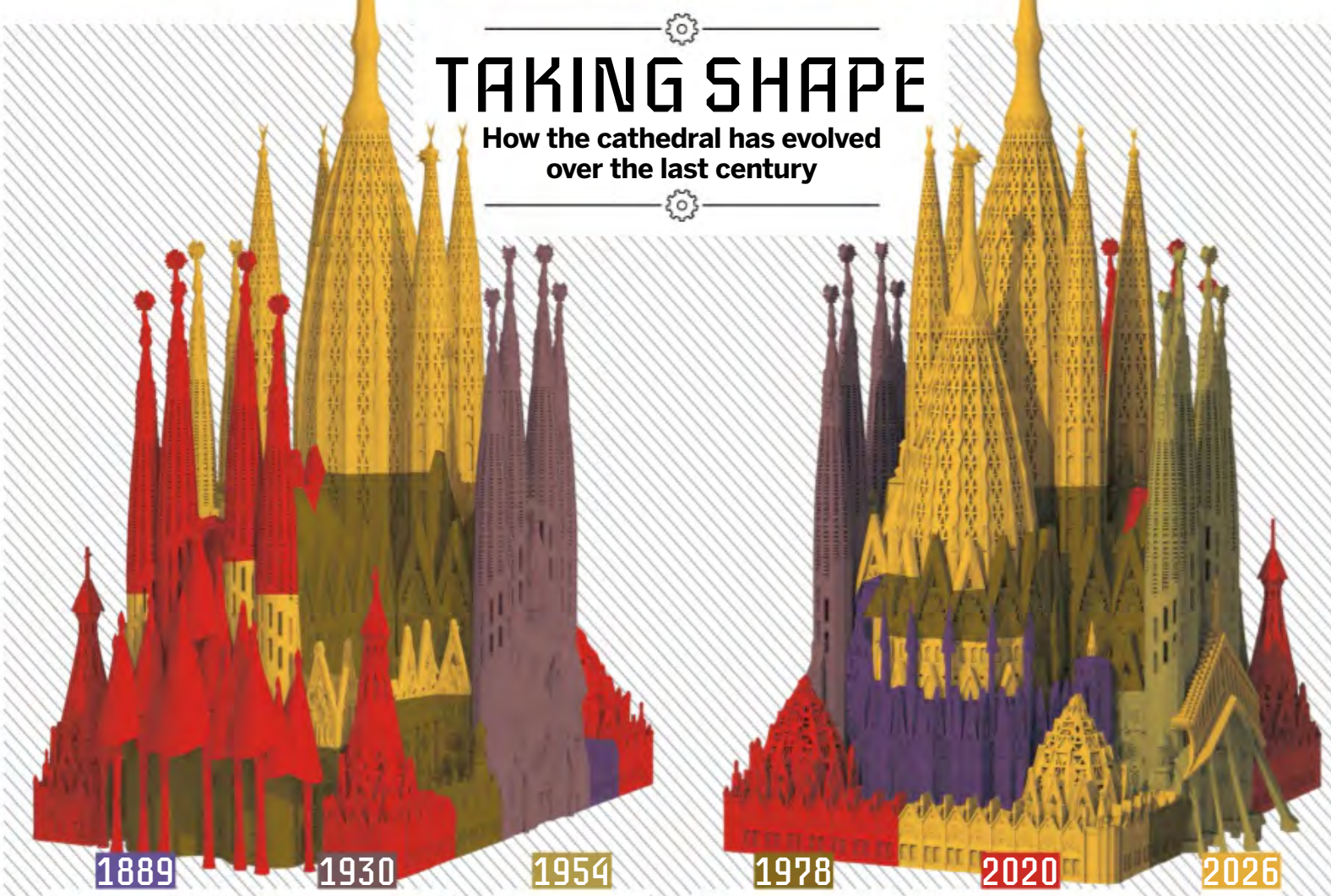
7

On 19 March 1882, Spanish architect Francisco de Paula del Villar launched the building of La Sagrada Familia basilica. His part in the project would be over when he resigned from the job just one year later following an argument with another architect on the team, but the basilica's evolution is still continuing to this day, meaning this modern wonder has been a work in progress for over 140 years.

La Sagrada Familia is due to be completed in 2026, meaning that it will have taken longer to build than the Egyptian pyramids. The original purpose of the building was to encourage Christianity in Barcelona at a time when the religion was in decline there. When Antoni Gaudi took over as chief architect in 1883, a new style was proposed. Gaudi's signature style included geometric patterns and biomimicry – shapes largely inspired by nature. These elements can be seen in fine detail throughout La Sagrada Familia, such as the branching columns creating a forest-like theme in the central church area.

TAKING SHAPE

How the cathedral has evolved over the last century



1889
After the crypt was completed, the apse was built. This is the area of a church where the altar is located.

1930
The bell towers were built between 1894 and 1930. This was the last part Gaudi saw built during his lifetime.

1954
Work on the Passion façade began. Gaudi used bone shapes to display the fear and cruelty of Jesus' death.

1978
Work started on the walls of the naves – the central rooms. There is one central nave with three entrances leading to it.

2020
Just eight per cent of the Glory façade had been completed pre-covid. This began development in 2002.

2026
Upon completion, the central tower of Jesus will be the tallest point, built to a height of 172 metres.

WONDERS BY NUMBERS

ONE

Every week there's at least one proposal at the top of the Atomium

23,000

Thousands of trees and shrubs make up the Agora Garden

THE TAJ MAHAL WAS MEANT TO BE 500 MILES AWAY IN BURHANPUR, BUT THERE WASN'T ENOUGH WHITE MARBLE THERE

€25 MILLION

The annual cost of La Sagrada Familia project is paid for by its visitors

2,000

Hundreds of fish were relocated from the Palm Jumeirah construction site to stop them becoming trapped

2,400 TONNES

The Atomium is four times as heavy as the Christ the Redeemer statue

44th

The number four is unlucky in Chinese culture, so this floor number is missing from Taipei 101

1,000

The Taj Mahal was built with the labour of hundreds of elephants

THE ORIGINAL ATOMIUM DESIGN COULD BE BLOWN DOWN BY STRONG WINDS

DID YOU KNOW? The 828-metre Burj Khalifa has been the tallest building since 2010

SAGRADA FAMILIA ARCHITECT ANTONI GAUDI WAS KILLED BY A TRAM

25KG
The average tree absorbs this much CO_2 annually

200 METRES
Taipei 101 is close to a major tectonic fault line

TAIPEI 101'S EIGHT MODULES LIGHT UP IN THE EIGHT SECONDS BEFORE NEW YEAR

1,000M²
The Agora Garden features a large photovoltaic canopy

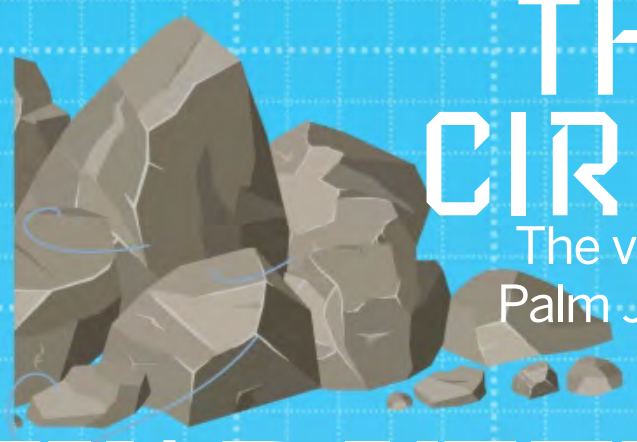
5,000
An entire city was built for thousands of Hoover Dam workers to live in

2010
La Sagrada Familia was declared a basilica by Pope Benedict XVI in this year

32 million rupees
The Mughal emperor spent the equivalent of 1 billion US dollars on the Taj Mahal

248 SQUARE MILES
The Hoover Dam created the US' largest reservoir

THREE GLOBAL CIRCUMFERENCES
The volume of rock and sand used to make Palm Jumeirah could build a two-metre-wide wall around the world



600
Palm Jumeirah's surface area is equal to hundreds of football pitches

WAR VETERANS WERE GIVEN PREFERENCE FOR HOOVER DAM CONSTRUCTION JOBS

MOLES, FRECKLES AND SKIN TAGS

How these unique patterns of pigment form on your skin

WORDS **AILSA HARVEY**

DID YOU KNOW? Moles were thought to be a sign that someone was a witch during medieval times

The colour of your skin – and how light or dark it is – is a result of your individual cell biology. Based on your genes, your skin is programmed to produce a certain amount of a pigment called melanin. Melanin plays a vital role in protecting the skin from the Sun's harmful ultraviolet (UV) radiation. The pigment is produced in cells called melanocytes, which are relatively evenly distributed throughout the skin. However, it is common for multiple areas of the body to contain clusters of these cells. When high numbers of melanocytes accumulate in one region, dark spots appear on the skin, called pigmented lesions. These include moles, freckles and skin tags.

Melanocyte clusters are mostly dark brown or black. Sometimes they appear alone on the body, while other forms such as freckles are closely spaced in large groups. People can develop moles and other pigmented spots as they age, but you will have the majority of your moles by the time you are around 25 years old. For the majority, this number is between 10 and 40 moles.

Did you know?

Most skin tags are one to five millimetres long

High numbers of pigment spots make your skin more sensitive to Sun damage, so care should be taken to reduce Sun exposure when UV levels are high. Checking for changes in moles' appearance can also help to ensure they haven't sustained damage. This being said, your mole count will vary during your lifetime. More moles usually appear during the hormone changes of puberty, while their colouring can darken throughout pregnancy. When people reach age 40 to 50, their moles tend to start fading and even vanish.

IDENTIFYING PIGMENTED LESIONS

You likely have at least one type on your body

FRECKLES

These speckled, flat brown marks most commonly appear on the face, across the nose and cheeks. Freckles are inherited and get darker and more prominent with Sun exposure.

LIVER SPOTS

Also called lentigines, these marks are similar to freckles, but are larger and appear on the hands and face. They are common on middle-aged people who have had years of Sun exposure.

SKIN TAGS

These lesions can be skin-coloured or darker than the skin. Usually caused by skin-on-skin friction, they form on the underarms, neck, groin and face, protruding from the skin's surface.

MELASMA

These light brown, dark brown or blue-coloured patches most commonly arise on the face. Rather than being caused by the Sun, these marks are a result of hormone changes.

MOLES

Moles are areas of the skin where there are high concentrations of pigment cells. They begin flat and dark in colour, but as people age they can become raised and their colour lighter.

SEBORRHOEIC KERATOSES

An accumulation of skin cells in the upper layer of skin, usually on the face, arms or legs. They are caused by ageing and Sun exposure and can have a waxy appearance.

Did you know?

Darker skin is better at blocking harmful UV rays

WHERE MOLES FORM

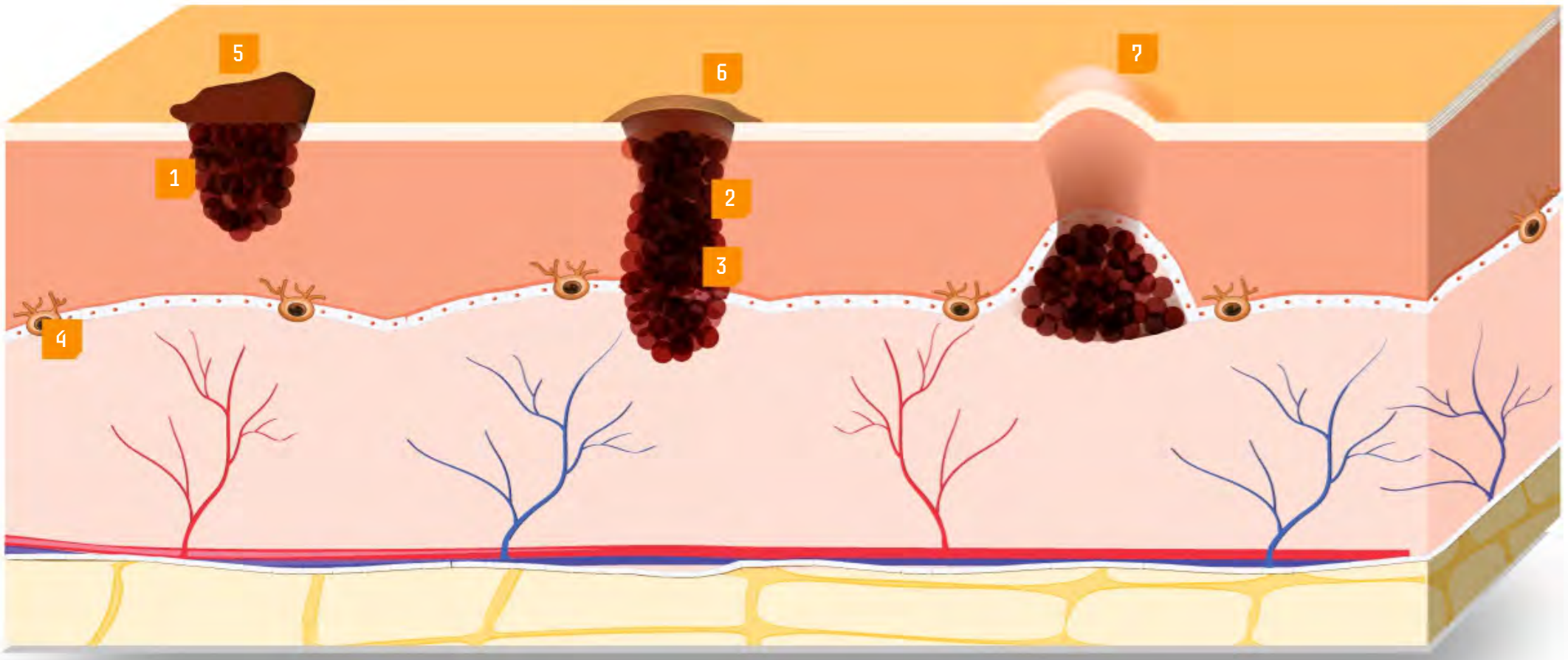
How different types of moles appear in the skin

1 JUNCTIONAL
These moles form at the very surface of the skin, in the epidermis.

2 COMPOUND
When a mole's pigment cells lie across two layers of skin at the epidermal-dermal junction.

3 INTRADERMAL
This type, in the dermis layer of skin, can form as a new mole or branch from a pre-existing melanocyte cluster.

4 MELANOCYTE
These pigment cells are made in the skin. If large numbers migrate to and colonise the same area, moles are formed.



5 DARK BROWN OR BLACK
These moles are often circular and uniform in shape. Being close to the surface makes them dark in colour.

6 BROWN
Compound moles can be irregular in shape and lighter than junctional moles.

7 SKIN-COLOURED
As the melanocyte cluster is deeper in the skin, intradermal moles are often a similar colour to the skin and present as raised bumps.

TRACKING CHANGES

Using the ABCDE rule can help you spot signs of cancerous moles, called melanomas

ASYMMETRIC
Most often, normal moles are uniform in shape. An irregularly shaped mole should be monitored for other changes and can be checked by a doctor.

BORDER
Moles usually have clear borders. Melanoma borders aren't smooth and can have complex and irregular outlines.

COLOUR
If a mole varies drastically in colour or contains light and dark patches, you should show it to a medical professional.

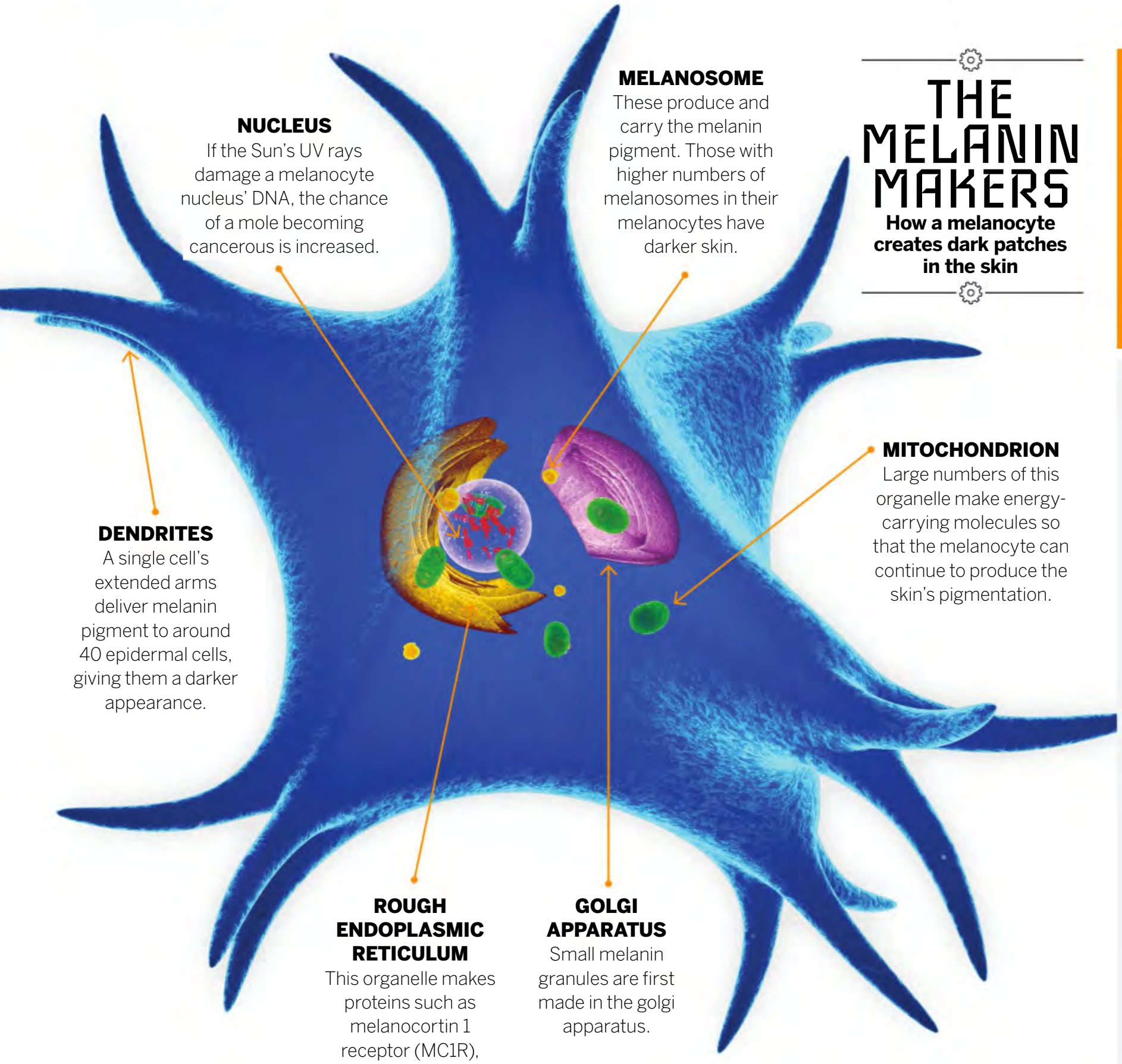
DIAMETER
Moles vary in size, but large moles that are six millimetres or bigger are more likely to be melanomas than smaller ones.

EVOLVING
E is the final ongoing factor to monitor. Most moles remain relatively similar in appearance over time. Any moles that change size or shape should be seen by a doctor.

DID YOU KNOW? The type of melanin found in the skin, eyes and hair is called eumelanin

THE MELANIN MAKERS

How a melanocyte creates dark patches in the skin



NUCLEUS
If the Sun's UV rays damage a melanocyte nucleus' DNA, the chance of a mole becoming cancerous is increased.

MELANOSOME
These produce and carry the melanin pigment. Those with higher numbers of melanosomes in their melanocytes have darker skin.

DENDRITES
A single cell's extended arms deliver melanin pigment to around 40 epidermal cells, giving them a darker appearance.

MITOCHONDRION
Large numbers of this organelle make energy-carrying molecules so that the melanocyte can continue to produce the skin's pigmentation.

ROUGH ENDOPLASMIC RETICULUM
This organelle makes proteins such as melanocortin 1 receptor (MC1R), needed for melanin production.

GOLGI APPARATUS
Small melanin granules are first made in the golgi apparatus.

5 FACTS ABOUT FRECKLES

1 BLANK AT BIRTH
You never see a baby with freckles because the skin has to be exposed to the Sun before they appear.

2 FRECKLING GENE
Your parents both need to have the MC1R gene mutation in order for you to develop freckles.

3 COME AND GO
Freckles darken and lighten year round depending on how much Sun your skin is exposed to.

4 NEVER CANCEROUS
Freckles themselves can't be cancerous. However, the more freckles you have, the more sensitive your skin is to the Sun.

5 HAIR-SKIN CORRELATION
80 per cent of people with ginger hair carry the MC1R gene, making them more likely to have freckles.

SKIN TAG REMOVAL

Moles can be removed using scalpels or lasers when they are deemed suspicious, cancerous or precancerous by doctors. Skin tags, on the other hand, are harmless. These lesions are made of collagen fibres, blood vessels and skin and usually form in skin folds, where two body surfaces regularly rub together. Although they aren't dangerous, many people opt to get these removed. Due to their tendency to form in areas of high friction, skin tags can become uncomfortable when moving around. When they get pulled or caught in clothes and jewellery, they can bleed. In some instances skin tags fall off by themselves, usually because their blood flow gets restricted and they die. It's important that you never try to remove a skin tag by yourself, unless advised by a doctor, because larger skin tags can cause significant bleeding and damage.

Lasers remove skin tags and moles by making microscopic cuts

WHY MIRRORS ARE SO REFLECTIVE

Is a mirror the same colour as the reflection it displays?

What makes looking glasses so good at reflecting light?

WORDS **LAURA MEARS**

Mirrors can reproduce an image of whatever is in front of them. They use a combination of glass and metal to reflect any light that hits their surface. Light travels through space as waves. According to the law of reflection, when the waves hit a surface, they always bounce back in the opposite direction. If that surface is rough, each wave will hit at a slightly different angle and they will all scatter in a different way. But if the surface is smooth, the reflections will all bounce off in the same direction.

Mirrors are ultra-smooth. When light hits them from the front, it bounces straight back. If it comes in from the left, it exits to the right. The reflective properties of mirrors mean that almost all the light that hits them bounces back. To a casual observer, a mirror looks the same colour as the world around it. It can be anything from vermillion red to periwinkle blue. But mirrors do actually have a colour of their own.

The reflective metal inside a mirror is usually silver, or a shiny grey. You can even recreate it on a computer in image-editing software using the hexadecimal colour code #C0C0C0. If a mirror were a solid piece of silver, that would be its colour. But the silver particles are sandwiched between a black back and a piece of solid glass.

Glass is made from sand, soda ash and limestone and contains traces of iron. This iron absorbs some of the light that passes through the mirror, making everything look slightly green. You can see this green cast more easily if you look at the mirror from the side. The thicker the glass or the higher the iron content, the greener the mirror will appear.

Did you know?

The first mirrors were just water in a dark bowl

HOW TWO-WAY MIRRORS WORK

Two-way mirrors, confusingly also known as one-way mirrors, work like a window on one side and a mirror on the other. Most famous as a way for police to observe criminals, you can also find them in teleprompters and research labs. They are surprisingly similar to traditional mirrors, with a few important differences. The reflective coating on the glass is thinner, meaning that it doesn't bounce all the light back to the observer. This means that around half of the light that shines on the mirror passes straight through. There's also no black backing. Instead there's space, or even a whole room, behind the glass. The mirror works because the room behind is darker than the room in front. The people looking into the mirror see their own reflection, while the people behind see straight through the glass.

In a two-way mirror the gap between your finger and its reflection disappears

DID YOU KNOW? In 4000 BCE, people in Mesopotamia (now Iraq) started using polished copper to see their own reflections

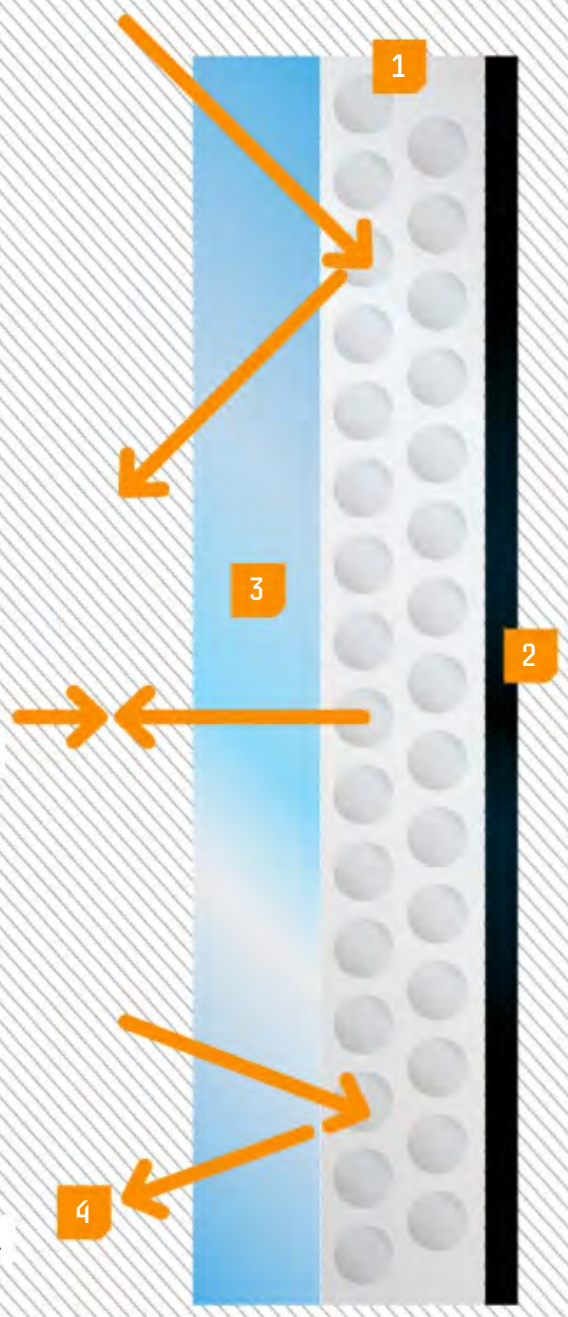
WHY DO THEY GO BLACK AT THE EDGES?

Old mirrors can discolour over time. Speckles of black start to appear around the edges, preventing reflections bouncing back. It's called 'de-silvering', and it happens when mirrors get wet. Most mirrors aren't water-tight, and if liquid gets under the glass, it can cause the silver coating to lift away. This reveals the black backing. It's possible to re-silver a damaged mirror, but it's an expensive and painstaking process. Take care when cleaning, and ventilate steamy rooms like the bathroom to stop condensation getting under the glass. Adding a frame can help to disguise the problem and prevent it getting worse.

When water gets into mirrors it causes damage to the silver coating

WHAT'S INSIDE A MIRROR?

Mirrors have three main parts: glass, silver and a backboard



1 REFLECTIVE COATING
The back of the glass has a thin coating of metal, most often silver or aluminium.

2 BACKBOARD
A black board protects the back of the mirror and stops light getting in from behind.

3 TRANSPARENT FRONT
The glass on the front of the mirror allows light in and out.

4 LIGHT
Light passes through the glass, hits the metal and reflects back out towards the viewer.

Mirrors don't have to reflect light; this acoustic mirror reflects sound

Wavy mirrors bend light in unexpected directions, distorting reflections

5 WAYS TO USE MIRRORS

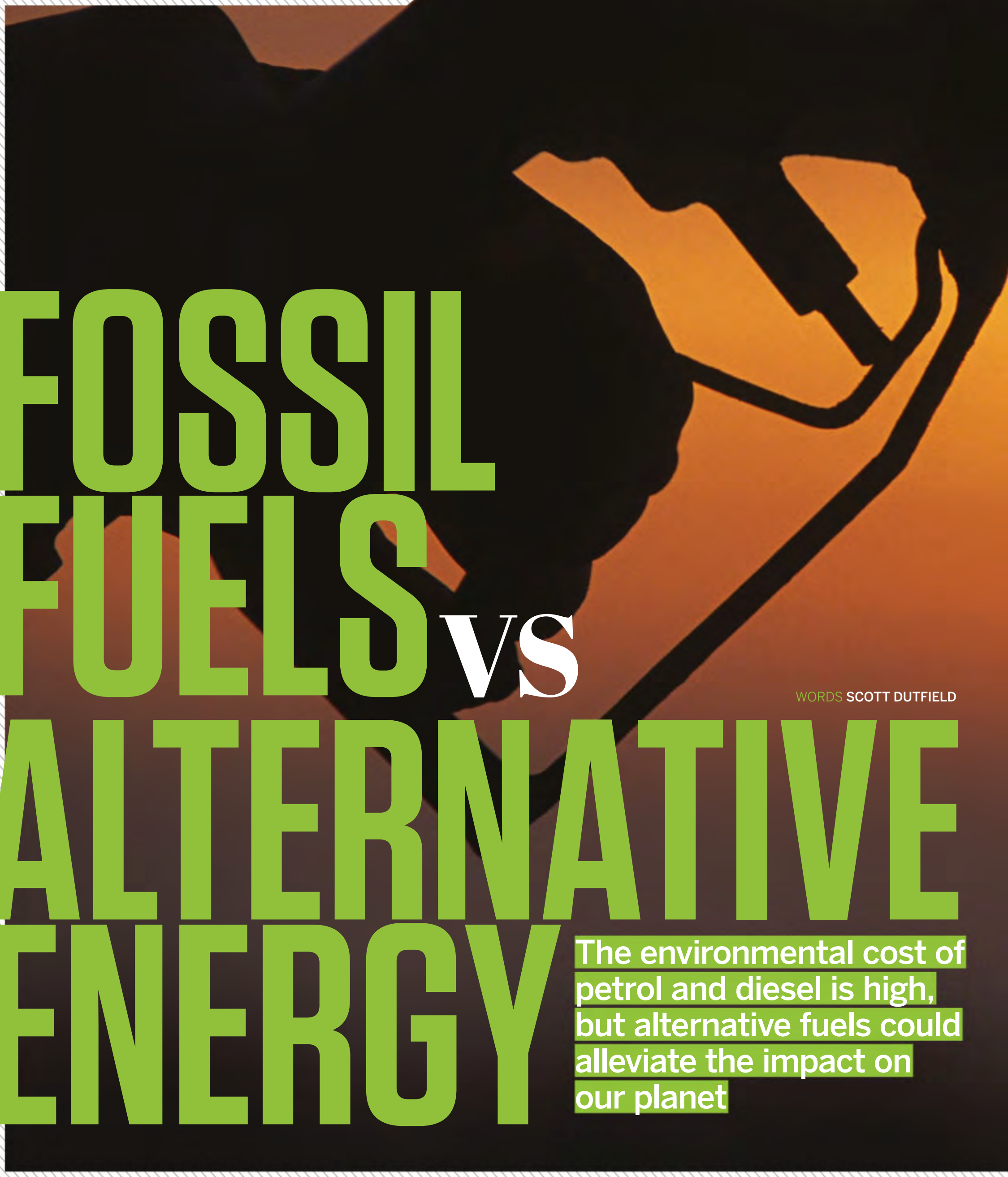
1 SPACE SCIENCE
Telescopes like NASA's James Webb use gold-coated mirrors to collect infrared light from ancient galaxies. The mirrors focus the light onto sensors, allowing astronomers to see back in time.

