THE MAGAZINE THAT FEEDS MINDS

HOW IT WORKS

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Discover the real science behind the misconceptions

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CELEBRATING 100 YEARS OF

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1985 1949

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Find out how caffeine actually affects your brain

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The clean gas that will power future cars

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How creatures build incredible structures

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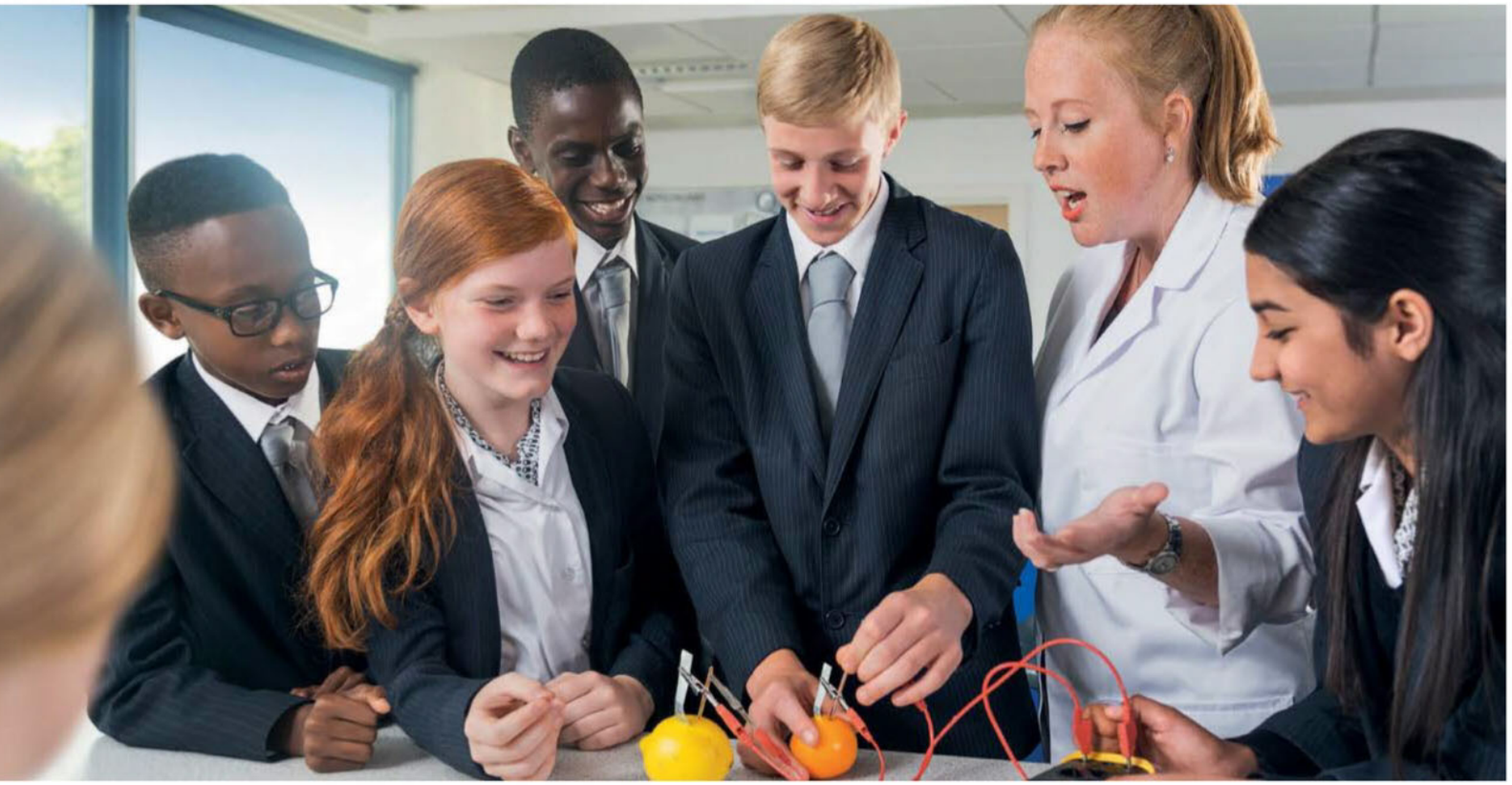

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ISSUE 72

WELCOME

The magazine that feeds minds!

Page 62
How do animals build such incredible homes?

Avengers: Age Of Ultron is out this month and the **How It Works** team are assembling to watch it. We all have our favourite spandex-clad supe; Erlingur identifies with Thor's Nordic roots while Jackie thinks Captain America's the perfect gentleman, but the rest of us are backing Iron Man. While most of the super-secret team were destined for greatness or the result of a lab experiment, Tony Stark was a self-made hero. He's the engineer who soldered his own suit and developed the tech to enable him to defend the world.

The citizens of the Marvel Universe owe him a debt, and we do to. A study showed that three-quarters of London students couldn't name a single engineer, but those who were interested in the profession were likelier to be inspired by Iron Man than Isambard Brunel. In such an important field, it shouldn't matter what inspires the engineers of tomorrow, just as long as it does. After all, the future of superheroes will be made up of Iron Men and Women, not Hulks.

Jodie

Jodie Tyley
Editor

Meet the team...

Andy
Art Editor
Working on the fighter-plane feature has made me a fan of this ultimate technological form of death from above.

Erlingur
Production Editor
The feature on real-life superpowers revealed my freakish good mental arithmetic skills may not classify as 'super.' I'm super disappointed.

Phil
Staff Writer
The Victorians gave us a variety of weird and wonderful inventions. Unlike portable baths, safety coffins are still available today.

Jackie
Research Editor
Coming soon to a cinema near you: virtual-reality 3D, fully immersive 4D and even snazzy next-generation laser projectors!

Jo
Assistant Designer
Animals can be just as houseproud as us. Find out more about the amazing animal architects in this month's issue!

Jo
Senior Staff Writer
The incredible Lytro camera could mark the end of all those out-of-focus cat photos and blurry pictures of latte art.

What's in store

Check out just a small selection of the questions answered in this issue of How It Works...

How do figure skaters pull off amazing tricks? **Page 60**

How did the Moeraki boulders form? **Page 67**

How are parachutes deployed? **Page 26**

What will the cinemas of the future be like? **Page 36**

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Meet the experts...

Laura Mears
Myths busted
If you've heard cockroaches can survive a nuclear apocalypse, you may have been myth-taken. Laura rounds up 50 of the most common science myths and reveals the scientific truth.

Hayley Paterek
Animal architects
Hayley's love for animals sparked her nickname, RSPC-Hay. Our creature correspondent gives us a tour of the grandest designs of the animal kingdom.

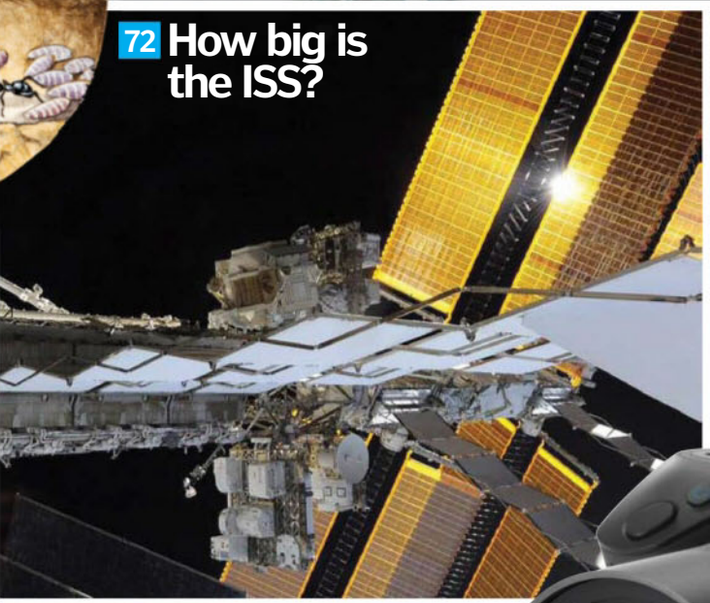
James Hoare
Ancient dentistry
No one likes a trip to the dentist, but at least they don't still think your nerves are worms that need to be yanked out! That's the kind of practice you'll learn about in James' five gruesome facts.

Lee Sibley
Hydrogen cars
The Editor of our sister magazine **Total 911** takes us into the future of fuel: hydrogen, and explains how automatic windscreen wipers know it's raining.

Ceri Perkins
Future cinemas
Cinemas are stepping up their game in a bid to lure you away from your TV. Discover the tech making movies better than ever inside Ceri's blockbuster feature.

14 FIGHTER PLANES

Inside the most iconic aircraft, from WWI to modern day



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REGULARS

Join our HOW IT WORKS Reader Panel today!

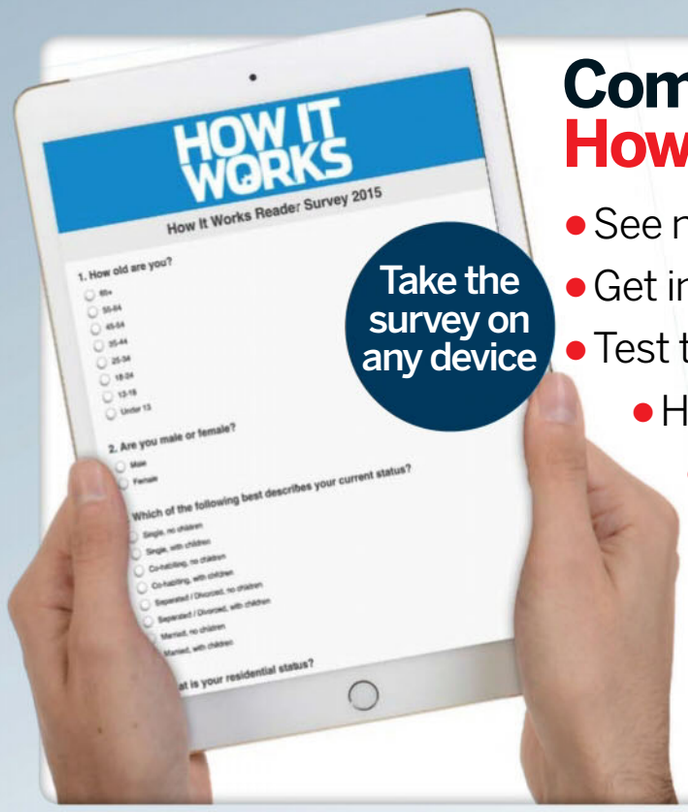
Take our three-minute survey at howitworksdaily.com/survey and win a place on our panel

Hi. We love making How It Works and we hope you love reading it too. But this year we want to make it even better, so we're asking for your help. By answering just a few questions, you could be selected to join our first-ever How It Works panel. I'm so excited to hear what you have to say and can't wait to learn more about you.

Jodie

Jodie Tyley
Editor

Join our panel and help us make the magazine even better!



Complete our survey to join our How It Works panel and:

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- Shape the future issues of the magazine
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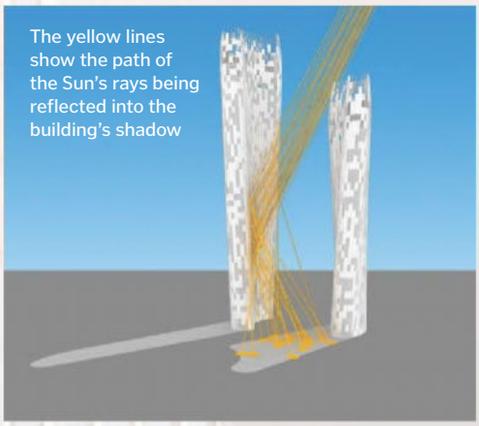
Skyscrapers that don't cast shadows

Smart structures work together to reflect sunlight into the shade

In the race to build taller skyscrapers, large areas of cities are being plunged into shadow as a result. To bring a bit of sunshine back into the lives of the people below, global architecture firm NBBJ has designed the first shadowless building. It used computer modelling and algorithms to create a pair of towers that work together to reduce shadows on the ground by 60 per cent. The concept is intended to be built in Greenwich, London, but the firm says its software can be used to design similar skyscrapers for cities all over the world.

The shadowless structures could be two of the 250 new skyscrapers planned for London

The glass structures will brighten up the shaded busy streets below



The yellow lines show the path of the Sun's rays being reflected into the building's shadow

Shadowless structures

To minimise the amount of shade below tall buildings, NBBJ's architects have proposed a clever mirroring system. The curved glass surface of the northernmost building reflects sunlight down into the shadow of the southern tower. The carefully shaped glass will even be able to redirect the light to fill in the shadow as it moves throughout the course of the day. The towers designed for London are wider at the top than at the bottom to reflect more light when the Sun is higher in the sky during the summer months. However, if designed for other locations, the buildings may need to be less top-heavy to account for the climate and Sun's position. To ensure the enormous mirrors do not magnify the Sun's rays to fry the people and objects below, the glass also diffuses as well as reflects the light for a softer, more natural effect.

Mushrooms glow for attention

Fungi have a clever trick for attracting insects

Several species of fungi are bioluminescent, meaning that they can produce light through a chemical reaction. This fact has been known for some time, but researchers have only just worked out why they do it. They discovered that this illuminated display helps the mushrooms attract insects, such as beetles, flies and ants, which can carry their fungal spores away. This helps the species reproduce and spread to new habitats, furthering their efforts to survive. The study also found the fungi use their circadian clock to tell them when it is dark enough to turn on their bioluminescence, so the chemical reaction isn't wasted during the day.

Some species of mushroom give off a green glow to help them get noticed

The 726-ton (1.6mn lb) booster will propel an unmanned Orion test flight beyond the Moon in 2018

Another step closer to Mars

NASA tests the most powerful rocket booster ever built

The booster designed to propel NASA's Space Launch System (SLS) rocket and Orion spacecraft to the Red Planet has undergone its first test. The most powerful rocket booster ever built was fired up for two minutes, the same amount of time it will take to lift the SLS off the launch pad. During the test, it generated about 1,633 tons (3.6 million pounds) of thrust, more than the amount produced by 14 Boeing 747-400s at takeoff, and temperatures inside the booster reached more than 3,093 degrees Celsius (5,600 degrees Fahrenheit).

'Butcher crocodile' was king before dinosaurs

The 'Carolina Butcher' topped the food chain 231 million years ago

When the supercontinent Pangaea was breaking apart, 2.7-metre (nine-foot) tall, sharp-toothed creatures roamed the area that would become North Carolina in North America. Palaeontologists have recently discovered parts of the skeleton belonging to Carnufex carolinensis, an ancestor of today's crocodiles. Nicknamed the 'Carolina Butcher', it is believed to have used its blade-like teeth to slice flesh from its prey, likely to have been armoured reptiles and the early relatives of large mammals. As its forearms were so short, it is also suspected the creature walked on two legs, much like a T-rex.

A 3D model of the creature was created from scans of its fossils

GLOBAL EYE

10 COOL THINGS WE LEARNED THIS MONTH

Giant black hole discovered

A supermassive black hole, 12 billion times the size of our Sun, has been discovered at the centre of an incredibly luminous quasar 12.8 billion light years from Earth. The quasar, named SDSS J0100+2802, is about 420 trillion times brighter than our Sun. The black hole powering the quasar is thought to be one of the largest ever found from the early universe.

A new laser can map whole rooms through a keyhole

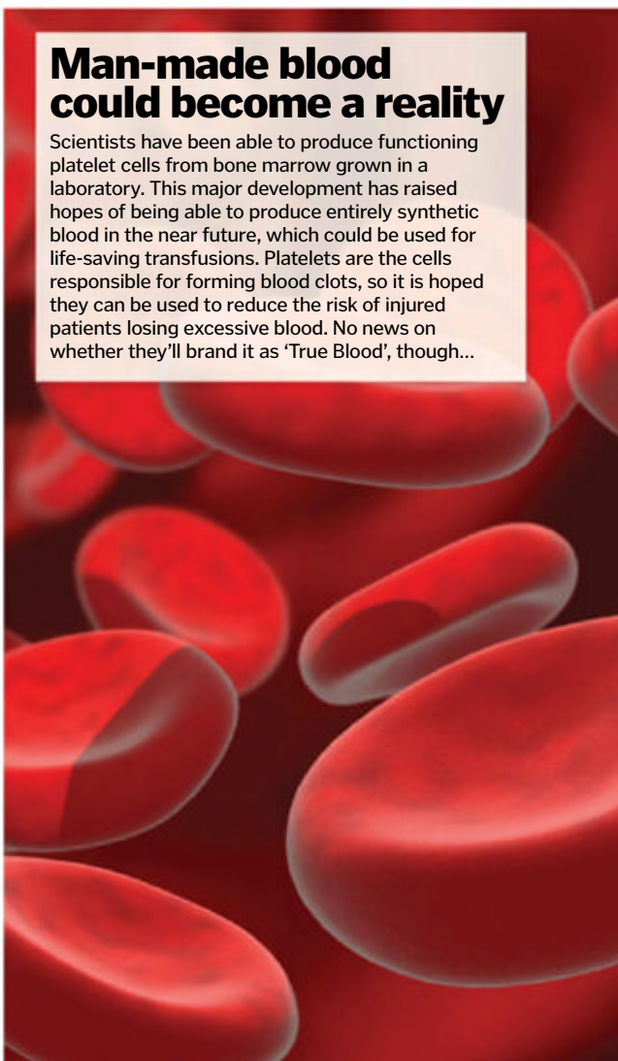
This new laser-imaging technique built on previous work carried out in 2012, which used lasers to see around corners. By altering the laser's pulse, it's possible to measure the distance travelled by the laser between the different objects within the room. With this information, a 3D image of the otherwise hidden room can be developed.

Genghis Khan's grandson to blame for pollution

It has been found that silver mined during the rule of Kublai Khan produced four times the pollution of modern-day mining methods. Feared as horseback barbarians, it seems the Mongols were also fond of mining and smelting silver, producing huge amounts of pollution.

Dragonflies have the best vision

Dragonflies have been found to have the best vision of all living species. With up to 33 different types of light-sensitive opsin proteins, dragonflies have far superior vision to humans, who only see colours in a combination of blue, green and red. They have also been revealed to be the world's most efficient hunters, with a 95 per cent success rate of catching their prey.



Man-made blood could become a reality

Scientists have been able to produce functioning platelet cells from bone marrow grown in a laboratory. This major development has raised hopes of being able to produce entirely synthetic blood in the near future, which could be used for life-saving transfusions. Platelets are the cells responsible for forming blood clots, so it is hoped they can be used to reduce the risk of injured patients losing excessive blood. No news on whether they'll brand it as 'True Blood', though...

Night-time sunscreen could battle skin cancer

New research has suggested that the application of a sunscreen at night may help battle skin cancer. Scientists have discovered that ultraviolet light's energy can cause damage to our DNA hours after we have finished sunbathing; chemicals that block this energy could form a new sunscreen to be applied at night.

There's new scientific proof of climate change

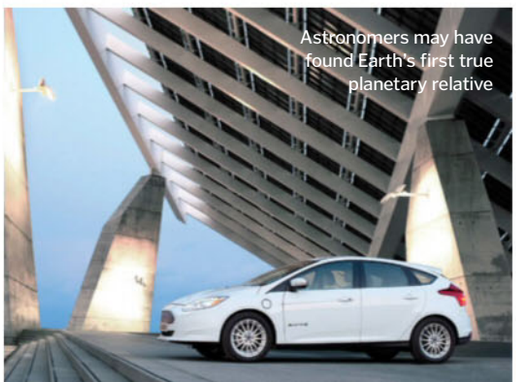
Researchers believe they have finally proved the science behind climate change. By using precision spectroscopy, scientists were able to witness first-hand the trapping of heat in the atmosphere by carbon dioxide and thereby prove its involvement in the greenhouse effect. They detected carbon dioxide's infrared spectral signature, which allowed them measure how much heat the gas traps in the atmosphere.

One gene enabled human intelligence

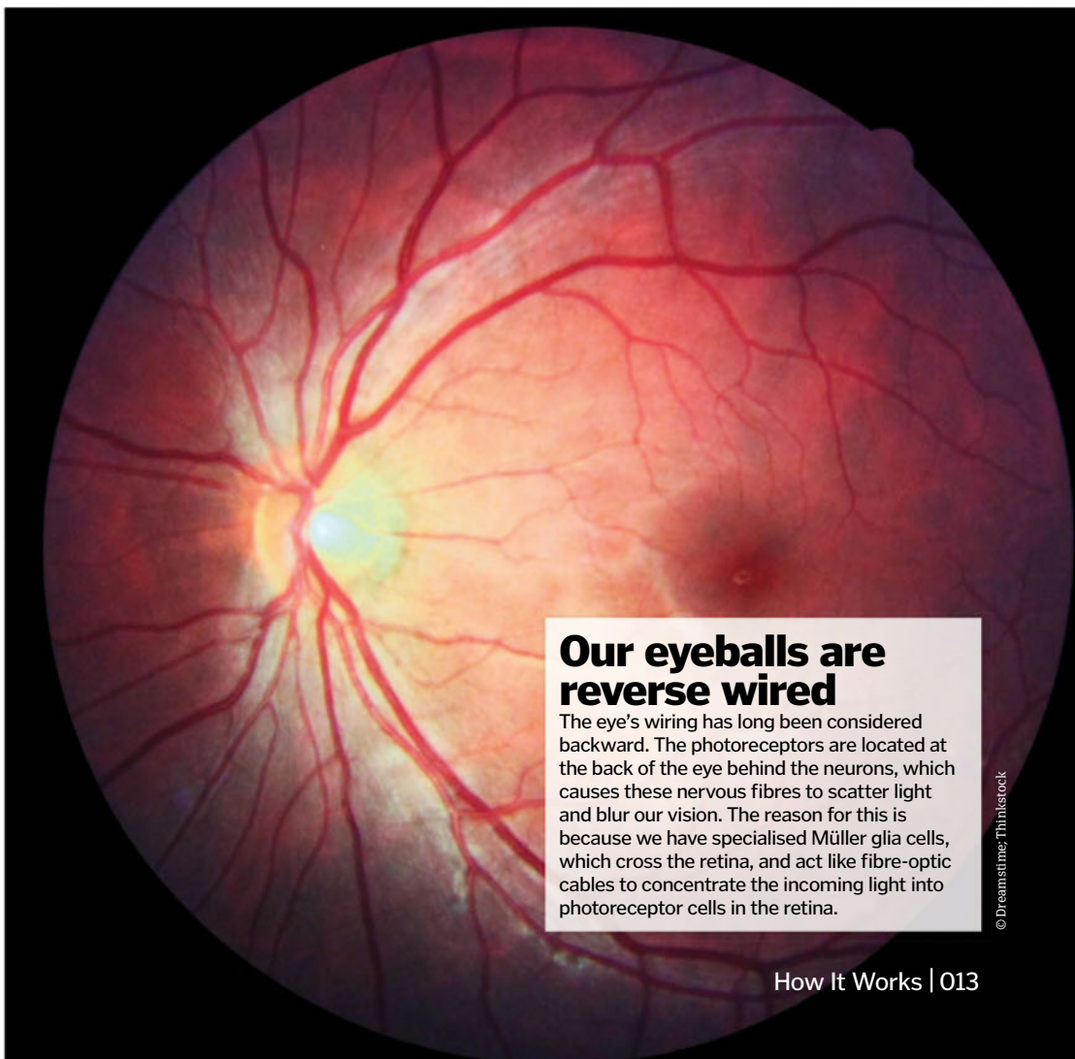
Scientists have identified the single gene they believe to be responsible for humans developing a greater intelligence than chimps. The ARHGAP11B gene is believed to have increased the quantity of neurons in our neocortex, which is the area of the brain responsible for abilities related to advanced intelligence, such as language and reasoning. This gene is believed to have developed after our ancient ancestors split from those of modern chimps over 5 million years ago.

Electric cars can be charged remotely

The new MyFord mobile app will enable owners of electric vehicles to manage their vehicles' charging remotely via their smartphone. This app will also enable users to check their car's range and plan charging stops during their journeys. It will be possible for drivers to make sure their car is fully charged at a specific date and time, and for a preferred cabin temperature to be established before they set off.



Astronomers may have found Earth's first true planetary relative



Our eyeballs are reverse wired

The eye's wiring has long been considered backward. The photoreceptors are located at the back of the eye behind the neurons, which causes these nervous fibres to scatter light and blur our vision. The reason for this is because we have specialised Müller glia cells, which cross the retina, and act like fibre-optic cables to concentrate the incoming light into photoreceptor cells in the retina.

1938
Supermarine Spitfire
The Supermarine Spitfire was used by the RAF and other Allied forces during WWII. It was designed as a short-range, high-performance interceptor aircraft, with a maximum speed of 595km/h (370mph). Originally fitted with eight .303 Browning machine guns, it helped defend Britain's coastline during the Battle of Britain.

1989
Harrier II
Introduced to active service in December 1989, the Harrier II is an example of a vertical and/or short-takeoff and landing (V/STOL) jet aircraft, perfect for use on aircraft carriers. It was frequently used in combat during missions in Kosovo, Iraq and Afghanistan.

1983
F-117 Nighthawk
The F-117 Nighthawk was equipped with pioneering stealth technology and was designed to have a minimal radar cross-section, making it very hard to detect by traditional monostatic radars. During its 25 years of service, only one was ever lost in combat.

CELEBRATING FIGHTER

FROM WWI TO MODERN DAY, INSIDE THE MOST ICONIC MILITARY AIRCRAFT

From daring dogfights over World War I France, to the computer-powered prowess of the modern era's jet fighters, the history of aerial warfare is nearly as old as flight itself.

In 1915, Dutch engineer Anton Fokker devised an interrupter gear, a simple mechanism that allowed a fixed machine gun to fire through a plane's running propeller blades. The first plane to use this was the Fokker Eindecker, which was so effective it began what the British Royal Flying Corps referred to as the 'Fokker Scourge'. This sparked an international race to create faster, more manoeuvrable and ever-more destructive aircraft.

By the end of the Great War, the tactical advantages of maintaining air superiority were well established and by 1939 and the dawn of the Second World War, another leap in aerial combat was already dominating the skies. Capable of hitting speeds of over 500 kilometres (311 miles) per hour, the Messerschmitt Bf 109 was over three times faster than the Eindecker. From its

1916
Sopwith Pup
Equipped with a rotary engine and weighing only 357kg (787lb), it had a range of over 300km (186mi). It was armed with only a single Vickers machine gun and has a fabric-covered, wooden framework. It was nicknamed the 'Pup' as it was smaller than the two-seat Sopwith 1.5 Strutter.

1949
F-86 Sabre
First used in 1949, the F-86 Sabre was used by more than 20 different nations prior to its eventual retirement in 1994. An example of a swept-wing, transonic jet fighter aircraft, it also featured a 'flying tail', which gave it superb manoeuvrability at altitude.

2005
Lockheed Martin F-22 Raptor
The F-22 Raptor is the leading stealth tactical fighter aircraft. Its F-119 engines are regarded as the most advanced ever produced. Pilots benefit from 360-degree awareness when flying. Their ability to super-cruise at Mach 1.5 without afterburners makes them particularly lethal.

100 YEARS OF PLANES

testing ground in the skies of the Spanish Civil War to the invasions of Poland and France, this powerful, lightweight and well-armed fighter set a new precedent for fighter planes.

Aerial warfare was now recognised as the key to strategic success on the ground. Luckily, Allied machines, such as the Rolls Royce-powered Spitfire that was already in service at the outbreak of the war, were able to out-class their German rivals. In the final months of the war, however, the future of fighter aircraft had already taken to the skies. Though it came too late and in too small a number to turn the tide of the war for Hitler, the Messerschmitt Me 262 was the first-ever jet fighter, capable of speeds of 870 kilometres (541 miles) per hour.

Some of the last propeller-powered combat was seen in the Korean War of 1950 to '53, before the world fully entered into the jet age. The skies of the Cold War became tensely patrolled by Soviet MiG-15s, American F-15 fighters and some of the fastest planes ever built. Specialist vertical takeoff and landing (VTOL) craft were developed for deployments on aircraft carriers, while secret stealth and surveillance technology was covertly advanced to wage the war in the shadows.

In modern warfare the job of the fighter plane is still crucial. The new generation of computer-assisted jets are capable of more roles and simultaneous operations than ever before; reducing the risk to the pilot, increasing the threat to the enemy and ensuring complete dominance of the skies. ▶

Modern-day tech

How the new generations of military tech changed the face of aerial warfare

Ever since the Messerschmitt Me 262, nicknamed the Swallow, first took flight in World War II, the jet age has seen fighter-plane technology soar. One key difference between the fighters of today and their ancestors is the need for flexibility. While warplanes were previously designed for specific tasks – such as fighter bombers, escort, or reconnaissance – today's aircraft are expected to perform a range of roles, even simultaneously. For example, the Eurofighter Typhoon carries over a dozen brackets under its fuselage. This enables it to carry any combination of air-to-air or ground-attack armament, or extra fuel pods for prolonged sorties, fulfilling the potential for every combat role.

With machines becoming ever faster and weapons systems leaving little to no room for error, even the lightning reactions of the hardiest flying maverick would struggle to last five minutes of air combat – that is, without the aid of computer technology. Though it goes without saying the role of a pilot still demands incredible levels of skill, endurance, multitasking and quick reactions under pressure, the onboard computer is now an essential component of any fighter plane.

The heads-up display (HUD), iconic from films such as *Top Gun*, was among the most important electronic upgrades to fighter cockpits. It relays target tracking, sensor, navigation and other data direct to the pilot. The HUD computer is connected to all the external and internal sensors of the aircraft, so it's able to collate, prioritise and even give guidance based on this data. This has enabled pilots to quickly engage threats, enact countermeasures and even land safely, all while keeping two eyes firmly focused on the danger zone.

Though within the last few decades fighter technology has leapt several generations, in step with the growing capabilities of computers, the principles of assisting pilot operation have remained the same. For example, the Human Machine Interface (HMI) and Flight Control System (FCS) of the Eurofighter accommodates voice input/output controls, Autopilot, Autothrottle and Flight Director Modes, all to assist handling. In addition, its latest generation of radar is able to identify and prioritise threats. With all this, it's no wonder fighter pilots still feel a special bond with these incredible machines.

Typhoon Tranche 3 Eurofighter

The technology inside Europe's £100 million fighter will take your breath away

Multifunction Information and Distribution System
The internal computer system incorporates all the autonomous sub-systems, such as targeting and monitoring, and presents them to the pilot through multiple cockpit and helmet displays.

Reinforced windows
The cockpit windows are made from super-resistant transparent acrylic called Röhm 249, shaped to give the widest possible view for the pilot.

CAPTOR-E AESA Radar
Active Electronically Scanned Array radar is capable of tracking multiple air and surface targets simultaneously, providing 200-degree coverage and automatically locking on to potential targets.

Multi-role arsenal
With 13 sockets available, the weapons carriage can be equipped to suit any single or multiple roles. The latest Typhoon will be capable of carrying the Storm Shadow cruise missile.

Stealth material
Over 70 per cent of the Typhoon's airframe is made up of carbon-fibre composite material, making its surface deliberately unstable and less visible to radar.

Twin engines
Two EJ200 power plants combine to a total of 180kN (40,500lbf) of thrust, but are lightweight enough to ensure the aircraft can reach Mach 2.0.

DECMU
Each EJ200 is wired to a Digital Engine Control and Monitoring Unit (DECMU), which tell engineers the exact condition of the engine in order for them to extend its life span and apply enhancements.

Towed decoy
As a last resort, a decoy can be deployed by the plane's defence system as countermeasure to any hostile fire.

Defensive sensors
The Defensive Aids Sub-System (DASS) automatically monitors, prioritises and responds to targets and threats from the outside world, both in the air and on the surface.

Future-proof electronics
Fibre-optic data buses are built into the aircraft to ensure it will remain compatible with future generations of weapons systems.

E-Scan radar
This watchful eye doesn't miss a thing

Wide view
The E-Scan is capable of monitoring multiple targets simultaneously, both ground and airborne, giving the pilot a 200-degree view of the battlefield.

Weapons integration
Fully connected to all the weapons systems, the radar can establish and lock on to targets without being prompted, leaving the pilot free to take instant action if required.

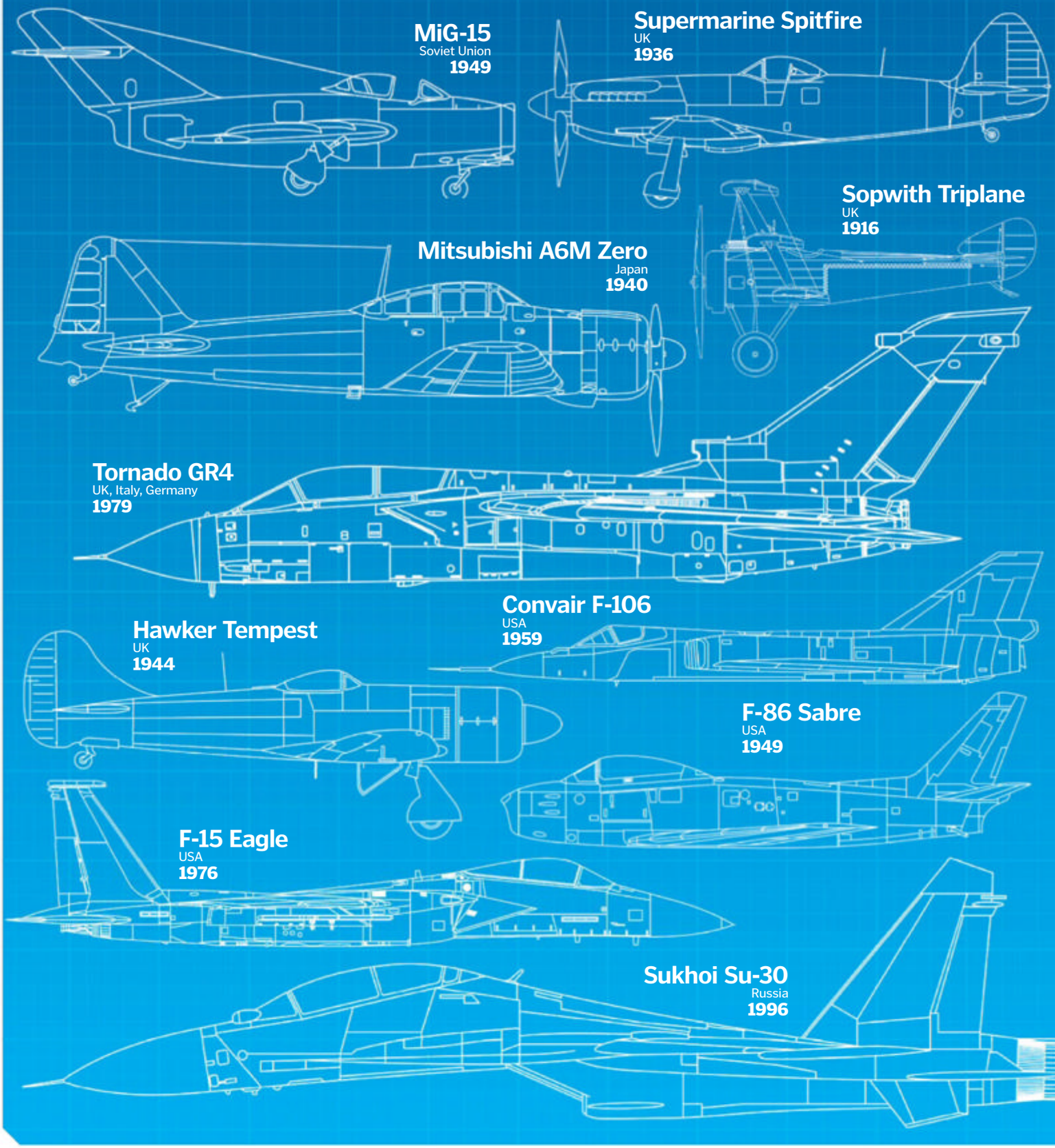
Air-to-ground ability
Some of the air-to-ground features include high-resolution maps, ground moving target identification and air-to-surface ranging.

