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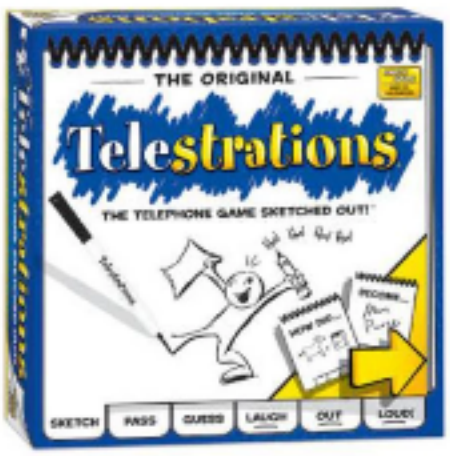

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ISSUE 130

WELCOME

The magazine that feeds minds!

"Planes before this felt like an old movie. Now, it is like living in a Star Wars reality"

How to build a fighter jet, page 22

Meet the team...

James
Production Editor
Is it really possible to build a colossal lift that will take us from the Earth's surface into geostationary orbit in space? Find out on page 80.

Scott
Staff Writer
Discover how some symbiotic relationships in the animal kingdom aren't as mutually beneficial as they seem on page 64.

Baljeet
Research Editor
Discover how incredibly versatile the element carbon is and how it holds the key to almost all life on Earth on page 34.

Jon
Art Editor
As one of the most tragic maritime disasters, find out how the 'unsinkable' Titanic ended up at the bottom of the ocean on page 42.

Ailsa
Staff Writer
Today, photography provides us with instant images, but this wasn't always the case. Check out the first instant camera on page 54.

This issue we've been lucky enough to have been taken around a huge factory in Texas: one that builds F-35 fighter jets. These advanced air-combat vehicles are popped out by the dozen in Lockheed Martin's impressive, hi-tech, and high-security Fort Worth facility. But you can find out exactly how they're made, step by step, on page 22. Also, some of our pages in this 10th anniversary issue of **How It Works** are augmented reality-enabled. Just download the app from page 4, follow the instructions and keep an eye out for the AR logo in each feature. Enjoy!

Ben Biggs Editor

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AR ZONE! NEW

Download the Zappar augmented reality app on your mobile device for free, here: zappar.com/getzappar/

When you see the AR ZONE! logo at the top of a page, use your Zapper app to scan the Zapcode.

Hold your mobile device over the pages and watch them come to life! Your device needs to be connected to the Internet for this to work.

HOW THE ZAPPAR APP WORKS

After being activated by the zapcode, the app reads anything you point your device's camera at 30 times a second, searching for distictive shapes we've trained it to recognise. When it sees something familiar, it places the augmented reality 3D image on your screen. It's like magic, but actually just really clever technology.

MEET THIS ISSUE'S EXPERTS...

James Horton
Former **HIW** member James is a biochemist and biotechnologist. He is currently doing a PhD in machine learning and evolutionary theory.

Jo Stass
Writer and editor Jo is particularly interested in the natural world and learning about the latest in technological innovations.

Jodie Tyley
The former editor of **HIW** and **All About History** has tackled many topics in her career, from science fiction to science fact and Henry VIII to honey badgers.

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

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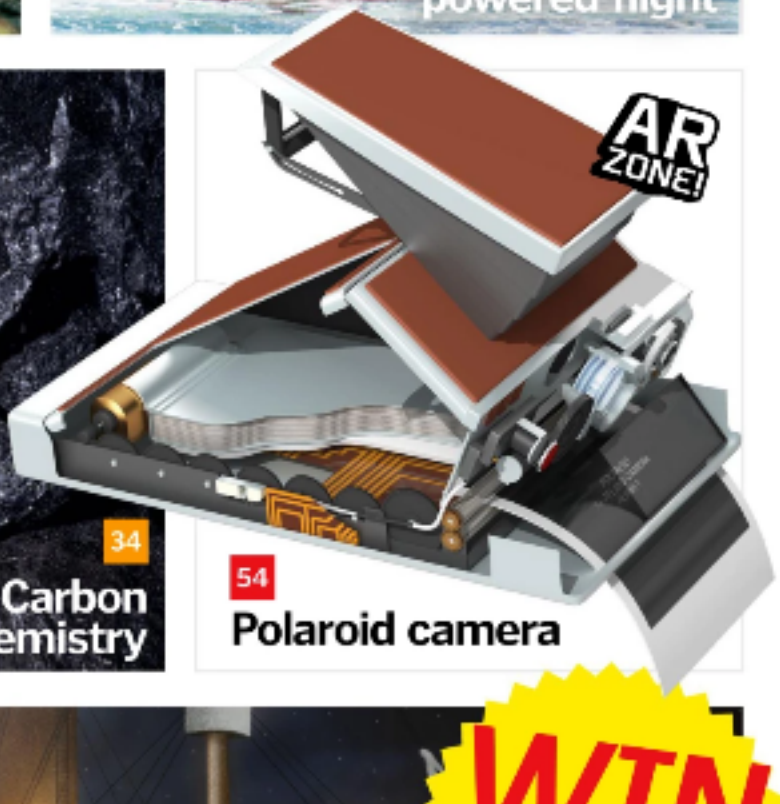

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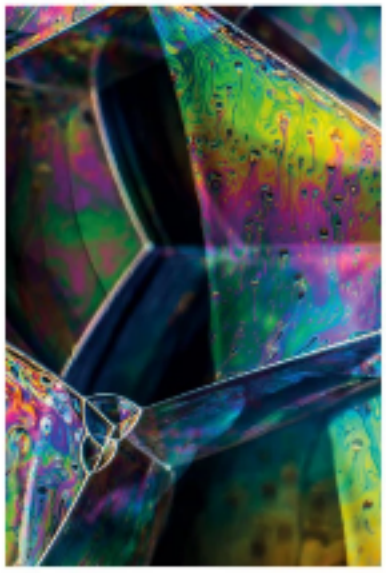

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Stephen Ashby
Stephen is a writer and editor with video games and computer tech expertise. He is endlessly intrigued by Earth science.

Steve Wright
Steve has worked as an editor on many publications. He particularly enjoys history feature writing and regularly writes literature and film reviews.

Elizabeth Howell
Science and space journalist Elizabeth is based in Ottawa, Canada, where she teaches technical writing and is president of a science writing and communication society.

Tom Lean
Tom is a historian of science at the British Library, working on oral history projects. His first book, *Electronic Dreams*, was published in 2015.

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

Soap bubbles splitting light

These are soap bubbles, clinging together to form an irregular cellular structure. Bubbles normally minimise their surface area for the volume of air they contain, creating a spherical shape. The iridescent surface sheen is where white light is refracted and split into bands of colour. The clear spots are too thin to refract, indicating the bubble is about to burst. This image was taken by Kym Cox for The Royal Photographic Society's Science Photographer of the Year competition. Find out about the competition at rps.org/spoty.

Seeing into the galactic centre

This galaxy, designated NGC 3169 and photographed by the Hubble Space Telescope in July 2019, is around 70 million light years from us, and is a spiral galaxy. The galactic nucleus is mostly obscured by cosmic dust, but Hubble has managed to take a shot that allows us to see the centre, which is a source of 'hard' x-rays. Cosmic dust is made of ice, hydrocarbons and other materials. It is left over from the enormous amount of star and planet formation that has happened in this galaxy in the last billion years.

Tragic end for the beached whale pod

This is one of five sperm whales stranded on the beach of Texel, a Dutch island, in 2016. Locals were unable to return them to the water and they died. But why did this pod end up here in the first place? Scientists still don't know exactly, but they've been doing it in greater numbers. Sea pollution could affect mental development, while ship and submarine sonar could interfere with the whales' echolocation.

GLOBAL EYE

Showcasing the incredible world we live in

The Fireworks Galaxy is known for its supernovas (seen in blue), but a mysterious x-ray explosion (green) has scientists scratching their heads

Fireworks Galaxy flare-up baffles scientists

Words by **Brandon Specktor**

Don't be alarmed, but the Fireworks Galaxy is exploding. Admittedly, it's been exploding for a while – at least since 1917 (give or take the 25 million years that light takes to travel from that galaxy to Earth), when astronomers first glimpsed a large star erupting into a supernova there. Since then, scientists have detected nearly a dozen stellar explosions in the galaxy, but none quite like a mysterious green blotch of x-ray light recently observed.

What makes that blotch special? For starters, it's not a supernova. The x-ray signature detected by NASA's Nuclear Spectroscopic Telescope Array (NuSTAR) is far more energetic than a typical supernova. But more importantly, the energetic x-ray blast also appeared and disappeared from the galaxy in about ten days – a briefer appearance than a supernova, which can brighten and fade over hundreds of days.

So, the greenish blast of invisible energy is probably not a supernova. What is it, then? A recent study published in *The Astrophysical Journal* provides a few guesses. The authors of the study, who glimpsed the mysterious blast of energy by chance while studying supernovas in the Fireworks Galaxy, said the mystery explosion likely involves one of the most powerful objects in the universe – possibly a black hole or neutron star – tearing apart one of its stellar neighbours. While black holes are black, their outer edges glow with intense radiation when nearby objects get pulled into the black hole's orbit.

It's possible, according to a statement accompanying the study, that the source of the green blast is a black hole that devoured a nearby star. As the black hole's overwhelming gravity rips that star to shreds, stellar debris could start spinning around the hole. The debris closest to the hole's event horizon could orbit so quickly that it gets hundreds of times hotter than the Sun in our Solar System. The debris could then radiate x-rays as it gets sucked into oblivion.

A neutron star, the ultra-dense corpse of a once-mighty star, could also be the culprit here. Neutron stars exert a gravitational pull billions of times stronger than Earth's. However, these stellar corpses spin so blazingly fast that it can be impossible for nearby debris to reach the object's surface.

Sometimes, however, a wobble in a neutron star's magnetic field can slow the object's rotation enough for debris to get pulled into the star's glowing halo of destruction, a feature similar to what might swirl around a black hole. The pulling in of debris could result in the sudden appearance and disappearance of an x-ray blast, like the one seen here. If that's the case, another flash of radiation is likely to appear in the same spot, following a future magnetic field wobble.

Scientists will continue monitoring the Fireworks Galaxy for possible repeat performances of this unusual x-ray event, waiting for another unlucky star to go out with a bang.

HEALTH

'Chemical exposure' linked to mysterious vaping disease

Words by Rachael Rettner

The number of Americans struck with mysterious, vaping-related lung illnesses is rising. The Centers for Disease Control and Prevention (CDC) has announced that it is aware of 450 possible cases of severe lung illnesses linked to vaping that are under investigation in 33 US states. Three deaths have been confirmed in connection with these illnesses. Many of the patients are teens or young adults. All patients reported using e-cigarettes, and many used the devices to vape marijuana.

So far, the cause of the illnesses is unknown; no single vaping device, product or substance has been tied to all of the cases, said Dr Dana Meaney-Delman, the manager of the CDC's investigation. Officials believe "chemical exposure" is likely to be behind these illnesses, but much more information is needed, Meaney-Delman said.

The CDC announcement coincided with the release of several new reports on vaping-related illnesses. One, published in *The New England Journal Of Medicine*, describes 53 patients from Wisconsin and Illinois who developed respiratory symptoms after vaping. Most of these patients were young, male and healthy prior to their illness. Patients had symptoms such as shortness of breath, coughing and chest pain, nausea, vomiting, fever and weight loss. All of the patients had vaped within the prior three months, and 84 per cent reported vaping marijuana products.

The report seems to suggest that vaping-related lung illnesses are a new phenomenon, and not something that simply went undetected in the past. The rate of monthly emergency room visits for severe lung illness in young adults was twice as high in June to August 2019 as the same months in 2018, the study found.

The CDC recommends that people consider not using e-cigarettes while the investigation is ongoing, and should not be used by children or adolescents, young adults, pregnant women or adults who currently don't use tobacco products.

Vaping has been linked to several cases of mysterious and fatal lung diseases

© Getty

ANIMALS

Tibetan mastiffs benefit from wolf genes

Words by Rafi Letzter

Tibetan mastiffs are huge dogs that survive high up in the mountains, and now we know their ability to thrive in such harsh and low-oxygen environs comes from an extra shot of wolfishness in their genes. The bulky dogs, which can weigh up to 70 kilograms, are "renowned for [their] hypoxia tolerance," according to the authors of a new study into these dogs' genes. That means Tibetan mastiffs can thrive at high altitudes, where the thin air and low oxygen levels would kill other breeds.

According to the recent study, at some point in the past the dogs interbred with wolves. Their descendants inherited gene mutations that code for two amino acids – small pieces of a protein – that make Tibetan mastiffs' blood better at capturing and releasing oxygen. The two tweaks alter the way the dogs and wolves produce haemoglobin, the iron-containing protein in blood that carries oxygen, the researchers revealed.

They compared haemoglobin from Tibetan mastiffs and Tibetan wolves with the haemoglobin from other domestic dogs, and discovered that Tibetan mastiffs and wolves have a significant advantage over other breeds in their ability to absorb and release oxygen in thin-air conditions.

From the genetic studies it appears that, in the distant past, Tibetan wolves sometimes had these mutations in a stretch of dormant DNA, which didn't code for a protein. At some point, those mutations got copied into an active gene, thereby giving the wolves altered haemoglobin. Then, as the animals moved into higher-altitude environments, the handful of wolves that had these mutations came to dominate the species, and they became the norm. Later on, the wolves passed on the tweaked gene to Tibetan mastiffs, and those that inherited the altered haemoglobin gene came to dominate the breed.

"Tibetan mastiffs can thrive at high altitudes, where the thin air would kill other breeds"

© Getty

"An autopsy revealed two small lacerations on her leg, one of which was over a large varicose vein"

"Attacks by roosters are very rare" say authors of a new report

STRANGE NEWS

Woman pecked to death by rooster

Words by **Rachael Rettner**

A woman in Australia who was attacked by a rooster died after the bird's pecking caused her leg to haemorrhage profusely, according to a new report of the case.

The 76-year-old woman was collecting chicken eggs on her rural property when an aggressive rooster began pecking at her lower-left leg, according to the report, published in the journal *Forensic Science, Medicine and Pathology*. The pecking led to a "significant haemorrhage," which caused the woman to collapse, the report said. An autopsy revealed two small lacerations on her leg, one of which was over a large varicose vein. Doctors concluded that the woman died from "exsanguination" due to bleeding from a varicose vein following the rooster attack, the report said.

Varicose veins are usually not harmful. But in rare cases, they can cause complications, including bleeding that is difficult to stop, according to the NHS. In a 2012 report published in the journal *BMC Research Notes*, researchers from Greece described the case of a 66-year-old woman who died from bleeding due to a ruptured varicose vein. Underlying conditions, such as heart disease, may increase the risk of death from varicose vein bleeding.

Attacks by roosters are "very rare," Dr Roger Byard, a professor of pathology at the University of Adelaide and co-author of the new report, told the Australian Broadcasting Corporation (ABC). "This case demonstrates that even small domestic animals may be able to inflict lethal injuries in individuals if there are specific vascular vulnerabilities present," the report said.

STRANGE NEWS

Underwater thieves steal research station

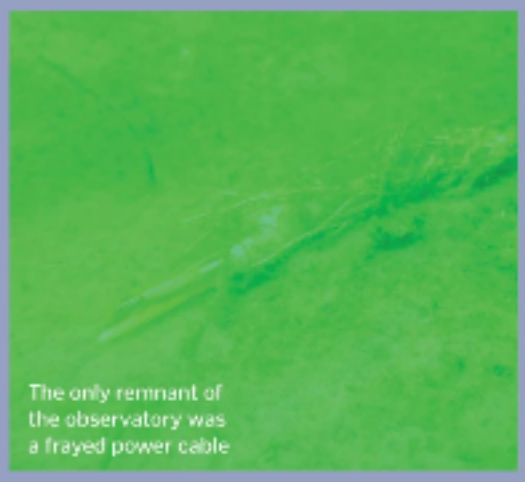
Words by **Rafi Letzter**

A research station the size of a small car has completely vanished from the bottom of the Baltic Sea. And it looks like the station's been stolen. The observatory, which was run by the GEOMAR Helmholtz Centre for Ocean Research, consisted of about 740 kilograms of equipment. Its job was to collect environmental data from the ocean floor and transmit that information to researchers on land. But on 21 August, the station stopped sending data.

At first, researchers suspected something had gone wrong with the transmission. But divers went to check on the site and found that the entire Boknis Eck Observatory had disappeared, with just a "shredded" power cable left behind.

The missing observatory had been in a restricted area 1.8 kilometres off the coast of Kiel in northern Germany, not far from the Danish border, the BBC reported. No storm, tide or large animal could have moved the station, GEOMAR said in a statement. Police are investigating, and GEOMAR asked that any members of the public who might have seen something report it.

The station had been carrying instruments for an environmental data-collection project that's been going on since 1957. The project has maintained a continuous record of key ocean variables, including temperature, salinity and levels of nutrients, oxygen and chlorophyll.



The only remnant of the observatory was a frayed power cable

HEALTH

First left-handed genetic markers found

Words by **Rachael Rettner**

Scientists have discovered the first genetic markers tied to being left-handed, according to a new study. In addition, these genetic markers may play roles in brain development and communication between different brain areas, the authors said. The findings, published in the journal *Brain*, "Shed considerably more light on the [biological] processes leading to left-handedness," study lead author Dr Akira Wiberg, a research fellow at the University of Oxford, said in a statement.

About one in ten people worldwide are left-handed. Scientists have known that genes contribute to being left-handed, but they didn't know which genes are involved. In the new study, the researchers analysed the genomes of about 400,000 people in the UK whose health records and genomic data are part of a database known as the UK Biobank. Of these, about 38,000 were left-handed.

The researchers looked for differences in the DNA of left versus right-handers, and they identified four genetic markers tied to being left-handed. Three of these markers were located in genes that provide instructions for making proteins involved in brain development and structure. For example, some of these genes were involved in the setup of microtubules, which make up the 'scaffolding' inside cells, known as the cytoskeleton.

The researchers also analysed brain scans of about 10,000 participants and found that these genetic markers are linked with differences in the brain's white matter – long nerve fibres that allow areas of the brain to communicate. In particular, the differences were most pronounced in tracts connecting language-related regions in the brain. "We discovered that, in left-handed participants, the language areas of the left and right sides of the brain communicate with each other in a more coordinated way," Dr Wiberg said.

This finding suggests that "left-handers might have an advantage when it comes to performing verbal tasks," but much more research would be needed to show this, he said.

Left-handed genetic markers may play a role in brain development

This photo of Nessie from 1934 turned out to be a hoax created with a toy submarine and a fake sea monster body

STRANGE NEWS

Loch Ness contains no 'monster' DNA

Words by Tom Metcalfe

The Loch Ness monster has haunted a deep Scottish lake for more than 1,000 years – in imagination, at least. But a scientific survey of the waters of Loch Ness found it contains no traces of "monster" DNA at all, adding weight to the already likely prospect that 'Nessie' doesn't really exist.

Geneticist Neil Gemmell of Otago University in New Zealand said an environmental DNA survey of Loch Ness saw no signs it was home to any giant reptiles or aquatic dinosaurs – a theory sometimes used to explain the mysterious monster, which has reportedly been seen several times since the 1930s. Gemmell said the survey revealed DNA traces of more than 3,000 species living beside or in Loch Ness – including fish, deer, pigs, birds, humans and bacteria. But "we did not find any giant reptiles; we didn't find any reptiles at all," Gemmell told Live Science. "We tested a variety of ideas about giant sturgeons or catfish that might be here from time to time, but we did not find those either," he explained.

One thing the researchers did find is that Loch Ness contains a lot of eels. And the researchers say it is possible, although unlikely, that sightings of Nessie may actually be sightings of overgrown eels. "Out of the 250-odd water samples that we took, pretty much every single sample has got eels in it," he said. "But are they giant eels? I don't know," he said.

IN ASSOCIATION WITH LIVESCIENCE

HISTORY

Salt saved ancient scrolls from destruction

Words by **Brandon Specktor**

The Temple Scroll – one of the longest and best-preserved of the Dead Sea Scrolls

The Dead Sea Scrolls are a marvel. Buried for roughly 2,000 years under piles of debris and bat guano in a chain of caves in the Judean Desert, the collection of nearly 1,000 fragmented manuscripts includes biblical texts, ancient calendars and early astronomical observations. Among these mysterious artefacts – many of which are now just ragged scraps of parchment – one impeccably preserved document stands out.

The Temple Scroll, named for its description of a Jewish temple that was never built, is one of the longest (eight metres long), thinnest and easiest scrolls to read. Why, out of thousands of faded fragments found in the Judean caves, has the Temple Scroll fared so well after two millennia?

In a new study published in the journal *Science Advances*, researchers attempted to find out by scrutinising a piece of parchment using every x-ray and spectroscopic tool at their disposal. They found that the scroll did indeed have something its ancient siblings did not – traces of a salty mineral solution not present in any other previously studied scroll, nor in any of the caves or in the Dead Sea itself. "Understanding the properties of these minerals is particularly critical for the development of suitable conservation methods for the preservation of these invaluable historical documents," the researchers wrote in the study.

Prior studies revealed that the Temple Scroll was unlike most other Dead Sea fragments, in that it was composed of several distinct layers; an organic layer made of the animal skin that served as the parchment's base, and an inorganic layer of minerals that may have been rubbed on during a parchment 'finishing' process.

To figure out what this inorganic layer was made of, and whether it was rubbed there intentionally, the team studied a fragment of the Temple Scroll using x-ray scans and Raman spectroscopy – a technique that reveals the chemical composition of a substance by watching how laser light scatters off various chemical elements. The researchers found that the scroll was coated in a mixture of salts made from sulphur, sodium, calcium and other elements. However, these salts did not match elements found naturally on the cave floor or in the Dead Sea, ruling out a natural origin.

It's possible that this salt coating has contributed to the Temple Scroll's uniquely well-preserved appearance, the team wrote – but it could also be an ingredient in the scroll's eventual destruction. As the salts detected on the scroll are known to suck moisture out of the air, their presence could "accelerate [the scroll's] degradation" if not stored properly, the authors also said.

Soyuz MS-14 landed 140 kilometres southeast of the town of Zhezkazgan in Kazakhstan

SPACE

Unpiloted capsule returns to Earth with humanoid

Words by **Tariq Malik**

On 6 September an uncrewed Russian Soyuz spacecraft returned to Earth, bringing a humanoid robot home and wrapping up a first-of-its-kind test flight to the International Space Station. The Soyuz MS-14 space capsule landed on the steppes of Kazakhstan, but sitting inside the spacecraft was no human crew. Instead, the Soyuz carried the humanoid robot Skybot F-850 and other Russian spaceflight gear.

Soyuz MS-14 is the first uncrewed Soyuz spacecraft ever to visit the International Space Station. The three-person vehicles have typically been used to ferry human crews to and from the laboratory over the years. Russia's space agency Roscosmos launched Soyuz MS-14 uncrewed on 22 August to test the vehicle's compatibility with an upgraded Soyuz 2.1a rocket. Roscosmos officials also used the flight to test other upgrades to the Soyuz capsule, designed to allow future robotic versions to return cargo back to Earth.

In addition to 657 kilograms of supplies, the spacecraft carried the 1.8-metre Skybot F-850, a space version of the country's FEDOR robots. The robot was equipped with sensors to record what a human might feel during a Soyuz launch on the 2.1a rocket.

Recently discovered aurora phenomenon STEVE ablaze in the sky

SPACE

A solar visitor is seen in the aurora

Words by **Stephanie Pappas**

A strong solar storm has brought the northern lights further south than usual, and it may have included something different than the aurora: a solar visitor dubbed STEVE. Researchers discovered STEVE, short for the strong thermal emission velocity enhancement, in 2016.

What makes it strange is that its light comes from across the spectrum, without the peaks in particular wavelengths that characterise regular auroras. "The big thing is we can clearly say now, 'It's not regular aurora,'" University of Alaska Fairbanks researcher Don Hampton, who recently analysed a STEVE event from 2018, said in a statement. "It's a new phenomenon – that's pretty exciting."

The northern lights occur when charged particles from the sun excite electrons in Earth's atmosphere. As a result, these electrons first move to a higher energy state, then settle down to their original, lower energy state. As they do so, each one releases a photon, a particle of light. The colour of the auroral light depends on the molecules the charged solar particles hit. If they hit oxygen, green and yellow result, for example, while nitrogen tends to make red and violet. STEVE, though, consists of light from across the electromagnetic spectrum, with a slight boost in the red range, explaining the phenomenon's mauve colour.

The new findings confirm that the particles that produce STEVE are quite toasty. "When you turn your electric stove on, those coils get red hot, right? If you look at it with a spectrograph, you would see broadband emissions," Hampton said in the statement. Similarly, STEVE's broad range of wavelengths indicate heat. "So, this is like very, very warm atmosphere emissions of some sort."

The researchers made their measurements using a new piece of Earthbound equipment called the Transition Region Explorer (TREx) spectrograph, which measures light wavelengths. Using this instrument, investigators captured a view of STEVE on 10 April 2018, near Lucky Lake, Saskatchewan.

As has often happened, STEVE was accompanied by a green 'picket fence' phenomenon, which consists of vertical, green bands of light that cross STEVE's usual pink bands. By looking at the wavelengths, the researchers confirmed that the picket fence is a variation on the usual aurora.

The next step, Hampton said, is to figure out how or if STEVE affects humanity. Solar storms that cause the aurora can also disrupt satellite communications, and it's not yet clear whether STEVE does the same thing or if its impact differs.

The southern black-throated finch is thought to be extinct in New South Wales, with only 1,000 left in Queensland

ANIMALS

Australian students in bid to save finches

Words by Yasemin Saplakoglu

A primary school in Australia is breeding endangered finches – but although the program is bringing awareness to the birds' plight, it won't save them, according to the Australian Broadcasting Corporation (ABC).

The southern subspecies of the black-throated finch, called *Poephila cincta cincta*, is native to northeast Australia. It is thought to be extinct in New South Wales, and only an estimated 1,000 are left in the wild in Queensland, according to the ABC.

But inside the classroom, they're thriving. Brett Murphy, a science, technology, education and maths (STEM) teacher at the Belgian Gardens State School in Australia, created the breeding program seven years ago, and with the help of his students has been successfully breeding the finches for the past six years. In the breeding program, the team now cares for 120 finches, which includes the black-throated finch (*Poephila cincta*) and other species, such as the Gouldian finch (*Erythrura gouldiae*). Students take care of these birds daily, feeding them and making observations of their health.

But while the breeding program is useful for raising awareness and appreciation, it will not save the finches out in the wild, Tony Grice, a member of the Federal Black-Throated Finch Recovery Team, told the ABC. The main threat to the species is habitat loss, he said. These finches thrive in open, grassy woodlands with water nearby. "Some of that loss is historical, and some, more recently, is loss of the woodlands it prefers to live in and degradation of those woodlands in various ways," Grice said. Breeding birds in captivity won't provide that habitat.

"In the breeding program, the team now cares for 120 finches"

HEALTH

Spanish babies develop 'werewolf syndrome'

Words by Isobel Whitcomb

Parents in Spain started panicking this summer when 17 children and babies mysteriously came down with hypertrichosis, or 'werewolf syndrome', a condition where their bodies and faces became covered in a dense layer of hair, according to news reports.

At first, doctors couldn't figure out what was wrong. Was it genetic? A metabolic disorder? At the end of August the Spanish Health Ministry finally announced that it had discovered the root of the problem. In a pharmaceutical mix-up, babies across Spain had been inadvertently dosed with a medication for alopecia, or hair loss. All the affected children had one thing in common: they were all taking the same medicated formula that supposedly contained omeprazole, a drug used to treat acid reflux disorders.

Early in July, the drug was identified as a suspected culprit for the condition and pulled from the shelves. A later investigation by Spain's Agency for Medicines and Health Products (AEMPS) revealed that instead of omeprazole, the formula the babies were drinking contained minoxidil, a drug used to stimulate hair growth. The mix-up happened when, at some point in the packaging process, the medication was mislabelled as omeprazole.

Unlike people with genetic hypertrichosis, the babies affected won't stay hairy – the excess hair should fall out after a few months.

WISH LIST

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K Ring

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With contactless payment quickly becoming the norm, wearable technology like the K Ring is making it easier to make a purchase. Enabling you to wear your card on your finger, the K Ring can make payments to anywhere that accepts Mastercard contactless payments. With no need for charging or pairing with a smartphone, the K Ring makes sure you've always got a way to pay.

Vue

■ Price: From $249 (approx £205)
enjoyvue.com

So far 2019 has seen an increasing number of launches for smart glasses, each with their own approach to streamlining the way we receive information from our phones. Vue is no exception. Designed with style in mind, these sleek glasses use bone-conduction technology to play music and phone calls in your ear. Once Bluetooth-paired with a smartphone, the wearer can change songs, answer calls or request the time with just a swipe or tap of the frame.

Leaf Chakra

■ Price: £129.99 / $139
bellabeat.com

Bellabeat has become one of the leading companies for combining women's fashion and technology. With an entire range of wellness trackers, the Leaf Chakra is a great addition to your arsenal of wearable technology. Worn as either a pendant or clip, this piece of high-tech jewellery can keep track of your sleep, meditation, fitness and reproductive health. Set reminders, alarms and follow in real time how your body is performing throughout the day with the accompanying app, jam-packed with your daily stats.

Move ECG watch

■ Price: £129.95 (approx $245)
www.withings.com

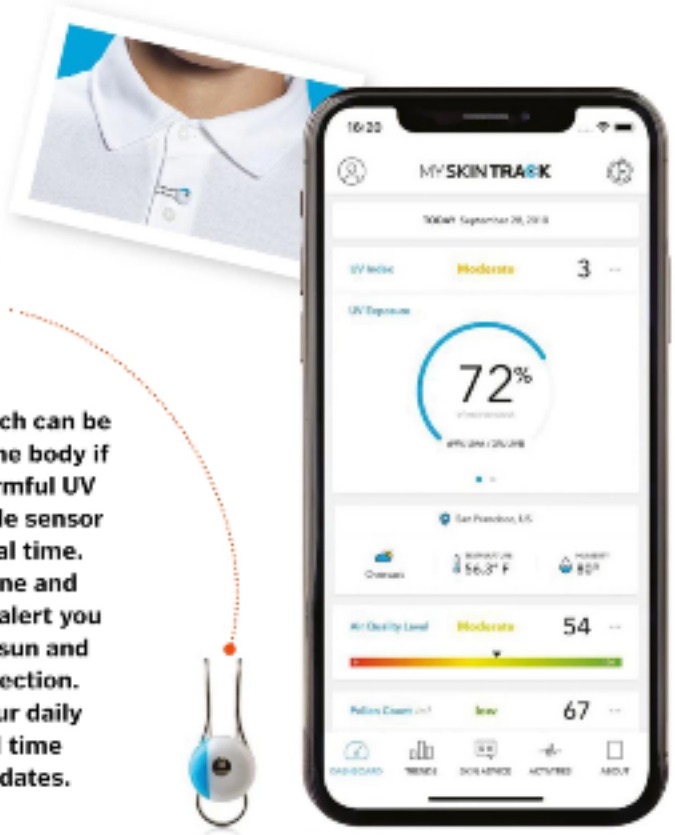
Combining the style of analogue with the high-tech function of a smartwatch, the Move ECG is the first wristwatch equipped with a medical-grade electrocardiogram. At the touch of its face, this BlueTooth smartwatch will measure your heart rate and its electrical pattern, then record the results on the accompanying Withings Health Mate App. The Move ECG is a great way to monitor your heart's health and help discover early signs of irregularities.

© Withings

Matte Parliament

■ Price: $89 (approx £75)
ekster.com

If you often find yourself stumbling through your wallet for the right credit card, ID or gym membership, then Ekster's smart wallet is for you. Coming in a range of styles and colours, this trigger-controlled wallet reveals your cards at the touch of a button. Making sure you're never without a way to pay, Ekster's range of wallets come with a pouch to house Ekster's tracker card. It can track your wallet around the world: by using the accompanying app these Bluetooth-paired wallets can be easily located when lost.