2 MICROMIRRORS
Mirrors on light microscopes bounce light through wafer-thin samples and into your eyes. Lenses focus the light, making it possible to see objects invisible to the naked eye.

3 PEEPING PERISCOPES
Periscopes use mirrors to bounce light through long tubes, allowing you to see around corners or over obstacles. You can find them in gun turrets and submarines.

4 MOON MIRRORS
When astronauts visited the Moon in 1969, they left a panel of 100 mirrors on the surface. Scientists can hit those mirrors with lasers to measure its distance from Earth.

5 EMERGENCY SIGNALS
Soldiers, explorers and hikers use mirrors to reflect pulses of light and send Morse code messages over long distances. This technique is known as heliography, or 'Sun writing'.



FOSSIL FUELS vs ALTERNATIVE ENERGY

WORDS **SCOTT DUTFIELD**

The environmental cost of petrol and diesel is high, but alternative fuels could alleviate the impact on our planet

DID YOU KNOW? The US is the largest producer and consumer of crude oil in the world

With petrol prices hitting an all-time high in parts of the world, many people are switching to alternative fuel sources. For example, electric car sales worldwide have more than doubled in the last two years. However, the monetary costs of gas guzzling aren't the only pinch people are feeling as the effects of climate change become ever apparent.

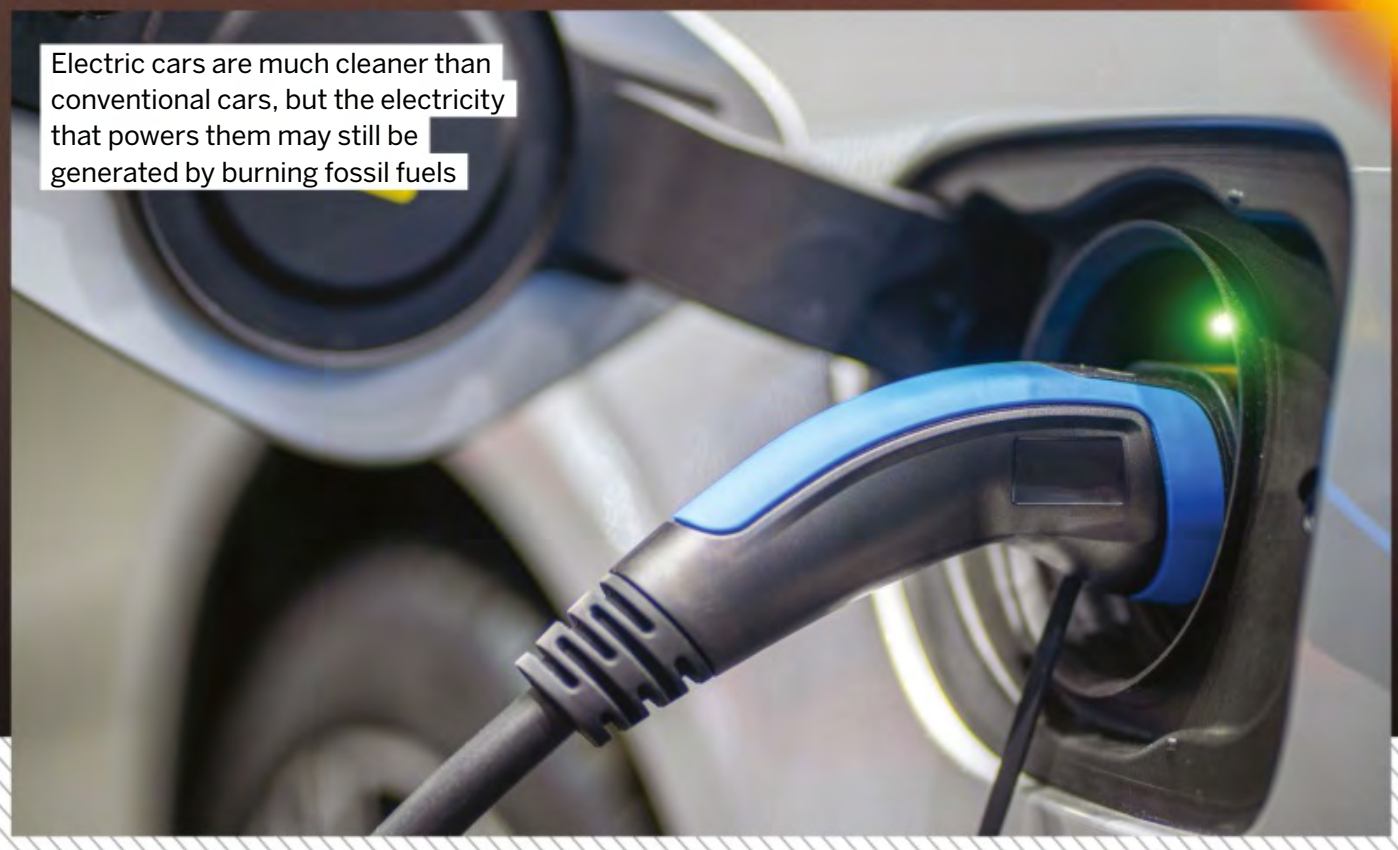
Around 25 per cent of the world's emissions of the most abundant greenhouse gas, carbon dioxide (CO_2), come from vehicles with combustion engines. Along with producing other greenhouse gases such as methane and nitrogen oxide, cars are filling the air with compounds that contribute to the effects of global warming. The reason why vehicles are such climate criminals is due to their fossil fuel diet.

Since the late 1800s we have been using petroleum to fuel combustion engines for transport. Petroleum is a hydrocarbon, meaning it's composed of hydrogen and carbon atoms. Its carbon-rich composition is the result of fossilised organic matter being heated and compressed over millions of years underground to form crude oil. This crude oil is then distilled into several substances, including petroleum.

Petroleum is highly combustible, and when injected into a vehicle's internal combustion engine can generate enough force to turn the wheels. Along with propelling a vehicle, burning petrol also releases toxic gases, including greenhouse gases like carbon dioxide. This is due to the carbon atoms breaking from hydrogen during combustion and binding with atmospheric oxygen to create carbon dioxide.

Petroleum isn't the only fossil fuel pumped into vehicles. Around 14.8 million vehicles around the world use compressed natural gas (CNG) to get their engines running. Sitting above the layers of oil and coal below Earth's surface are pockets of natural hydrocarbon gas, containing methane, nitrogen and carbon dioxide, which like petroleum can be used for the propulsion of a vehicle. To make it suitable for use as a fuel source, the natural gas is compressed to less than one per cent of its volume at normal atmospheric pressure.

Natural gas is often branded as a more sustainable alternative to petroleum and touted as the 'cleanest burning hydrocarbon' by fossil fuel producers. Although it's technically true that natural gas is the cleanest burning fossil fuel – producing around five to ten per cent less carbon dioxide than petroleum fuel – it's still one of the dirtiest fuel types on Earth.



Electric cars are much cleaner than conventional cars, but the electricity that powers them may still be generated by burning fossil fuels

GRABBING GAS

Where to find the natural gas buried deep below the surface

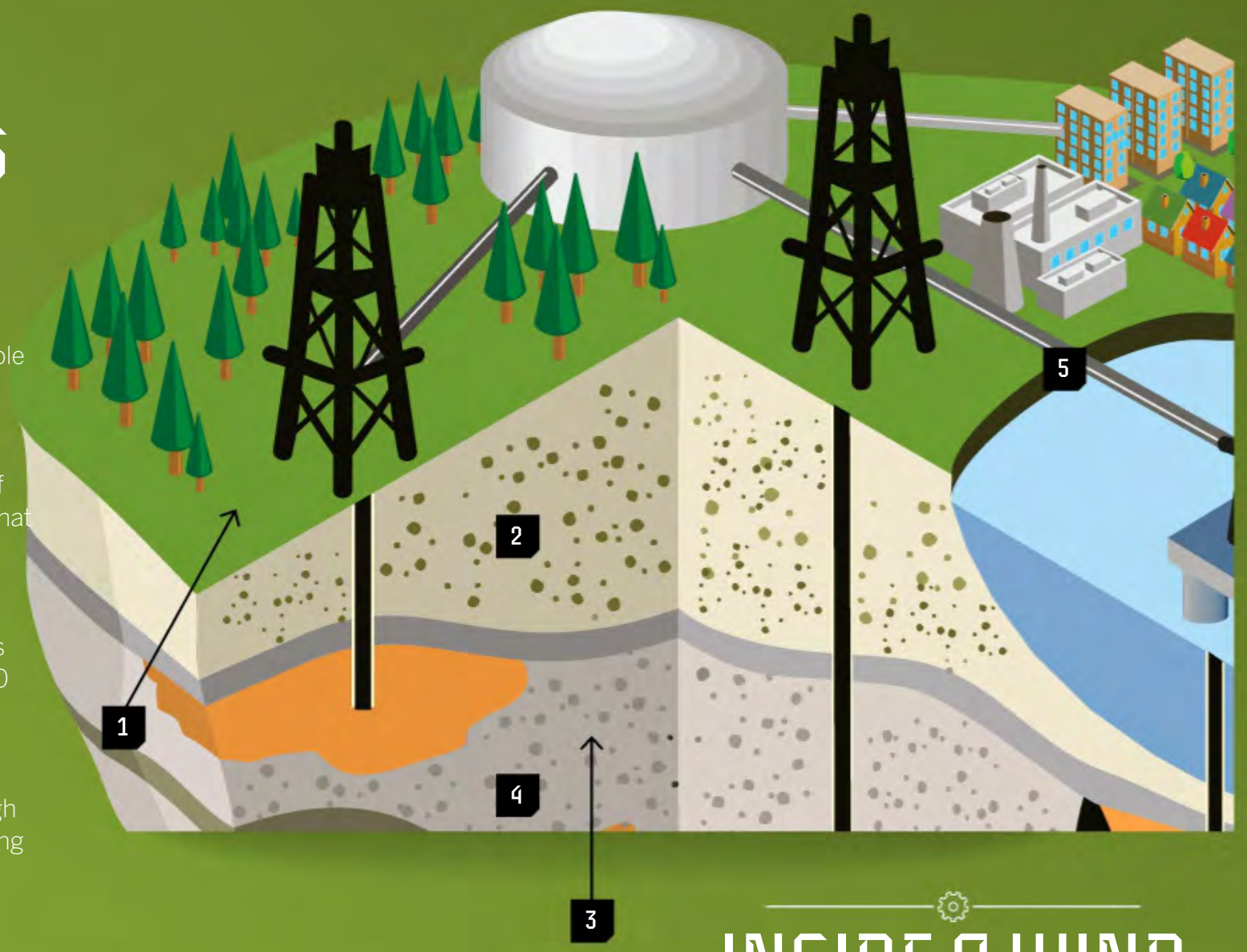
1 CONVENTIONAL NATURAL GAS
Natural gas is usually trapped under permeable rock and is often found on top of oil.

2 SHALE-RICH GAS
A fine-grained shale can sandwich a layer of trapped natural gas, but it's so impermeable that the gas cannot escape.

3 DEEP NATURAL GAS
These pockets of natural gas, also known as unconventional gas, are found at least 4,500 metres below the surface.

4 TIGHT GAS
Some pockets of gas are trapped within tough impermeable rock deep underground. Fracking is used to create channels to the gas by injecting highly pressured water and chemicals into the ground.

5 COALBED METHANE
Gas can be found in layers of coal. When coal is mined the gas is vented and collected.



INSIDE A WIND TURBINE

How to harness the power of renewable energy

BLADES
Three blades are typically used in horizontal wind turbines to catch wind currents, which cause them to turn.

ROTOR
The rotor drives the shaft, the speed of which is amplified by a gearbox.

GENERATOR
This is the site of electricity production, where the spinning rotor turns a shaft connected to an electrical generator.

ANEMOMETER
This is a sensor that measures the speed and direction of the wind and replies to the information on the yaw motor.

POWER UP
The kinetic energy created by the moving blades is transformed into electrical power at the generator.

YAW MOTOR
The yaw motor will adjust the position of the head of the turbine to pass the direction of moving wind.

DID YOU KNOW? One electric car on the road saves 1.5 million grams of CO_2 annually

HYDROGEN

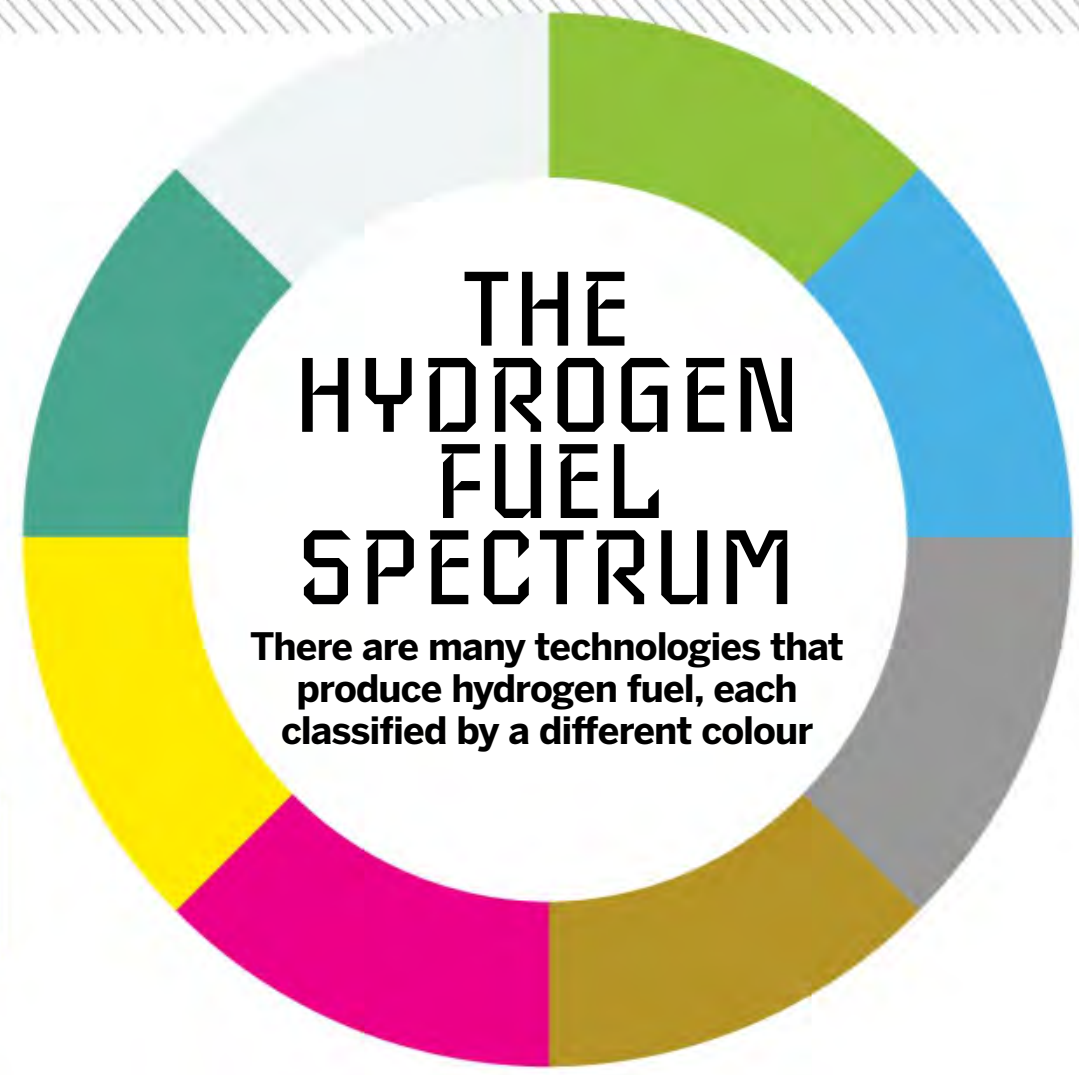
Hydrogen was discovered as a potential fuel source in the early 1800s, but it wasn't until the 1960s that a hydrogen fuel cell was put into a vehicle for propulsion. Unlike the by-products of burning petroleum, hydrogen fuel does not emit any tailpipe emissions, with water vapour being the only waste product during combustion. Hydrogen fuel is either stored as a pressurised gas or liquid. The combustion of hydrogen fuel is itself environmentally friendly, releasing no harmful greenhouse gases. However, like electrical power, the overall environmental impacts of hydrogen are largely attributed to the source of its production.

Hydrogen fuel is commonly classified by colour to signify its origins. For example, renewably sourced hydrogen is called green hydrogen and is produced through a process called electrolysis. This involves breaking the hydrogen and oxygen atoms that make up water apart using an electrical current. The resulting free hydrogen atoms can then be stored and used in some vehicles as fuel. However, the most common hydrogen fuel comes from sources that use fossil fuels or greenhouse gases such as methane to extract hydrogen for fuel, so aren't fully sustainable.

Hydrogen also isn't the most efficient fuel available. During the production of hydrogen by electrolysis, up to 35 per cent of energy is lost. In its liquid form, hydrogen needs to be stored at -252 degrees Celsius to prevent it from evaporating, which means energy must be spent to maintain this temperature.

Did you know?

Hydrogen makes up 75 per cent of normal matter in the universe



THE HYDROGEN FUEL SPECTRUM

There are many technologies that produce hydrogen fuel, each classified by a different colour

GREEN
Produced through renewable means, such as wind turbines. No greenhouse gas emissions are released.

BLUE
Produced by a process of steam reforming by combining heated water and natural gas. Any carbon dioxide is captured.

GREY
Produced during the steam reformation of natural gas or methane, but any carbon dioxide is not captured.

BROWN
Produced by converting carbon-rich material such as coal into hydrogen through a process called gasification.

PINK
Generated using the steam released as a by-product of nuclear energy production.

YELLOW
Yellow hydrogen is produced solely through the electrolysis of water using solar energy.

TURQUOISE
Generated by splitting the hydrogen atoms in methane into hydrogen and solid carbon, with no carbon dioxide.

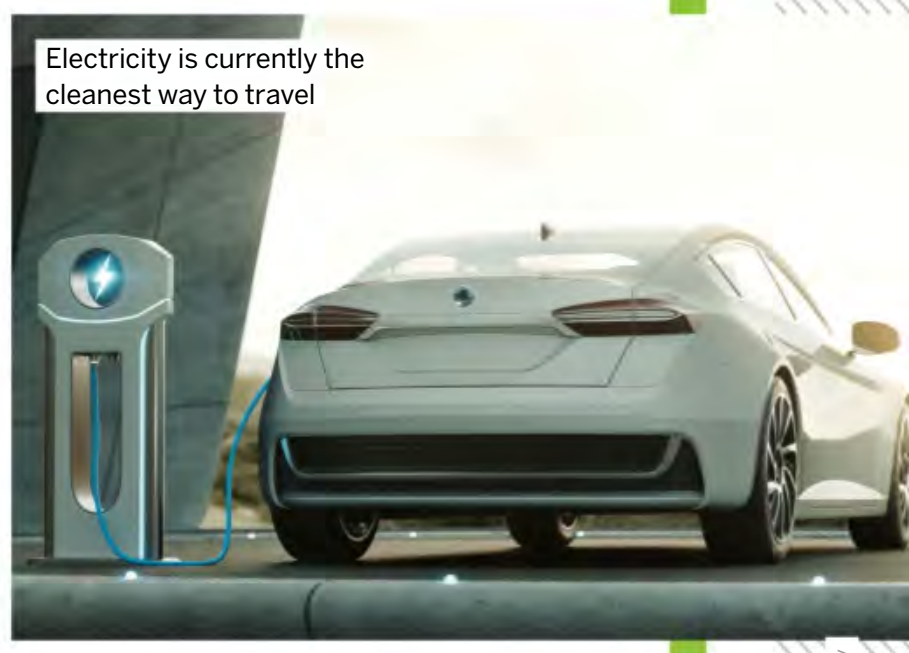
WHITE
Naturally occurring hydrogen gas harvested through fracking.

ELECTRICAL ENERGY

There are more than 16 million electric cars driving on roads worldwide, which collectively consume roughly 30 terawatt hours of electricity every year. As a type of fuel for vehicles, electricity is undoubtedly the most environmentally friendly, since it doesn't emit any of the traditional greenhouse gases ejected by vehicles, known as tailpipe emissions.

However, there's still one environmental downside that hangs over the head of electric fuel: its origin. Although electrically powered vehicles are clearly the way forward in tackling emissions from cars, the initial electricity supply for electric vehicles largely originates from dirty energy. Coal and gas remain the largest sources of electricity globally. In the US, for example, the annual carbon emissions for an all-electric vehicle are around 1.7 tonnes due to the source of electricity, despite each vehicle emitting zero gases itself.

Only around 30 per cent of the world's energy comes from renewable sources such as wind farms and solar panels. As the world shifts to more renewable sources of energy, electric energy will only become greener and more environmentally suitable, unlike fossil fuel alternatives.



Electricity is currently the cleanest way to travel

POWERED BY PLANTS

Biodiesel is an alternative fuel that works in a similar way to petroleum. Whereas petroleum fuel comes from underground oil reserves formed out of the decomposed matter of plants and animals, biodiesel comes from the oil of plants and animals still on the surface. Typically, biodiesel oil is obtained from plants, including rapeseed, palm and soybean, and animal fats or tallow. Through a process known as transesterification, these oils are converted into a fuel source through several chemical reactions.

Biodiesel is then combusted in engines the same way as petroleum, resulting in the release of carbon dioxide into the atmosphere, albeit on a much lower level. However, the carbon dioxide that biodiesel emits is largely offset by the amount of carbon dioxide that biodiesel crops absorb during photosynthesis.

Although biodiesel is kinder to the environment in terms of reducing greenhouse gas production, there are many challenges involved in its production, such as fertiliser-induced land pollution, soil erosion and monopolising land use – to meet the current fuel demands of the US, 563,000 square miles of land would be required to grow enough biodiesel crops.

Rapeseed oil is one of the many crops used to produce biodiesel

BOOZY FUEL

Bioethanol works on a similar principle as biodiesel, using agriculturally grown crops to produce a sustainable fuel. However, rather than extracting oils, bioethanol production involves fermenting vegetation and distilling it into a concentrated and combustible alcohol.

Bioethanol is already used at petrol pumps. When filling up their car in the UK, drivers will typically use E10 petrol. E10 petrol is a combination of 90 per cent petrol and 10 per cent ethanol – hence 'E10'. There are also E85 fuels that consist of 85 per cent ethanol, reducing the amount of petrol used and thus tailpipe emissions, including nitrogen oxide pollution. However, one major drawback of high-bioethanol percentage fuels is their ability to create harmful ground-level ozone, as well as increasing emissions of a potentially carcinogenic chemical called acetaldehyde.

Corn is one of many crops that can be fermented to become bioethanol

Did you know?

There are 1.4 billion cars on Earth

DID YOU KNOW? A net zero on CO_2 emissions is needed by 2050 to maintain a global temperature increase of 1.5 degrees Celsius

BATTLE OF THE FUELS

How does each type of fuel compare when it comes to environmental sustainability?

CARBON DIOXIDE PRODUCTION

HYDROGEN: 0

ELECTRIC: 0*

NATURAL GAS: 1.95 kilograms per cubic metre

BIODIESEL: 0.7 kilograms per litre

PETROLEUM: 2.3 kilograms per litre

*DIRECT EMISSIONS

METHANE AND NITROGEN OXIDE PRODUCTION

HYDROGEN: 0

ELECTRIC: 0

NATURAL GAS: 6.8 grams per mile

BIOETHANOL (E85): 4.0 grams per mile

PETROLEUM: 1.9 grams per mile

TIME UNTIL FOSSIL FUELS RUN OUT

PETROLEUM: 50 years

NATURAL GAS: 53 years

COAL FOR ELECTRICITY PRODUCTION: 114 years

MILEAGE FOR EACH FUEL IN AN AVERAGE TANK

NATURAL GAS: 175 miles

PETROLEUM: 200 miles

HYDROGEN: 255 miles

ELECTRIC: 325 miles

MOST POPULAR FUEL TYPE IN NEW CARS**

NATURAL GAS: 0.4 per cent

OTHER FUELS, INCLUDING BIOFUELS: 2.3 per cent

PETROLEUM: 59.6 per cent

ELECTRIC AND PETROLEUM HYBRIDS: 37.6 per cent

**EUROPE ONLY

PETROLEUM ACCOUNTS FOR 90 PER CENT OF THE WORLD'S TRANSPORTATION REQUIREMENTS

A typical passenger vehicle emits about 4.6 tonnes of carbon dioxide per year

95 PER CENT OF THE HYDROGEN PRODUCED IN THE UNITED STATES IS MADE BY NATURAL GAS

The electricity needed to power electric vehicles generates up to 30 per cent less carbon dioxide than petroleum

IN 2021, 10,000 TONNES OF OIL WAS SPILT INTO THE OCEAN BY OIL TANKERS

Did you know?

A gastropod's tongue is called a radula

Crithe huna sea snails measure just two millimetres long

WHAT ARE GASTROPODS?

These slimy animals have twisted shells and topsy-turvy insides

WORDS **LAURA MEARS**

Including well-known slugs and snails, this group of animals walk on their organs. Gastropod literally means 'stomach foot', and there might be as many as 150,000 different species. As a group, gastropods have been around for 500 million years. That makes them far older than the dinosaurs. They live all over the world, from the bottom of your garden to the bottom of the ocean. Gastropods are a type of mollusc, and they share some important biological features. They have a flat, muscular foot, a soft body called a mantle and often – but not always – a hard outer shell. They also have completely twisted internal organs: their stomachs are U-shaped and their bottoms are on top of their heads.

Gastropod shells contain sheets of calcium. They are made from bricks, shaped like prisms or plates, which stack together in opposite directions for maximum strength. The calcium the animals need to make these bricks comes from their diet or from the water they live in. It travels through the digestive system, then the circulatory system and finally into a group of cells just under the opening of the shell. They keep adding to their shells throughout their lives, forming growth rings a bit like the rings of a tree.

Like the bodies inside them, gastropod shells grow asymmetrically. Scientists have found that the cells that make the shell are different on the left compared to the right. This means that the shell twists as it grows. Slight differences in how these cells are arranged has given rise to dozens of different shell shapes, from the spirals of a garden snail, the pyramids of a limpet and the spikes of a giant conch.

DIGESTIVE GLAND
Instead of a liver and a pancreas, snails have a digestive gland. It makes enzymes and absorbs food.

STOMACH
The stomach is a simple sack where food and saliva mix to start the process of digestion.

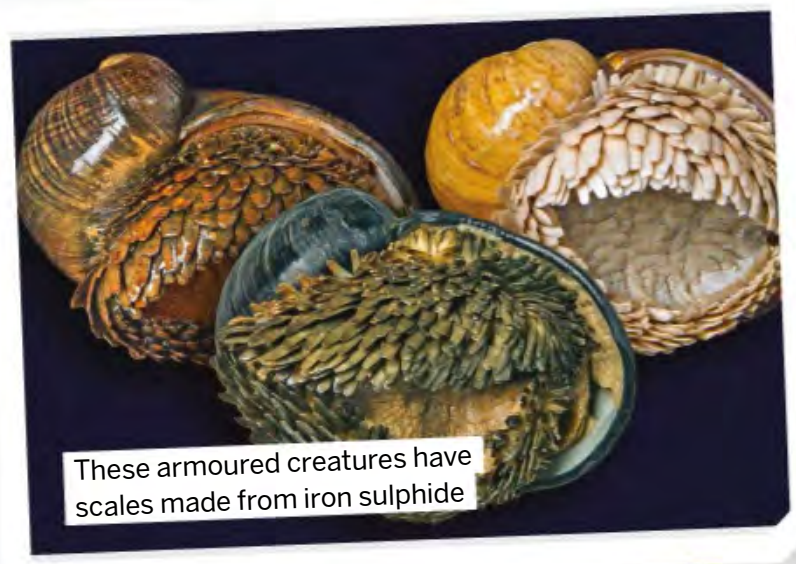
HEART
Snails don't have many blood vessels. Their hearts pump blood straight into their body cavity.

FOOT
The muscles in a snail's foot contract and relax in waves that travel from tail to head.

DID YOU KNOW? The limpets on the south coast of England are eating so much chalk that they're causing coastal erosion

THE SNAIL THAT LOOKS LIKE A KNIGHT

Magma flows into the ocean at hydrothermal vents. The water here is hot enough to boil, but a few intrepid creatures have decided to call it home. In the Indian Ocean, one of these residents is the scaly-foot gastropod, also known as the sea pangolin. It looks like the snail version of a Medieval knight. Its entire body is covered in scales that are made from iron from the centre of the Earth. But the existence of these unusual creatures is under threat. Their volcanic homes are rich in the same minerals we use to make batteries, so many companies want to mine them for profit. Concerned about the impact this might have, scientists Julia Sigwart and Chong Chen approached the International Union for Conservation of Nature (IUCN) for help. These deep-sea knights are now listed as endangered on the IUCN Red List of Threatened Species.