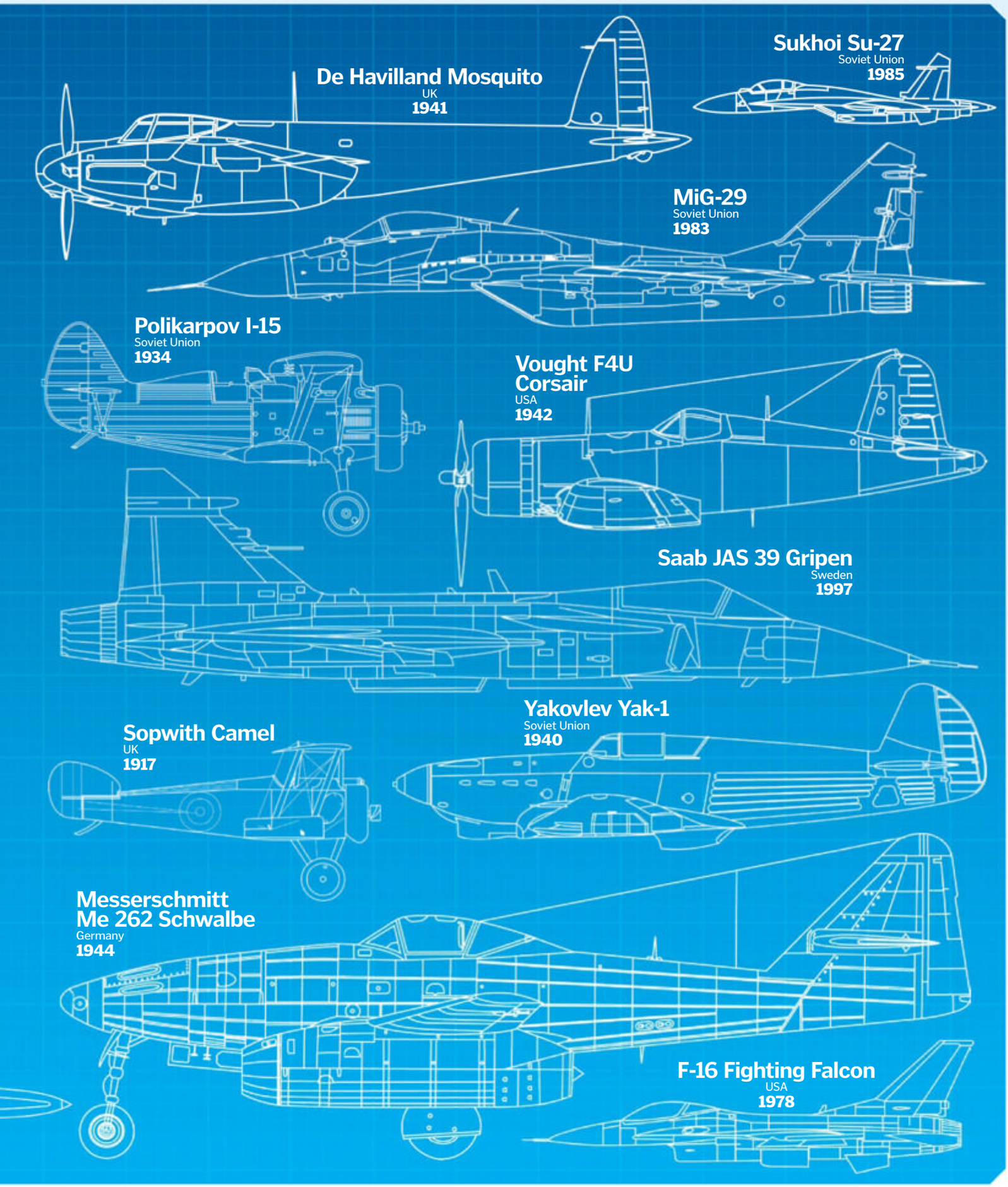
Data link
As well as its primary radar functions, the E-Scan keeps pilots in contact with one another through Data Link capabilities.

High-res mapping
The E-Scan's increased range means pilots can conduct high-resolution synthetic-aperture radar (SAR) scans of the terrain below without coming into dangerous range with the enemy.

AVIATION HISTORY

Discover how warplanes have developed through the ages




De Havilland Mosquito
UK
1941
Sukhoi Su-27
Soviet Union
1985
MiG-29
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1983
Polikarpov I-15
Soviet Union
1934
Vought F4U Corsair
USA
1942
Saab JAS 39 Gripen
Sweden
1997
Sopwith Camel
UK
1917
Yakovlev Yak-1
Soviet Union
1940
Messerschmitt Me 262 Schwalbe
Germany
1944
F-16 Fighting Falcon
USA
1978

Evolution of the fighter plane

How the old war dogs of the skies reached new heights in their time

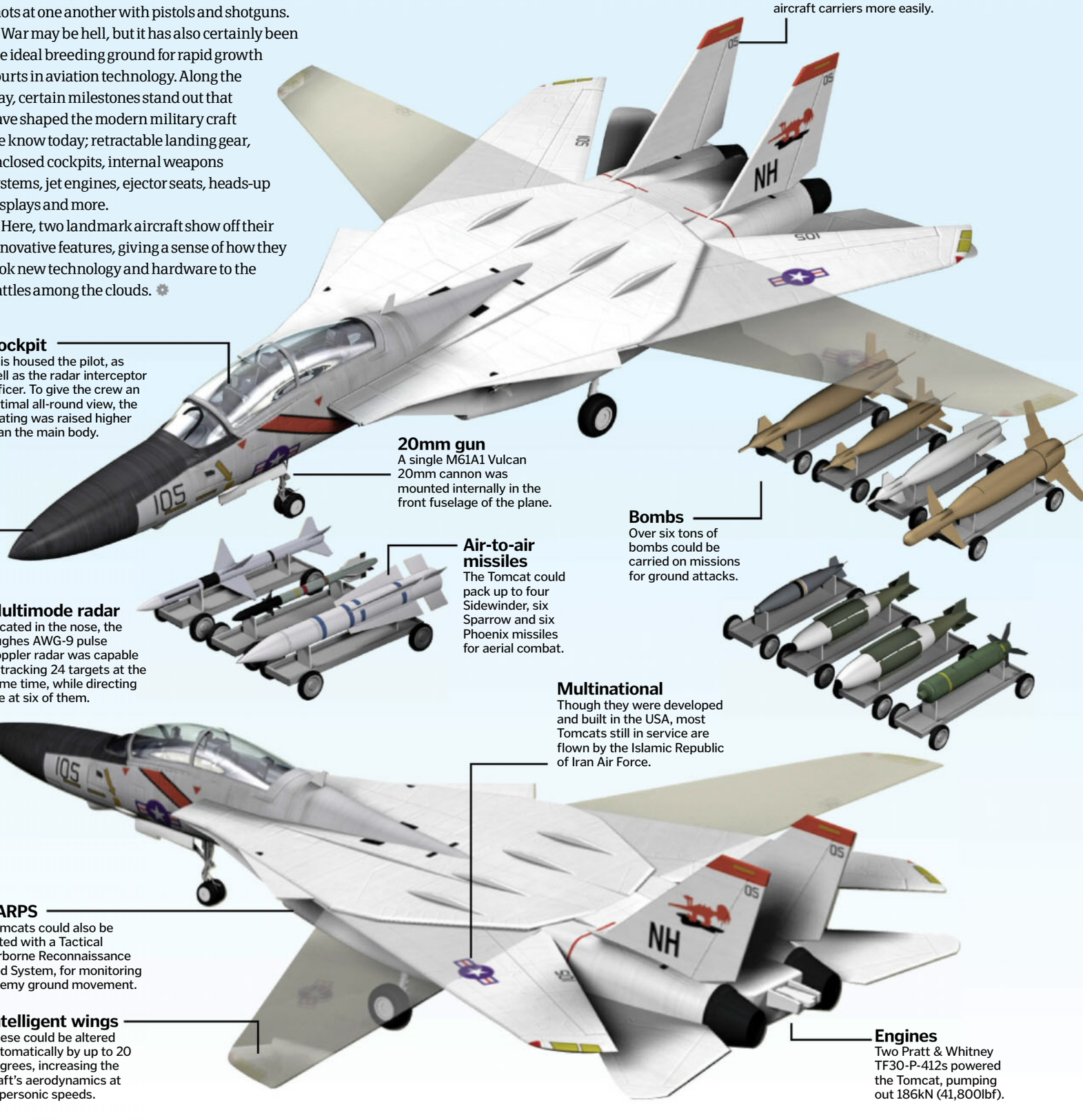
Almost as soon as we were able to fly, we have been inventing new ways to destroy one another in the air. Aerial combat has come a long way from pilots leaning out of their cockpits and taking pot shots at one another with pistols and shotguns.

War may be hell, but it has also certainly been the ideal breeding ground for rapid growth spurts in aviation technology. Along the way, certain milestones stand out that have shaped the modern military craft we know today; retractable landing gear, enclosed cockpits, internal weapons systems, jet engines, ejector seats, heads-up displays and more.

Here, two landmark aircraft show off their innovative features, giving a sense of how they took new technology and hardware to the battles among the clouds.

Grumman F-14A Tomcat

A cat with formidable claws – in the shape of sidewinder missiles and cutting-edge avionics



Tail
This twin tail gave the plane extra stability. The butterfly-shaped airbrake enabled it to land on aircraft carriers more easily.

Cockpit
This housed the pilot, as well as the radar interceptor officer. To give the crew an optimal all-round view, the seating was raised higher than the main body.

20mm gun
A single M61A1 Vulcan 20mm cannon was mounted internally in the front fuselage of the plane.

Bombs
Over six tons of bombs could be carried on missions for ground attacks.

Air-to-air missiles
The Tomcat could pack up to four Sidewinder, six Sparrow and six Phoenix missiles for aerial combat.

Multimode radar
Located in the nose, the Hughes AWG-9 pulse Doppler radar was capable of tracking 24 targets at the same time, while directing fire at six of them.

Multinational
Though they were developed and built in the USA, most Tomcats still in service are flown by the Islamic Republic of Iran Air Force.

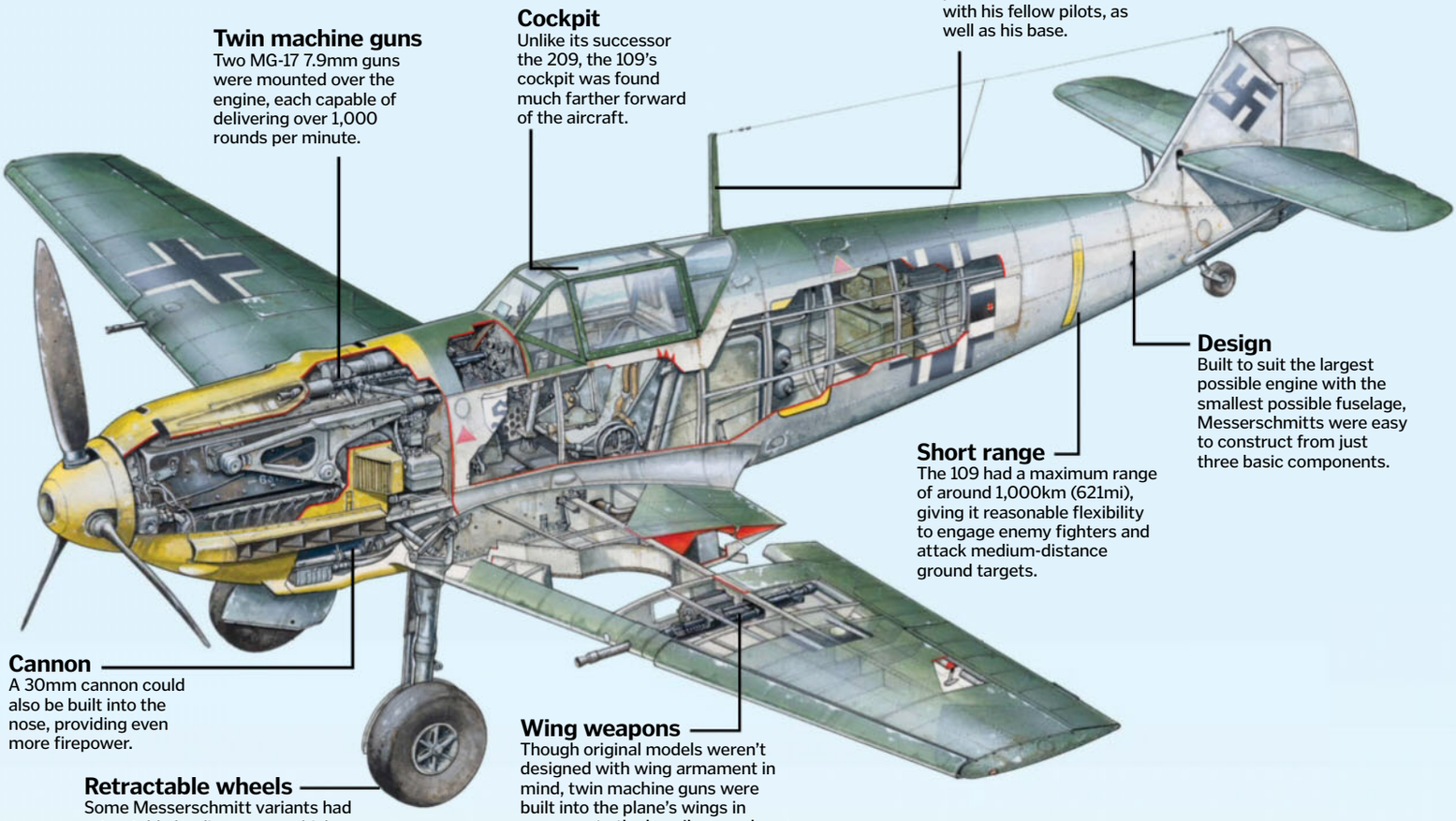
TARPS
Tomcats could also be fitted with a Tactical Airborne Reconnaissance Pod System, for monitoring enemy ground movement.

Intelligent wings
These could be altered automatically by up to 20 degrees, increasing the craft's aerodynamics at supersonic speeds.

Engines
Two Pratt & Whitney TF30-P-412s powered the Tomcat, pumping out 186kN (41,800lbf).

Messerschmitt Bf 109

This scourge of the skies dominated the battles over early WWII Europe



Twin machine guns
Two MG-17 7.9mm guns were mounted over the engine, each capable of delivering over 1,000 rounds per minute.

Cockpit
Unlike its successor the 209, the 109's cockpit was found much farther forward of the aircraft.

Antenna
A high-frequency antenna, connected to a FuG 16Z radio, kept the pilot in communication with his fellow pilots, as well as his base.

Design
Built to suit the largest possible engine with the smallest possible fuselage, Messerschmitts were easy to construct from just three basic components.

Short range
The 109 had a maximum range of around 1,000km (621mi), giving it reasonable flexibility to engage enemy fighters and attack medium-distance ground targets.

Cannon
A 30mm cannon could also be built into the nose, providing even more firepower.

Retractable wheels
Some Messerschmitt variants had retractable landing gears, which made them more aerodynamic.

Wing weapons
Though original models weren't designed with wing armament in mind, twin machine guns were built into the plane's wings in response to the heavily armed British Spitfires.

The future of warplanes

With the increasing use of unmanned drones to target and monitor enemy positions and combatants, it has been suggested that traditional fighter jets could eventually lose any purpose in future warfare. In 2013 the Northrop Grumman X-47B prototype unmanned aircraft was the first of its kind to perform a carrier-launch and recovery, signalling a possible future of unmanned strike-bomber aircraft. Boeing's QF-16s – retired F-16 jets modified to be controlled remotely – are now regularly used for aerial target training. While these pilotless jets are used as real-life targets to test missile systems, they demonstrate just how accurate remote flight is becoming.

Both government and industry leaders have admitted that future military aircraft will have to be more closely integrated with artificial intelligence, even with suggestions that manned jets may work alongside pilotless craft. Studies by the Defense Advanced Research Projects Agency (DARPA) have revealed that drones operate more effectively in packs, prompting further research into how drones could work with one another, rather than rely solely on human controllers in combat scenarios. Even before the fifth generation of fighter jets become widely available, including the F-35 Lightning II and Shenyang J-31, world governments are already looking at cost-effective, as well as cutting-edge solutions for the sixth generation of military aeronautics.

The F-35 Lightning II is currently the fifth-generation of fighter aircraft for several global Air Forces and Navies

The humble windscreen wiper has some clever technology powering it

Auto windscreen wipers explained

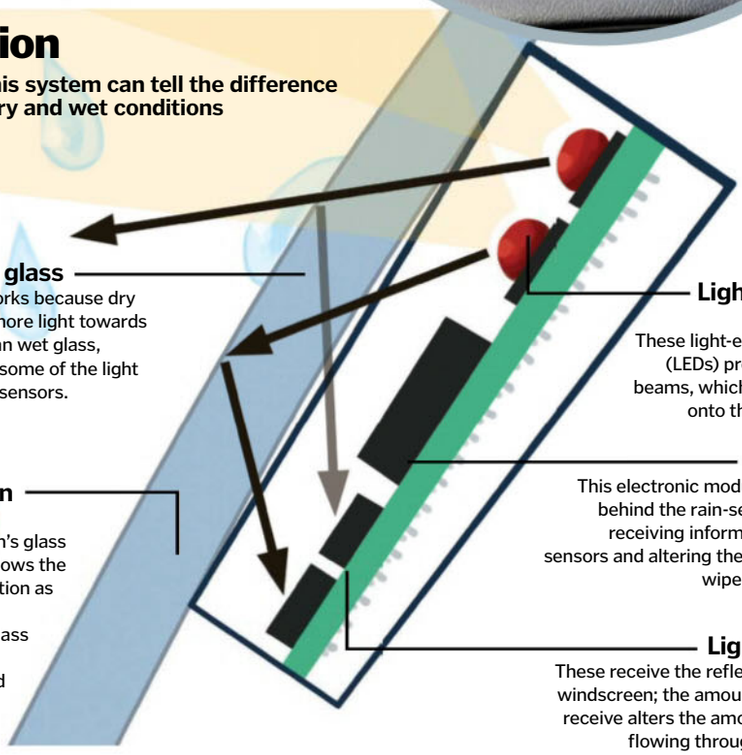
Find out how this clever system keeps your windscreen clear using invisible light

The intermittent windscreen wiper system has undergone much refinement since its first appearance in a 1970 Citroën SM. Although it may seem simple to flick a switch and turn on your wipers manually, automatic wipers have the advantage of reducing distraction and improving visibility. A popular automatic system uses invisible infrared light which is projected across the windscreen and reflected back toward an array of sensors. When rain hits the windscreen, the water droplets refract the light so less of it bounces back toward the sensors. The sensor, typically located on the back of your rearview mirror, detects these changes in the amount of light received. Software will then determine the required wiper speed depending on how much light is refracted by the water.

McLaren has reportedly been developing technology that will consign the windscreen wiper to history. By using ultrasound, its device effectively creates a force field over the windscreen, stopping water from staying on the glass. Whether this will be as efficient as full-speed wipers during a heavy downpour is yet to be seen.

In action

See how this system can tell the difference between dry and wet conditions



Dry vs wet glass
This system works because dry glass reflects more light towards the sensors than wet glass, which refracts some of the light away from the sensors.

Windscreen properties
The windscreen's glass composition allows the system to function as the reflective properties of glass are well understood and can be used effectively.

Light-emitting diodes
These light-emitting diodes (LEDs) produce infrared beams, which are projected onto the windscreen.

Processor
This electronic module is the brain behind the rain-sensing system, receiving information from the sensors and altering the activity of the wipers accordingly.

Light sensors
These receive the reflection from the windscreen; the amount of light they receive alters the amount of voltage flowing through the system.

One configuration transforms the Kormaran into a diving and sunbathing platform

The world's first shapeshifting powerboat

From a catamaran to a speedboat at the touch of a button

The Kormaran is set to make waves – both figurative and literal – in the boating industry. By operating the hydraulic arms electronically, the driver is able to change the Kormaran into six configurations, including a three-hull 'trimaran'. This works by moving the outer hulls by differing amounts, altering the number of hulls in contact with the water. A hydrofoil formation is also possible, which results in extremely efficient travel thanks to an 80 per cent reduction in water resistance due to the hull not touching the water.

Measuring 6.4 metres (21 feet) long, it is built using quality materials such as carbon fibre, titanium and teak. The Kormaran's power comes from the 493-horsepower triple-jet drive, enabling it to reach a top speed of 70 kilometres (43 miles) per hour, at which it can travel for up to 200 kilometres (124 miles). As you would expect, this technology comes at a price. It is reported to cost around €1 million (£720,000 or $1,070,000) plus VAT, but the Austrian company will argue this is good value for money, as you effectively get six boats for the price of one!

animal adoptions

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Hydrogen cars: fuel of the future

How this gas powers vehicles with zero emissions

Believe it or not, hydrogen-powered vehicles have been around for decades. However, it is only in the midst of diminishing crude oil supplies that automotive manufacturers have accelerated attempts to utilise alternative fuelling for their vehicles, and it's only now that hydrogen technology has really developed into a feasible form of fuelling for mass-produced vehicles.

Hydrogen-powered vehicles, otherwise known as fuel cell vehicles (FCVs), are seen as an eco-friendly alternative for future motoring. Hydrogen power works by chemically combining high-pressure hydrogen and oxygen to produce electric power. While oxygen for this chemical reaction is garnered from the atmosphere, the hydrogen is stored in large tanks mounted low down within the body of the car, keeping the vehicle's centre of gravity low, which is important for stability and handling.

There are many advantages to hydrogen-powered vehicles over their more traditionally fuelled contemporaries. Hydrogen is the most abundant element in the universe, is easy to store and transport, and hydrogen-powered cars only produce water as a waste product, meaning zero harmful emissions are released into the atmosphere. It is for these reasons that some of the biggest manufacturers have taken to this technology, including Mercedes-Benz, Volkswagen and Toyota.

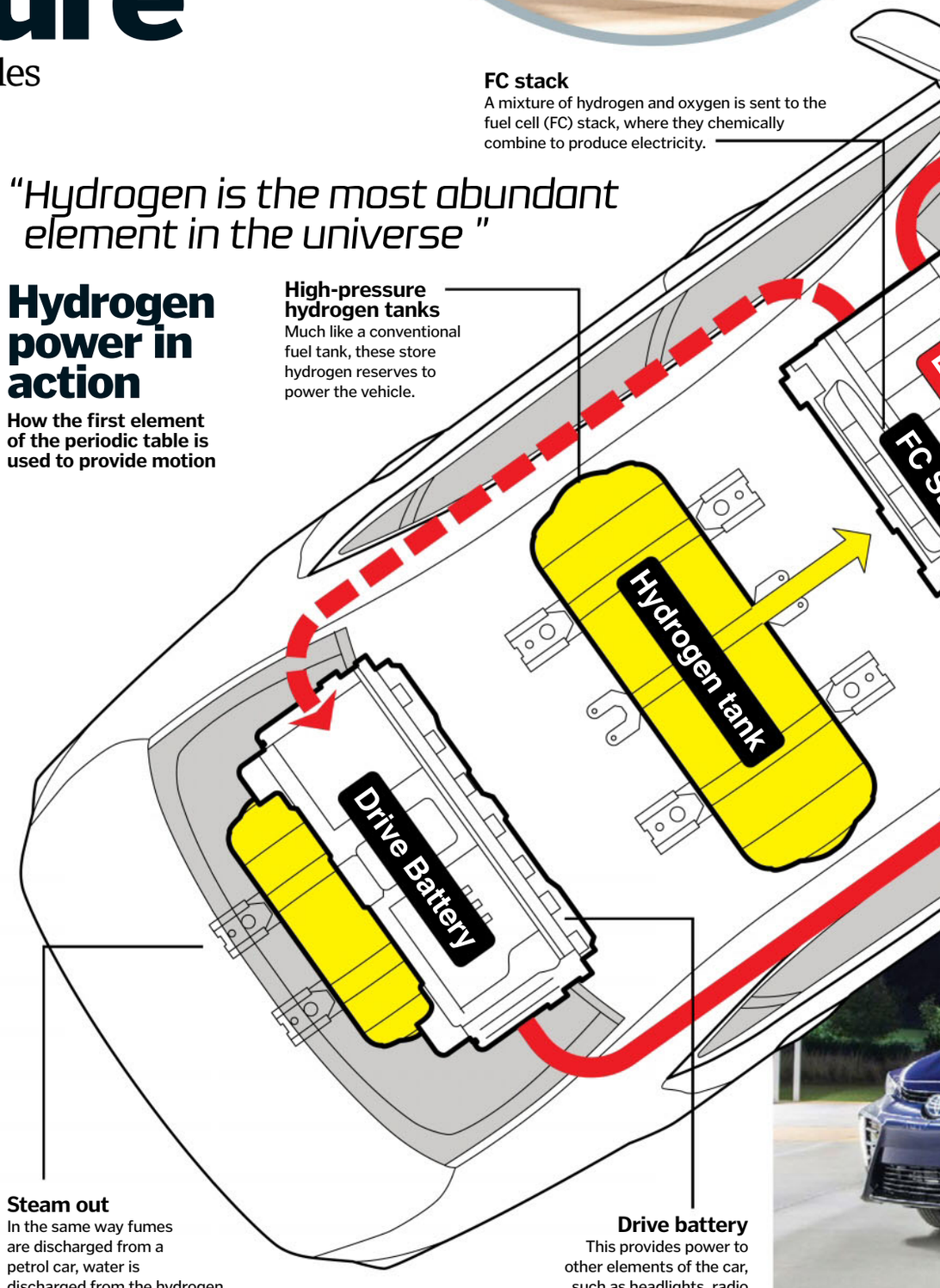
Hydrogen-powered cars have also had to overcome some basic problems, including making suitable space within a compact modern vehicle in which to store hydrogen tanks and additional electric motors. Weight is also an issue, as carrying heavy hydrogen tanks can be detrimental to a vehicle's performance.

Manufacturers are adapting the technology for worldwide use, with an end product of a car that isn't compromised on looks, performance or utility, isn't harmful to the environment and is powered by an energy source that isn't likely to be in short supply any time soon.

"Hydrogen is the most abundant element in the universe"

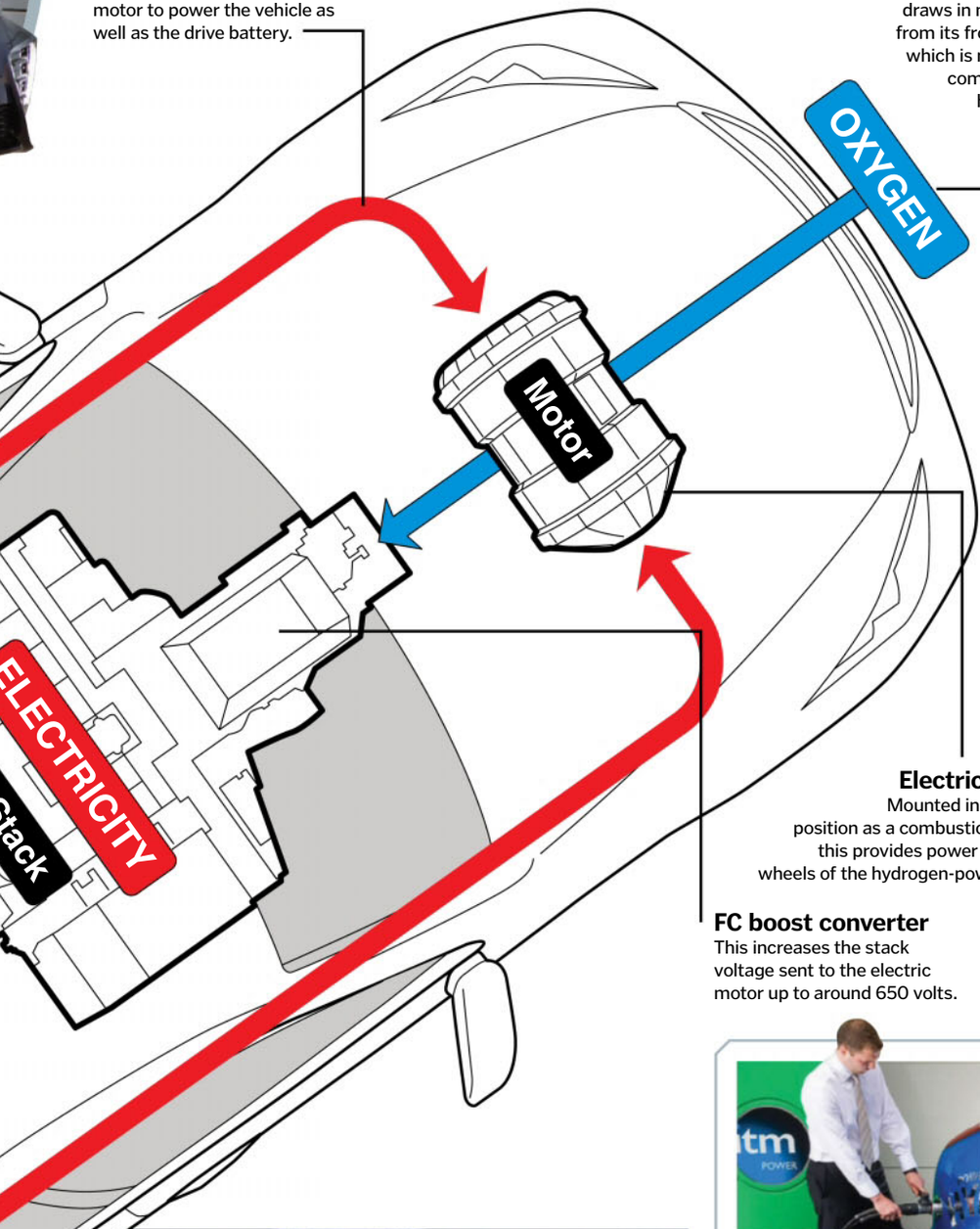
Hydrogen power in action

How the first element of the periodic table is used to provide motion



Electricity supply
The electricity harvested from the FC stack is sent to the electric motor to power the vehicle as well as the drive battery.

Air in
Much like a petrol-powered car, a hydrogen vehicle draws in natural air from its front vents, which is needed to combine with hydrogen.



Electric motor
Mounted in the same position as a combustion engine, this provides power to all four wheels of the hydrogen-powered car.

FC boost converter
This increases the stack voltage sent to the electric motor up to around 650 volts.

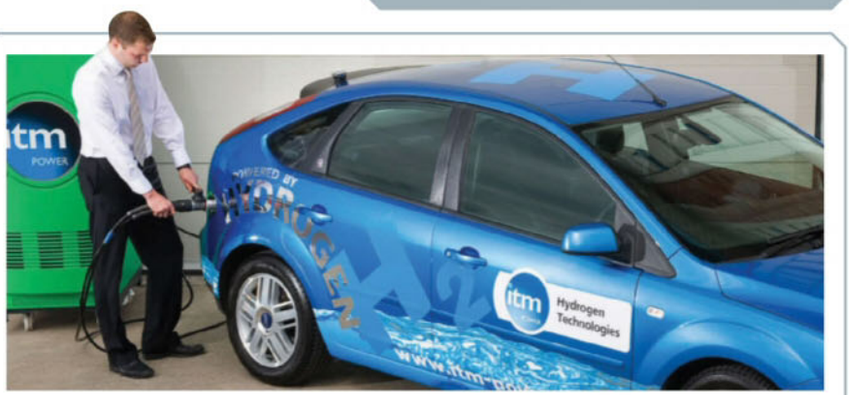
Driving clean

Hydrogen power is just one form of alternative fuelling earmarked for vehicles of the future. With a diminishing supply of known fossil fuels left on Earth, the planet's supply of crude oil – used to produce petroleum and diesel fuel – is set to run out in the next 50 years or so. As a consequence, manufacturers have spent vast sums of money on research and development, particularly in the last decade, for both short-term and long-term development of automobile fuelling. In the short term, manufacturers have successfully found ways to make fuel last longer in vehicles by making engines more fuel-efficient.

Cars now have more gears to keep revs lower, and many have stop/start engine cutout technology. As a result, a vehicle's average fuel efficiency has increased significantly, with cars now frequently capable of 4.7 litres per 100 kilometres (60 miles per gallon) rather than 9.4 litres per 100 kilometres (30 miles per gallon) a decade ago. In the long term, manufacturers are developing other ways to power vehicles, such as electric-only cars.

Electric-only cars such as the Tesla Model S have enjoyed a huge increase in sales in the last five years

The hydrogen-powered Toyota FCV will go on general sale in late-2015



Changing the face of refuelling?

Evolution of vehicle technology, particularly the powering of them, has changed the very concept of how we think when it comes to refuelling a vehicle. The surge in sales of electric and hybrid vehicles has given birth to the rise in recharging points not only in garages and service stations, but in supermarket and shopping centre car parks as well. This means that instead of a motorist having to fill up at a petrol station, they can now simply park up, plug a cable into their car and leave it to charge while they go about their daily business. It gets better: purchasing an electric car today will also buy you your own home-charge kit, meaning motorists can plug their car into the mains at their home and let it charge overnight, ready for use the next day. For hydrogen-powered cars, the process is a little different: a manual refuelling of sorts is still needed, but can be done at home, meaning inconvenient visits to the petrol station could well be a thing of the past.

How parachutes are deployed

Learn how a parachute safely returns a person in free fall to the ground

During free fall, our bodies accelerate at just under ten metres (33 feet) per second squared until we reach a terminal velocity of about 55 metres (180 feet) per second. Hurtling toward the ground at 200 kilometres (124 miles) per hour would be ill-advised without a parachute strapped to your back. Although Leonardo da Vinci is credited with the first parachute design, found scribbled into the margin of his notebook, Louis-Sébastien Lenormand was the first person to demonstrate the parachute in 1783. Early parachutes were made of silk, but these days they are made of synthetic, lightweight materials such as nylon or Kevlar.

Once you've jumped clear of the plane, you deploy the parachute by pulling on the ripcord that releases the pilot chute. The pilot chute will quickly open and when the air hits it with enough force the main chute will be pulled from its container. It is vital that the main chute is packed precisely, so that it opens correctly behind you and the suspension lines connecting it to your harness do not become tangled. The main parachute is actually designed to open slowly. If the main chute were to open quickly to its full size, it would reduce your free fall speed very suddenly, jerking your body harshly and potentially damaging the parachute itself.