My Skin Track UV

■ Price: £54.95 / $59.95
laroche-posay.us

Basking in sunlight on a tropical beach can be great for the mind, but terrible for the body if you don't protect yourself from harmful UV radiation. My Skin Track UV wearable sensor works to keep you protected in real time. Personalised to your skin type, tone and concerns, this compact sensor can alert you when you've spent too long in the sun and when it's time to top up your protection. Using the app you can monitor your daily progress and also receive in real time humidity, pollution and pollen updates.

APPS & GAMES

Wanna Kicks

■ Developer: **LLC WANNABY**
■ Price: **Free / Google Play / App Store**

'Try before you buy' has gone virtual with this augmented reality app. Simply select the shoes you want to try and see them appear on your feet through the phone's camera.

Smart Closet – Fashion Style

■ Developer: **Rabbit Tech Inc.**
■ Price: **Free / Google Play / App Store**

Search through clothes from thousands of brands and upload pictures of your wardrobe to this smart style app, which will offer outfit suggestions based on your style.

Inkhunter

■ Developer: **INKHUNTER, Inc./Kateryna Khotkevych**
■ Price: **Free / Google Play / App Store**

Getting a tattoo is a lifelong commitment, but with this augmented reality app you can search through different designs or upload your own and virtually try them out on your skin.

Sizer

■ Developer: **Sizer Technologies / Body-Pass Inc.**
■ Price: **Free / Google Play / App Store**

Shopping for the right size online can be rather challenging, but this body-scan app can record your body measurements, enabling you to buy the clothes that fit you best.

Words by **Elizabeth Howell**

HOW IT WORKS VISITS THE TEXAN F-35 FACTORY THAT BUILDS STEALTH FIGHTERS FOR THE USA AND THE WORLD

HOW TO BUILD A FIGHTER

JET

Just a short drive away from Dallas, Texas is the town of Fort Worth, home to the massive and super-secure facility where one of the world's most advanced fighter jets is built.

Lockheed Martin has thousands of people working here around the clock on the F-35s. In fact, about 18,000 employees work in the aeronautics business in Fort Worth. It's too many to fit on the floor at one time, so people work in shifts. There are engineers, technicians and machinists. Then there are the many people that support them as they build the plane: the cleaners, the cafeteria workers, the security personnel and so many more.

Visitors zip down the aisles in carts, carefully stopping at pedestrian crossings on the way. On either side of each aisle is a marvel of engineering – the F-35 coming together, piece by piece; wings, cockpits, tail fins, fuselage. Electronic screens mounted above each F-35 show what country it's destined for, and how well the workers are meeting their deadlines.

It's an awe-inspiring sight to see something so technologically advanced being assembled before your eyes. Towards the end, the green-hued body transforms into grey sophistication in the painting room, where two car-sized machines called Thor and Zeus assist workers with the delicate work. The fighters emerge, cloaked in low-visibility grey, and after a few more checks go to a flight line, where they are

"Lockheed Martin has thousands of people working around the clock on the F-35"

Landing gear is tested for the first time in the facility on this F-35

© Lockheed Martin

tested in flight. Each F-35 must pass a series of flight tests before being shipped to their customers, which include the UK, Turkey, Belgium, Denmark, Australia, Israel and others. So in a sense, this town-sized facility is a gateway to the entire world.

The largest building in the factory was once the biggest air-conditioned room in the world. Air conditioning was rare during the years of World War II, when President Franklin D. Roosevelt chose Fort Worth as a location to build US bomber planes. But it's a necessary thing. It stops plane parts from warping, which would make construction difficult – and of course, it's a far more comfortable environment for workers.

Many aircraft companies worked here over the decades, finally ending up with Lockheed

"Lockheed Martin was producing the popular F-16 and later the F-22 fighters"

Martin in the 1990s. Lockheed Martin was producing the popular F-16 and later the F-22 fighters at the time. But while the company had a reputation for reliable fighters, militaries worldwide were itching for something new.

What they needed was a 'fifth-generation fighter' – a plane that only had a small 'signature' in radar, meaning that it would be difficult to detect. They wanted an electronic cockpit that the pilot could change, so that they would have the information needed for any mission. And they wanted a fighter that was a good bet for the future – something that could interface with drones and could carry the latest weaponry.

Lockheed Martin's proposal to build the F-35 wowed the military, and in October 2001,


The jet's wings and fuselages are joined in the Electronic Mate and Alignment station (EMAS)


Two mechanics prepare the front fuselage of an F-35 test aircraft


Each F-35 is lowered into a hole in the floor to check the wheels, rather like a mechanic's vehicle pit


The final phase of building the wings of a conventional take off and landing F-35 variant

Rise of the modern fighter jets

1980 · 1990 · 2000

McDonnell Douglas F-15 Eagle

A formidable and manoeuvrable warplane, it's among the most successful fighters of the Cold War.

General Dynamics F-16 Fighting Falcon

The F-16 multi-role fighter is a versatile and effective warplane, able to attack air and ground targets.

Mikoyan MiG-31 Foxhound

This long-range interceptor is the backbone of Russia's military. It's among the fastest aircraft, with precision strike and defence abilities.

Boeing F/A-18E/F Super Hornet

Based on aircraft carriers, it's currently the most capable multi-role fighter, able to attack air and surface targets.

Dassault Rafale

This is a French multi-role fighter with the latest avionics, it is able to track up to 40 targets at a time, and is capeble of firing at four targets simultaneously.

Eurofighter Typhoon

This fighter carries advanced missiles with modern avionics, and has multi-role abilities as an interceptor and ground-attack fighter.

The F-35 is a versatile jet, capable of fullfilling multiple functions and be based on land or on ships

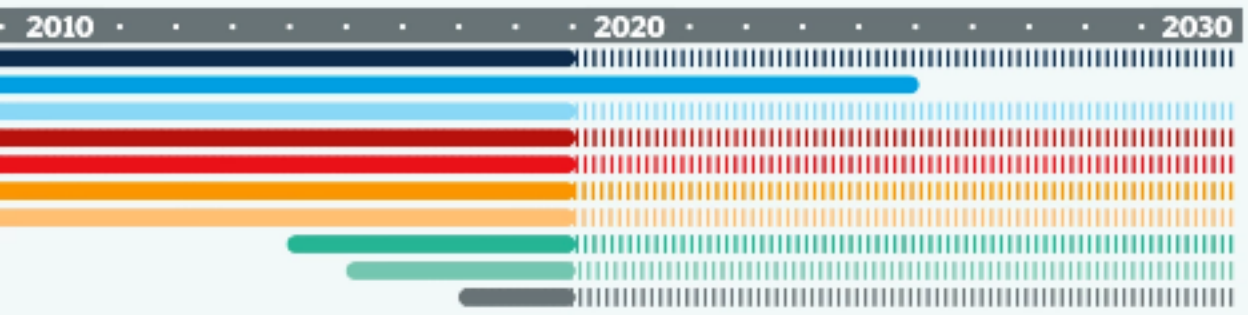
Is it a plane or a golf ball?

The F-35 is covered in something special: a composite skin machined so accurately the pieces are virtually seamless on the jet. This completely eliminates any small joining flaws that are detectable by radar.

In the past, stealth aircraft relied on epoxy resin between exterior pieces. Radar is adept at detecting sharp edges. This means it will see any small, sharp edges between panels. Even an expert layer of epoxy will eventually dry, harden and crack, requiring frequent inspections and replacement.

With new technology the panels match so closely there's no sharp edges or epoxy to maintain. As a result the F-35 has very low visibility. If radar catches it at all, what it sees is something more like the size of a golf ball.

The flexible overhead gantry (or FOG) machine peforms precision machining of the jet's skin



Lockheed Martin/ Boeing F-22 Raptor

Almost invisible to radar, and carries a powerful array of weaponry. It is extremely advanced, considered one of the best aircraft ever built.

Sukhoi Su-35

A very fast and highly manoeuvrable jet, the Su-35 is capable of operating over a long range and achieving high altitudes, with carrying a heavy armament.

Lockheed Martin F-35 Lightning II

Similar to F22, but smaller and with only one engine. Its stealth technology makes it hard to detect. The F-35B can take off and land vertically.

Chengdu J-20

China's own stealth fighter, this fifth-generation jet has long-range air superiority capabilities. It is also able to carry out high-speed operations.

AR ZONE! SCAN HERE

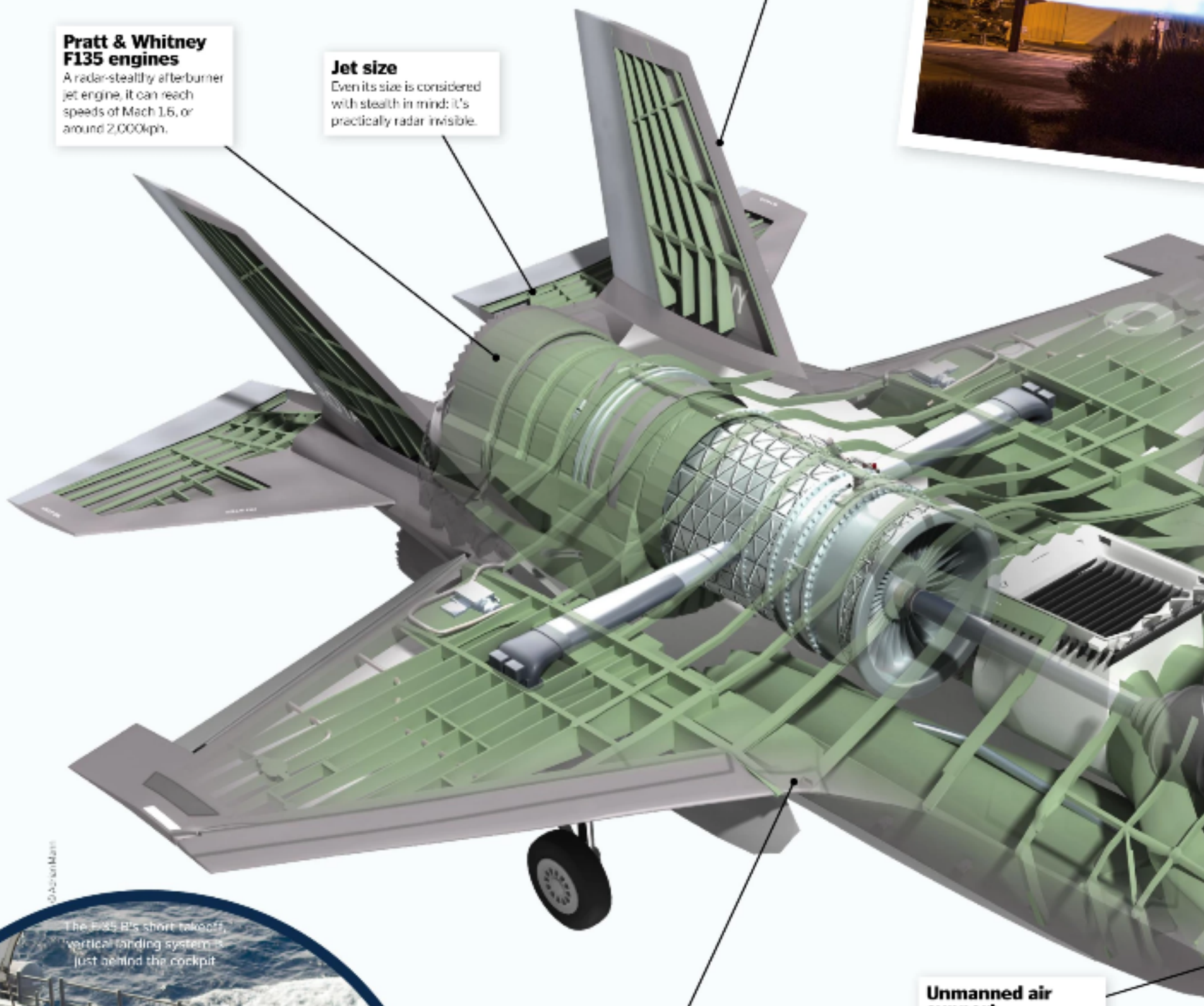
Inside the F-35B

This short take-off/vertical landing stealth fighter is designed to operate from ship or land

Stealth fibre coating
The jet is coated with radar-absorbing materials, making it seem about the size of a golf ball in scans.

Pratt & Whitney F135 engines
A radar-stealthy afterburner jet engine, it can reach speeds of Mach 1.6, or around 2,000kph.

Jet size
Even its size is considered with stealth in mind: it's practically radar invisible.



The F-35 B's short takeoff, vertical landing system is just behind the cockpit

Internal bomb bay
The F-35 has an internal bomb bay to keep the weapon payload safe from prying radar beams.

Unmanned air support
The jet can pair up with uncrewed drones, allowing the pilot to control the AI wingmen and find targets.

EOTS – Electro-Optical Targeting System
Infrared search and tracking provides precision air-to-air and air-to-surface targeting for the F-35.


The F-35's F135 jet engine and afterburner being tested

Lockheed was awarded a contract to develop and build the F-35. After a development and testing period, F-35s were first operational in 2015, and today there are hundreds of these aircraft flying all over the world in wartime operations, and also in air shows.

Called the Lightning II, or just the Lightning for the RAF, there are three types: the F-35A that can land and take off on a conventional runway; the F-35B 'hover' jet; and the F-35C that can be based on aircraft carriers. The F-35 is so flexible and capable that it can be used in just about any environment imaginable.

While the F-35 program is based in the US, more funding comes from allies that work with the US under the North American Treaty Organization, or NATO. These allies include the UK, which plans to buy 138 F-35 aircraft over the life of the programme. So far, the UK has 18 aircraft – all the F-35B 'hover' variety – stationed at RAF Marham in Norfolk.

British companies are a big part of the F-35 production, including a repair hub run by Sealand Support Services Ltd. in North Wales. With so many F-35s projected to operate from the UK, having a repair hub in the country is essential. Otherwise, every maintenance job would require shipping the F-35 across the ocean and back to Lockheed Martin's facility.

British pilots even get their own training, because all Royal Air Force and Royal Navy F-35 pilots must go through a test and training facility in Cranwell. The pilots learn how to operate in high g-forces – when forces several times stronger than Earth's gravity pull upon them. You can feel this kind of 'push' at the bottom end of a roller coaster, and it's the same for a pilot when they dive towards the ground or turn quickly. At Cranwell, the facility can take a pilot up to nine gs – nine times Earth's gravity – in only one second.


F-35s have technology to help pilots work together and communicate more easily

So what is the F-35 known for, among all the other fighter jets available? The F-35 is built for stealth. The machinists must be carefully trained because even small gaps in between parts of the fuselage or wings show up clearly on radar. In the past, machinists used to put in an epoxy – a sort of a glue – to keep everything together. However, the epoxy cracks over time and needs to be repaired. The new process

"The F-35 is so flexible and capable that it can be used in just about any environment imaginable"

State-of-the-art glass cockpit
The pilot can give the aircraft voice commands and use the touchscreen to scroll through menus and selections.

Pilot helmets
The helmet connects the pilot and jet, and a pilot can mark a target simply by looking at it.

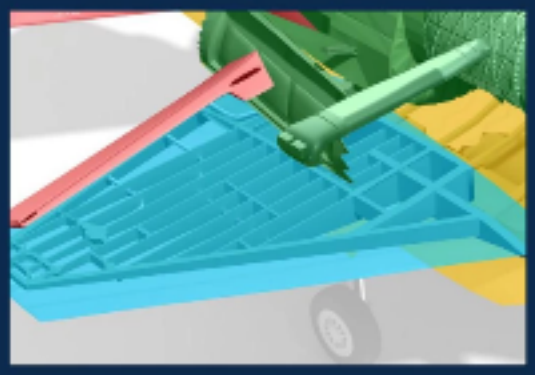
AESA radar
The most advanced and largest radar antenna on an aircraft, it can scan in any direction.

Building the F-35

How the major components of the F-35 come together at the factory

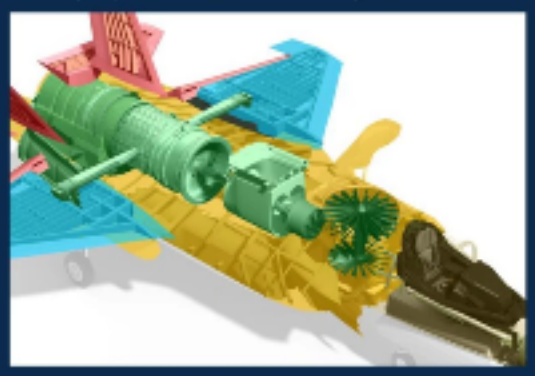
Forward fuselage assembly

The nose and cockpit section are assembled in the forward fuselage section, using precision robotics and automation. Parts are x-rayed for imperfections.



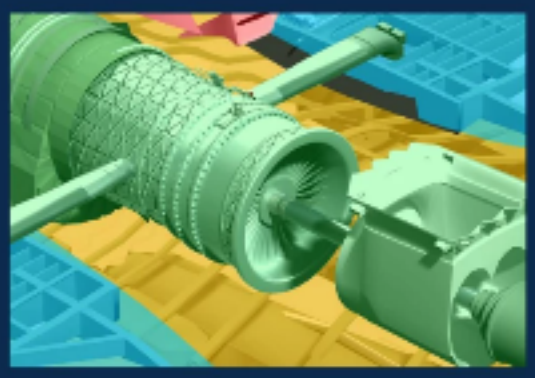
Wing build section

As the largest part of the F-35, the wing is built in one piece. A pulse line is used, and assembly stations are vertically adjustable for faster assembly at each station.



Putting it together

'Electronic mate and alignment system' stations use precision tools, like lasers and alignment computers, to assemble stealth components with high precision.



Ready to go

In the final assembly, the control services, engine and final touches are added, before they head to final checks on fuel systems, flight tests and radar cross section tests.

425+

The number of F-35s the factory has produced and delivered to the world's military

890+

Over 890 pilots have been trained to fly the F-35

1

The F-35 is a single-seat stealth precision fighter jet

"While it feels simple to the pilot, this technology is some of the most challenging engineering undertaken in a stealth fighter"

Cockpit assembly and preparations are made for the F-35's low-visibility paint job

8.6 million

F-35 computer systems have as many lines of software code as modern video games

18

The number of bases worldwide that are home to F-35s

215,000

Over 215,000 flight hours have been logged in F-35s

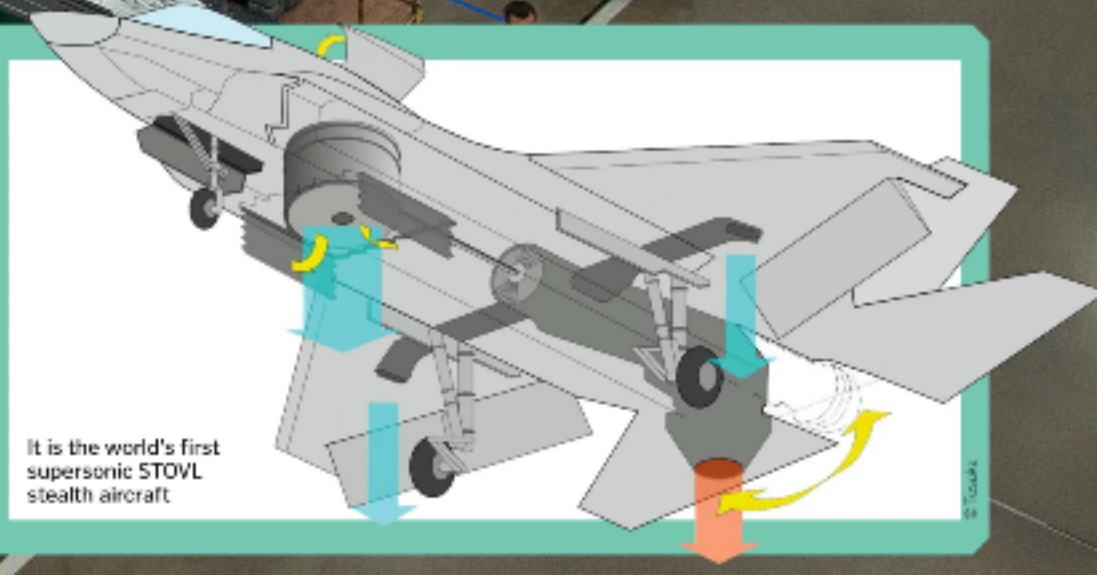
8

Eight nations currently operate F-35s

F-35B's short take-off/ vertical landing (STOVL)

With the push of a button and a verbal command, the F-35B jet transforms around the pilot from conventional flight mode to hovering mode. It looks like a tractor beam has captured and held the jet in place, locked in an indefinite hover until directed otherwise. This is possible because of an engine that can swivel 90 degrees during takeoff or landing.

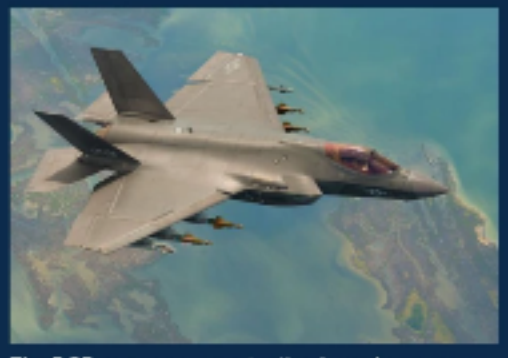
The pilot is connected to the jet through the flight helmet, with full control through voice and physical commands. The STOVL technology is some of the most challenging engineering undertaken in a stealth fighter. But even rookies can fly this, as the jet is no more complicated to fly than many sophisticated drones.



It is the world's first supersonic STOVL stealth aircraft

Beast mode

The F-35 can carry 2,600 kilograms of internal weapons in stealth mode, penetrating into enemy territory virtually unnoticed. Once air dominance is established and the skies belong to the F-35, it can head back for restocking. There, it is converted to 'beast mode' – without the need for stealth – patrolling with up to 10,000 kilograms of internal and external weaponry. Combining these stealth/beast weapon capabilities with the potential to control drones and robotic wingmen, you can see why the F-35 rules the sky.



The F-35, seen weapons testing here, has a range of weapon capabilities in stealth and beast mode

F-35s utilise their short take-off and vertical landing capabilities

This is AM-1, Norway's first F-35, being finished with low observable coatings

means the F-35 is built to last and shouldn't need to visit the hangar for repairs quite so often.

If you love video games, the F-35 cockpit is a gamer's dream. The design is so secretive that very few people know what it looks like. But from what pilots say, it's like playing with the best iPad ever. Long gone are the days where there were a huge number of dials and nothing could be changed without taking apart the cockpit. The F-35's cockpit is fully electronic, and pilots can call up data they want to see, ignoring the other stuff that isn't necessary for the mission at that time.

Virtual reality fans will also love the helmet, which is a similarly secretive technology. Lockheed says that pilots wearing this headset can not only view things in front of them, but they can even look at the floor and – thanks to special cameras mounted under the plane – see the terrain whizzing by underneath. No enemy fighters can sneak up on an F-35's belly, that's for sure. If there are friends flying nearby, each pilot's helmet can include the view the other pilots see as well. So F-35 pilots can help their buddies in combat, or see any obstacles that other planes might miss. This enables a whole new era of teamwork.

And speaking of teamwork, an F-35 pilot can also work closely with unmanned 'drone' planes that may be assisting in the mission. Drone planes are an excellent choice to get up close to a target, because if they're shot down, the F-35 pilot is still safe. Using the cockpit and helmet, the pilot watches what the drone is doing and can provide guidance as needed. It's a neat setup that will become more common as drone technology improves.

This means that the F-35 jet not only works for today but is also a fighter jet of the future. The UK and other military forces around the world hope to use this fighter jet for the next generation – perhaps even up to 2070.

So if you haven't seen one yet, go to your nearest air show and see this futuristic fighter race through the sky for yourself.

Which countries have F-35s?

1. Japan
2. Israel
3. Australia
4. Italy
5. Norway
6. South Korea
7. United Kingdom
8. United States

Billie Flynn is a former Royal Canadian Air Force squadron leader and fighter pilot

Q&A

F-35 senior experimental test pilot

We ask Billie Flynn what it's like to be the first to try out Lockheed Martin's new tech

How is flying the F-35 different to other jets you've flown?

Being in the F-35 is like flying in the most sophisticated virtual reality and video game that ever existed, wearing a helmet like Tony Stark wore in the *Iron Man* and *Avenger* movies. Everything about the F-35 feels like a science fiction fighter jet. Planes before this felt like an old movie. Now, it is like living in a *Star Wars* reality.

What new skills do pilots need to develop to fly the F-35?

I think the most interesting transition for everyone in the F-35 is to understand that those video game skills – and it terrifies every mother and father when their kids spend more time on video games – are directly applicable to understanding how an F-35 is supposed to be used. We see around our aircraft for hundreds and hundreds of kilometres [in all directions]. Our touchscreen iPad displays are filled with the most sophisticated information. Someone who is skilled at video games will adapt to that level of sophistication and complexity far better than an older generation of pilots.

How adaptable is the F-35 to the technologies of the future?

We are at the beginning of a lifetime that will last 40 to 50 years. We're going to expect our F-35 to evolve, to do so many things differently in the air and on the ground – and for our troops – than we ever thought imaginable at the beginning of its lifetime. We have an extraordinary cockpit, with an aircraft powered by 8.6 million lines of software code, just in the beginning of its lifetime. We can adapt over the coming generations to do things we never thought possible when we first... designed the plane.

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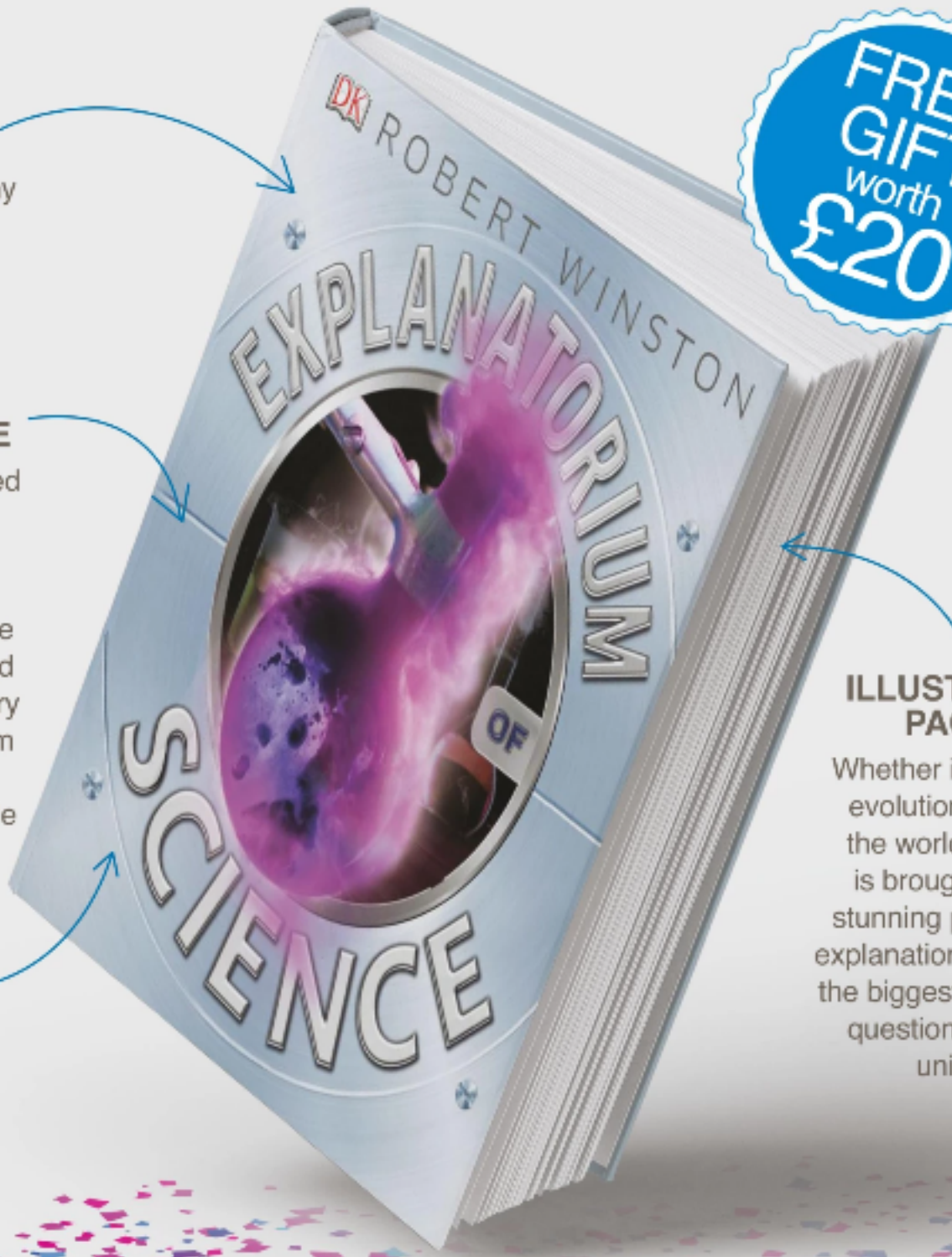

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THE MAGIC OF CARBON CHEMISTRY

Discover how this protean wonder-element can make more than 9 million different chemical compounds

Words by **Laura Mears**

Carbon is so versatile and so important that the Royal Society of Chemistry call it the 'King of the elements'. It's everywhere, and we use it for everything.

Carbon sits at position six on the periodic table. It has six protons, six neutrons and six electrons. Two of those electrons fill up an electron shell close to the nucleus, while the other four sit in a half empty shell around the outside. These outer electrons, known as the valence electrons, are the key to carbon's incredible properties.

The electrons in an atom's outer shell are the ones that take part in chemical bonds. How many bonds depends on how much room there is in the shell, and the amazing thing about carbon is that it's got space for four. This means that it acts like a plumbing cross-piece, becoming a four-way connector that links different atoms together. It can build straight chains, chains with branches, and chains joined end to end to make loops. And it doesn't just bond to itself. The edges of carbon chains can terminate in tiny hydrogen atoms, making them slippery like oils. Or they can connect to other groups of elements, called 'functional groups', each of which has different chemical properties.

Carbon works like elemental scaffolding, and the shapes, sizes and chemistry of the molecules it creates vary enormously.

Another important feature of carbon is that, although the bonds it makes are strong, they're not unbreakable. Carbon-based

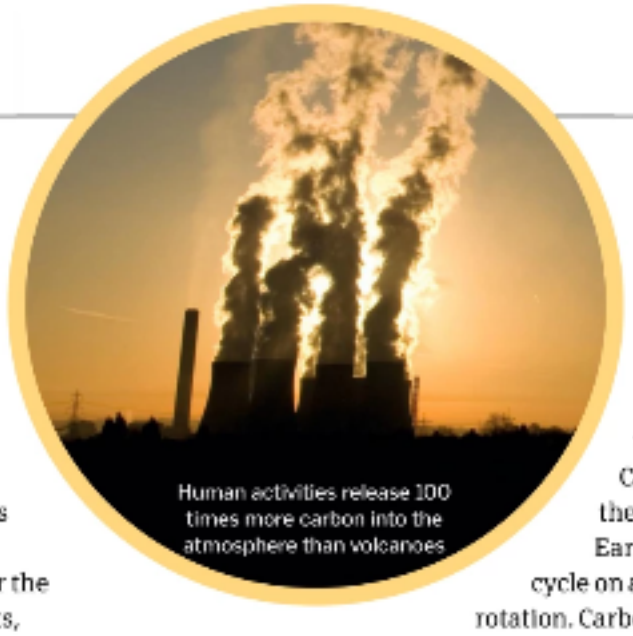
DID YOU KNOW? *Carbon forms the backbone of the largest stable synthetic molecule ever made, the 10-nanometre wide PG5*

Stronger than steel

A stretched carbon fibre is twice as strong as steel but only a quarter of the density. Woven into mats and embedded in epoxy resin, this tough, flexible material is stiff, strong under tension and resistant to chemicals. It's resilient enough to build lightweight bikes, boats, cars, planes and artificial limbs, and it's all down to the way the layers of carbon slot together.