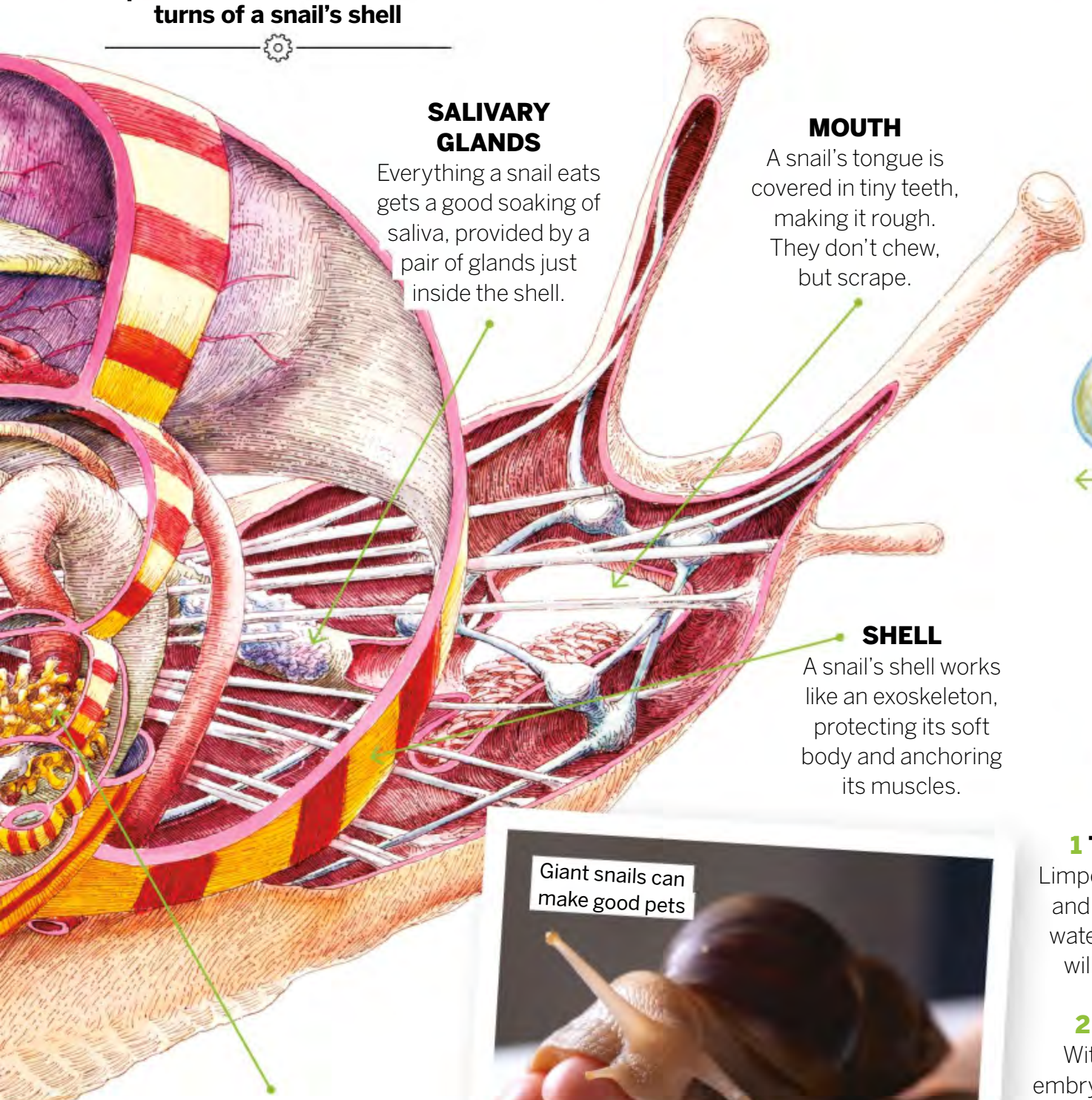


These armoured creatures have scales made from iron sulphide

GASTROPOD ANATOMY

There are lots of organs packed into the twists and turns of a snail's shell

"Like the bodies inside them, gastropod shells grow asymmetrically"



SALIVARY GLANDS
Everything a snail eats gets a good soaking of saliva, provided by a pair of glands just inside the shell.

MOUTH
A snail's tongue is covered in tiny teeth, making it rough. They don't chew, but scrape.

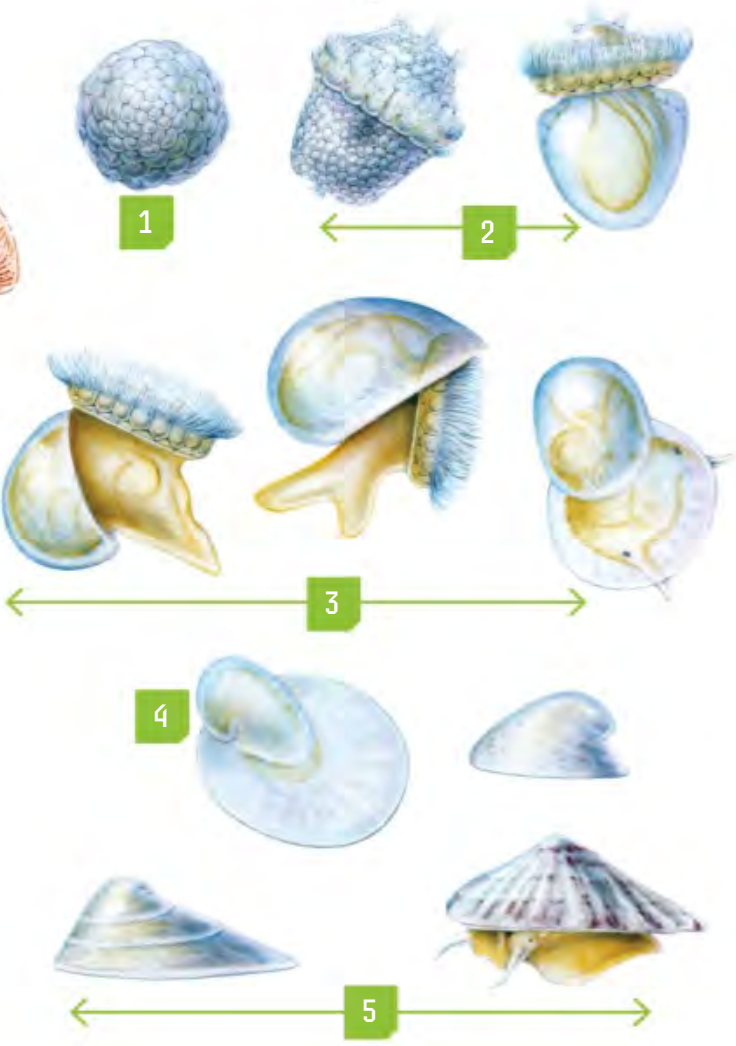
SHELL
A snail's shell works like an exoskeleton, protecting its soft body and anchoring its muscles.

REPRODUCTIVE ORGANS
Many snails have both male and female reproductive organs. This means they can reproduce all on their own.

Giant snails can make good pets

LIFE CYCLE OF A LIMPET

These rock-loving gastropods start their lives as tiny free-floating plankton



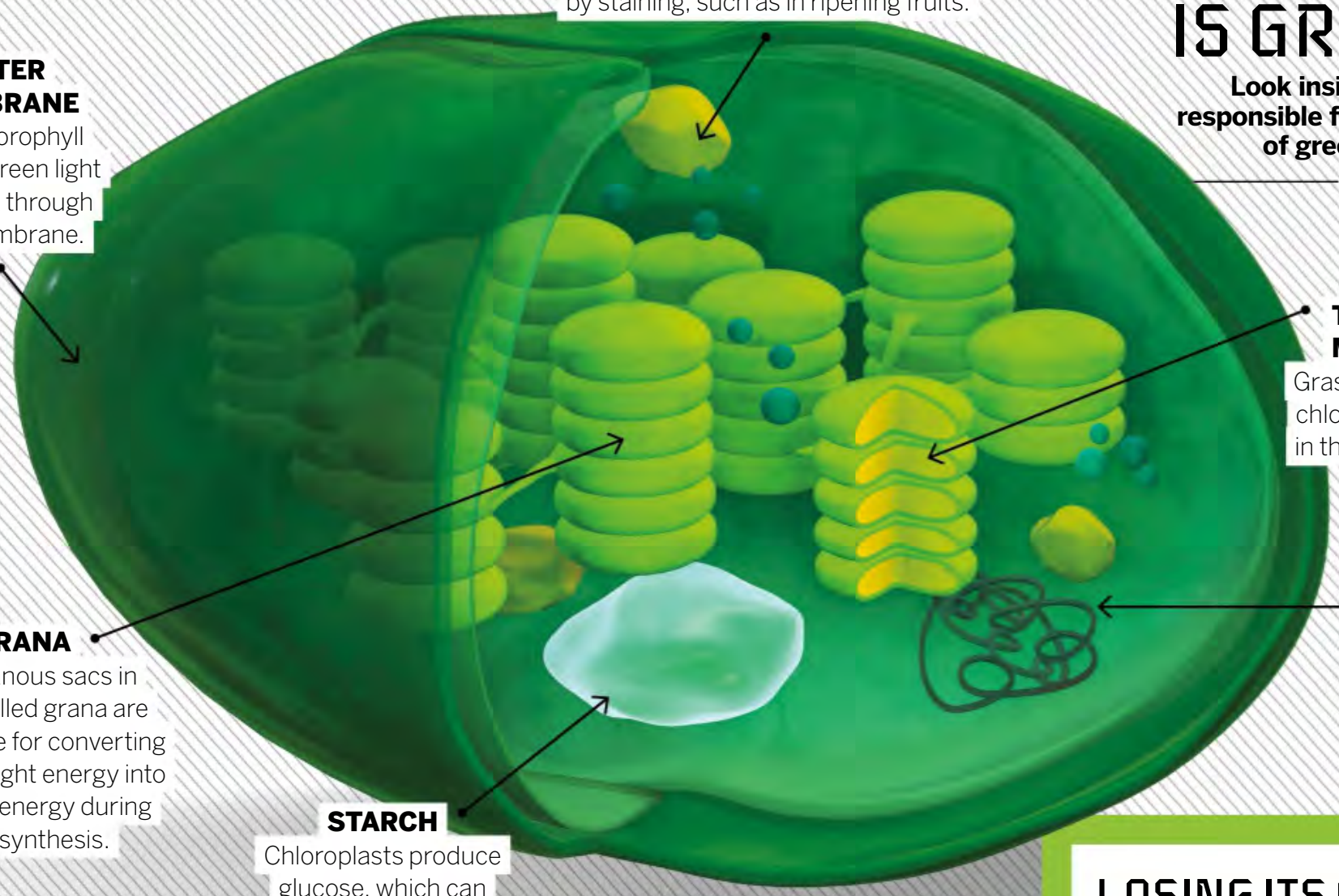
1 THE BEGINNING
Limpets release their sperm and eggs straight into the water, hoping that the two will meet and combine.

2 TAKING SHAPE
Within a day, the limpet embryo has started to flatten on the side where the shell will grow.

3 HATCHING OUT
The developing larva lives in the open ocean for up to two weeks, floating around as plankton.

4 TOUGHENING UP
The larva settles on a rock and starts to feed. It uses minerals to make its shell.

5 GETTING OLD
The limpet keeps adding to its shell as it gets older, making visible growth lines on its surface.



PLASTOGLOBULI
These lipid pigments can grow in number to alter the colour of plants by staining, such as in ripening fruits.

OUTER MEMBRANE
The chlorophyll reflects green light back out through the membrane.

THYLAKOID MEMBRANE
Grass' green pigment chlorophyll is located in these membranes.

GRANA
Membranous sacs in stacks called grana are responsible for converting absorbed light energy into chemical energy during photosynthesis.

DNA RINGS
The DNA produces proteins and lipids for membrane production.

STARCH
Chloroplasts produce glucose, which can be stored as starch for later use.

THE GRASS IS GREENER

Look inside the cells responsible for the colouring of green plants

WHY IS GRASS GREEN?

The same molecules that feed grass also give it its colour

WORDS **AILSA HARVEY**

Like many of the plants on Earth, grass is mostly green. This is because there are millions of cells called chloroplasts in every blade of grass. Within these cells is a pigment called chlorophyll. We see grass as green because it is one of the few visible wavelengths from the Sun that chlorophyll doesn't absorb. Instead, after sunlight reaches grass, the green wavelengths are reflected off the plant. So when they reach our eyes, we see grass as green.

But the main role of these cells isn't to look pretty. Grass gets its green colour as a consequence of one of the plant's most vital processes – photosynthesis. Within chloroplasts, the green-giving pigments absorb large amounts of light so that they can use its energy to produce glucose for food. Red and blue wavelengths are prioritised by the plants, as they provide the most energy for photosynthesis. The green wavelengths are reflected while the red and blue are absorbed. While green is the most important colour for us in identifying healthy grass, it's the least important for the plant itself.

Not all grass is the same variety

Did you know?
Humans can see more shades of green than any other colours

LOSING ITS COLOUR

At different times of year and in different weather conditions, grass can appear different shades of green. Grass grows at different rates based on its location, type or the weather. In spring, it is likely to grow most rapidly, producing new cells such as chloroplasts. The higher the concentration of chloroplasts within a blade of grass, the more green pigment there will be too. When grass turns brown or yellow it might still be alive, but very low on chlorophyll.

If you notice that the bottom of the blades of grass are losing their green colour, this is often due to the amount of water the grass is getting. When grass becomes dry, the lower parts of the blades will begin to turn brown, but if the opposite is true and you are overwatering the grass, it may appear yellow. This is because if the soil is waterlogged, oxygen can't get to the plant and the grass becomes oxygen-deprived.

Green is the colour of healthy grass

AIRFIX

QUICK BUILD

The excitement is building

Airfix.com/QB

and all good retail stockists YouTube

HORNBY HOBBIES
Official Product

SUPER DRONES

How unmanned flying machines are changing the world

WORDS SCOTT DUTFIELD

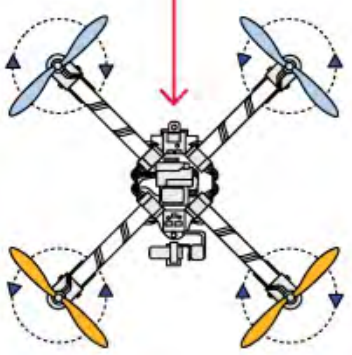
DID YOU KNOW? The furthest delivery drone journey was 11.22 miles, taking 31 minutes to complete

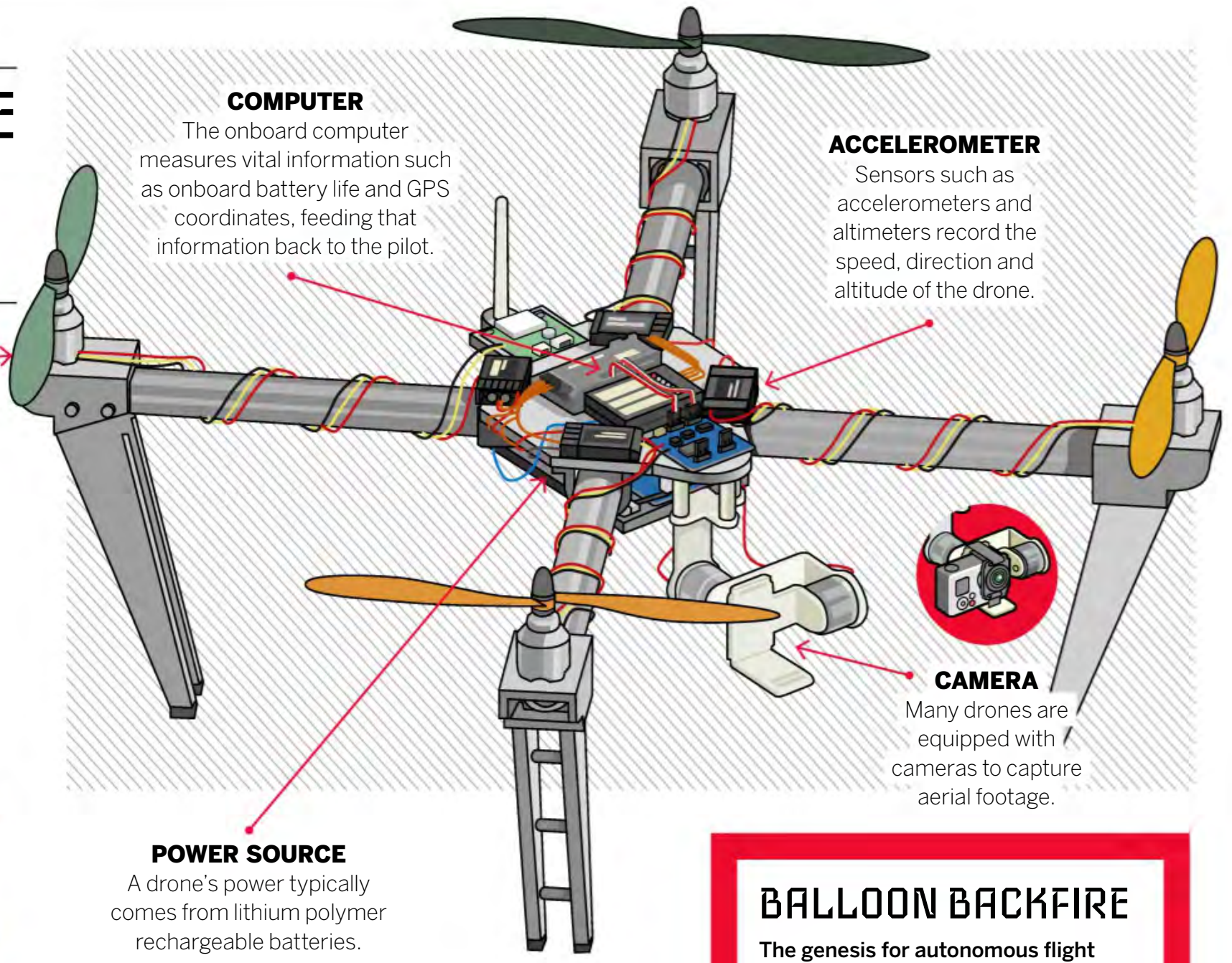
BEHIND THE BLADES

How alternating rotation allows drones to glide effortlessly through the air

ROTORS
Each of the drone's rotors are made up of propellers and motors that, when spinning, generate a downward thrust that lifts the drone into the air.

HOVERING
For drones to hover, two of the four rotors move clockwise while the others move counterclockwise.





COMPUTER
The onboard computer measures vital information such as onboard battery life and GPS coordinates, feeding that information back to the pilot.

ACCELEROMETER
Sensors such as accelerometers and altimeters record the speed, direction and altitude of the drone.

POWER SOURCE
A drone's power typically comes from lithium polymer rechargeable batteries.

CAMERA
Many drones are equipped with cameras to capture aerial footage.

Drones, also referred to as unmanned aerial vehicles (UAVs), are autonomous or remotely controlled vehicles. One of the earliest examples of remotely controlling a vehicle came from the brilliant mind of Nikola Tesla. Renowned as an electrical engineer and the inventor of the alternating current, Tesla also tried his hand at building a working drone back in 1898. The 1.2-metre-long boat drone used radio signals to remotely control its manoeuvres. This was the first time a vehicle had been controlled by radio signals and driven without being physically manned by an onboard pilot.

Once Tesla's prototype was built, the world of remote-controlled UAVs began to blossom. Inventors from across the world developed new ways to pilot a vehicle without the need for a human on board. In 1917, through a complex system of timed cranks, bellows and barometers, American inventor Charles Kettering created the first aerial drone, the Kettering aerial torpedo, also known as the Kettering Bug. The primitive drone was designed to carry bombs to assist troops on the ground, and although 50 were built, none saw combat.

The first modern-day aerial drones wouldn't make their way into the skies until Israeli inventor Abraham Karem created the rotary drone in 1973, which uses several propellers spinning together to lift a drone off the ground. His first drone was designed as a decoy for radar surveillance for the Israeli Air Force during the Yom Kippur War. Karem later went on to invent one of the most well-known military UAVs, the Predator drone, which first flew in 1994. Karem's invention truly showed the world what was possible with drones.

Nowadays, there are several types of drones or UAVs, typically split into two categories: rotary and fixed-winged. The easily recognisable rotary drones typically rely on four alternatively spinning blades to generate enough downward force to lift them off the ground. While airborne, the orientation of the blades can then be controlled to alter the direction the drone flies in. The rotary nature of this type of drone means that UAVs can vertically take off and land, hover, as well as move in every direction during a flight.

The agility of rotary drones means that they are typically used for aerial photography, surveillance, monitoring and delivery purposes. We could even see the humble taxi get an aviation makeover in a few years thanks to drone technology. One of the benefits of rotary drones is their low impact on the environment. As

Did you know?

The US' smallest military drone weighs less than a kilogram

BALLOON BACKFIRE

The genesis for autonomous flight may have occurred in 1849 when Austria launched an attack on the city of Venice, Italy, during a period of revolts that swept through Europe. Soldiers aboard the Austrian SMS Vulcano vessel turned to balloons to carry out an aerial assault on the city. Around 200 incendiary balloons were constructed to carry up to 14 kilograms of explosives each and fitted with 30-minute fuses. The pilotless balloons were launched successfully, but few made it to Venice thanks to a change in the wind's direction that caused many to explode over the Austrian forces.

An illustration of Austria's balloon bombs heading towards Venice

The Bayraktar TB2 combat drone is being used by Ukrainian forces against Russia

people, nations and corporations work towards achieving a net zero on carbon emissions by 2050, many industries are looking to drones as an all-electric alternative to transportation. Commercial delivery drones are typically equipped with a lithium-ion battery that sustains flight times of around 30 minutes, making them a great alternative for local deliveries. Without an internal combustion engine, these drones emit no environmentally harmful gases, such as carbon dioxide and methane.

As rotary drones become increasingly common, the infrastructure to support them for commercial and professional use is evolving. For example, the UK is set to unveil the largest automated drone superhighway in the next couple of years. The 164-mile skyway will connect cities around the UK, including more remote locations such as the Isles of Scilly off the coast of Cornwall. The highway consists of ground-based sensors that will relay information to a system similar to air traffic control, but for drones. The information will include each drone's location and will guide and assist autonomous drones to prevent collisions.

Fixed-wing drones, on the other hand, employ a rigid wing similar to an aeroplane, utilise the aerodynamic force called lift to remain in the air for longer and don't need the constant supply of energy needed to spin the blades of a rotary drone. One of the industries where drones – in particular fixed-winged drones – are making the most advancement is in the armed forces. With their ability to enter dangerous airspace without risking the lives of pilots, they've quickly become the go-to for surveillance and intelligence gathering. As drone technology evolves, military drones are becoming a much bigger part of the military ranks, equipped with weapons such as guns, missiles and bombs.

To date, thousands of drones have entered the war in Ukraine. The main military drone used by Ukrainian forces is the Baykar Bayraktar TB2. This serves a dual purpose of surveillance and air strikes by dropping laser-guided bombs. The drone can fly up to an altitude of 7,600 metres and fly at a maximum speed of 140 miles per hour, making it a formidable weapon against Russian forces. Similarly, Russia has also deployed military drones, typically the Orlan-10, for similar purposes of surveillance and bomb drops.

Did you know?

The largest drone exporter is Israel

The future of military drones lies in their autonomy. Currently, the most advanced drones used in warfare are known as precursors, using artificial intelligence to detect and engage with targets. Israel Aerospace Industries, for example, uses its Harpy drone, which scouts for an enemy radar signal and, once located, crashes into the source. However, fully autonomous weaponised drones are not yet in existence. The creation of autonomous weapons is a controversial topic that divides nations. Countries such as the UK, US and Russia oppose a ban on autonomous weapons, while nations such as Iraq, China and Austria oppose their use.

"Many industries are looking to drones as an all-electric alternative to transportation"

DID YOU KNOW? There are 314,689 registered commercial drones in the US as of 2022

INDUSTRIAL REVOLUTION

The many ways that UAVs are advancing industry

1 SPECIAL DELIVERY

Receiving your packages by drone might seem like something out of a science fiction novel. However, in the past few years tech giants have been working hard and fast to make it a reality. With its latest model, the MK27-2, Amazon is one step closer to making Prime Air a reality. Later this year Amazon will begin drone delivery in California after approval from the Federal Aviation Administration (FAA). The MK27-2 will be able to deliver packages up to 2.3 kilograms and has a range of 15 miles.

2 MEDICAL SUPPLIES

One of the most important ways drones are revolutionising delivery systems is in the world of medicine. Drones have the ability to respond to emergencies much quicker than other means of transport and can deliver vital medicines to remote areas. The National Health Service (NHS) in the UK announced that courier drones will ferry chemotherapy drugs from a hospital in Portsmouth to the Isle of Wight as part of a pilot scheme. Instead of the typical four-hour journey, drones cut the drug delivery time to just 30 minutes.

3 WILDLIFE MONITORING

Drones offer another set of eyes in the sky to watch over the world's wildlife. For example, the National Oceanic Atmospheric Administration (NOAA) is using UAVs to remotely survey beluga whales in Alaska. Similarly, an organisation called Wildlife Drones is using UAVs to track some of the most endangered species on Earth, such as the highly trafficked pangolin. By ditching handheld radio trackers and replacing them with drone-bound receivers, researchers can gather more data in a shorter amount of time.

4 SPACE EXPLORATION

The first drone to journey beyond Earth's atmosphere landed on Mars in February 2021. Ingenuity is a remote-controlled UAV used by NASA to demonstrate the first powered flight on another planet. Beyond proving flight is possible on Mars, Ingenuity will continue to explore the distant planet and provide information about flying on Mars. Due to the 140 million mile distance from Earth, Ingenuity isn't remotely controlled by a NASA pilot; the UAV takes off and lands based on preprogrammed conditions such as Martian wind speed.

5 FARMING AND AGRICULTURE

Farmers and agricultural engineers use drones for crop monitoring to accurately plan harvests and improve processes such as the delivery of fertiliser. The use of drones in agriculture is often referred to as precision farming due to the high level of precision that drone servers can map out land use.

SEND IN THE DRONES

The UAVs that are leading the charge in battle

MQ-9 REAPER

The Reaper is a remotely controlled tactical drone used by the US and UK Armed Forces for an array of operations, including intelligence gathering, communications and weapon strikes. The UAV is packed with sensory technology, including infrared sensors, optical cameras and radar. The almost-5,000-kilogram drone is controlled by three crew members on the ground, flying the drone to altitudes of more than 15,000 metres. During targeting strikes, the Reaper can release up to eight laser-guided missiles.

TARANIS

Designed and built in the UK, Taranis is one of the biggest military drones on the battlefield, with a wingspan of almost 12 metres. The technological abilities of Taranis have largely been kept a secret, but what we do know about the military UAV is that it's a remotely piloted drone. It can reach high speeds of 700 miles per hour and is virtually invisible to radar.

DID YOU KNOW? The fastest drone on Earth, the Falcon HTV-2, can reach speeds of 13,000 miles per hour

MQ-25 STINGRAY

Designed for US Navy missions, the MQ-25 Stingray is a UAV that provides in-air refuelling for fighter jets such as the Lockheed Martin F-35C and Boeing F/A-18 Super Hornet. It's almost 23 metres long and can carry almost seven tonnes of fuel during flight. The Stingray is remotely controlled by a pilot but autonomously dispenses fuel to fighter jets when connected.

GREMLINS

The United States Defense Advanced Research Projects Agency (DARPA) is developing launchable drones called Gremlins. The Gremlins are designed to be launched from a mother cargo plane and offer tactical and surveillance support from above. Each of the Gremlins is around 680 kilograms in weight, with a wingspan of around 3.5 metres. The intention is to release Gremlins in a swarm to gather intelligence and carry out assaults in dangerous airspace.

MQ-28 GHOST BAT

The Ghost Bat drone is being developed by Boeing Australia. Although the full scope of the drone's capabilities isn't yet known, its roles on the battlefield will likely include surveillance and reconnaissance. This military drone is named after the ghost bat, a carnivorous species native to Northern Australia. The pair share some qualities, such as the ability to sense and hunt down a target in groups. In the wild, ghost bats often hunt as a group, and this UAV is designed to fly alongside fighter jets to offer a helping hand during tactical operations.

Did you know?

The global drone market is worth £9.8 billion ($12 billion)

Satellites make tempting targets for rivals looking to knock out communications

ANTI-SATELLITE WEAPONS

Rival nations have developed powerful technology capable of knocking out satellites as the battle for space heats up

WORDS **MARK SMITH**

Orbiting high above our heads is technology that has changed every aspect of our lives. From the GPS on your phone to the sport you watch on TV, satellites have become a cornerstone of modern life. But as well as civilian use, they're also the lynchpin to secure military and government communications. It stands to reason that any hostile state wishing to cause disruption would target these satellites. Known as anti-satellite weapons (ASATs), they have been around almost as long as satellites themselves.

When the Soviet Union launched the world's first satellite, Sputnik 1, in 1957, the US feared that its Cold War rivals would develop an orbital network of nuclear-armed satellites. It responded with its first ASAT, an air-launched ballistic missile called Bold Orion. The Soviets responded with their own ASAT. These were known as co-orbitals and would essentially fly alongside satellites and blow themselves up, taking the satellite with them.

Did you know?

There are more than 4,500 active satellites

The technology has continued to evolve, with China entering the race in 2007 when it destroyed an old weather satellite with a ballistic missile. Continuing tests have led to a dangerous rise in space debris orbiting Earth, and in April this year the US became the first country to announce it was banning the use of missiles against satellites.

ASATs can be broadly divided into two types: those that use brute force and those that don't. Kinetic-energy ASATs physically crash into satellites and can be virtually anything that can reach altitude, from ballistic missiles to drones and other satellites.