A parachute slows you down by increasing your air resistance. Parachutes decrease your terminal velocity by around 90 per cent, allowing you to land at a safe speed of around five metres (16.4 feet) per second. This should be slow enough for you to land gently on your feet when you reach the ground.

Pilot chute
This small, auxiliary parachute functions to deploy the main or the reserve parachute. These can be spring-loaded, pull-outs or throw-outs.

Parafoil cells
This is a typical parafoil parachute. It is split into cells that channel air and allow speed and direction to be controlled easily.

Suspension lines
Multiple suspension lines connect the parachute's canopy to the parachute pack. If the lines are too short the drag may be decreased, meaning the parachute will fall faster.

Slider
The slider works to slow down the speed at which the parachute deploys, reducing the risk of damage to the canopy and of the suspension lines becoming entangled.

Steering toggle
A parachute is equipped with two steering toggles attached to the break lines at the back of the parachute. By pulling both, you can slow your descent.

Body straps
These straps attach the parachute securely to the individual and must be tightly fastened to hold the parachute in place.

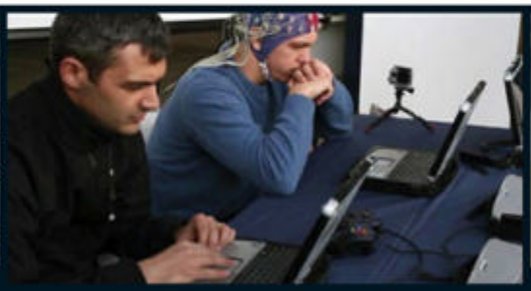
The AAD sits snugly at the top of the pack and is easily accessible to the owner.

Automatic activation device

Many experienced skydivers will tell you that their automatic activation device, or AAD for short, is the most important part of their parachute set up. This self-contained mechanical device attaches to the reserve parachute container, and functions to deploy the reserve parachute in a scenario where an individual is incapable of doing this. AADs constantly monitor a diver's falling speed and altitude so that they know when to activate. If the diver is still falling at a freefall speed when the activation altitude is reached, the AAD will instantly cause the main chute to be cut away and the reserve chute to be deployed. This is particularly useful in situations where an individual has lost consciousness after beginning their freefall, or become distracted and hasn't monitored their altitude closely. The latest AADs, such as the Vigil 2+, recalculate an individual's free fall speed every 0.125 seconds, allowing for variations in normal free fall to be accounted for.

REAL-LIFE SUPERPOWERS

REVEALED: THE TECH THAT CAN MAKE YOU STICK TO WALLS AND REGENERATE LIMBS



We've all dreamed of being one of the superheroes we read about in comic books or watch in big screen blockbusters, but the abilities that make these characters so extraordinary have always been completely fictional – until now.

Amazing advances in technology are enabling humans to develop exciting new ways to mimic the inhabitants of the superhero realm. From gloves that help you climb like Spider-Man, to contact lenses that give you Superman's telescopic vision, the superhero dream is fast becoming reality.

However, these real-life developments aren't being made by billionaires hoping to fight crime and take down dastardly villains; they are actually the ideas of scientists and doctors looking to enhance the human body for more everyday benefits. For example, an implant that speeds up the re-growth of human tissue could be used to reduce the risk of infections and cut medical costs, rather than conceal Wolverine's retractable claws. And a suit that can sense obstacles in any direction could help the visually impaired safely find their way around, instead of providing costume-clad heroes with the means to predict an oncoming attack.

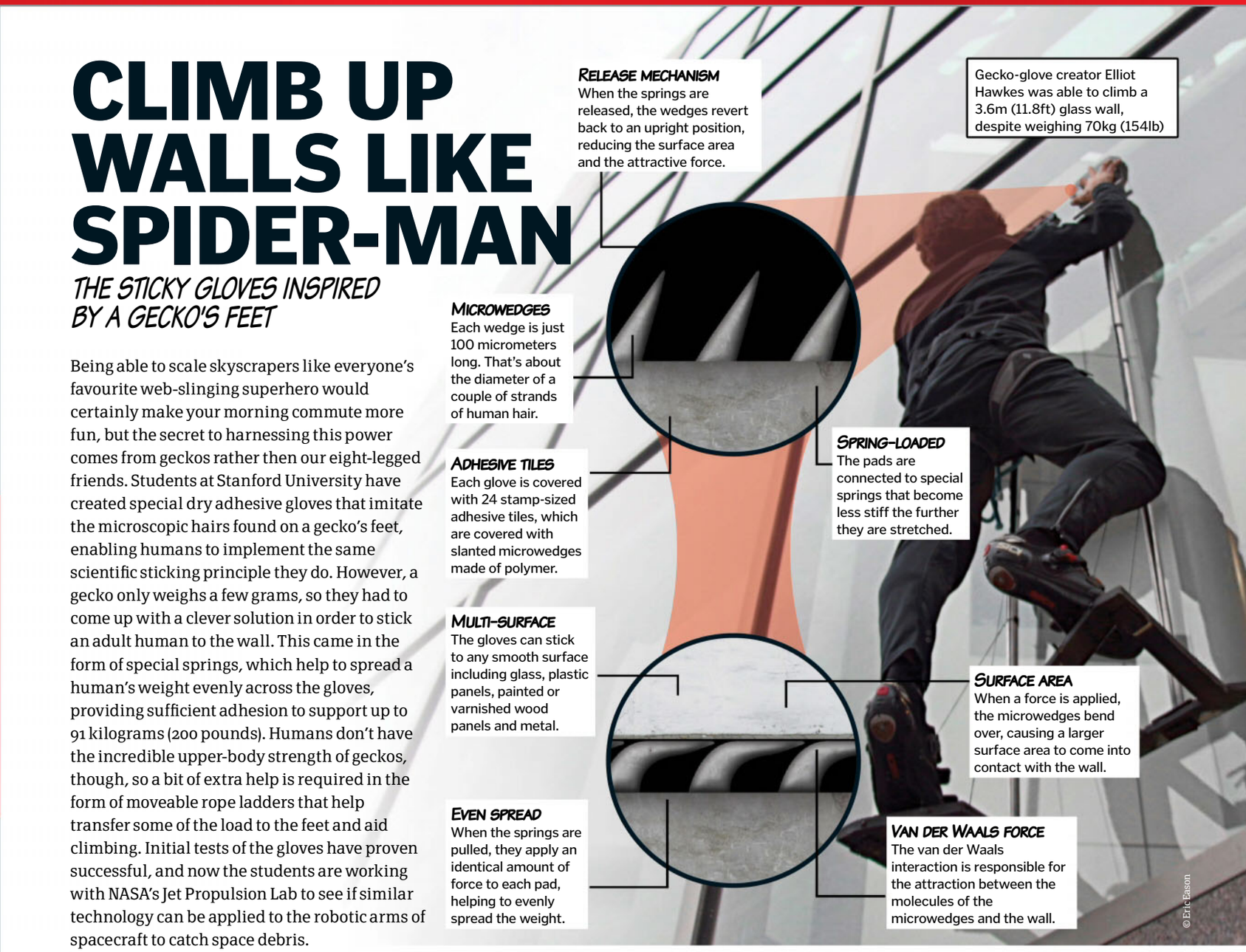
While some of these genius ideas are still in the development phase, others are a lot closer to reality than you might think. Defence contractor Raytheon has already created an amazing Iron Man suit designed to give the US Army's soldiers super-strength, and ship builders are currently using a similar robot exoskeleton to help them lift heavy machinery. You can even get started creating your own superhero gadget at home, as students at the University of Rochester, New York, have found a way to create an invisibility device from readily available materials.

It may not be time to don your mask and cape just yet, but over the next few pages you can browse the incredible gadgets and gizmos that could be kitting out your very own Batcave in the not-so-distant future.

CLIMB UP WALLS LIKE SPIDER-MAN

THE STICKY GLOVES INSPIRED BY A GECKO'S FEET

Being able to scale skyscrapers like everyone's favourite web-slinging superhero would certainly make your morning commute more fun, but the secret to harnessing this power comes from geckos rather then our eight-legged friends. Students at Stanford University have created special dry adhesive gloves that imitate the microscopic hairs found on a gecko's feet, enabling humans to implement the same scientific sticking principle they do. However, a gecko only weighs a few grams, so they had to come up with a clever solution in order to stick an adult human to the wall. This came in the form of special springs, which help to spread a human's weight evenly across the gloves, providing sufficient adhesion to support up to 91 kilograms (200 pounds). Humans don't have the incredible upper-body strength of geckos, though, so a bit of extra help is required in the form of moveable rope ladders that help transfer some of the load to the feet and aid climbing. Initial tests of the gloves have proven successful, and now the students are working with NASA's Jet Propulsion Lab to see if similar technology can be applied to the robotic arms of spacecraft to catch space debris.



RELEASE MECHANISM
When the springs are released, the wedges revert back to an upright position, reducing the surface area and the attractive force.

Gecko-glove creator Elliot Hawkes was able to climb a 3.6m (11.8ft) glass wall, despite weighing 70kg (154lb)

MICROWEDGES
Each wedge is just 100 micrometers long. That's about the diameter of a couple of strands of human hair.

SPRING-LOADED
The pads are connected to special springs that become less stiff the further they are stretched.

ADHESIVE TILES
Each glove is covered with 24 stamp-sized adhesive tiles, which are covered with slanted microwedges made of polymer.

MULTI-SURFACE
The gloves can stick to any smooth surface including glass, plastic panels, painted or varnished wood panels and metal.

SURFACE AREA
When a force is applied, the microwedges bend over, causing a larger surface area to come into contact with the wall.

EVEN SPREAD
When the springs are pulled, they apply an identical amount of force to each pad, helping to evenly spread the weight.

VAN DER WAALS FORCE
The van der Waals interaction is responsible for the attraction between the molecules of the microwedges and the wall.

GET YOUR SPIDERSENSE TINGLING

Sensors spread across your body can alert you to an oncoming obstacle in a matter of milliseconds

The ability to predict an oncoming obstacle or villain is important for any superhero, but we mere mortals have just created a suit that can help us do the same. It may not look quite as slick as Spider-Man's skin-tight ensemble, but the SpiderSense suit can alert you to any person or object within a 152-centimetre (60-inch) radius, even if you're blindfolded. It contains several sensor modules, each containing a range finder and a servo motor. The range finder continually emits a sonar pulse that bounces off of any nearby obstacles, enabling a sensor to calculate its distance from you. When an obstacle is detected, the servo motor – the same one found in most remote-controlled aeroplanes – activates an arm that applies pressure on your skin. The closer you get to the obstacle, the more pressure the arm applies, allowing you to judge its proximity and act accordingly. Inventor Victor Mateevitsi hopes the tech can help the visually impaired and those in low-visibility situations, such as firefighters entering smoke-filled buildings, to navigate safely.

SUPER-SUITS

FORGET CAPES AND LYCRA OUTFITS, REAL-LIFE SUPERHEROES USE ROBOT EXOSKELETONS

Iron Man's superpowers don't stem from a radioactive spider bite or exposure to gamma rays; they are simply the result of some very clever engineering – and quite a bit of money too. It makes sense then that we should try to replicate his powerful suit, and some companies are already coming incredibly close.

Raytheon, a US defence contractor, has developed a super-strong robotic exoskeleton for the US Army. Soldiers can simply strap into the suit and its high-pressure hydraulic system will enhance their strength, agility and endurance, enabling them to be extremely physically active without risk of exhaustion or injury. The current version must be tethered to its power source, an internal combustion hydraulics engine, but an untethered version is expected to be operational by 2020.

It's not just the military that can benefit from exoskeletons, though, as Lockheed Martin has also designed a suit specifically to help workers operate heavy machinery. The FORTIS helps to carry the weight of tools, enabling the operator to work for longer between breaks required to recover from muscle fatigue.

The wearer can punch through 7.6cm (3in) of wood with minimal effort

RAYTHEON XOS 2

The incredible exoskeleton that can help you lift immense weights without breaking a sweat

SENSOR
When you move your arm, a sensor attached to the hand detects the force of the movement.

CYLINDER ACTUATOR
The hydraulic fluid moves the cylinder actuators in the joints, which in turn moves a series of cables.

JOINTS
The XOS 2 has 30 cylinder actuators and computers controlling each of the different joints in the exoskeleton.

CABLES
The cables act as muscle tendons, pulling on the exoskeleton's limb to move it in the desired direction.

Lockheed Martin FORTIS

The suit that supports up to 16kg (36lb) of heavy tools so you don't have to

The main skeleton is made from high-strength aluminium and steel, and weighs about 95kg (209lb)

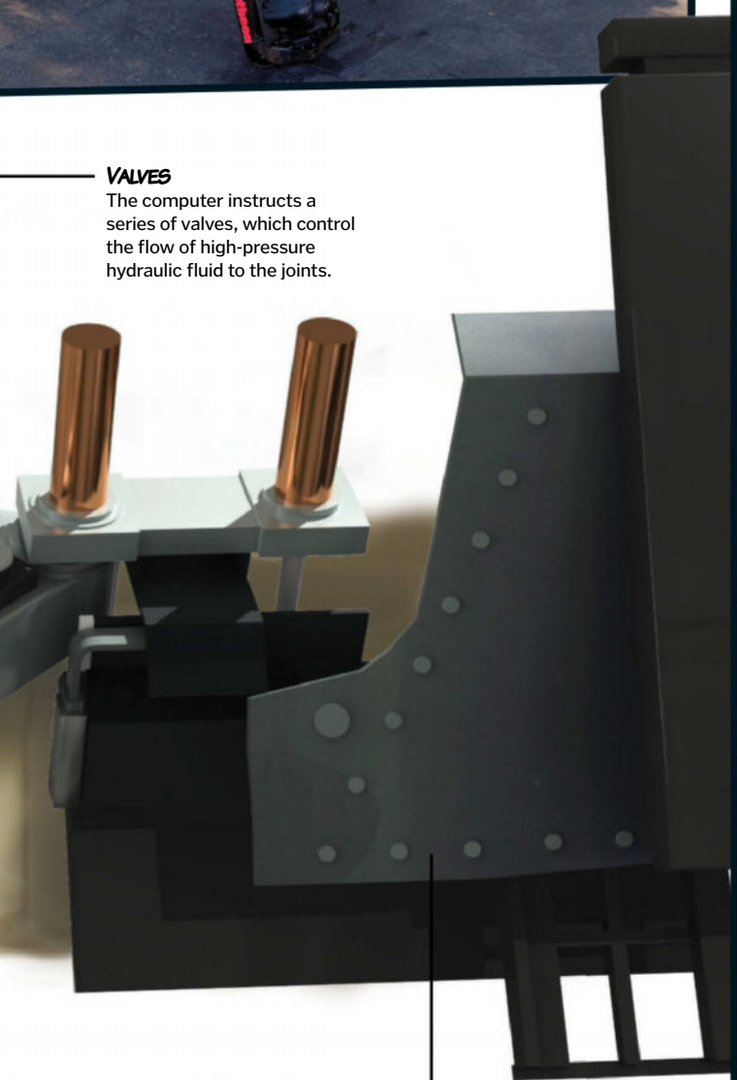
Torso mount
The weighted back plate counters the weight of the ZeroG arm, preventing the wearer from losing their balance.

Carrying the load
The weight of the tool is transferred to the ground, instead of the wearer's arm, via the stirrup.

Mechanical arm
The heavy tool is mounted onto the ZeroG arm, an articulated swing arm that attaches to the frame at the waist.

Lightweight frame
The 13.6kg (30lb) aluminium and carbon-fibre frame has plastic joints at the ankle, knee and hip so the wearer can move freely.

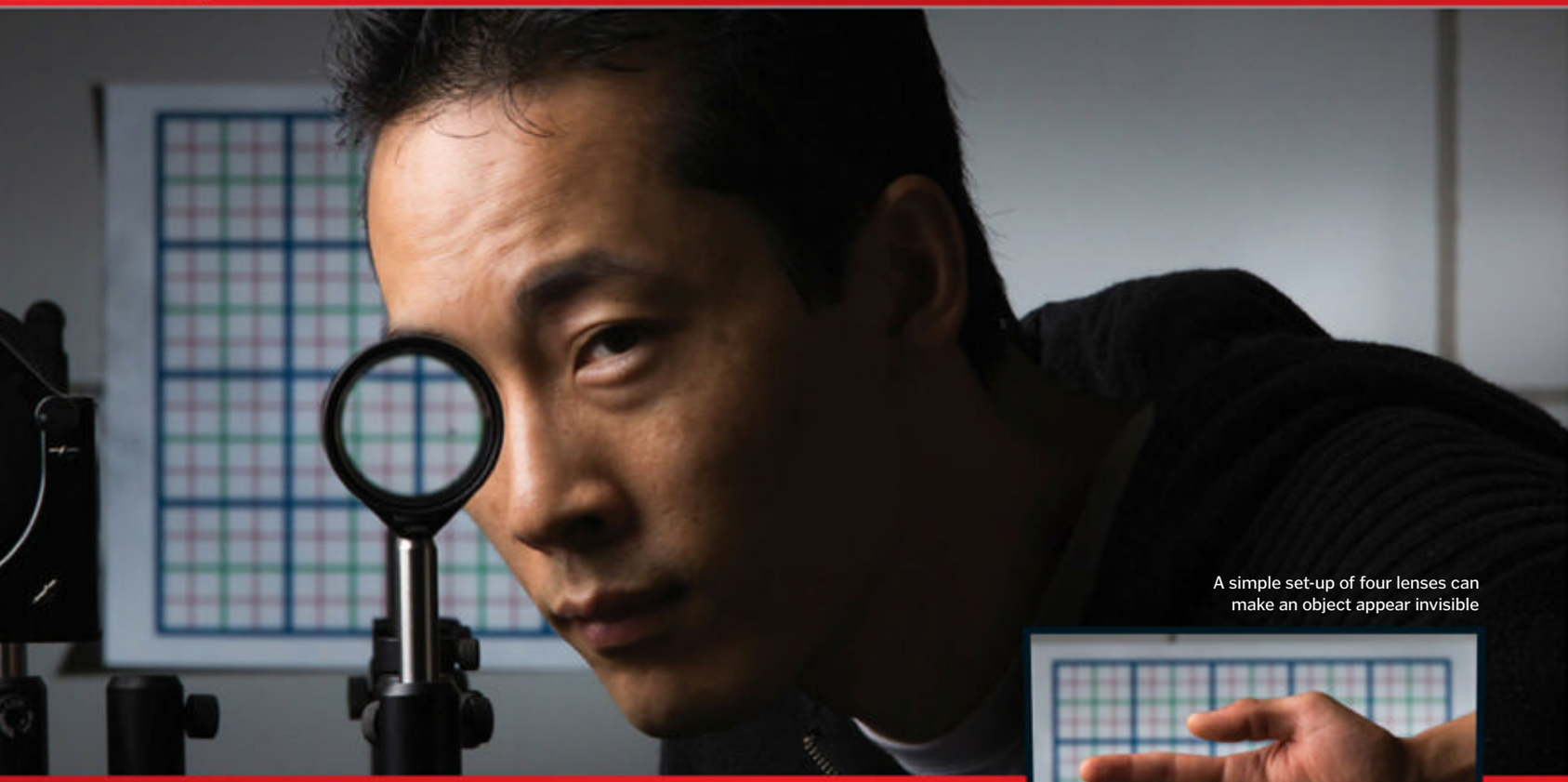
Ankle joint
The stirrup is attached to the ankle, rather than the shoes, allowing the wearer's foot to rest on the ground normally.



Valves
The computer instructs a series of valves, which control the flow of high-pressure hydraulic fluid to the joints.

Computer
The computer uses the sensor's data to calculate how to move the exoskeleton to mimic the arm's movements and minimise its strain.

A worker can operate a 7.3kg (16lb) grinder for three minutes unaided, but the FORTIS extends this to 30 minutes.



A simple set-up of four lenses can make an object appear invisible

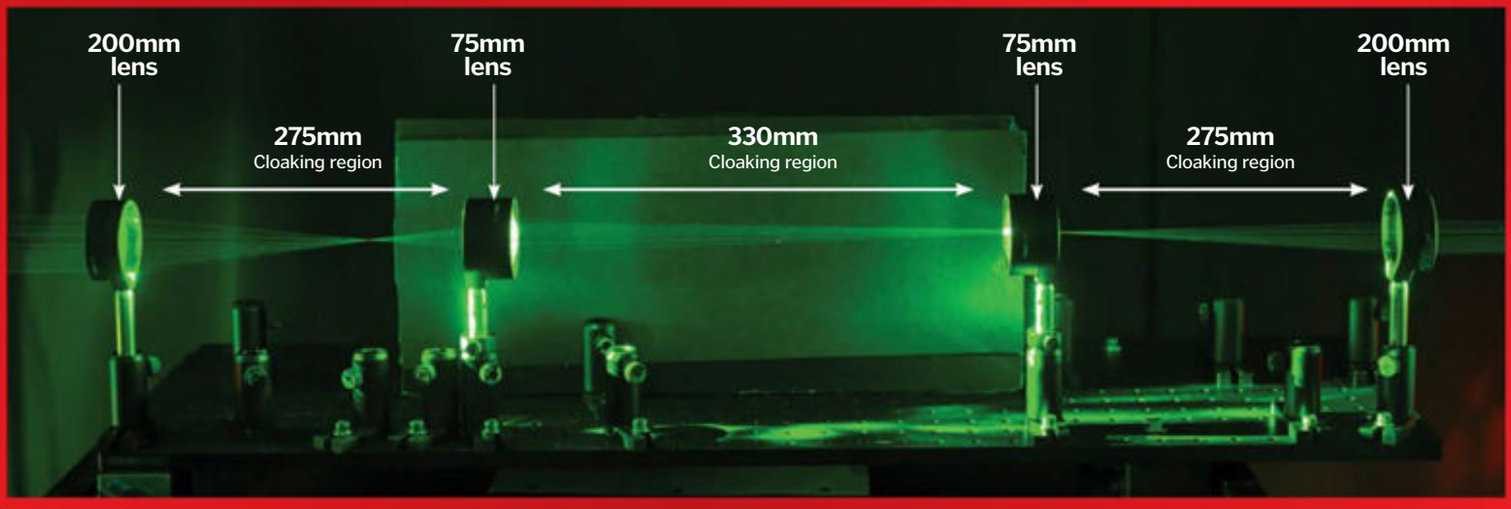
BUILD YOUR OWN INVISIBILITY CLOAK

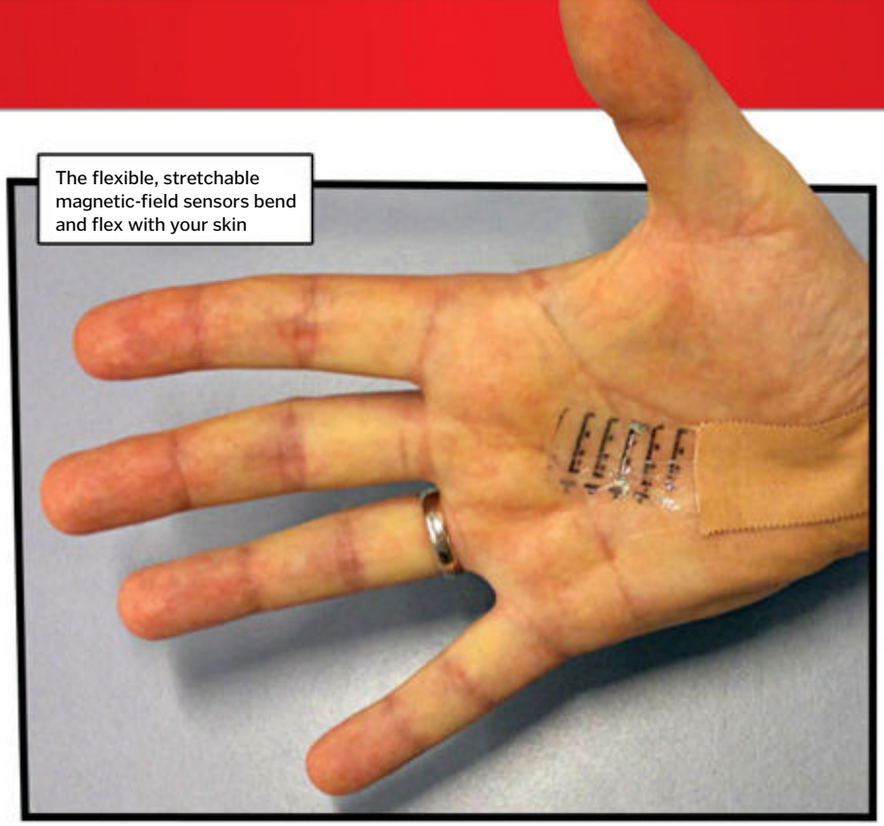
USE A SIMPLE SET OF LENSES TO SEE THROUGH OPAQUE OBJECTS

Invisibility and the power to see through objects are two of the most sought-after superpowers, but did you know that not only are they already possible, but you can also demonstrate them yourself at home? Students at the University of Rochester have developed a cloaking device using inexpensive, readily available materials that pass light around an object to make it look as though it isn't there. This optical illusion requires four lenses of varying focal lengths, positioned at specific distances from each other. As light rays enter the first lens, they focus and then diverge outward to bend around an object positioned within the cloaking region. This process inverts the image of the background behind the object, so another set of lenses is needed to turn the image up the right way again. The device also allows for multidirectional cloaking, meaning you can look through the first lens from any angle and still see an accurate view of the background behind your invisible object.

This simplified set up will only cloak objects within a doughnut-shaped region around the edge of the lens, but a more complex and advanced version has been built, which will solve this problem.

The team behind the Rochester Cloak device hope that it could be put to good use by surgeons, allowing them to look through their hands to see exactly what they are operating on, and by truck drivers, allowing them to see through blind spots on their vehicles.





The flexible, stretchable magnetic-field sensors bend and flex with your skin

MAGNETIC SIXTH SENSE

THE ARTIFICIAL SKIN THAT HELPS YOU NAVIGATE USING EARTH'S MAGNETIC FIELD

Birds and sharks don't need GPS to help them navigate the skies and oceans, but even some superheroes are still reliant on this technology to help them find their way around cities and evil lairs. We could soon be able to do away with sat navs and Google Maps completely, though, as scientists have developed an electronic skin that enables humans to sense magnetic fields and use them to navigate.

The artificial skin contains thin metallic films of cobalt and copper, which reveal changes of the electrical resistance when exposed to a magnetic field. By measuring this resistance change, your proximity to a magnetic field source can be calculated and transmitted to an LED display, giving you a visual representation of your distance from it.

This magnetic field sensor is prepared on a flexible foil called polyethylene terephthalate (PET), similar to the material used to make transparent sheets for overhead projectors, and then applied to an elastic support to make it stretchable. One square meter (10.8 square feet) of the skin is less than two micrometers thick, less than one-tenth the thickness of a human hair, and weighs just three grams (0.1 ounces). This means it can be fixed on or even under your own skin, without you being able to feel its presence.

STRETCHABLE BREAKTHROUGHS

DR DENYS MAKAROV EXPLAINS THE FUTURE POSSIBILITIES OF HIS INCREDIBLE INVENTION

Did sensors like these already exist before your invention?
There were other groups trying to develop magnetic field sensors that are bendable, but we went much further and developed stretchable magnetic-field sensors you can use for on-skin applications. So at the moment, we are the only group in the world that has this technology.

What are the other potential uses for this technology?
The sensors can also be used for biomedical applications, especially for functional medical implants. In conjunction with a magnetic-field source, they can be applied to monitor, in real-time, the displacement of joints or artificial joints, as well as the expansion and contraction of muscles. For example, the real-time activity of the heart muscle can be monitored to detect potential cardiovascular irregularities. The advantage would be to recognise potential health risks at early stages. When combined with wireless communication modules, the sensors can provide immediate alerts to a mobile device or even warn doctors upon detecting muscle dysfunctions.

Another application, surprisingly, is for electrical machines. If you want to make electric motors more efficient, for example to increase the range of an electric car between charges, then you need to optimise the design of the electric motor. This can be done based on the information obtained from magnetic-field sensors, which are measuring the magnetic fields between the rotor and stator of the motor. There is strong interest from car manufacturers in ultra-thin and flexible sensor solutions, because the standard magnetic-field sensors available on the market are simply too thick and rigid and don't fit into the gap between the rotor and stator.

When do you expect the sensors to become available for general use?
We are already providing flexible magnetic-field sensors to industry partners for field testing, but stretchable sensors are not yet commercialised. For medical applications there are many issues to solve. You have to prove they are biocompatible, that they are not going to disturb the function of the organs and so on. So I would say that is a little further away. Maybe within the next five to ten years, we will have on-skin electronic devices that are stretchable and don't contain any rigid components.

SPEEDY SELF-HEALING

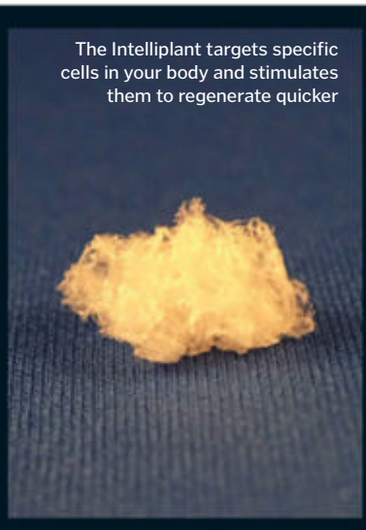
THE SMART IMPLANT THAT CAN REGROW SKIN AND BONE JUST LIKE WOLVERINE

In addition to his reinforced metal skeleton complete with retractable claws, Wolverine also has the ability to self-heal at an incredibly fast rate. The human body is actually quite good at healing damaged tissue, but has never been able to match the instantaneous regeneration of this member of the X-Men crew – until now, that is.

A medical implant infused with tissue regeneration molecules called growth factors has now been developed to speed up the body's natural healing process. It may not be quite as quick as Wolverine's superpower just yet, but it could significantly shorten recovery times for patients with damaged skin and bone tissue.

As well as having incredible healing powers, FeyeCon's Intelliplant also has a number of other clever benefits. First, it's made from biodegradable materials, so once the damaged tissue has healed, it gradually dissolves into natural substances already present in the human body. It can also be infused with antibiotics, to minimise the risk of infection when the body tries to attack this foreign object within it.

Scientists working on the project are still fine-tuning the Intelliplant for use with different types of human tissue, but this revolutionary product is expected to be available in hospitals very soon.



The Intelliplant targets specific cells in your body and stimulates them to regenerate quicker

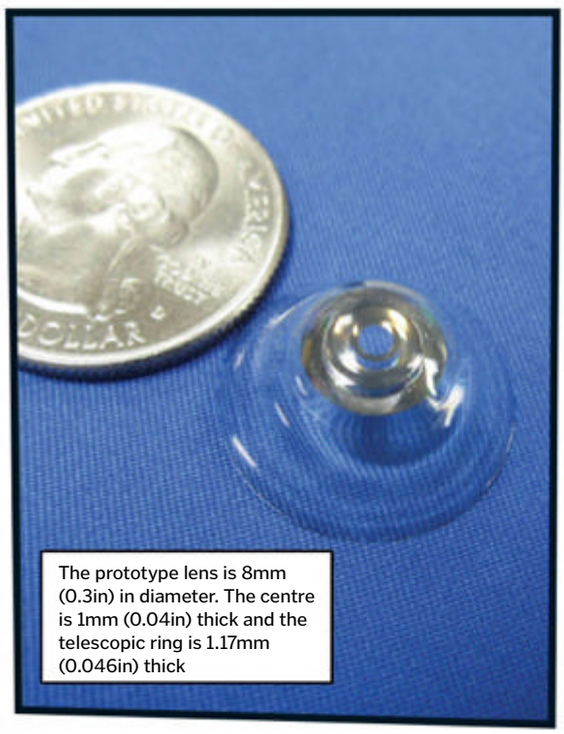
TELESCOPIC EYESIGHT

CONTACT LENSES THAT LET YOU ZOOM IN WITH A WINK

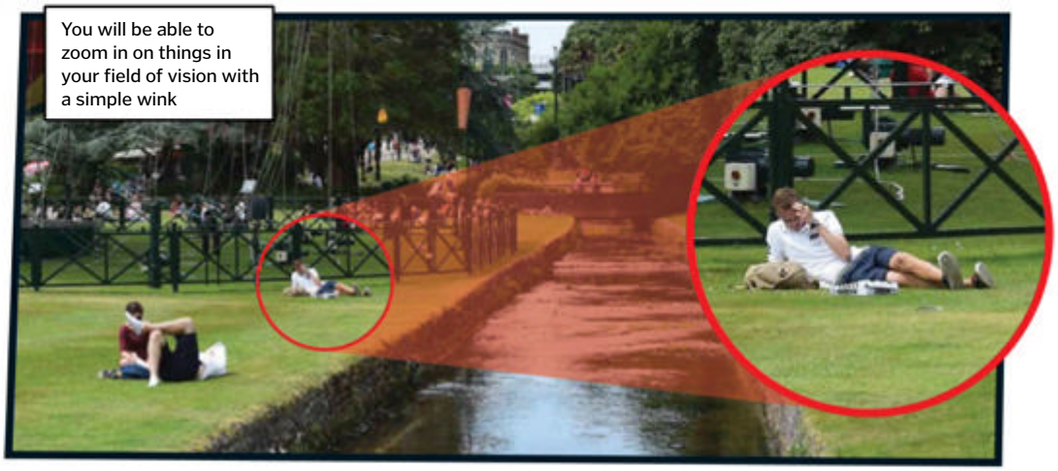
Superman has telescopic vision to help him spot trouble from miles away, but humans are replicating this power for an entirely different purpose. Age-related macular degeneration (AMD) is the leading cause of blindness in older people all over the world, and results from damage to a part of the eye called the macula, which handles fine detail.

To help strengthen the vision of AMD sufferers, researchers from San Diego and Switzerland have developed a telescopic contact lens that can magnify your vision by 2.8 times. The rigid contact lens is larger than an ordinary lens, but still a big improvement on the current treatment for AMD, which involves having to wear bulky glasses with telescopic lenses. Special glasses do still need to be worn with the contact lenses, but these are adapted from a pair of Samsung 3D glasses that have been fitted with a particularly useful high-tech feature.

Sensors on the frames allow you to switch between normal and telescopic vision with a wink. Winking your right eye activates 2.8 times magnification, while winking your left eye turns it off. Eric Tremblay who led the research team at the Swiss Federal Institute of Technology says: "At this point this is still research, but we are hopeful it will eventually become a real option for people with AMD."