Individual layers of graphite are some of the strongest structures in the known universe, but they're slippery. Each honeycomb sheet of carbon atoms is strong on its own, but the stacks slide around on top of each other forming flakes and faults. In carbon fibres, the arrangement is different. The sheets of graphene aren't smooth. They form long, thin ribbons that intertwine in random folds, locking together to form tough, lightweight fibres that don't tear apart.

Carbon fibre is five times stronger than steel, and it's also lighter and more flexible than steel



Human activities release 100 times more carbon into the atmosphere than volcanoes

molecules are stable enough that they won't fall apart, but, given the right amount of energy, they can be reworked into something new. This makes carbon the perfect backbone for the molecules of life. Fats, carbohydrates, proteins and nucleic acids (DNA and RNA) are all built around carbon.

There are 100 million billion metric tons of carbon on Earth today, and it's all been around longer than the Solar System. Our Sun is the grandchild of the very first stars in the universe. It was born about 4.6 billion years ago out of a cloud of dust and gas created by a supernova explosion. That dust and gas contained every of atom carbon on our planet, and more.

> "Carbon is a four-way connector that links different atoms together"

Carbon reacts with oxygen to make the infrared-trapping gas, carbon dioxide. Too much can cause a runaway greenhouse effect that makes planets impossible to inhabit. Just look at Venus – its surface temperature is 462 degrees Celsius!

Luckily, Earth didn't become a greenhouse, it became an incubator for carbon-based life. And in a strange way, life and Earth have been working together to keep it that way ever since.

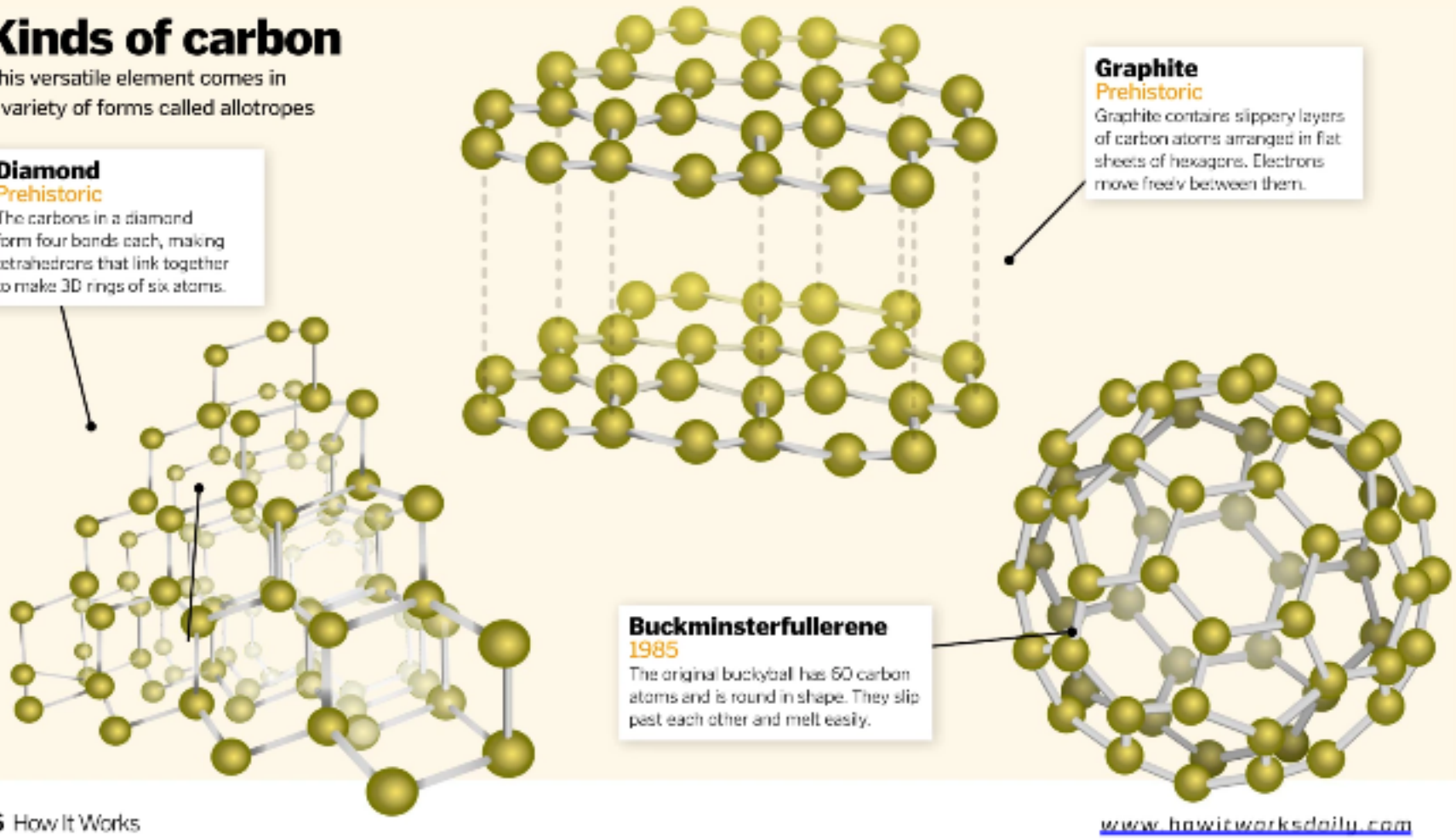
Carbon is Earth's thermostat.

Earth has a slow carbon cycle on a 100-million-year rotation. Carbon dioxide in the atmosphere reacts with water to make carbonic acid, which eats away at the rocks. This releases trapped calcium. Shell-making organisms in Earth's oceans combine that calcium with carbon-containing ions to make calcium carbonate. When they die and drop to the sea floor, their remains become limestone, locking carbon away underground. Slowly, this carbon returns to the atmosphere as Earth's crust shifts and shakes. Volcanic activity melts the rocks and releases carbon back into the air at a rate of around 130 to 380 million metric tons every year.

Layered over the slow cycle is a fast carbon cycle, governed by plants. They take in carbon dioxide and use energy from sunlight to trap carbon in organic molecules. These molecules then pass through the food chain, becoming

Kinds of carbon

This versatile element comes in a variety of forms called allotropes

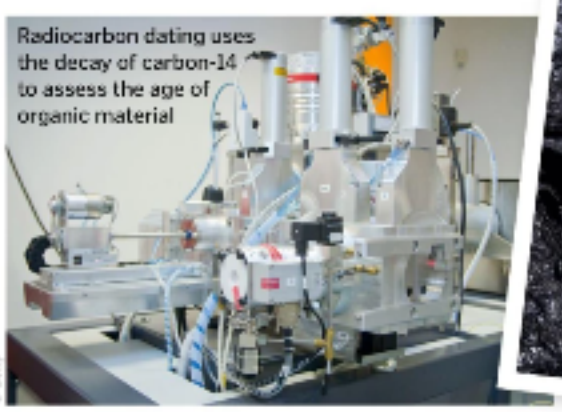


Diamond
Prehistoric
The carbons in a diamond form four bonds each, making tetrahedrons that link together to make 3D rings of six atoms.

Graphite
Prehistoric
Graphite contains slippery layers of carbon atoms arranged in flat sheets of hexagons. Electrons move freely between them.

Buckminsterfullerene
1985
The original buckyball has 60 carbon atoms and is round in shape. They slip past each other and melt easily.

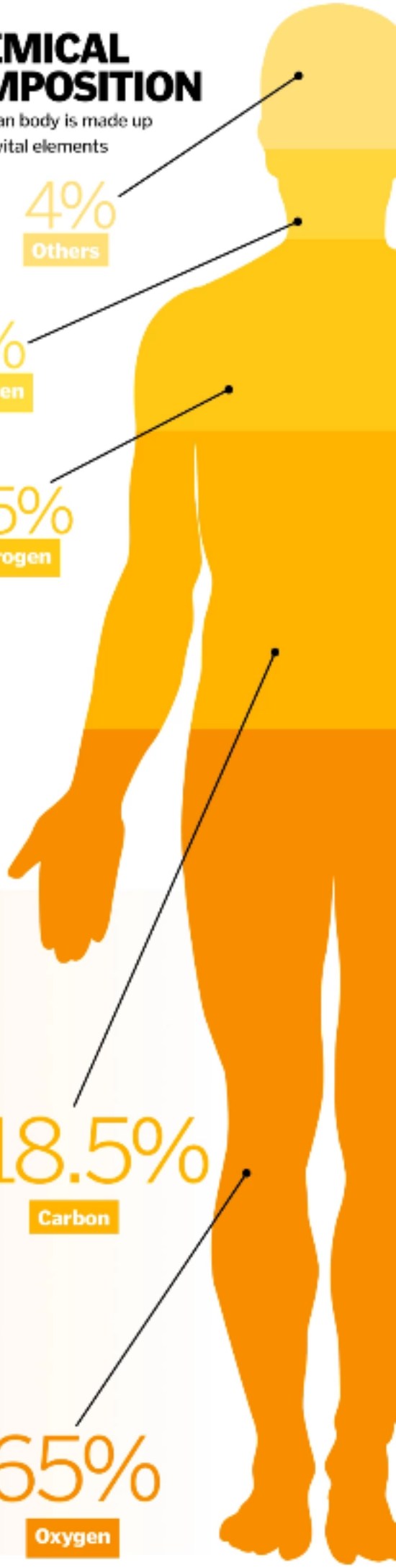

This aerial photo shows a coal mine in action

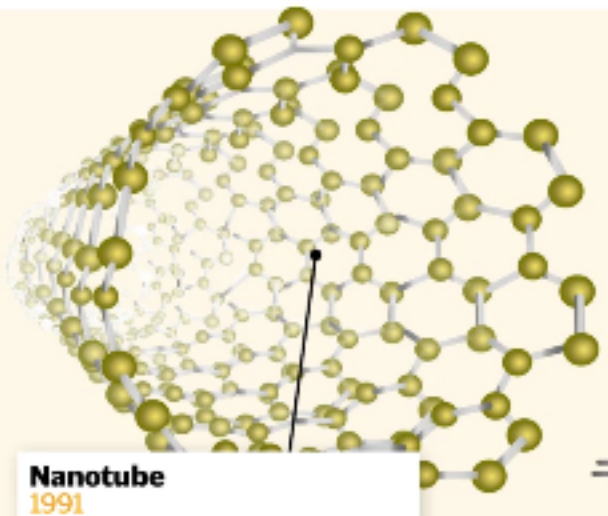

Radiocarbon dating uses the decay of carbon-14 to assess the age of organic material


It's hard to believe that coal and diamonds are made from the same element

CHEMICAL COMPOSITION

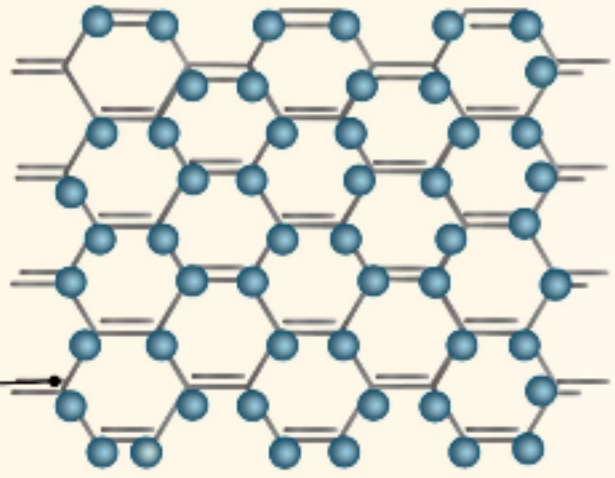
The human body is made up of these vital elements





Nanotube
1991
These hollow cylinders look like rolled up graphene sheets. They resist stretching and conduct electricity.

Amorphous
Prehistoric
A disorderly arrangement of carbon atoms is common in coal. It contains pockets of graphite and diamond, with properties in between.



Graphene
2004
As the world's thinnest material it is 1 million times thinner than the diameter of a human hair. It is strong, lightweight and flexible – properties that make it useful in a range of industries.

Reading the carbon clock

High-energy cosmic rays help us to work out when ancient plants and animals died

Cosmic rays
The Sun sends high-energy particles whizzing into Earth's atmosphere. When they hit atoms, they can push out energetic neutrons.

Nitrogen-14
Most of the nitrogen in Earth's atmosphere exists as the isotope nitrogen-14, which contains seven protons and seven neutrons.

Food chain
Plants and animals add tiny amounts of carbon-14 to the fats, carbohydrates, proteins and nucleic acids in their bodies.

Start the clock
When the plants and animals die, they stop taking in new carbon-14.

Ticking clock
As time passes, more and more carbon-14 decays.

Stop the clock
To work out when something died, scientists compare the amount of carbon-14 to carbon-12.

Radioactive decay
Carbon-14 is radioactive. It decays with a half life of 5,730 years, losing a proton to become nitrogen-14.

DID YOU KNOW? *Earth is around 0.18% carbon, the Sun is around 0.3% carbon, and the universe is around 0.5% carbon*

Carbon-14
When a neutron hits nitrogen-14, it pushes out a proton. This makes carbon-14, which contains six protons and eight neutrons.

Photosynthesis
Plants take up carbon dioxide from the atmosphere. One in every trillion molecules contains carbon-14 instead of carbon-12.


Volcanoes turn rocks into carbon dioxide, completing the carbon cycle

5 FACTS ABOUT CARBON: THE BASIC BUILDING BLOCK OF LIFE

1 You are 18.5% carbon
Almost all of your body is made up of just four elements. You're 65% oxygen, 18.5% carbon, almost 10% hydrogen and 3% nitrogen.

2 Pencils beat diamonds
Graphene is so strong that you can stretch it by around 25 per cent before it snaps, making it stronger than both steel and diamond.

3 Carbon kills small stars
Helium fusion makes carbon, but the Sun is too small to burn it, so when the Sun runs out of helium, it will gradually grow cold and die.

4 Soot causes cancer
In 1775, doctors noticed a strange kind of skin cancer that only affected chimney sweeps. Contaminated soot from incomplete combustion was triggering the disease.

5 Carbon strengthens tyres
Car tyres get their colour from carbon, but it's not just there for show. It makes the tyres strong and protects them from the Sun.

foliage and flesh before returning to the air as carbon dioxide.

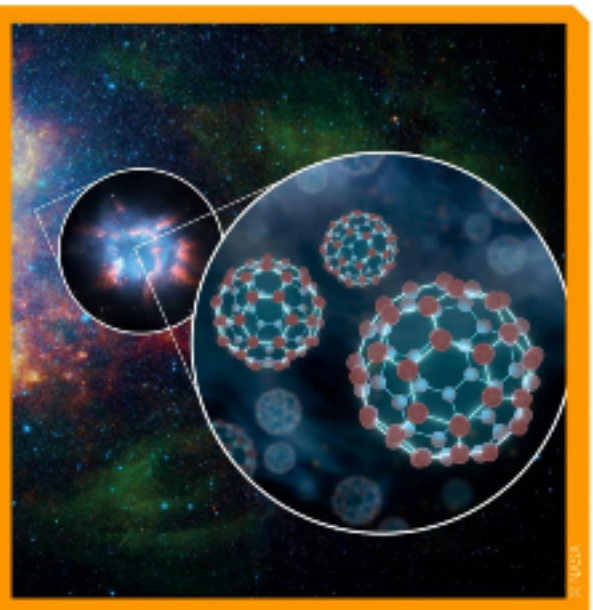
Carbon has been so fundamental to life on our planet that its very existence is now inextricably linked to living things. Around 80 per cent of Earth's rocky carbon is limestone, made from the shells and skeletons of sea creatures. Most of the rest exists as fossil fuels, coals, oils and gases, made from the compressed remains of plants and animals.

The story of carbon is written into the very fabric of our planet, but it's not finished yet... We are currently releasing around 100 times more carbon into the atmosphere than volcanoes, and it's messing with Earth's thermostat. Carbon dioxide levels were 280 parts per million 150 years ago, and now they're 412 parts per million.

This incredible element made our planet what it is today. Now, the race is on to find innovative ways to work with carbon to ensure our future.

Buckyballs in space

We used to think that molecules with more than 12 atoms wouldn't be able to survive in interstellar space, but we were wrong. In 2019, the Hubble Space Telescope confirmed that there are electric buckyballs floating between the stars. These giant molecules contain 60 carbon atoms each, and the telescope revealed that they're ionised. The energy from nearby stars has pulled away one of their electrons, leaving them with a positive charge. Finding these chunky molecules in outer space could help to answer some puzzling astronomical questions. Scientists have spotted more than 400 strange patterns of light absorption called Diffuse Interstellar Bands, or DIBs, made by unknown molecules in outer space. It could be that complex carbon chemicals are the cause.


Electric buckyballs have been spotted between the stars

Inside a bionic heart

Swapping muscle for metal, how does this artificial organ keep blood flowing?

Cardiovascular disease is one of the world's biggest killers, accounting for 31 per cent of all deaths globally. Although a lot of cases are treatable with a heart transplant, finding a donor is becoming increasingly difficult: only around 4,000 hearts are available globally each year.

The creation of a total artificial heart (TAH) could be revolutionary for saving lives. Several iterations have been tried over the past few decades, but none have had the ability to completely copy the heart's function for more than a few years.

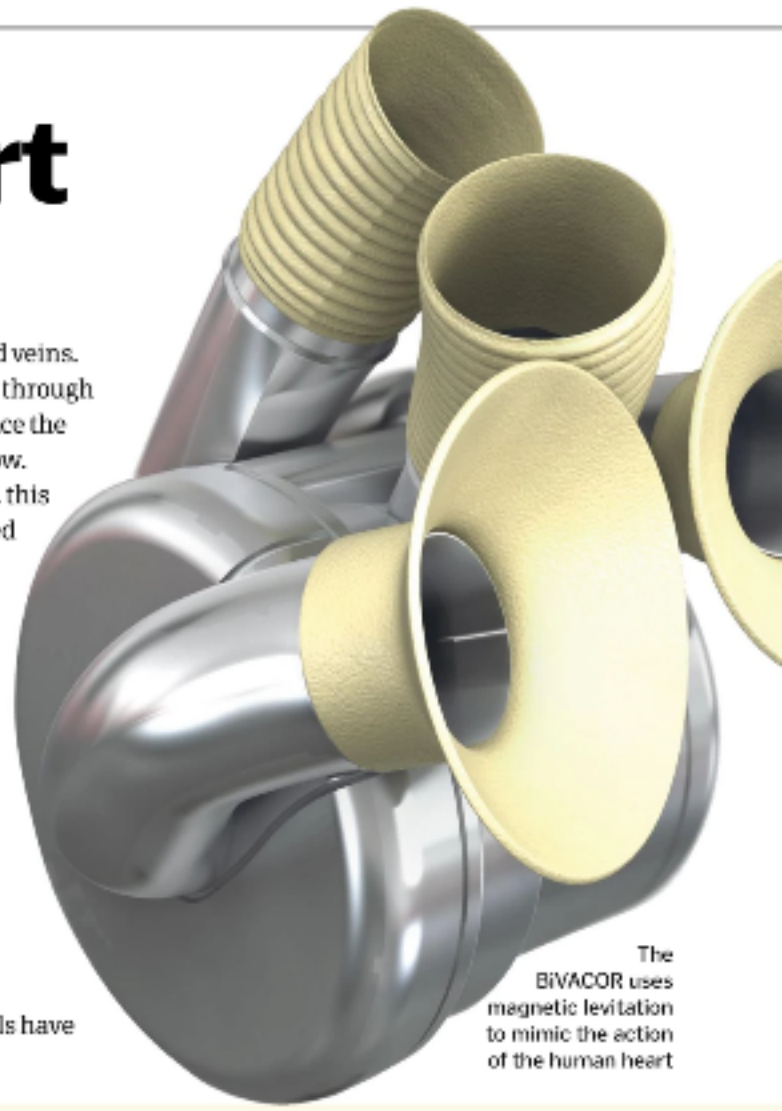
The latest and arguably most promising development of a TAH comes in the form of the BiVACOR, a 3D-printed titanium pump that utilities an autonomous magnetic rotor to circulate blood.

One of the common issues found in previous TAH technology has been the physical wear and tear of a device's moving parts. Using magnetic levitation (maglev), the BiVACOR's central spinning rotor is magnetically suspended inside an electromagnet bearing. As electricity passes through the magnet the rotor spins, propelling the blood around the body's arteries and veins. Maglev prevents physical wear and tear through normal friction, and it is thought to reduce the complications that would normally follow.

> "The rotor spins, propelling the blood around the body's arteries and veins"

Smaller than a can of coke, this compact device is constructed using a form of metal 3D printing called selective laser sintering (SLS). This process involves repeated layers of fine titanium dust being melted by a laser to slowly print the final form.

The BiVACOR has shown promising results during its animal trials, with bovine (cow) subjects surviving the full 90-day test period. However, the device is still in its development stages, and no human trials have been carried out so far.



The BiVACOR uses magnetic levitation to mimic the action of the human heart

How important is your pulse?

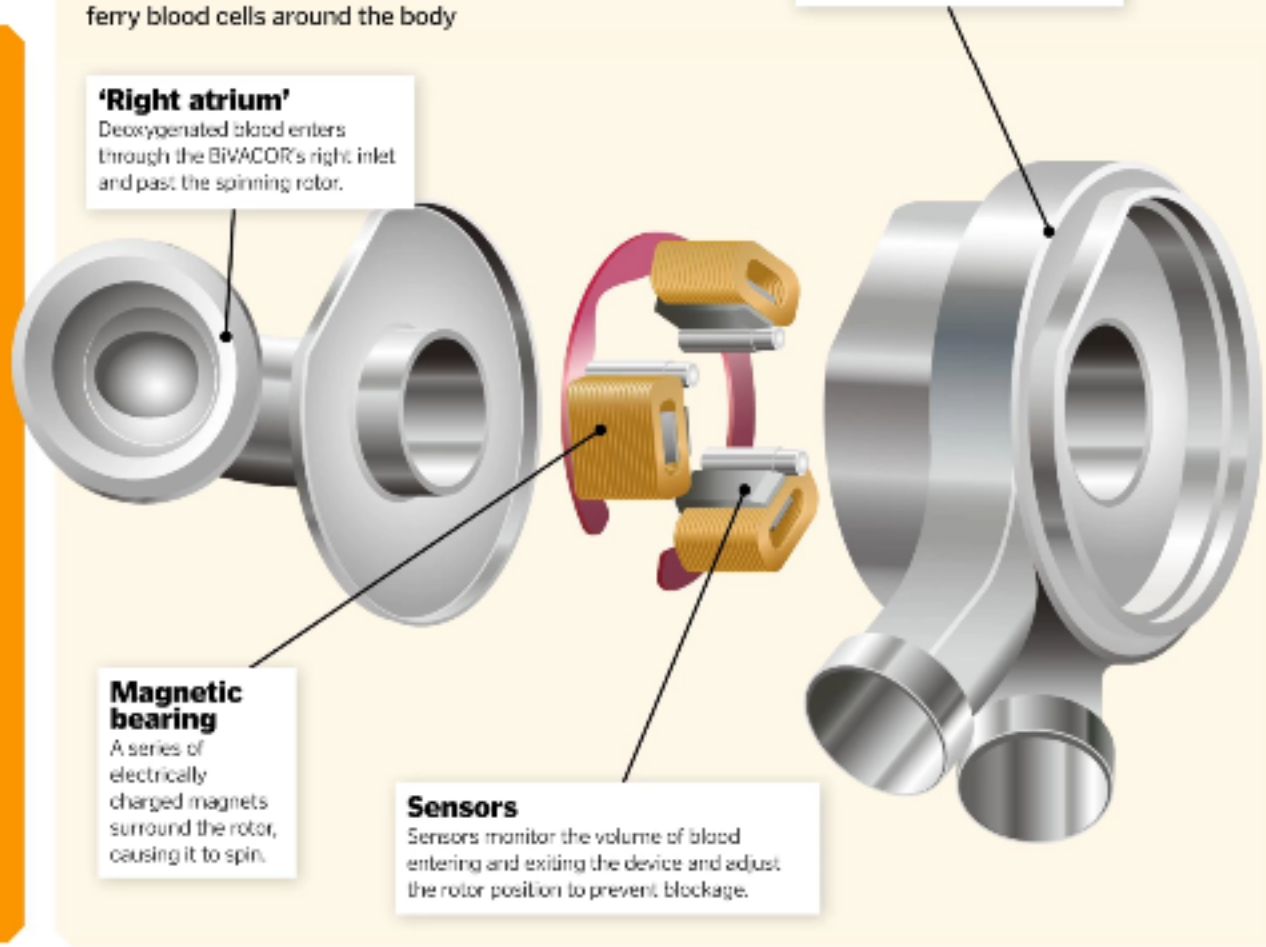
The way our blood moves around the body can play a role in our health. Apart from being an indicator of a beating heart, pulsating blood flow is thought to assist in washing out small blood clots in our arteries, for example.

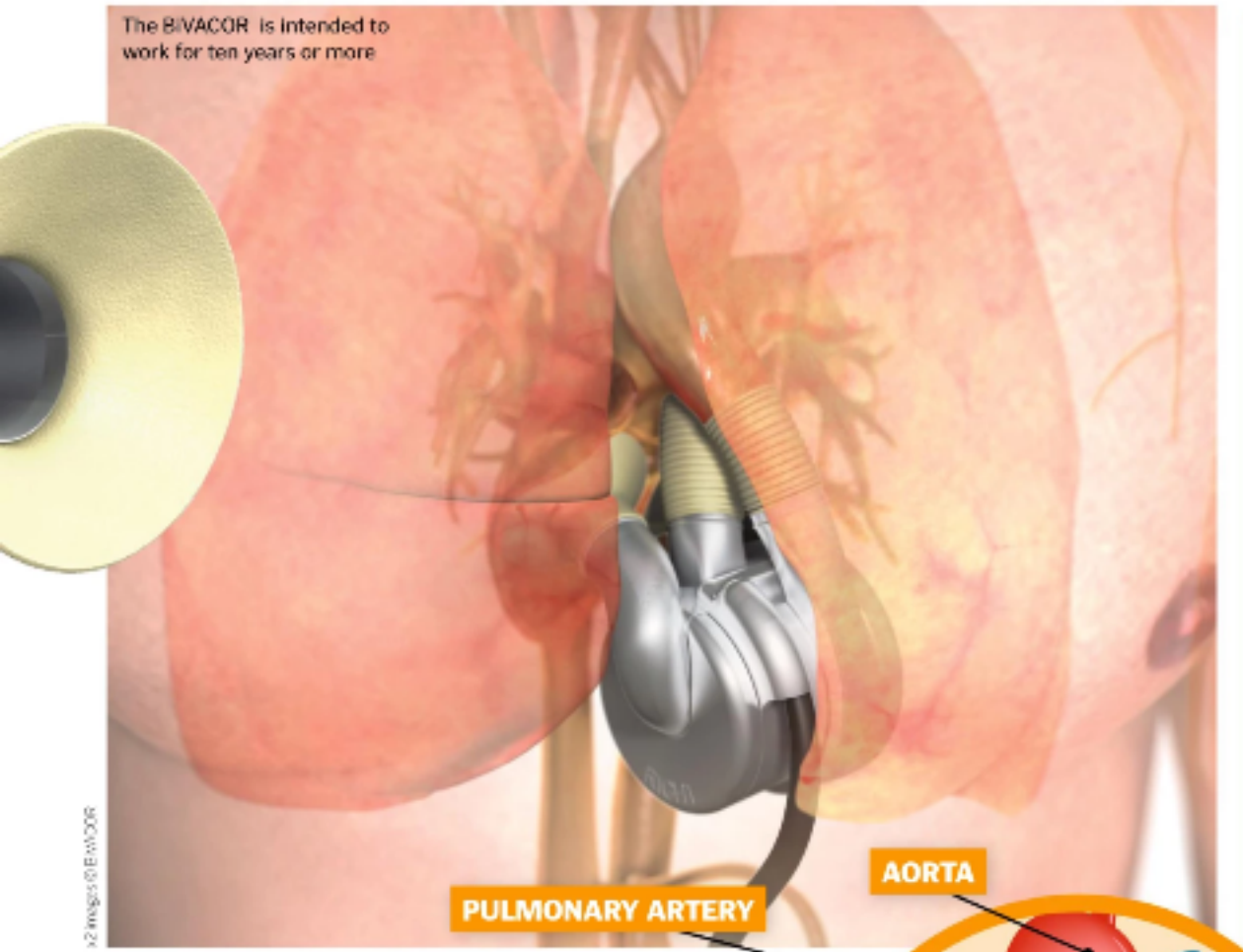
Using the BiVACOR, the maglev rotor continuously circulates blood and removes the presence of a pulse. However, the internal electromagnet can be programmed to mimic each heartbeat with an external device.

The ECG of BiVACOR animal test subjects followed similar patterns to a typical heartbeat

Inside an artificial heart

Discover how BiVACOR uses magnets to ferry blood cells around the body



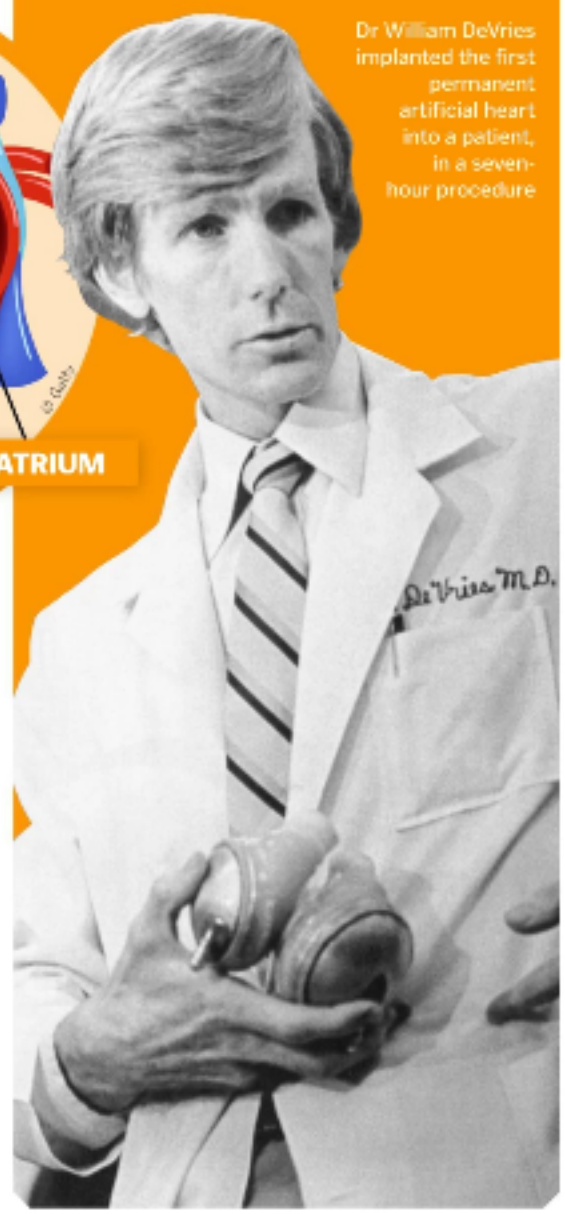


A change of heart

The concept of implanting an artificial heart isn't a new one. In the early 1980s American physician Robert Jarvik designed the first artificial heart, later called the Jarvik-7. Made from aluminium and polyurethane, the Jarvik-7 housed two rubber diaphragms to act as the artificial heart's ventricles. With the help of an external compressor, each diaphragm contracted and inflated to mimic the heart's natural pumping action.