The other type of ASAT is the non-kinetic type. They use non-physical attacks such as cyber attacks or jamming and blinding satellites with lasers. These attacks can all be carried out from the air, low orbit or even ground installations.

"Anti-satellite weapons have been around almost as long as satellites themselves"

A NEW PEACE?

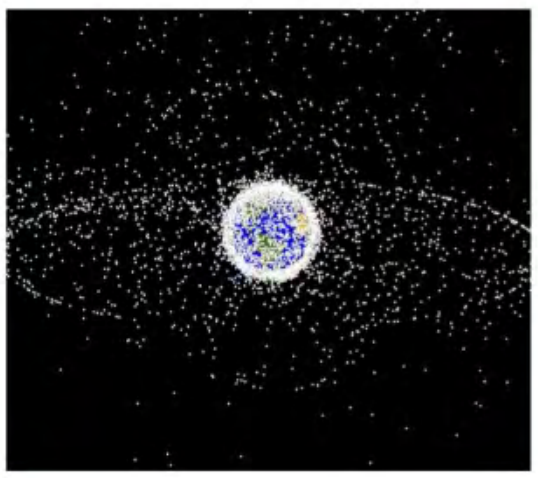
The US, China, Russia and India have all destroyed their own satellites in ASAT tests. But there is a growing movement towards getting rid of ASATs. The US made the first move this year when it announced it was banning tests on the use of ballistic missiles against satellites. The plan was set into motion after the Chinese government shot down one of its own satellites and created thousands of pieces of debris orbiting Earth. It left astronauts on the International Space Station (ISS) having to take evasive action as the shrapnel field passed by.

Astronauts on the ISS have to make evasive manoeuvres due to debris

DID YOU KNOW? Amazon plans to rival SpaceX's Starlink by launching its own network of 3,236 satellites over the next few years

WHEN JUNK GETS OUT OF CONTROL

Imagine what happens when satellites are destroyed and turn into junk orbiting Earth. Then imagine what happens when that junk crashes into other space vehicles and they too turn into junk. This scenario is called Kessler syndrome and is what happens when the amount of space debris in orbit reaches a point where it just creates more and more, which can cause havoc for any space program. It's named after former NASA scientist Donald Kessler, who described the basic idea in his 1978 paper *Collision Frequency of Artificial Satellites: the Creation of a Debris Belt*. He and coauthor Burton Cour-Palais said the likelihood of satellite collisions would increase as more and more spacecraft were launched. Projects such as the European Space Agency's Clean Space program are trying to tackle the problem through methods such as the robotic salvage of derelict satellites.



NASA estimates there are more than 27,000 large pieces of space junk

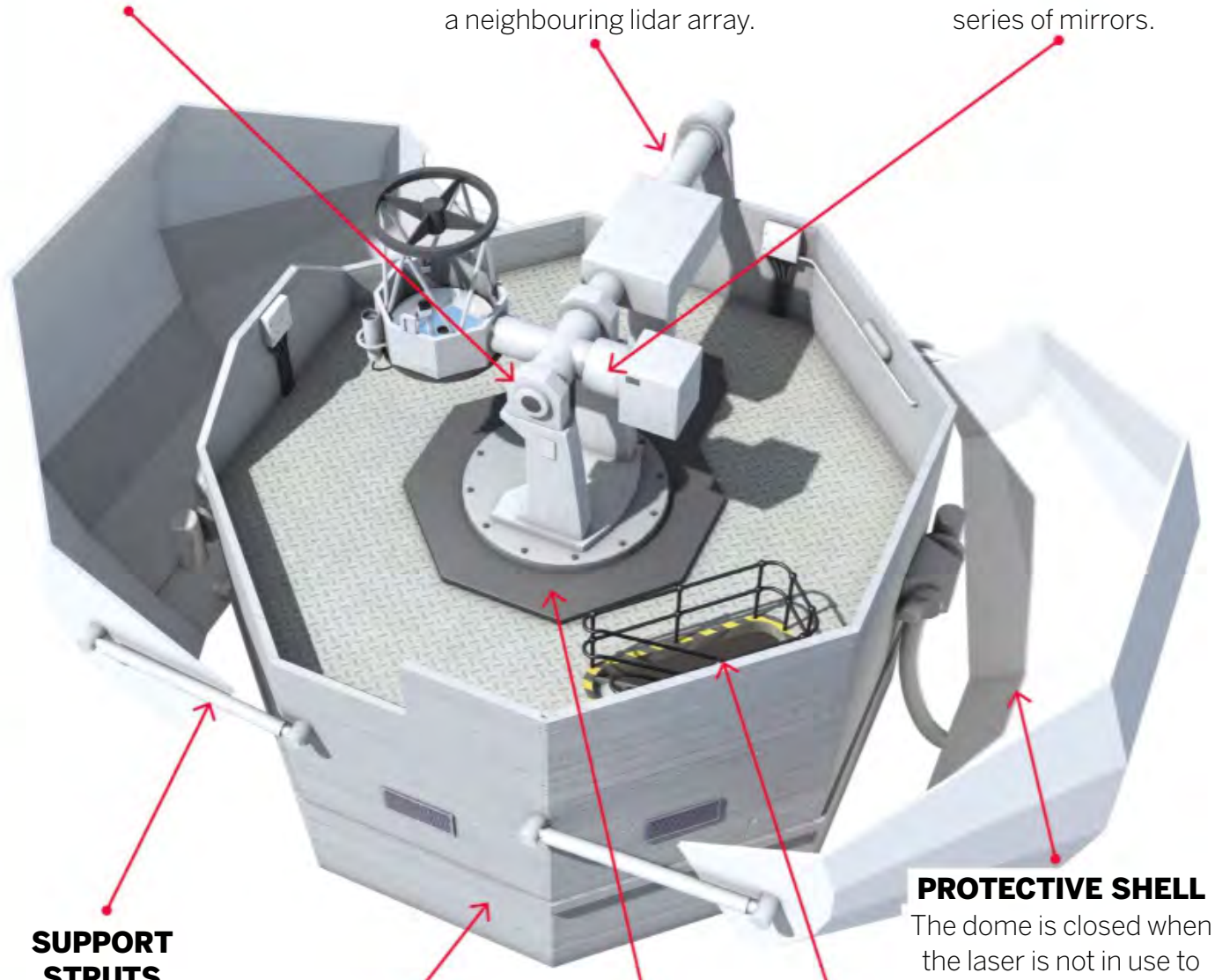
SATELLITE KILLER

Russia's Kalina anti-satellite laser weapon is like something from a Bond movie

EMITTER ARRAY
The lens focuses the powerful laser onto the orbiting target satellite.

TUNNEL LASER
The Kalina system receives a laser beam via a tunnel from a neighbouring lidar array.

LENS CONFIGURATION
The laser is routed to the telescope via a series of mirrors.



PROTECTIVE SHELL
The dome is closed when the laser is not in use to protect it from the elements and damage.

SUPPORT STRUTS
Strong metal support struts provide the mechanism for opening and closing the dome.

BASE STRUCTURE
The base structure provides a platform for the Kalina laser system.

ROTATING PLATFORM
The platform can be rotated to allow the laser to be directed at its target.

SERVICE WALKWAY
The area where repair crews can carry out maintenance and servicing.

ON THE MAP

ASAT-capable countries

An Indian anti-satellite weapon during the country's Republic Day parade

HAZARDOUS ASTEROIDS

There's a real possibility Earth could be hit by an asteroid, but it's an avoidable disaster

WORDS ANDREW MAY

It's one of Hollywood's favourite disaster scenarios: a chunk of rock hurtling through space on a collision course with Earth. But this scenario isn't just science fiction – there really are rocks in space, in the form of asteroids, and some of them do have orbits that cross Earth's. It's also no longer science fiction to suggest that a future space mission might be able to avert such a disaster. NASA's Double Asteroid Redirection Test, or DART, is a mission currently flying through space aiming to test one possible way of doing this. But before we examine it, it's worth recalling just what asteroids are and why some of them are potentially hazardous to life here on Earth.

Asteroids are essentially just chunks of rock that orbit the Sun like tiny planets. They range in size from a few metres to hundreds of miles across, and there are millions of them in the main asteroid belt between Mars and Jupiter. In smaller numbers, however, asteroids can be found throughout the Solar System. Those that have orbits that come close to Earth's own orbit around the Sun are called near-Earth asteroids, although that's a somewhat misleading term as they're not actually near us all the time. As they travel around their orbits they'll spend a lot of time at great distances – on the far side of the Sun, for example – but at other times they can pass very close to Earth.

If the closest approach of an asteroid to Earth's orbit is less than 4.6 million miles and it's more than 140 metres in size, it's classified as a Potentially Hazardous Asteroid, or PHA. This doesn't necessarily mean the asteroid is going to collide with Earth, because even if their orbits intersect they would both have to arrive at the intersection at exactly the same time. But it's a sensible precaution to keep track of as many PHAs as possible, so we know exactly where they are and where they're going.

Probably the most famous impact event is the one that led to the extinction of the dinosaurs 65 million years ago. That's believed to have been caused by an asteroid around six to nine miles across, which may not sound large enough to have caused an extinction event that spanned a planet more than 7,900 miles in diameter, but the speed the asteroid was travelling at meant it was carrying a lot of energy – enough to gouge out a crater 93 miles in diameter and hurl vast amounts of debris into the atmosphere.

That's really the upper end of what we might expect from an asteroid impact. But even at the lower end of the PHA scale, an asteroid of just 140 metres would result in a crater several miles across, and in all likelihood a higher death toll than any natural disaster in human history. That's the bad news. The good news is that an asteroid impact is the one kind of natural disaster that, in principle, we can do something to prevent. Since the impact arises from a very predictable situation – the intersection of two orbiting bodies – preventing it simply means changing the asteroid's orbit so that it will no longer hit Earth. It's to test the feasibility of doing this that NASA has launched its DART mission.

DID YOU KNOW? The International Astronomical Union's Minor Planet Center has catalogued over 600,000 asteroids

Asteroids can enter the atmosphere and fall to Earth, like the Chelyabinsk meteor in 2013

The Light Italian Cubesat for Imaging of Asteroids (LICIACube) prior to launch

An artist's impression of NASA's DART spacecraft approaching Didymos and Dimorphos

ASTEROID TRACKING

Keeping track of potentially hazardous asteroids is the task of NASA's Planetary Defense Coordination Office. This makes use of a network of observatories, both on the ground and in space, to scour the skies in search of asteroids that might present a threat to our planet. One of the most important of these facilities is Kitt Peak National Observatory in Arizona, which is home to the Spacewatch Project. This was originally established in 1980 as a general scientific study of asteroids – wherever they were in the Solar System – but more recently has become focused primarily on objects that might pose an impact hazard to Earth. Using a range of different telescopes, the Spacewatch team, together with research collaborators, have observed around 1,900 potentially hazardous asteroids – more than 80 per cent of all those discovered worldwide to date.

Kitt Peak National Observatory is at the forefront of the search for PHAs

THE DART MISSION

NASA's DART spacecraft was launched on 24 November 2021 en route to the asteroid Didymos and its smaller companion Dimorphos, which orbits around the larger body like a tiny moon. DART is the first space mission designed to test a method that might be needed to protect our planet from a potentially disastrous asteroid impact at some point in the future. It will achieve this with the simple action of crashing into Dimorphos in the hope that this will slightly alter its orbit around Didymos.

DART, which stands for Double Asteroid Redirection Test, is expected to reach Didymos in late September 2022 at a distance of 6.8 million miles from Earth. That's too far away for mission controllers to operate the spacecraft in real time, so it will have to carry out the impact manoeuvre autonomously. DART's main onboard instrument is the Didymos Reconnaissance and Asteroid Camera for Optical navigation (DRACO), which it will use both for scientific imaging of the asteroid and for navigation, ensuring it crashes into Dimorphos and not the much larger Didymos.

Around ten days before the encounter, DART will deploy a smaller companion spacecraft built by the Italian space agency, LICIACube. It's hoped this will capture images of the impact, as well as the resulting dust cloud and possibly even the impact crater on Dimorphos. But the effects of the collision are unlikely to be very dramatic – even though DART will be travelling at the high speed of 15,000 miles per hour – because it's so tiny in comparison to its asteroid target. The impact is expected to change Dimorphos's orbit around Didymos by around one per cent – a difference that should be large enough to be measured by telescopes on Earth.

Did you know?

Didymos is the Greek word for twin

DID YOU KNOW? DART uses a solar-powered ion drive in place of conventional rocket thrusters

REDIRECTING AN ASTEROID

If the mission goes to plan, DART will slightly alter the orbit of Dimorphos

1 BIG BROTHER
This is the larger of the two asteroids in the binary system.

2 LITTLE SISTER
The actual target of the DART spacecraft is the smaller asteroid orbiting around Didymos.

3 COLLISION
The main function of the spacecraft is to crash virtually head-on with Dimorphos.

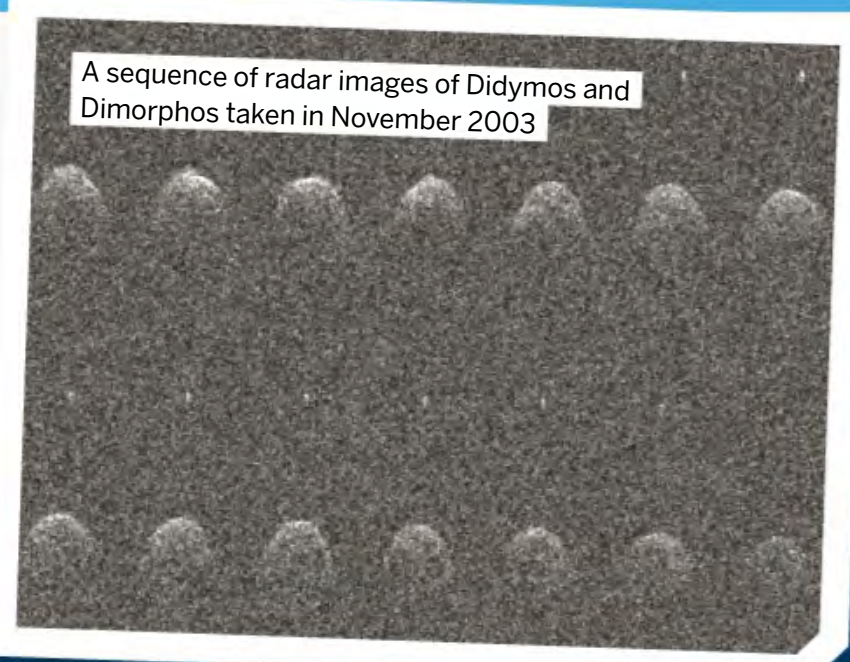
4 OBSERVER
This small spacecraft will be deployed by DART to take photos of the impact and its effects.

5 ORIGINAL ORBIT
The orbit of Dimorphos around Didymos would remain constant in the absence of an impact.

6 NEW ORBIT
The impact is expected to alter the orbit of Dimorphos, probably making it slightly smaller.

INTRODUCING DIDYMOS

The Didymos asteroid was discovered by the Spacewatch Project at Kitt Peak National Observatory in 1996, although it was only later that radar images indicated it was actually a binary system. It's now known that Didymos itself is around 800 metres in size, while its smaller companion Dimorphos is just 160 metres across. This kind of binary asteroid is ideal for a DART-type test because it's much easier to detect small changes in its orbit than it would be with a lone asteroid. As for what those changes will be, only a practical test can tell us, since they depend to a large extent on the unknown interior structure of the asteroid.


A sequence of radar images of Didymos and Dimorphos taken in November 2003

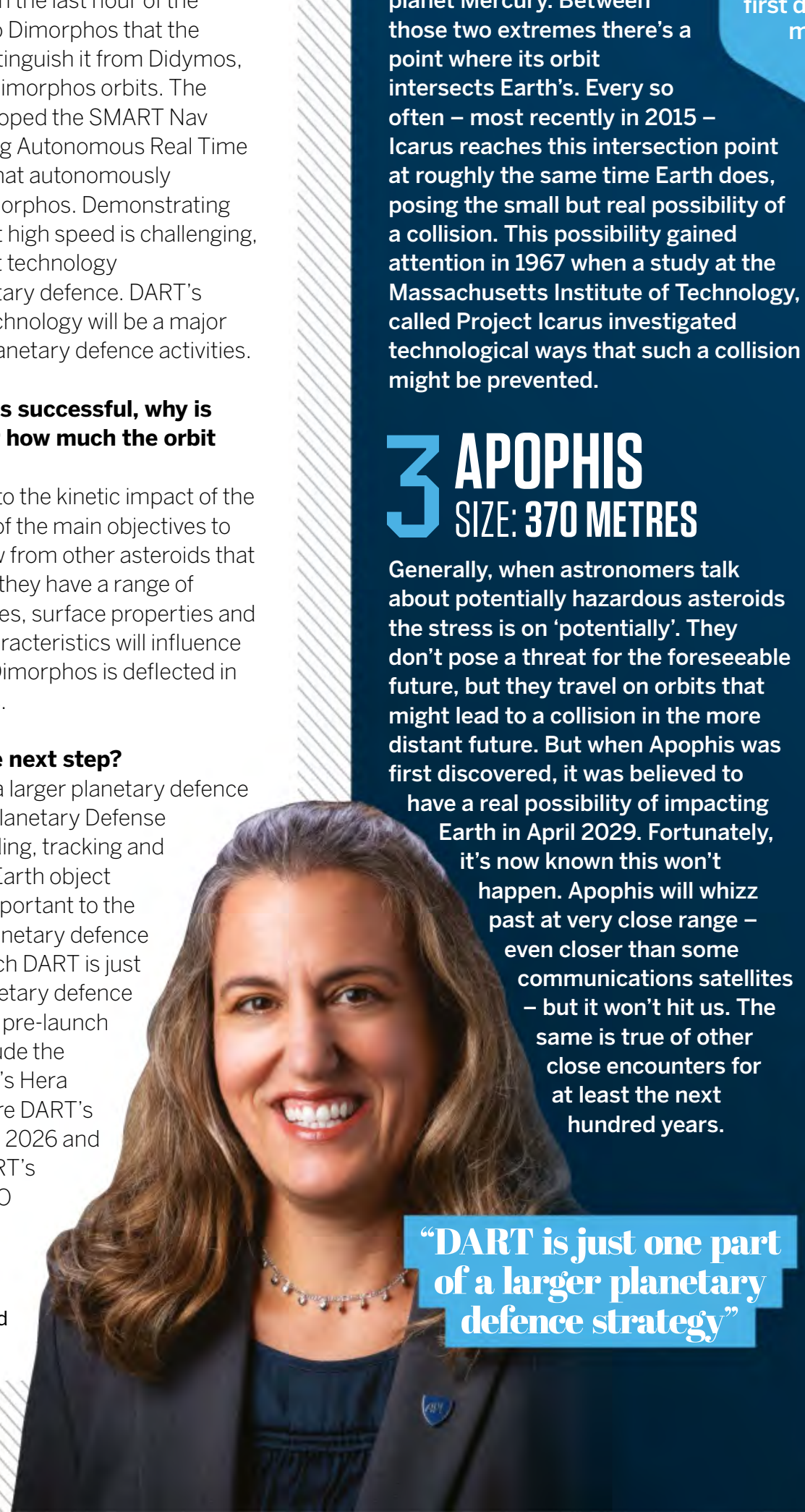
GETTING READY FOR THE DART MISSION

We speak to planetary scientist Nancy Chabot from Johns Hopkins University's Applied Physics Laboratory (APL) about DART

What will the DART mission tell us about the viability of asteroid deflection?
One of the major challenges is targeting a small asteroid in space at very high speed when that asteroid has never been imaged by spacecraft previously. It is only within the last hour of the spacecraft's approach to Dimorphos that the onboard camera can distinguish it from Didymos, the larger asteroid that Dimorphos orbits. The DART team at APL developed the SMART Nav [Small-body Maneuvering Autonomous Real Time Navigation] algorithms that autonomously navigate it to impact Dimorphos. Demonstrating this capability in space at high speed is challenging, but it's also an important technology demonstration for planetary defence. DART's demonstration of this technology will be a major result to inform future planetary defence activities.

Assuming the impact is successful, why is there uncertainty over how much the orbit will change?
How the asteroid reacts to the kinetic impact of the DART spacecraft is one of the main objectives to be investigated. We know from other asteroids that have been explored that they have a range of shapes, internal structures, surface properties and strengths, and these characteristics will influence how much the asteroid Dimorphos is deflected in its orbit around Didymos.

After DART, what's the next step?
DART is just one part of a larger planetary defence strategy led by NASA's Planetary Defense Coordination Office. Finding, tracking and characterising the near-Earth object population is crucially important to the success of any future planetary defence mitigation efforts, of which DART is just the first test. Future planetary defence missions currently in the pre-launch development phase include the European Space Agency's Hera mission, which will explore DART's target asteroid system in 2026 and see the crater left by DART's collision, and NASA's NEO Surveyor mission to find near-Earth objects.



Chabot is coordination lead on the DART mission

1 ICARUS
SIZE: 1,400 METRES

Discovered in 1949, asteroid Icarus takes 409 days to complete an orbit around the Sun. Since that's 12 per cent longer than Earth's year of 365 days, you might think it puts it safely outside our own orbit. But Icarus travels on a very elliptical orbit, the outermost point of which is outside the orbit of Mars, but at its innermost point is closer to the Sun than the planet Mercury. Between those two extremes there's a point where its orbit intersects Earth's. Every so often – most recently in 2015 – Icarus reaches this intersection point at roughly the same time Earth does, posing the small but real possibility of a collision. This possibility gained attention in 1967 when a study at the Massachusetts Institute of Technology, called Project Icarus investigated technological ways that such a collision might be prevented.

Did you know?
LICIACube is Italy's first deep-space mission

2 TOUTATIS
SIZE: 2,450 METRES

Toutatis travels on an eccentric orbit, taking it all the way from the main asteroid belt between Mars and Jupiter at its outermost point to within Earth's orbit at its innermost. This orbit takes just over four years to complete, and almost every orbit since it was first discovered in 1989 has involved a relatively close pass of Earth. But even the closest of these, such as those in 2004 or 2012, couldn't be classed as near collisions since the minimum distances were still as large as 4 and 18 times the distance from Earth to the Moon respectively. During the 2012 encounter, the first really clear pictures of the asteroid were obtained in two different ways: by radar imagery using NASA's Deep Space Network antenna in Goldstone, California, and by China's Chang'e 2 space probe, which was specially diverted to fly past the asteroid.

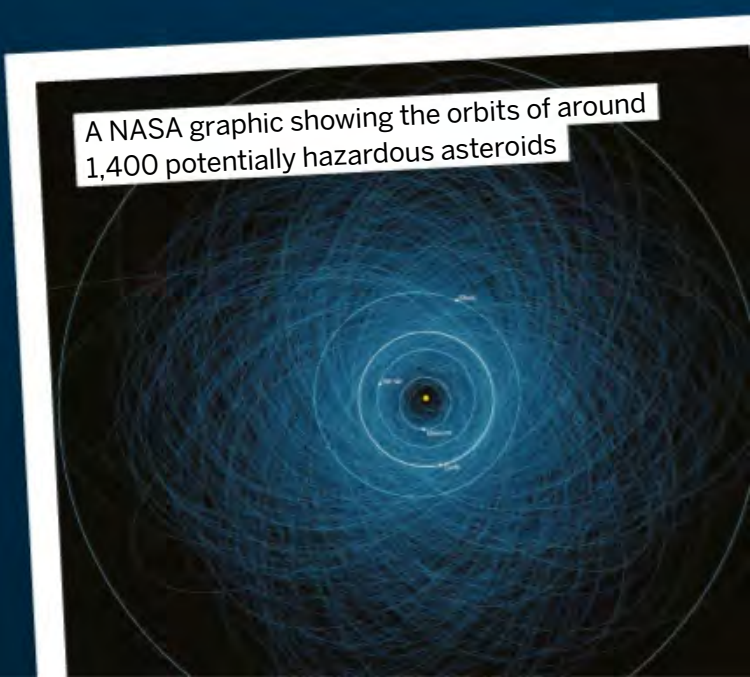
3 APOPHIS
SIZE: 370 METRES

Generally, when astronomers talk about potentially hazardous asteroids the stress is on 'potentially'. They don't pose a threat for the foreseeable future, but they travel on orbits that might lead to a collision in the more distant future. But when Apophis was first discovered, it was believed to have a real possibility of impacting Earth in April 2029. Fortunately, it's now known this won't happen. Apophis will whizz past at very close range – even closer than some communications satellites – but it won't hit us. The same is true of other close encounters for at least the next hundred years.

4 BENNU
SIZE: 490 METRES

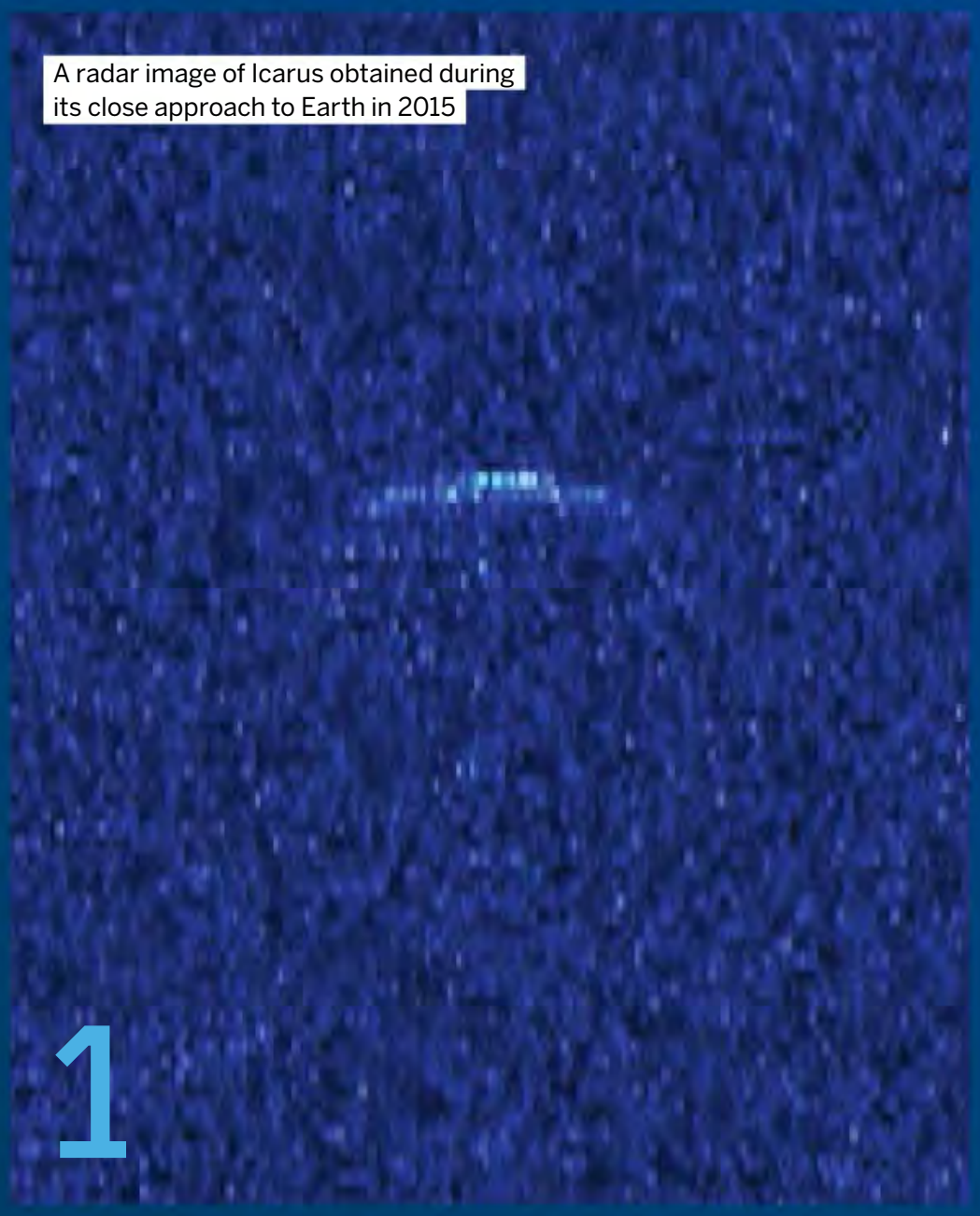
Bennu is another asteroid that makes occasional close passes of Earth and is large enough to cause serious devastation if it were to hit the planet. As with Apophis, that's not going to happen in the foreseeable future, but even so it helps to understand such objects as thoroughly as possible. That was the rationale behind NASA's OSIRIS-Rex (Origins, Spectral Interpretation, Resource Identification, Security, Regolith Explorer) mission, which visited Bennu in 2021 and is now en route back to Earth with a sample of rock collected from it.