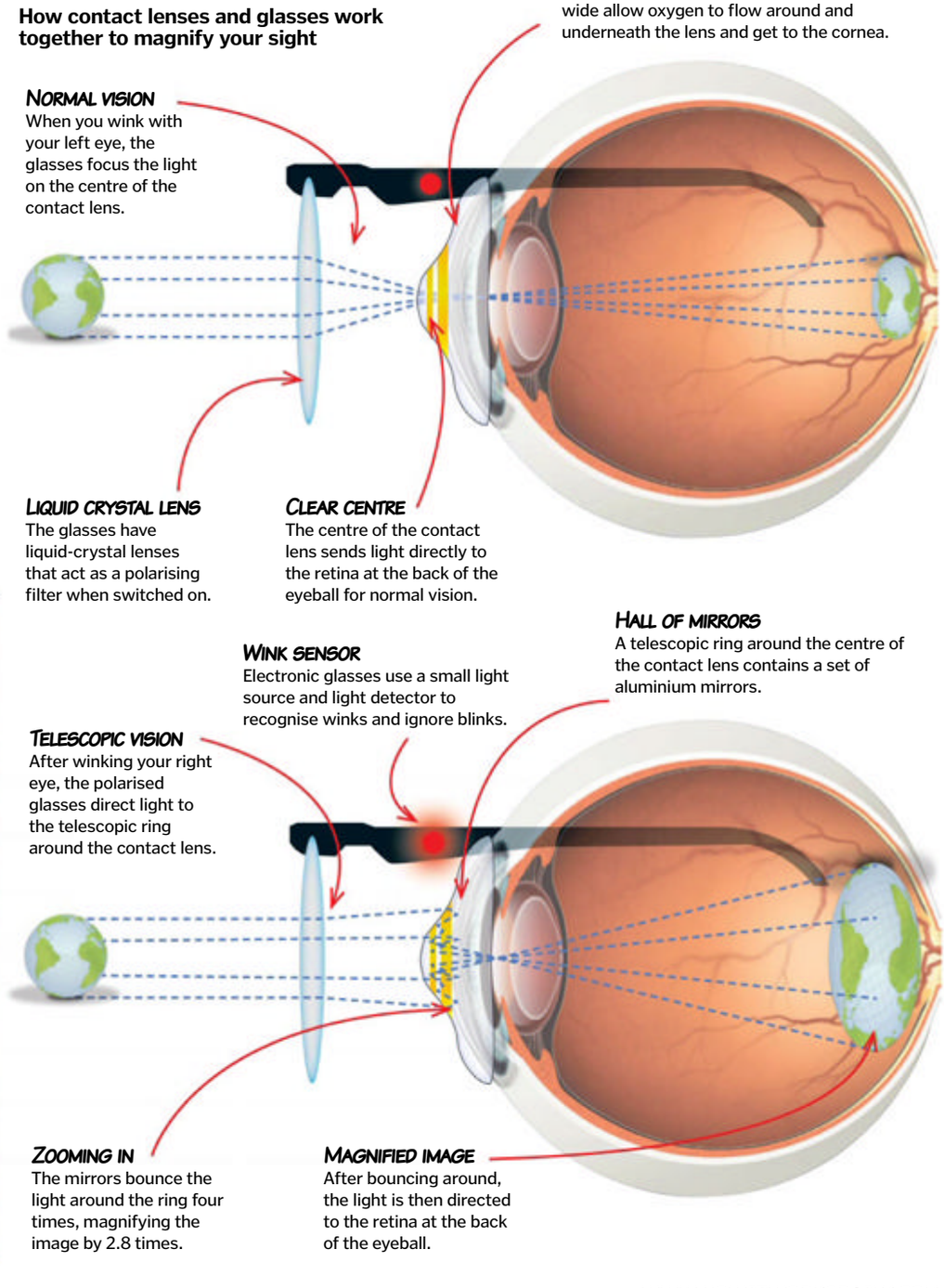
The prototype lens is 8mm (0.3in) in diameter. The centre is 1mm (0.04in) thick and the telescopic ring is 1.17mm (0.046in) thick



You will be able to zoom in on things in your field of vision with a simple wink

Wink to zoom

How contact lenses and glasses work together to magnify your sight



MIND CONTROL

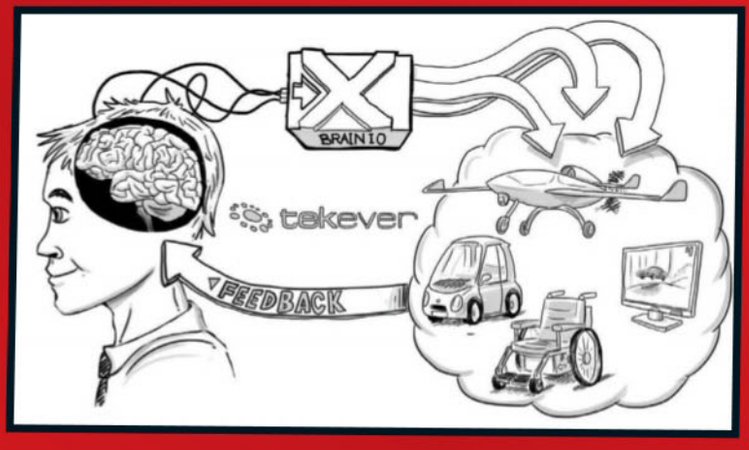
MANIPULATING THE WORLD WITH THOUGHT ALONE

Being able to move and control physical objects with your mind would certainly save you quite a bit of effort in your day-to-day life, but unfortunately telekinesis is only the work of science fiction. However, with a bit of intervention from technology, brainpower can be harnessed to perform all sorts of useful functions.

This real-life superpower is made possible by attaching electroencephalography (EEG) sensors to the scalp, which can measure brain activity. When you concentrate on an object, your brain's prefrontal lobe, located just behind your forehead, fires neurons which create electromagnetic waves. These waves are strong enough to induce a voltage in EEG sensors, which can be interpreted by a computer algorithm and translated into electronic commands for a connected device.

The aerospace tech firm Tekever is currently using this technology to fly drones using just the power of thought. Pilots wearing EEG skullcaps train their brain to think about moving a small circle on a computer screen up to turn the drone left or down to turn it right. The sensors then detect the activity occurring in specific parts of the brain to issue instructions to the software that controls the drone. The company hopes that one day this technology could be used to control much larger aircraft to help reduce the workload of pilots and also to enable physically disabled people to fly an aircraft.

Tekever has completed successful test flights of its brain-powered drone in Portugal



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How the movie industry is poised to fight declining sales with virtual reality tech & more

THE FUTURE OF CINEMA

Over the last century, the film industry has grown exponentially from its humble beginnings, expanding across the globe to upward of 135,000 movie screens, and become an integral part of modern culture. But behind the scenes, all is not well. Anguished industry leaders are wringing their hands over a worrying new trend: people aren't going to the movies as much as they used to.

Box office revenues fell by five per cent between 2013 and 2014 in North America – declines that meant some of the country's premier cinema chains' profits plummeted by more than 50 per cent. The Motion Picture Association of America found that between 2012 and 2013, the number of 18-to-24-year-olds classed as 'frequent moviegoers' fell by 17 per cent, with the 12-to-17 age bracket dropping by 13 per cent. These groups have traditionally been relied upon to come through the doors week after week and empty their wallets over films and snacks.

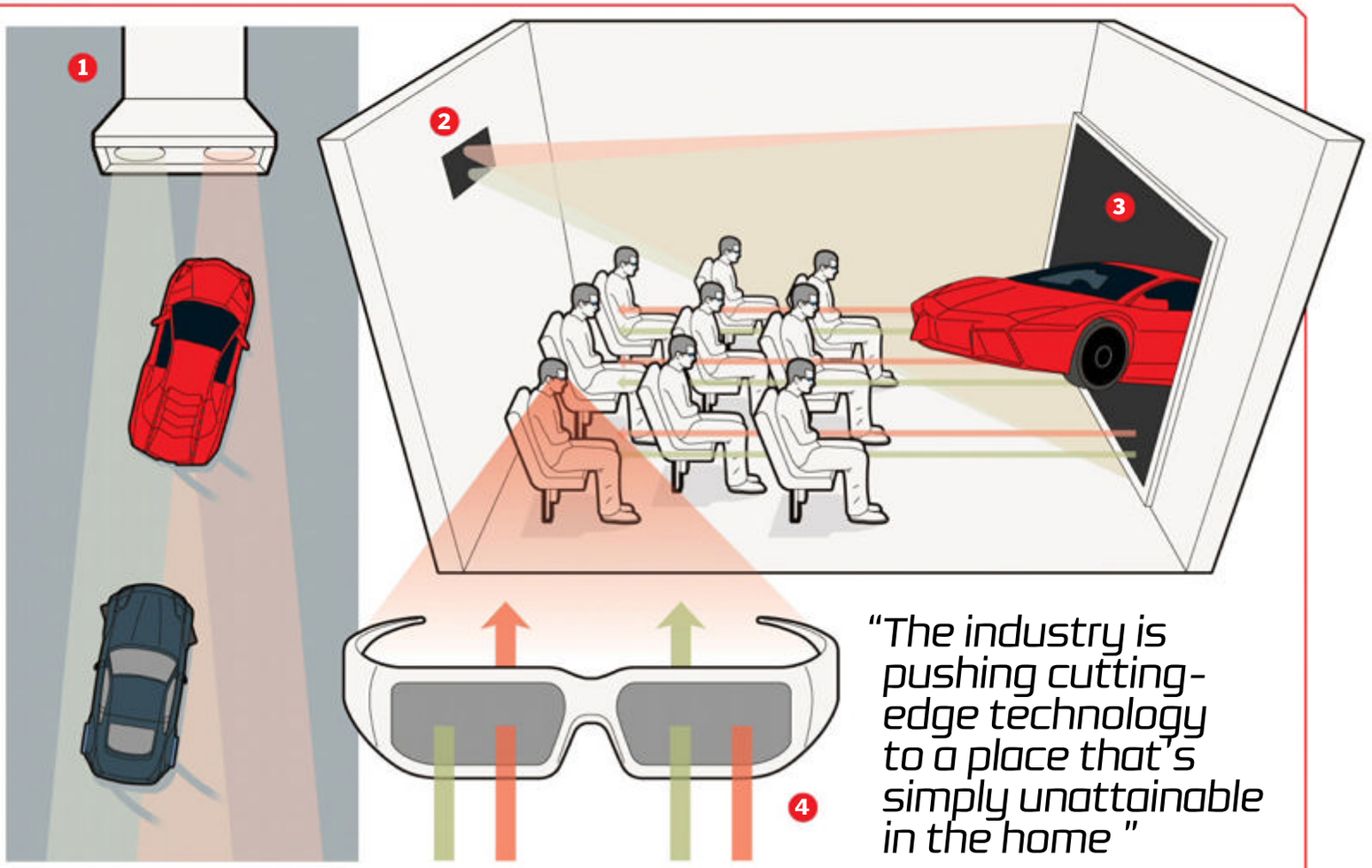
For today's teenagers, the allure of the silver screen is just not what it was for their parents and grandparents. Gone are the days when the whole community would descend on the picturehouse of a Friday evening, eager to catch the latest release.

The ubiquity of smartphones, tablets and laptops, along with the proliferation of on-demand screening services, mean the next movie is seldom more than a couple of clicks away. In rich countries, families have the means to create convincingly cinematic experiences in the comfort of their own homes with huge flatscreens and surround sound systems.

But like any good action hero, the motion-picture industry is fighting back. On multiple fronts, creators are pushing cutting-edge cinema technology to a place that's simply unattainable in the home, to add extra facets to the moviegoing experience and motivate people to leave the house and head for the movie theatre.

One obvious tack is: bigger and better. Covering the bigger angle is IMAX – cinemas with giant, immersive, field-filling screens that swallow audiences into the action. After the technology was debuted during the 1970 world's fair, IMAX went public in 1994 and began its romance with Hollywood, pioneering a way to digitally remaster film for its humongous curved screens. Today, there are over 800 IMAX screens across the globe, many housed within traditional cinema multiplexes, and they're as popular as ever.

As for "better", the laser-projection revolution is now upon us. For almost 100 years, film projectors



"The industry is pushing cutting-edge technology to a place that's simply unattainable in the home"

How RealD 3D works

RealD is the most widely used technology for watching 3D films at the cinema

1 Stereoscopic capture
The brain perceives depth and distance by merging images from each eye. In 3D filmmaking, special cameras capture two side-by-side images to simulate the perspectives of a viewer's left and right eye.

2 Sequential projection
Left and right eye images are beamed sequentially at a rate of 144 frames per second through a single digital projector, with each passing through a circularly polarising light filter of opposite handedness.

3 Silver screen
A special screen embedded with silver (or other metallic) dust perfectly maintains the polarisation of each image when it reflects the projected light back toward the audience.

4 Special specs
RealD glasses are fitted with a pair of oppositely handed circular polarisation filters, which allow each eye to view only its intended frames. This creates the impression of depth in the picture.

have used electric-arc lamps – first carbon, then xenon – as their light sources. In a traditional film projector, light passes through the 35-millimetre film and a magnifying lens to project the image onto the screen. Over the last decade or so, more and more cinemas have been switching to digital projectors as a way to cut costs and improve picture quality at the same time.

Digital projectors continue to use xenon arc lamps, but a series of prisms and filters splits it into its constituent colours – red, blue and green – and directs each at one of a trio of spatial light modulator (SLM) chips. These measure just a few centimetres across, but split the light into millions of tiny beams, one for each pixel in the frame, according to the digital movie file, before it passes through the projector optics.

The digital setup slashes distribution costs – hard drives are much easier to ship than bulky reels of film – and enables a pristine image to be projected over and over again without ever scratching or losing clarity. Today, over 80 per cent of the world's cinemas have converted to digital, but some film aficionados complain the format loses 35-millimetre film's rich contrasts between light and shadow.

Enter laser projectors. The new kid on the block – which made its commercial debut in 2012 – might finally be the holy grail of film projection. It works just like a digital projector, but uses individual red, blue and green laser light sources in place of the xenon lamp. Its pictures have unparalleled sharpness and superior colour range; finally something to rival the vibrancy and beauty of high-quality film stock. Not only that, but laser projectors also produce images about twice as bright as bulb projectors and are extremely efficient, potentially lasting for ten years in commercial use – a gigantic improvement on the operating life of a xenon bulb, which is typically between 500 and 2,000 hours.

Of course, improvements in lumens and contrasts may be all well and good for film connoisseurs, but they're unlikely to tempt the average 15-year-old through the door. To snare them, cinemas are looking to augment the experience of going to a film. Emerging 4D cinemas offer interactive encounters that blur the line between cinema and amusement park; 3D film technology is much improved, and ambitious studios like DreamWorks are even seriously pursuing futuristic plans to marry virtual reality with film.

The next five years are set to see the swiftest and most significant technological advances in the history of motion pictures, coming soon to a cinema near you!

How virtual reality will transform cinema

Step into your own private movie theatre, or even into the movie itself!

DreamWorks – the production company responsible for animation blockbusters like *Kung Fu Panda*, *Madagascar* and *How To Train Your Dragon* – is developing technology that will take audiences right into the heart of its fantastical worlds. Its innovative new format – dubbed 'Super Cinema' – expands the film frame from its current limited screen dimensions into a fully immersive 360-degree swathe, with the viewer at the centre. The idea is that when this is combined with virtual reality (VR) headsets such as Oculus Rift or Gear VR – special goggles that allow wearers to see simulated 3D worlds – viewers will be able to turn their gaze in any direction, to whichever part of the scene captures their attention.

Computer graphics are created by one of two means – real-time rendering or pre-rendering. Real-time rendering is used heavily in other interactive experiences like videogames; the game decides which frame to draw depending on which way the player looks. Unfortunately, this is a time-consuming process, and with graphics as complex as today's CGI animations, this method would slow the frame rate to the point where the viewer start to see the still images switching or the film stalling altogether. Pre-rendering – where each possible view is already drawn and ready to load – makes the process significantly faster and the quality of the experience much smoother.

There are some downsides, though. Each 360-degree film would need to include all possible views of each frame, bumping up file sizes and production times astronomically. Super Cinema would also lack positional tracking – the ability to make minor geometrical adjustments to the image depending on how a person tilts their head – and wouldn't account for person-to-person variations in interpupillary distance (the distance between the eyes), which could make the film disorienting for some viewers.

Key to the success of Super Cinema will be a quality virtual-reality headset. Very few are actually available to consumers just yet, but the market looks set to be flooded with offerings in the next couple of years. Top of every technophile's wish list is the Oculus Rift, whose creators are also pursuing the idea of VR cinema, albeit a little differently. The most recent developer version of the headset runs a 'game' that allows wearers to recreate the moviegoing experience – including picking seats, looking around the theatre and watching the film on a huge screen in a choice of 2D and 3D – wherever the headset is worn – at home, on the bus or in class...

"Super Cinema expands the film frame into a fully immersive 360° swath"

1 Tracker stand
Articulated with several joints in order to get the perfect angle on the headset wearer.

2 Tracker control board
Includes a CMOS image sensor, crystal oscillator and webcam controller.

3 Lens assembly
Fitted with a wide-angle lens that allows the camera to see as much as possible of the headset at any time.

4 Infrared filter
Allows only infrared light to enter into the camera.

External hood
Covered by a web of 40 infrared LEDs whose movement is tracked by the external IR unit.

Interchangeable lenses
Unit ships with two additional sets of lenses with varying focal lengths, to allow for users with differing eyesight prescriptions.

Beyond 3D:

Introducing the fourth dimension

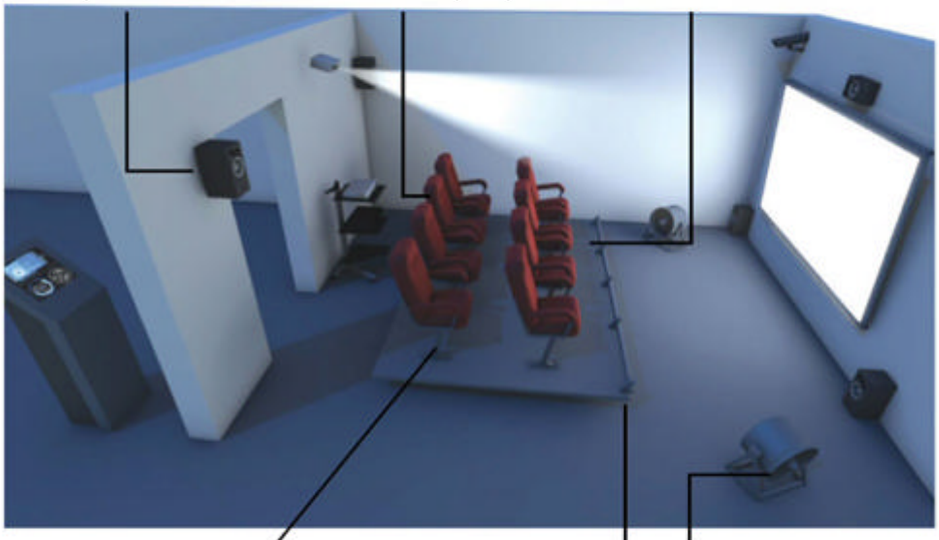
For those eager to feel even closer to the action, 4D cinemas combine the visual richness of 3D film with physical and tactile sensations – flashing lights, air jets, water sprays, scents, smoke, chair movements and more – that sync with and enhance the on-screen drama.

Seats are grouped in small clusters and a large air compressor located behind the auditorium drives their movements, which are pre-programmed, along with other effects, for each film. Some theatres are even touting experiences labelled '5D', '6D' and up, but unfortunately, that's little more than a marketing ploy – with each individual physical effect added to the screening being classed as its own extra 'dimension'.

Sound system
Standard 5.1 surround sound speaker system, augmented by ceiling speakers to offer directional "voice of god" moments.

Vibrating pads
Produce tactile sensations to heighten the drama – for example, a deep rumbling to accompany an avalanche beginning to roll.

Moveable racks
Can move chairs up and down, side to side and tip forward, backward and sideways to mirror the on-screen action.



Tickle stick
Activated by air jets in the chairs – designed to make audiences jump out of their skins during spider scenes!

Hall effects
Includes bubbles, mist, aromas, strobe lighting, and even fire!

Effects jets
Water and air jets intensify scenes with wind, rain, blood and guts, or speed.

How frame rate affects perception

When we watch a film, what our eyes actually see is a stream of still photographs switched so fast through the projector that our brain perceives them as one seamless motion picture, a bit like a hi-tech flipbook.

The threshold below which the brain is able to start perceiving individual images is 16 frames per second (fps), and the higher the frame rate, the more real the reel appears. With this in mind, the film industry grew up around a frame rate of 24fps as a way to balance production costs with painting reality convincingly on screen.

Today, big studios can afford to film movies at higher rates, ostensibly to offer their audiences a greater sense of immersion. But it turns out this can backfire. Peter Jackson's *The Hobbit* (2012) was filmed at 48fps and many people complained. After decades of conditioning, we've become accustomed to 24fps as an integral part of the 'cinematic' feeling, so audiences find hyperrealism disorienting, and a barrier to getting lost in the movie experience.

Inside IMAX

Watching an IMAX movie is without question one of the most arresting film experiences in the world. Invented in Canada in 1970, by the end of 2013 there were 837 IMAX theatres in 57 countries across the world. Its defining feature is humongous screens – so large that the images completely fill the viewer's field of vision, giving them a feeling of immersion so strong that some even feel motion sickness during especially dynamic scenes!

IMAX technology

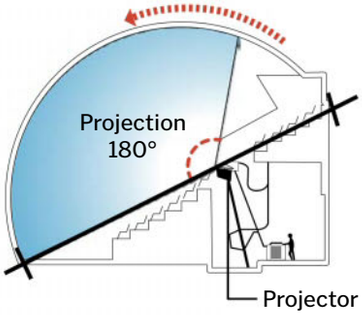
IMAX cinemas display gigantic images with incredible resolution, for a completely immersive experience

Audio system

Six-channel sound system directs 12,000 watts of sound out of thousands of tiny holes across the entire screen.

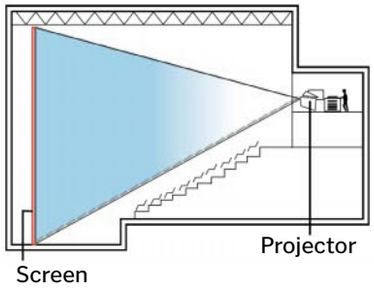
Seating

Steeply racked so that even children's views are unobstructed, and people can gaze up and down as in real life.



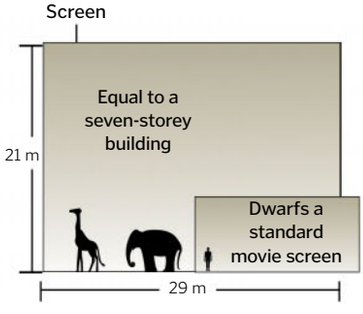
OMNIMAX dome

Hemispherical dome made of metal and coated with highly reflective white paint wraps the entire audience in larger-than-life images.



Flat IMAX

Uses a silver-coated flat screen that reflects light more intensely than a white screen.



Film format

15/70 – 70mm (2.8in) film with 15 perforations per frame – results in a frame size about ten times that of standard 35mm film, giving IMAX movies incredible clarity.

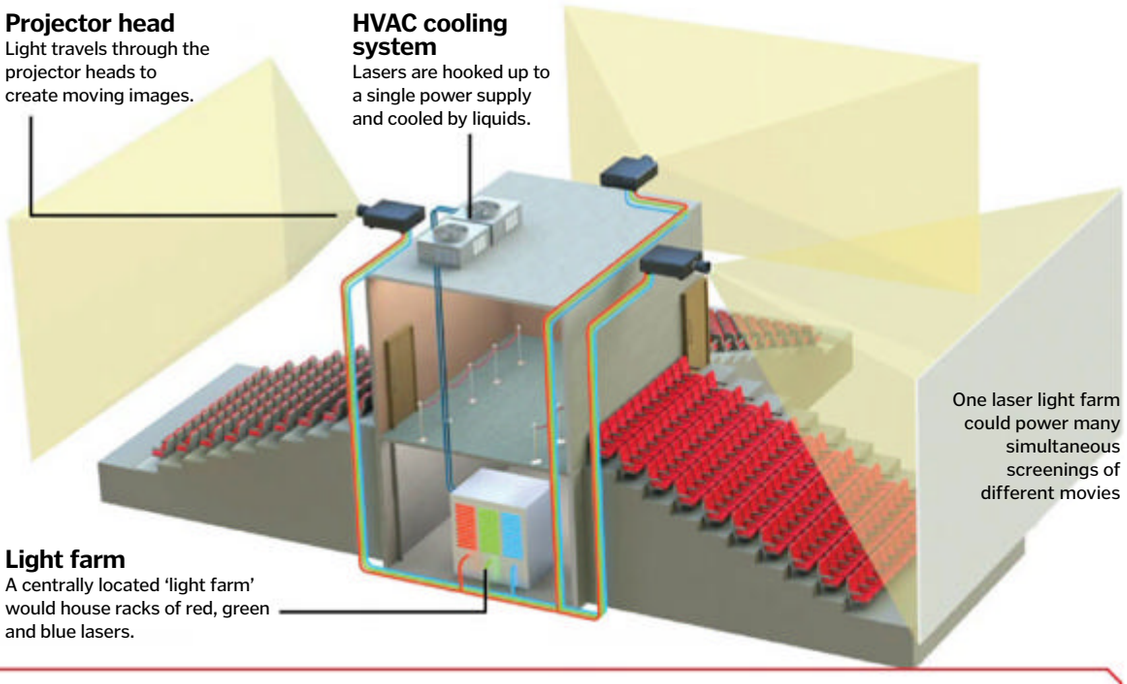
IMAX 3D
Viewers wear glasses with lenses that produce 3D vision.

Laser multiplexes of the future

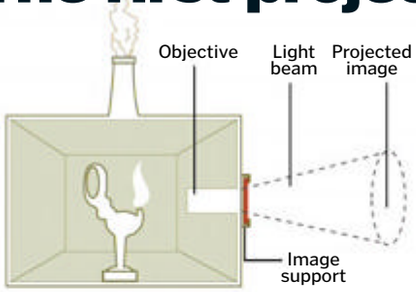
A switch from bulb projectors to laser projectors would open up the possibility of all the screens in a multiplex cinema being fed by one light source. A centrally located 'light farm' would host racks of high-powered red, green and blue lasers connected to a single power supply and cooled by liquids circulating from the cinema's rooftop HVAC system. Light would travel to each auditorium's projector head – fitted with the spatial light modulators and optics to create the moving images and focus them onto the screen – via armoured fibre-optic cables in the walls of the theatre.

In this setup, the laser light farm would be responsible for simultaneous screenings of different movies in each auditorium. The cinema's running costs could be dramatically reduced since there would no longer be a need for dedicated projection booths, and the projectors and light farm could even be controlled by off-site networked operators.

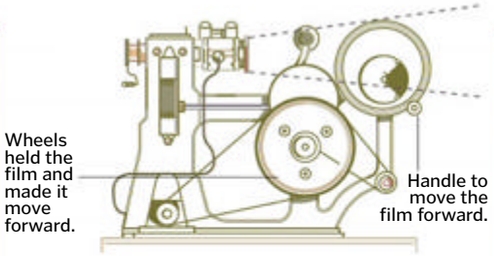
There is still no success in developing quieter popcorn for cinema



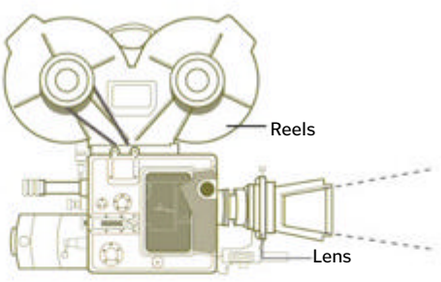
The first projection systems



Ca 17th century
The 'magic lantern' was the first system resembling modern projectors. They used candles or oil lanterns as light sources.



1895
The Lumière brothers invented a projector that took its mechanical inspiration from a sewing machine, and presented it in Paris.



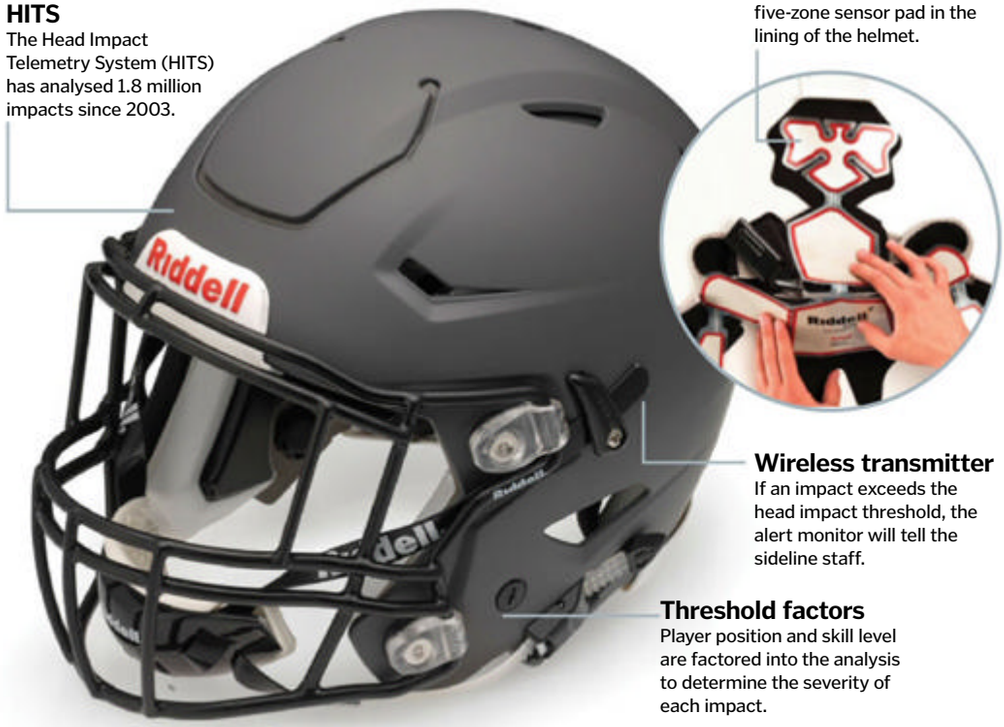
1932
The rise of colour cinema. Technicolor cameras superimpose three films in red, blue and green to deliver full-colour spectrum images.

Smart football helmet

Learn how this tech monitors the head impacts of NFL players

According to the NFL's data, 692 concussions were diagnosed in players between 2012 and 2014. Further to this worrying statistic are the findings of 79 deceased NFL player autopsies; 96.2 per cent of the subjects had suffered from a degenerative brain disease called chronic traumatic encephalopathy (CTE). Players are bigger and faster than ever before, making the dangers of head trauma even more severe.

American sports equipment company Riddell has designed the InSite Impact Response System (IIRS) to help reduce the risk of this. The system is composed of the Player Unit, Alert Monitor and Player Management Software. The Player Unit lines the helmet, and features a five-zone sensor pad measuring impact severity. This reports when a player experiences a singular or set of impacts exceeding a specific danger threshold. It measures impact by assessing the effects of duration, location and the type of acceleration the head experiences, combining these readings for the most accurate assessment.



HITS
The Head Impact Telemetry System (HITS) has analysed 1.8 million impacts since 2003.

Sensor pad
The player unit features a five-zone sensor pad in the lining of the helmet.

Wireless transmitter
If an impact exceeds the head impact threshold, the alert monitor will tell the sideline staff.

Threshold factors
Player position and skill level are factored into the analysis to determine the severity of each impact.

How guitar amps work

Discover how they can convert the sound of strings into a thundering stadium anthem

It is widely accepted that the introduction of the guitar amplifier changed music forever. Whether you're into Jimi Hendrix or Eric Clapton, it's hard to imagine either without their legendary riffs blasting out through guitar amps.

A three-way process is used to amplify the strings' sound. The strings vibrate at a particular frequency; once plucked their signal passes through the guitar's pickups to the preamplifier. The preamplifier boosts the voltage of the signal generated by the guitar. The preamp also reduces the noise and interference within the guitar's sound, which could distort the resulting overall sound when amplified.

The power amp now amplifies the whole signal and sends it to the speaker, which emits the guitar's sound at an adjustable volume. Amps for both the electric and acoustic guitars as well as bass guitars are commonplace today, shaping the sound of all genres of modern music.

The 'combo' amplifier

Inside a combination guitar amp that contains both the amplifier and speaker

Speaker
This part of the amp produces the amplified sound. The wattage, and therefore power, can vary depending on preference.

Mounting bracket connectors
These two red wires connect the mounting bracket to the speaker via two small nodes.

Reverb box
Many amps now come with the reverberation effect built in. This imparts an echo on the guitar's sound.

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Plugs from around the world

Learn why we are unlikely to see a universal plug any time soon

If you ever plan on charging your laptop abroad, be sure to check before you travel – many countries don't have a national standard of electrical outlets so you could find yourself grappling with as many as six different plugs and sockets!

As travelling became affordable to the masses, the problem of using the correct plug for our electrical devices from home started to grow. In an age where technological advancements continue to amaze, it seems bizarre that we cannot introduce a plug we can use globally.

Why so many countries have different plugs is mainly down to the fact they prefer to develop their own standards. Harvey Hubbell designed a "Separable Attachment-Plug", which allowed non-lighting devices to use a light socket for power. This was adapted and refined to create a three-pronged plug which included the addition of a grounding wire to provide protection from electric shocks.

Throughout the early-1900s, inventors around the world were creating their own version of this pioneering plug. During this period, international plug compatibility was not of concern, as electronics hadn't reached many parts of the world. With every country having different historical circumstances, the plug came in at different times where different technologies were available. Even as recently as the 1950s, the UK was developing a plug with no consideration for the rest of the world.

The question on any frequent traveller's lips is, "when will we see a universal plug?" At the moment, the consensus is never. Although it would make sense, the motivation for countries to pay for a universal plug is very low, considering they have all invested heavily in their own systems. Moreover, there would be an inevitable interim period where multiple plug standards would exist within one country, which we know from experience to be dangerous. Even if countries decided to adopt a standard plug system, at least two standards would have to exist – a 110-volt flat plug along with a 240-volt round plug. However, two would be a vast improvement on over a dozen types globetrotters currently have to deal with.

Type K

Found in Denmark and Greenland, the type K has an unusual, U-shaped earth pin. It is thought the type K will soon be a thing of the past because Danes regularly import appliances from the rest of Europe that are fitted with the more widely used type F plugs.

Type A & B

The type A is fairly standard across most of North America. The two blades are of different width and the plug is not grounded. Type B has a third, rounded prong for grounding. Most North American sockets are now compatible with both types.

Type L

The usage of type L plugs is rather sporadic; these plugs only crop up in Italy, Chile and North Africa. The type L is atypical as it is a symmetrical three-pronged plug. It is possible to insert it in either direction, as it is unpolarised.

Type N

The type N, found in Brazil, is the plug suggested by the International Electrotechnical Commission (IEC) to be used around the world as a universal plug. Until the type N arrived, Brazil was using an incredible ten different types of plug.