Jarvik-7 first saw the inside of a human chest in 1982, lowered in by the hands of American surgeon Dr William DeVries. The first recipient of the human-made heart, a 61-year-old dentist from Seattle, survived for 112 days following the surgery before the device ultimately caused irreversible complications, resulting in his death. Two years later a second attempt was made, with the 52-year-old patient surviving 620 days before a series of strokes brought on by blood clots ended his life.

By 1990 the Jarvik-7 had been removed as an approved form of treatment, but the device gave scientists a valuable insight for future developments.



Dr William DeVries implanted the first permanent artificial heart into a patient, in a seven-hour procedure

TITANIC

HOW THE 'UNSINKABLE' SHIP SANK

Thousands of people cheered as the world's largest ship was launched, but nobody anticipated its tragic end

Words by **Ailsa Harvey**

The air was buzzing with excitement ahead of the launch of Titanic in 1912. Measuring 269 metres in length, it was the largest and most extravagant ship anyone had ever known. Departing for its maiden voyage, around 2,200 people boarded Titanic along its route from Southampton, England, to New York City, USA. For over 1,500 of them it would be the last trip they ever made.

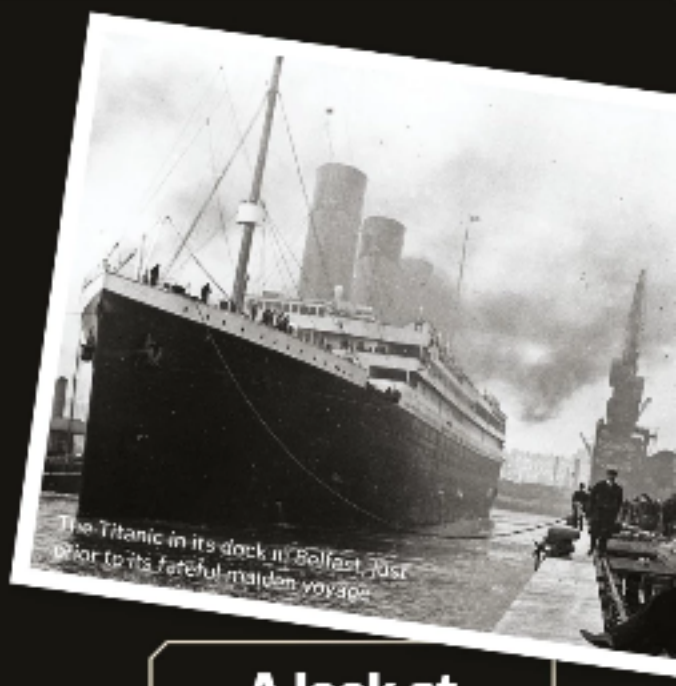
The passengers were a diverse mix; wealthy holiday-makers and working-class immigrants searching for new opportunities in the land promising the 'American dream'. Due to less space being allocated per person in lower classes, there was a third-class majority on board. Classes were strictly confined to specific areas of the ship.

Titanic was designed to prioritise comfort rather than speed, but was comfort also prioritised over safety? Carrying some of the richest people in the world at that time, it was a huge leap forward in luxury travel. Conditions in second-class cabins were similar to other cruise ships' first class, and Titanic's passengers were provided with gyms, pools, libraries and huge restaurants.

Problems with the vessel occurred from the outset, with a series of accidents and near-misses. While the deaths of those aboard Titanic when it sank are well-documented, the first victims were in fact its builders. It took around 3,000 men to build Titanic over two years. During construction, before the ship had even touched water, eight workers lost their lives, and there were 28 serious accidents recorded.

Further accidents nearly occurred when the ship left Southampton ahead of its maiden voyage. When pulling away from the port, it came within a couple of metres of crashing into another vessel. Many of the passengers were alarmed by this bumpy start to the journey but were unaware of how this event would soon pale into insignificance.

On the whole, passengers were confident that they were safe while confined to this ship, isolated in the ocean. The luxury liner was branded 'unsinkable' by ship designers,



The Titanic in its dock at Belfast, just prior to its fateful maiden voyage

A look at the iceberg

1,600KM

The distance travelled by the iceberg before it hit Titanic

It was one of many floating further south than usual

30 METRES

Its estimated height above water – a fraction of what lay beneath

The iceberg probably calved from a glacier on Greenland's west coast

1.5 MILLION TONS

The iceberg displaced nearly 30 times Titanic's weight in water

The snow that went into creating the iceberg fell 100,000 years ago

"I cannot imagine any condition which would cause a ship to founder"

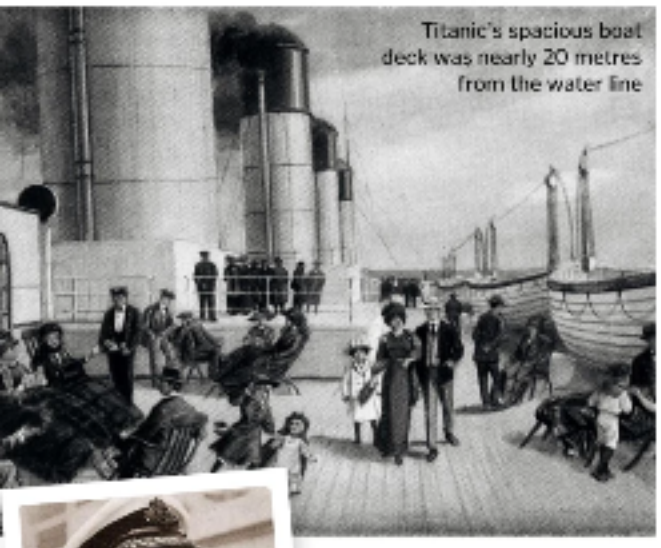
because it was built to stay afloat even with major flooding. But this unsinkable ship would go down – both into the ocean and history.

During the evening of 14 April and into the morning of 15 April in 1912, just four days after setting off, Titanic sank. Two hours and 40 minutes after hitting an iceberg, the ship lay in pieces below the surface of the Atlantic.

Some passengers had always doubted its safety, but other people died because they refused to leave on lifeboats, clinging to the hype of the world's safest ship liner. Why would you voluntarily enter treacherous waters when you're on a ship you've been assured could never sink?

The captain also showed the misplaced confidence held by most in shipbuilding at the time. Before his final voyage he said, "I cannot imagine any condition which would cause a ship to founder. I cannot conceive of any vital disaster happening... modern shipbuilding has gone beyond that."

Unsurprisingly, the disaster raised many questions about what was and wasn't done at the time. Every action taken that fateful night has been analysed and scrutinised during inquiries. The wreckage, which still lies below the water, has been inspected in order to pinpoint where exactly the design failed. How could this tragedy have been prevented?



Titanic's spacious boat deck was nearly 20 metres from the water line

Fighting the flood

While engine rooms were thrown into turmoil, above deck passengers kicked iceberg remnants, oblivious to the damage

The first act
After hitting the iceberg, the first officer, William Murdoch, immediately orders the closure of the watertight doors in the engine rooms.

Darkness under deck
Even when water damage causes the engine rooms to go dark just before midnight, some workers use lamps to continue working.

The first cracks
On the port side of the ship, water suddenly surges into Boiler Room Six before the doors have fully closed.

14 April

9:20pm
Titanic's captain, Edward John Smith, a very experienced sailor, retires to his cabin for the evening.

10:55pm
A nearby liner warns that it's stopped due to surrounding ice, only to receive an angry response for interrupting wireless operators.

11:00pm
After enjoying a ten-course meal, which will be their 'last supper', most first-class passengers return to their rooms.

11:30pm
The lookouts notice low-lying mist near where the iceberg is. If they had binoculars with them, this is when they may have spotted it.

11:35pm
Lookout Frederick Fleet spots the iceberg straight ahead. He rings the bell three times and calls to the Bridge.

Some of the survivors from Titanic. They were the lucky ones who made it onto the lifeboats and were rescued by Carpathia

Evacuation
When the watertight doors are locked, the crew have to escape the flooding compartments using emergency ladders.

Stop
Ordered to stop the engines, workers quickly react to shut off the steam. Within 15 seconds all engines are still.

The iceberg caused multiple slashes in Titanic's hull, flooding five compartments

"Iceberg! Right ahead!"

These were the words yelled by Frederick Fleet, the man who first spotted the icy death trap. As one of two lookouts, alongside Reginald Lee, Fleet was keeping watch when Titanic hit the iceberg.

Spotting danger in the water was made more difficult than usual that night, as the sea was incredibly calm. This reduced the ability to spot objects in the water as no telltale waves were crashing against the iceberg.

On this particular night, the pair stood in the crow's nest, high on the ship's mast, without equipment that could have perhaps saved the many lives lost. Having misplaced the binoculars, it was made impossible to spot the looming ice before it was too late. In the inquiry, Fleet commented that he would have seen the iceberg in time if he'd had the binoculars.

Fleet and Lee's shift ended at midnight and they were replaced by new lookouts. After helping women and children onto lifeboats, they both survived the sinking to tell the story.

How the water spread

After colliding with the iceberg, the front of the ocean liner suffered damage and five of its 16 compartments ruptured. The ship was designed to stay afloat with 12 of its compartments intact, but with only 11 holding the ship together, it wasn't long before the flooded front began to pull the bow of the ship downwards.

The design included a series of emergency doors that would close to prevent water spreading. However, the bulkheads, which were watertight walls separating the compartments, weren't tall enough, and the water swiftly spilled over the top.

Scientists later discovered that a series of thin gashes inflicted on the hull by the iceberg allowed water to stream into the ship, rather than one large slash as was originally believed. It is speculated that the poor quality of the steel used in rivets holding the hull together contributed to Titanic's rapid demise.

15 April

11:40pm
First Officer William Murdoch orders engines to be reversed, turning the ship. The right side of the ship scrapes the iceberg.

11:50pm
Water quickly surges into the front sections of the ship, flooding it with around four metres of cold Atlantic water.

12:00am
The captain is told the ship only has a couple of hours before it sinks. He gives the order to call for help over the radio.

12:05am
An order is given to the crew to uncover the lifeboats and allow only women and children on.

12:20am
Carpathia receives Titanic's distress signals. It goes to assist but is 107 kilometres away. The journey will take three hours.

12:20am
The ship's musicians move from first class to the deck, intending to calm passengers. None of the musicians will survive.

The last communication

Radio logs show the wireless operators' pleas for help during the final hours

CQD Emergency (an old distress signal)

SOS Emergency (a new signal that began in 1906)

OM Old man (a common phrase at the time)

12:15
CQD Titanic 41.44 N 50.24 W.

12:17
CQD CQD SOS Titanic position 41.44 N 50.24 W. Require immediate assistance. Come at once. We struck an iceberg. Sinking.

12:20
Come at once. We have struck a berg. It's CQD OM. Position 41.46 N 50.14 W.

12:25
Carpathia: Shall I tell my captain? Do you require assistance?

12:26
(To Carpathia) Yes. Come quick.

12:30
(To Frankfurt) 41.46 N 50.14 W. Tell your Captain to come to our help. We are on the ice.

12:32
Carpathia: Putting about and heading for you.

12:36
Frankfurt: What is the matter with u?
(To Frankfurt) We have collision with iceberg. Sinking. Please tell Captain to come.
Frankfurt: O.K, will tell.

12:45
(To Olympus) S.O.S.

1:10
(To Olympus) We are in collision with berg. Sinking head down. 41.46 N 50.14 W. Come soon as possible.

1:25-1:27
Corona: Baltic coming to your assistance.
Olympic: 1:24 am GMT 40.52 N, 61.18 W. Are you steering southerly to meet us?
(To Olympic) We are putting the women off in the boats.

1:30
We are putting the passengers off in small boats.

1:37
Baltic: We are rushing to you.

1:45
Come as quickly as possible OM. Engine room is filling up to boilers.

2:17
CQ- (signal stops as the power shuts down).

3:58
Birma: Steamship full speed for you. Shall arrive 6-0 in morning. Hope you are safe. We are only 50 miles now.

The final moments

With 1,500 people still on the ship, the Titanic plunged into the freezing water

2:17am

Tipping point
As the front of the ship sinks below the water, hundreds of people are washed into the ocean.

2:18am

Blackout
Titanic's lights fail, leaving the ship in total darkness.

Split in two
With the bow filled with 16,000 tons of water, the ship tears apart at its weakest point.

2:19am

The first plunge
After breaking loose from the stern, the bow plummets towards the seabed.

Brief hope
Freed from the weight of the bow, the stern begins to rise, giving hope to those who were still on board.

12:45am
The first of eight distress rockets are fired into the sky by the crew, hoping to

1:00am
The water appears at the base of the Grand Staircase on E Deck, as people continue to load

2:00am
Propellers on the stern are visible above sea level as the front continues to

2:20am

"Require immediate assistance. Come at once. We struck an iceberg. Sinking."

Standing vertical
Shortly after, the stern of the ship rises up once more, pouring an avalanche of Titanic's contents into the ocean.

Vanishing beneath
Once vertical, the remainder of Titanic disappears below the surface. The rudder swings to one side, causing the huge ship to spiral the whole 3.7 kilometres to the bottom.

Laid to rest
The bow crashes into the ocean floor 27 minutes before the stern, despite beginning its descent just a minute earlier.

2:17am
The captain relieves the last crew members from their duties. He soon announces that it is "every man for himself".

2:20am
Titanic, having broken in two, finally slips underwater. It claims the lives of 1,500 passengers and crew.

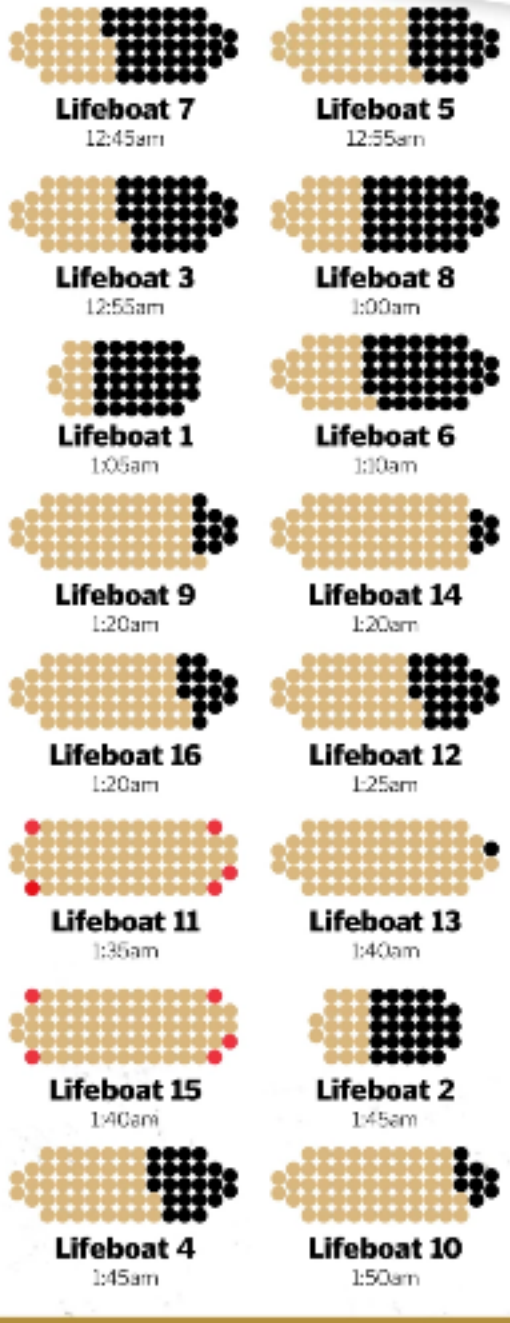
3:30am
The Carpathia arrives to collect the survivors and take them to New York City.

Lacking lifeboats

Titanic had 20 lifeboats to carry 1,178 of the 2,200 people. A lifeboat drill due that day was cancelled, and in a disorderly process boats left half-empty. Only 705 escaped in these boats.

KEY

Taken · Overflow · Empty



www.howitworksdaily.com

Meet Stephenson's Rocket

Discover the single most important object in the modern age and meet the humble makers who built the modern world from their kitchen tables in Brass, Steel and Fire at the National Railway Museum

Built in 1829 by English locomotive manufacturers Robert Stephenson and Company, Rocket has become one of the UK's most historically significant objects. It achieved a then-remarkable top speed of 48 kilometres per hour, winning the contact for the company to produce locomotives for the railway and securing the engine's place in history. The engine operated on the world's first inter-city passenger railway in 1830, ushering in the railway age.

This bold prototype changed the course of history with its experimental engineering. Throughout the Brass, Steel and Fire exhibition you will meet the ordinary people who, fascinated by innovations like Rocket, transformed their kitchens into makeshift workshops and crafted extraordinary machines entirely from scratch. Vicars, lace makers and miners breathed life into hissing, steaming miniature locomotives in makeshift workshops built inside their homes. Discover their beautifully intricate homemade creations, including some of the oldest of their kind. Learn how their small-scale experiments pushed the boundaries of engineering, influencing the course of the Industrial Revolution. And for the first time in 20 years, you'll have a chance to see the world-changing locomotive that kickstarted a golden era of innovation in action, as Rocket travels to York to complete the final leg of a national tour of UK museums, organised by the Science Museum Group.

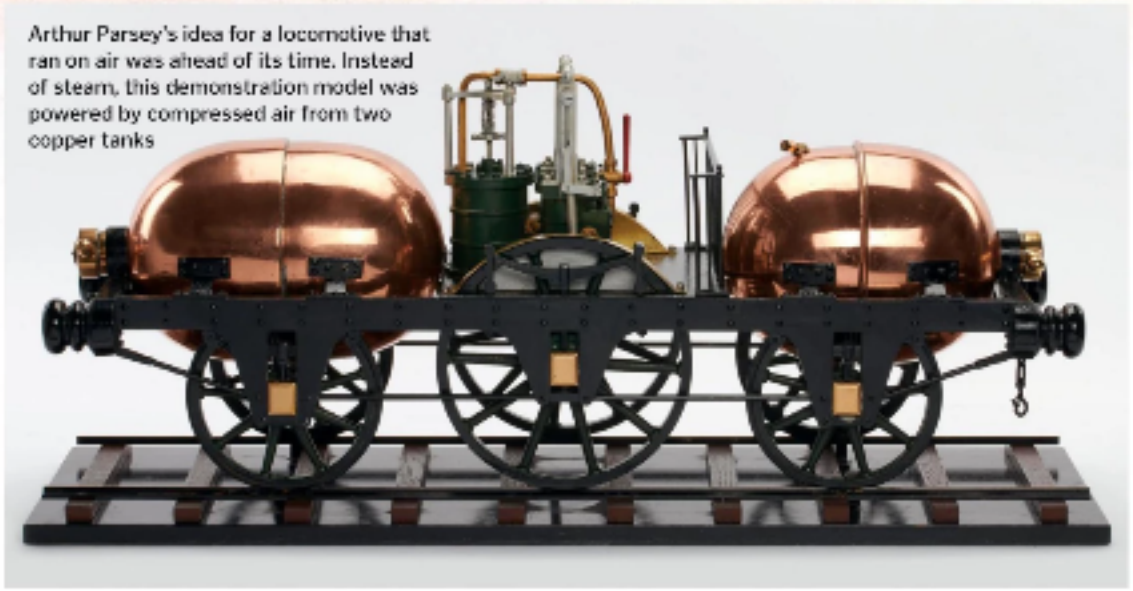
The Rocket appeared on the back of the old 1990 to 2002 issue UK £5 note

How Rocket worked

Stephenson's most famous invention brought together several existing locomotive innovations

Blastpipe
This fed the exhaust from the cylinders to the bottom of the chimney, pulling air through the fire. This was more effective combined with Rocket's multi-tube system.

A photograph of Robert Stephenson, taken 27 years after his Rocket success



Arthur Parsey's idea for a locomotive that ran on air was ahead of its time. Instead of steam, this demonstration model was powered by compressed air from two copper tanks

This quirky 1820s model steam engine was redesigned again and again by engineer Simon Goodrich as he experimented with the latest locomotive developments

Multi-tube boiler
Rocket had 25 smaller copper fire tubes in the boiler that carried hot exhaust from the firebox. It made it a much more efficient machine.

Learn more

See the original Rocket in all its restored glory in Brass, Steel and Fire at the National Railway Museum, from now until 13 April 2020.

"It achieved a then remarkable top speed of 48kph, winning the contract for the company"

Horizontal cylinders
Twin cylinders nearly 1.5 metres long were set from a horizontal, rather than a vertical position. Their position allowed the pistons to drive the wheels directly, improving efficiency and reducing breakdowns.

Separate firebox
Removing the firebox from the boiler increased efficiency and reduced the amount of smoke Rocket produced.

Water mill power houses

This simple mechanism uses flowing water to reduce the need for manual labour


A water wheel's rotations turned giant stones called millstones. These were used to crush grain

Looking at the man-made objects that surround you, how many have been made completely by hand? The answer is probably not many. Before water mills were invented, every step in production involved manual labour. Water mills provided the first power for man that didn't require animals or humans to produce.

Using a water wheel placed in flowing water, kinetic energy is able to sustain consistent mechanical energy. The combination of the wheel and the mill it attaches to is a water mill.

The mechanical output from these structures greatly benefitted communities by carrying out jobs such as driving saw mills, grinding corn and flour, moving pumps, making vegetable oils and powering textile mills. For centuries flour was a staple food and in high demand, so this production method has helped to feed society from Roman times into the modern period.

Different countries developed the system for different purposes. While Greek mills were used to grind grain, many Syrian mills were used for converting cotton into cloth. For these textile mills, which appeared in France during the 11th century, the water's motion was used to lift wooden hammers that beat the cloth.

These simple energy uses came before the arrival of steam power or electricity. In the early 20th century, similar principles were used to produce sustainable electrical energy. The invention of the water turbine means that in developed countries, water mills were no longer as useful. However, there are still over 20,000 operating in Nepal and approximately 200,000 in India, where they are often relied on for processing grain.

The explosive power of flour

There is a dark history associated with water mills – particularly those that produced flour. Flour mill explosions have been catastrophic, with the worst cases resulting in the loss of life. In 1878 at the largest flour mill in the US, Washburn A Mill, an explosion killed 18 workers.

How can this powdered grain hold the power to kill? Suspended flour particles are rich in flammable carbohydrates and are said to be more explosive than coal dust. When airborne, the dust carries far more oxygen than the flour you may lay on your kitchen counter. Flour mills produce large masses of particles, remaining close together in the air. It only takes one particle to ignite in order to set off a chain reaction of exploding particles, creating an inferno.


Before the invention of mills, people smashed grains between stones to produce flour

The wheel at work

How did this early hydropower source operate?

Directing water
River water is channelled through a chute towards the water wheel.

Pushing the wheel
The water drops from a height. As it fills up wells on the wheel, the one-sided weight pushes the wheel down, causing it to turn.

Constant rotation
The movement of the wheel enables the rotational energy to be used for anything that require a circular motion.

Water release
Once used for the rotation, the water drops off the wheel and back into the river for a sustainable system.

Moving the machinery
These rotations can be used for grinding and pumping actions, taking this laborious chore away from humans.

Turning the cogs
Cogs and gears attached to the mill transfer the rotational energy from the wheel to the machinery.

CORGI

Creator of high quality, die-cast metal collectables for over 60 years

Harry Potter

WIZARDING WORLD

STEP ABOARD

it is going to be a bumpy ride!

As seen in Harry Potter and the Prisoner of Azkaban

EVEN MORE MAGIC

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Water jet-powered flight

How do these jet ski accessories use water to keep you airborne?

There could be some time to wait before we are commuting to work by jetpack or hopping on a hoverboard to go shopping, but hydroflight is giving us a glimpse into the future of flying transport.

Ditching the concept of the combustion engine for water power, hydroflight jetpacks and flyboards are firing people up in the air, albeit while tethered to a motor. The principle of hydroflight involves using a jet ski or personal watercraft (PWC) to generate enough force through a connecting pipe to lift a person out of the water.

When the operator turns on the jet ski's throttle it causes the motorised blades beneath to accelerate. This 'impeller' sucks up large amounts of water from the body of water the PWC sits on, and pumps it out the other side. The expulsion of water generates enough force to move the jet ski forward.

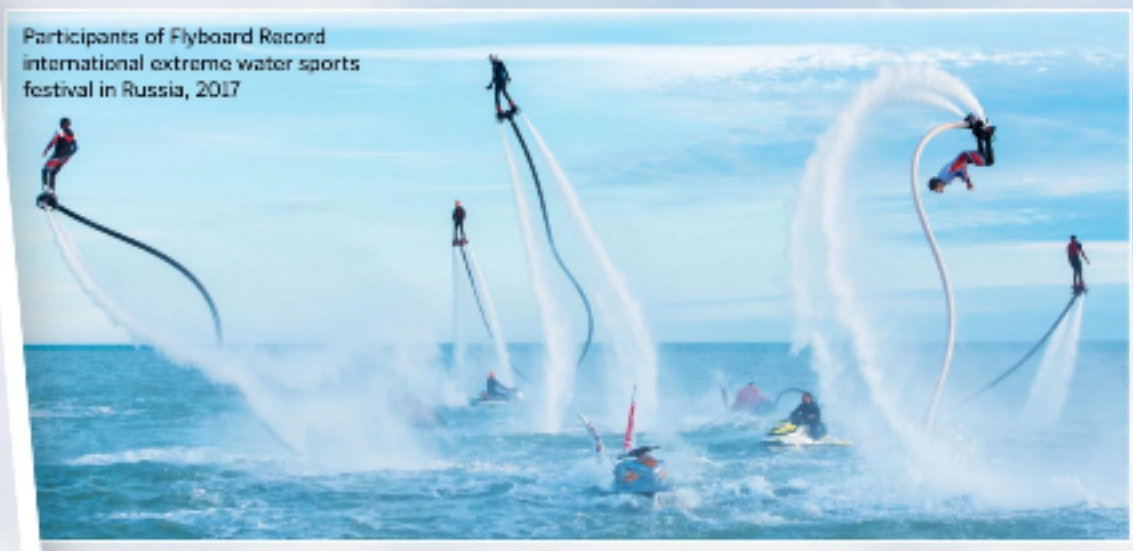
When that expelled water is pumped into a hose rather than back into the ocean, that generated force flows through the hose, leaving the jet ski stationary. By placing a jetpack at the end of the hose and directing the release of water downwards, a pilot can utilise the generated force to fly in the air.

"Directing the release of water downwards, a pilot can utilise the generated force to fly"

The first hydroflight jetpack, JetLev, came from inventor Raymond Li in 2009. He initially attempted to house a motor capable of generating enough thrust on his back, but it wasn't until he outsourced that task to a PWC that his invention really took off. Li and his JetLev rose from the water's surface, starting a whole new industry that has expanded enormously since then.

Now a common sight at many popular holiday destinations around the world, hydroflight has diversified from the jetpack design into flyboards and even into flying jet skis.

Flyboards use the force of the water to propel them upwards



Participants of Flyboard Record international extreme water sports festival in Russia, 2017

Flying with water

How these water-driven boards launch into the air

Pilot
Maintaining their balance, the pilot controls the flyboard's direction by using their body, similar to how a snowboarder turns.

Remote control
While thrust is usually controlled by an instructor seated on a jet ski, professional flyboarders hold a remote control to alter the power that's generated.

Nozzle
In order to generate an upwards motion and lift the pilot into the air, water is directed downwards through two nozzles, positioned across the weight of the pilot to provide balance.

Flyboard
Utilising the force of the pumped water, a flyboard provides a surface for the pilot to stand as the water jets downwards.

PWC
The personal watercraft is the main driving force behind hydroflight, acting as a floating engine for a flyboard.

Up, up and away

Flying high in the sky, French inventor Franky Zapata has taken the concept of hydroflight flyboards and created the world's first jet-powered hoverboard. Having previously excelled in hydroflight, Zapata set his sights on the sky, untethered by water propulsion.

With the aid of two compact jet engines, the Flyboard Air™ drinks paraffin fuel held in the pilot's backpack, which holds enough to sustain a ten-minute flight. Crossing the 35 kilometres of the English Channel earlier this year, Zapata reached speeds of up to 177kph.

His demonstrations have also revealed the potential for the technology's military applications, from flying soldiers to hoverboard stretchers.

The Flyboard Air™ is capable of auto-hovering to maintain its altitude without the use of the throttle

AR ZONE! SCAN HERE

How a Polaroid camera works

Take a look inside the instant camera that inspired generations of photographers

The invention of Polaroid cameras marked the beginning of a new era for photography. Today, we may take for granted the ability to instantly analyse our photos – zooming in on details on a digital screen before declaring the result unsuitable and taking another.

But prior to the 1950s, photographers had to wait between 30 minutes and two hours for their photos to be developed. If an image turned out badly, your subject could be gone, along with your opportunity for the perfect shot. This was until one man sought to change all that.

Instant photography was brought about by Edwin Land, although his three-year-old daughter also gets some of the credit. When spending a day at the beach, she didn't understand why she couldn't see the picture her father had taken of her. This made Land ask himself the same question, sparking the ideas that circulated in his mind. The outcome meant his daughter would grow up never needing to wait for a photograph again.

"Polaroid's Land Camera gained instant popularity, selling out in a day"

The first instant camera appeared in 1947. Named after its inventor, it was called the Land Camera. Consisting of a roll of positive paper and developing chemicals, the camera worked by bringing the exposed negative and the positive paper together through rollers.

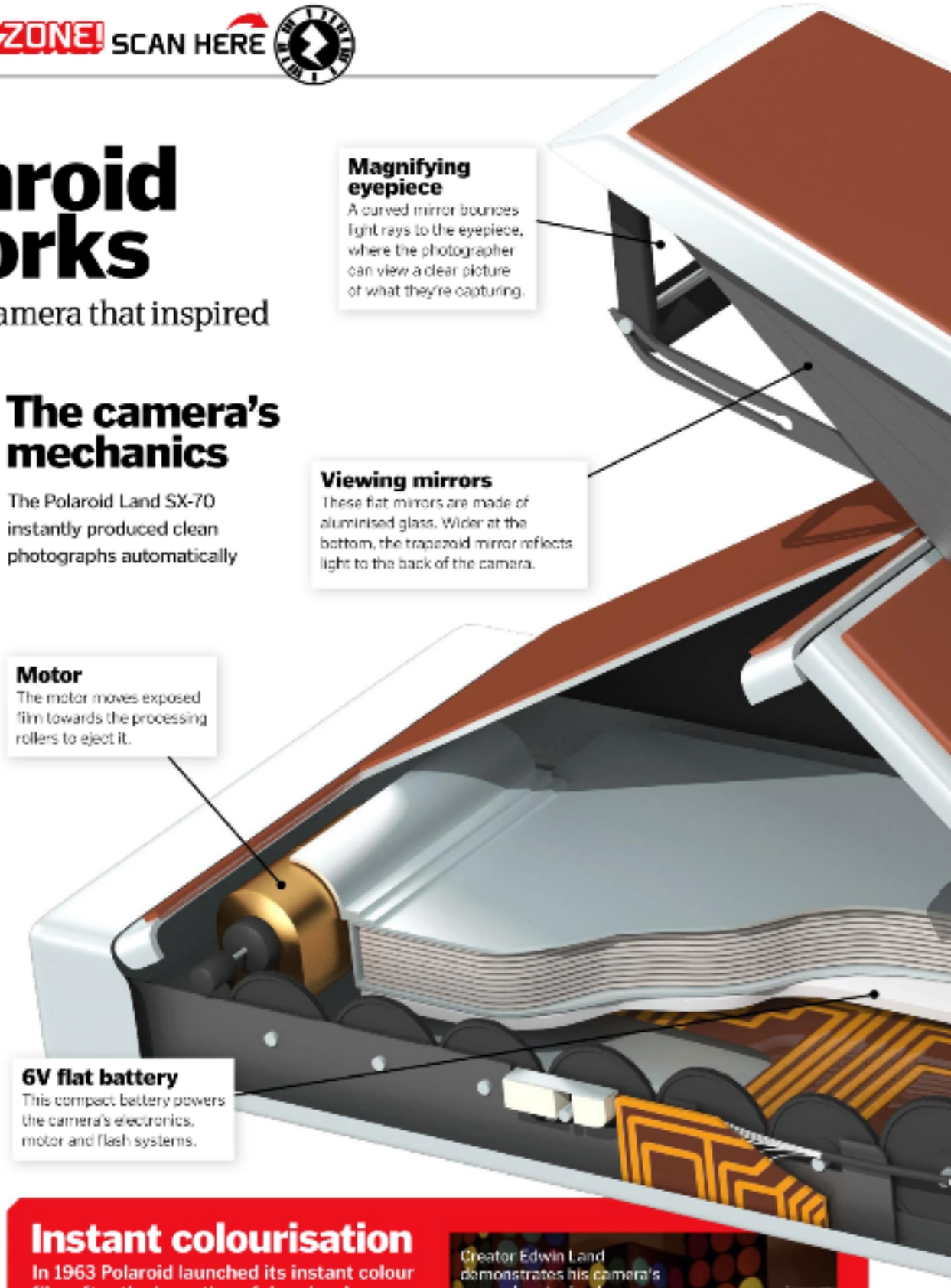
In the click of a button, the camera's shutter opened, allowing light to enter. This hit the extremely photosensitive film, and the light recreated the scene before the camera.