"DART is just one part of a larger planetary defence strategy"



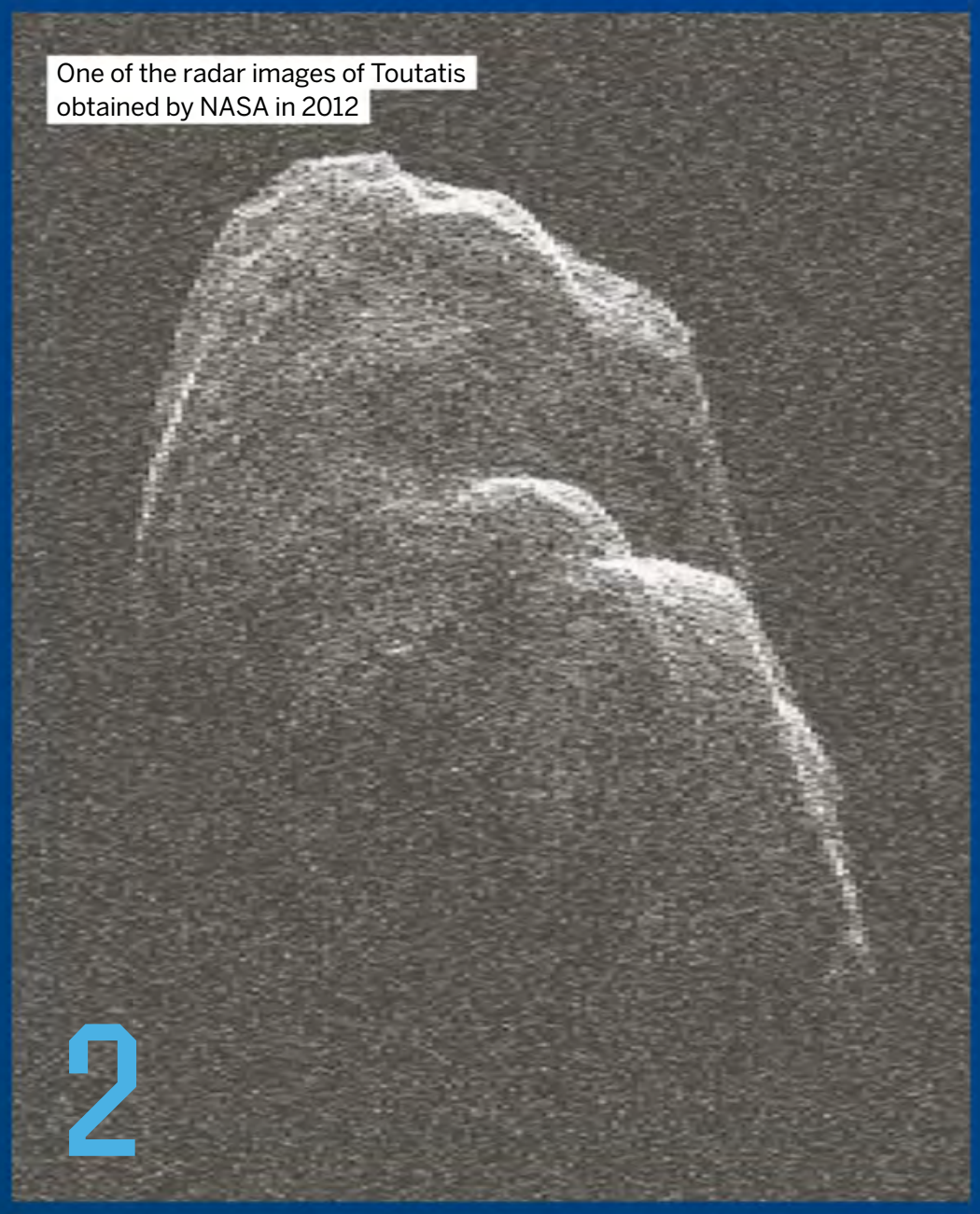
A NASA graphic showing the orbits of around 1,400 potentially hazardous asteroids

DID YOU KNOW? The 1908 Tunguska event in sparsely populated Siberia was the largest asteroid impact in recorded history



A radar image of Icarus obtained during its close approach to Earth in 2015

1



One of the radar images of Toutatis obtained by NASA in 2012

2

An artist's rendering of Apophis passing by Earth in 2029

3

A composite image of Bennu acquired by OSIRIS-REx in 2018

4

An artist's rendering of a Vulcan Centaur blasting into space

INSIDE THE VULCAN CENTAUR ROCKET

One of America's newest space launch systems uses a new fuel and has reusable parts

WORDS **ANDREW MAY**

SPACE FORCE

One of Vulcan Centaur's biggest users will be NASA. But another important customer is the US Space Force, a separate branch of the US armed services alongside the Army, Navy, Air Force and Marine Corps. Prompted by the recognition that space – particularly in the form of surveillance and communication systems – has become indispensable to modern military operations, it's the role of the Space Force to protect US interests in the space domain. Where in the past military space launches were the province of the Air Force, they now fall within the remit of the Space Force. As an example, in July 2022 a ULA Atlas V rocket launched a pair of spacecraft – a missile-warning satellite and a technology demonstrator platform – on behalf of the Space Force.

The official Space Force logo is reminiscent of the classic *Star Trek* emblem

United Launch Alliance (ULA) is America's most experienced space launch operator, with its well-established Atlas V and Delta IV. Now the company has a new rocket in the pipeline called Vulcan Centaur. As with its predecessors, this will be able to launch satellites into a variety of orbits – including geosynchronous ones – for NASA and other US government customers. But it's hoped the new rocket will be able to do this more cheaply thanks to an initiative the company refers to as SMART – Sensible, Modular, Autonomous Return Technology. This allows the most expensive parts of the rocket to be recovered after launch and refurbished for reuse.

Parts of the new design use well-established technology, such as the Centaur upper stage and the same type of solid rocket boosters as Delta IV. More innovative is the main Vulcan core stage, which will employ a completely different type of rocket engine to previous ULA launchers. This is the BE-4, designed and manufactured by Jeff Bezos' Blue Origin. Unfortunately, the BE-4 has proved to be one of the main stumbling blocks on Vulcan Centaur's journey to flight readiness, which was originally expected in 2020. One reason the BE-4's development is progressing slower than planned is that it's a hugely ambitious piece of engineering. More powerful than the Space Shuttle's main engines, it's designed to be fuelled by methane, which is a brand-new fuel in the context of space launch systems. Several companies – prominently SpaceX, as well as Blue Origin – are developing launchers around it, but the fact remains that to date no methane-fuelled rocket has made it into space.

Nevertheless, it's hoped that Vulcan Centaur will change that before the end of this year.

Did you know?

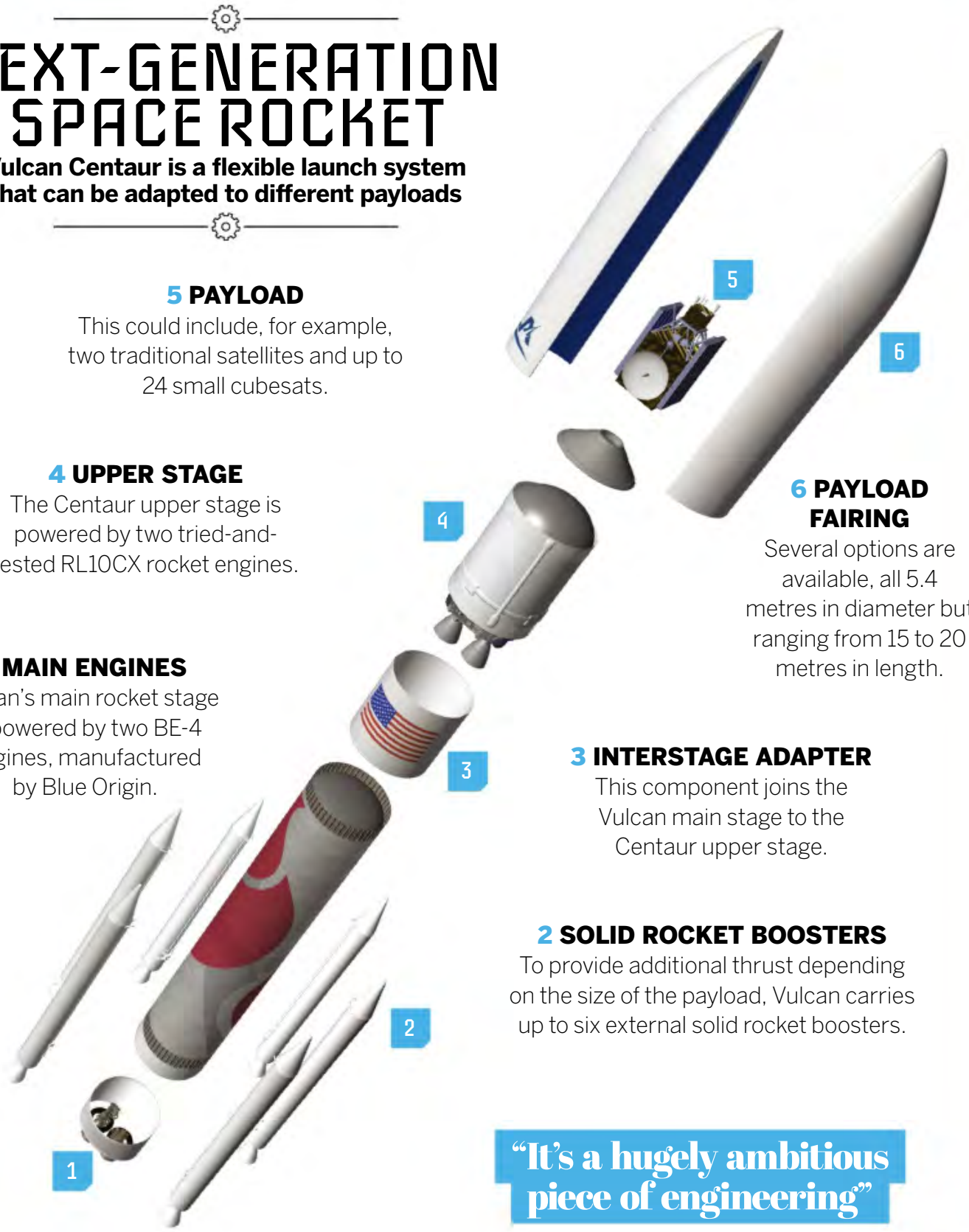
ULA is a joint venture between Lockheed and Boeing

A Vulcan Centaur booster stage seen during testing in February 2021

DID YOU KNOW? On its first flight, Vulcan Centaur's payload will include the ashes of *Star Trek* creator Gene Roddenberry

NEXT-GENERATION SPACE ROCKET

Vulcan Centaur is a flexible launch system that can be adapted to different payloads



5 PAYLOAD
This could include, for example, two traditional satellites and up to 24 small cubesats.

4 UPPER STAGE
The Centaur upper stage is powered by two tried-and-tested RL10CX rocket engines.

1 MAIN ENGINES
Vulcan's main rocket stage is powered by two BE-4 engines, manufactured by Blue Origin.

6 PAYLOAD FAIRING
Several options are available, all 5.4 metres in diameter but ranging from 15 to 20 metres in length.

3 INTERSTAGE ADAPTER
This component joins the Vulcan main stage to the Centaur upper stage.

2 SOLID ROCKET BOOSTERS
To provide additional thrust depending on the size of the payload, Vulcan carries up to six external solid rocket boosters.

"It's a hugely ambitious piece of engineering"

THE CENTAUR UPPER STAGE

Unlike the methane-fuelled, partially reusable Vulcan booster, there's nothing revolutionary about Vulcan Centaur's upper stage. In its basic design, Centaur is one of America's oldest and most successful pieces of space hardware. Originally conceived at the very dawn of the Space Age in the late 1950s, its first successful flight – atop an Atlas booster – took place on 27 November 1963. Since then, Centaur has flown over 260 times, sending one spacecraft after another on its way into the history books, from America's first lunar soft lander, Surveyor 1, back in 1966 to the Curiosity and Perseverance Mars rovers of today.

NASA's Surveyor 1 launched atop a Centaur upper stage

ROCKET COMPARISON

VULCAN CENTAUR

HEIGHT: 62 metres

MAX PAYLOAD: 27,200 kilograms

COST PER LAUNCH: $100 to 200 million

DELTA IV HEAVY

HEIGHT: 72 metres

MAX PAYLOAD: 28,800 kilograms

COST PER LAUNCH: $350 million

ATLAS V

HEIGHT: 58 metres

MAX PAYLOAD: 18,850 kilograms

COST PER LAUNCH: $150 million

SPACEX FALCON 9

HEIGHT: 70 metres

MAX PAYLOAD: 22,800 kilograms

COST PER LAUNCH: $67 million

ARIANE 5

HEIGHT: 52 metres

MAX PAYLOAD: 20,000 kilograms

COST PER LAUNCH: €140 to 185 million

WWII's WEIRDEST INVENTIONS

Take a closer look at some of the strangest things the Allied and Axis powers came up with to take on their adversaries

WORDS JONATHAN GORDON

Throughout human history, wars have been a cauldron for invention. In fact, hardship of any kind can lead to new concepts and ways of thinking to emerge. World War II had no shortage of hardship or inventiveness, some of the latter being as devastating and diabolical as the planet had ever seen. Here, however, we thought we would concentrate on some of the stranger concepts. Whether successful or not, the tools and weapons we have chosen display a kind of outside-of-the-box thinking or disregard for convention that can so often lead to great ideas.

More often than not, the things that stood in the way of these inventions really making an impact was a lack of resources or being slightly too far outside the realms of possibility for technology at the time. From giant weapons that dwarfed the battlefield to funny ways of rethinking the tank, even the ideas that were failures have gone on to be adapted or reborn as entirely new devices and innovations that continue to affect our lives and have a massive impact on modern fields of battle. Let's take a look at some of World War II's stranger contributions to military tactics.

DID YOU KNOW? WWII started on 1 September 1939, lasting until 2 September 1945

GUSTAV RAILWAY GUN

The biggest gun ever made

MADE BY: GERMANY DATE: JULY 1942

The thinking behind the Gustav gun doesn't appear to have been too sophisticated. It was big... very big. The barrel alone was over 47 metres long and the whole machine weighed around 1,350 tonnes. The reason it was so big was that it was needed to break through the defences of the heavily fortified Maginot Line, and that meant munitions of a size and weight previously unheard of.

The gun itself was originally commissioned in 1934 by the German Army from Krupp AG, a leading arms manufacturer. It was requested to be completed by the spring of 1940 to launch an assault on the Maginot Line and begin the invasion of France. However, complications in its construction meant it wasn't ready for test firing until 1941, and it was first deployed in Sevastopol in early 1942.

While Sevastopol was devastated by the German offensive, the Gustav only fired 48 rounds before it wore out its barrel – it had fired 250 in testing already. It also needed 4,000 men to move it into position and 500 men to fire it. After a brief appearance in Warsaw in 1944 to quell an uprising, the gun appears to have been scrapped to avoid its being captured.

Practicality ●●●●○○○○○○
Innovation ●●●●●○○○○○
Expense ●●●●●●●○○○
Weirdness ●●●○○○○○○○

Did it work?
It certainly packed a punch, but it was used sparingly and wasn't actually built in time to do the job it was meant to

SHERMAN CRAB

Enter the mine flail

MADE BY: BRITAIN DATE: 1944

Did it work?
The Sherman Crab was pretty effective and was deployed from 1944 as the Allies advanced on Axis positions in Europe

The idea of having a tank mounted with a rotating cylinder with chains attached to it that could detonate mines ahead of it to clear a path for other resources had been kicked around for some time in British circles before it came into full effect with the Sherman Crab. South African Captain Abraham du Toit is credited with the original concept of mounting such a device on the front of a tank and shared the idea with other mechanical engineers before heading to Britain to develop it further.

As it happened, multiple parallel schemes for this concept were in development from 1942, with the Sherman Crab ultimately endorsed and requested for production by General Percy Hobart. While du Toit's own thinking called for a flail powered by its own engine, the Crab's flail was linked to its main engine. It was also fitted with cutters on the rotor so that it could munch through barbed wire.

It was not without its issues, as the flails could become tangled – something that was improved with later design upgrades – and it could only move at 1.2 miles per hour while it was clearing mines. It could also only catch so many mines, and the chains could be blown off in the process, requiring repair down the line. In 1948 du Toit received a bonus from the Royal Commission on Awards to Inventors for his contribution to the war effort for the initial concept and development.

Practicality ●●●●●○○○○○
Innovation ●●●●●●○○○○
Expense ●●●○○○○○○○
Weirdness ●●●●●○○○○○

GOLIATH TANK

Mighty name, small stature

MADE BY: GERMANY DATE: EARLY 1942

Did it work?
Not really. While plenty were made and used, they had rather a lot of shortcomings

Nicknamed the Doodlebug by US forces, the Goliath tanks were deceptively named since they were actually small, single-use remote-controlled vehicles that could be driven close to Allied tanks or camps and detonated. Powered either with an electric or petrol engine, Goliath was deployed against a specific target via a control box connected with a wire, allowing it to be steered. It was mostly used for blowing up enemy defences or mine clearance, although it could also be used against tanks and had a range of 650 metres. Over 7,500 Goliaths were produced, and they went on to inspire remote-controlled devices in the post-war years. However, they were expensive, which given they could only be used once made them very inefficient. They were also very slow, moving at less than six miles per hour, which meant that unless a tank was stationary it was unlikely to ever catch up with one.

Practicality
Innovation
Expense
Weirdness

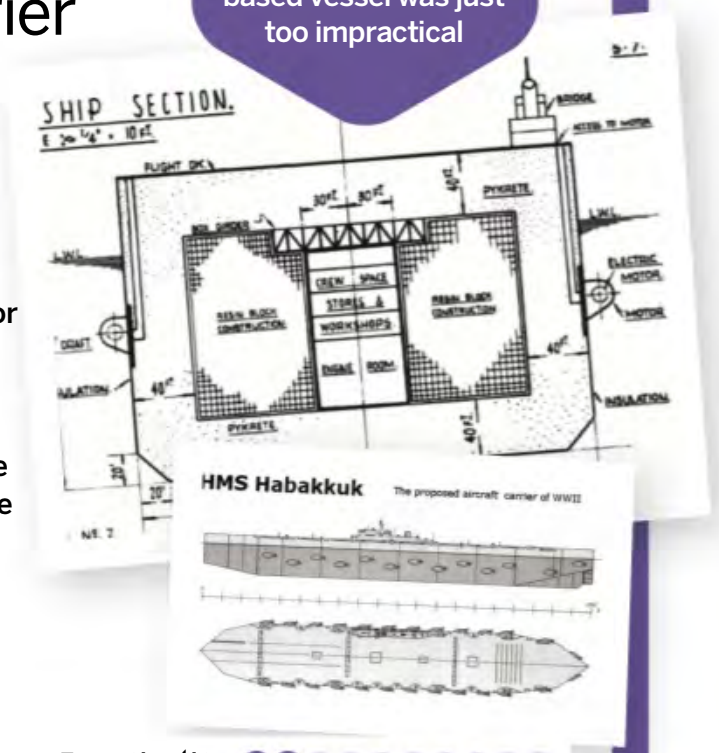
PROJECT HABAKKUK

The iceberg aircraft carrier

MADE BY: BRITAIN DATE: 1943

Did it work?
Not at all. It was an innovative idea, but maintaining an ice-based vessel was just too impractical

In an attempt to remedy the issue of limited steel and aluminium supplies with which to build new ships, Geoffrey Pyke pitched a rather innovative idea: aircraft carriers made from ice. His proposal was to use an iceberg – whether naturally forming or manufactured – flatten it and hollow it out to use it as a means for aircraft to be transported and deployed on the ocean. Pyke began work with Austrian biologist Max Perutz to devise a way to use a glacier to build a ship, although they found that ice would crack under its own weight for the sizes they would need. The discovery of pykrete, a mixture of wood pulp and ice, turned a fanciful notion into something plausible, with a prototype built in Patricia Lake, Alberta, Canada. The pykrete was buoyant and very strong, but still needed insulation and cooling. To keep the ice from melting, a refrigeration system was needed to keep it running, although the prototype took three summers to melt in Patricia Lake.



Practicality
Innovation
Expense
Weirdness

THE NELLIE

A rabbit out of Churchill's hat

MADE BY: BRITAIN DATE: 1939

Practicality
Innovation
Expense
Weirdness

As war in Europe was commencing again, minds naturally returned to the years of conflict just a couple of decades previous and the toil that the Great War involved. But in those intervening years technology had advanced greatly and new solutions to the challenges of that war could now be found. As First Lord of the Admiralty, Winston Churchill was in charge of some of these ideas, one of which was 'White Rabbit', a trench-digging machine that could dig ahead of a column of infantry and move the trench lines without endangering troops. Codenamed Cultivator No. 6 and later moved to the Ministry of Supply division for Naval Land Equipment (NLE), it picked up the name Nellie. Using two 12-cylinder high-speed diesel engines, the Nellie became something of a beast, unable to be carried by conventional transport into the field. For all that, though, by 1940 it was becoming clear that smaller, fast-moving tanks were making trench warfare redundant. As clever as the Nellie could have been, it didn't really have a place in this conflict.

Did it work?
33 Nellies were made by 1941, but by 1943 the project was cancelled, although a handful were retained

WILDLIFE AT WAR

Even the animal kingdom wasn't safe from WWII's strangest ideas

ANTI-TANK DOGS

This is a pretty famous one as the Soviet Union first trained dogs to approach tanks and drop bombs beneath them, then turned to a triggered device that detonated a bomb strapped to a dog when the original plan didn't work. Trained dogs did this from 1941 to 1942, but were not terribly effective. Some were killed before reaching tanks, some detonated returning to the Soviet lines and some went towards Soviet tanks since that is what they originally trained with.

PIGEON MISSILE

Could pigeons be trained to recognise a target and use their natural homing abilities to direct ordinance on target? That was the question asked by B. F. Skinner in the US. With screens that projected images from outside into compartments in the missile, the pigeons were expected to peck on the screen when they saw the correct location, moving when the image left the centre and in so doing keeping the missile on target.

DID YOU KNOW? An estimated 40 to 50 million people died during WWII

YOKOSUKA MXY-7 OHKA

Rocket-fuelled cherry blossom

MADE BY: JAPAN DATE: 1945

As US forces advanced on Japanese positions in the Pacific and the Japanese government worked to hold them off, kamikaze attacks were becoming more and more common from 1944 onwards. By 1945 a new and even more devastating form of suicide fighter was devised by Ensign Mitsuo Ohta with the help of the Aeronautical Research Institute of the University of Tokyo. What would become the Ohka, which translates to 'cherry blossom', was a single-seater, rocket-propelled bomb. However, since it needed to be deployed at short range it did not necessarily need a highly experienced pilot to control it. Most typically attached to a Mitsubishi G4M 'Betty' bomber, the Ohka was taken to its destination, released, needed gliding to aim at its desired naval target and would then activate its three rockets to dive. It could reach speeds of nearly 620 miles per hour in a full dive. This speed meant ships had little time to react. However, not long after their deployment in April 1945, US forces realised they had to take out the Bettys to avoid the issue. While some ships were lost or damaged early on, fewer and fewer were harmed in the following days.

Did it work?

No. US Navy tactics to pick off the planes carrying the Ohkas meant they were very ineffective in the field

Practicality ●●●○○○○○○○
Innovation ●●●●○○○○○○
Expense ●●●○○○○○○○
Weirdness ●●●●●○○○○○

BAT BOMBS

Another US concept was using bats with incendiary devices attached to them to start fires in Japan. A shell casing with over a thousand compartments would be filled with hibernating bats, each strapped with a timed bomb. As the shell fell, a parachute would eventually deploy, opening up the outer casing and releasing the bats from their compartments, where they would then seek shelter in the woods or eaves of buildings. Tests suggested it might prove effective, but the project was canned when it became clear it wouldn't be ready until mid-1945.

EXPLODING RATS

A rather devious concept conceived by the British Special Operations Executive, the idea was to fill dead rats with plastic explosives and leave them around boiler rooms in Germany. The hope was that they would then be disposed of in the furnace and explode. That alone might have proved rather small, but if it in turn caused a boiler explosion then the damage would be extensive. The scheme didn't get far though, as the first shipment was intercepted by the Germans, but their continued hunt for booby-trapped rodents meant a lot of wasted resources.

PANZER VIII MAUS

The 188-tonne tank

MADE BY: GERMANY DATE: JULY 1944

What was it with Nazi Germany and big things? Like so many of the attempted superweapons of the Axis forces, this was perhaps too large for its own good. The Maus was a massive new tank – the biggest created at that time – weighing 188 tonnes with armour 200 millimetres deep at its thickest points. The intention was for it to be a battering ram against the enemy lines, punching holes through anything that the Allies could throw against it and barely taking a scratch in the process. There were a number of issues, however, not least that actually getting the thing to move with an engine that could actually fit inside the tank was a challenge. Several engines were tried, but it only ever reached a maximum speed of 12 miles per hour. Then there was the fact that with its immense weight it couldn't use any bridges, but this led to it becoming submergible with a pressurised cabin. While five were originally ordered, only two prototypes were completed, and even then only one gun to mount on them. Not long after this happened, the Soviet Army captured the testing ground for the Maus in Böblingen.

Did it work?

It was perhaps beginning to, but the massive issues the Maus faced meant it was never field ready

Practicality
Innovation
Expense
Weirdness

THE GREAT PANJANDRUM

Pinwheel of death

MADE BY: BRITAIN DATE: 1944

It was 1943 and the plans for the invasion of mainland Europe by Allied forces were taking shape at pace. There were a few logistical problems, however, with the plan for sea-based landings on the west coast of Europe, not least the Atlantic Wall defences that stretched down the coast of Norway to the border between France and Spain. The Allies needed something that could launch from the landing vessels without assistance from personnel – who would be taking fire – could scale the beaches and blow a hole in the defences big enough for a tank to pass though. Enter the Panjandrum, a one-tonne bomb contained in a drum between two wooden wheels, three metres in diameter, fitted with cordite rockets to propel the device forward. While this device was supposed to be secret, it was tested on a public beach in Devon where crowds gathered to watch despite safety warnings. While the Panjandrum seemed to get from boat to shore fairly well, it kept turning uncontrollably afterwards, sometimes losing rockets that shot off in all directions. Despite several attempts to vary the number of rockets and adding a third central wheel to stabilise, it simply wouldn't stay on course.

Practicality
Innovation
Expense
Weirdness

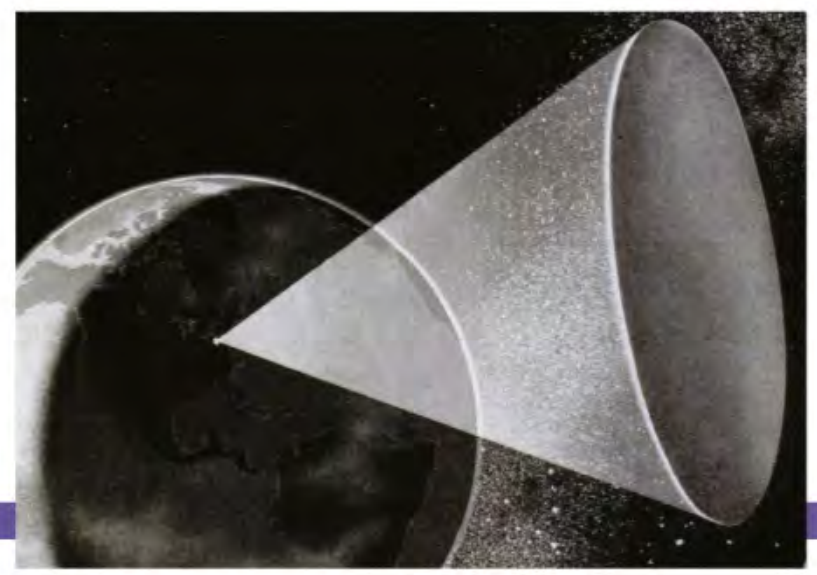
Did it work?

The Allies never found a way to stabilise the Panjandrum, so it was abandoned just before the Normandy landings

THE SUN GUN

Was this WWII's most bizarre plan?

The original Sonnengewehr, or sun gun, proposed by German physicist Hermann Oberth in 1929, would have involved a 100-metre-wide concave mirror being placed into orbit around Earth, able to reflect concentrated sunlight back on a desire target and utilising our star as a weapon. During World War II, the concept was revived by the German Army Artillery, who expanded the idea to include a space station that would orbit 5,100 miles above the planet attached to a 'mirror' made of metallic sodium stretching 3.5 square miles, manoeuvred by thruster rockets to find its target. They thought that at this size it would be able to burn a city or boil an ocean. Not surprisingly, this ambitious superweapon was never attempted. It was estimated by German scientists that it might take another 50 to 100 years to perfect the technology needed to utilise the Sun in this way.



FU-GO BALLOON BOMB

An intercontinental weapon

MADE BY: JAPAN DATE: 1944

The US had entered the war, but while so many other nations involved were seeing their major cities attacked and infrastructure decimated, Americans were relatively well protected by the expanse of ocean between it and the enemy, both east and west. Still, the Japanese needed to do something to quell the advance of American troops, and the concept of free-floating, unmanned balloons packed with explosives that would use the naturally occurring jet stream over the Pacific to reach the US was taken up. The Fu-Go bombs, made from paper and glued together with potato flour, would float to America and strike fear into the population, damaging buildings with high-explosive bombs and starting fires with thermite bombs with no way of knowing where they would go – at least, that was the theory. Only a fraction even reached America; casualties were very low and the national panic that Japan hoped they would create never emerged. They were, however, a type of intercontinental weapon the likes of which hadn't been attempted before, a concept that would go on to dominate the post-war arms race.

Practicality ●●●○○○○○○○
Innovation ●●●●●○○○○○
Expense ●●●○○○○○○○
Weirdness ●●●●●●○○○○

Did it work?

With only a handful of casualties, the balloons didn't cause the national panic Japan had hoped

AVRE BOBBIN

The carpet layer

MADE BY: BRITAIN DATE: 1944

The plans for a beach landing on D-Day were gathering pace and new concepts for how to deal with every conceivable challenge the forces might face were being thrown at the wall. A previous attempt at a beach landing at Dieppe had shown a lot of the potential shortcomings, such as not being able to get tanks in position to offer cover to ground troops. Some tanks simply hadn't been able to move on the shingle surface. While some teams worked on explosive wheels to punch through defences and others looked to clear minefields, this Armoured Vehicle Royal Engineers tank had the very simple task of laying a carpet down for the following tanks. The Bobbin, named after the spindle of canvas it carried between two steel arms, was intended to ride ahead of a tank column as they mounted the beach, giving them a more consistent surface to drive on and hopefully prevent them from sinking into the sand. Further tanks that carried wood or were partially amphibious were also designed under the command of Major General Percy Hobart, from which the term Hobart's Funnies has been derived. They certainly were peculiar, but also rather ingenious.

Practicality ●●●●●●○○○○
Innovation ●●●●●○○○○○
Expense ●●●●○○○○○○
Weirdness ●●●●●●○○○○

Did it work?