Type G

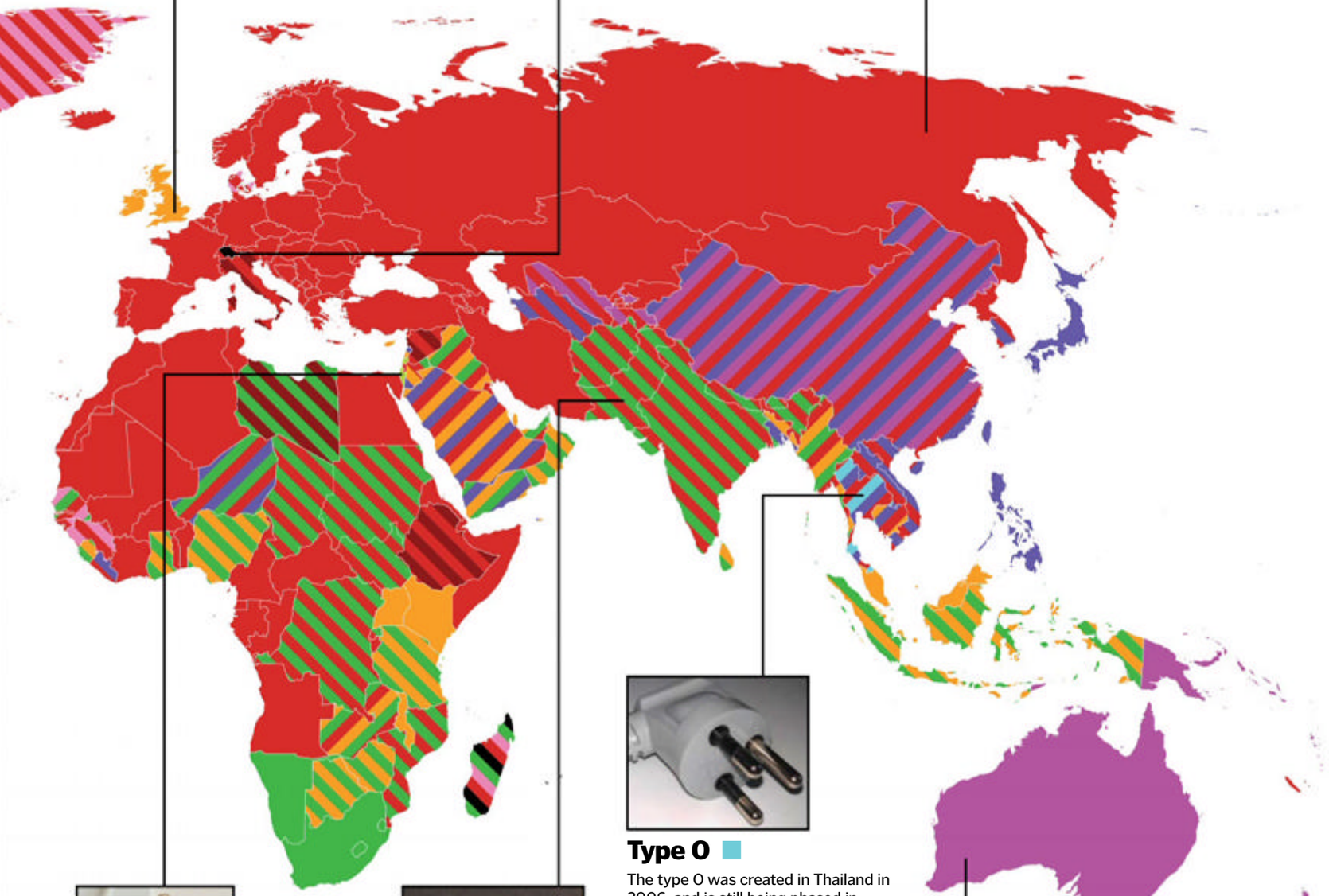
Type G plugs are synonymous with the United Kingdom, but are also found in other countries such as Singapore. This has three rectangular prongs. The type G is one of the safest kinds of plug in the world, but has the downside of being bulky.

Type J

This plug type is found in Switzerland and Liechtenstein, although Switzerland has their own standard, the SEC 1011. It's structurally similar to type C, other than its additional grounding pin. A type J socket will accept a type C plug perfectly.

Type C, E and F

All three of these plugs operate in the 220 to 240-volt range. Type C is credited with being the most widely used international plug. Type E is found in France and Belgium. Type F is found across Europe, and was designed in Germany after WWI.



Type O

The type O was created in Thailand in 2006, and is still being phased in. Why Thailand decided to design and implement a new type of plug when multiple alternatives already exist is a mystery, and highlights the difficulties of adopting a new standard.

Type H

The type H is unusual as it is used solely in Israel. Originally, it was three flat prongs in a V-shape, but since 1989 this design has been phased out in favour of three circular pins. The Type H socket will also accept type C plugs.

Type D & M

The type D is mainly used in India but is compatible with type C sockets. This plug was the standard in Great Britain before 1947. Type M is found in South Africa and is a three-pin, grounded plug. It requires 220 to 240 volts and looks like a type D with larger pins.

Type I

The type I is found in Australia and New Zealand, and is available in a two or three-pronged option. This type was favoured over the UK's type G because Australian manufacturers could produce flat pins more easily than round ones.

Light field photography

The Lytro Illum camera is available now for £1,299.99 ($1,599)

Find out how this camera takes a photo first and focuses later

Taking a photo only to discover your main subject is out of focus is a common and frustrating problem. It's okay if you can simply take the photo again, but what if the moment you captured was fleeting, or you don't notice the issue until you get home?

If you own a Lytro camera, you'll never experience this heartache again. Clever light field technology means you can refocus your photos – and even change the perspective – after you've taken them. It does this by using a microlens array and a special light field sensor to determine from which direction rays of light enter the camera. This allows it to record a multidimensional light field, which is passed through special software.

Complex algorithms are then able to simulate what the image would look like if you had focused on a different focal plane or taken it from a different angle and all of these possibilities are pieced together to create one adjustable image. Light field technology isn't new, but Lytro is the first to use it in a commercial camera. Its latest model is the Lytro Illum, which has an 8x optical zoom lens, ten-centimetre (four-inch) LCD screen and can shoot 3D images too.

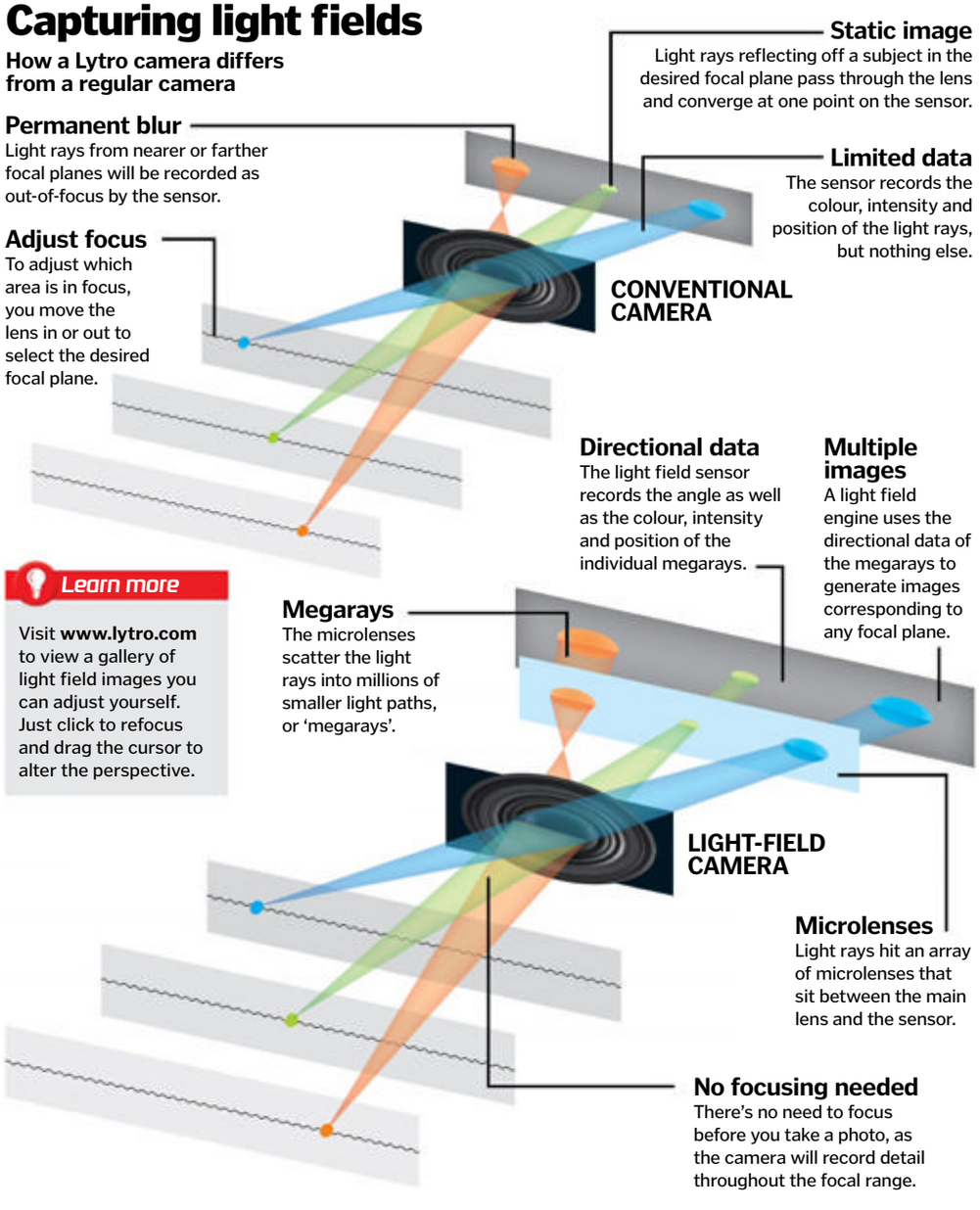
Refocusing images

Once you've taken your photo, all you need to do is tap the out-of-focus area of the image on the camera's touchscreen and it will instantly become sharp, or swipe over the image to adjust the perspective. You can even change your mind about the angle and focus by tapping and swiping as many times as you like. When you take the image off of the camera, it will be saved as a Light Field Picture (.lfp) file, which will contain all of the light field information. To view it you will need Lytro's free desktop or mobile app, which allows you to click and drag to adjust your shot and share it online. If you share your photo through Lytro's online platform, your friends will be able to adjust it too, but if you convert the image to a .jpg file then it will become a normal, unchangeable digital photo.

Choose whether the foreground or background is in focus with a simple click or tap

Capturing light fields

How a Lytro camera differs from a regular camera



Learn more

Visit **www.lytro.com** to view a gallery of light field images you can adjust yourself. Just click to refocus and drag the cursor to alter the perspective.

SAVE RHINOS NOW

10% OF OUR PROFITS HELP FIGHT POACHING

An animal in crisis
In eastern Africa, poachers use automatic weapons to slaughter endangered rhinos. The animals are shot and the horns are hacked away, tearing deep into the rhinos' flesh with the rhino left to die.

Make a difference today
Ol Pejeta is a leading conservancy fighting against this cruelty. It needs more funds so more rangers and surveillance can be deployed on the ground to save rhinos from this horrible treatment.

Join World of Animals
World of Animals magazine takes a stand against these atrocities and is proud to be in partnership with the Ol Pejeta Conservancy – 10% of our profits go towards saving rhinos in the fight against poaching

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50 SCIENCE MYTHS BUSTED

Doe bumblebees really defy the laws of physics? And will vitamin C actually protect you from the common cold? Discover the truth behind 50 of the world's most common myths

Rain is teardrop-shaped

01 Raindrops are often drawn with a pointed top and rounded bottom, but these simplified pictures are not even close to the truth. Raindrops form high up in the atmosphere when water clings to tiny particles of dust, and as the molecules gather together they form temporary bonds that pull the shape into a sphere. As the raindrops fall through the air, they collide with gas molecules and become distorted, widening and flattening out across the bottom. The top half forms a dome as surface tension struggles to keep the droplet together, but for raindrops over four millimetres (0.16 inches) in diameter, the weak bonds are not strong enough to hold the water together, so the droplets break apart.

1 Spherical drop Raindrops naturally form into spheres because it is the shape with the smallest surface area.

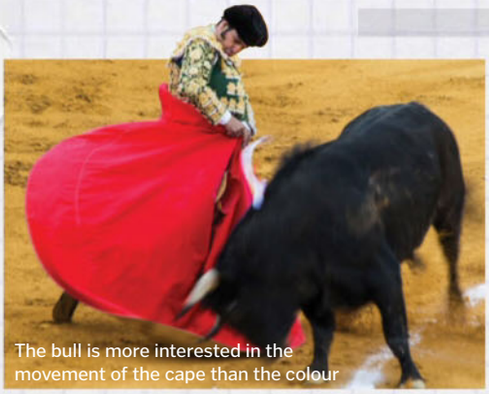
2 Surface tension Water molecules cling to one another with weak hydrogen bonds, creating surface tension.

3 Hamburger-shaped As the drops fall toward the ground, they collide with the air and the pressure flattens out the bottom edge.

4 Parachutes The largest raindrops are unable to hold themselves together and as they drop they start to distort into a parachute shape.

5 Breaking apart Raindrops over 4mm (0.16in) in diameter break up as they fall.

6 Smaller droplets The smallest droplets remain spherical as they tumble toward the ground.



The bull is more interested in the movement of the cape than the colour

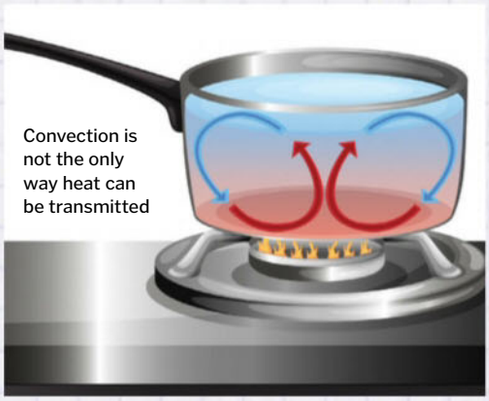
The colour red makes bulls angry

02 Bullfighters are famous for their red capes, but the idea that the colour is a trigger to anger the animals is a myth. While we can see light in red, green and blue wavelengths, bulls, like most other mammals, only have two-coloured vision. They are effectively red-green colour blind, and are more interested in the movement of the cape than its colour.

Cockroaches can withstand radiation because their cells divide less often than our own

Cockroaches can survive a nuclear apocalypse

03 Cockroaches are capable of withstanding much higher levels of radiation than humans and are often listed amongst the animals that will inherit the Earth in the event of a nuclear apocalypse. However, while adult roaches can survive radiation levels equivalent to those released by the Hiroshima nuclear bomb, their fertility is adversely affected by much lower levels of radiation.



Convection is not the only way heat can be transmitted

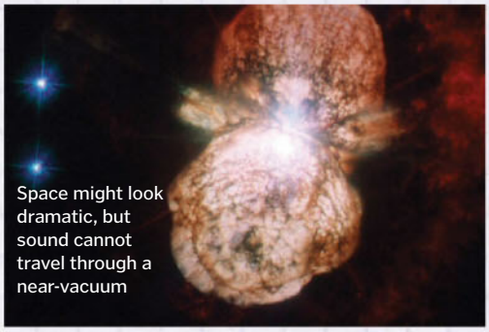
Heat rises

04 This simple myth persists because for many situations it appears to be true. As liquids and gases gain energy, they heat up and expand, which lowers the density compared to cold fluid, causing the hot region to rise. However, heat also transferred by infrared radiation and conduction, both of which can occur in any direction.

There is no link between the MMR vaccine and autism

Vaccinations cause autism

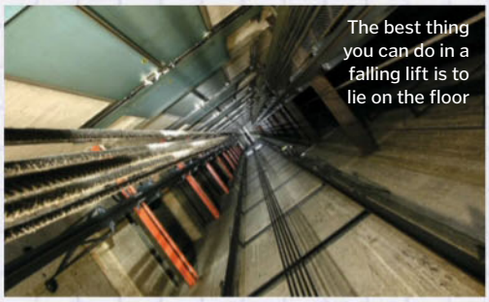
05 This is one of the most dangerous science myths of all and was born out of a combination of fraudulent research and irresponsible media hype. The 'evidence' supporting a link between the MMR vaccine and autism was misreported, and the results were distorted by the media, which spread the idea there was a link between autism and immunisation. Repeated investigations have confirmed the original data was false, but the myth has caused lasting damage and the rate of measles infections in the UK has risen as a result.



Space might look dramatic, but sound cannot travel through a near-vacuum

A firefight in space would be loud, just like in the movies

07 Sound propagates when vibrations are transferred from one particle to the next, but in outer space there are so few particles, spread so far apart, that the vibrations cannot travel. So despite the popular Hollywood scenes depicting loud explosions, in space nothing makes a sound.



The best thing you can do in a falling lift is to lie on the floor

In a falling lift, you should jump before you hit the floor

08 People often wonder whether they could jump just before a falling lift hits the floor, avoiding the impact of the crash, but unfortunately this tactic will not work. You are falling at the same speed as the lift, and as you push away from the floor in the opposite direction you are only counteracting a fraction of that downward acceleration.

The Large Hadron Collider could create a black hole and destroy the Earth

06 With the upgraded LHC being switched on again at CERN in 2015, the apocalyptic myths about black holes are resurfacing, as people are wondering whether two protons slamming into one another at high speed could produce a black hole. Some physicists think that is possible, but the resulting black hole would be microscopic and would do no damage to the Earth.

The LHC is not capable of creating a black hole that could destroy the Earth

Antibiotics can treat flu

09 Antibiotics are bacteria-busting drugs, so they are no use against flu or the common cold, both of which are caused by viruses. Antibiotics work by blocking the chemical processes bacteria use to survive and reproduce, but viruses hijack our own cells to replicate and are unaffected by these drugs.

Drawing on skin causes ink poisoning

10 Inks used to be made from dangerous chemicals, but today most pens have water or alcohol-based inks and are nontoxic. It takes a large amount of ink to cause poisoning and the most common routes of ingestion are either swallowing or inhaling, not drawing.

Bats are blind

11 Bats are well known for using echolocation to find their way through the darkness, but their mastery of hearing does not mean they are blind. All bats have eyes and can see. Some of the larger fruit-eating species have eyesight even better than our own.

Go out with wet hair and you'll catch a cold

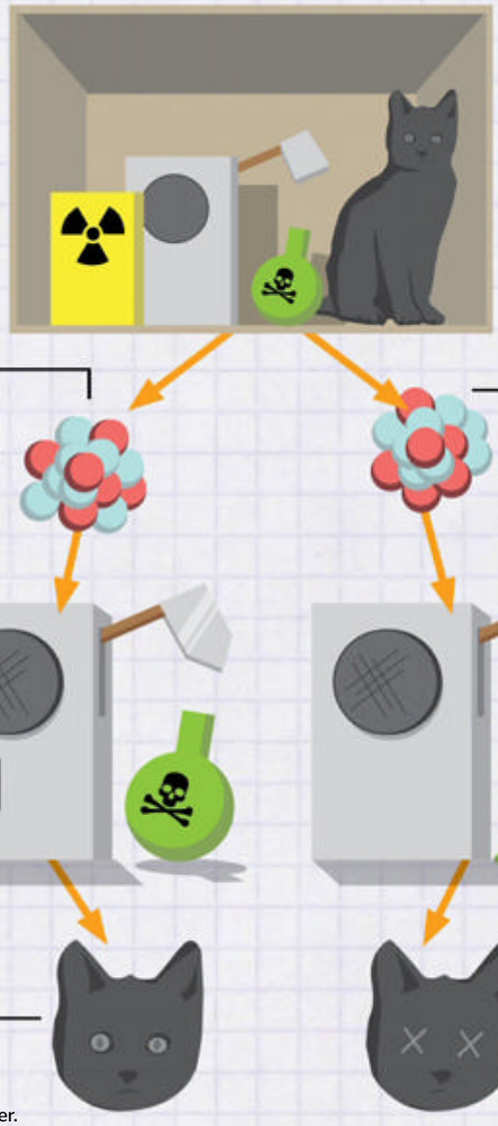
12 There is nothing special about wet hair that will increase your chances of catching the cold virus, but there is actually a grain of truth behind this myth. Getting chilly can increase your likelihood of developing the symptoms of a cold; possibly by decreasing the blood flow to your nose, thus enabling the virus to replicate.

White spots signal calcium deficiency

13 The white marks that appear on fingernails are known as leukonychia, and many people believe they are the result of mineral deficiency. However, the real cause is most often damage to the nails from knocks, bumps and even wearing false nails, all of which can cause abnormal marks to form at the nail plate.

Schrödinger's cat is both dead and alive

14 In 1935, Erwin Schrödinger devised a thought experiment involving a cat locked in a steel box with a Geiger counter, a radioactive substance, a vial of poison and a hammer. If radioactive decay triggers the Geiger counter, the hammer will strike the vial of poison and kill the cat. However, because radioactive decay happens at random, you cannot know whether the cat is dead or alive until you look inside the box. Does this mean that the cat is both dead and alive at the same time? Well no, despite popular belief, Schrödinger was actually trying to point out the absurdity of quantum theory with an impossible example and was not suggesting that a cat could be both dead and alive.



Link to quantum mechanics
When quantum particles are observed, they behave like particles, but when no one is looking they act like particles and waves at the same time.

Radioactive material
Unstable atoms spontaneously emit ionising radiation, but it is impossible to predict exactly when this might happen.

Hammer
If the Geiger counter detects radiation, it activates the hammer, which strikes the vial of poison.

Poison
The hammer breaks the vial of poison, releasing it into the box and killing the cat.

Geiger counter
Any radiation released within the box will be detected by the Geiger counter.

Observer effect
In parallel with the ideas of quantum mechanics, the act of opening the box would force the cat to adopt one state or the other.

Alive and dead?
Until you open the box, you cannot know for sure whether the cat is dead or alive.

Sinks drain in different directions on either side of the equator

15 It is often claimed that the spin of the Earth affects the way water drains out of the sink, and that to the north of the equator it swirls down the drain in a clockwise direction, while to the south it turns anticlockwise. While the Earth's spin does affect the rotation of hurricanes in what is known as the Coriolis effect, the amount of water in a sink is so small that Earth's spin does not affect the direction it drains, so in reality it is down to way the water is poured into the bowl and whether there are any imperfections in the surface.

The direction the water drains is not decided by the spin of the Earth

Bumblebees shouldn't be able to fly

16 The myth that bumblebee flight is impossible under the laws of physics has been traced back to the first half of the 20th century, when our understanding of flight was much more basic than it is today. According to early calculations, the wings of a bumblebee were too small to generate enough lift, however, using smoke and high-speed cameras, scientists at the University of Oxford watched bumblebees fly. They are not aerodynamic, but they do not break any laws of physics in the air.

Bumblebees don't look very aerodynamic, but their flight does not defy physics

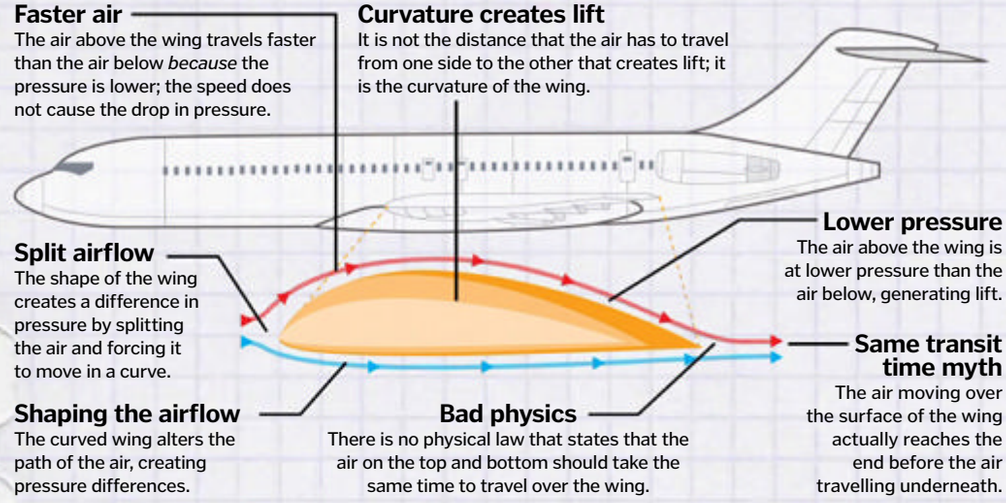
Groups of lemmings deliberately hurl themselves off cliffs

17 A film made by Walt Disney in 1958 called *White Wilderness* showed footage of lemmings leaping into the sea in an apparent mass suicide. However, in 1983 it was found the footage had been staged, using imported animals and tight camera angles to disguise the environment. In reality, the crew had herded the lemmings over the edge. It is true that when lemming populations get too high the animals disperse, gathering in numbers near the edges of rivers before attempting to swim across, but they do not deliberately jump to their deaths.

Lemmings are able to swim, so they jump into the water to disperse, not to die

Air takes the same amount of time to travel over and under an aircraft wing

18 One of the most famous misconceptions about aeroplane flight is that their wings are shaped so that the upper surface is longer than the lower surface, and that this forces the air moving over the top to move faster than the air underneath, which in turn creates a pressure difference and generates lift. However, as NASA points out; if this were true, how could planes fly upside down? If you take aerofoil with upper and lower surfaces of equal length, you generate lift even though the air has to travel the same distance.



Bananas grow on trees, and those trees can walk

19 Banana plants might look like trees, but they are actually herbs with 'trunks' made from tightly wrapped leaves. The bananas themselves are classified as berries. Beneath the ground the plants have a network of sideways-branching roots known as rhizomes, which spread out laterally and creep away under the soil. From these hidden roots, new leaves can spring up far from the original stem, making it appear as though the banana plant has moved.

Special 'superfoods' will do wonders for your health

20 Foods like blueberries and kale top the charts for their claimed health benefits, but the whole concept of 'superfoods' is a fabrication. There is no legal definition of a superfood, and the claimed health benefits are often based on experiments performed in test tubes with abnormally high amounts of the beneficial chemicals. These kinds of marketing myths can be dangerous, and not only is there no evidence to support many superfood claims; some supplements may even be harmful to human health.

The rust on a dirty nail causes tetanus

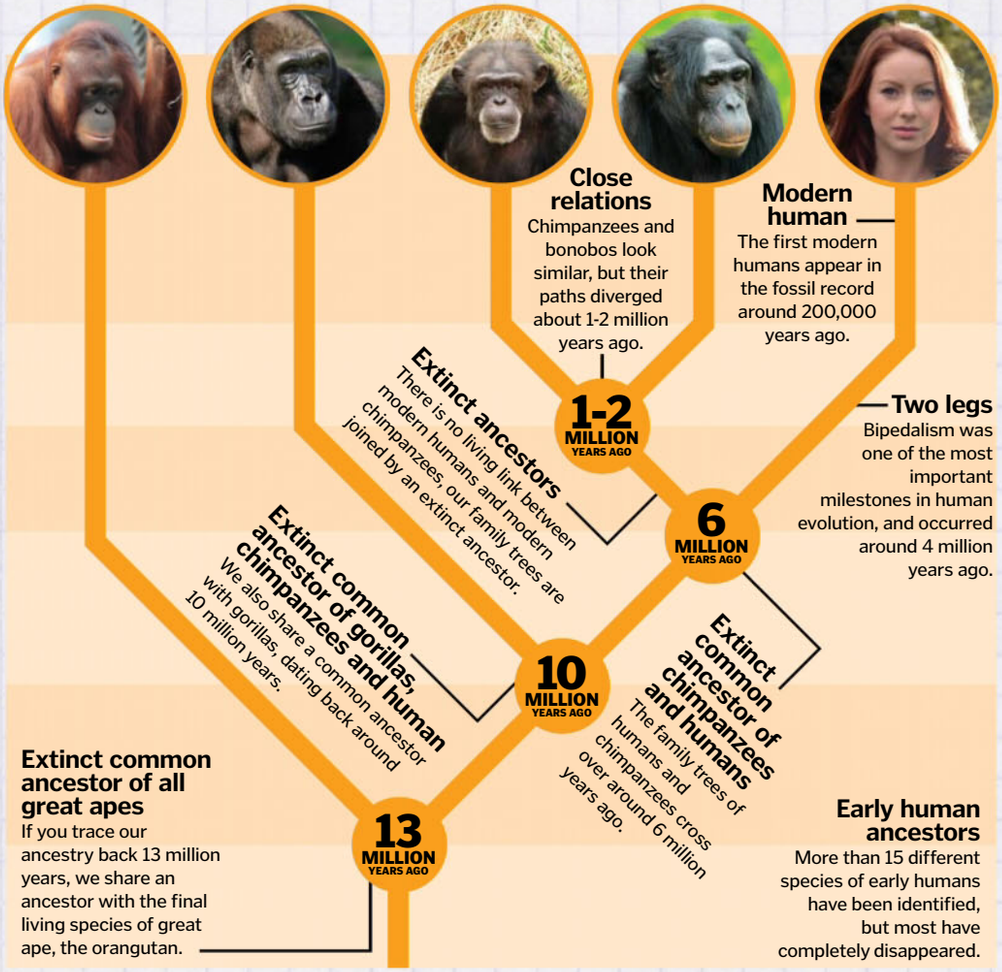
21 It is well known that if you are cut with rusty metal, you should check that your vaccinations are up to date, but it is not the rust itself that causes tetanus. Tetanus is the result of a bacterial infection called Clostridium tetani, which exists as spores in the soil, and can survive for decades at a time. If metal is rusty, it means it has probably been left outside for an extended period, making it more likely to have come into contact with the bacteria.

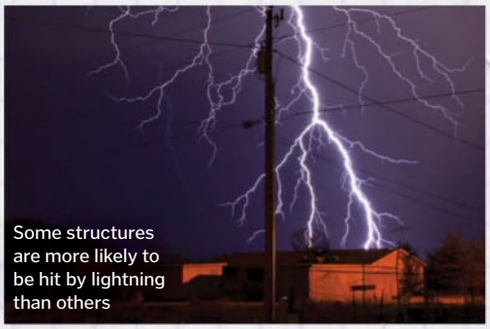
Swimming after eating gives you cramp

22 It is often claimed that entering the water on a full stomach can lead to deadly cramps, but if this were true, then why would endurance swimmers risk eating during a race? The pressure of a full stomach can cause a stitch, but in the event of this happening in the water, it is very unlikely the pain would be so bad that it would result in drowning.

Humans evolved from chimpanzees

23 One of the most common misinterpretations of the theory of evolution is the idea that we are descended from chimpanzees. We are closely related; we are both primates and share 98.8 per cent of the same DNA, but the African apes are our cousins, not our ancestors. If you traced the family trees of chimpanzees and humans, the two would cross over at a point around 6 million years ago. This common ancestor was neither a human nor a chimpanzee, and the descendants of that now-extinct species went down different evolutionary paths, leading to the modern species we see today.




Some structures are more likely to be hit by lightning than others

Lightning doesn't strike in the same place twice

24 If the Earth were an even sheet, with equal distribution of elements, lightning would have the same probability of striking each area, so the chance of two strikes in the same place would be low. However, our planet is lumpy, and variations like the height of a building, the moisture in the soil and even the positioning of leaves can make lightning more likely to strike in one place repeatedly.


The smell of a human will not prevent birds from returning to their nests

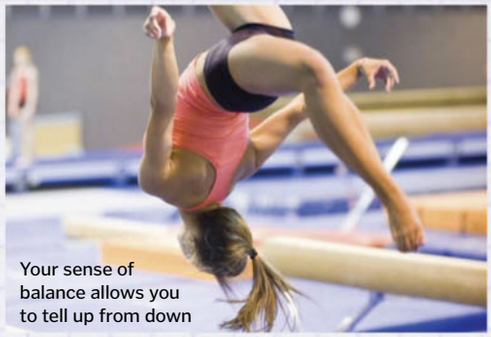
Birds abandon chicks touched by humans

25 Birds have keen eyesight but a poor sense of smell, so there is no evidence that the scent of a human would result in the abandonment of a chick. They are known to abandon their young when they feel threatened, but for most birds it would take more than an approaching human to trigger this behaviour.


Pears contains the toxic preservative formaldehyde

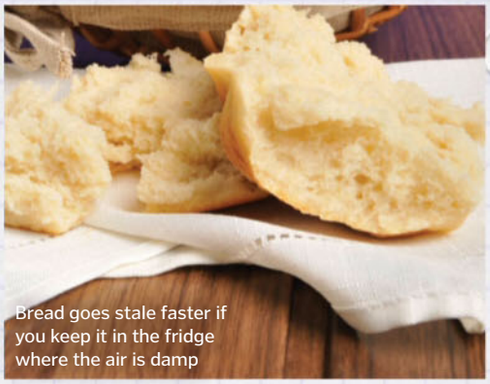
Natural products are safer than man-made

26 There is much scepticism about man-made products and products often advertise themselves as being 'all natural', but there is nothing inherently safe about naturally occurring chemicals. Everything is toxic in a high enough dose, whether man-made or naturally occurring, and how something was made is not as important as what it contains.


Your sense of balance allows you to tell up from down

Humans only have five senses

27 Humans have five main senses: vision, hearing, touch, taste and smell, but the list does not end there. We have many more senses, including equilibrioception, the sense of balance, and nociception, the sense of pain. We also have proprioception, the ability to tell where our bodies are in space, and thermoception, the sense of hot and cold.


Bread goes stale faster if you keep it in the fridge where the air is damp

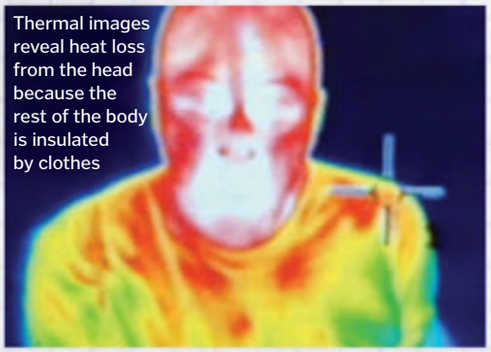
Bread goes stale because it dries out

28 Stale bread feels dry and can be rejuvenated with a splash of water, but it has not dehydrated. Instead, the water has become bound up in hard starch crystals. The process can be slowed down by adding more fat to the bread recipe, or by keeping the bread in a cool, dry place.

Imperfections in old glass windows and bottles were there when the objects were first made

Glass pools at the bottom of windows

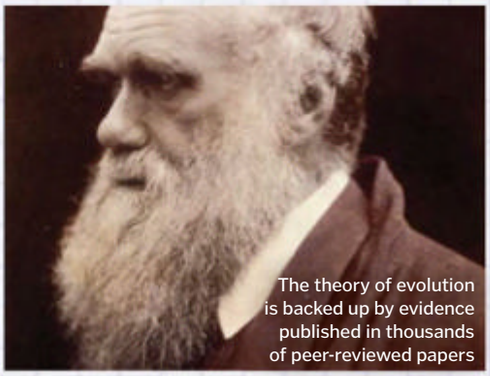
29 Old windows are often thicker at the bottom than they are at the top, and it was once thought that glass was as a slow-moving liquid. However, glass is now classified as an elastic solid, and according to chemists and glass experts, any imperfections in old windows were introduced at the time they were made.



Thermal images reveal heat loss from the head because the rest of the body is insulated by clothes

You lose most of your heat through your head

30 In the winter, people are often advised to put a hat on under the pretext that most of your body heat escapes through your head. In fact, there is nothing particularly special about this body part and it loses heat at around the same rate as any other; it's just that the rest of our bodies are often covered with clothes.