Light energy ionised the film's silver halide coatings, converting them to metallic silver atoms. The number of silver atoms on each part of the film was proportional to the light exposed on the image. After around 60 seconds, the negative paper was peeled from the positive image to reveal the finished photograph.

Polaroid's Land Camera gained instant popularity, selling out on the first day. The product made $5 million in its first year, and at Polaroid's peak 1 billion shots were being snapped a year.

The camera's mechanics

The Polaroid Land SX-70 instantly produced clean photographs automatically



Magnifying eyepiece
A curved mirror bounces light rays to the eyepiece, where the photographer can view a clear picture of what they're capturing.

Viewing mirrors
These flat mirrors are made of aluminised glass. Wider at the bottom, the trapezoid mirror reflects light to the back of the camera.

Motor
The motor moves exposed film towards the processing rollers to eject it.

6V flat battery
This compact battery powers the camera's electronics, motor and flash systems.

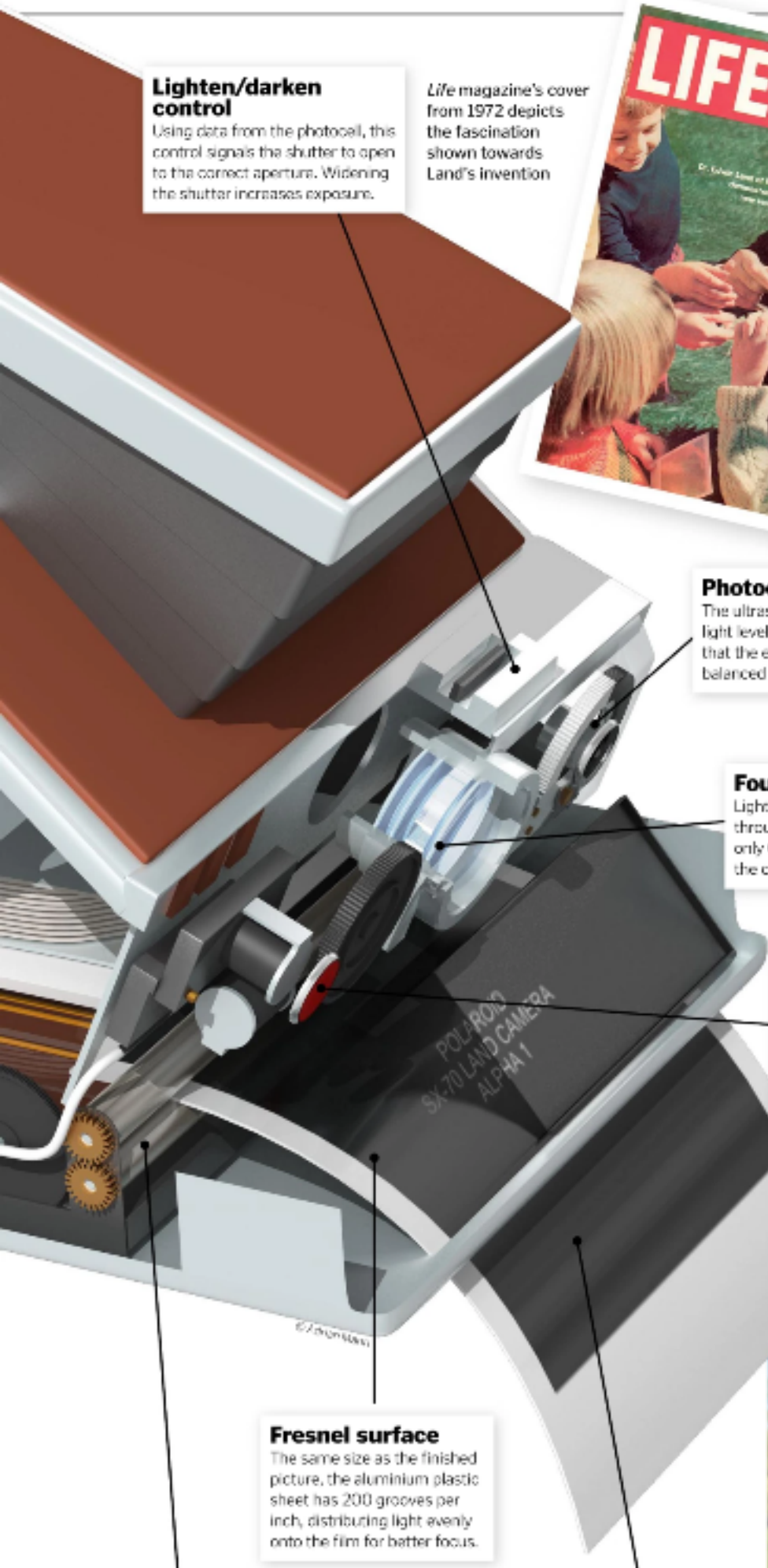
Instant colourisation

In 1963 Polaroid launched its instant colour film after the invention of dye-developer molecules. Whereas black and white instant cameras use one film covered in silver halides, coloured Polaroids have three, with each coating representing a different part of the light spectrum: blue, green and red.

Colour photography wasn't new, but there was something striking about holding a picture identical to what stood before you just seconds before. As well as amateurs using it to create lasting memories, renowned photographers also praised this new addition. Andy Warhol used these cameras to create early selfies, and his photographs of himself and others acted as a sketchbook, inspiring his colourful work.

Warhol took his Polaroid camera everywhere with him, continuously shooting and documenting his surroundings. When he died he left over 60,000 Polaroids and snapshots behind.

Creator Edwin Land demonstrates his camera's new colour technology



Lighten/darken control
Using data from the photocell, this control signals the shutter to open to the correct aperture. Widening the shutter increases exposure.

Photocell
The ultrasensitive cell detects the light levels in the environment so that the exposure can be balanced for each shot.

Four-element lens
Light enters the camera through the lens. Measuring only 0.4 inches, its size keeps the camera thin when folded.

Two-bladed electronic shutter
Once pressed, the shutter lets light in. Light initiates the production of a picture when it reaches the camera's film.

Fresnel surface
The same size as the finished picture, the aluminium plastic sheet has 200 grooves per inch, distributing light evenly onto the film for better focus.

Processing rollers
The rollers feed the film out of the camera to present the photographer with their image.

Developing picture
The picture is released here, and the image begins to appear on the film. Contrary to popular belief, shaking the film isn't good for development.

Life magazine's cover from 1972 depicts the fascination shown towards Land's invention

Closing the shutters on Polaroid

Polaroid continued in business for 50 years, retaining sales even when the technology became outdated. Only at the end of 2008 did the company stop making this product.

The shift of photography from film to digital reduced consumer demand. As technology was advancing, Polaroid decided to stop manufacturing Land Cameras – there were simply not enough people buying them.

However, Land's legacy lives on. Polaroid features are now considered fashionable, and nostalgic photographers continue to enjoy the feeling of a 'real' photograph in their hand. Polaroid Originals recently released the Polaroid Pop, an instant digital camera that embraces old and new technologies.

The Model 95 Land Camera revolutionised photography

Land Cameras were renamed Polaroids after the invention of polarising discs

Inside the Huawei Mate 20 X 5G

Take a look under the bonnet of one of the new 5G smartphones

Huawei is leading the way in 5G, not just because the Chinese company has created much of the technology used in the initial UK rollout. The tech giant has also started putting 5G phones into the hands of customers across the country – and this is one of the first. The Huawei Mate 20 X 5G model is almost identical to the standard Mate 20 X, but with one important difference. It can take advantage of the new, faster 5G network.

The phone is powered by the Balong 5000, Huawei's first seven-nanometre 5G chipset. It supports both the non-standalone (NSA) and standalone (SA) 5G architecture, which means it can get better speeds today, and will go even faster in the future as the UK network improves.

That, of course, is the big news here. But the phone has plenty of other tricks up its sleeve. The 7.2-inch OLED screen goes from edge to edge, with only the smallest notch at the top of the screen for the camera. Inside, you'll find a 4200 mAh battery that you can power up in just a few minutes using one of Huawei's special high-speed chargers.

On the back you'll find a three-lens Leica camera. The main camera is 40MP, allowing you to capture incredible details, while an 8MP camera with a telephoto zoom lens will help you capture distant shots. Finally, the 20MP camera gives you an ultra-wide-angle lens, so you can take incredible landscape photos and awesome macro shots.

Huawei's 5G model will bring faster internet speeds to your smartphone

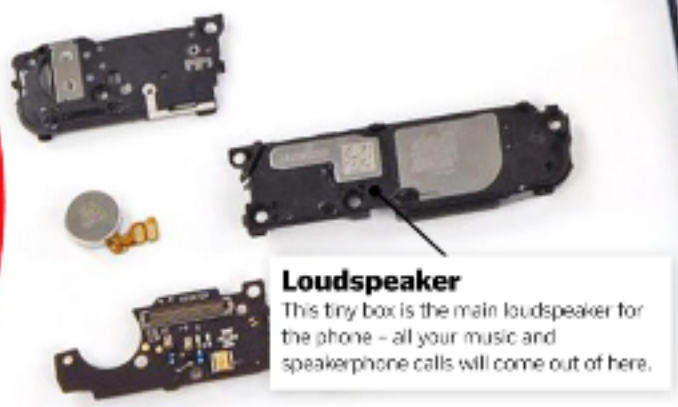
How a 5G phone works

A surprisingly small number of components go into this superfast device

The screen
This 7.2-inch display has a resolution of 1080x2244 – that gives you a pixel density of a whopping 345 pixels per inch.

Front-facing camera
This tiny 24MP selfie camera is the reason for the tiny notch at the top of the screen.

Camera housing
This is where you'll find all three of the rear-facing cameras – along with a tiny flash module.



Loudspeaker
This tiny box is the main loudspeaker for the phone – all your music and speakerphone calls will come out of here.

The optional M-Pen offers 4,096 levels of pressure sensitivity for natural writing and drawing

5G competition

Samsung Galaxy S10 5G
The big name

Samsung's first foray into the 5G world uses its best-selling Galaxy brand, and adds a camera cut right out of the screen to avoid a distracting notch. This is sure to be a big hit.

LG V50 ThinQ 5G
Dual-screen fighter

LG has a different tactic to stand apart in the 5G world. This smartphone supports a second screen add-on that gives you twice the space. It's not a foldable phone, but it's the next-best thing.

OnePlus 7 Pro 5G
The photo pro

This one's all about visuals. As well as a 48MP camera, wide-angle and 3x optical zoom lens, it also offers a QHD+ screen with a 90Hz refresh rate for smooth viewing.

Motherboard
This board houses all of the phone's chips and memory. Importantly, this is the board that holds the phone's 5G chip.

NFC and antenna
This piece of plastic enables you to use features like contactless payments. It is also how the phone connects to the network.

Rear casing
The back of the phone is the first part you remove if you want to get inside – although it's stuck down with adhesive.

SIM tray
This SIM tray has two slots – one for a 5G SIM card, and one that only accepts 4G cards.

Battery
The 4200 mAh battery should keep the phone running for a full day, but 5G requires a lot of power. Thankfully it can fast-charge for a power boost!

"The phone is powered by the Balong 5000, Huawei's first seven-nanometre 5G chipset"

Road to a driverless future

Instead of you driving your car, soon your car could be driving you

Words by **Ailsa Harvey**

They may still be a work in progress, but driverless cars are leading us towards a future where taxi drivers are out of a job and no one holds the role of designated driver on a night out. Car companies like Lexus, BMW and Mercedes are developing this innovative technology in a race to release the first commercial self-driving car.

Until recently, driverless cars were reserved for sci-fi films, but soon the roads could be covered in our 'Batmobile' equivalents. Tesla estimates that its cars, with "full self-driving" capabilities, should be available before the end of next year.

They may still seem an entirely futuristic prospect, but the first research on these vehicles was conducted in around 1500. Admittedly a much simpler concept, limited in possibility and not needing as many safety precautions, Leonardo da Vinci designed a self-propelled cart. This cart is sometimes considered to be the world's first robot as it could move without being pushed or pulled. Steering was set in advance to determine its path – a method not too dissimilar to our future cars.

Much later, in 1933, the development of autopilot systems meant that aircraft used in

"Companies like Lexus, BMW and Mercedes are developing this innovative technology"

Yandex is testing over 100 of its driverless cars in Russia, tracked with manual controls

Nissan aims to release its driverless car in 2020. It lets you choose if and when you do the driving

Traffic tamers

Saying goodbye to drivers could, in turn, mean saying goodbye to traffic jams. With instant radio feedback closely following movements ahead, self-driving cars can communicate with each other and will likely have faster reaction times than humans.

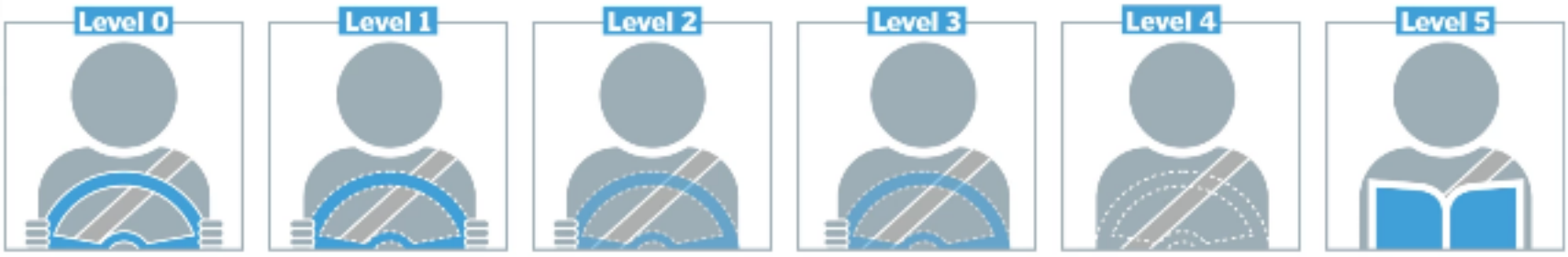
Anyone can cause a traffic jam. By simply tapping your brakes, a chain reaction results in a wave of cars behind you being forced to do the same. Scientists have shown that driverless vehicles use their fuel and time more efficiently, improving vehicle flow by around 35 per cent.

Introducing just a few driverless cars has shown to double the average speed of surrounding vehicles. However, it may take a while before these perks are truly seen, as some believe we need to wait until there is a driverless majority before it has a significant impact on traffic.

This is an example of the interior you could expect inside new driverless cars

Driving automation levels

From hands-on to hands-free, these different levels measure how much the car takes control



Fully manual
Like the majority of cars that are currently on the road, this level requires a person to control every aspect of driving.

Driver assistance
In this level, just one aspect of driving is automated. Examples include the steering, speed or controlling the brakes.

Steering and speed
Partial automation means that the car can drive itself. However, at this level someone is still required to monitor driving.

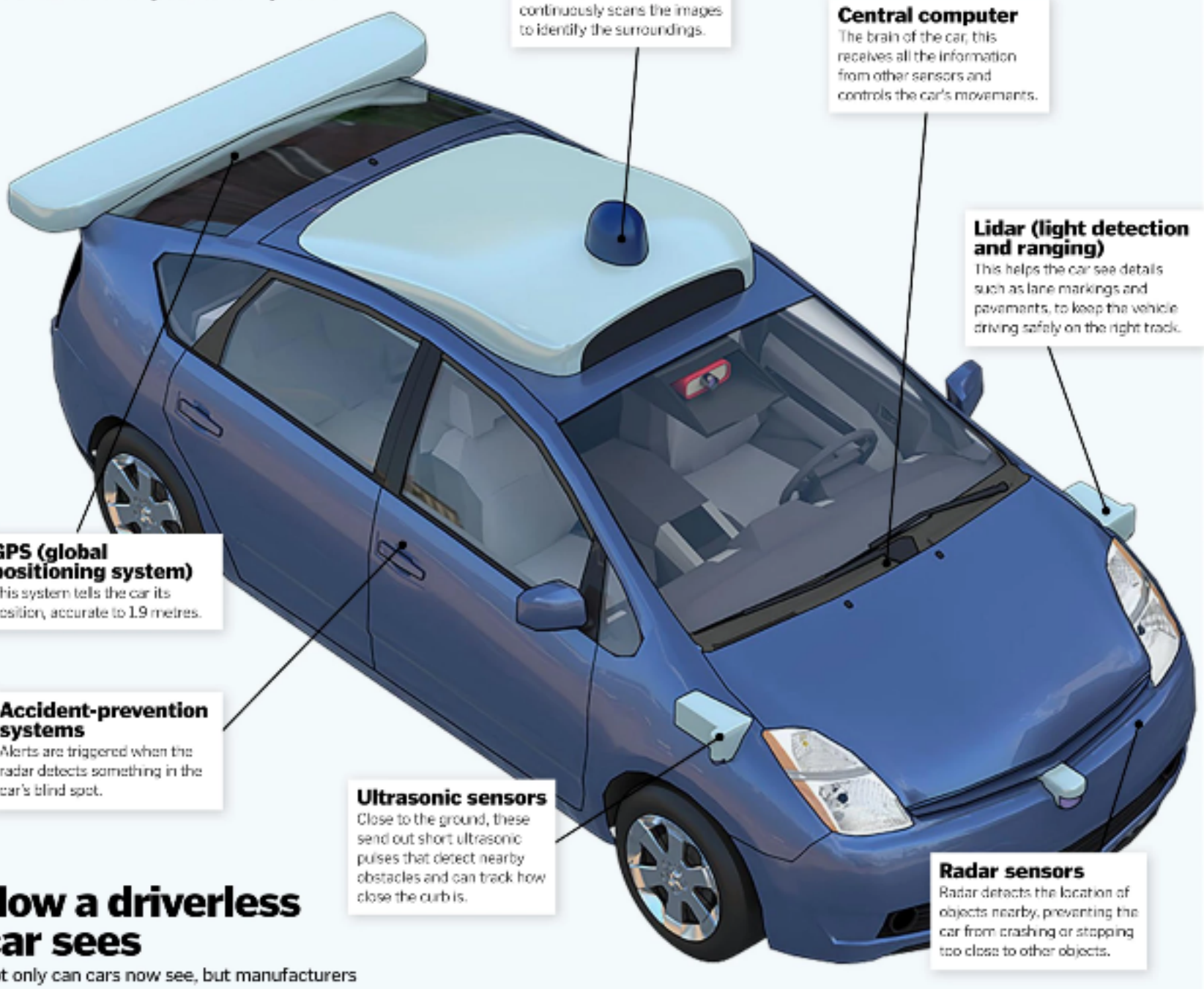
Environment detection
The vehicle starts monitoring the driving environment, but human override is required if the system fails.

High automation
Able to act itself if things go wrong, a level 4 vehicle can perform all driving tasks. However, human override can still be used.

Full automation
Humans aren't needed for any aspect of driving, as the vehicle can do it all. Highly responsive, it can be used in all conditions.

Crucial components

Each part of the car plays a vital role in steering and safety – tasks that are usually carried out by humans



Video cameras
Visual information picked up by cameras is sent to a powerful processor, which continuously scans the images to identify the surroundings.

Central computer
The brain of the car, this receives all the information from other sensors and controls the car's movements.

Lidar (light detection and ranging)
This helps the car see details such as lane markings and pavements, to keep the vehicle driving safely on the right track.

GPS (global positioning system)
This system tells the car its position, accurate to 1.9 metres.

Accident-prevention systems
Alerts are triggered when the radar detects something in the car's blind spot.

Ultrasonic sensors
Close to the ground, these send out short ultrasonic pulses that detect nearby obstacles and can track how close the curb is.

Radar sensors
Radar detects the location of objects nearby, preventing the car from crashing or stopping too close to other objects.

How a driverless car sees

Not only can cars now see, but manufacturers claim they can see better than us

Camera
Detecting lane lines and reading road signs, cameras can only view what the sunlight or headlights light up.

Radar
Beneath the car's metal shell, radar observes surroundings for hundreds of metres. Radio waves bounce off objects, relaying information on the speed and direction.

Lidar
Sending out millions of light pulses each second to reflect off of nearby objects, lidar detects shapes even in the dark.

Deliveries by 'robovan'

The recent advancement in autonomous vehicles means that the parcels you order online could be delivered to your house by robots. That ten-second interaction with a delivery driver, as they hand over the parcel you've been waiting for, may soon be completely unnecessary.

Chinese start-up company Neolix has created a robovan to make this happen. Already in use on public roads, more than 100 of these driverless delivery vehicles have been tested around China. The 'robovans' look like very small vans and are similar in price to a regular car.

Capable of carrying heavy loads and suitable for use in day and night, the vans can be tracked by customers with an app. The only limitation, which the company is currently working on, is how to deliver packages if nobody is in to collect them. Accessible locker systems and walking robots are among the ideas being tested.

Confident that driverless is the future, Neolix has begun mass production of its delivery 'robovans'

long flights were able to fly without pilots continuously having to control the plane. Sperry Gyroscope Co. was the company that designed the first autopilot prototype, and gyroscopes still play a huge part in driverless vehicle technology.

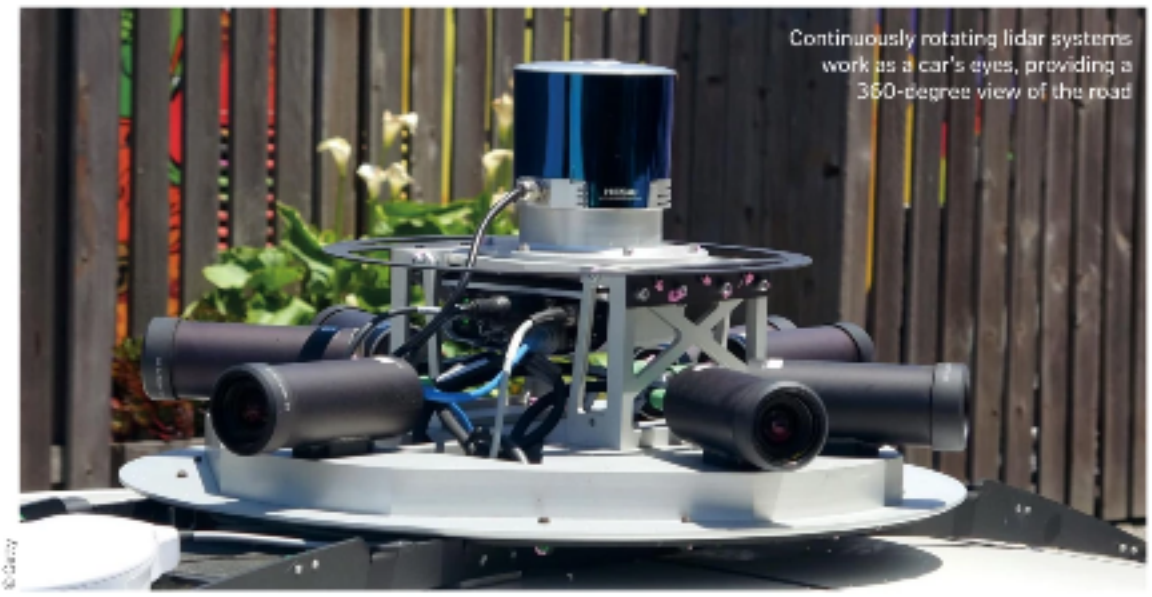
An important first step in developing the safety of driverless cars arose in 1987, when German engineer Ernst Dickmanns installed cameras and 60 micro-processing modules onto a saloon to enable it to detect other objects on roads. Using them at the front and back of the vehicle, the system was programmed to only focus on relevant objects. Driverless cars use this to ensure that, when on the road, they can spot hazards and prevent crashes.

However, after a pedestrian was killed by a driverless Uber car in 2018, questions were raised into whether this new technology will ever be safe enough. While they hold the potential to prevent accidents caused by human

"Gyroscopes still play a huge part in driverless vehicle technology"

error, if both manual and autonomous cars are using the road at the same time, there is a higher chance of one acting in a way the other doesn't expect, increasing the chances of collisions.

Currently, the closest most have got to testing the transport of tomorrow is using autopilot – a feature that Tesla introduced to its vehicles in 2015. Somewhere between manual and driverless, this hands-free tool for motorway travel was provided as a single software update for drivers. Overnight, customers were able to experience just a taste of the freedom that driverless cars will provide.



Continuously rotating lidar systems work as a car's eyes, providing a 360-degree view of the road

The driverless future is near

39.5%
The global increase in the driverless car industry each year

33 million
The number of driverless cars expected to be sold annually by 2040

50+
Google owns a large number of self-driving cars currently on the road

90%
Fewer traffic fatalities are estimated to occur in the driverless future

40+
Car and car parts manufacturers have announced they are working towards self-driving cars

10 seconds
The time it takes for a driver to take back full control of some current self-driving vehicles

257 kph
The speed reached by a self-driving sports car in testing

The most common accident involving self-driving cars is being hit from behind

A driverless car's AI could decide to risk its passengers' safety to save others outside

Inside a South Pole explorer

The Venturi Antarctica is an eco-friendly snowcat offering safe passage for scientists and researchers

Far from their usual high-speed racing cars, automotive creators Venturi have built the world's first zero-emissions snowcat. The Venturi Antarctica is heading to the southern ice cap following the success of a trial run in Canada earlier this year.

Constructed with the environment in mind, this three-seater vehicle is completely battery-powered, operating without any form of combustion engine. The ice trekker has been in development since 2013, with several earlier models paving the way for an Antarctic-ready vehicle. With a top speed of 25 kilometres per hour, the latest version of the Antarctica has a range of 50 kilometres and can withstand temperatures of -50 degrees Celsius, typical of an Antarctic summer.

Although it won't have researchers racing through the glaciers, the Antarctica could revolutionise study site accessibility. As a purpose-built vehicle, the compact snowcat can enable scientists posted on the icy continent to study areas that were practically unreachable before.

Antarctica is a very environmentally sensitive region, so zero-emission vehicles such as this can secure research efforts without polluting the Antarctic atmosphere.

A road less travelled

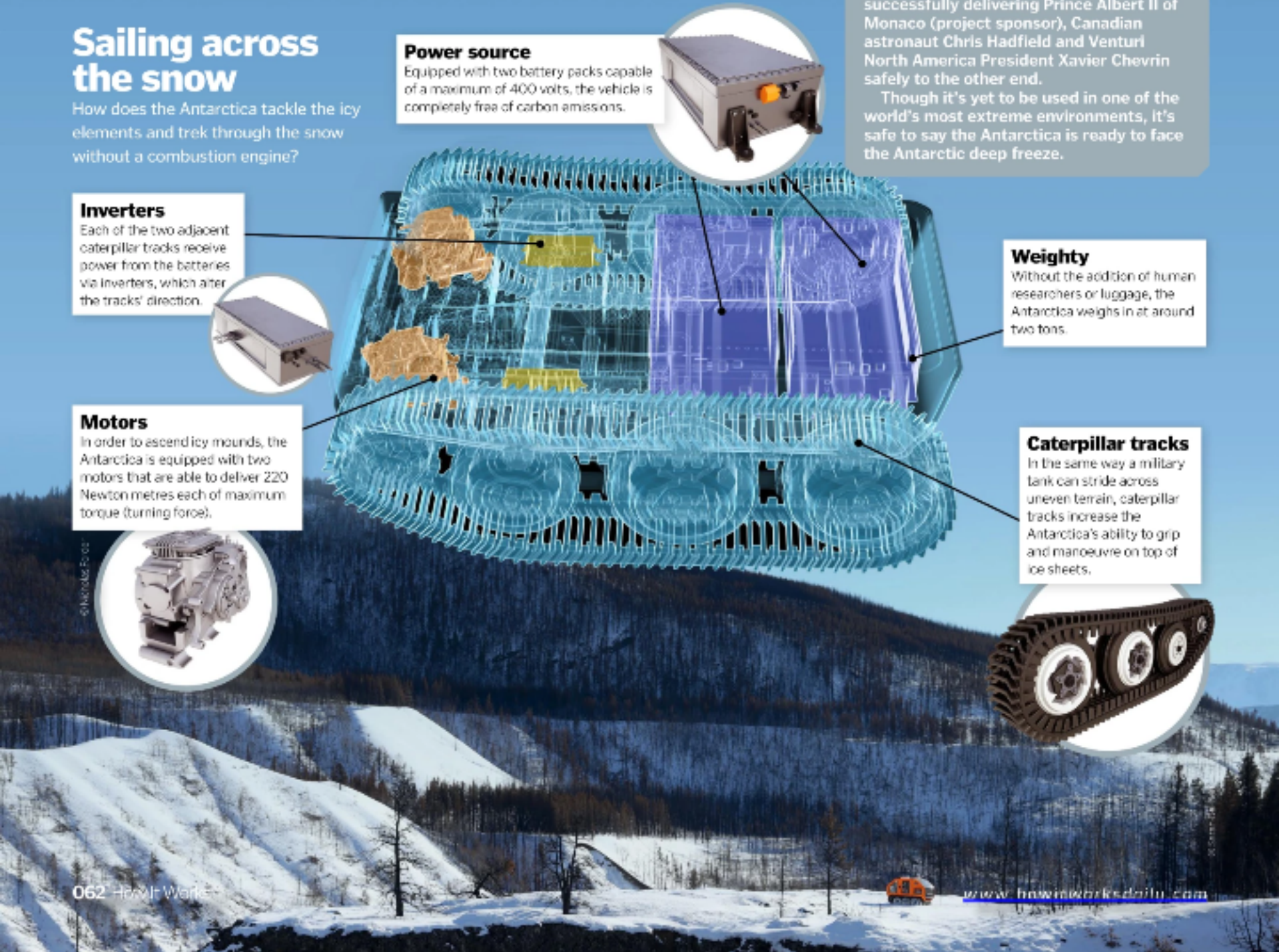
Assessing whether or not the Antarctica is up to the challenge of the harsh polar conditions, the Venturi team first journeyed to Canada for a trial run. Facing one the world's most dangerous roads, the Antarctica, along with three passengers, travelled from Dease Lake to Telegraph Creek. This 42-kilometre highway is littered with obstacles and is known for its treacherous, barrierless roads and unforgiving weather. With -30 degree Celsius temperatures, landslides and wild animals such as bears, it's a wonder any vehicle could make it.

However, the Antarctica did it, successfully delivering Prince Albert II of Monaco (project sponsor), Canadian astronaut Chris Hadfield and Venturi North America President Xavier Chevrin safely to the other end.