The original canvas matting meant the paths weren't very durable, but reinforcement upgrades helped down the line

Babbage's Difference Engine No. 2, built by the Science Museum in London

DID YOU KNOW? The British government spent £17,500 on the Difference Engine No. 1, equivalent to around £1.5 million today

Inside the first MODERN COMPUTER

Why the Difference Engine wasn't finished in time to make history

WORDS **SCOTT DUTFIELD**

The history of the modern-day computer is a 200-year journey of technological evolution contributed to by countless inventors and scientists from across the world. One of the pioneering minds on the computer's timeline was Charles Babbage, an English mathematician that designed several machines to automatically complete complex calculations. In the early 1800s, Babbage was tasked by the British Admiralty with producing an accurate table of logarithms – printed tables used to perform bigger calculations commonly used in navigation – as a former professor of Cambridge University. Having trawled through many existing printed tables, Babbage became disgruntled by the number of comparative errors between them. To remove the chance of human error from creeping its way into these tables, Babbage set out to mechanise the process of creating them.

The first iteration of Babbage's mechanical solution was called the Difference Engine No. 1, the design of which called for a giant hand-cranked machine that used interlocking gears and large numerical columns to make calculations. With need of an investor to finance his project, the mathematician turned to the British government for support. Babbage's financial request was granted, and Babbage enlisted the help of engineer Joseph Clement to carry out the machine's construction. In Babbage's designs, a fully realised Difference Engine consisted of 25,000 parts to complete its calculations. The machine was designed in two parts: the first was the calculating machine and the second was a printing press to document the calculation.

Did you know?

The first electronic computer was completed in 1945

To automatically generate the logarithm tables, Babbage's Difference Engine used one of the oldest mathematical methods to solve equations, called the finite difference method.

This method is used to calculate the value of a polynomial – an algebraic equation – using repeated addition rather than multiplication and division.

The calculating mechanism of the engine consisted of eight columns of stacked gears with the numbers zero through to nine written on them in order. These columns were called registers, and each displayed a 31-digit number vertically. To perform a calculation, the initial polynomial values were manually entered into the first of the eight registers. By turning a handle, all the gears in the engine would rotate, calculating the answer to the equation through the addition of all the numbers in each register. The final value and the answer to the equation were then displayed on the final register.

In 1842, after 20 years of development and thousands of pounds spent to create only a small demonstrative portion of the machine, known as the 'beautiful fragment', Babbage's funding was withdrawn following a parliamentary vote. Babbage didn't return to the Difference Engine

"A fully realised Difference Engine consisted of 25,000 parts"

BABBAGE'S BIG NEW PROJECT

Babbage turned his attention to a new and more ambitious project in 1834: creating the first fully automatic steam-powered calculating machine. Unlike the Difference Engine, the Analytical Engine was designed as a more general device with a set of punch cards for instructions on calculations, as well as acting as a 'store' for results. The machine's storage was designed to contain 1,000 50-digit numbers. The Analytical Engine laid out some of the essential features that led to the creation of the modern-day computer. Unfortunately, like the Difference Engine, only a piece of the machine was ever seen by Babbage before his death.

Babbage worked on the Analytical Engine until his death

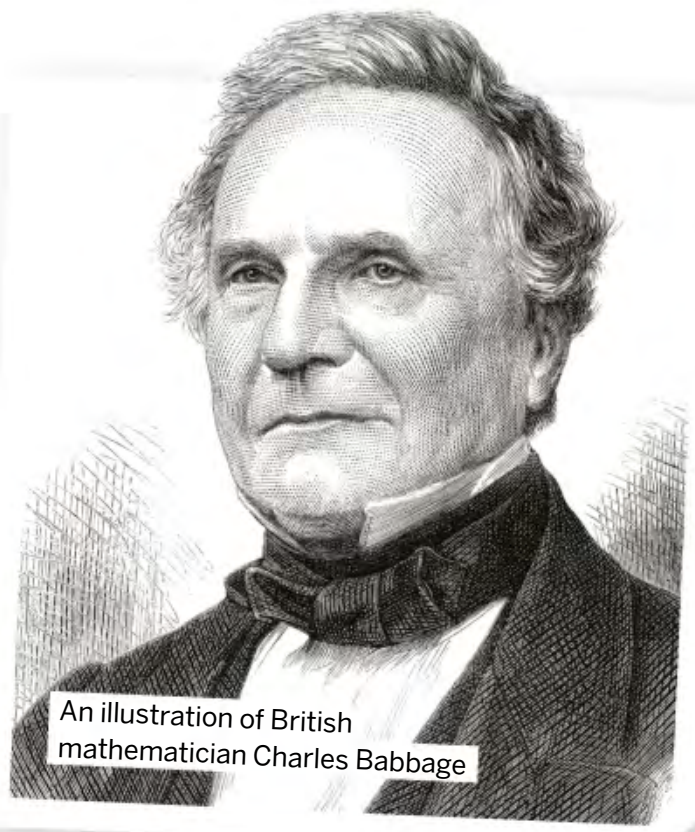
project until 1847, when he began designing a simplified version of the machine which used less than half the number of original parts than the first version. After two years of redesign, Babbage revealed the blueprints for the Difference Engine No. 2. He presented the new and improved plans to the British government, but the pitch fell on deaf ears and the Difference Engine No. 2 remained unfinished. Many speculate that if Babbage had been able to complete his work and secure the funding needed to build the Difference Engine, it would have been a success, and who knows how the evolution of the computer might have changed as a result.

Upon Babbage's death in 1871, 20 detailed drawings of the Difference Engine No. 2 were donated to the Science Museum in London. Presumably intended to remain as a historical reference to his work, the plans assisted future scientists and engineers in completing the machine more than 200 years after Babbage's birth. Work began on building the Difference Engine No. 2 in 1979 when Australian computer scientist Allan G. Bromley interpreted Babbage's work. With some funding help from Microsoft, part of the machine was completed by 1991. Finally, in 2002 the first full-scale engine was built at the Science Museum in London under the watchful eye of Doron Swade, then senior curator of computing and IT. The final engine weighed around five tonnes and measured 3.4 metres in length.

Although Babbage's work on the automation of calculations and computation is something to be commended, unfortunately his work was largely ignored or revised during the evolution of the modern-day computer. However, Babbage is still remembered as a great mind in the fields of mathematics and engineering despite failing to complete the construction of a machine that would have been deemed the first mechanical computer in the world.

Did you know?

The demonstration piece of No. 1 had 2,000 parts



An illustration of British mathematician Charles Babbage

2 COLUMNS
There are eight columns to the machine, each containing rows of numerical wheels showing a sequence of the numbers zero through nine.

1 RAW MATERIALS
The Difference Engine is made up of 8,000 parts cast in bronze, iron and steel.

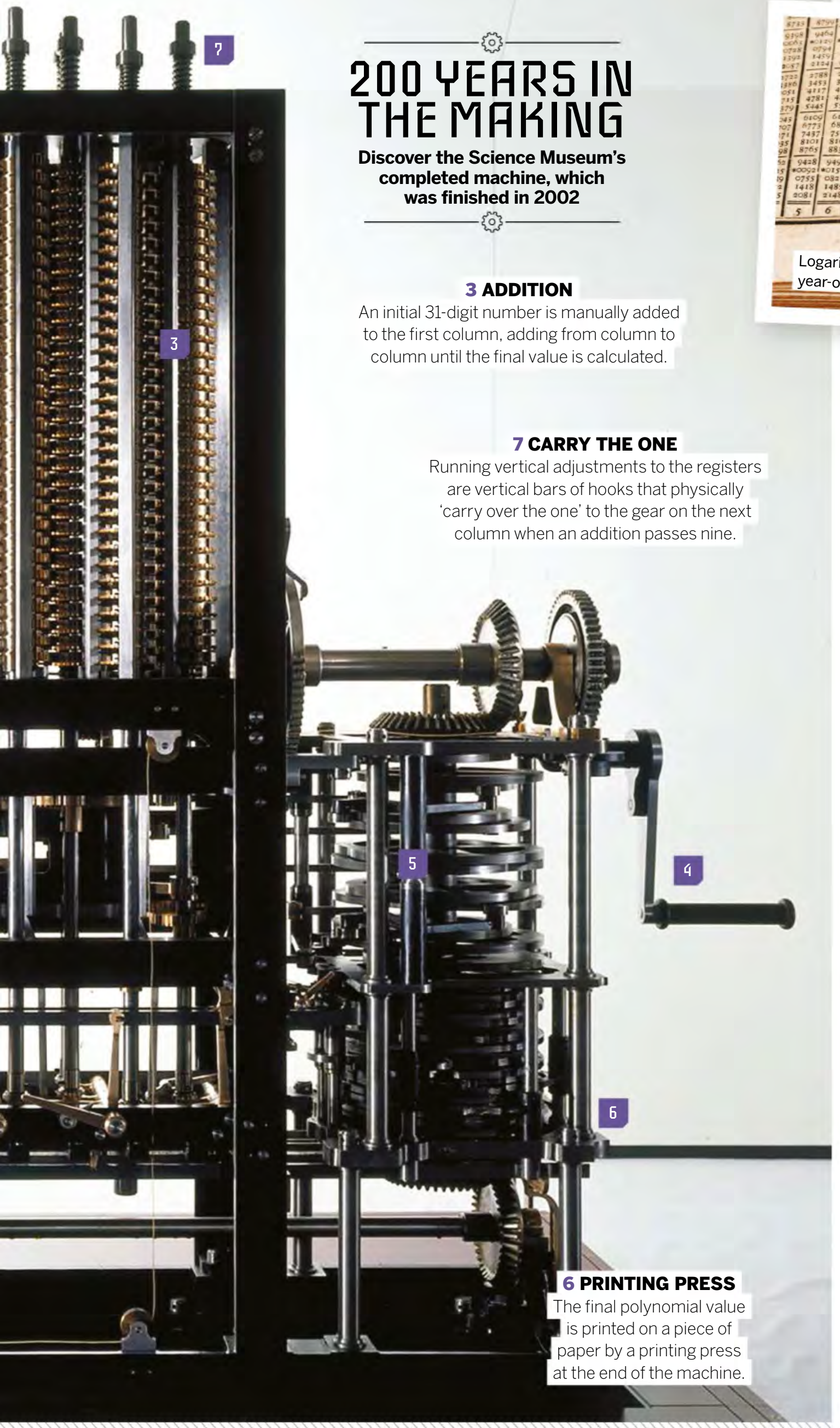
4 A COMPLETE CYCLE
Four turns of the handle produce the final 31-digit number displayed on the final column.

5 MICROPROGRAM
This device drives all the internal motions and timing of the engine to carry out repeated additions.

DID YOU KNOW? Babbage also invented the ophthalmoscope for eye examinations

200 YEARS IN THE MAKING

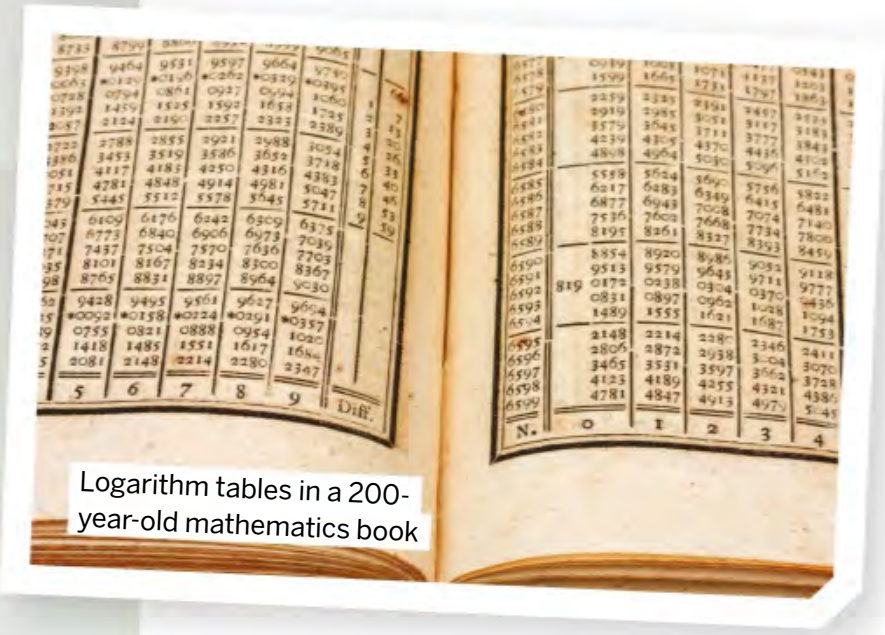
Discover the Science Museum's completed machine, which was finished in 2002



3 ADDITION
An initial 31-digit number is manually added to the first column, adding from column to column until the final value is calculated.

7 CARRY THE ONE
Running vertical adjustments to the registers are vertical bars of hooks that physically 'carry over the one' to the gear on the next column when an addition passes nine.

6 PRINTING PRESS
The final polynomial value is printed on a piece of paper by a printing press at the end of the machine.



Logarithm tables in a 200-year-old mathematics book

THE FIRST COMPUTER PROGRAMMER

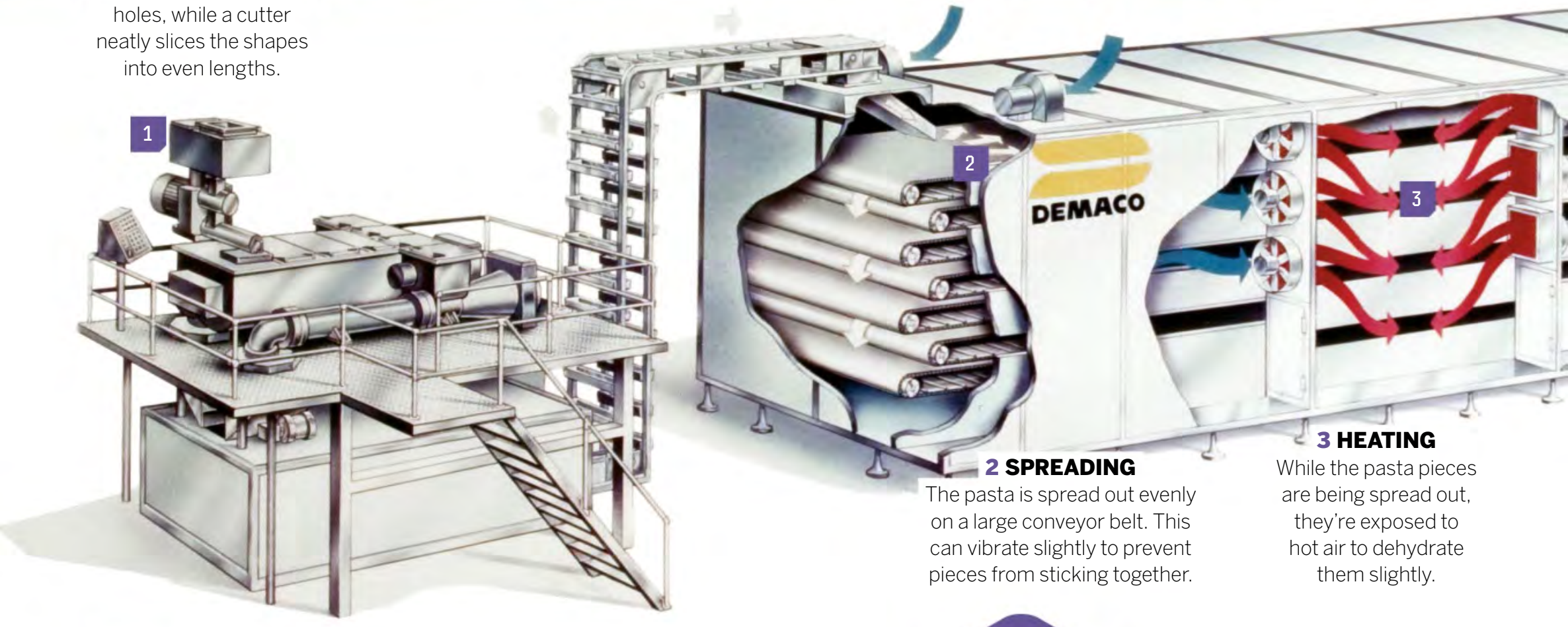
Inspired by Babbage's work on the Difference Engine, Ada Lovelace, one of the greatest mathematicians of the 19th century, joined his effort to create the Analytical Engine. Lovelace translated the work of Italian mathematician and engineer Luigi Federico Menabrea, who had written a paper about Babbage's Analytical Engine. During this time, between 1842 and 1843, Lovelace added her own clarifying notes to Menabrea's paper, as well as her own mathematical solution to the problem. A true visionary, Lovelace saw the potential of the Analytical Engine beyond simple mathematics. By replacing numbers with letters and even music notes, Lovelace illustrated the basis for a programmable computer with limitless functions.

Ada Lovelace helped Babbage design the Analytical Engine

HOW PASTA IS MADE

The surprisingly scientific process behind this popular food staple

WORDS AILSA HARVEY



1 EXTRUDING
Pasta dough is pushed through different-shaped holes, while a cutter neatly slices the shapes into even lengths.

2 SPREADING
The pasta is spread out evenly on a large conveyor belt. This can vibrate slightly to prevent pieces from sticking together.

3 HEATING
While the pasta pieces are being spread out, they're exposed to hot air to dehydrate them slightly.

Typically, pasta only requires very simple ingredients – flour and water or egg – and yet the production of this food allows people to store it long-term and create diverse meals with many different shapes and textures. The three ingredients combine two main chemical compounds: proteins and carbohydrates.

Not all the proteins from the wheat are released when flour is produced for pasta due to the pasta flour granules being larger than in all-purpose flour. This quality ensures that pasta dough is stretchy and versatile when the ingredients are mixed together, rather than sticky like bread. If the dough was too sticky, making such a range of intricate shapes wouldn't be possible. Either egg or water can be used in a pasta recipe to provide the moisture that keeps the pieces of flour together in a dough. The simplest option is to use water, but some prefer egg as it adds more flavour and nutrients and can make the dough easier to handle.

Starch, which is the carbohydrate in pasta, is held together by proteins. But when cooking pasta, it transforms into softer, larger and lighter pieces. This is because as the stiff pasta soaks in boiling water, the protein and starch interactions are manipulated. Starch granules will begin to increase in size before they open up and the surrounding water enters. As the starch and water mix, they gelatinise to create the soft, squishy consistency of cooked pasta. This process is irreversible, so leave your pasta in the water for too long and you could return to a disappointingly sloppy meal.

Did you know?

Pasta starch gelatinises at around 55 degrees Celsius

DID YOU KNOW? There are over 600 types of pasta, with spaghetti being the most popular worldwide

WHERE DID IT COME FROM?

The word 'pasta' means 'paste' or 'dough' in Italian, and most people instantly associate pasta with Italy. However, the exact origin of this food is hard to pinpoint. Because it is a simple recipe with only a couple of ingredients, there are a variety of foods with similar make-up. The flour used to make traditional Italian pasta is hard, ground durum wheat – a variation which may have descended from Asian noodles.

Venetian explorer Marco Polo is often credited with returning to Italy from China and sharing the recipe of pasta in the 13th century. However, the dish can be traced further back to the 4th century. Ancient artwork discovered in an Etruscan tomb shows pasta being made with similar tools to those used in many kitchens today – this is used to argue against the legend of Marco Polo.

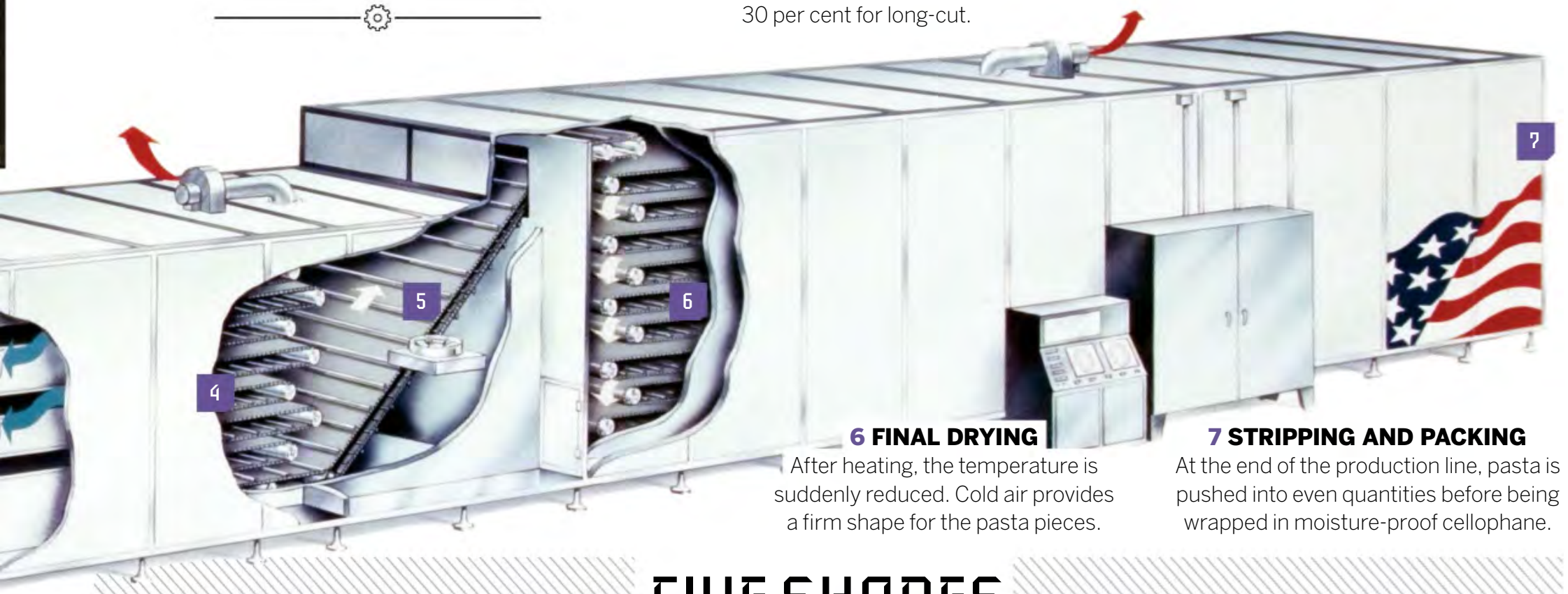
Without industrial machines, homemade pasta is hung up by hand

INSIDE A PASTA PRODUCTION LINE

How pasta is mass-produced in factories

4 PRELIMINARY DRYING
The drying process needs to be slow to prevent the pasta shapes cracking. The moisture content is reduced by five per cent for short-cut pasta and around 18 to 30 per cent for long-cut.

5 TRANSPORTING
As pasta moves between processes, segmented diagonal conveyor belts separate pasta into even loads.



6 FINAL DRYING
After heating, the temperature is suddenly reduced. Cold air provides a firm shape for the pasta pieces.

7 STRIPPING AND PACKING
At the end of the production line, pasta is pushed into even quantities before being wrapped in moisture-proof cellophane.

FIVE SHAPES

CASARECCE
The S-shaped die used to make casarecce produces a scroll-shaped pasta designed to hold a lot of sauce in the grooves.

ROTINI
Rotini, commonly mislabelled as fusilli, has externally facing grooves. As it exits the mould, it twists in circles.

PAPPARDELLE
Pappardelle is the largest ribbon-shaped pasta. Sometimes these ribbons reveal a wavy pattern at the edges as the dough moves through the die.

GRAMIGNA
As dough enters the graminga die, it's pushed through at an angle. This causes the dough to curl before it's cut into even lengths.

MACCHERONI
Maccheroni is made when dough is pushed through narrow tubes, commonly with ridges on the outer perimeter.

Beefier turbochargers have larger air intakes because more air equals more power

WHAT IS A TURBOCHARGER?

How turbochargers improve car performance, from increasing their speed and acceleration to making engines more eco-friendly

WORDS **MIKE JENNINGS**

If you're into cars, you've probably heard about turbos, or turbochargers. They're popular for good reason: these futuristic-sounding devices can drastically improve your car's performance or efficiency. They're quite simple devices, revolving around how much oxygen gets pumped into an engine.

A turbocharger uses two main parts that work together: a compressor and a turbine. The turbine – powered by exhaust fumes – rotates a compressor fan that sucks in cool air and compresses it, increasing its density and temperature. A heat exchanger chills this hot dense air, and then it's pumped into the car's engine. This means that the engine gets more oxygen than it would without a turbocharger, meaning it can burn fuel at a faster rate. That in turn means more power sent to the wheels.

A more powerful engine means improved performance, and many people associate turbochargers with powerful motors. But these days they're not just found on the fastest supercars. Most manufacturers now use them on standard cars because smaller engines with turbochargers can deliver the same performance as a larger turbo-free engine. This ensures the engine is more efficient and environmentally friendly, which is a big selling point for car companies.

Indeed, if you see a car's model name with an addition like TDI, EcoBoost or even just a D, that usually means it's got a turbocharger inside. Almost every diesel car has a turbocharger, and they're popular on petrol models too. And manufacturers have gone beyond the humble turbocharger to improve performance in pricier, sportier cars. Some have two turbos, which reduces the lag you experience while waiting for a single turbo to activate. Others use superchargers, which deliver compressed air in a different way to a traditional turbocharger.

Did you know?

Formula 1 cars used turbochargers from 1977 to 1989

The turbine in a turbocharger can spin at 150,000 rpm

SUPERPOWERS

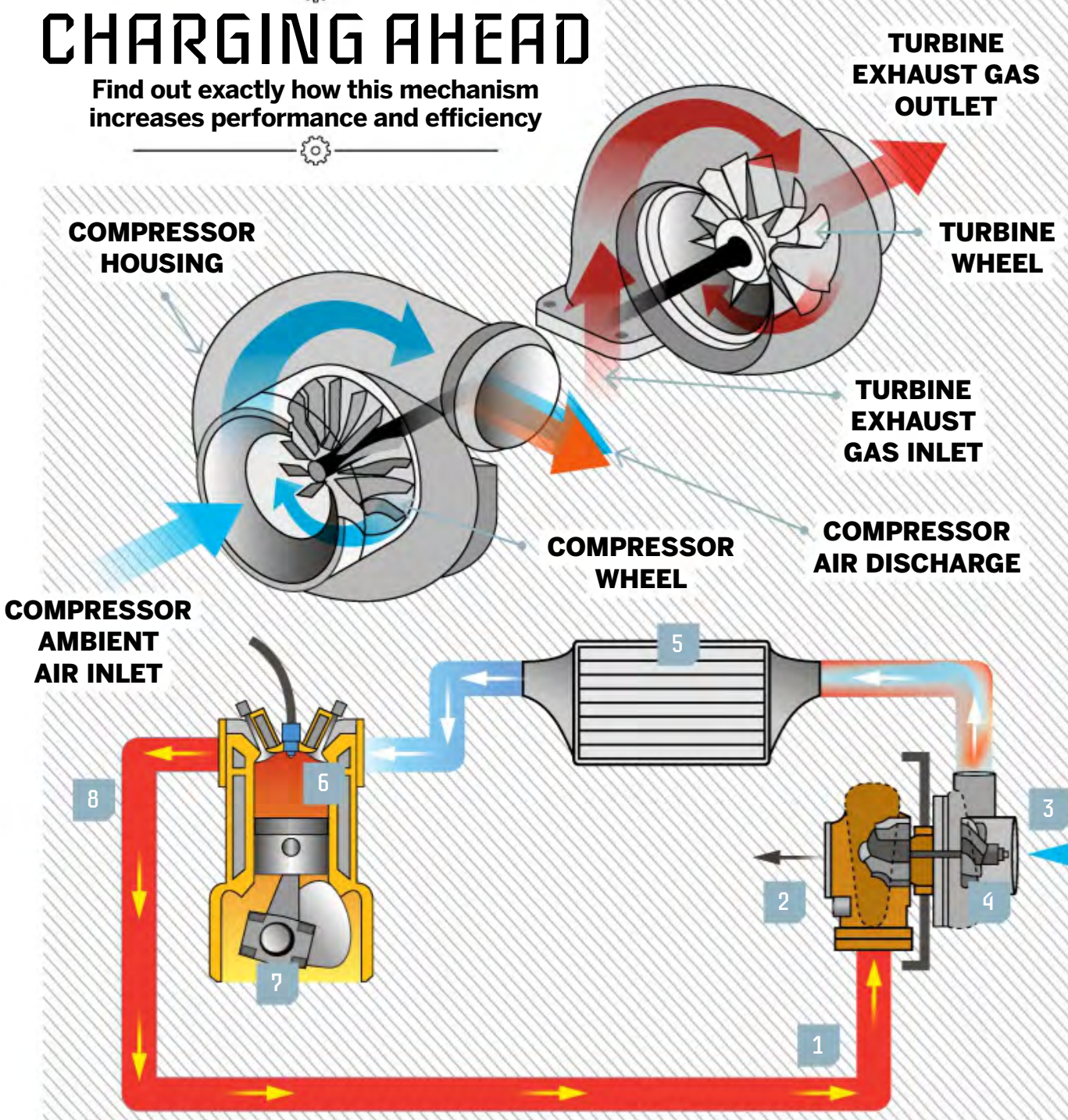
Turbochargers experience a delay between the driver pressing the accelerator and delivering a power boost. This is called turbo lag and is particularly noticeable when your car engine is running at low rpm (revolutions per minute). But a supercharger solves this. Instead of relying on exhaust gas, a supercharger's turbine and compressor are powered by the engine's crankshaft. That's always turning, so you don't have to wait for the charger to start working and you get instant power no matter your rpm level. That immediate power increase is great, but a supercharger isn't a perfect solution. Because a supercharger relies on engine power to function, it means your engine needs to work harder – the entire system is less efficient. This is why superchargers are usually used to deliver more performance rather than improved engine efficiency.

Superchargers rely on power from the crankshaft for an immediate speed boost

DID YOU KNOW? The first two turbocharged cars arrived in 1962: the Chevrolet Corvair Monza and Oldsmobile Jetfire

CHARGING AHEAD

Find out exactly how this mechanism increases performance and efficiency



1 GAS IN
Waste gas from the car's engine funnels towards a turbine. Its kinetic energy rotates the turbine at high speeds.

2 SPINNING AROUND
The turbine spins the compressor, which sucks ambient air into the engine – usually from beneath the bonnet.