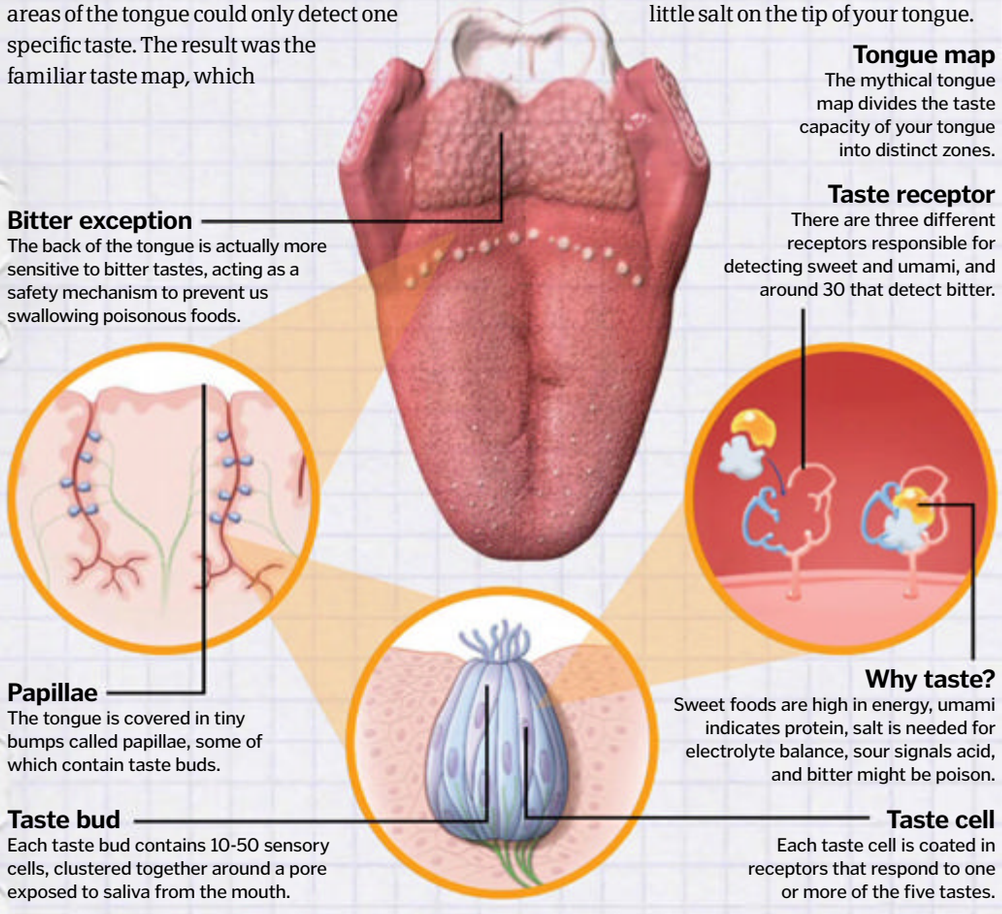
The theory of evolution is backed up by evidence published in thousands of peer-reviewed papers

A theory is just an idea

31 In day-to-day usage, the word 'theory' is often taken to mean the same as 'idea', or 'educated guess', and as a result scientific theories like evolution and the Big Bang are sometimes treated with suspicion. In science, a theory is built using evidence, and is close enough to the 'truth' that it can be used to predict what might happen next.

Different parts of your tongue respond to different tastes

32 This myth was born in 1901 when German scientist DP Hanig tested people's responses to different tastes on different parts of the tongue. His test subjects reported they were able to taste certain things better in different areas, but the research was mistranslated, leading people to believe certain areas of the tongue could only detect one specific taste. The result was the familiar taste map, which arranged the surface of the tongue into different zones; the tip detecting sugar, the front sides salt, the rear sides sour and the back of the tongue bitter. Incredibly, it wasn't until 1974 that scientists challenged the well-established myth, even though you can easily disprove it at home by putting a little salt on the tip of your tongue.



Tongue map
The mythical tongue map divides the taste capacity of your tongue into distinct zones.

Bitter exception
The back of the tongue is actually more sensitive to bitter tastes, acting as a safety mechanism to prevent us swallowing poisonous foods.

Taste receptor
There are three different receptors responsible for detecting sweet and umami, and around 30 that detect bitter.

Papillae
The tongue is covered in tiny bumps called papillae, some of which contain taste buds.

Why taste?
Sweet foods are high in energy, umami indicates protein, salt is needed for electrolyte balance, sour signals acid, and bitter might be poison.

Taste bud
Each taste bud contains 10-50 sensory cells, clustered together around a pore exposed to saliva from the mouth.

Taste cell
Each taste cell is coated in receptors that respond to one or more of the five tastes.

The heat of a chilli is in the seeds

33 Many cooks mistakenly believe the hottest part of a chilli is the seeds, when in fact the heat-producing chemical is concentrated in the white pulp that surrounds them. The chemical is known as capsaicin and it activates nerves that normally transmit signals about temperature. Chilli seeds are destroyed in the mammalian digestive system and scientists think the plants produce capsaicin as a deterrent. Birds are unaffected by the fiery chillies and their digestive systems actually help the seeds to germinate.

Shaving causes hair to grow back thicker

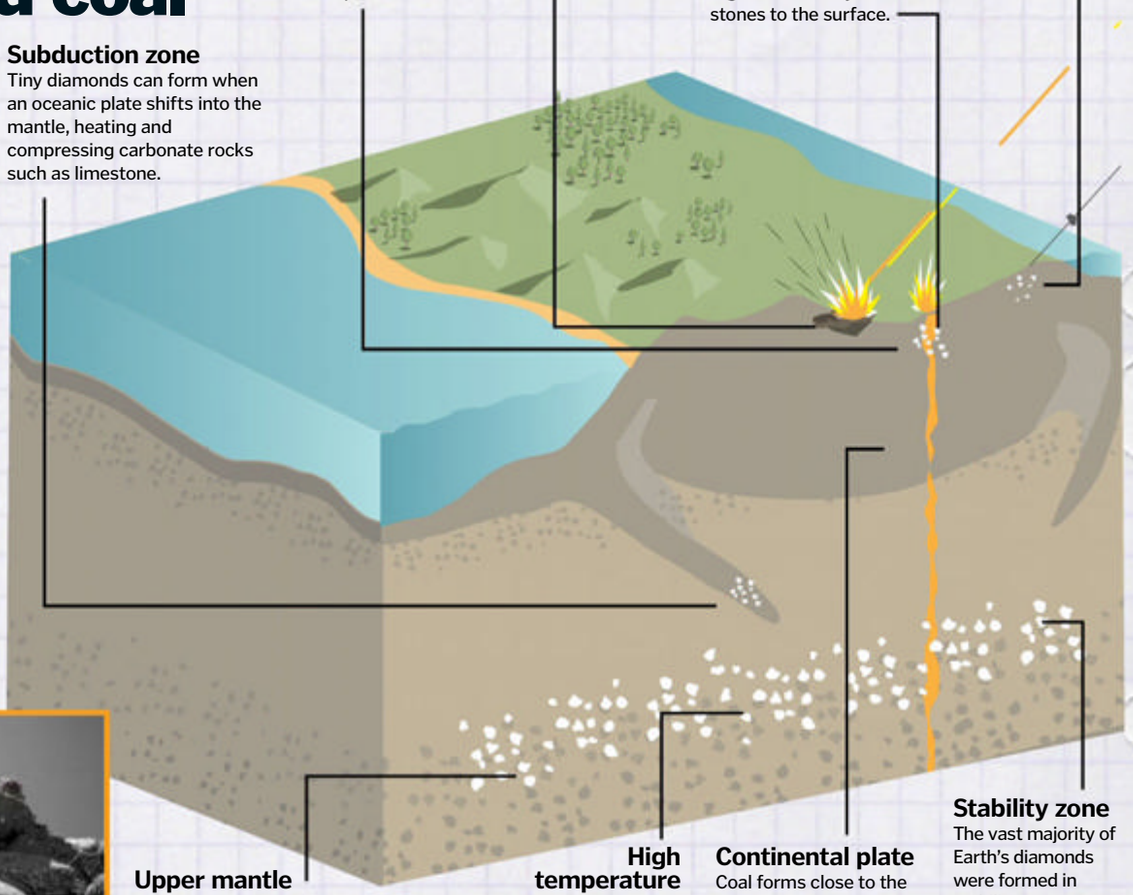
34 Shavers are often convinced that their hairs grow back thicker after they have been razored, but there is no evidence to support this idea. The perceived increase in thickness or coarseness of the hairs is actually to do with their shape. Before hairs are cut they have soft, tapered ends, and they tend to fall or curl under their own weight, but when they are trimmed the hairs end abruptly in a sharp, flat cut, which stands upright against the skin.

During an earthquake, you should hide in the nearest doorway

35 Doorframes used to be one of the last structural features of a house to collapse during an earthquake, but technological advances have changed the way that modern houses are built and it is no longer the safest place to stand. New advice recommends dropping to the floor and curling up, preferably beneath a sturdy piece of furniture like a bed or a table, and protecting your head and neck with your arms.

Diamonds are made from compressed coal

36 Diamond and coal are both formed from carbon, but it is not true that one is made from the other. Coal is formed from the remains of prehistoric plants and tends to be found around 3.2 kilometres (two miles) below the surface of the Earth, while most diamonds are formed from carbon-containing minerals found in the upper mantle, around 150 kilometres (90 miles) beneath the ground. The diamonds are delivered to the surface by a rare form of volcanic activity known as a deep-source eruption, which pushes upward through the mantle carrying the diamonds toward the surface and traps them in a pipe of igneous rock.



Coal diamonds
It is possible that coal near the surface could be transformed into diamonds at subduction zones and asteroid impact sites.

Asteroid impact
When asteroids slam into the Earth, the impact heats and compresses the crust and can form tiny diamonds.

Deep-source eruption
Volcanic eruptions beginning deep underground shoot through diamond-forming regions and carry the stones to the surface.

Meteorite fall
Diamonds can form in space, as tiny nanodiamonds have been found inside fallen meteorites.

Subduction zone
Tiny diamonds can form when an oceanic plate shifts into the mantle, heating and compressing carbonate rocks such as limestone.

Upper mantle
Most diamonds form deep inside the Earth's mantle, well below any coal deposits.

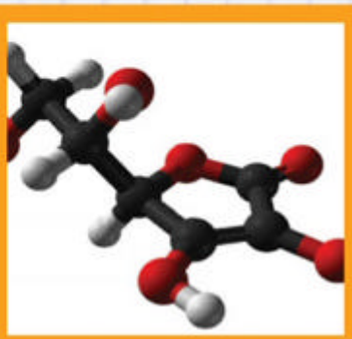
High temperature
At this depth, the temperature exceeds 1,050°C (2,000°F).

Continental plate
Coal forms close to the surface, within the tectonic plates that make up the Earth's crust.

Stability zone
The vast majority of Earth's diamonds were formed in stability zones beneath the continental plates.

Close-up TV harms your eyes

37 There is no evidence that sitting too close to the television is bad for your eyesight; however, the myth is not completely unfounded. Although moving closer to watch your favourite programmes does not cause near-sightedness, it could indicate an underlying problem with your eyesight.



Vitamin C protects you from illness

38 Many people choose to load up on vitamin C supplements in the winter in an effort to stave off the common cold, but there is little evidence that it actually works. In a large-scale study of over 11,000 people, scientists found no significant difference between people who took daily supplements and those who did not.

Hens need a rooster to lay eggs

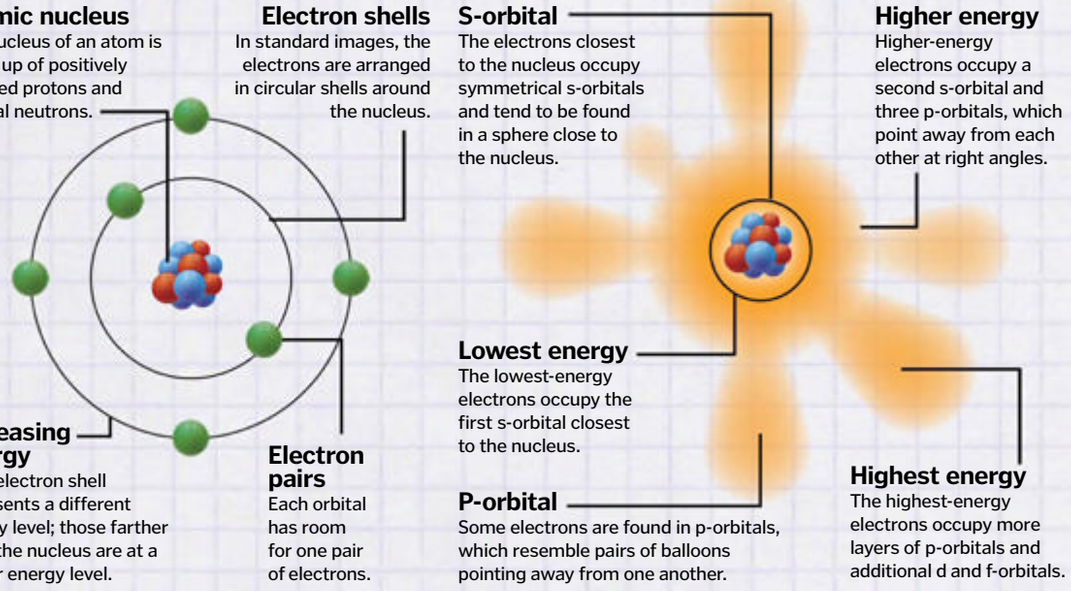
39 It is a common misconception that hens need a rooster in order to lay eggs. Hens are able to store sperm inside their bodies, allowing eggs to be fertilised before they are laid. If there is no sperm available, the eggs are still produced and are laid even though they will not develop into chicks.

The Sun is burning

40 The Sun might look like a ball of fire in the sky, but it is not really burning. The Sun is a nuclear fusion reactor, and the light and heat that it emits is the result of energy released when hydrogen atoms slam together and fuse to form helium.

Electrons orbit atomic nuclei like planets orbit the Sun

41 Looking at the standard textbook image of the atom, it is easy to imagine that the electrons orbit the nucleus in circles, like planets revolving around the Sun, but the diagrams are misleading. Rather than representing the orbits of the electrons, these images show their energy levels. In reality, we cannot know where an electron is and where it is going at the same time, so it is not possible to map out the path they take around the atomic nucleus. Instead, physicists map three-dimensional regions of space known as orbitals, which predict where each electron is likely to be.



Baking soda absorbs smells

42 Baking soda is a common kitchen ingredient that reacts with acids like vinegar to produce bubbles of carbon dioxide. It is hailed as a deodoriser because it can also neutralise smelly acids, like those found in sweat. However, on non-acidic smells it makes little difference, and as it absorbs water from the air it forms a crust that prevents its acid-neutralising action.

Salt makes water boil quicker

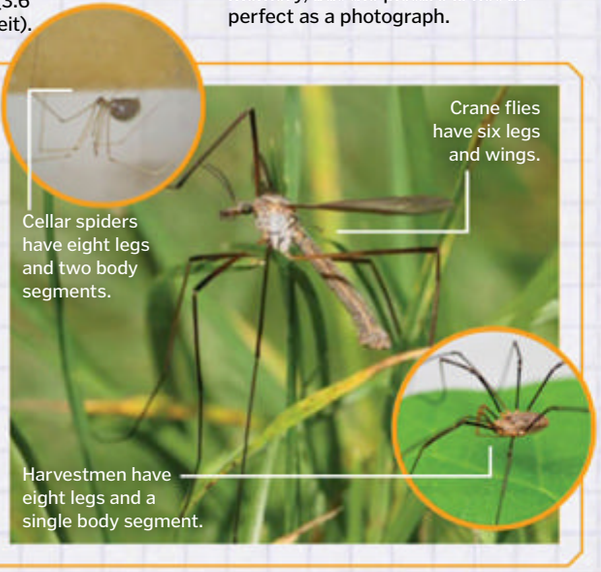
43 People add salt to their cooking water in the hope that it will boil faster, but it actually makes the water boil at a higher temperature. In the kitchen this effect is barely noticeable; it takes about 230 grams (8.1 ounces) of salt to increase the boiling point of one litre (0.26 gallons) of water by just two degrees Celsius (3.6 degrees Fahrenheit).

Some people have photographic memories

44 Many people have claimed to be able to recall an image in perfect detail, but no case has ever been confirmed. Some people are able to hold an image in their mind for a short time after it has been taken away, a phenomenon known as eidetic memory, but the picture is not as perfect as a photograph.

Daddy long legs are the most venomous spiders, but they cannot bite through your skin

45 There are three different invertebrates people commonly know as 'daddy long legs', crane flies, harvestmen and cellar spiders. Cellar spiders are venomous, and their fangs are anatomically similar to those of brown recluse spiders, which are capable of biting people, but there is no evidence that their venom is powerful enough to kill a human. Harvestmen and crane flies are not spiders and have neither fangs nor venom.



The Moon has a dark side

46 The moon is tidally locked to the Earth, meaning we always see the same side of its surface, but the other side is not in permanent shadow. Like the Earth, the Moon turns on its axis and all of its surface experiences both day and night.

Popping candy could burst your stomach

47 Popping candy is made by mixing molten sugar syrup with pressurised carbon dioxide gas. When the candy melts in your mouth, trapped bubbles release their pressure with a pop. The amount of gas released is very small and stories of children dying after eating a combination of popping candy and carbonated drinks are merely urban legend.

Fur and hair are different

48 Despite names and appearances, there is no real difference between the fur and hair. Both are both made from exactly the same material, keratin, and they are both produced by follicles in the skin. In fact, fur and hair are the same as eyelashes, whiskers and even porcupine quills.

Oil is not attracted to water

49 Amazingly, oil molecules are more strongly attracted to water than they are to one another, (which is why an oil droplet will spread out across the surface and does not stay together as a ball). The reason the fluids do not mix is because the water molecules are more strongly attracted to each other than they are to the oil.

Club soda is a miracle stain remover

50 Carbonated water is hailed as a miracle stain remover, but it turns out it is no better than plain water for removing an unwanted mess. Some people claim the bubbles contribute to loosening the stain from the fabric, but in head-to-head cleaning tests both liquids are equally effective.

Hand sanitiser

Discover how this clever gel cleans your hands without the need for soap and water

Hand sanitisers are an effective way to prevent the spread of most viral and bacterial diseases, including the influenza virus and rhinovirus, the cause of the common cold. They do this by killing the germs within just a few seconds.

The pathogen-killing ingredient is alcohol, often in the form of either ethanol or isopropanol. When it comes into contact with bacterial or viral cells, it can use one of two methods to destroy them.

The first method is to dissolve the cell membrane, leaving it unprotected from its environment, so it dies. However, this is only effective on bacterial cells. The second method is to denature the cell's proteins, a process that involves unfolding the protein's structure, so it no longer functions properly. Proteins carry out vital tasks for bacterial and viral cells, so these microbes quickly die when their proteins are denatured.

After killing the first layer of germs on your skin, the alcohol quickly evaporates, leaving any remaining bacteria with no means for adapting and becoming resistant to it, something antibacterial soap doesn't do.

Hand sanitisers are a necessity in any hospital

What makes a candle burn?

How this 2,000-year-old invention actually works

The wax that makes up a candle's body is made of a carbon and hydrogen compound called paraffin. As a solid it isn't actually very flammable and if you were to hold a flame against it, it would melt and then evaporate rather than burn.

This is where the wick comes in. When you light the string at the top of the candle, the liquid wax is drawn up the wick by capillary action (the ability of a liquid to flow upwards against gravity in a small tube). It becomes so hot that it turns into a gas, which mixes with oxygen in the air and combusts.

We take for granted that a candle burns with a yellow, cone-shaped flame, providing light. The reason this happens is due to a process called incomplete combustion, which produces bits of soot. This soot gets extremely hot, causing each particle to glow and produce the characteristic yellow colour.

Cellulite explained

Learn why 98 per cent of all cellulite occurrences are in women

Although it has physically existed for a while, the term cellulite was largely unheard of before the 1960s. Also known as gynoid lipodystrophy by scientists, cellulite has undergone extensive research, with the aim to find out what causes these unsightly bumps to form on our skin.

Two types of cellulite have been identified. Primary cellulite has no causal factors and forms naturally when enlarged fat cells push into the outer skin layer, causing an uneven 'dimpled' surface to form. Secondary cellulite forms either when the skin is damaged by infections, or by extensive and rapid weight loss, which can leave the skin loose, as it contracts very slowly.

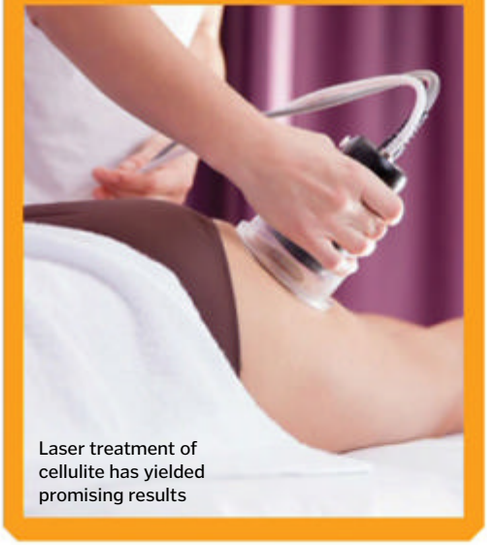
Men are just as capable as going through these processes as women, which begs the question of why cellulite formation in women is so much more common. To find the answer, scientists had to look more closely at how the formation of fat tissue and skin structure differed between the sexes. They found that men's fat tissues are entangled in one singular mass, allowing them to grow outward evenly. Meanwhile, women's fat tissues are constructed in a side-by-side formation, which means that when the fat content grows, they have no option but to push upward, pressing against the skin and forming cellulite.

There is also a hormonal difference between the sexes that contributes to this. Oestrogen could be a factor in cellulite formation, as it interacts with fat and skin. After puberty, this hormone makes the female body store surplus fat to help prepare it for pregnancy. Oestrogen also helps explain why cellulite levels differ between women and between the sexes, as some women have more oestrogen than others, while men have very little oestrogen at all.

Cellulite treatments

A number of possible treatments have been trialled to help both men and women rid themselves of cellulite. A procedure using lasers has been performed with good results. This actually requires minor surgery, with a laser fitted to the end of a cannula (a very fine metal tube) inserted under the skin. The laser can then be used to divide the fibrous bands that hold the fat cells together, helping to reduce the 'orange peel' appearance and smooth out the skin. The laser can also stimulate the production of collagen, helping to keep the skin tight.

Laser treatments aim to be a more permanent solution to cellulite, unlike some of the other treatments available. These include ultrasound therapy, which claims to melt away fat and even out cellulite. Unfortunately, this treatment's results only lasts for a few months. Topical caffeine treatments have been proposed, which aim to decrease fat levels by speeding up metabolism, but these methods have been met with mixed reviews.



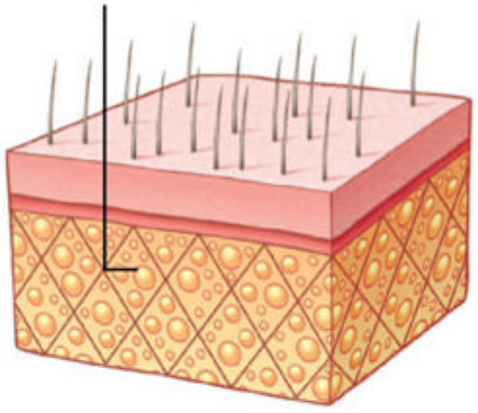
Laser treatment of cellulite has yielded promising results

Under the skin

See the differences between men and women's fat cells

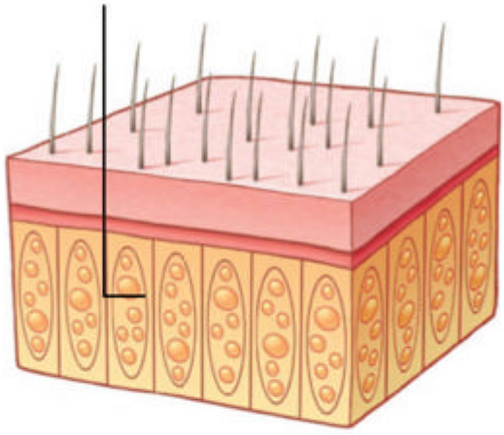
Crisscross collagen

Within a male, the skin's collagen holds fat cells in place by forming a crisscross pattern.



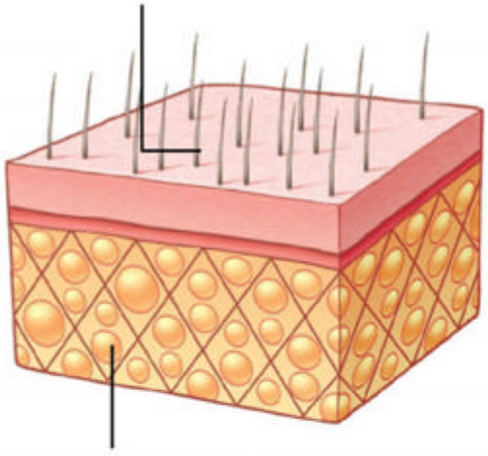
Collagen bands

Within a female, the skin's collagen forms a circular structure around the fat cells.



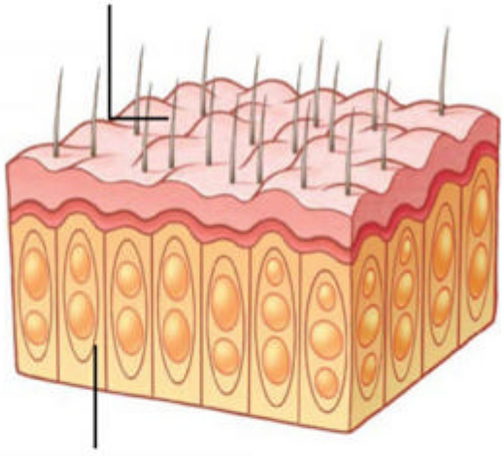
No visible cellulite

In spite of the enlarged fat cells, the male's skin surface shows little or no sign of any cellulite.



Irregular skin surface

Cellulite has formed due to the enlarged fat cells stretching the collagen chambers out toward the surface.



Male cell enlargement

When males put on weight, the fat cell collagen chambers stretch evenly due to their structure, resulting in no change to the skin's surface.

Female cell enlargement

When females put on weight, the fat cells cause the collagen chambers to push up into the skin, causing cellulite to form.

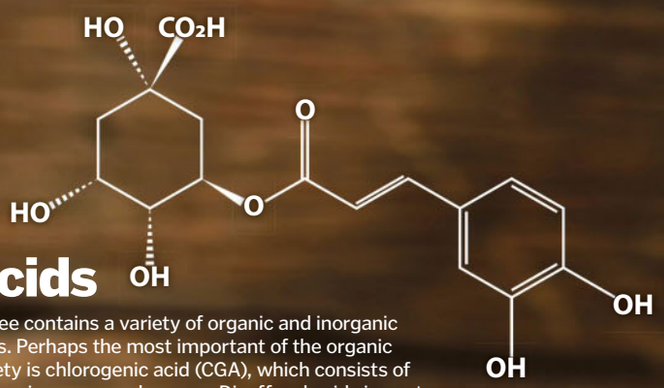
The chemistry of coffee

What makes your morning caffeine boost smell and taste so good?

Whether it's a milky latte or a double shot of espresso, coffee has become an important morning ritual for many people all over the world. Its rich taste and aroma serves as a welcoming wake-up call and the caffeine helps keep you alert for the rest of the day, but did you know this is all down to the 1,000 different chemical compounds present in every cup? Acids, alkaloids, carbohydrates and proteins, either found in raw coffee beans or produced by the roasting process, work together to create a complex mixture of flavours and that distinctive coffee smell.

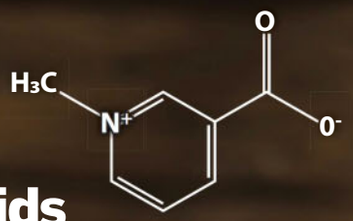
What's in your cup?

The chemical compounds that make up the perfect cup of coffee



Acids

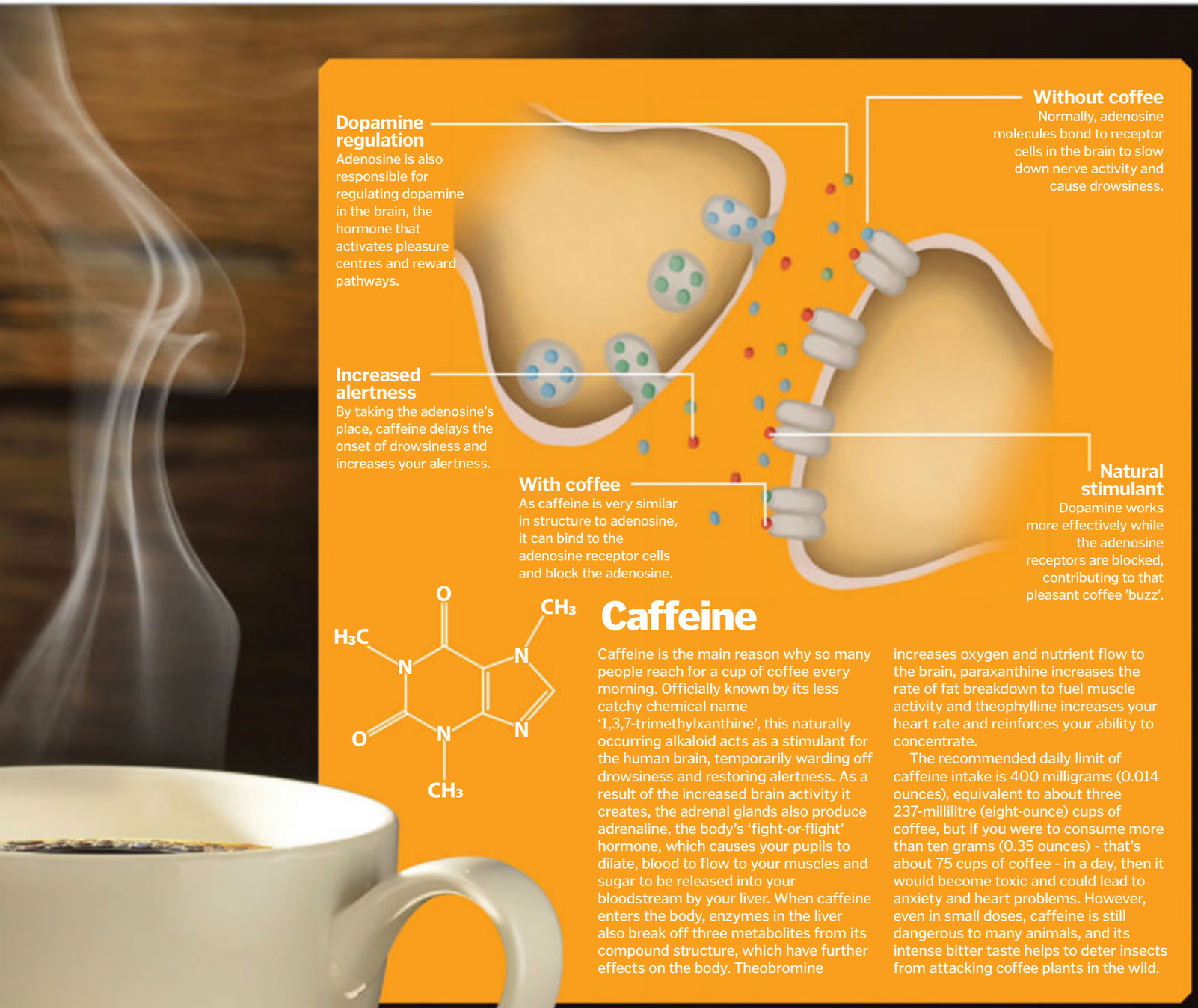
Coffee contains a variety of organic and inorganic acids. Perhaps the most important of the organic variety is chlorogenic acid (CGA), which consists of two main compound groups. Dicaffeoyl acids impart a metallic, bitter taste while monocaffeoyl acids slowly decompose during the roasting process. This causes them to split into quinic and caffeic acids, which contribute to the coffee's body and bitter aftertaste. Other organic acids found in coffee include citric acid, which has a strong, sour taste; and acetic acid (used in vinegar), which in low concentrations imparts a clean, sweet-like acidity and aroma.



Alkaloids

Although caffeine is probably the best-known alkaloid in coffee, there is another lesser-known alkaloid compound that has some surprising benefits. Trigonelline prevents mucus-like acid by-products and other bacteria from sticking to your teeth, helping to prevent cavities. It also decomposes during the roasting process to form carbon dioxide, water, nicotinic acid and aromatic compounds called pyridines. Pyridines are responsible for the coffee's sweet, earthy taste, while nicotinic acid – also known as niacin or vitamin B3 – helps your digestive system, skin and nerves function normally and is also important for converting food to energy.

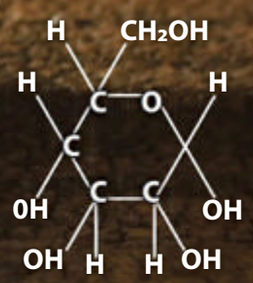
"There are 1,000 different chemical compounds present in every cup of coffee"



Caffeine

Caffeine is the main reason why so many people reach for a cup of coffee every morning. Officially known by its less catchy chemical name '1,3,7-trimethylxanthine', this naturally occurring alkaloid acts as a stimulant for the human brain, temporarily warding off drowsiness and restoring alertness. As a result of the increased brain activity it creates, the adrenal glands also produce adrenaline, the body's 'fight-or-flight' hormone, which causes your pupils to dilate, blood to flow to your muscles and sugar to be released into your bloodstream by your liver. When caffeine enters the body, enzymes in the liver also break off three metabolites from its compound structure, which have further effects on the body. Theobromine increases oxygen and nutrient flow to the brain, paraxanthine increases the rate of fat breakdown to fuel muscle activity and theophylline increases your heart rate and reinforces your ability to concentrate.

The recommended daily limit of caffeine intake is 400 milligrams (0.014 ounces), equivalent to about three 237-millilitre (eight-ounce) cups of coffee, but if you were to consume more than ten grams (0.35 ounces) - that's about 75 cups of coffee - in a day, then it would become toxic and could lead to anxiety and heart problems. However, even in small doses, caffeine is still dangerous to many animals, and its intense bitter taste helps to deter insects from attacking coffee plants in the wild.



Carbohydrates and proteins

Carbohydrates, such as sucrose – also known as table sugar – make up about 50 per cent of coffee's dry weight, but decompose during roasting. However, they still play an important role in the production of coffee's distinct aroma by way of the Maillard reaction, which takes place during the production of all thermally processed foods. When the beans are roasted and reach temperatures of 150 degrees Celsius (302 degrees Fahrenheit), their free proteins combine with their sugars to form aromatic compounds. These include furans, which impart sweet caramel notes; pyrazines, which have a nutty, earthy quality; and ketones and diacetyl, which create a buttery taste.