Though it's yet to be used in one of the world's most extreme environments, it's safe to say the Antarctica is ready to face the Antarctic deep freeze.

Sailing across the snow

How does the Antarctica tackle the icy elements and trek through the snow without a combustion engine?



Power source
Equipped with two battery packs capable of a maximum of 400 volts, the vehicle is completely free of carbon emissions.

Inverters
Each of the two adjacent caterpillar tracks receive power from the batteries via inverters, which alter the tracks' direction.

Weighty
Without the addition of human researchers or luggage, the Antarctica weighs in at around two tons.

Motors
In order to ascend icy mounds, the Antarctica is equipped with two motors that are able to deliver 220 Newton metres each of maximum torque (turning force).

Caterpillar tracks
In the same way a military tank can stride across uneven terrain, caterpillar tracks increase the Antarctica's ability to grip and manoeuvre on top of ice sheets.

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Why Animals live together

Different organisms can benefit from living with each other – but is it always a fair deal?

Words by **Scott Dutfield**

Nile-dwelling crocodiles use feathered dentists to clean their teeth

Pollination is the perfect example of mutualism between two organisms

Lurking in the muddy waters of the River Nile, a crocodile carefully balances its eyes and snout above the surface. On the riverbank, a plover bird pecks at the ground.

Eyes trained on the feathered body, the crocodile paddles towards the unsuspecting plover before leaving the water and mounting the bank. With the crocodile's mouth now fully open, revealing the razor teeth within, the plover rushes over as if to greet the giant reptile. Rather than fear for its life, it begins to peck at the gaps between the crocodile's teeth, collecting ticks and debris as it goes. Undisturbed by this feathered flossing, the crocodile patiently waits for the plover to finish.

Each benefiting from the removal of parasitic pests, this reptile-bird interaction is a classic example of a symbiotic relationship. On a 'scratch my back and I'll scratch yours' basis, many symbiotic relationships in nature can be beneficial for both animals concerned. However, not every partnership is equal.

The principle of 'symbiosis' was first outlined to describe lichen, a plant-like organism that consists of both a fungus and algae. It was then later applied to different animals that lived in mutually beneficial relationships, and has since expanded to include three different types of relationship: mutualistic, commensalistic and parasitic. Each category describes varying levels of beneficial behaviour and interaction.

When two organisms both benefit from a relationship, it is known as mutualism. Benefits of having a buddy in the animal kingdom typically centre around food, protection and transport. Where one animal, such as the Egyptian plover, benefits from a tasty meal, the other benefits from the removal of parasites.

Examples of symbiosis in this form abound in the animal kingdom. For example, in the shallows of the Pacific a crustacean and sea

"Many symbiotic relationships in nature can be beneficial for both animals"

Three types of symbiosis

Mutualism
This is where both parties benefit from the relationship, for example exchanging protection for food.

Commensalism
Only one individual benefits from interacting with the other, such as for transport, without causing it any harm.

Parasitism
One individual benefits at the cost of the other's health, such as blood-sucking ticks feasting on a host.

anemones come together to form the sea's only cheerleading crab. Often called the pom-pom crab or boxer crab, this high-spirited critter swipes two anemones from the seabed and holds them in its claws. Known for their stinging ability, they offer the crab protection and a new way to catch food, while the anemones gets a free ride to feed on organisms. The same principle applies to many different forms of marine life, such as the relationship between clownfish and anemones.

Above the ocean waves, examples of mutualism can be found across the world, from the oxpecker bird tackling the ticks dwelling in zebra ears to the hunting partnership of coyotes and badgers. However, one of the most abundant forms of mutualism comes in a global partnership between plants and animals: pollination. Here, a species of bird, mammal or insect feasts on the nectar of plants, while brushing up against the plant's pollen or seeds, which are then dispersed by the animal when it moves on. By visiting many flowers, bees introduce pollen and fertilise plants on their nectar-gathering journey, while deer might disperse seeds in their dung after feasting on nutritional fruit.

There are, however, relationships in which only one animal benefits from interacting with another, known as commensalism. It's a one-sided deal, but the species will take advantage of another without causing them any harm. On the underbelly of a whale shark, there are often several long fish hitching a ride. These marine hitchhikers are called remoras, and

"Species will take advantage of another without causing them any harm"

Clownfish find protection in the anemone's tentacles, while they chase away fish that would eat the anemone

Microscopic mutualism

Sometimes two species can work so well together that they form a whole new organism

Algae
Nestled between fungal fibres, algae cells create simple sugars as a waste product through the process of photosynthesis, which a fungus feeds on.

Reproduction
A fungus typically reproduces by releasing spores. For this lifelong friendship, when it comes to reproduction, lichen still release spores, but bundled within them are algae cells.

Fungi
Lichen is comprised of two different types of fungus, and in return for consuming the algae's by-products they offer physical structure for the algae. Research has found that there may be a possibility that fungus also offers UV protection.

This boxer crab wears gloves made of anemones to combat its opponents and get food

Cattle egrets feast on the insects disturbed by the cattle in a commensalistic relationship

Ant farmers

The process of farming may seem like a completely human concept, but certain species of ant will create farms of aphid livestock. These aphids are used in a similar way to our dairy herds, with the ants wrangling the aphids and feasting on their secretions.

When aphids chomp down on plant life, they produce a sugary juice called honeydew as a by-product – and ants love the taste of it. Offering protection in return, farmer ants fiercely defend their aphid stock, even preemptively eating the eggs of aphid predators, such as ladybirds.

Although this dairy farm-style deal can be considered mutualistic, ants take extreme measures to keep aphids in check. Aphids are wingless, but if a colony becomes too small or resources are limited, then individuals will grow wings to search for greener pastures. That is, unless an ant comes to pluck their wings first.

Observed actively removing aphid wings to keep them in check, scientists have also found that a chemical in ant footprints has a tranquillising effect on aphids, making them walk slower and stay in line.

Ants act as farmers to keep their aphid livestock alive

5 FACTS ABOUT UNLIKELY FRIENDS

1 Crab & urchin
Often called the carrier crab, these crustaceans have been observed crawling along the sea floor with a spiky sea urchin on their back. The crab gains an armoured shield against predators, and the urchin gets a ride to new feeding grounds.

2 Mongoose & warthog
Seen biting at the ears of warthogs, mongooses take pleasure picking away at the many parasites living within a warthog's fur. One species gets a tasty meal, while the other gets a deep clean.

3 Tarantula & frog
A group of frogs, called microhylid frogs, share their leafy homes with a group of tarantulas. It is thought that these eight-legged bodyguards offer the frogs protection, and the amphibians provides them with parasite removal services.

4 Zebra & ostrich
With poor eyesight but great hearing and smell, zebras seem to have partnered up with ostriches as a sensory replacement to detect predators. With excellent vision but poor hearing and smell, ostriches also benefit from their stripy neighbours.

5 Goby fish & shrimp
Residing on the sea floor, goby fish and pistol shrimp work together to create themselves a perfect home. After the shrimp builds a burrow in the sea floor, the goby acts as a bodyguard against predators.

"These spineless worms grow within the bowels of their host, feasting on the digesting food"

thanks to a specially modified dorsal fin they can stick to larger fish for easy travel. Equipped with tiny, harmless spindles, this suction cup fin creates enough friction to adhere to a scaly surface. By slightly changing the fin's shape, a remora can quickly detach. Without any benefit to the shark, remoras not only conserve energy, but after a shark has torn apart its prey, they can scavenge the floating debris.

Golden jackals that have been expelled from their pack have also been witnessed to follow another species' movements to benefit themselves. Hot on the heels of a tiger, these jackals will stalk big cats in the hope of feasting on the remains of their latest kill. Undisturbed by the shadowing jackal, the tiger neither benefits from nor is hindered by its activity, whereas the jackal might get a quick and easy meal from the tiger.

In parasitism, however, one organism in this symbiotic relationship benefits at the expense of the other. The origin of the word parasitism means 'one who eats at the table of another' – an appropriate description as most parasites are blood-suckers or nutrient vampires. Often stealing just enough to feed themselves, parasites feast without completely killing their hosts. Ticks and fleas, for example, live on their host's skin or nestled between their hairs, drinking the warm blood of their host mammal. Although just a few drops are more than enough to keep these tiny organisms alive, they pose an infection risk from the bacteria that they can transmit.

Some parasites work from the inside out, such as tapeworms. Once ingested as larvae, these spineless worms grow within the bowels of their host, feasting on the digesting food and even the surrounding tissue.

However, to ensure their position as a parasite, there are those that have evolved to become a physical part of their host. Hiding in the jaws of its fishy victims, the tongue-eating louse, a small marine arthropod, slowly replaces the tongue of its host fish, where it remains indefinitely. This parasite takes exploitation to a horrifying new level – in 2014, it gave one British man a fright when he discovered a set of eyes staring at him from inside the mouth of a sea bass he'd freshly purchased from his local supermarket.

Crustacean got your tongue?

Discover how this tongue-eating louse replaces its host's tongue

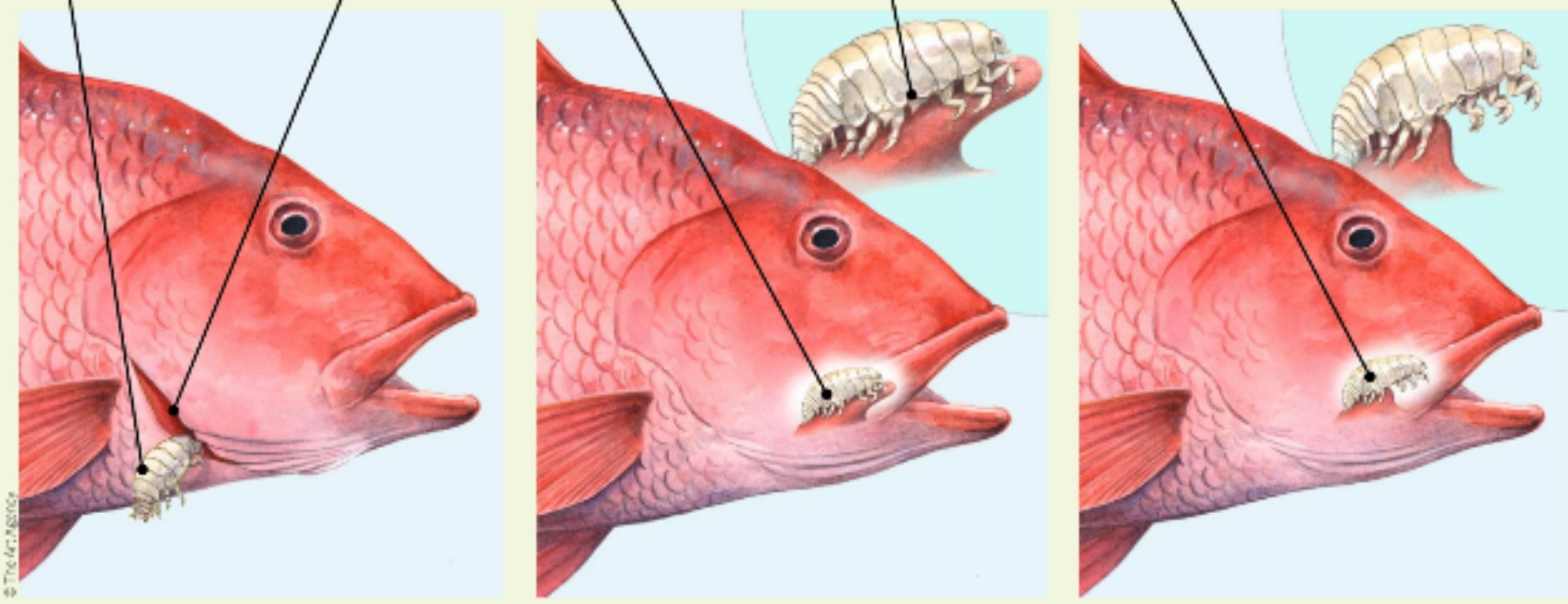
Tongue-tied
There are around 380 tongue-eating louse species in the oceans, some preferring fish.

Through the gills
Cymothoa exigua enters through the gills of a fish and makes its way towards the tongue.

Tight grip
The parasite then latches onto the tongue, gripping tightly with its legs.

Tasting the tongue
As a haemoparasite, the small crustacean begins to drink blood from the tongue.

Lifelong friend
Though it never drinks enough blood to kill the fish, *Cymothoa exigua* continues to feast until the original tongue has withered away, remaining indefinitely as a 'pseudo-tongue'.



Remora fish attach to the belly of larger fish for a free ride through the water

Parasitic parents

Raising offspring in the animal kingdom can be an energy-draining activity. Searching or hunting for food, protecting them from predators and making sure they survive long enough to become fully formed adults are endeavours that some species don't intend to undertake.

Outsourcing these responsibilities to another is a method the European cuckoo has come to rely on. Known as brood parasitism, these large birds switch one of the eggs of another bird for their own. Once hatched, these very different-looking chicks will gradually knock the other eggs out of the resident bird's nest, leaving it alone under the care of its foster parents. None the wiser about the feathered infiltrator, the foster parents will continue to feed and protect the chick until it reaches maturity and fledges the nest.

A 12-day-old cuckoo chick being fed by a foster reed warbler parent

These tongue-eating parasites literally steal a part of a fish's body and replace it with themselves

Japan's iconic Mount Fuji is unusually symmetrical for a volcano

Volcanoes: Making mountains from magma

Earth's volcanoes connect the planet's surface to its fiery core

Volcanoes are mountains and gateways to Earth's crust. These openings allow magma, volcanic ash and gas to escape during volcanic eruptions.

When a volcano erupts it can result in a huge, fiery explosion, throwing scalding lava into the air, or a gentle stream of lava running down the volcano's surface.

Often volcanoes are found where tectonic plates meet. These rocks make up the Earth's crust and are continuously moving, causing plates to rub against each other. The friction created by the movement of these plates creates a high temperature that turns the crust into molten hot rock, called magma. Regions with volcanoes formed during the movement of tectonic plates are called hotspots.

High pressures in the Earth's crust pushes magma up cracks in the tectonic plates until it emerges above ground level. When magma reaches the surface, it is called lava. As lava cools and hardens into volcanic rock, it forms a solid mountain of lava. Every time a volcano erupts, pouring lava over the surface, it adds to the body of the volcano.

Not all volcanoes form in the same way. The viscosity of the lava that's released determines how steep or gentle the volcano's slope will become. This is dependent on how quickly lava cools to form the rock.

Volcanoes can also be found underwater in the form of submarine volcanoes. Because the lava instantly comes into contact with cool water, underwater eruptions often go unnoticed. If the top of these volcanoes come close to the water's surface, it's possible to see steam and debris being thrown above the sea. There are estimated to be over 1 million submarine volcanoes. Larger ones have the potential to grow above the water and become islands.

The loudest sound in history

In 1883, the eruption of Indonesian volcano Krakatoa destroyed the island it occupied. The enormous blast was heard as far away as Perth, Australia, and felt in New York City, USA.

The largest eruption in modern times, it killed over 36,000 people. Of these fatalities, most of the nearby inhabitants died from thermal injury, and many more were victims of the resulting tsunami when the volcano collapsed.

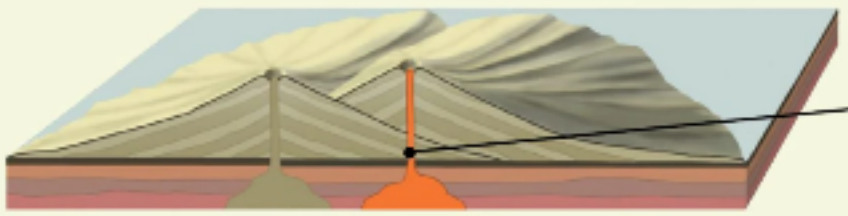
The fiery rage of Krakatoa left behind a huge crater as its only trace. However, soon a new volcano began to grow. Anak Krakatau means 'child of Krakatoa', and is the name of the active volcano that currently sits in its place. Between the Indonesian islands of Java and Sumatra, the volcano's latest activity was in December 2018 when a section collapsed and triggered another deadly tsunami.

A photo of a Krakatoa eruption. The sound from the one in 1883 reached 310 decibels, even louder than the atomic bomb explosions in WWII

Volcano variations

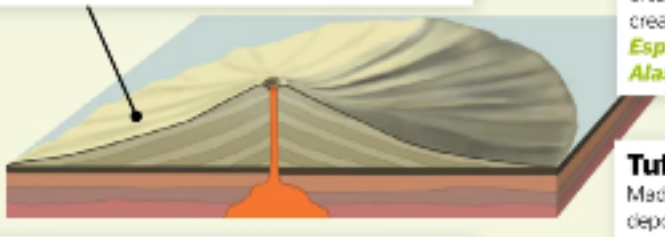
From mega-mountains to hollow lakes: how do different volcanoes form?

Shield volcano
With shallow slopes, these volcanoes are formed by low-viscosity lava flows. The thinner lava travels far before it cools and solidifies.
Mauna Loa, Hawaii

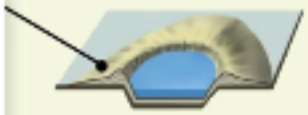


Complex volcano
These volcanoes have multiple cones stemming from the same lava flow. New domes are formed when lava starts using alternative vents.
Pacaya, Guatemala

Stratovolcano
Alternating between layers of lava and ash, highly viscous lava hardens near the top of this volcano type to form steep cones.
Mount Fuji, Japan



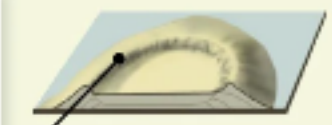
Maar
Maars are shallow craters, surrounded by eruption deposits. Usually located below ground level, water often flows into the crater, creating a lake.
Espenberg maars, Alaska



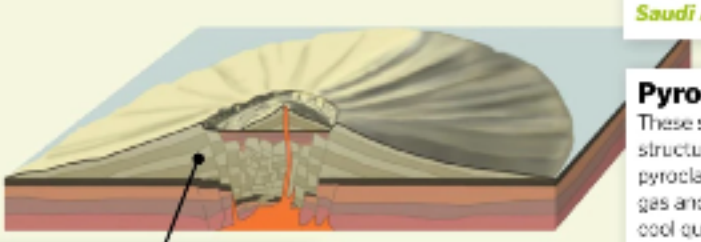
Caldera
Some volcanoes collapse inwards when magma is lost in an eruption. They have a large hollow at the top.
Akademia Nauk, Russia

Tuff cone
Made of pyroclastic deposits, tuff cones have high rims with a crater in the top.
Daphne Mayór, Galapagos Islands

Tuff ring
These formations are similar to tuff cones but are only around five meters high, with ground-level craters.
Harrat Khaybar, Saudi Arabia

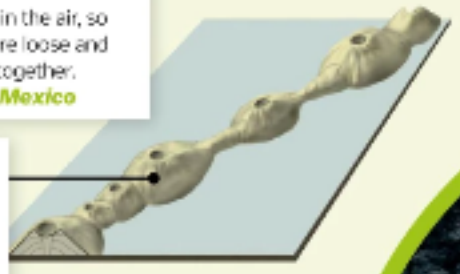


Somma volcano
When the original cone collapses into a caldera, eruptions continue and lava deposits create a new cone inside.
Mount Gharat, Gaua



Pyroclastic cone
These small, steep volcanic structures consist of pyroclastic fragments. Hot gas and volcanic matter cool quickly in the air, so fragments are loose and not welded together.
Paricutin, Mexico

Crater row, fissure vent
A few metres wide and many kilometres long, lava erupts through fissure vents without causing explosions. This creates small cones along the vent.
Holuhraun, Iceland



Lava dome
Caused by a slow eruption of viscous lava that builds up underground, a mound of earth rises up to form lava domes.
Borawli, Ethiopia

© Alamy

Pahoehoe lava flows unbroken and is incredibly smooth

How different lava flows

Lava is the product of volcanic eruptions. The two main types of basalt lava are called pahoehoe and a'a. Named in Hawaii, these terms are now widely used.

A'a lava has a rough top surface and sometimes bottom, and an incredibly dense interior. The coarse pieces on top are formed by lava pulling apart and separating as it flows.

Pahoehoe is strikingly different, with its smooth, flowing appearance. It usually flows at least ten times slower than a'a lava. Pahoehoe lava can turn into a'a lava later, but the reverse process is impossible.

They may differ immensely in structure, but their chemical compositions are identical. This means these different lava types differ entirely due to the conditions they face. Pahoehoe is smooth and ropy as a result of lava cooling slowly. When lava cools quickly, it breaks into stoney pieces, which is a'a lava.

"The coarse pieces on top are formed by lava pulling apart"

A'a lava has a rough surface, covered with a layer of loose fragments called 'clinkers'

© Image 3 Getty

Ice crystals in cirrostratus clouds can create a halo of refracted light around the sun

How clouds reveal the weather

Shaped by the landscapes they cross, clouds warn us about incoming storms and even form on other planets

The sky is often abundant with clouds. We usually take little notice of them hovering above our heads, but sometimes we fear the weather they may bring. Continuously appearing and fading out of sight, what are these unique shapes that parade across the sky?

Clouds are created when rising air cools down enough to release the water vapour it contains, and the condensation produced in this process makes clouds visible. Cloud masses consist of tiny droplets of liquid, frozen crystals and other suspended particles, such as sea salt, dust and dirt. These particles are known as cloud condensation nuclei.

The volume, source and occurrence of clouds differ around the world according to the climate conditions. Near the equator, hot air rises at the most rapid rate, which results in heavy, tropical rainfall.

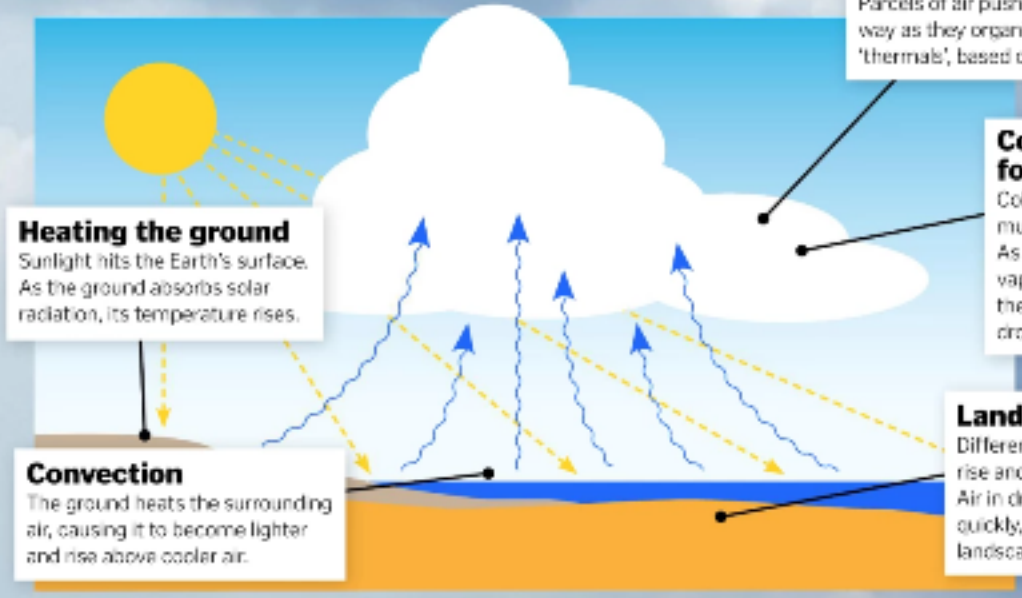
In desert areas, meanwhile, the extreme lack of moisture means clouds are scarce. With no shade, temperatures soar in the day. But the desert also demonstrates the role clouds play in retaining heat: at night, deserts can become bitterly cold because there is no moisture in the air to hold onto heat.

The mountainous regions of Earth act to obstruct wind flow, which has a fascinating impact on resulting clouds. When air reaches these barriers, it is pushed drastically upwards, creating a unique form of clouds called lenticular clouds. In appearance, these are often compared to a stack of plates, and they are even mistakenly reported as UFOs from time to time.

Cumulonimbus clouds develop from cumulus clouds to become tall structures

How do clouds form?

A journey to the clouds: how air carries water into the sky



Clouds that are out of this world

Earth is not the only planet with a cloud-embellished atmosphere. However, not all clouds hold the same properties. On many other planets they are not water-based, although those on Mars are most similar to Earth's as they also contain water.

Venus is surrounded by clouds of sulphuric acid. This is due to the atmosphere on the Solar System's hottest planet being about 96 per cent carbon dioxide. They move at impressive speeds of 360 kilometres per hour in an easterly circulation around the globe.

Clouds on Venus share some similarities to Earth's, as they are capable of producing lightning. Flybys of the planet detected that lightning occurs at least half the rate that it appears on Earth.

Gas giant Jupiter is surrounded by a 50-kilometre layer of thick clouds. Formed in three decks, its uppermost layer is formed of ammonia crystals, which produce storms hundreds of times more powerful than those on Earth.

All of the planets in the Solar System produce clouds, except for Mercury, the closest planet to the Sun.

Jupiter's Great Red Spot is actually a storm twice the size of Earth that's been raging for 300 years

© Getty

Reading the clouds

There are more than 100 cloud variations, grouped into ten types

Cirrus
From the Latin word meaning 'curl of hair', these clouds are thin, white and wispy. Acting as storm warnings, they appear before tropical cyclones.

Cirrostratus
These transparent clouds reveal high levels of moisture in the air. Formed of ice crystals, cirrostratus indicate warm weather.

Cirrocumulus
Arranged in rows of small 'cloudlets', they have a grain-like appearance. These rarer formations can be seen during cold, fair weather.

Altostratus
Obscuring the sky with thin grey sheets, altostratus clouds let little sunlight through. They are usually seen before warm weather.

5 km

Cumulonimbus
These multi-level clouds can be found at heights of 21,000 metres or more. They emerge before heavy rain, hail and tornadoes.

Altocumulus
These common clouds appear on warm summer mornings before cooler afternoons. Also known as 'sheep-backs', the patches mimic sheep's woolly bodies.

Cumulus
These white, round and fluffy-looking clouds are closest to the clouds you probably drew as a child. They are usually seen on clear, sunny mornings.

Stratocumulus
Stratocumulus look like dishevelled cumulus clouds. Spaced out with blue sky in between, they demonstrate weak convection in the atmosphere.

2 km

Nimbostratus
Covering the sky in a thick, dark grey sheet, these clouds block out the sun and produce widespread rain or snow.

© Getty

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HOW TO MAP THE MILKY WAY

Why this spacecraft, Gaia, is measuring the precise location of a billion stars

Words by **Andrew May**

Gaia may not be a household name like NASA's Hubble telescope, but as space-based observatories go it's just as sophisticated and just as valuable to astronomers. It's not designed to produce spectacular images of galaxies and nebulae like the ones Hubble is famous for, but instead it's designed to measure the positions of stars and other astronomical objects with unprecedented precision.

Gaia was launched by the European Space Agency (ESA) on 19 December 2013 – not into Earth orbit, but to a more distant location known as the 'second Lagrange point', or L2 for short. It's about 1.5 million kilometres away – four times further than the Moon – in the opposite direction from the Sun. That may sound like an arbitrary place for the telescope, but it's the ideal spot for an astronomical observatory, as we'll see later.

Gaia arrived there a few weeks after launch, and then spent several months testing and calibrating its complex suite of instruments, before starting serious observations in July 2014. The mission was originally planned to last five years, but that's since been extended at least to the end of 2020, and may even continue beyond that.

Gaia's primary mission is concerned with a branch of astronomy known as astrometry – the science of fixing the precise position of a star. That's not just its two-dimensional

DID YOU KNOW? *The science of astrometry can trace its origins to the Greek astronomer Hipparchus in the 2nd century BCE*

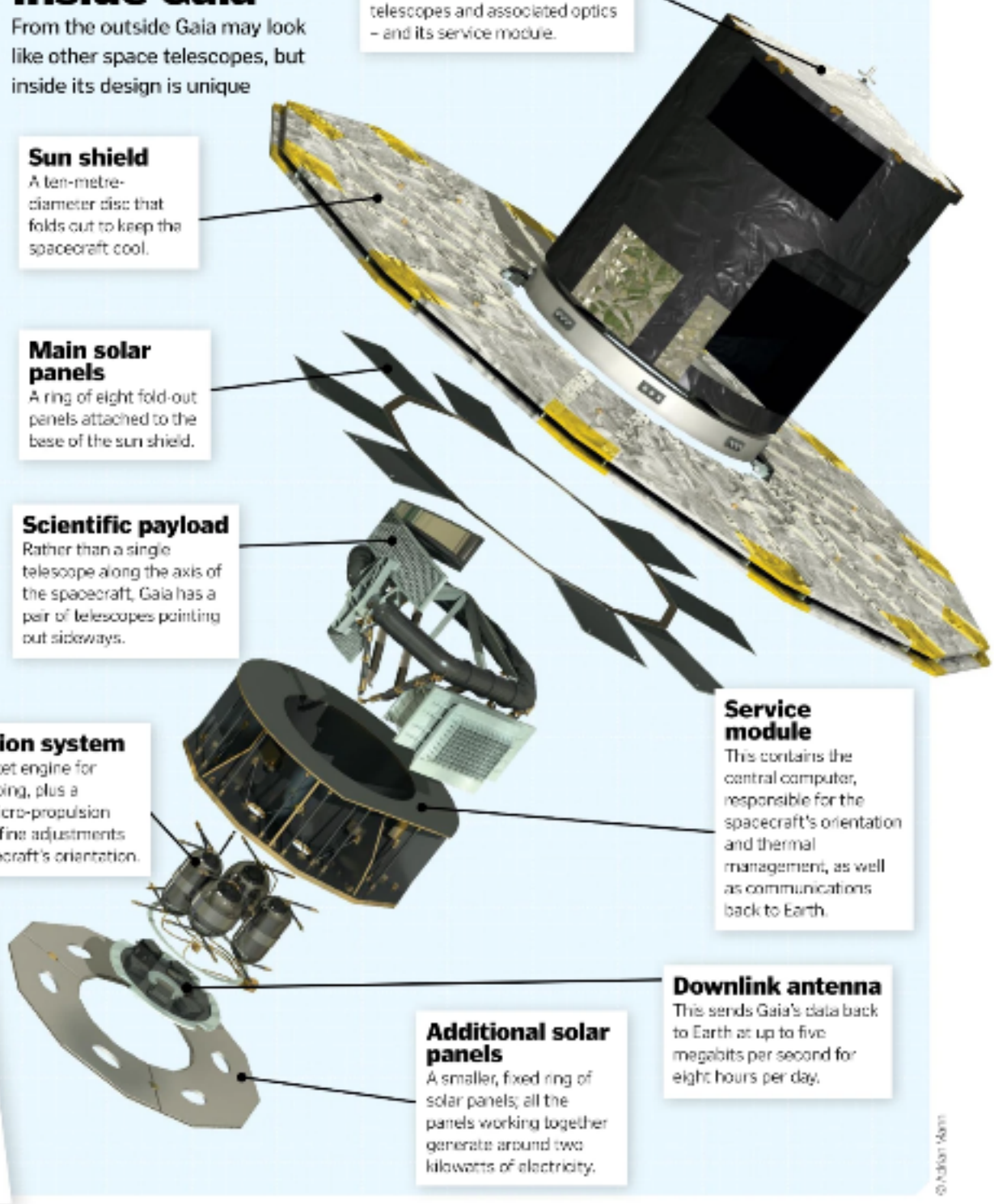
position in the sky, but its distance away from us as well. In principle this can be determined by measuring the star's parallax – the angular change in its position as the telescope moves around the Sun. The problem is, the angle involved is minuscule, and it gets smaller the further away the star is. Until the first astrometric satellite, Hipparcos – also operated by ESA – was launched in 1989, only about 8,000 stars had parallaxes large enough to be detected by ground-based telescopes. Hipparcos multiplied that figure by 15, increasing it to almost 120,000 – but that was only the first step. Gaia is going to measure the parallax of 1 billion stars – 8,000 times as many as Hipparcos. This huge figure represents a sample of around one per cent of all the stars in the galaxy. Equally important, the sample will be evenly distributed across the whole galaxy, rather than being limited to nearby stars, as

The launch of Gaia by a Soyuz rocket on 19 December 2013

© ESA

Inside Gaia

From the outside Gaia may look like other space telescopes, but inside its design is unique



Thermal tent
Protective covering for the spacecraft's payload – the twin telescopes and associated optics – and its service module.