3 FEELING THE SQUEEZE
As its name suggests, the compressor takes this ambient air and squeezes it tightly, increasing its density.

4 GETTING HEATED
The compression process agitates the oxygen molecules, so the compressed air heats up.

5 CHILLED OUT
The air needs to be cooled before it reaches the engine, so it passes through a heat exchanger.

6 FEEL THE BURN
The compressed cool air enters the engine's cylinders and helps fuel burn at a faster rate, increasing the engine's output.

7 POWERFUL STUFF
The increased cylinder and piston speed mean that more power reaches the driveshaft and wheels, improving the car's power output.

8 EXHAUSTING WORK
Once that's all done, hot exhaust gases blow past the turbine again on their way out of the car.

> **"Turbochargers are popular for good reason: they improve a car's performance or efficiency"**

PLANES, TRAINS AND AUTOMOBILES

A turbocharger might sound like a modern bit of kit, but they've been around for years. A turbocharger-style device was patented by a Swiss engineer back in 1905 and prototypes initially appeared on aircraft engines by 1915. The first commercial turbochargers were built in 1925 and used on German ships, and that design was then used on railways, other ships and industrial machinery.

After World War II, turbochargers were becoming smaller and more reliable, and they started to appear on trucks and tractors. Turbochargers started to appear on cars in the 1960s and became widespread by the 1980s. And they've been present ever since.

The Boeing B-17 Flying Fortress was the first WWII plane with a turbocharger

Win!

ONE OF TWO AIRFIX BUNDLES

WORTH OVER **£100**

This month we're giving two winners the chance to grab a mystery bundle of Airfix goodies. From the Spitfire fighter aircraft to the Ford Mustang, Airfix is the largest manufacturer of scale model kits in the UK. Each of the mystery bundles will include models from the enormous range of starter kits and brick-based QUICKBUILD models – which ones might you get?

For your chance to win, answer the following question:

How tall is the Empire State Building?

A: 38 METRES **B:** 381 METRES **C:** 3,800 METRES

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

Terms and Conditions: Competition closes at 00:00 BST on 3 October 2022. By taking part in this competition you agree to be bound by these terms and conditions and the Competition Rules: **www.futuretcs.com**. Entries must be received by 00:00 BST on 03/10/2022. Open to all UK residents aged 18 years or over. The winner will be drawn at random from all valid entries received and shall be notified by email or telephone. The prize is non-transferable and non-refundable. There is no cash alternative.

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BRAINDUMP

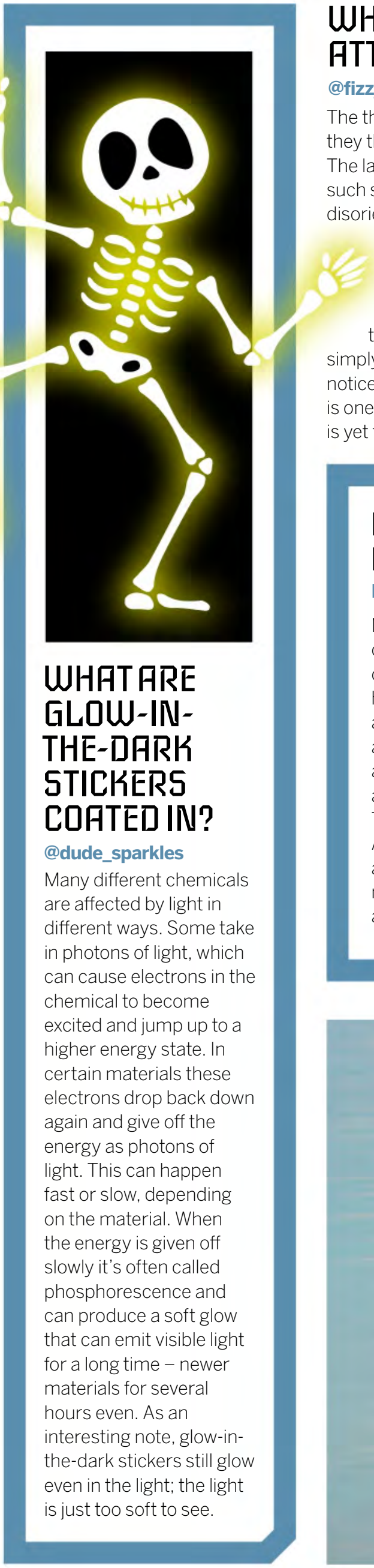
Amazing answers to your curious questions

Did you know?
The first rollercoaster in the US opened in 1884

What is negative g-force?

Alex Harris

If you accelerate downwards faster than the rate of natural free fall, you will experience what is known as a negative g-force. As you accelerate, the liquid in your body – your blood – moves slower than the solid parts of your body due to the inertia of the blood, often resulting in a feeling of weightlessness. Examples would be travelling in a car accelerating over the crest of a hill or riding on a rollercoaster that accelerates downwards. Negative g-forces can result in the blood gathering in your head and giving everything a slight red tinge – something pilots often experience in high-speed dives.



WHAT ARE GLOW-IN-THE-DARK STICKERS COATED IN?

@dude_sparkles

Many different chemicals are affected by light in different ways. Some take in photons of light, which can cause electrons in the chemical to become excited and jump up to a higher energy state. In certain materials these electrons drop back down again and give off the energy as photons of light. This can happen fast or slow, depending on the material. When the energy is given off slowly it's often called phosphorescence and can produce a soft glow that can emit visible light for a long time – newer materials for several hours even. As an interesting note, glow-in-the-dark stickers still glow even in the light; the light is just too soft to see.

WHY ARE MOTHS ATTRACTED TO LIGHT?

@fizzysgirl

The theory that moths fly towards light because they think it's the Moon has never been proven. The latest thinking is that because moths have such sensitive eyesight, lights blind and disorientate them. When a light comes into their field of vision they see it as a donut. When they change course to fly towards the light they are actually trying to fly to the dark spot in the middle. Another theory is that moths aren't attracted to light – it's simply that humans can't see in the dark so only notice moths when they are in well-lit places. This is one of the fundamental scientific questions that is yet to be answered.

ARE ALL ANIMALS IN ANTARCTICA CARNIVOROUS?

Ed Mills

Most animals you think of are carnivores, but there are a lot of herbivores in Antarctica hidden away. Most Antarctic animals, such as penguins, albatrosses and seals, forage at sea where they eat krill, fish and other penguins and seals. There is little vegetation on the Antarctic continent, but there are two flowering plants, some moss and a lot of lichen and algae. Some insects forage on these. However, all life in Antarctica either lives in, or is tied to, the ocean. In the Southern Ocean, the most abundant animals are krill and salps. These graze on plankton – small free-floating organisms such as algae – so there are probably more species of carnivore than herbivore, but in terms of numbers most animals in Antarctica are actually herbivores.

Why do we float in the Dead Sea?

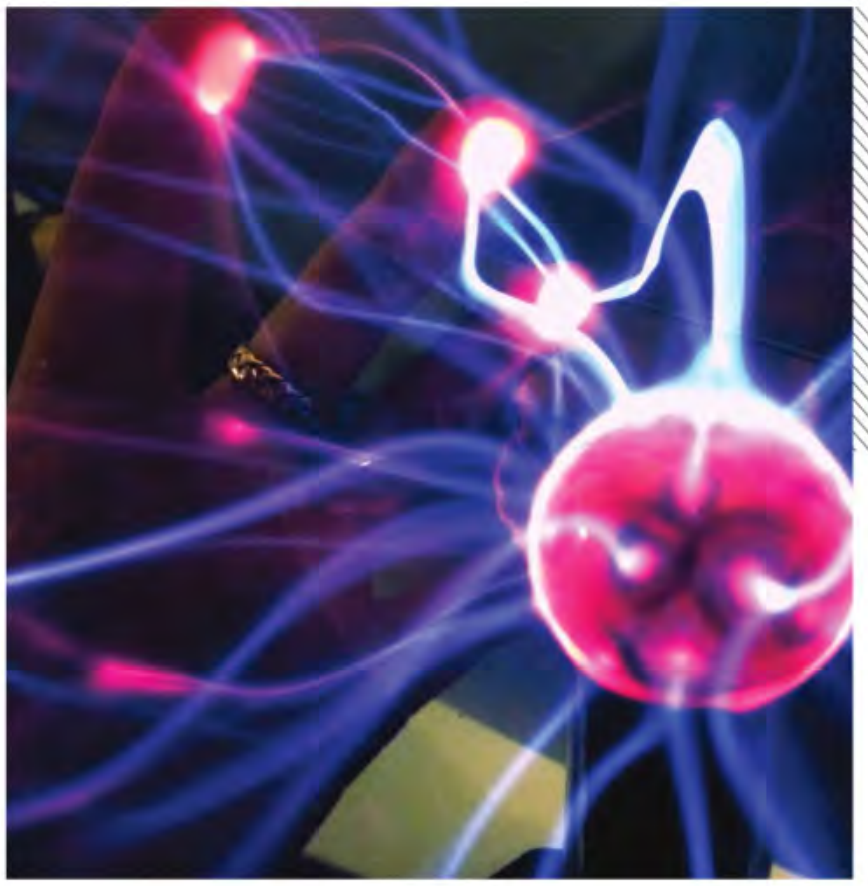
Matthew Mason

The key to this strange phenomenon is the high level of mineral salt within the Dead Sea. In fact, sitting at roughly 31.5 per cent, the Dead Sea has a salinity roughly ten times that of a standard ocean. The consequences of this are twofold: firstly, no water-dwelling creature or plant can survive in the Dead Sea, and secondly, humans can float due to its high density compared to our average mass. Simply put, the Dead Sea's high salt content has the effect of making the human body more buoyant.

HOW IS MAGNETISM MEASURED?

Darryl Deakin

The strength of a magnet is most commonly measured using a magnetometer, also known as a gaussmeter, used to measure everything from Earth's magnetic field to small magnets. A magnetometer consists of a small conductor or semiconductor at the tip of a probe, through which an electrical current is passed. The effect of the magnetic field on the electrons in the conductive material can then be measured. The International System unit for measuring magnetism is the tesla, which measures something called magnetic flux density, but tesla are only really useful for measuring very large magnetic fields. A more suitable way to measure smaller magnetic fields is to use the unit gauss. One tesla equals 10,000 gauss. Earth's magnetic field is about half a gauss, a fridge magnet about 100 gauss and a large electromagnet like that in an MRI machine could be up to 1,500 gauss. There are several factors that affect the results of any measurement, like the distance from the magnet the reading is taken, the magnet's size and whether or not the magnet is attached to anything. A more practical measure of a magnet's strength is to measure how much weight it can lift.



What is an electric arc?

Alan Pooley

When electricity jumps between two conducting electrodes, such as two exposed pieces of wire, it makes an electric arc. The air between the electrodes becomes ionised, allowing electrons to jump across and create a visual 'bridge'. An electric arc can produce high heat and a powerful light, making it useful in areas such as welding. Lightning is an example of a naturally occurring electric arc; the atmosphere is ionised and creates the visual spectacle.

COULD WE RESTOCK THE OCEANS BY RELEASING FISH BRED IN CAPTIVITY?

Leon Briggs

Demand is for apex predators such as salmon and tuna, high up in the food chain. But they require a lot of food made from other marine fish, which means further depletion of wild fish stocks. Fish farms encounter the problems of any intensive monoculture where individuals of a species are crammed together: disease and pollution. There is evidence that farmed fish spread diseases to wild populations, have a damaging effect on the genetics of wild fish stocks through interbreeding and that they are less able to survive in the wild. There's also environmental damage, so it looks as if marine fish farming may be more of a threat to wild fish stocks.

WHY DOES WD-40 STOP HINGES SQUEAKING?

Derek Smith

WD-40 stands for Water Displacement 40th attempt. It was designed for preventing corrosion by displacing the water that causes it. It was first used to protect missiles from corrosion and became commercially available in 1958. WD-40's ingredients are a secret; the makers avoided revealing its ingredients by not filing for a patent, but it's known to consist of oil suspended in a volatile hydrocarbon. When WD-40 is sprayed, the suspended oil can get into crevices where the hydrocarbon evaporates, leaving behind the oil lubricant. Every surface has some degree of imperfection at the molecular level. The long hydrocarbon chains in oils and grease serve to provide a layer between the two surfaces and help them move over each other easily. WD-40 wasn't designed as a lubricant, so isn't the best to use on fast-moving mechanical parts.

Why do elephants have a trunk and a mouth?

Brian Holmes

The answer is nearly as simple as the reason you have a nose and a mouth: the trunk is a bit like an extended nose – and top lip – and noses and mouths do quite different things. The mouth of an elephant is mostly for chewing and swallowing. It contains the teeth and the tusks if they have them – these are incisor teeth that grow so long that they stick out of the mouth either side of the trunk – and also the tongue.

The trunk, on the other hand, is used for lifting, grasping, smelling, throwing dust over themselves, smacking baby elephants, making a noise, creating a shower, greeting other elephants and breathing, as the nostrils run all the way up inside it. When eating and drinking, the trunk and mouth are both used, but for different purposes. The trunk selects and prepares the mouthful and then passes it to the mouth for chewing and swallowing. Also, elephants do not drink through their trunks any more than you could drink through your nose. Instead the trunk sucks up the water, holding up to perhaps ten litres, and then blows the water into the mouth for swallowing. Elephants have a trunk and a mouth because they need both.

Did you know?
You can tell elephant species apart by their ears

WHY DO DRINKS FIZZ UP WHEN THEY HIT THE GLASS?

Jimmy Cook

Carbonation is the process of dissolving carbon dioxide (CO_2) in water (H_2O), enhancing the taste and texture of fizzy drinks. It was first discovered by English chemist Joseph Priestley in the late-18th century when he invented soda water. The result is usually carbonic acid (H_2CO_3), which gives fizzy drinks a slightly acidic taste, or 'bite'. When the drink is bottled it is pressurised from the gas. However, CO_2 is poorly soluble in water. When you open the bottle, CO_2 is quickly released, therefore releasing the pressure, producing fizz and a hissing noise – this is called effervescence. Shaking the bottle or pouring the liquid will speed up the release of CO_2, making the drink fizz even more. It's only a matter of time before your drink is completely flat, so drink it quick.

WHY IS THE SEA SALTY?

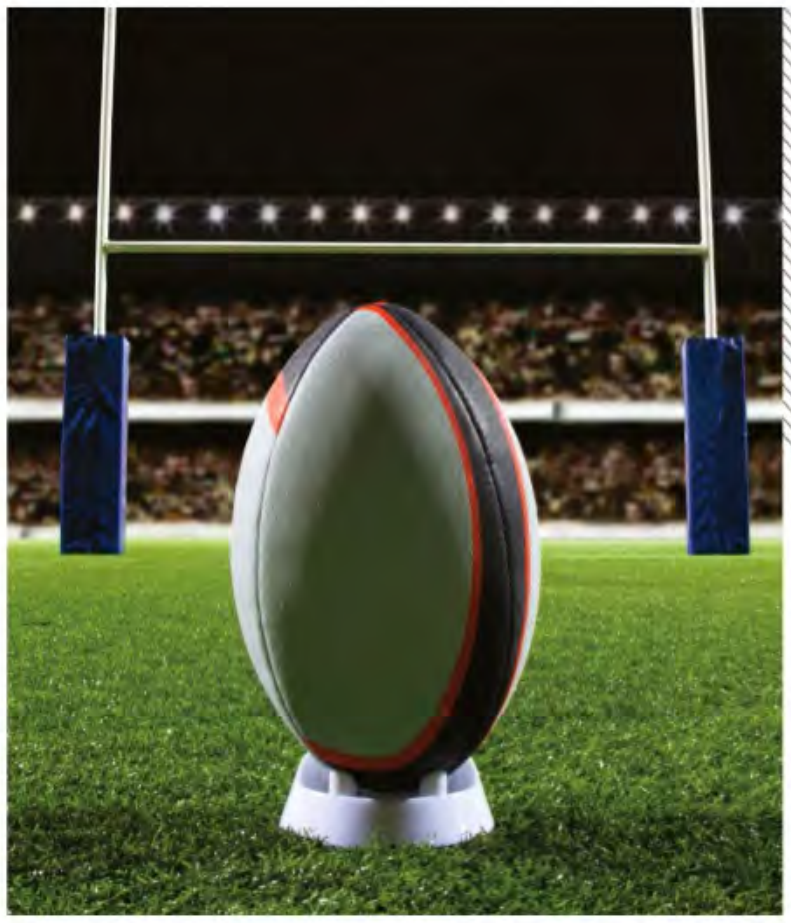
Paul Minchin

Undersea volcanoes on mid-ocean ridges and hydrothermal vents release metallic and non-metallic ions – which together make salts – into the deep ocean. Rainwater, which is slightly acidic, erodes rocks on land, dissolving mineral ions and carrying them to the sea in rivers. Also, winds blow dust containing minerals off the land and into the sea. The water cycle is completed when water is evaporated from the sea surface to form rain clouds, but the salts are left behind in the ocean. After hundreds of millions of years' accumulation, the result is an average of about 3.5 per cent salinity for seawater worldwide. The fact that this degree of saltiness remains relatively stable is due to the fact that salts are also being taken out of solution by marine animals, in seafloor sedimentary rock formation and tectonic subduction. It has been calculated that the ocean contains 5.5 trillion tonnes of salt – enough to cover the entire planet to a depth of 45 metres.

WHY DO PIGEONS BOB THEIR HEADS WHEN THEY WALK?

Claire Proctor

The head-bobbing walk of pigeons has prompted many theories over centuries. Many authors have believed that, like a crank, there must be a physical connection between the bird's head and feet. But perhaps the truth is stranger than folktales, as the bird is believed to use head bobbing to boost its eyesight, particularly as an aid in judging distances. Birds with sideways-looking eyes don't have the benefit of stereo vision, so looking at the world from a single point of view seems very flat. But by bobbing their heads the birds are able to compensate for monocular vision by observing the world from slightly different positions, helping with depth perception. This will boost the attributes necessary for survival: finding food and avoiding predators.



Why are rugby balls oval, not round?

Kyle Moran

The rugby ball was not always oval shaped. Early rugby balls were made out of inflated pig's bladders, encased in leather and hand-stitched. The smelly bladders had to be inflated by lung power alone, and therefore the balls varied in size – they were more plum-shaped than oval. In 1870 Richard Lindon invented an inflatable rubber bladder and a brass hand pump. Because of the stretchy rubber, the shape gradually changed from a sphere to an oval. Over the years, the shape has changed slightly to make the ball more streamlined for passing and easier to hold.

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The latest book releases for curious minds

THE RED PLANET

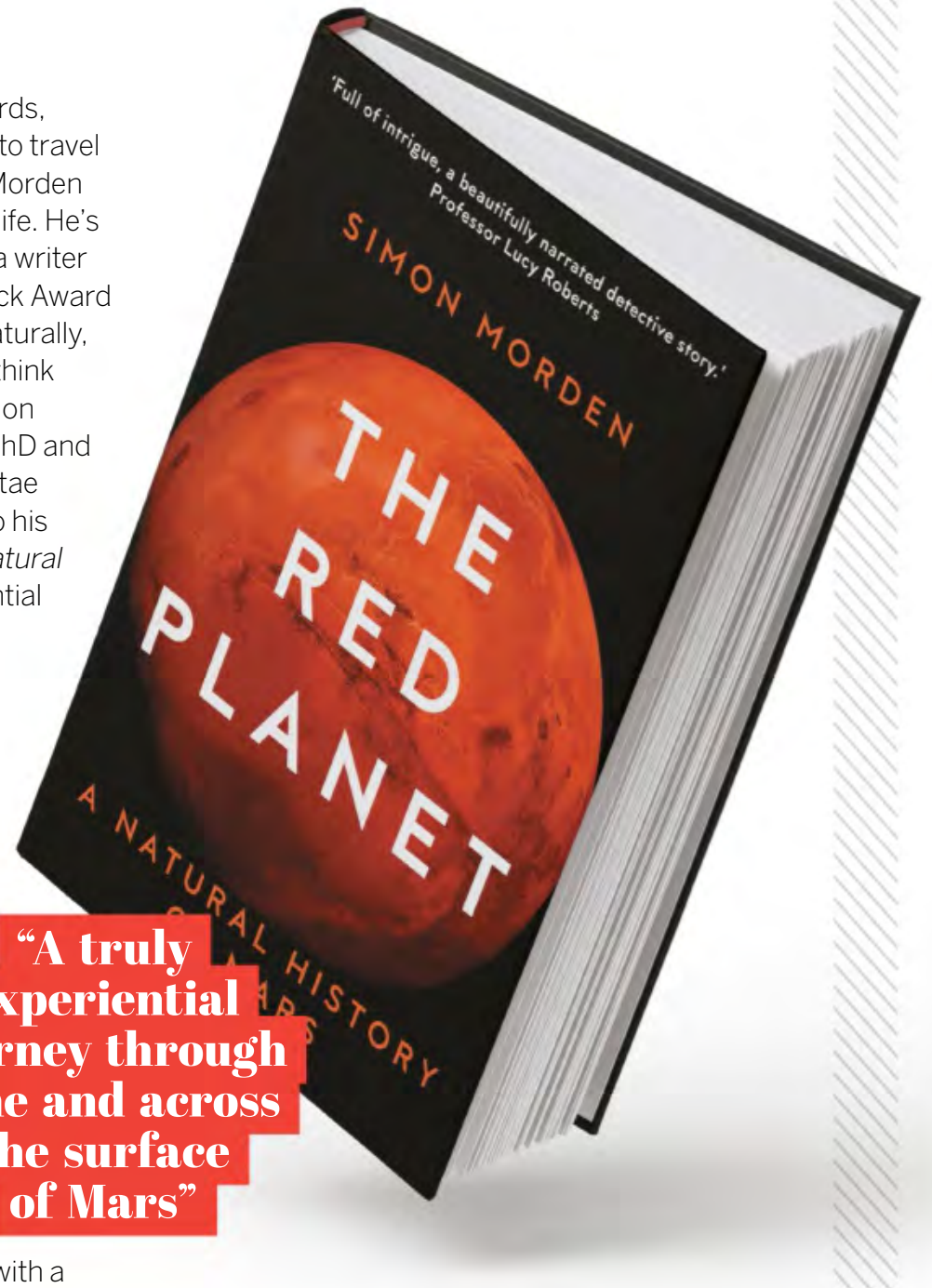
GO ON A TOUR OF MARS

AUTHOR **SIMON MORDEN**
PUBLISHER **ELLIOTT & THOMPSON**
PRICE **£14.99 / $26.95**
RELEASE **OUT NOW**

For a man who, in his own words, realised he was never going to travel to space, author Dr Simon Morden has made much of his lot in life. He's a planetary geologist and geophysicist, a writer who has won the prestigious Philip K. Dick Award for his fictional series Metrozone and, naturally, he's a science fact writer too. We like to think that after the success of his science-fiction novels, Morden wanted to lean into his PhD and redress the balance on his curriculum vitae with something both factual and close to his heart. The result is *The Red Planet: A Natural History of Mars*, which is a truly experiential journey through time and across the surface of Mars.

The Red Planet is split into a loose chronology of the history of Mars, from its formation through to the present day and into the future, detailing the many mysteries that still baffle planetary scientists today: what happened to the former volcanism on Mars, where did all the water go and why is the northern half of the planet flat and significantly lower than the rugged southern half? Morden poses the question and offers possible answers – or at least stepping stones to a possible answer – with a level of insight that only an expert could respond with. Has life ever existed on Mars or will we ever find evidence of it in the extreme Martian environment? He answers this by querying the inevitability of life: if it is simply a matter of the right environment, then yes, Mars once had life.

But for all his credentials as a scientist, it's Morden's pedigree as a science-fiction author that sets *The Red Planet* apart from the myriad of other tomes on the natural history of Mars. He switches much of the heavy terminology out for metaphor, stitching sections together with an easy, flowing narrative punctuated by vivid chapters that let you peer through the porthole of a spacecraft onto ancient lava fields, sail across a Martian ocean or drive a buggy across a chilly icescape. It's as much about imagination and artistic license as it is established fact and expert opinion, so step aside dry textbooks and jargon-stuffed research papers, *The Red Planet* is a benchmark in digestible space education for the masses.



"A truly experiential journey through time and across the surface of Mars"

BE THE CHANGE: BE KIND

RISE UP AND MAKE A DIFFERENCE TO THE WORLD

AUTHOR **MARCUS SEDGWICK**
ILLUSTRATOR **THOMAS TAYLOR**
PUBLISHER **OCTOPUS BOOKS**
PRICE **£10.99 / $14.99**
RELEASE **OUT NOW**

The concept of kindness is a large mountain to climb. However, award-winning author Marcus Sedgwick has attempted the ascent in this rousing children's guide. After setting out the basics of what it means to be kind – and a few ethical quandaries for self analysis – Sedgwick fills the pages of this thought-provoking activity book with big concepts in the philosophy of kindness.

From examples of extreme altruism to antithetical egoism – two very different forms of kindness – Sedgwick lays out the work of great philosophical minds throughout history for a young audience that's still understanding how the world works.

There is an apparent 'rise-up' spirit throughout the book, intended to inspire the next generation to be empathetic and compassionate to others. As an activity book, this may make a useful toolkit for home readers, or could be utilised in a classroom environment to explore and discuss what it means to be kind.

WEATHER, CAMERA, ACTION

A METEOROLOGIST'S GUIDE TO THE SKY

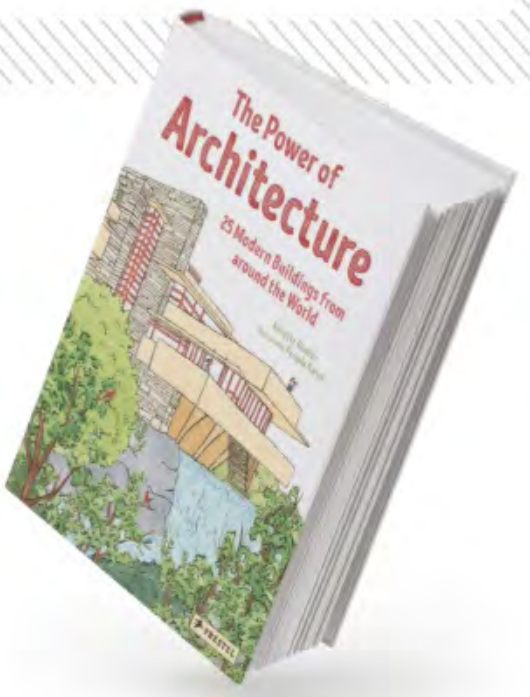
AUTHOR **LIAM DUTTON**
ILLUSTRATOR **GIORDANO POLONI**
PUBLISHER **TEMPLAR PUBLISHING**
PRICE **£16.99 (APPROX. $20.50)**
RELEASE **29 SEPTEMBER**

As a weather presenter for Channel 4 News, author and meteorologist Liam Dutton has had nearly two decades of experience in explaining the weather. This comes across in his expert narration of global weather for children. Throughout *Weather, Camera, Action*, Dutton is cartoonified and placed in extreme weather locations as his character navigates the world. Encountering dust storms, hurricanes, volcanic lightning and much more, this whirlwind of an adventure is set to amaze. Have you ever wondered what the rarest clouds to spot are? Did you know that light-scattering sandstorms create vivid sunsets or that the longest tornado raged for four hours straight? This will likely answer all your weather-related questions in the form of fast facts, weather record-breakers and top tips to control the climate.

Complementing the text, engaging diagrams and illustrations explain the science behind each phenomenon. The weather can vary drastically, so each page is carefully illustrated with a new theme and colour, achieving smooth transitions between sections. From daily weather patterns to out-of-control events, young readers will gain a new appreciation for our planet's moods, the human relationship with the weather and the interconnected Earth.

THE POWER OF ARCHITECTURE

25 MODERN BUILDINGS FROM AROUND THE WORLD



AUTHOR **ANNETTE ROEDER**
ILLUSTRATOR **PAMELA BARON**
PUBLISHER **PRESTEL PUBLISHING**
PRICE **£14.99 / $19.95**
RELEASE **20 SEPTEMBER**

Many of the world's most famous buildings are centuries old. The stories that can be told about a building this long-standing are fascinating, but what about newer builds? *The Power of Architecture* explores some of the most modern architectural designs from a range of countries across the world while explaining their features and purpose to children.

Each unique building covers a double-page spread to display its magnificence, with illustrations that provide a detailed vision of its architecture. A good example of this is Munich's Olympic Stadium, which is designed to create a mountainous appearance among the trees with its pointed tent covering. This can even be scaled by mountaineers with climbing equipment and ridden down on a zip line. The other 24 architectural pieces include a historic memorial for persecuted witches in Norway, a futuristic building that optimises natural light and several pioneering buildings built for entertainment with sustainability in mind.

Whether they're built far off the ground, underground or even on waterfalls, as you turn the pages it's impossible to predict which innovation will greet you next. Towards the back of *The Power of Architecture*, an illustrated timeline places the builds in chronological order of their completion, leaving you wondering what architectural marvel is next.

THE SCIENCE OF OUR CHANGING PLANET

FROM GLOBAL WARMING TO A SUSTAINABLE DEVELOPMENT

AUTHOR **TONY JUNIPER**
PUBLISHER **DORLING KINDERSLEY**
PRICE **£9.99 / $14.99**
RELEASE **OUT NOW**

In a time of social media perpetuating untruths and 'alternative facts' about the state of the world and its changing climate, this book is the informative light at the end of the tunnel. From the overpopulation problem and consumer demands to anthropogenic climate change and the consequences of biodiversity, this book leaves no environmental issue unturned.

Each page is packed with stats and facts about a whole host of topics, presented in creatively comprehensive infographics and diagrams. Although this is hardly an afternoon read with tea and biscuits, what *The Science of our Changing Planet* does offer is an encyclopaedic reference book to keep you in the know about how the planet is being altered by the people that live on it. One of the biggest takeaways from this book is the call to arms for sustainability and the achievement of global goals to conserve Earth.