The physics of figure skating

Find out how science helps a figure skater execute fearless flying stunts

Figure skaters appear to glide effortlessly across the ice, performing breath-taking moves and spins, often at unimaginable speeds. At their core, these impressive performances rely on simple scientific principles, including friction, momentum and Newton's third law – every action has an equal and opposite reaction.

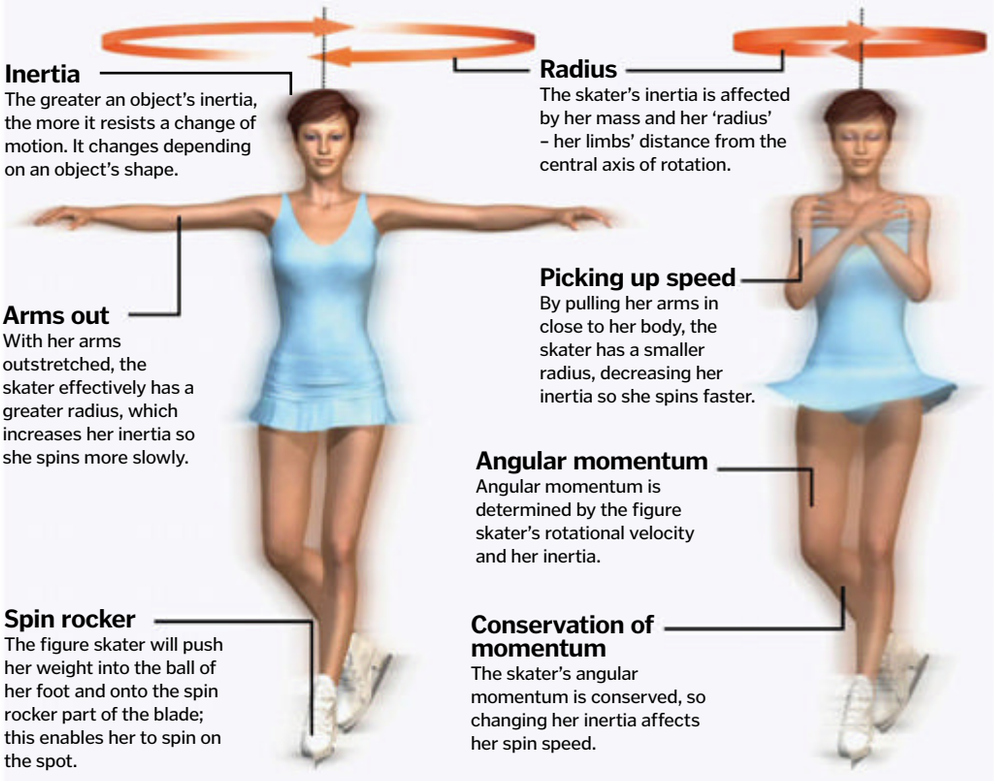
It's actually a lack of friction and the physical properties of the ice that enable a skater to glide, turn, speed up and stay in motion during a routine. Friction is a resisting force that occurs when two objects slide against one another, dissipating their energy of motion. A figure skater performing on smooth ice with sharpened skates will therefore encounter very little resistance. Some friction is still required for skating, though, as it enables skaters to start a stroke and come to a complete stop.

Newton's third law helps to explain how a figure skater is able to move and execute jumps on the ice. To put it simply, a skater will apply force down onto the surface of the ice; the ice then generates an upward force, which pushes back and helps to propel the skater into the air.

Figure skating routines that feature dramatic spins also rely on angular momentum. The amount of momentum depends on the skater's weight, speed and the distribution of mass from the centre of the body. Because of this, skaters will often tuck their arms in during a spin to reduce their radius, which in turn enables them to pick up more speed as they spin.

Science of spinning

Find out how a skater can pick up speed on ice



Inertia
The greater an object's inertia, the more it resists a change of motion. It changes depending on an object's shape.

Radius
The skater's inertia is affected by her mass and her 'radius' – her limbs' distance from the central axis of rotation.

Arms out
With her arms outstretched, the skater effectively has a greater radius, which increases her inertia so she spins more slowly.

Picking up speed
By pulling her arms in close to her body, the skater has a smaller radius, decreasing her inertia so she spins faster.

Angular momentum
Angular momentum is determined by the figure skater's rotational velocity and her inertia.

Spin rocker
The figure skater will push her weight into the ball of her foot and onto the spin rocker part of the blade; this enables her to spin on the spot.

Conservation of momentum
The skater's angular momentum is conserved, so changing her inertia affects her spin speed.

Figure skate design

Figure skates' unique design helps to ensure the athlete is able to glide and complete complex manoeuvres on the ice. The prominent metal blade, which is attached to the bottom of the boot, has a slight inward curve added when it is sharpened. This is known as the rock and offers two edges to skate upon, the inside and outside edge. Skaters will use the edges to move across the ice and pick up speed. It's also possible to skate on both edges, which is known as skating on flat.

The sweet spot, which is just below the ball of the foot, is known as the spin rocker and is the area on the blade that the skater will use to spin. The spikes at the tip are called toe picks and are used primarily for fancy footwork and jumping.

How suntans develop

Find out how our skin reacts to being exposed to the Sun

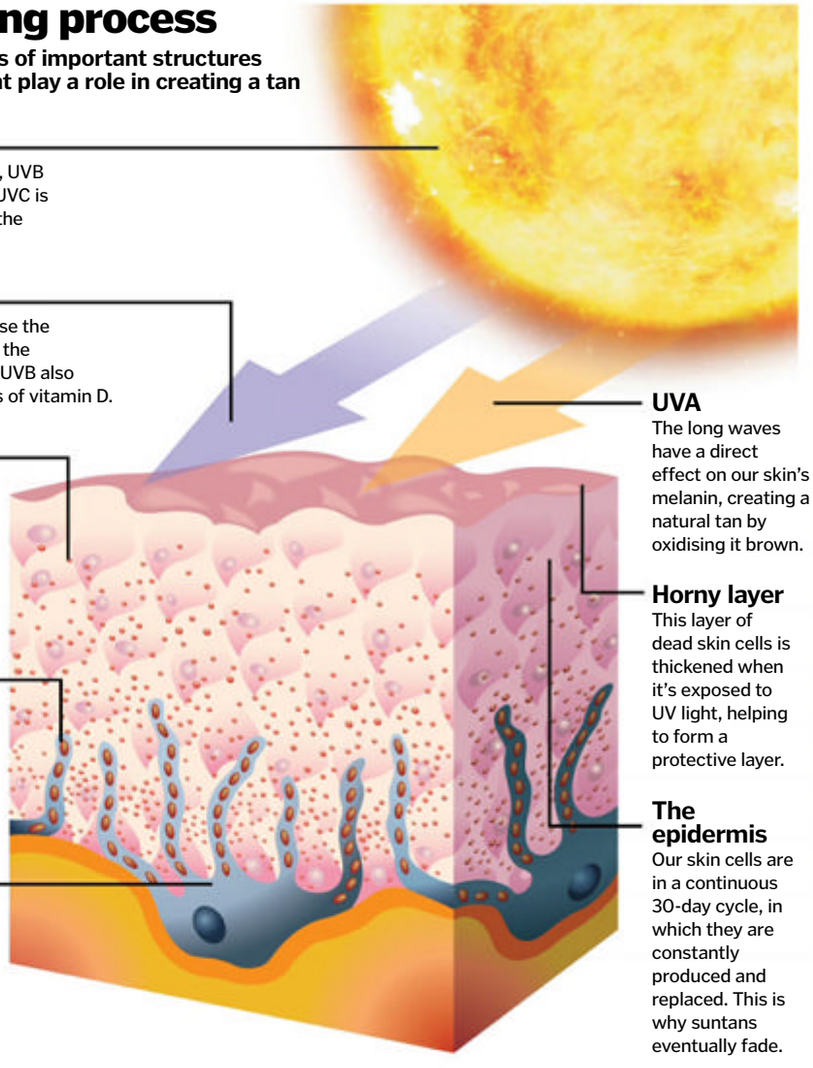
Medical professionals continue to warn us about the dangers of exposing our skin to too much sunlight. In spite of this, many of us still spend too long sunbathing in the hope of achieving the even bronzing that so many celebrities flaunt.

When we expose our skin to strong sunlight or a sunbed, the UV radiation we absorb prompts melanocytes in our skin to react by producing more melanin pigment. Melanin is the pigment responsible for our skin's colour and it protects the cells by absorbing UV radiation that would otherwise damage skin cells. People with naturally darker skin have more melanin and so are inherently better protected against sunlight. Nevertheless, excessive UV exposure damages melanoyctes' DNA, which can lead to a deadly form of skin cancer known as melanoma.

Recent science suggests the process of tanning has addictive qualities. An experiment using mice showed that as well as producing melanin, UV radiation produced pleasure chemicals called endorphins, which are also produced after a person ingests addictive drugs.

The tanning process

Learn the locations of important structures within the skin that play a role in creating a tan



The Sun
The Sun produces UVA, UVB and UVC light, but the UVC is mostly blocked out by the Earth's atmosphere.

UVB
These short waves cause the melanocytes to initiate the production of melanin. UVB also promotes the synthesis of vitamin D.

Melanin
This pigment browns when it absorbs UVA light. It also increases in size and then surrounds each skin cell.

Melanosomes
These are produced within the melanocytes and contain the enzyme tyrosinase, which synthesises melanin.

Melanocytes
These are specialised skin cells. They are responsible for the production of melanosomes and can send them to the surrounding skin cells.

UVA
The long waves have a direct effect on our skin's melanin, creating a natural tan by oxidising it brown.

Horny layer
This layer of dead skin cells is thickened when it's exposed to UV light, helping to form a protective layer.

The epidermis
Our skin cells are in a continuous 30-day cycle, in which they are constantly produced and replaced. This is why suntans eventually fade.

Keeping hydrated

Why is it important to drink enough water?

About 60 per cent of a typical adult human's body weight is water and it is vital for transporting carbohydrates, vitamins, minerals and oxygen to the cells and carrying waste away. This helps to keep the brain alert, absorb nutrients from food into the bloodstream, filter out waste products through urine, regulate blood pressure and body temperature and lubricate the muscles and joints. Water leaves your body through sweat, urine and even your breath, so must be replenished by drinking regularly.

The amount of water you need to consume depends on a number of factors, including your age, the ambient temperature and how much you exercise. However, it is recommended that a typical adult should drink two litres (0.5 gallons) or water per day. About 80 per cent of this intake usually comes from our drinks, while the other 20 per cent comes from water content in food. Even if you lose just one per cent or more of your body weight through fluid loss, you become dehydrated. If you don't replenish your body's fluid levels within 24 hours then you will start to suffer severe reduction in your physical and cognitive performance.

Drinking water is the best method of hydration as it contains no sugar, calories or additives

AMAZING ANIMAL ARCHITECTS

Take a closer look at the incredible engineering achievements of the animal kingdom

Humans are not the only species on Earth capable of building extraordinary structures. The natural world is in fact full of ingenious animals that can achieve just as impressive feats of engineering.

Building behaviour is common in mammals, birds, insects and arachnids. Many animals learn to build by observation and even through communication. However, in some cases building is thought to be instinctive.

Animals will often construct their own habitats for shelter against potential predators and the outside elements. Many dwellings are also built for nesting purposes and to catch, store and even cultivate food.

Animal architecture can also be quite sophisticated; with many structures incorporating clever ventilation systems for temperature control, and even secure entry and exit points to keep unwanted visitors away. Complex builds are often undertaken as a group, which helps speed up construction time. For example, an army of ants can move up to 50 tons of soil per year in just 2.6 square kilometres (one square mile)!

Maintaining a habitable structure is also a collective effort, and most animals work together to ensure they are regularly repaired or expanded as the colony grows. For some species, such as the beaver, this will involve sourcing materials from their environment. Animals that dwell underground, however, like ants and rabbits, will simply hollow out soil from their surroundings.

Many animal-made structures also play an important role in the ecosystem and even support other life forms. This includes termite mounds, beaver dams and sociable weaver nests, which can also be home to other species. This is largely due to the fact that a lot of structures are designed to protect against predators, an appealing realty prospect for smaller species. Many are also camouflaged well in their surroundings, as they can appear unassuming from the exterior, but inside you'll often find a hive of activity.

Animal structures can vary significantly in design, size and strength, from intricate spider webs to complex beehives and bird nests. But the thing they all share in common is that each can help ensure a species' survival.

Ants are among the strongest species on Earth in relation to their size

Ant architects

An army of ants can construct vast underground cities in a week

A single ant is capable of carrying up to 50 times its own weight, so working together as a colony means they're able to accomplish impressive feats. In fact, within a week a large army of garden ants can construct an underground city big enough to house thousands of insects.

Established deep underground, ant nests are made up of multiple chambers and connecting tunnels. Each chamber has a different use; some store food while others are used as nurseries for the young and resting spaces for busy worker ants. You'll find the queen ant in the central chamber where she will lay her eggs.

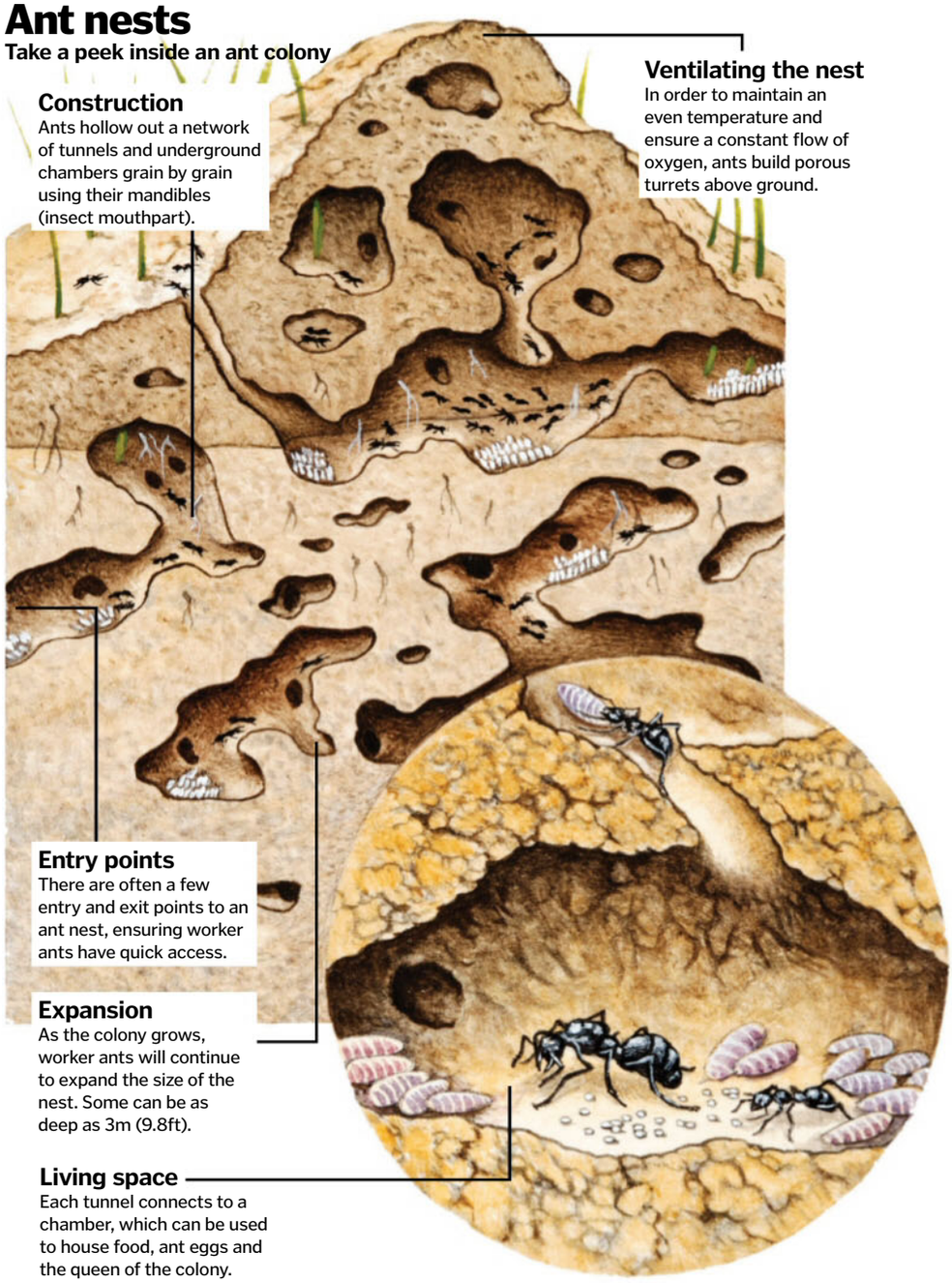
Porous turrets are also built above ground to ventilate the nest and maintain an even temperature inside.

"Building behaviour is common in mammals, birds, insects and arachnids"

Ants have separate entry and exit points on their hives

Ant nests

Take a peek inside an ant colony



Termite megacities

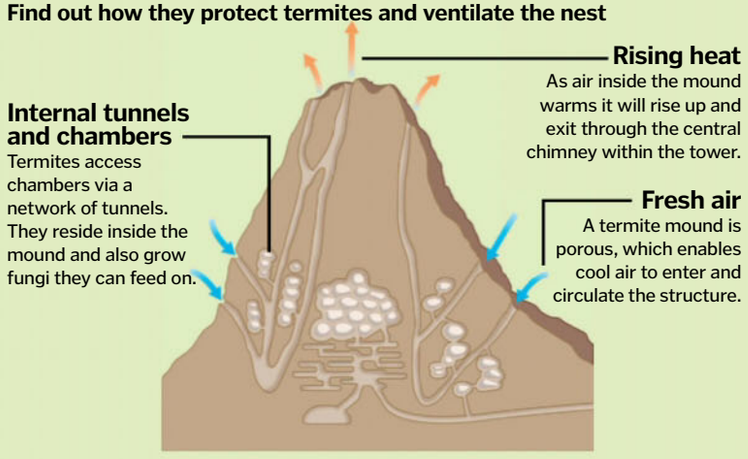
A towering termite mound, made up of soil, dung and termite saliva, can take four to five years to build and will continually evolve over time. Like ants, termites are social animals and work together to erect these impressive structures, which can be over five metres (16.4 feet) tall.

Although a mound appears solid, it's actually porous, enabling air to circulate through interior tunnels and chambers. Its unique ventilation system helps to maintain the temperature inside, which is where termites reside, raise larvae, store food and even farm and tend to symbiotic fungi to feed on.

Towers are built facing north to south to help regulate heat. Air will enter the mound through tiny exterior holes and then circulate around the structure, helping to lower the temperature as well as provide fresh oxygen to the insects. As this air then warms, it will rise and exit the mound via the central chimney.

Termite towers

Find out how they protect termites and ventilate the nest



Beaver lodges

Nestled safely in the centre of a pond, discover how beavers build their warm and dry abodes

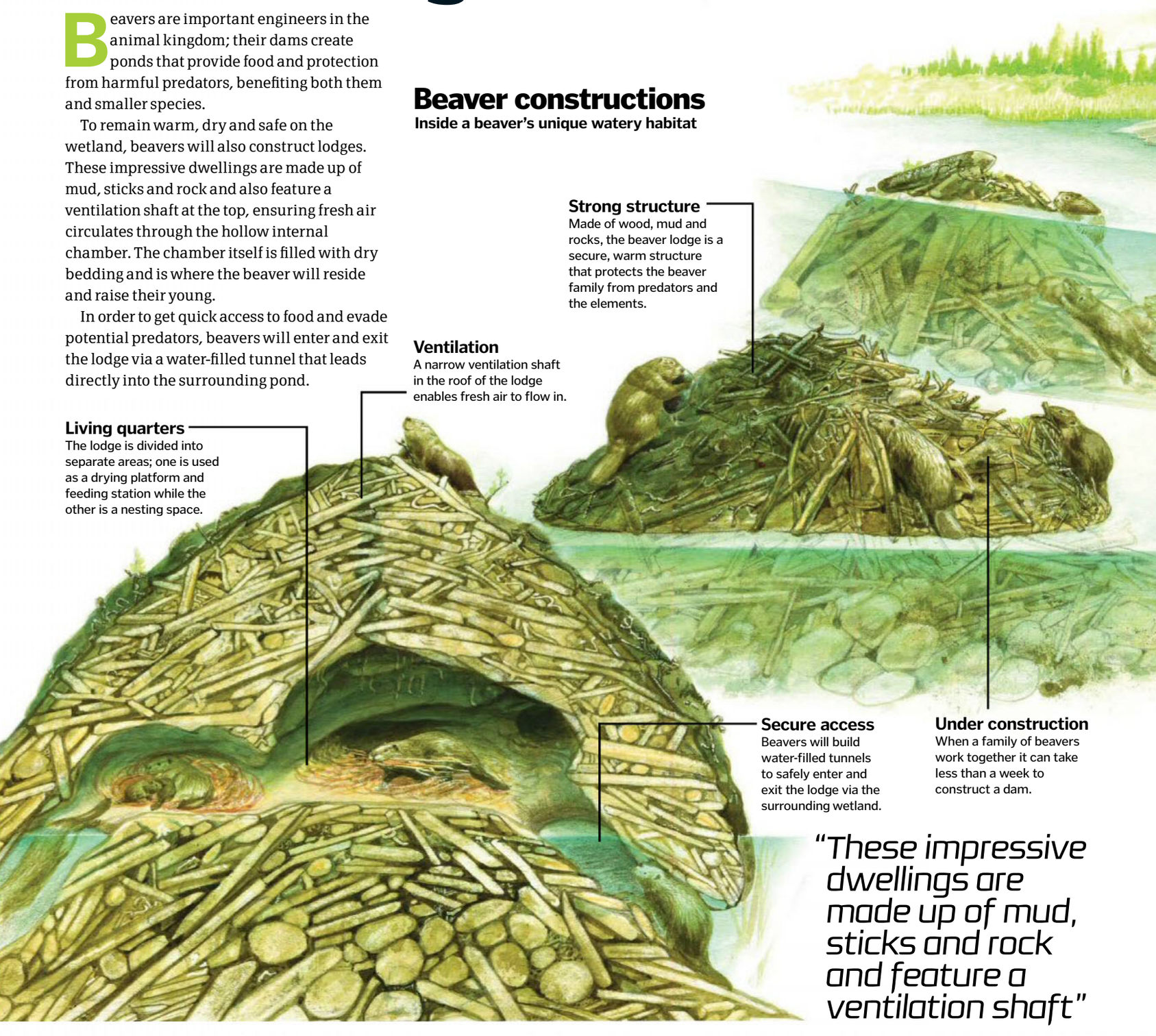
Beavers are important engineers in the animal kingdom; their dams create ponds that provide food and protection from harmful predators, benefiting both them and smaller species.

To remain warm, dry and safe on the wetland, beavers will also construct lodges. These impressive dwellings are made up of mud, sticks and rock and also feature a ventilation shaft at the top, ensuring fresh air circulates through the hollow internal chamber. The chamber itself is filled with dry bedding and is where the beaver will reside and raise their young.

In order to get quick access to food and evade potential predators, beavers will enter and exit the lodge via a water-filled tunnel that leads directly into the surrounding pond.

Beaver constructions

Inside a beaver's unique watery habitat



Strong structure
Made of wood, mud and rocks, the beaver lodge is a secure, warm structure that protects the beaver family from predators and the elements.

Ventilation
A narrow ventilation shaft in the roof of the lodge enables fresh air to flow in.

Living quarters
The lodge is divided into separate areas; one is used as a drying platform and feeding station while the other is a nesting space.

Secure access
Beavers will build water-filled tunnels to safely enter and exit the lodge via the surrounding wetland.

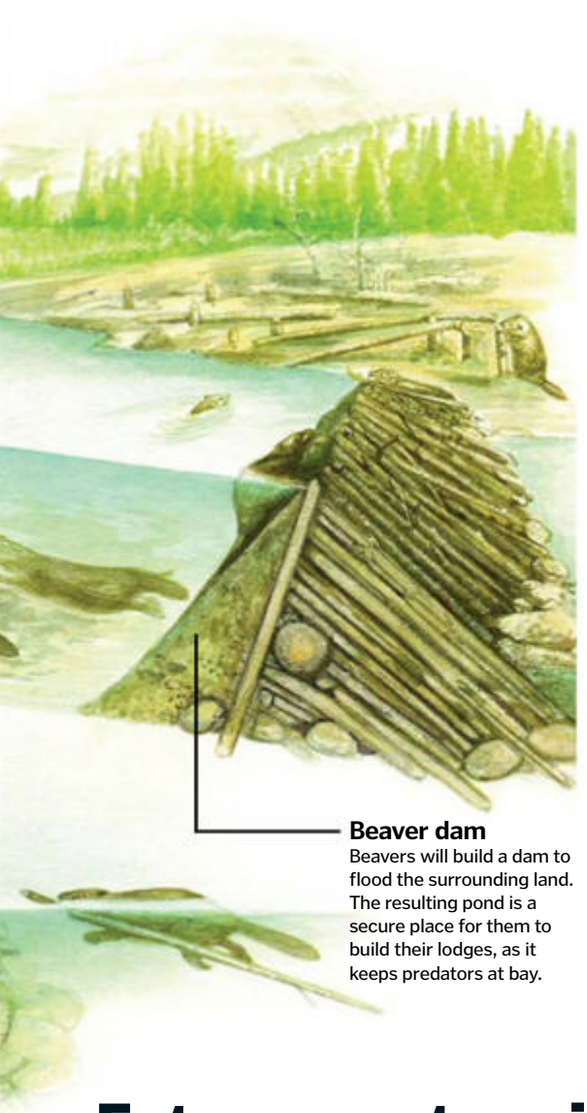
Under construction
When a family of beavers work together it can take less than a week to construct a dam.

"These impressive dwellings are made up of mud, sticks and rock and feature a ventilation shaft"

Beavers eat grass, shrubs and woody plants. They carry food in their mouths to take back to the lodge for their young

Beavers forage for wood and rocks to build their lodges on ponds

Beavers fell trees using their front teeth for building materials as well as food



Beaver dam
Beavers will build a dam to flood the surrounding land. The resulting pond is a secure place for them to build their lodges, as it keeps predators at bay.

Underground rabbit warrens

Rabbits are sociable animals that live close together in colonies underground. As a nocturnal species their unique warren system provides protection from predators while they rest during the day. It's also a safe and secure place for them to raise their young.

Warrens can be extensive in size and often go as deep as three metres (9.8 feet) underground. To build one, rabbits will burrow through soil using their front claws, creating an often-vast system of interconnecting tunnels that lead on to larger living and nesting areas. There are also at least two entry and exit points, commonly positioned at either end of the warren, ensuring inhabitants have safe access to their underground lair as well as the outside when in danger. Entry and exits points are also small in diameter, or around 15 centimetres (5.9 inches), which helps to stop predators from following them inside.

Rabbits burrow underground and create chambers where they can safely rest and raise their young

Extravagant sociable weaver nests

A flock of sociable weaver birds will build a home like no other. These nests can take over an entire acacia tree and house hundreds of birds. What's more, some of these unique structures are over 100 years old!

Building and maintaining the nest is a communal effort. Large twigs and dry grass are used to construct the small internal nesting chambers, which is where the birds reside and raise young. These are then lined with fur and soft plant material for insulation. However, the exterior and entrance tunnels are covered in sharp straw and sticks for protection.

During the hot summer months in South Africa, many birds will occupy the outer nesting areas, but in winter they move further in toward central chambers for added warmth.

Other bird species will often take up residence in a sociable weaver's nest, including pygmy falcons and red-headed finches. This can provide the sociable weavers with extra protection, as it means more birds are on the lookout for potential predators.

Sociable weavers create huge nests out of twigs, dry grass and straw

The mysterious Moeraki boulders

There are only around 50 boulders left on the beach today, after many were taken during the 19th century

Learn the origins of these legendary boulders located on New Zealand's Koekohe Beach

Maori legend states the Moeraki boulders are eel baskets, washed up after a large canoe was sunk. Their actual origins could hardly be more different; in reality they formed roughly 60 million years ago. These boulders, which can weigh up to 7,000 kilograms (15,432 pounds) and measure up to three metres (9.8 feet) across, are actually calcite concretions.

The process that formed them is similar to that which forms oyster pearls, where layers of material repeatedly cover a central core. For the boulders, this core would likely have been a bone fragment, wood or a fossilised shell. Over time, lime minerals in the sea accumulated around the central nucleus, allowing each concretion to grow into perfect, spherical boulders. This process could have taken up to around 5 million years. These boulders would have resided in the cliffs, as this was where the original seabed would have been. Erosion over time has worn away the cliffs, releasing them onto the beach. The Moeraki boulders now have legal protection, so it is an offence to damage, graffiti or remove them from their location.

The geology of rubies

Find out why scientists are struggling to prove the precise mechanism that forms these precious gemstones

Rubies are actually a type of rare mineral called corundum. Corundum is made up of densely packed aluminium and oxygen atoms, which are colourless on their own. However, when chromium ions replace some of the aluminium, bright red hues appear in the gemstone. Burmese warriors believed that placing rubies under their skin made them invincible in battle. Although this was not the case, rubies do have a hardness of 9.0 on the Mohs scale, beaten only by diamond among minerals.

How rubies are formed is still debated by scientists, but there are leading theories. It is widely accepted that plate tectonics are involved, specifically where the continents of India and Asia collide to form the Himalayas. What has baffled scientists is why rubies occur only erratically within this area's marble. Geologists need access to Burma's Mogok mine to prove or disprove any theory they put forward. Due to the delicate political situation in this country, this is not currently an option.

Ruby formation theories

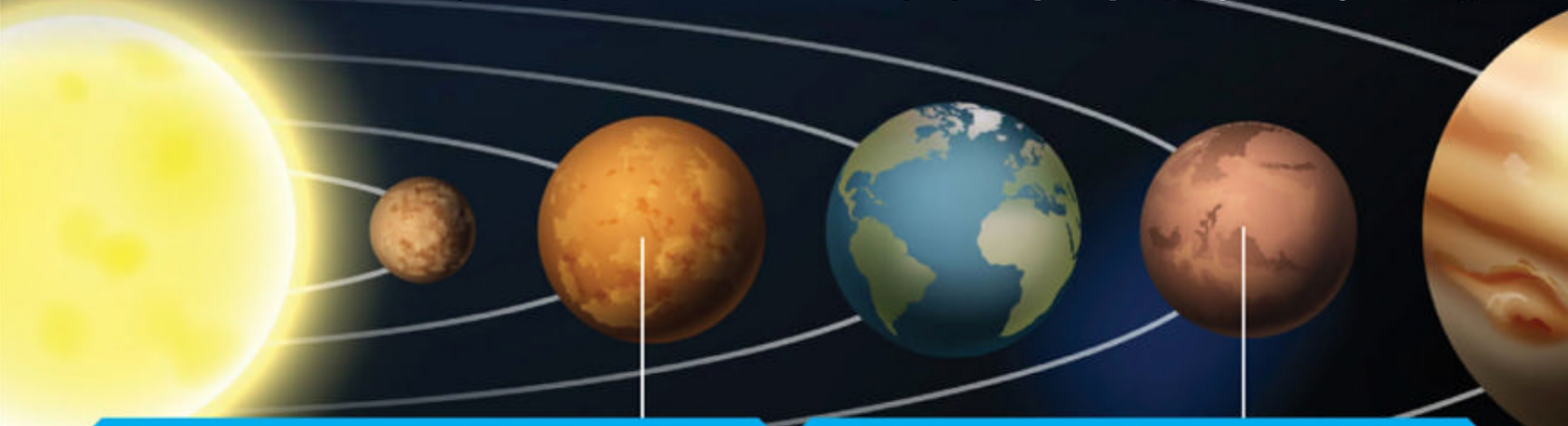
Some researchers believe the key to ruby formation is salt's presence within the limestone. This salt would have mixed with the detritus (dead organic material) and helped form the limestone that produced rubies. Once the limestone became heated, the salt lowered the melting point of the mixture (a flux), allowing the aluminium to have enough mobility to mix with the chromium. Crystals of salt have been found within the ruby-containing marble, which aids this theory's likelihood of becoming widely accepted. Other geologists believe the process requires a liquid to transport silica away before rubies can develop. Silica will actually stop corundum formation, so there would be no chance of rubies forming in areas with high levels of this compound.

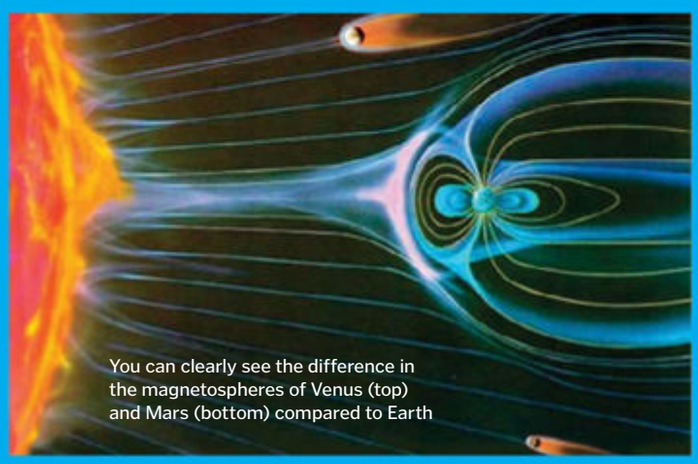
Auroras on other planets

Find out what causes these magnificent light shows on the other planets in our Solar System

For many years, the auroras seen on our planet were thought to be the souls of the dead moving to the afterlife. An aurora on Earth is actually caused by the Sun and can be thought of as a form of space weather. Solar winds hit Earth with highly charged particles, but our planet's magnetic field deflects most of them before they reach the atmosphere. Every so often these winds are boosted by solar flares or coronal mass ejections, which release huge amounts of plasma. When these intense solar winds reach Earth, some of the ionised particles get trapped in the magnetic field. These particles are then accelerated along the field lines toward the poles where they can enter the upper atmosphere, colliding with gas particles that cause them to emit bright light. This process creates the mesmerising aurora borealis and aurora australis, more commonly known as the northern lights and the southern lights respectively.

On Jupiter, Saturn, Uranus and Neptune, auroras form in a similar manner to how they form on Earth. However, on Mars and Venus they form very differently, as neither of these planets possess a significant magnetic field.





You can clearly see the difference in the magnetospheres of Venus (top) and Mars (bottom) compared to Earth

Venus

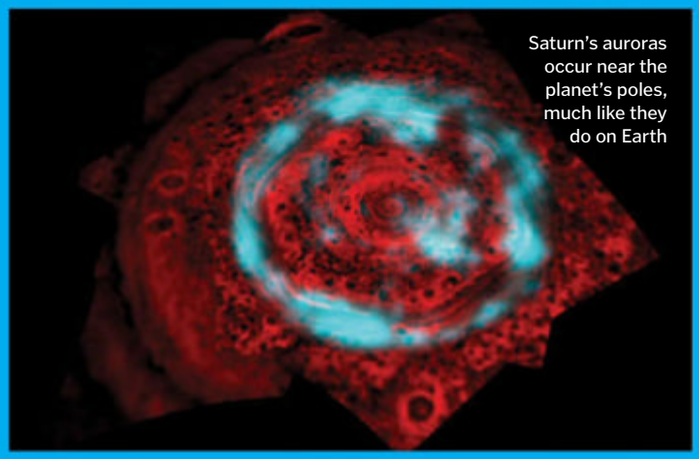
Similar to Mars, Venus does not possess its own planetary magnetic field, but flashes of light from the planet have been identified as auroras. Scientists have found that the same process that causes auroras on Earth can form a gigantic magnetic bubble around Venus, allowing auroras to occur. This is possible due to Venus having a magnetotail, which was formed by ionosphere and solar wind interaction. The fact that magnetic reconnection can occur within Venus' magnetotail suggests auroras are the cause of the light that scientists have observed emitting from this planet.