Sun shield
A ten-metre-diameter disc that folds out to keep the spacecraft cool.

Main solar panels
A ring of eight fold-out panels attached to the base of the sun shield.

Scientific payload
Rather than a single telescope along the axis of the spacecraft, Gaia has a pair of telescopes pointing out sideways.

Propulsion system
A small rocket engine for station-keeping, plus a cold-gas 'micro-propulsion system' for fine adjustments to the spacecraft's orientation.

Service module
This contains the central computer, responsible for the spacecraft's orientation and thermal management, as well as communications back to Earth.

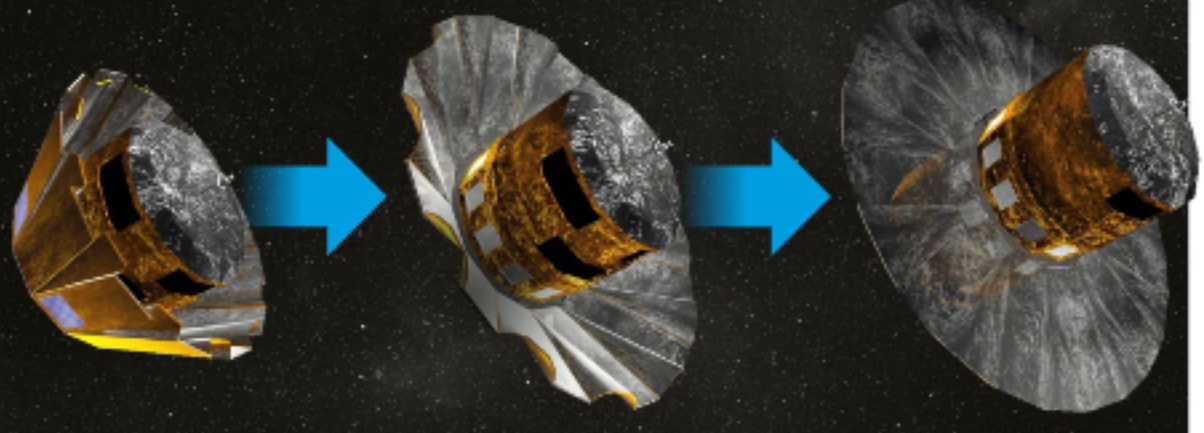
Downlink antenna
This sends Gaia's data back to Earth at up to five megabits per second for eight hours per day.

Additional solar panels
A smaller, fixed ring of solar panels; all the panels working together generate around two kilowatts of electricity.

© Adrian Mann

Unfolding sun shield

Gaia's optical instruments have to operate at a very low temperature, -110 degrees Celsius, in order to achieve the desired measurement accuracy. At the same time, the spacecraft needs to be located in direct sunlight, so that its solar panels can provide enough energy to run all the equipment. To reconcile these two conflicting requirements, Gaia is fitted with a huge disc-shaped sun shield, more than ten metres in diameter. Made up of 12 hinged segments, the sun shield was neatly folded up around the spacecraft during launch, before opening out into its operational configuration once it was safely in space.



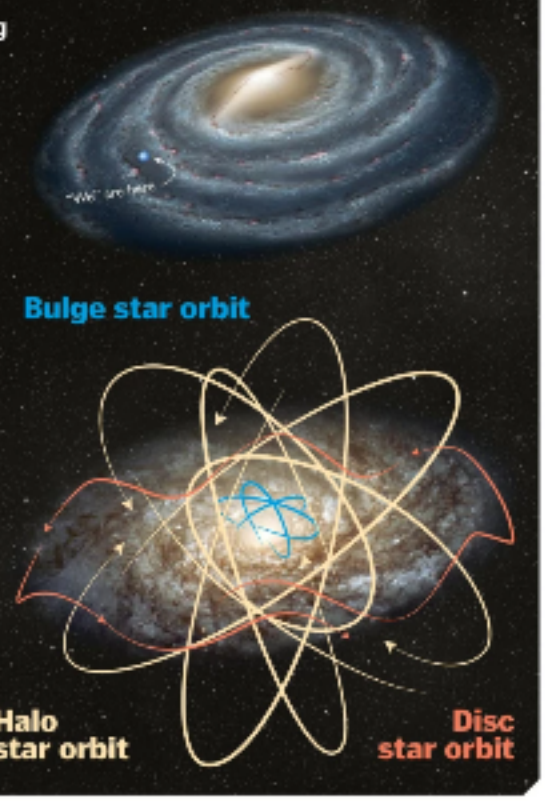
© ESA

Shifting night sky

It's hard to map the stars when they're moving

Gaia's most important job is to establish the distance to a star by measuring its parallax – the amount it appears to wobble in the sky over the course of a year. If stars always remained in fixed positions in the galaxy, the only movement during this time would be Gaia's annual orbit around the Sun. So any apparent change in a star's position would have to be due to parallax and nothing else, and Gaia's task would be easy.

In reality, stars – including our own Sun – don't stand still; they travel in huge orbits around the centre of the galaxy. Unlike planets in a solar system, these orbits aren't always neat circles or ellipses, but can be complex trajectories. The result, seen from Gaia's perspective, is that each star has its own unique 'proper motion' – reflecting its real motion through space – on top of the parallax effect Gaia is trying to pin down. This means that Gaia has to make a whole series of measurements, spread over several years, in order to separate the star's steady drift (proper motion) from its year-by-year oscillatory motion (parallax).

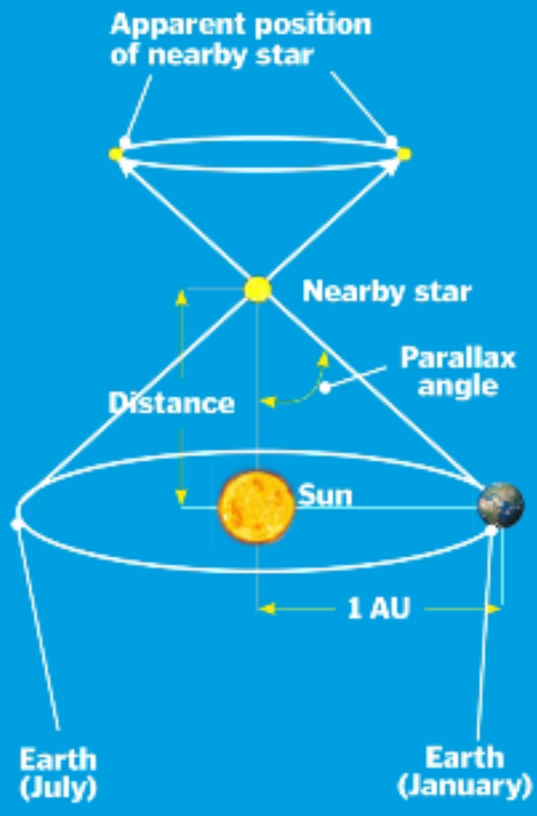


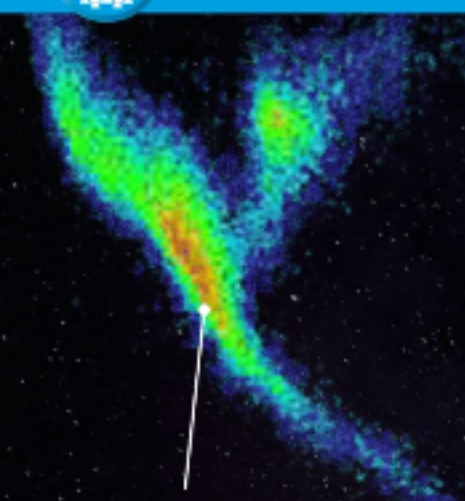
This view of Gaia prior to launch gives an idea of its huge size

What is parallax?

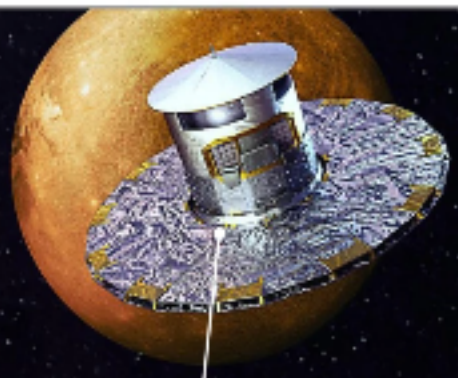
Parallax is the most reliable of the various methods astronomers use to measure distances to objects outside the Solar System. It's based on the same principle that if you look at a raised finger alternately with one eye and then the other, it appears to jump back and forth against the background. That's because each eye sees it from a different angle. If you measure the size of the angular jump (and you know how far apart your eyes are) you can calculate the distance to your finger.

Astronomers exploit the same effect by measuring the angular shift in a star's position between two opposite points of Earth's orbit around the Sun, six months apart. The angles involved are tiny – less than an arcsecond even for the nearest stars (there are as many arcseconds in a degree as there are seconds in an hour). Due to the fuzziness of Earth's atmosphere, ground-based telescopes can only measure parallaxes down to about 100th of an arcsecond, but Gaia is working in a much more stable environment. It can measure angles as small as 100,000th of an arcsecond – like looking at a 2p coin on the surface of the Moon.

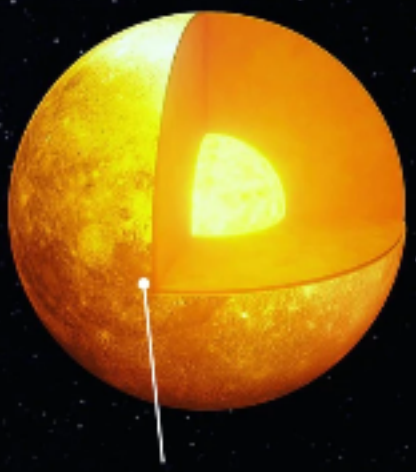




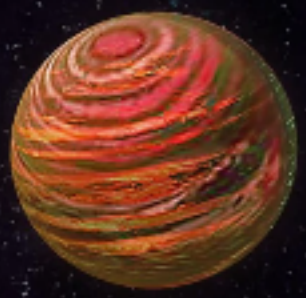
Galactic structure
We can get the clearest picture yet of the galaxy, from its spiral arms and central bulge to the outer halo.



History of the galaxy
Our knowledge of the timeline of star formation and the galaxy's changing chemical composition, as well as accurate ages for its oldest stars, can be increased.



Brown dwarfs
So faint they're almost impossible to detect from Earth, Gaia will revolutionise our knowledge of these tiny stars.

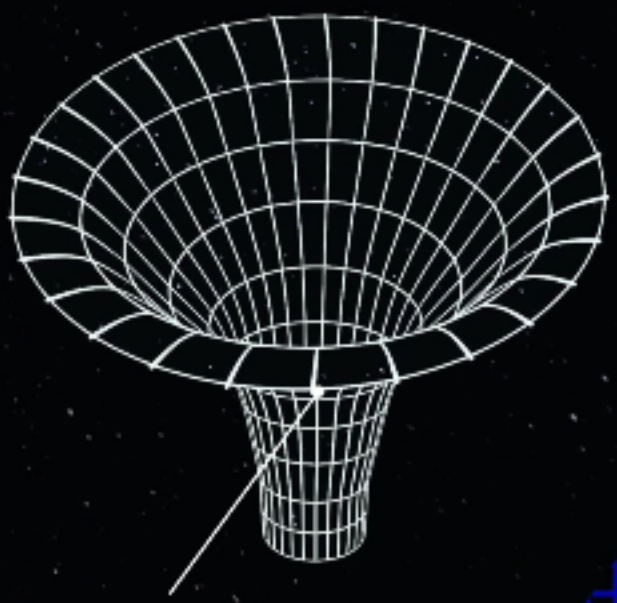


Physics of stars
Although a well-studied field, there are still gaps in our knowledge – for example in the physics of white dwarfs – that Gaia can fill.

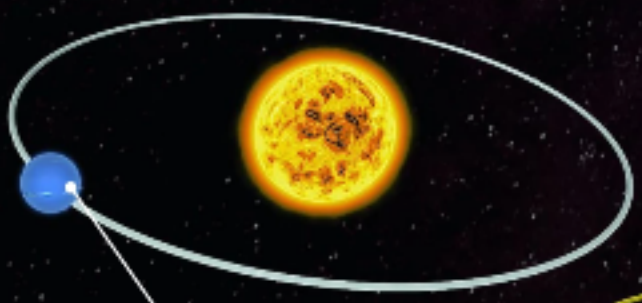
Solar System
As well as stars, Gaia will look at thousands of asteroids, including ones close to Earth and others beyond Neptune.

What Gaia could discover

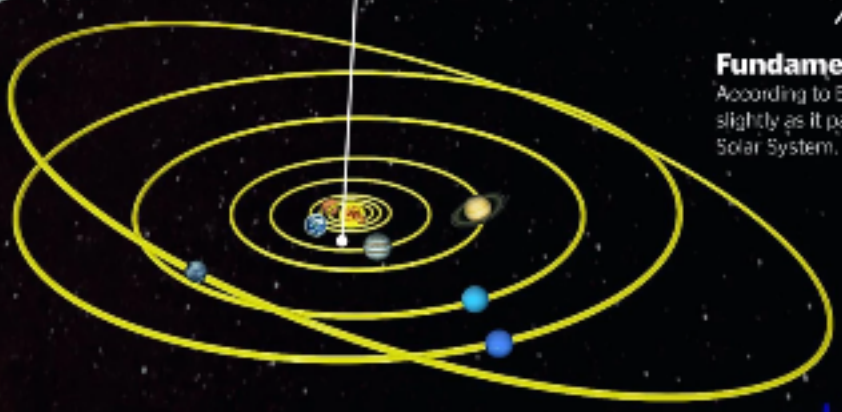
The observations made by Gaia will feed into virtually every branch of astronomy



Fundamental physics
According to Einstein, starlight is bent slightly as it passes objects in the Solar System. Gaia can test this.



The scale of the universe
Parallax is the first rung on the cosmic distance ladder, which can be calibrated to unprecedented accuracy using Gaia's data.



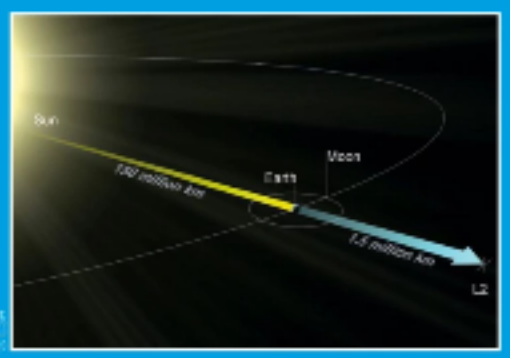
Planets around other stars
A hot topic thanks to NASA's Kepler telescope, Gaia's high-precision astrometric measurements will detect many more of these.

Nicholas Forder

A good spot for a space telescope

In common with other space observatories, Gaia's instruments need to be kept at a carefully controlled temperature. Putting it in Earth orbit, like the Hubble, isn't ideal because it alternately experiences bright sunlight and deep shadow. That could be avoided by placing it in its own orbit around the Sun – like NASA's Kepler telescope – but then it would end up drifting further and further from Earth.

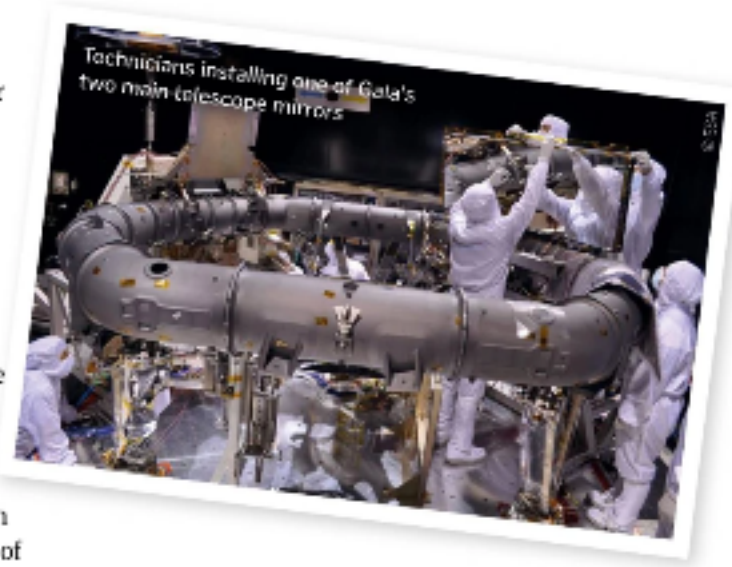
Fortunately there's one spot – called L2, or the second Lagrange point – that provides the best of both worlds. About one per cent further on from the Sun than the Earth, the gravitational pull of the two bodies combine in just the right way so that Gaia can keep pace with the Earth without actually orbiting around it.



was the case with Hipparcos and the earlier ground-based parallax measurements.

Gaia uses a trick pioneered by Hipparcos that makes it easier to measure incredibly tiny parallax angles. Rather than a single telescope, it has two identical telescopes pointing in different directions. By combining the two images and processing them together, this means that only relative – rather than absolute – positions of stars have to be measured, making the task a lot simpler. ESA's aim is to obtain parallaxes for every star that Gaia looks at – which is an impressive enough goal in itself. But on top of that, Gaia has other instruments that will be used on a subset of the stars observed, for example to measure Doppler shifts – which indicate a star's velocity along the line of sight – as well as various physical properties of stars, like temperature and chemical composition.

Observing 1 billion stars may sound challenging enough, but Gaia isn't just going to look at each of them once or twice, but around 70 times. That's necessary in order to obtain sufficiently accurate measurements of parallax, as well as the star's true motion through the galaxy. The result will be one of the biggest scientific databases ever created – over 100,000 gigabytes of raw data, increasing to perhaps ten times that amount after it's all been processed. The result – the first two instalments of which have already been released into the public domain – will be the biggest and most complete census of the galaxy ever undertaken.


Technicians installing one of Gaia's two main telescope mirrors

"The result will be one of the biggest scientific databases ever created – over 100,000 gigabytes of raw data"

Making sense of it

In the course of its mission, Gaia is expected to transmit hundreds of thousands of gigabytes of data back to Earth. A mechanically steered radio antenna would interfere with the precise astronomical measurements, so an electronic antenna with no moving parts is used instead. After it's picked up by ESA's network of ground stations, the raw data is passed to Gaia's Data Processing and Analysis Consortium (DPAC) – a team of 450 scientists spread across Europe and beyond. Their job – one of the biggest and most challenging in the history of data processing – is to make scientific sense of all that data. Once that's done, it's released into the public domain on a roughly annual cycle.

Space elevators

The idea of a lift to destinations beyond Earth's atmosphere has been dreamt of by scientists for over a century

Travelling into space, a prospect which once seemed an almost impossibility, could one day be as simple as stepping into an elevator. The concept has been studied for decades, proposing to transport cargo into space. Aiming to eventually carry humans, they would provide a permanent and cheaper alternative to rockets.

Imagine getting into a lift, knowing you'll reach your level a few days later, or even in a week's time. Space elevators will consist of a cable that needs to be substantial enough to cover the 35,786 kilometres between the Earth's surface and the edge of geostationary orbit – the point where satellites follow Earth's rotation.

In the proposed design, a cable roughly 100 million times longer than its width attaches to an enormous orbiting counterweight. Gravity working on Earth pulls the cable downwards towards its surface, while the opposing centrifugal force pulls the counterweight outwards.

The concept of a space elevator was first described by Konstantin Tsiolkovsky in 1895, albeit much simpler. Inspired by the Eiffel Tower, he put forward the idea of building a tower high enough to reach into space. The theory made sense, but in practice it was flawed, as the bottom of the tower would be unable to withstand the weight above it. Using tension, the new cable system is more mechanically viable.

Unlike traditional elevators, space elevators won't use moving cables to lift a platform. Instead they'll use 'climbers', with people or objects inside, travelling along a single stationary cable. Many of these climbers would need to be moving at the same time and in both directions to prevent the vibrations disrupting their motion.

While there have been many proposed plans for the construction of space elevators, studies show that they are implausible until a suitable material that can support the tension created in such a huge contraption is found.

Making space travel less expensive

Last year, over 100 rockets were launched into orbit. When these rockets are used, parts of them are destroyed and the expense required to rebuild these rockets for space travel is huge. Sending just one kilogram into space using this method costs tens of thousands of dollars.

Not only is the building of rockets costly, powering them with a constant supply of fuel adds to this expense.

This is where space elevators show potential. Some predictions state that space elevators could make space travel 1,000 times less expensive than it is today. They would make the worlds beyond our planet more accessible with reusable climbers removing one limitation of journeys into space.

While the elevator would initially be extremely expensive to build, over time it could make launches more cost effective.

Space elevators could mean an end to this kind of rocket-powered resupply mission

Engineering the elevator

Space elevators may appear on the Moon before Earth, as less gravity makes them easier to install

Ground station
Anchoring the tether to the Moon or planet, these are the loading and unloading stations.

Tether
This cable is the road to space. Made from carbon nanotubes 100 times stronger than steel, they have the ability to stretch around 100,000 km into orbit.

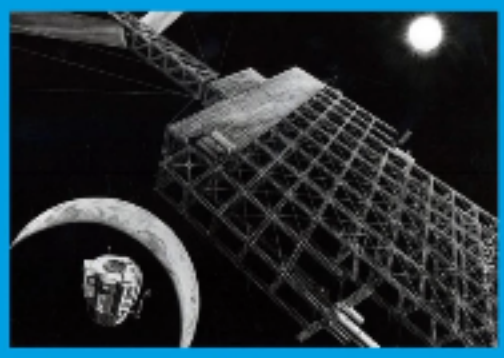
Climber power source
Using a combination of lasers and the sun, these solar panels power climbers for their journey into orbit.

Climber
Like cars, these are used to transport cargo into space. Designed similarly to current spacecraft, they could eventually replace rockets for human travel.

Solar space elevator power

These space elevators could have a further use in sourcing energy for Earth. Solar panels attached to these structures in space are able to absorb many times more energy than they would do on Earth. This is due to the Sun's light in space being unfiltered. Clouds and other weather that obstruct the Sun's rays from reaching a solar panel on Earth are not found past geostationary orbit.

These panels have the potential to generate large amounts of electricity that, rather than solely being used to transport climbers into space, could be supplied to stations and cities on Earth.



A solar-powered satellite in geostationary orbit could be the source of an elevator's power

"Space elevators could make space travel 1,000 times less expensive"

Articulated manned manipulator
An example of a manned machine responsible for handling cargo, such as potential materials mined on the Moon.

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BRAIN DUMP

Because enquiring minds need to know...

MEET THE EXPERTS

Who's answering your questions this month?


JODIE TYLEY


TOM LEAN


LAURA MEARS


JAMES HORTON


JO STASS

How long would it take to run a light year?

Liam Fausti

A light year spans nearly 9.5 million million kilometres. Let's assume that the runner is as quick as the world's fastest ever marathon runner, Eliud Kipchoge, who completed the Berlin Marathon in just over two hours in 2018. We'll also say that they'll never age, and they'll never tire. Even then it would take the runner over 51 million years to run an entire light year. **JH**

A non-stop world-record marathon runner would need 51,927,536 years to span a light year

Want answers?

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Why do trains always run on tracks instead of roads?

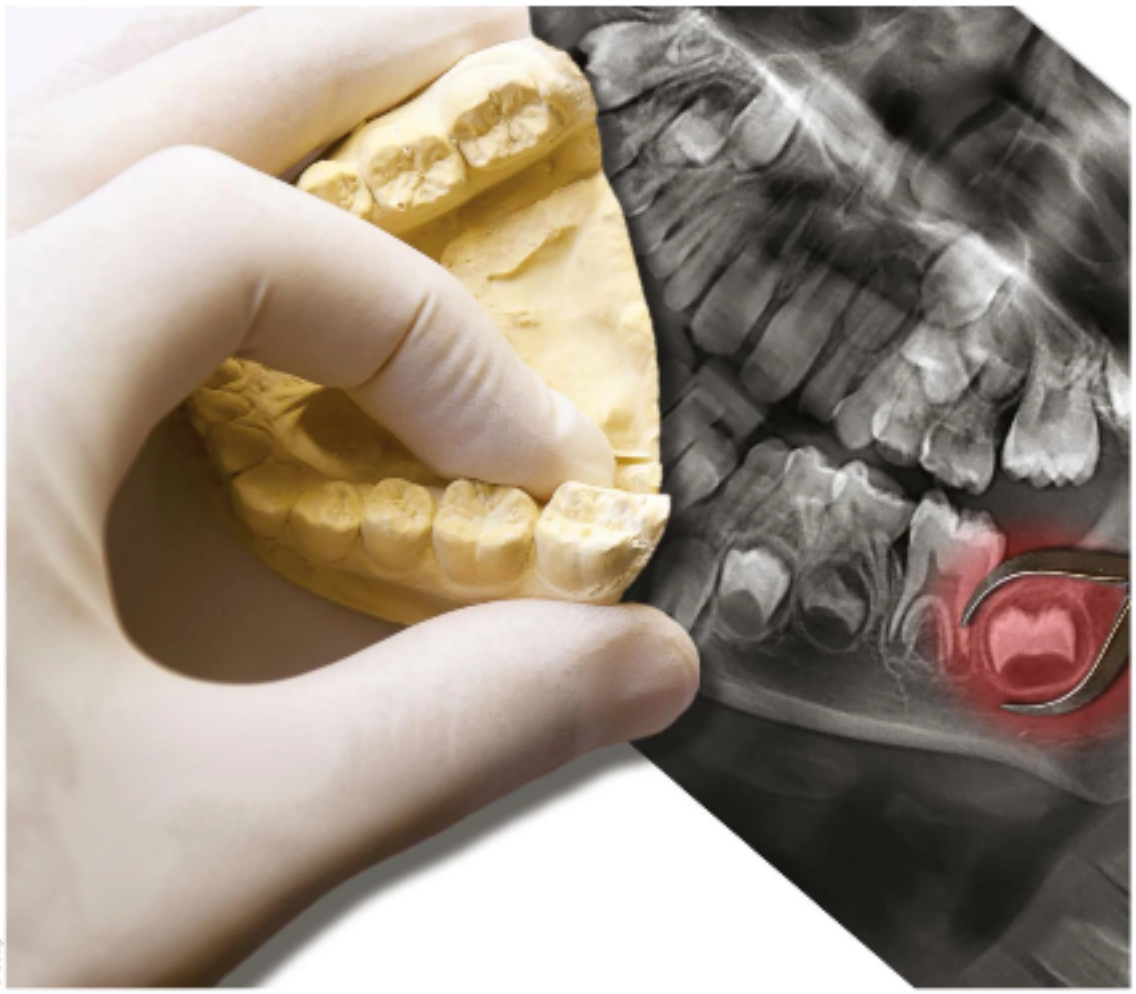
Jonny Bombardier

Trains can go much faster than cars, because there is less friction between steel wheels and steel tracks than there is between rubber tyres and tarmac roads. **JS**

How much plastic is in the sea?

Liam Fausti

We've only recently started to realise the extent of plastic pollution, and there doesn't seem to be an agreed figure for how much plastic is in the sea already. However, it's estimated that 8 million tons of plastic end up in the ocean every year, creating many problems for sea life. **TL**



Do all animals have wisdom teeth?

Bailey McClellan

All other toothed mammals have these teeth, but we have evolved not to need them due to our modern diet of mainly softer, cooked foods. Wisdom teeth, also known as third molars, grow towards the back of your mouth and are used for grinding up very tough foods, such as plants and raw meat. **JS**

When was Britain joined to Europe?

Maria Carmen Vasquez

About 8,000 years ago Britain was a peninsula connected to the European continent by a landmass, called Doggerland, until a tsunami flooded the area to leave Britain an island. **TL**

BRAIN DUMP

Can parasites get parasites?

Abdul Khan

■ Parasites that infest other parasites are called 'hyperparasites'. Take crypt-keeper wasps, for example. They parasitise gall wasps, which parasitise plants. Gall wasps trick trees into building safe chambers for their larvae, forming strange growths called galls.

When the larvae mature, they usually burrow their way out, but crypt-keeper wasps intercept the process. They lay their eggs inside the galls, next to the gall wasp larvae. Under the influence of a crypt-keeper larva, a gall-wasp larva can only chew a tiny hole in its gall before it gets stuck. This gives the crypt-keeper larva time to eat the gall wasp larva, chewing through from tail to head and out into the open. **LM**

© iStock

Why can't I touch my toes?

Alessia Bartolomeu

■ The main factors in being able to touch your toes are the flexibility of your hamstrings (back of your thighs), the range of motion of your hips and the length of your arms and torso compared to your legs. Regular stretching can help you to touch your toes. **JT**

© Getty

How do you get bedbugs?

Dennis Pierre

■ Bedbugs are small insects that love to live inside furniture, such as sofas or beds, and can bite humans, leaving itchy marks on the skin. One way they can get into your home is by hitching a ride on you, your clothing or possessions if you've come into contact with an infested site (like a cinema seat or a hotel bed). Alternatively, they can hide inside any furniture or soft furnishing you bring into your home. **JS**

© iStock

How fast is the world's fastest computer?

Xiaotong Xi

■ Summit, a supercomputer at Oak Ridge National Laboratory in Tennessee, USA, can process 200,000 trillion calculations per second. It has 4,608 computer servers and is the size of two tennis courts. **JH**

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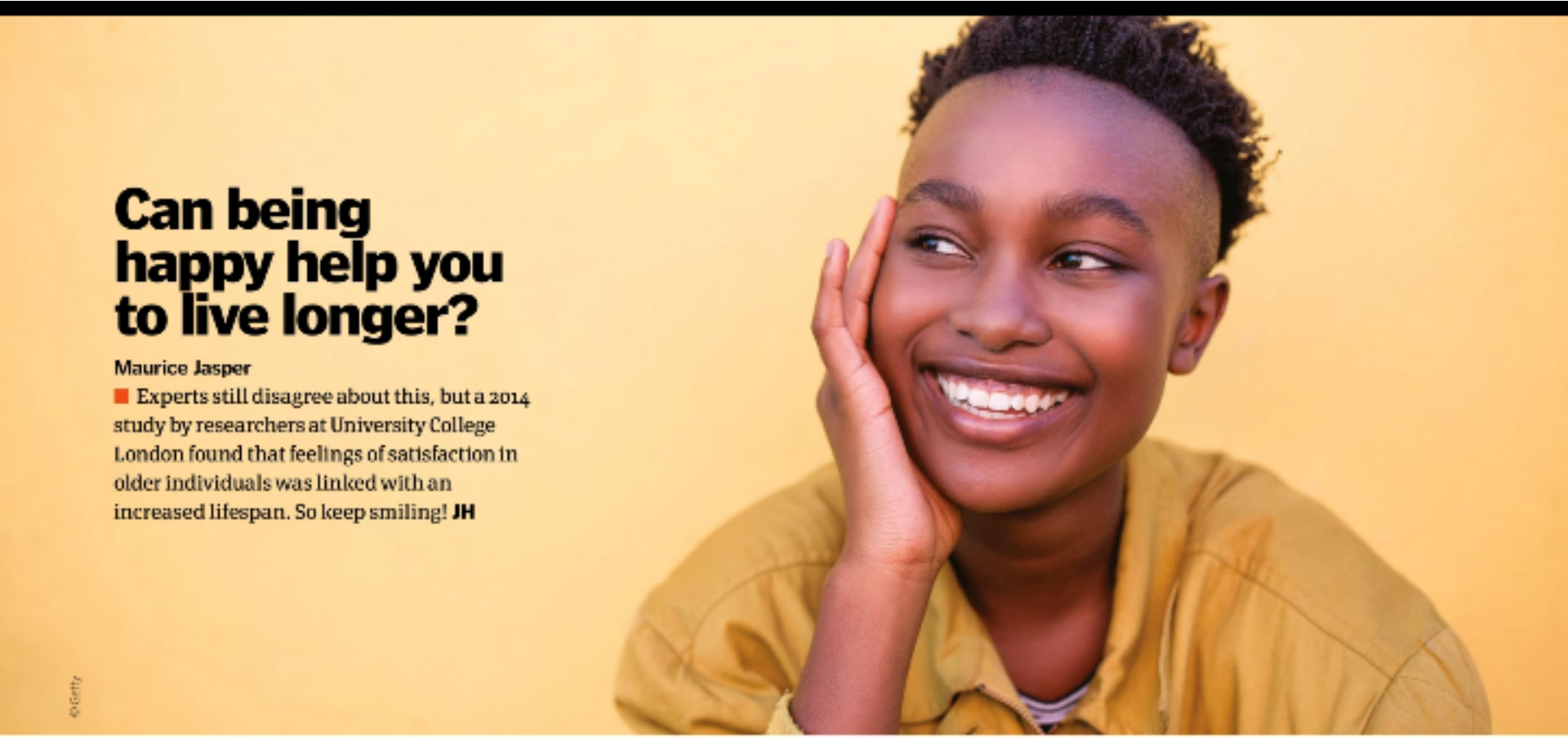

Can being happy help you to live longer?