"This book leaves no environmental issue unturned"

BRAIN GYM

Give your brain a puzzle workout

Sudoku

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

EASY

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

MEDIUM

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

HARD

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

Word search

Find the following words

VULCAN
WONDER
ATOM
DRONE
GRASS
MIRROR
ACID
ENERGY
SKIN
TURBO
COMPUTER
ASAT

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

What is it?

Hint: The fruit of a common flower

A

Spot the difference

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

Answers

Find the solutions to last issue's puzzle pages

Q1 600 LIGHT YEARS
Q2 PAW PADS
Q3 NONE OF THEM
Q4 64 MILLION
Q5 THREE MONTHS
Q6 J

What is it?

FINGER CUTICLES

Spot the difference

QUICKFIRE QUESTIONS

Q1 Which of these elements is liquid at room temperature?

- Oxygen
- Gold
- Hydrogen
- Mercury

Q2 Which of these animals has no brain?

- Starfish
- Earthworm
- Pigeon
- Ant

Q3 Why does Italy's Leaning Tower of Pisa lean?

- Its foundations are weak
- It's a marketing ploy
- An earthquake moved it
- It's a slim tower

Q4 What was the first animal to be sent into space?

- Dog
- Cat
- Chimpanzee
- Fly

Q5 How much was the world's biggest speeding fine?

- $1,000
- $10,000
- $100,000
- $1,000,000

Q6 Which power plant releases the most radiation?

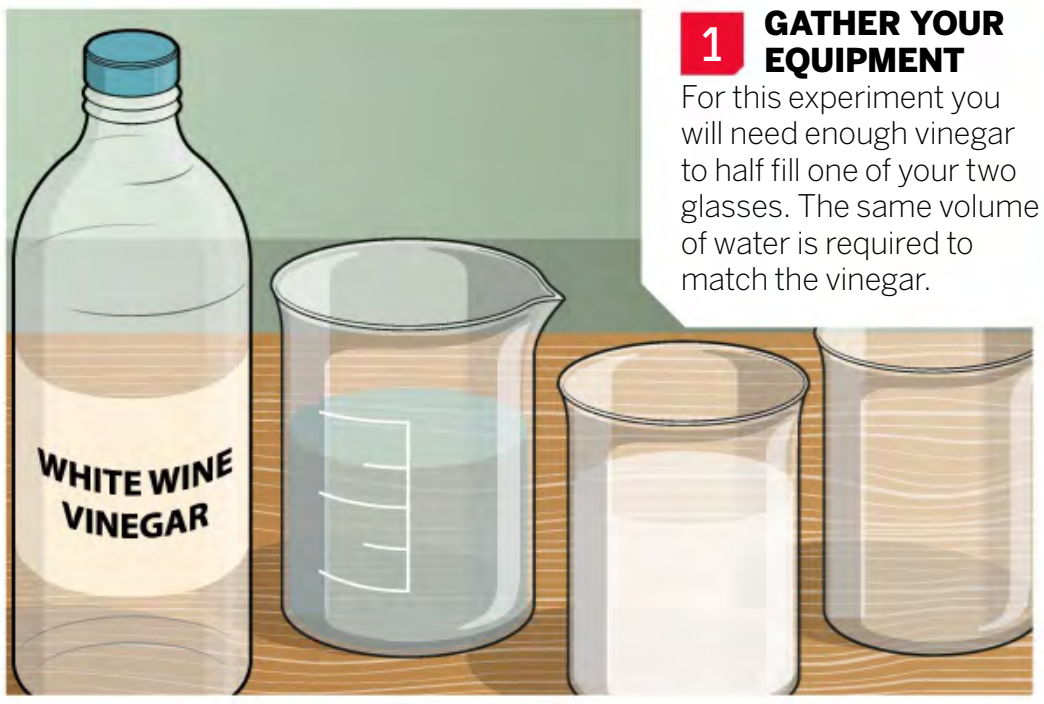
- Nuclear
- Coal
- Gas
- Hydroelectric

HOW TO...

Practical projects to try at home

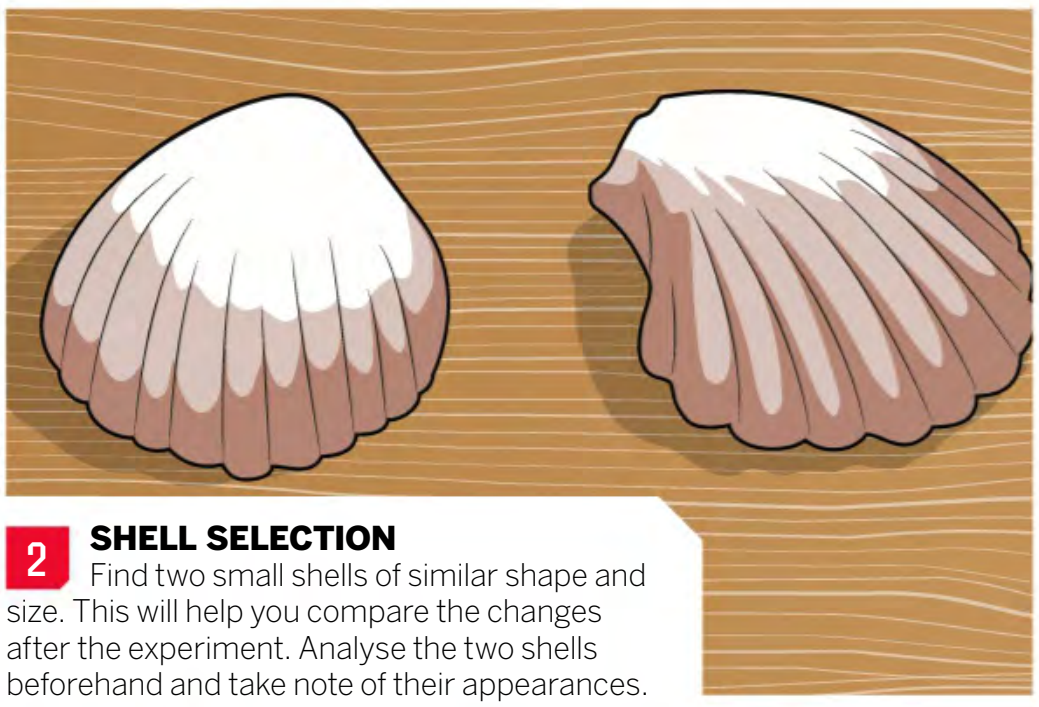
TEST FOR OCEAN ACIDIFICATION

Watch as seashells vanish before your eyes



1 GATHER YOUR EQUIPMENT

For this experiment you will need enough vinegar to half fill one of your two glasses. The same volume of water is required to match the vinegar.

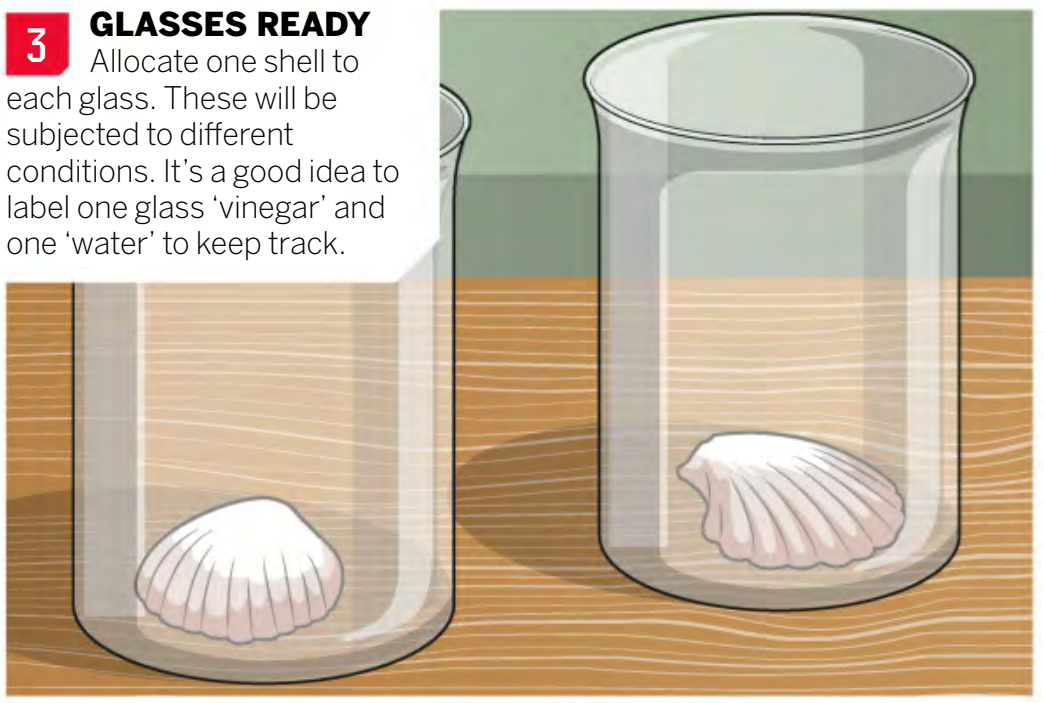


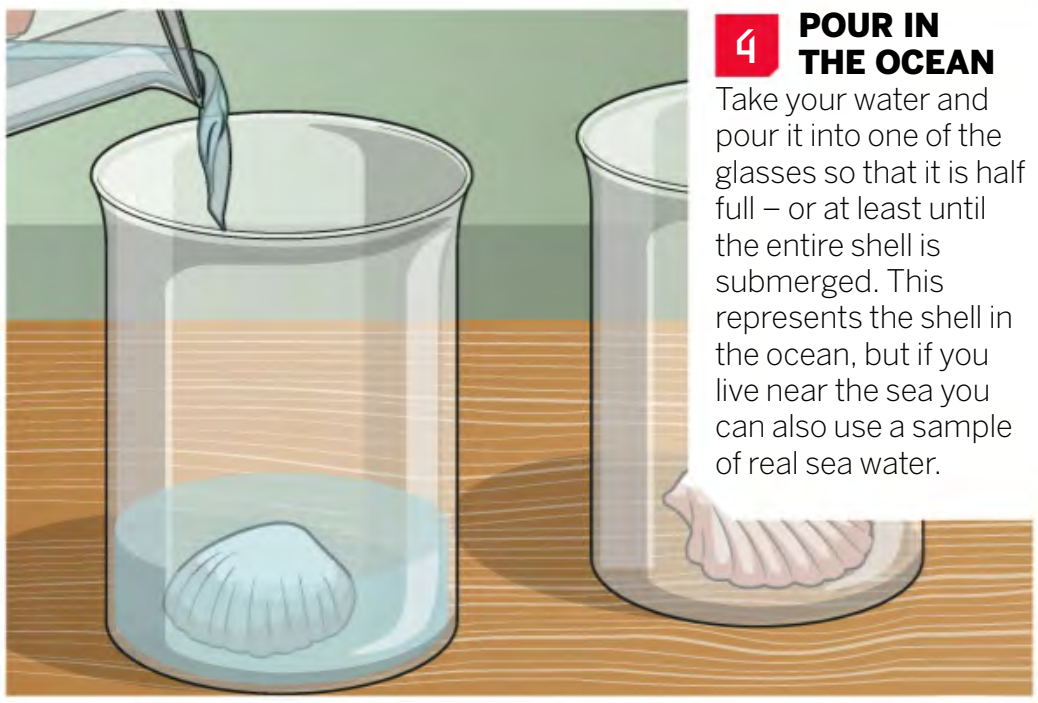
2 SHELL SELECTION

Find two small shells of similar shape and size. This will help you compare the changes after the experiment. Analyse the two shells beforehand and take note of their appearances.

3 GLASSES READY

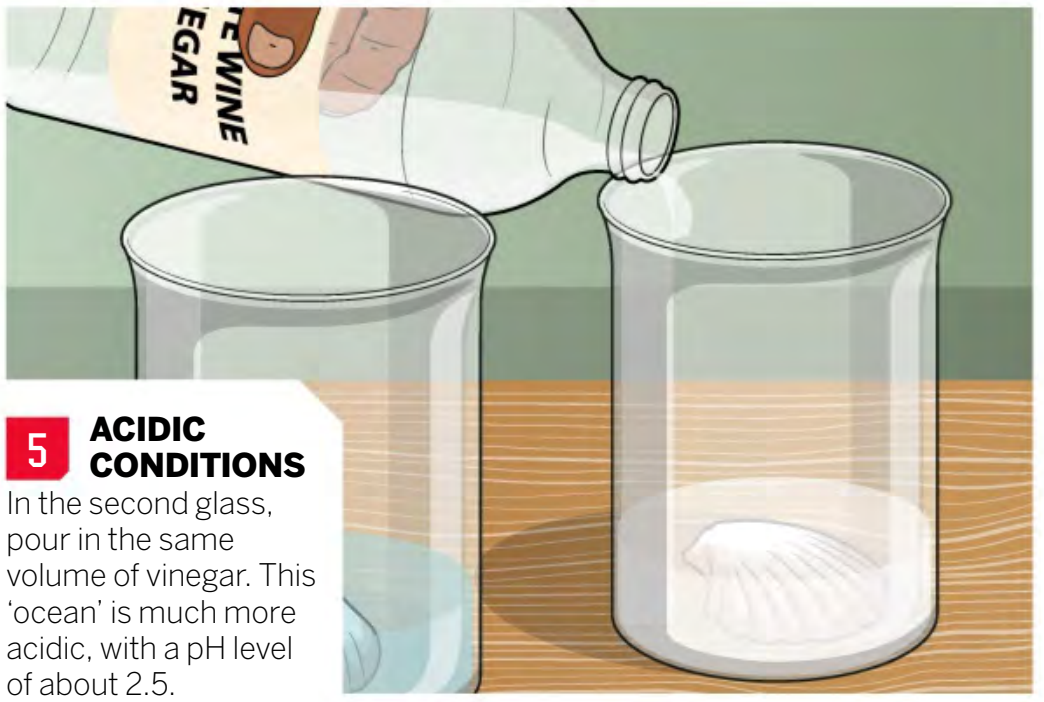
Allocate one shell to each glass. These will be subjected to different conditions. It's a good idea to label one glass 'vinegar' and one 'water' to keep track.





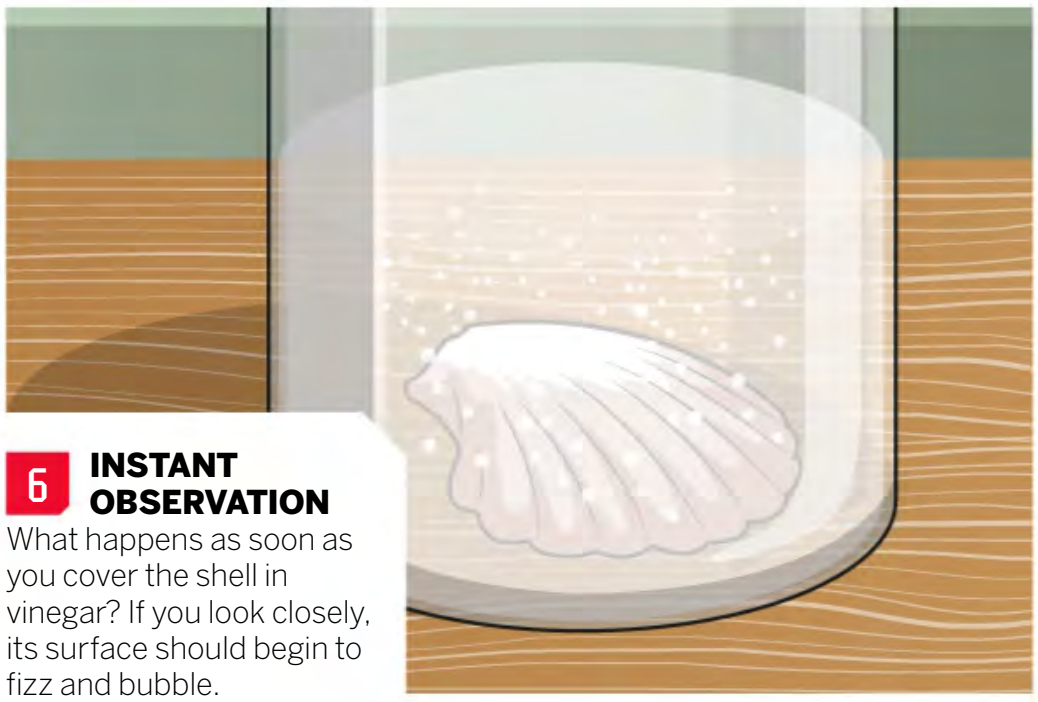
4 POUR IN THE OCEAN

Take your water and pour it into one of the glasses so that it is half full – or at least until the entire shell is submerged. This represents the shell in the ocean, but if you live near the sea you can also use a sample of real sea water.



5 ACIDIC CONDITIONS

In the second glass, pour in the same volume of vinegar. This 'ocean' is much more acidic, with a pH level of about 2.5.



6 INSTANT OBSERVATION

What happens as soon as you cover the shell in vinegar? If you look closely, its surface should begin to fizz and bubble.

NEXT ISSUE
MAKE YOUR OWN ICE-CREAM IN A BAG

KIT LIST

- Two seashells of similar size
- Two clear glasses
- Water
- White vinegar

DON'T DO IT ALONE!

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

7 MONITOR CHANGES

After a day, or even a few days, the shell in the water shouldn't have changed much in appearance. Make note of what it looks like after a few hours, a day and so on.

8 ACIDIC DESTRUCTION

What happens to the shell in vinegar after a few hours, a day and a few days? You should be able to see subtle deterioration, with the shell eventually dissolving and turning the vinegar cloudy as it disappears completely.

SUMMARY

The shells in this experiment are made of calcium carbonate. The acetic acid in the vinegar reacts with the shell to break up calcium carbonate, forming bubbles of carbon dioxide. This gas is released from the carbonate, while calcium is released into the water. This process is harmless when contained within a small glass, but what if this happened on an ocean-wide scale? As more carbon dioxide is released into the atmosphere by global warming, the concentration of the gas that's dissolved in ocean water increases. This decreases the water's pH over time, meaning that it becomes more acidic.

For sea creatures that depend on these shells to use as their homes, drastic changes in ocean acidity have catastrophic consequences on their rate of survival. Just as your seashell was weakened by the vinegar and eventually vanished inside the glass, these animals' homes simply wouldn't be able to exist in highly acidic conditions.

Had a go? Let us know!

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

INBOX

Speak your mind

ASK ABOUT ALLERGIES

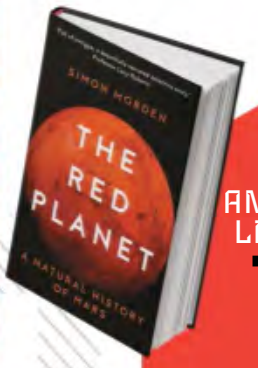
Dear **HIW**,
My friend is severely allergic to nuts, and it sounds like a really common allergy. Why has this allergy become so common?
Eoghan Dillon

For some, eating nuts results in rashes or swelling of the mouth and throat

LETTER of the MONTH

This question is an interesting one, and scientists are currently looking for answers. In the West in particular, allergies have generally been on the rise in the last few decades, with two per cent of adults in Europe reported as having food allergies. In 2016, there were five times as many people in the UK with peanut allergies in particular compared to 1995. Because allergies are more likely in western, urban countries, some of the possible contributors include pollution, less encounters with microbes and the significant evolution of diets.

Allergies in general may be increasing because with less pathogenic infections to fight against, the body is more likely to begin fighting usually harmless substances such as nuts. Nuts – and peanuts, which are technically legumes – are common allergies due to their protein content. Their proteins bind more easily to the immune system's antibodies than the contents of other foods, triggering higher numbers of allergic reactions. In many countries, diets have included more fats and oils from foods like nuts in recent years. As the prevalence of these foods increases, so do incidences of allergic reactions.



WIN!

AN AMAZING PRIZE FOR LETTER OF THE MONTH

THE RED PLANET

Piecing together the latest research, theories and informed speculation, *The Red Planet* is as close as we can get to an eye-witness account of this incredible place

NAIL-PAINTING CHEMISTRY

Dear **HIW**,
I was taking off my nail polish today and wondered why it is so difficult to get off. What chemicals are in nail polish and what is in the remover?
Cat Jamieson

The chemistry of nail polish is more complex than it may seem when you are painting your nails. As it dries, a film forms over the surface of the nails. A polymer in the polish – most commonly nitrocellulose – is dissolved in the solvent when it is wet, but after removing nail polish from its bottle and spreading it thin onto the nails, the solvent evaporates and the polymer film forms.

The easiest way to remove nail polish is to buy a bottle of nail polish remover. In this liquid is a chemical called acetone. Made up of carbon, hydrogen and oxygen, this organic solvent is colourless and highly flammable. It replaces the solvent that evaporated and works to break apart the nail polish and return it to a liquid that can be lifted from the nails.

Although acetone-based removers work well to remove nail polish, they can be harsh on the nails due to their strength, making nails feel dried out. Other effective removers include ethyl acetate and butyl acetate.

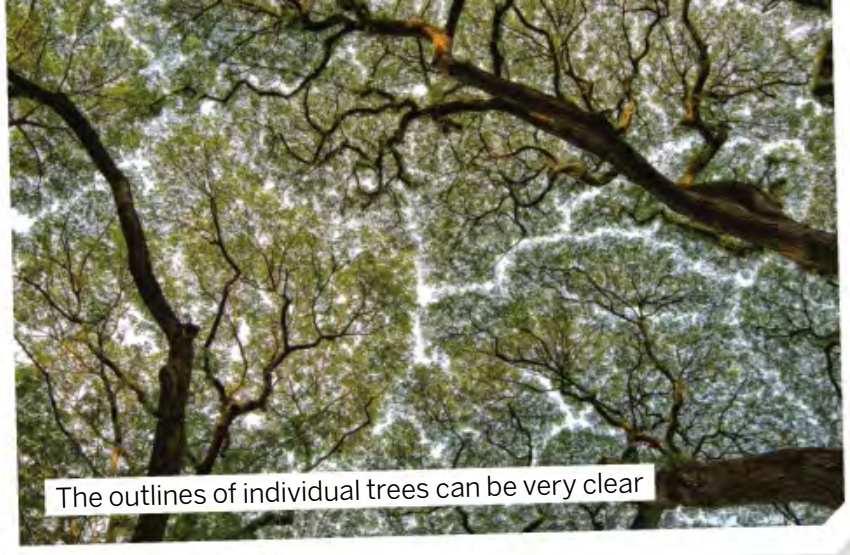
Acetone removers are made up of chemical compounds benzene and propylene

GREENPEACE VOYAGE

Dear **HIW**,
Greenpeace is mentioned sailing through the Weddell Sea in **HIW 161**, and I'm wondering what engines their vessel MV Arctic Sunrise has on board. If they're running on diesel this makes them out to be hypocrites as they're supposed to be caring for the planet.
Michael H

We featured a news story about a colony of Gentoo penguins discovered by scientists aboard the MV Arctic Sunrise, powered by a single MaK marine diesel engine. The ship was built in 1975 and bought by Greenpeace in 1995. Since then, Greenpeace has considered energy usage more for newer ships, such as the Rainbow Warrior III, which uses wind power.

MV Arctic Sunrise was once a seal hunting vessel



The outlines of individual trees can be very clear

BRANCHING OUT

Dear **HIW**,
Trees have an amazing ability when growing branches to avoid branches that are already there. How do they do it?
Stephen C

A tree's branches grow towards the light, and they usually avoid areas that will leave their leaves in the shade. Branches, which are usually covered in shade-creating leaves, are therefore avoided as the trees expand into open spaces. Trees are also able to sense nearby plants by picking up on far-red light that bounces from other branches. In some instances, forest canopies display light borders where branches and leaves of trees have actually stopped growing to prevent collisions with other plants. This phenomenon is called crown shyness. One theory for how this occurs is due to the wind making trees blow against each other. To prevent further damage to the branches' flowers and leaves, their growth in these areas is slowed or stopped.

Illustration of the varicella-zoster virus

LINGERING CHICKEN POX

Dear **HIW**,
How does chickenpox reappear as shingles decades later?
Merle Ann

Chickenpox remains dormant in the body's nervous system. If your immune system becomes weakened, the chickenpox virus (varicella-zoster) can be reactivated and travels down the body's nerve pathways, reaching the skin in the form of a painful rash. Not everyone who has had chickenpox will get shingles, and it's unclear exactly why people do. However, it's most common in older people with weak immune systems.

WE ASKED YOU

This month on social media, we asked you: which animal do you think has the most impressive home?

@SONEW.O_O
Diving bell spider

@NEKONOYUREII
Seahorse

@CYRUSTHEVIRUS_YEET
Humans

@FATEMEH.JINYOUNG
Beavers

@MERLE.HAHA
Cheese mites! Imagine living in your favourite cheese and snacking as you go around the house

@MAIA_H3
Honeybee or weaverbird

@DOODLENEWS
Termites! Their mounds are like mini monuments that take years to perfect

HOW IT WORKS

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FAST FACTS

Amazing trivia that will blow your mind

4,000 YEARS OLD

The oldest pasta discovered was noodles found in a sealed bowl in northeast China

13,171 MILES

The Great Wall of China took around 20 years to complete and spans over 13,000 miles long

70 MILLION YEARS AGO

Grass first appeared on Earth just before the dinosaurs disappeared

DRONES HAVE BEEN BANNED FROM US NATIONAL PARKS SINCE A TOURIST CRASHED ONE INTO A HOT SPRING

TWO

Children under the age of 24 months usually don't recognise themselves in a mirror

15%

Your skin is nearly one-seventh of your body weight

139 METRES

For nearly 4,000 years the Great Pyramid of Giza was the world's tallest construction

47,000 miles per hour

The Atlas V rocket set a new speed record when it launched in 2006

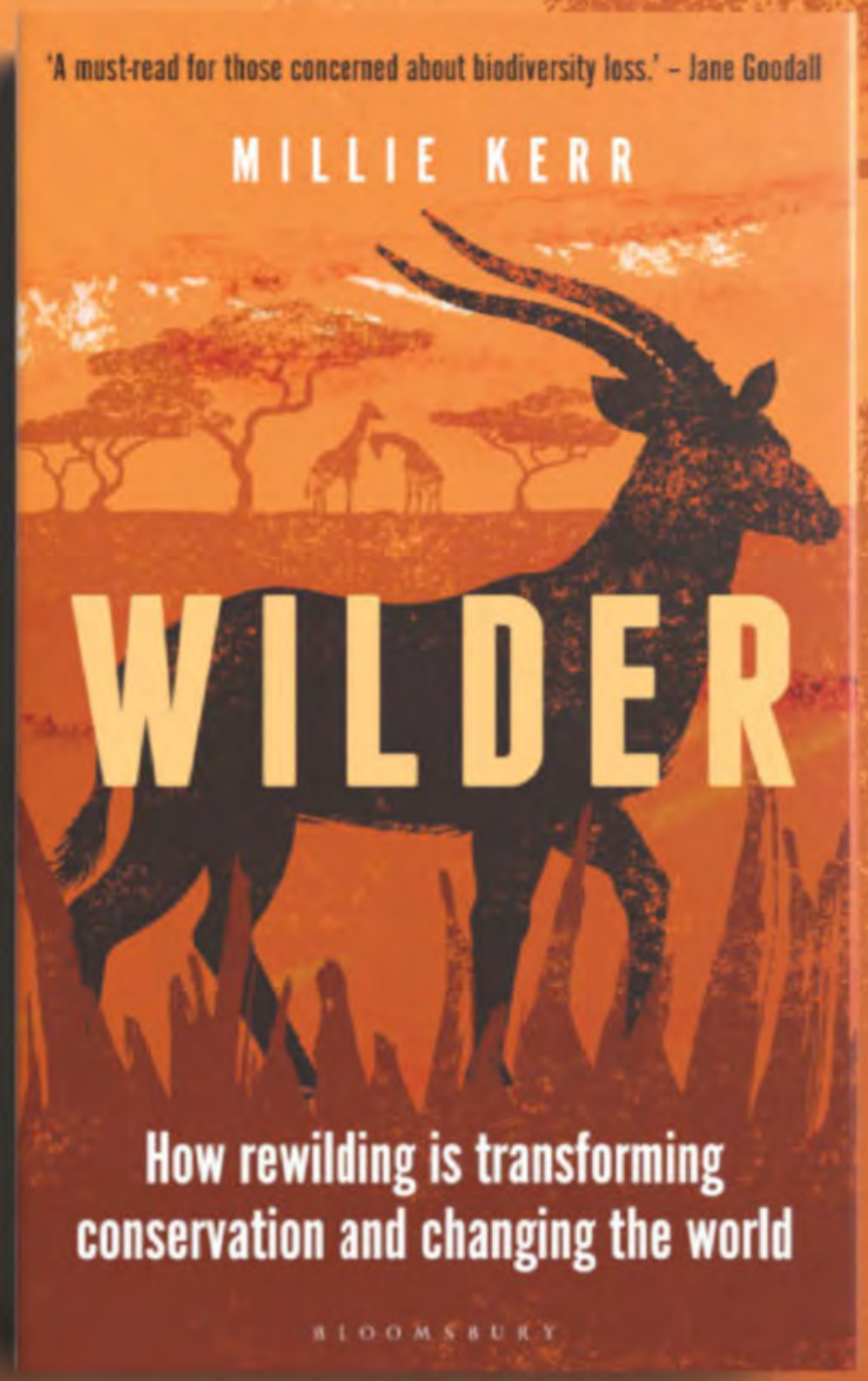
THE WORD 'ASTEROID' COMES FROM THE GREEK WORD FOR 'STAR-SHAPED'

Adolf Hitler's nephew, William, was born in Liverpool and strongly opposed his uncle

657,019

The biggest oil tanker in the world weighed over half a million tonnes fully loaded

TAKE THE NEXT STEP IN CONSERVATION AND HELP CHANGE THE WORLD



'A must-read for those concerned with biodiversity loss.'
Dr Jane Goodall

'*Wilder* is essential reading for anyone interested in the future of conservation.'
Lucy Cooke

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Dominic Truman,
Agricultural Service Technician

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