Maurice Jasper

Experts still disagree about this, but a 2014 study by researchers at University College London found that feelings of satisfaction in older individuals was linked with an increased lifespan. So keep smiling! **JH**

What does the 'D' in D-Day stand for?

Clive Burchell

The 'D' in D-Day actually means 'day'. Although the invasion of occupied France, which began on 6 June 1944, is the best-known operation to feature a D-Day, it was in fact a common term used during military planning to denote the first day of an operation or invasion. Every subsequent day in the planning stage would therefore be dubbed D-1, 2, 3 and so on. Military planning also commonly used H-Hour to specify an exact hour of the launching of an operation. **JT**

Troops from 48th Royal Marines on Juno Beach, Normandy, France, during the D-Day landings

The Falcon Heavy rocket is an important step in SpaceX's plans to land on Mars

When will our next manned mission to the Moon or Mars be?

Ali Puddlechurch

NASA hopes to land people on the Moon again as early as 2024, but people visiting Mars for the first time is much more difficult. NASA suggests it could have a manned Mars mission in the 2030s, but SpaceX ambitiously predicts that it could get people to Mars by 2024. As with any ambitious new development, there is a lot of uncertainty because the financial and technical challenges are huge. **TL**

BRAIN DUMP

Do I have to eject my USB drives before shutting down?

Katie McClelland

It's recommended that you 'eject' a USB drive before removal to prevent any half-copied files from being severed mid-transfer, which corrupts them. But a proper shutdown procedure will stop the transfer of any files, so it's safe to remove a USB after the computer is switched off. **JH**

What is the Rosetta Stone?

Matt Todd

Discovered in Egypt in 1799, this broken piece of stone slab bears an inscription about Ptolemy V on the first anniversary of his coronation in 196 BCE. The same message is written in three different types of writing (scripts): Ancient Greek, hieroglyphs and demotic Egyptian. The stone is important because it enabled scholars to decipher hieroglyphs for the first time. **LM**

Which organs can I live without?

Raj Hart

The human body is surprisingly robust and rather amazingly can still function even when missing a multitude of organs. Some of these organs are inessential but help to defend us against harmful microorganisms, such as our tonsils and appendix. And in some cases we have a spare, such as with kidneys and lungs. Overall, a person could continue to lead a fairly normal life without an appendix, tonsils, a lung, a kidney, the spleen, some lymph nodes, adenoids, sex organs, a heap of bones from the ribcage (up to six) and the fibula in the calf. **JH**

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The human body is very robust and can continue to survive without several organs

What is the biggest tablet device in the world?

Jebb Stones

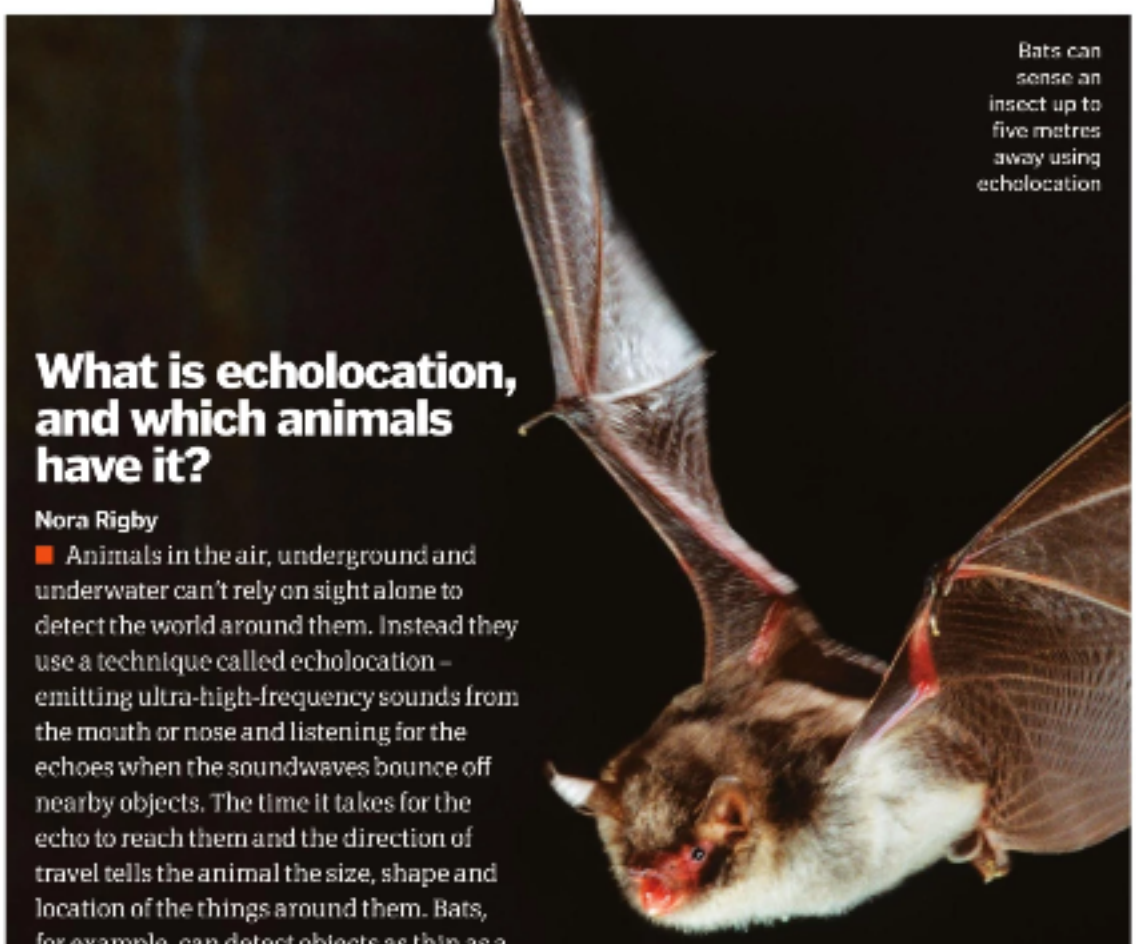
If we're including April Fools jokes, the record would go to the 42-inch sLablet by Ocado. The largest real-life tablets we could find are the 27-inch Lenovo Yoga Home 900 and the 18.4-inch Samsung Galaxy View. **JS**

Why are there so many castles in Britain?

Laura Torres

Britain was in a state of civil war for much of the Middle Ages, as nobles feuded with each other or revolted against the king. Lords and kings built castles for protection and to control lands. Other castles were built by invaders to stamp their authority, such as the motte and bailey castles built after the Norman Conquest. At other times castles were built to defend against foreign invaders, like Henry VIII's coastal forts, or later as homes. Castles were also built when England, Scotland and Wales fought wars with each other. As a result of this long and warlike history, over 1,500 castles were built in England alone. **TL**

Bodiam Castle is one of many strongholds built for a noble family in the 14th century



Bats can sense an insect up to five metres away using echolocation

What is echolocation, and which animals have it?

Nora Rigby

Animals in the air, underground and underwater can't rely on sight alone to detect the world around them. Instead they use a technique called echolocation – emitting ultra-high-frequency sounds from the mouth or nose and listening for the echoes when the soundwaves bounce off nearby objects. The time it takes for the echo to reach them and the direction of travel tells the animal the size, shape and location of the things around them. Bats, for example, can detect objects as thin as a human hair in the darkness. Other animals that use echolocation include dolphins, whales and some birds and shrews. **JH**

Where does the phrase 'cold feet' come from?

Samuel Thorn

People have been using the phrase 'cold feet' to mean having second thoughts for at least 100 years, but no one is quite sure why. Some people think the phrase comes from soldiers complaining of frostbite before battle so that they wouldn't have to fight. Others point to a similar phrase in an Italian proverb from the 1600s, where to be 'cold in the feet' means to have no money. **TL**

There are many theories as to why we say 'cold feet' when someone has second thoughts

BOOK REVIEWS

The latest releases for curious minds

Interplanetary Robots

True stories about unmanned space missions, past and future

■ Author: **Rod Pyle** ■ Publisher: **Prometheus Books**
■ Price: **£14.99 / $18** ■ Release: **Out now**

There are plenty of stories about Earth's manned space missions. From triumph to tragedy, the personal stories of those brave men and women have been told in every format – TV shows, interviews, books and films. But while we are always keen to hear the stories of the people who have visited the stars, the same can't often be said for the machines that have done the same.

However, in recent years, with funding to agencies like NASA cut back, manned missions have been the minority. And, likely buoyed by clever, anthropomorphic Twitter accounts, the interest in unmanned missions has risen. For anyone excited about Curiosity's ongoing Mars mission or intrigued by the prospect of the AREE rover landing on Venus at some point in the future, this book will surely grab your attention.

Focusing entirely on the unmanned space missions of the past and future, *Interplanetary Robots* tells the stories of mankind's previous attempts (both successful and not) to chart the stars and explore the planets in our Solar System. In alternating chapters, author Rod Pyle looks back at one of the pioneering spacecraft that helped us glimpse new parts of our Solar System, and future missions that may help us understand more about our universe.

Pyle draws on his experience working at NASA's Jet Propulsion Laboratory (JPL), and includes regular anecdotes about his experiences on the team. We also hear about the moment that Mars 'died' for an eight-year-old Pyle as Mariner 4 beamed the first grainy photos of a barren desert back to Earth and shattered the dreams of science-fiction writers everywhere. And the moments before the Curiosity rover landed as he and other space journalists waited patiently together at NASA to see the results.

What the book does a great job of is highlighting how, despite being entirely robotic, these missions had human stories at their core. He tells these stories – and those of the missions themselves – in engaging prose. And as he looks to the future, he's sure to spark excitement in the growing number of us looking to the stars. It's unlikely all the missions he mentions will reach the launchpad, but as NASA and others set their sights on the Moon once more, this book is a nice way to prepare.

★★★★☆

"Despite being entirely robotic, these missions had human stories at their core"

Science The Sh*t Out Of Life

Anything Matt Damon can do...

■ Author: **Colin Stuart, Mun Keat Looi**
■ Publisher: **Andre Deutsch**
■ Price: **£12.99 / $19.95**
■ Release: **Out now**

Mark Watney in *The Martian* survived being stranded on Mars by using a whole load of science, and while it's unlikely that any of us will ever have to face that particular scenario, there are still a number of ways that it can be applied to everyday life.

For the most part, the conundrums that Colin Stuart and Mun Keat Looi attempt to resolve are that bit more trivial: how to cure a hangover, how to be a better saver and the best way to get ketchup out of a bottle. Not all of them are especially helpful (we're looking at you, hangover solution – don't drink really doesn't count), but some might have you surprised.

Refreshingly, this isn't number-heavy either. While some books of this ilk focus purely on the figure-crunching, this is more focused on keeping things fun and relatable, and appealing to the regular reader rather than the average scientist. You do want to know how to build the perfect paper aeroplane, right?

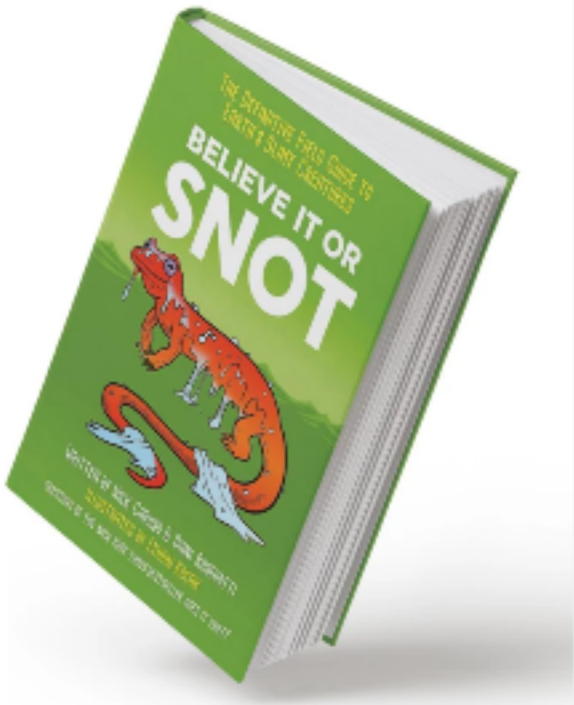
So in short, this is a handy manual for those who need help navigating some of the more trivial decisions in life, or who just want to see things from another direction. Either way, there's plenty of fun to be had.

★★★★☆

Believe It Or Snot

Who nose what to expect?

- Author: **Nick Caruso, Dani Rabaiotti**
- Publisher: **Quercus**
- Price: **£9.99 / $16**
- Release: **17 October (UK) / 22 October (US)**



We were fans of *True Or Poo* – probably because of the title, to be honest – so it was always going to be likely that we would find something to enjoy here too (again, mainly because of the title). And we weren't disappointed.

Saying that, the title is a bit of a misnomer. It isn't just focused on slimy creatures; everyday mammals like giraffes and dogs have their nostrils and their contents put under the microscope, and the chances are you'll like what you find. Want to know how much slime a hagfish can produce in a minute? Reckon birds aren't especially snotty, for lack of a better word? You could have your world rocked.

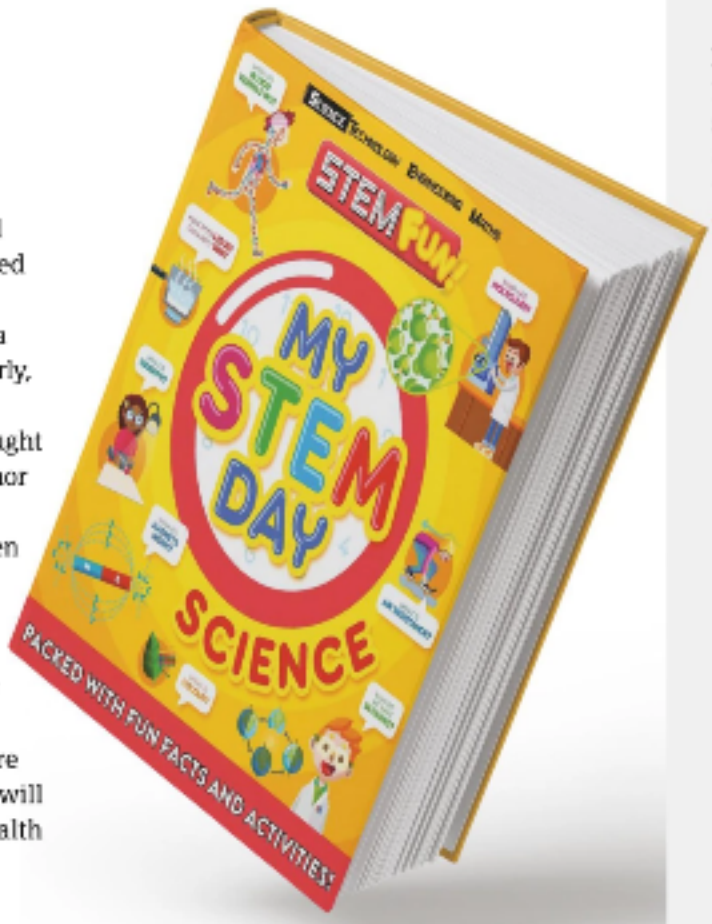
Inevitably, its appeal will be more for younger readers. Some spoilsports tend to grow out of this subject matter. If you haven't, though, then this is something that might well be worth picking up.

★★★★☆

My STEM Day: Science

Your guide to everything around us

- Author: **Anne Rooney**
- Publisher: **Carlton Kids**
- Price: **£7.99 (approx $10)**
- Release: **Out now**



STEM (science, technology, engineering and mathematics) is benefitting from an increased focus, and it's a handy thing to have some aptitude for. With this in mind, it's perhaps a good idea to get your kids familiar with it early, which is where this book comes in.

We always like science when it's being taught in a relatable and relevant way, and the author has clearly taken the same approach here, talking us through the processes that happen on occasions like the school run, exercising and gardening. The diagrams that are included are helpful, but what caught our eye was the interactive guides, which really keep the focus on interactive learning.

We wish our textbooks at school were more like this. Even so, we're glad that kids today will have the opportunity to benefit from the wealth of accessible knowledge this book offers.

★★★★★

Inventor Lab: Awesome Builds For Smart Makers

DK gets interactive

- Author: **DK**
- Publisher: **DK Children**
- Price: **£12.99 (approx $16)**
- Release: **Out now**

We're great fans of DK and the way the publisher seamlessly blends excellent photography and illustrations with enlightening articles and captions. This book, however, comes with a difference: rather than reading about how things work, you get to make them work yourself.

Starting with the very basics, such as guides to circuit components like capacitors, resistors and transistors, and how to use all the required equipment, it then takes you through how to create various devices. These include electromagnetic cranes, door alarms and even a remote-controlled snake. There's no shortage of options here.

Even if you don't have the necessary equipment on hand to create some of the things in this book, there's still plenty to recommend. The instructional annotations serve an educational purpose, as well as a refresher for those who have unlearned what they previously knew.

In short, this has all the production values you've come to expect from DK, who are probably rivalled only by Haynes in terms of sheer ingenuity. If you're yet to discover their delights, start by getting this one for your budding young inventor. You won't regret it.

★★★★★

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FIND THE FOLLOWING WORDS...

LIGHTNING
CARBON
BIONIC
ICEBERG
POLAROID
DRIVERLESS
ANTARCTICA
SYMBIOSIS
VOLCANO
GAIA
WATERMILL
ELEVATOR

Quickfire questions

Q1 Which of these substances is harder than diamond?

- Titanium
- Lonsdaleite
- Spider silk
- Kevlar body armour

Q2 How many pounds of thrust can an F-35 engine produce?

- 100,000
- 10,400
- 4,440
- 40,000

Q3 There are ____ stars in the Milky Way.

- 10 million
- 10 billion
- 100 billion
- 1 trillion

Q4 What year did Krakatoa erupt?

- 1883
- 1738
- 1837
- 1783

Spot the difference

See if you can find all six changes we've made to the image on the right

Sudoku

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

EASY

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

DIFFICULT

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

What is it?

Hint: Thousands of tiny scales cover the wings of this creature.

A .....

Spot the difference

Check your answers

Find the solutions to last issue's puzzle pages

Quickfire questions

Q1 100

Q2 Galileo

Q3 2034

Q4 Sperm whale

NEXT ISSUE
Turn milk into glue

Get in touch
Send your ideas to...
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Make a fire snake

Create a snake using sugar, baking soda and an amazing chemical reaction

DON'T DO IT ALONE
IF YOU'RE UNDER 18, MAKE SURE YOU HAVE AN ADULT WITH YOU

1 Create your insulator

To make your snake, first get a large bowl and then fill it with sand. Ask an adult to douse it in lighter fluid. Sand is fireproof and works very well as an insulator, so it should keep the bowl protected when things start to heat up.

2 Prepare your mixture

The lighter fluid will act as fuel and helps maintain the heat of the flame for longer. Next you need to mix ten grams of baking soda (sodium bicarbonate) with 40 grams of sugar. Pour this mixture onto the sand.

3 Light it up

To light the mixture, you'll need a long-necked match or a long-necked lighter. Ask an adult to help, and be very careful – the lighter fluid will ignite very quickly, so don't get too close to the flame.

4 Snake attack!

After a little while, a large black blob will appear in the mixture and start to grow bigger. This is because as the baking soda and sugar get hot, they both release carbon dioxide gas, which begins to expand.

5 Carbon snake

The reaction also creates sodium carbonate, and as the carbon dioxide gas is created, the pressure pushes this upwards. The black colouring comes from the carbon in the mixture. It's getting big now!

6 The snake's tail

After a while – probably around 20 minutes – the flames will start to go out and the snake will stop getting bigger. All of the baking soda and sugar have been used up at this stage, so there's nothing left to burn.

SUMMARY...

The chemical reaction in the bowl is activated by heat energy. When the mixture gets hot, the baking soda breaks down into sodium carbonate, carbon dioxide and water vapour. The sugar breaks down into carbon dioxide and water vapour too, adding more expanding gas and helping propel the carbon snake upwards.

Had a go? Let us know!

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

FREE eBOOK BUNDLE

Book of the Elements

Since ancient times, scientists and philosophers have attempted to discover, classify and synthesise the Earth's elements. Now, thanks to the hard work of dedicated individuals, we have the periodic table: the ultimate guide to the elements, organised by atomic number and electron configuration. In the **How It Works** *Book of the Elements* we introduce you to the basics of elements and compounds, as well as taking a more in-depth look at the history of key discoveries. Every known element on the planet is covered in detail, from lanthanoids to actinoids, alkali metals to transition metals and halogens to noble gases. You'll find everything you need to know about the universe's building blocks right here.

Book of Combat Machines

The introduction of the first tanks during the Great War marked the start of an arms race that has continued to this day, and as we get our first glimpse at the next generation of military machines, it's incredible to think how far technology has come. In this new edition of *Book of Combat Machines*, we chart the history and development of these awesome military vehicles, from the fearsome German Tiger tanks of the Second World War, to the rise of the nuclear-powered submarine, to the hi-tech fighter jets that now rule the skies. We'll show you all the facts and figures you need to become a combat machine expert, as well as breaking down each vehicle for an inside look at the technology that makes these tanks, choppers and battleships tick.

Book of Amazing Technology

Today's world has been shaped by innovation in technology, so much so that modern life is incomparable to that of mere decades ago; how we communicate, travel and explore our world is almost unrecognisable. Smart gadgets and domestic inventions like mobile phones and drones have revamped our daily lives, but we often forget how the world has gradually evolved around us thanks to pioneering minds and engineering genius. So take a look around you and imagine what your life would be like without the amazing technology featured in this bookazine. It's time to celebrate the coolest concepts that have come to fruition, including robots, electric vehicles, interstellar travel, virtual-reality headsets and superdrones.

Claim yours now: **tinyurl.com/yxpzoyhg**

INBOX
Speak your mind...

Get in touch
If you have any questions or comments for us, please send them to:

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Letter of the month

A word to the wise...

Dear **HIW**,
Why do we have wisdom teeth and why are they called 'wisdom teeth'?
Willow Collinwood

Thank you for your question, Willow. It seems strange that as adults four new teeth should erupt at the back of mouths, especially as we've managed to eat food perfectly well without them. However, once upon a time, our ape ancestors needed these dental late bloomers to survive. Around 100 million years ago early humans chowed down using only their bare hands and teeth, until around 2.6 million years ago when they began using tools to cut up food. Wisdom teeth, or our third set of molars as they are also known, are flat and wide teeth tasked with grinding down food – cutting it is the job of our incisors. The reason these molars sprout up later on in life is down the size of our jaws. Typically erupting between the ages of 17 to 25, these often painful protrusions can only break through our gums once our jaws are big enough.

Although our 'adult' teeth usually emerge at around the age of six, our jaws are not yet big enough to support four extra molars in our mouths. But by the time we reach our mid-twenties they should be big enough to support them. However, unlike our ancestors, whose jaws were big enough to house all 32 adult teeth, evolution has made our jaw shorter. This has led to what many now experience as impact teeth: growing wisdom teeth intruding on their neighbours. Wisdom teeth are commonly removed to prevent them from causing dental damage. As to why we call them our 'wisdom teeth', this is a reference to the idea that we grow wiser with age. Because these teeth only appear when you're older, you must be wiser when you have them. This is thought to have begun during the 17th century, when these new molars were known as 'teeth of wisdom'. By the 19th century this had been shortened to 'wisdom teeth'.

WIN! HOW TECHNOLOGY WORKS

Demystify the devices that have become integral to our lives, from basic mechanics to digital technology. This book is jam-packed with clear, easy-to-understand graphics and fascinating facts.

What's happening on... social media?

This month we asked you what you all think the biggest technological discoveries will be in the next 10 years...

@Fadinha28
"The possibility of living on another planet?"

@angep1969
"The cure for cancer and mobile phone devices so small they could be implanted"

@sophie_car11
"Advances in gene therapy specific to the individual"

@dterry20
"Shopping with no queues – i.e. walk in scan phone, pick up goods, walk out – payment via app!"

@mejabel
"I'm hoping for a working, 3D-printed kidney!"

@Lilacsprite
"Smart roads, biodegradable aviation/automotive fuel, biodegradable 'plastics'"

NEXT ISSUE...

Issue 131 on sale **31 OCTOBER 2019**

Available in print from all good newsagents and **myfavouritemagazines.co.uk**, or as a digital edition for iOS and Android. To enjoy savings on the RRP and to make sure you never miss an issue, check out our subscription offers on pages 32 (UK) and 63 (US).

HOW IT WORKS TURNS 10!

Hi.
I'm sending this on behalf of my son Max, who is an avid reader and subscriber. When he gets told to go and read in bed he is at his happiest! Thanks for the great and informative magazine.

Here's Oscar Black (aged 9), enjoying his **How It Works** collection.

Here's a photograph of Evie, then aged 16 months, reading a copy of **How It Works**. She's now four years old and was recently looking at an article about venomous snakes.

Grant is an athlete who reads **How It Works** to occupy himself during many hours on the bike.

Hi,
How It Works. My daughter Jessica Hall loves her **How It Works** so much, she even multitasks with them, using them for Hide and Seek! Thanks for a great magazine and happy anniversary.

Cameron skateboards to work daily, so when a new issue comes out, he sometimes has no choice but to take **How It Works** with him.

www.howitworksdaily.com

HOW IT WORKS

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FAST FACTS

Amazing trivia to blow your mind

24 MEGATONS

THE THERMAL ENERGY RELEASED BY WASHINGTON'S 1980 MOUNT ST. HELENS ERUPTION

610M

THE DISTANCE BETWEEN TITANIC'S WRECKED BOW AND STERN

520 MILLION-YEAR OLD FOSSIL WORMS SHOW ONE OF THE EARLIEST EXAMPLES OF SYMBIOSIS

1820

THE YEAR FABIAN VON BELLINGSHAUSEN SIGHTS ANTARCTICA

5,472 KILOMETRES

IN 2015, A DRIVERLESS CAR SUCCESSFULLY DROVE RIGHT ACROSS THE USA

67%

OVER TWO THIRDS OF THE EARTH IS COVERED IN CLOUD AT ANY GIVEN TIME

WATERMILLS CAN BE USED TO GENERATE ELECTRICITY: AS HYDROELECTRIC PLANTS

THE SLIDE HOVERBOARD (BY CAR MAKER LEXUS) RIDES ON A MAGNETIC TRACK AND USES SUPERCONDUCTORS COOLED BY LIQUID NITROGEN

1%

THE GAIA SPACE TELESCOPE IS MAPPING A FRACTION OF THE MILKY WAY'S STARS

2,000KPH

THE F-35 CAN ACHIEVE SPEEDS OF ABOUT MACH 1.6

363,000KM

THE MINIMUM DISTANCE A SPACE ELEVATOR WOULD HAVE TO STRETCH TO REACH THE MOON

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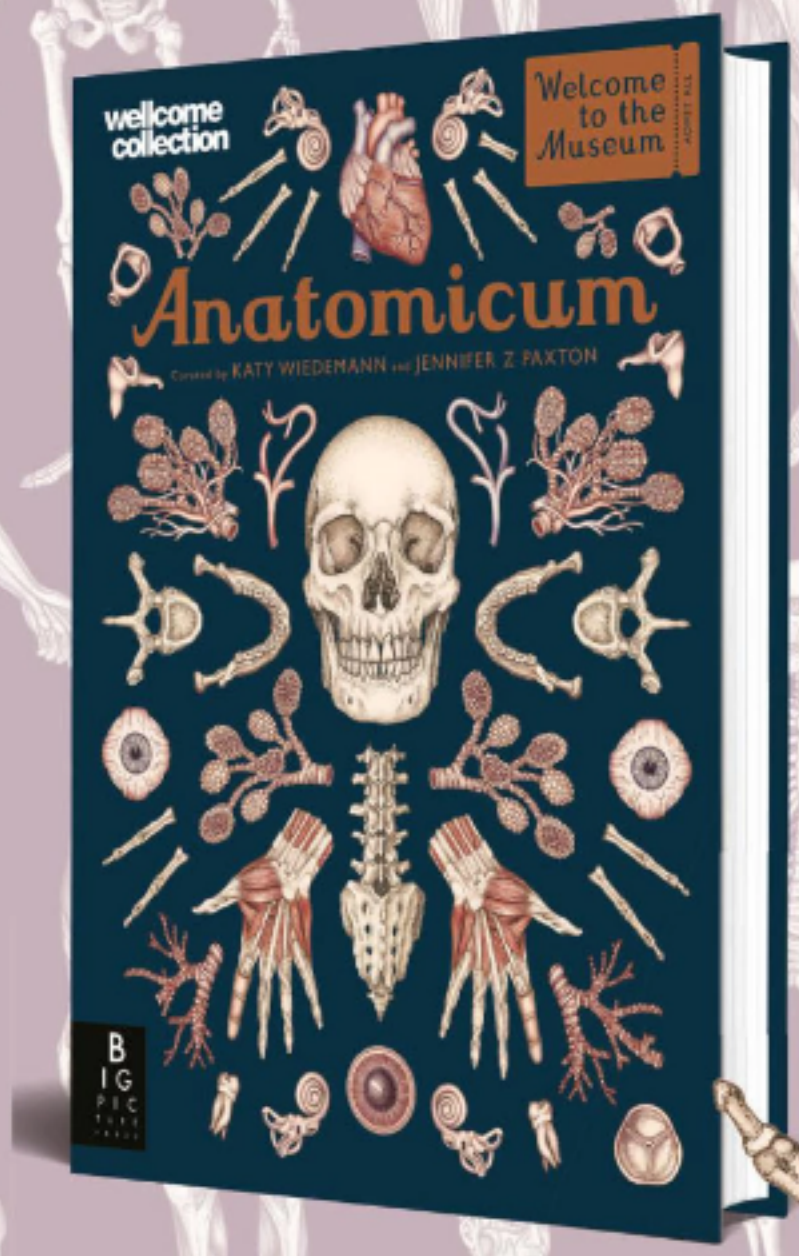

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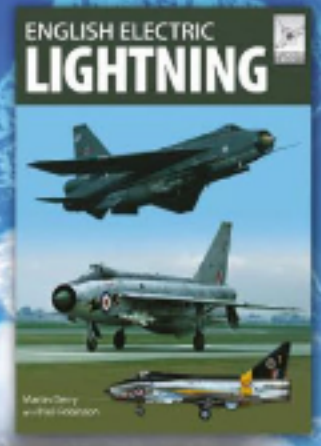

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