NASA's Mars Atmosphere and Volatile Evolution (MAVEN) spacecraft observing the 'Christmas Lights Aurora' on Mars

Mars

On Mars, auroras appear near areas of magnetised rock within the planet's crust rather than near the poles, when charged solar particles concentrate toward them. This is because it lacks a self-generated magnetic field, possessing only 'crustal magnetic anomalies'. Scientists found that the location of the light emissions corresponded with the location of the strongest magnetic fields found on Mars. It is thought these anomalies are the last traces of Mars's planetary magnetic field, which it displayed at some time in its history. This type of aurora formation is totally unique to Mars as far as scientists are aware.

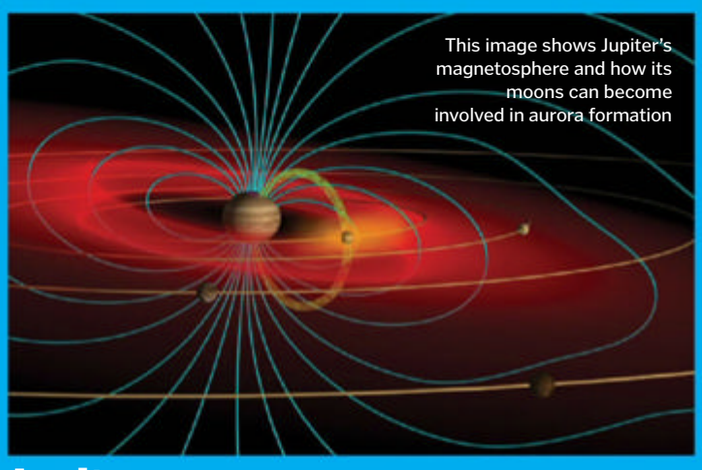
"On Jupiter, Saturn, Uranus and Neptune, auroras form in a similar manner to how they form on Earth"



Saturn's auroras occur near the planet's poles, much like they do on Earth

Saturn

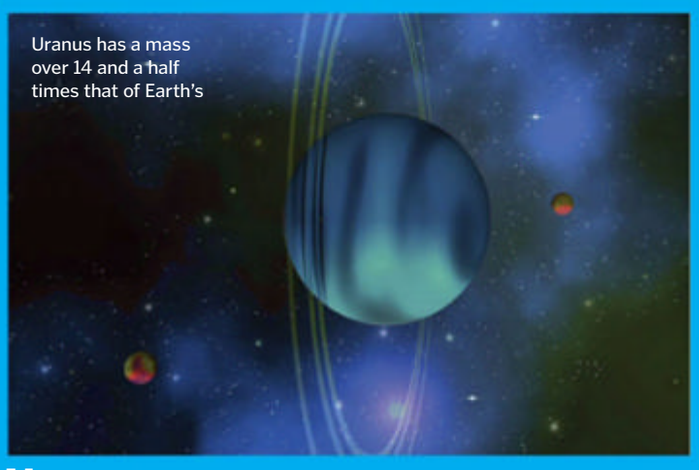
Saturn's auroras differ from Earth's in their size; they can stretch to amazing heights of 1,000 kilometres (621 miles) above Saturn's cloud tops. The charged particles come from the Sun's solar winds blasting past the planet. The particles smash into hydrogen in Saturn's polar atmosphere, ionising the gaseous atoms, which causes photons to be released and leads to the aurora. This planet's auroras are actually not visible to the human eye, due to the fact that the emitted light lies in an infrared and ultraviolet spectrum we can't see. It's thought that as on Jupiter, Saturn's moons may also influence the auroras.



This image shows Jupiter's magnetosphere and how its moons can become involved in aurora formation

Jupiter

Although some of the auroras found on Jupiter form in a similar manner to those on Earth, many are formed due to the trapping of particles within its own magnetic environment. Unlike Saturn's main aurora that changes size as the solar winds vary, Jupiter's main auroral ring maintains a constant size. This is due to its formation through interactions within its own magnetic environment. Jupiter's moons are also believed to be able to influence auroras. Io, Jupiter's volcanic moon, is thought to produce gases that travel into Jupiter's atmosphere, where they can contribute to the planet's aurora formation.



Uranus has a mass over 14 and a half times that of Earth's

Uranus

The presence of auroras on Uranus was detected in 2011 by the Hubble Space Telescope. It is thought this was possible due to heightened solar activity during this period, which increased the amount of charged particles carried in solar winds from the Sun. The auroras formed on this giant ice planet appear far away from the north and south poles, unlike on Earth. This is because of the planet's magnetic field, which is inclined at an angle of 59 degrees to the axis of its spin. These auroras are fainter than their Earth counterparts and last only a couple of minutes, unlike those on our planet, which may last for hours at a time.

Why does Venus have a Y?

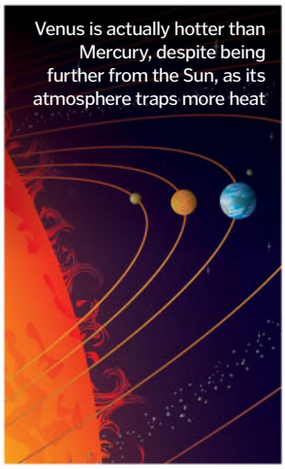
Solving the mystery of the Y-shape pattern seen on Venus

Venus is so bright that it can be seen during the day, particularly when the Sun is low on the horizon

Venus's famous Y-shape pattern was first seen in 1974, when Nasa's Mariner 10 spacecraft was sent to observe both Venus and Mercury. The Y spans almost the whole planet; the Y's arms are more than 17,000 kilometres (10,500 miles) long and the stem is around 19,200 kilometres (11,900 miles) in length. Venus's winds are incredibly strong, capable of moving the upper part of the atmosphere at up to 400 kilometres (250 miles) per hour. These winds circle the planet roughly every five Earth days. However, Venus takes around 243 Earth days to complete a full rotation – moving less than seven kilometres (four miles) per hour at the equator – so the wind speed is much quicker than the planet's own spin. The rate at which these winds circle the planet changes due to the varying circumference of Venus at different latitudes. For example, at the north and south poles, the winds circle the planet at a much quicker rate. The difference in this rate is the cause of the formation of the Y shape, as the clouds at the top and bottom of the Y complete their circular trip around the planet quicker, giving rise to the arms of the letter 'Y'. Scientists believe it was crucial to find out the origins of this pattern, as this helps their understanding of why the planet's atmosphere rotates 60 times faster than its surface.

Backward planet

One of the most intriguing qualities of the planet that sits second closest to our Sun is that it rotates backward, known as a 'retrograde' rotation. It is the only planet in the Solar System to do this; if you were to stand on Venus you would see a sunrise in the west and have to wait just shy of 117 days before seeing it set in the east. The reason for this bizarre fact is still hotly debated; one theory that has been put forward is that another planetary body similar in size to Venus collided with it at some point in history. After the forces from this collision had evened themselves out, Venus was left with its current rotational speed and direction. Without knowing this planet's history in detail, it is hard to apply weight to any of the theories out there.



Venus is actually hotter than Mercury, despite being further from the Sun, as its atmosphere traps more heat

The weather on Venus

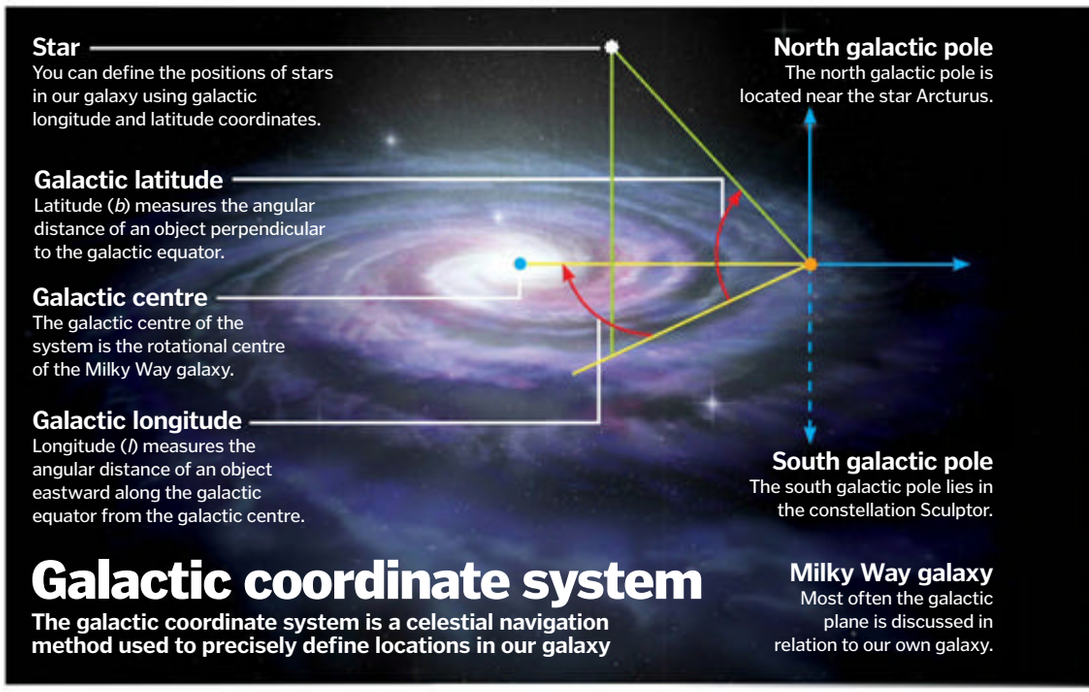
Although Venus is sometimes referred to as Earth's twin due to their comparable sizes, their atmospheres differ vastly. The average temperature on Venus is a rather hot 460 degrees Celsius (860 degrees Fahrenheit), making it unlikely for life as we know it to exist. When you also consider that its atmosphere is a toxic mix containing carbon dioxide and nitrogen with clouds of sulphuric acid and the surface pressure is 90 times that of Earth, it seems unlikely for any weather to occur. In spite of this, NASA has confirmed there is lightning on Venus, potentially even more than there is on Earth. Future missions to the planet will have to take into account potential interference from lightning strikes.

What is a galactic plane?

Find out everything about our galaxy's equator

The galactic plane is the plane in which the majority of a disk-shaped galaxy lies. It essentially slices the galaxy in half fromone side to the other, and the directions perpendicular to the plane are known as the galactic poles. Typically scientists are talking about the Milky Way, our galaxy, when referring to the galactic plane and poles.

The galactic plane is not always easy to define; even in the Milky Way, which is a barred spiral galaxy and fairly regular, not all of its stars lie precisely within the plane. The International Astronomical Union defined the locations of the north and south galactic poles as part of the galactic coordinate system, a spherical coordinate system used to specify the location of objects relative to the Sun and the centre of the galactic plane. The galactic coordinate system works similarly to the geographic coordinate system that we used to specify locations on Earth, with locations given in degrees latitude (*b*) and longitude (*l*).



Binary planets exist

Double planets aren't just the stuff of science fiction; they exist in our Solar System

A double or binary planet is an informal classification to describe a binary system containing two planetary-mass objects. Planetary-mass objects, also called planemos, are objects with enough mass to round under their own gravity but don't have star-like core fusion. Planemos can be objects we don't actually consider 'true' planets, like moons and dwarf planets.

Because there isn't a formal definition, exactly what makes a binary planet system is up for debate. Many are so close together that their gravitational interaction causes them to orbit around a common centre of mass, or barycentre. The Earth and Moon have sometimes been called a binary planet system, and the Moon is the largest moon in the Solar System in relation to the size of its parent planet. However, some make the distinction that the barycentre must be located outside of the planets, and with the Earth-Moon system, the barycentre is found 1,700 kilometres (1,050 miles) below the Earth's surface. Pluto and its satellite Charon fit this definition better as Charon's diameter is about half that of Pluto's and their barycentre lies in the space between them. There may be distant binary exoplanets as well – even habitable ones...

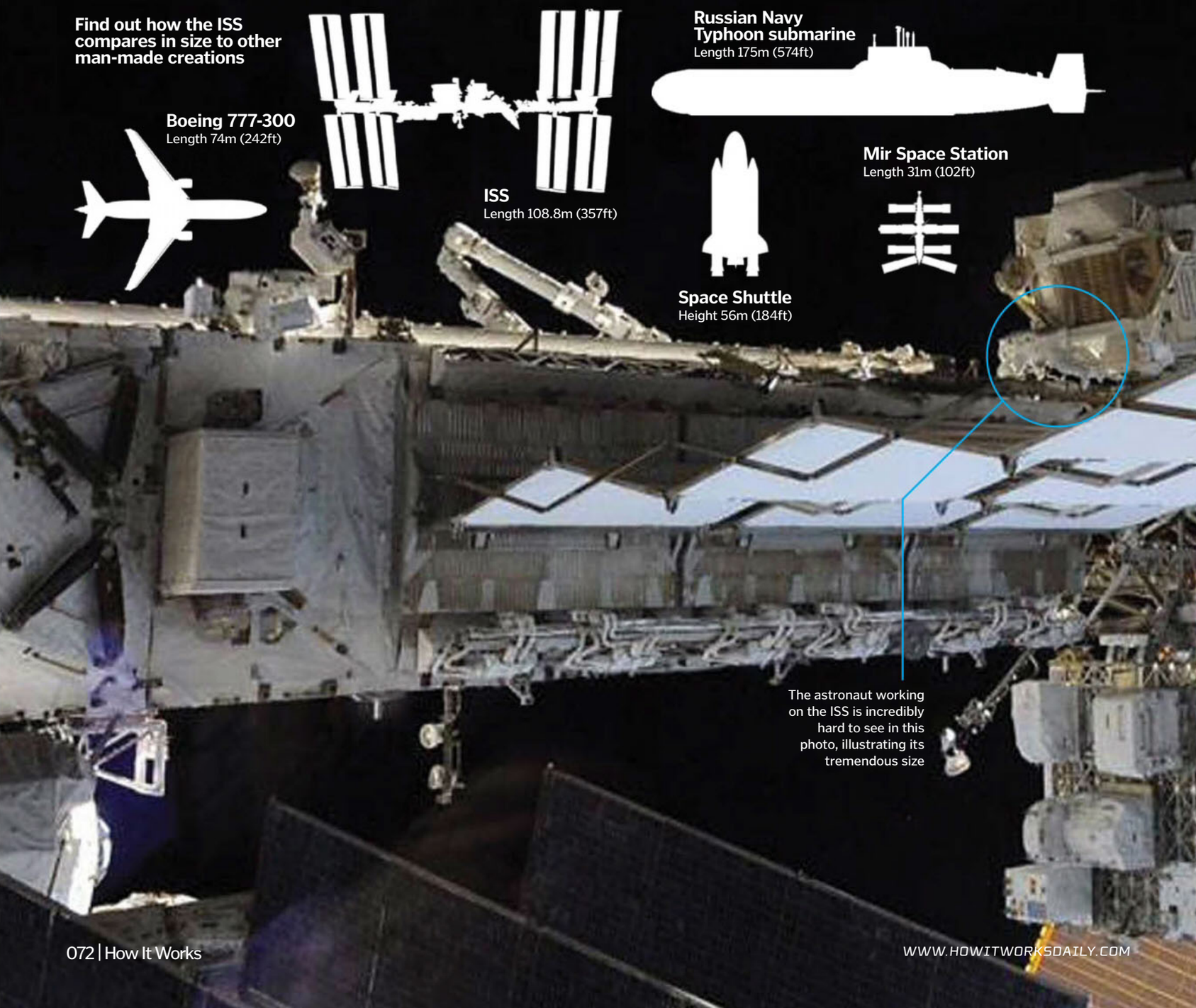
Pluto and Charon are often called a binary planet system, as they orbit each other around a point in space between them

How big is the ISS?

Learn just how massive humanity's home in orbit has become

The size of the International Space Station is incomparable to anything else ever launched into space. With a total mass of approximately 420,000 kilograms (925,000 pounds), it resides 400 kilometres (250 miles) above Earth in one of the lowest possible orbits, meaning that it's visible with the naked eye from the ground. The ISS measures 108.8 metres (357 feet) from end to end, just shy of an American football field's length. Much of its size is a result of the eight solar arrays that power the ISS, giving it a wingspan of 73 metres (240 feet). The 0.4 hectares (one acre) of solar panels produce enough electricity to power the equivalent of 40 homes back on Earth. Living space on the ISS is comparable to a six-bedroom house, and is equipped with a gym, two bathrooms and a 360-degree bay window, providing unrivalled views of Earth for the crew of up to six members.

At the time of its tenth anniversary back in 2010, the ISS had travelled over 2.4 billion kilometres (1.5 billion miles) and hosted more than 200 people. The ISS is still our best space laboratory; the research potential related to both life on Earth and in space is still vast, but the future of the ISS has been in danger. A decision had to be made as to whether it was worth keeping a piece of 1990s solar-powered technology that costs billions of dollars every year to operate and maintain. The United States had previously considered decommissioning the ISS by 2016, but more recently NASA and Roscosmos have agreed to keep the station in orbit until 2024, after which Russia will focus on a station of their own. So the ISS will continue to serve humanity for a few more years at least.



"The ISS measures 108.8 metres (357 feet) from end to end, just shy of an American football field's length"

How Vesuvius destroyed Pompeii

The catastrophic eruption that buried an entire city

At noon on 24 August in 79 CE, Mount Vesuvius erupted near the bay of Naples in southern Italy in what would become one of the most devastating natural disasters of ancient times.

The nearby cities of Pompeii and Herculaneum were completely buried by the ash and pyroclasts that spewed from the volcano, helping to preserve them in extraordinary detail. We also have detailed information about the eruption itself thanks to Pliny the Younger, who wrote two letters detailing what he saw from his mother's house in Cape Misenum. His famous description of the plume as "shaped like a pine" caused this type of eruption to be named a Plinian eruption.

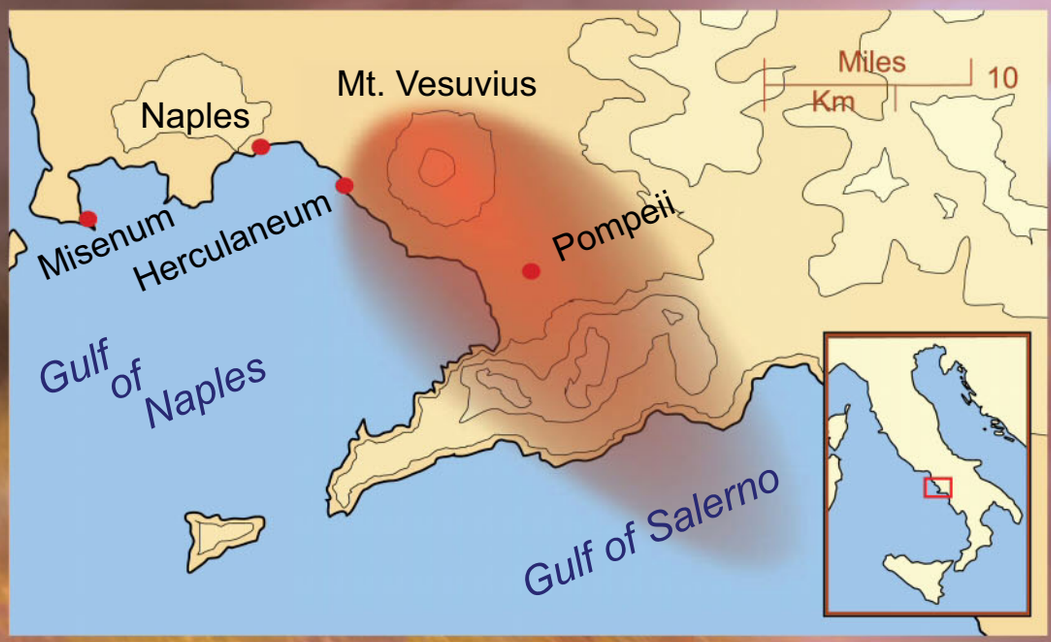
20 hours of terror

How that fateful day unfolded

1 10am, 24 August, 79 CE
For four days prior to the eruption, small earthquakes are felt throughout the city of Pompeii. As this happens every year without consequence, the inhabitants think nothing of it. Many of them congregate in the public forum, the political, religious and commercial heart of the city.

2 1pm, 24 August
After several small explosions, Vesuvius erupts, sending a tall cloud of lava and ash over 20km (12mi) into the sky. The cloud blocks out the Sun, plunging everything into darkness, and violent tremors cause buildings to collapse. People run toward the coast in search of rescue, but rough seas make escape by water impossible.

3 9pm, 24 August
Hot ash and lumps of volcanic rock rain down over Pompeii, which is downwind from the volcano. People become trapped in their houses as debris blocks the doors, and roofs begin to collapse from the weight of the ash and rock. Many people are also killed by the emissions of sulphuric gases.



4 12am, 25 August
The ash cloud reaches its maximum height of 30km (19mi) and then collapses, sending a pyroclastic surge of hot gas and rock down the volcano's northwest slope toward Herculaneum. Moving up to 700km/h (435mph) and with temperatures up to 400°C (752°F), the surge instantly kills everyone it touches.

5 6am, 25 August
As dawn breaks, the cloud collapses for the last time, sending another pyroclastic surge toward Pompeii that kills everyone in its path. By the time the eruption is over, Pompeii is buried underneath 5m (16ft) of volcanic material, while Herculaneum is buried under 20m (66ft).

"By the time the eruption is over, Pompeii is buried underneath 5m (16ft) of volcanic material"

Anatomy of the eruption

Initial explosion

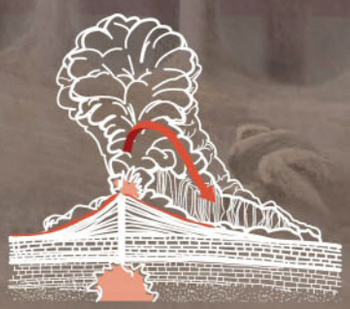
After more than 800 years of inactivity, pressure inside the volcano became too great. The built-up gases burst through the thick layer of lava that had plugged the crater and a column of ash climbs upward.

Spreading cloud

The wind blows the cloud toward the southeast, and it spreads to nearly 100km (60mi) in width from side to side. Ash falls on Pompeii at a rate of 15cm (6in) per hour for an entire day.

Pyroclastic flows

As the ash cloud collapses, volcanic debris rolls down the sides of the volcano toward Herculaneum, which is 6km (3.7mi) away, and Pompeii, which is 10km (6.2mi) away. Anyone in the path of the flow had their body burned to the bone in seconds.



Buried alive: 19th-century safety coffins

The Victorians took steps to avoid many people's worst nightmare

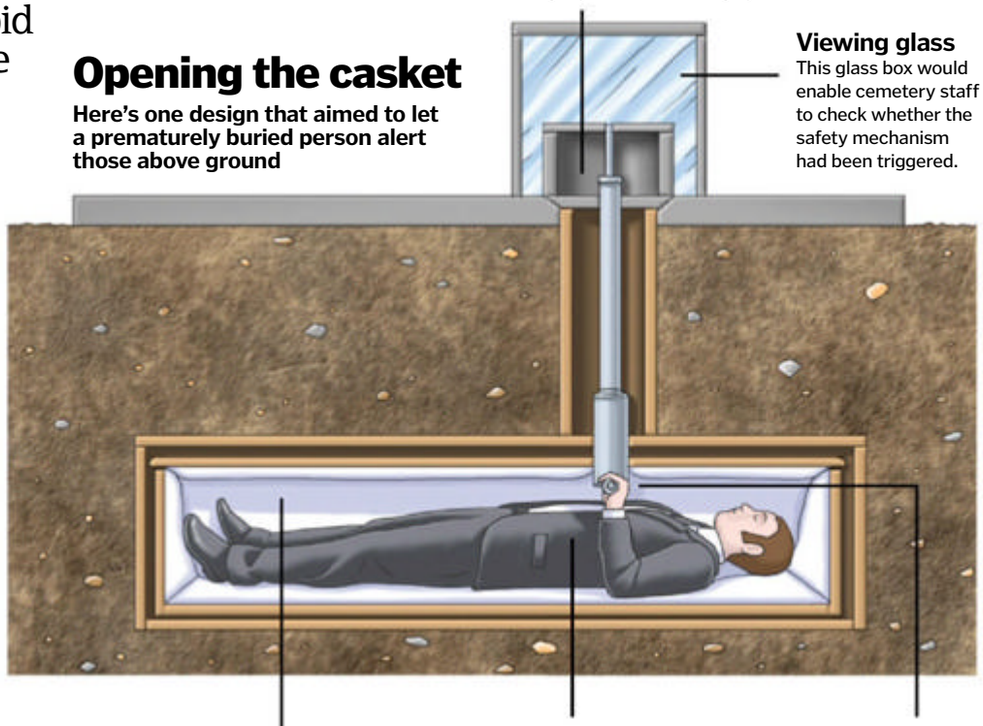
During the 19th century, the inaccuracies of medical practices meant there was a real risk of a living person being considered dead when they were not, leading to a premature burial. With techniques such as applying hot bread to the soles of feet and checking for a reaction used to determine death, it's not hard to imagine why.

A number of systems were proposed to act as safety coffins. One German system worked using bells, which were attached to the buried person at the head, feet and hands by rope. Bizarrely, a spring-loaded ejector coffin was also proposed, though it was considered to be too shocking to suddenly see a buried body thrown from the ground into a cemetery.

Although modern medicine can accurately say whether or not a person is dead, it would seem that not everyone is convinced. As recently as 1995, an Italian watchmaker Fabrizio Caselli built a casket fitted with a torch, an oxygen tank, a two-way microphone-speaker and a system to alert people above ground. Clearly the fear of premature burial is still alive and well.

Opening the casket

Here's one design that aimed to let a prematurely buried person alert those above ground



Sign of life
The object that would be pushed out into the viewing glass varied, although it would always be brightly coloured and highly visible.

Viewing glass
This glass box would enable cemetery staff to check whether the safety mechanism had been triggered.

Fatal flaw
One major flaw of safety coffins was their lack of an oxygen supply; victims would have suffocated quickly after burial.

Effect of decomposition
Soon after death, the body bloats, which could trigger the safety coffin mechanism, falsely alerting people above ground.

Mechanism activation
To operate the device, the person in the coffin simply had to push the handle upward toward the surface.

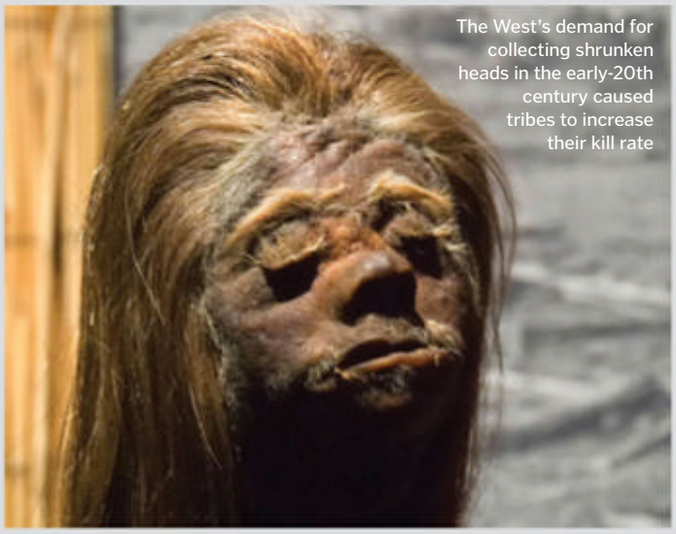
The process of shrunken heads

Find out how and why tribes of the Amazon rainforest shrunk the heads of their enemies

Shrunken heads are a somewhat alien concept to modern society, yet it is believed they were still being produced during much of the 20th century. The only recorded examples of head shrinking are in South America by Jivaroan tribes in Peru and Ecuador.

Tribesmen shrunk people's decapitated heads due to their belief of a vengeful spirit, or muisak, inhabiting the body. To stop this spirit and to gain power over the victim's soul, the hunters removed their enemies' heads and shrank them.

First, the warriors would remove the skin and hair from the skull, and seal the eyes and lips shut with pegs. The head skin would then be boiled for half an hour, shrinking it to around a third its original size. The eyes and lips were then sealed more tightly by being sewn shut with woven fibre. By filling the head with hot stones and sand through the hole at the base of the neck, it was possible to shrink it even further until the desired size was achieved. The finished product was typically worn around the warrior's neck, signifying victory in battle.



The West's demand for collecting shrunken heads in the early-20th century caused tribes to increase their kill rate

"Tribesmen shrunk heads due to their belief of a vengeful spirit, or muisak, inhabiting the body"

Why is Magna Carta so important?

Discover how this 800-year-old document made Britain the country it is today

It's a myth that Britain has never had a revolution. 800 years ago this year, on 15 June 1215, King John of England signed a document that was not only a revolution in paper, but the foundation for every uprising against the crown that followed and the cornerstone of democracy in the English-speaking world.

This document is *Magna Carta*. Meaning 'the great charter' in Latin, *Magna Carta* was the first time the king's power – which many believed came straight from God – had been restricted. Angered by the taxes levied by their unpopular king in order to fight an expensive and disastrous war against France, *Magna Carta* was mainly concerned with protecting the wealth and power of England's nobility, but the 3,600-word contract contained three important clauses that over the centuries that followed would profoundly alter English society: It guaranteed a fair trial for everyone, removed the king's ability to issue taxes at will and made it clear that if the monarch were to break the conditions of *Magna Carta*, he could be overthrown.

True to their word, when King John sneakily petitioned the Pope to overrule *Magna Carta* mere months after it had been signed, saying it conflicted with an earlier decree from the head of the church, the Barons went to war to protect their rights. This example would be followed time and time again to justify men standing up for their rights against the crown, most famously in the English Civil War and the American Revolution.

Five charter facts

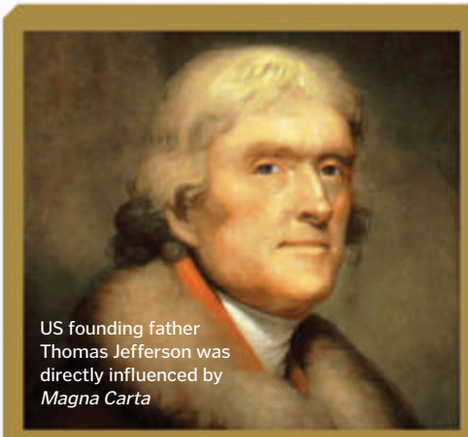
1 Latin literature
The whole document is written in continuous Medieval Latin, although later editions divided the points into 63 clauses.

2 A single author
The whole document was written by just one scribe who abbreviated some words to save space on the page.

3 Still on the books
Of the 63 clauses, three of them are still part of English law – defending the rights of the church, the rights of London and other towns, and the right to a fair trial.

4 Natural ink
Magna Carta is written in iron gall ink, made from the 'galls' of a tree (growths caused by fungus or bacteria), iron sulphate and water.

5 Parchment perfect
Magna Carta was written on a dried sheepskin parchment.



US founding father Thomas Jefferson was directly influenced by *Magna Carta*

Magna Carta in North America

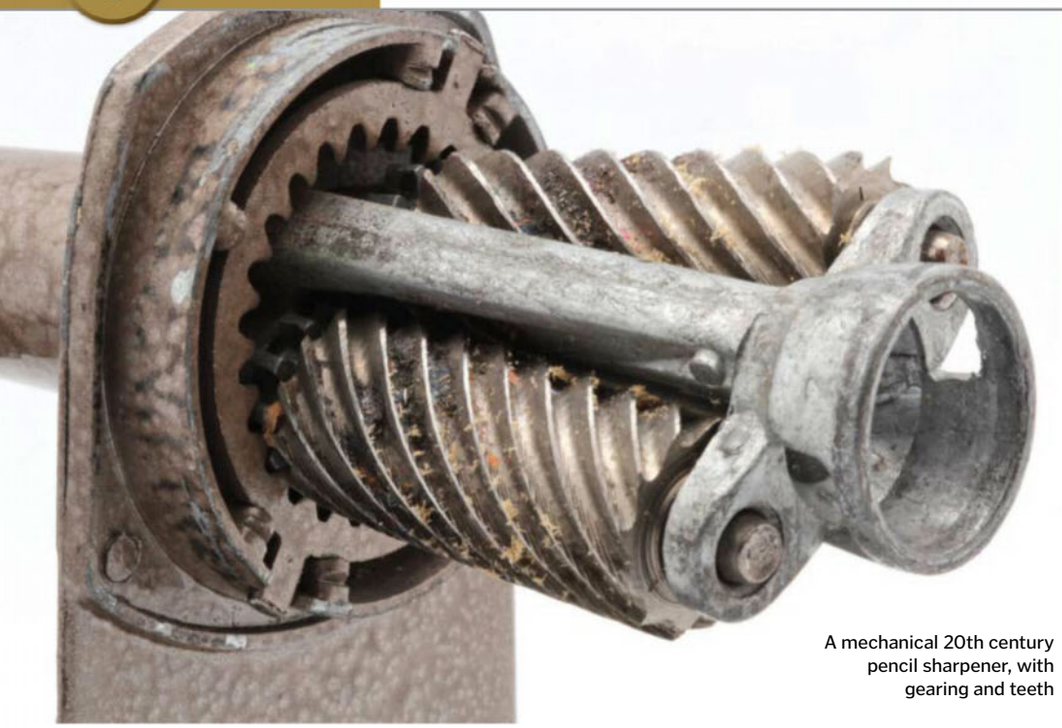
The rights of the free man against the tyranny of kings enshrined in *Magna Carta* didn't just give the American colonists reason to turn against George III and his unwanted taxation in the American Revolution, but it inspired them to write their own.

Both the 1776 Declaration of Independence and the 1789 Bill of Rights are influenced by the earlier document and nine of the provisions of the latter are taken directly from *Magna Carta*. Thomas Jefferson, one of the Founding Fathers and principal author of the Declaration, even owned a copy of English barrister Edward Coke's legal interpretation of *Magna Carta*, *Institutes of the Lawes of England*.

Magna Carta was revised by later monarchs and a copy from 1297 is permanently held by the US National Archives, displayed alongside the two documents it inspired as the birth certificates of the United States of America.

1215 edition
This is the one of the four surviving copies of the original *Magna Carta* issued in 1215. The charter was issued again in 1216, 1217, 1225 and 1297.

The king's seal
King John didn't 'sign' *Magna Carta* with his name, but with his royal seal, which was pressed into wax. Later versions of *Magna Carta* were signed by different monarchs.



A mechanical 20th century pencil sharpener, with gearing and teeth

Who invented the pencil sharpener?

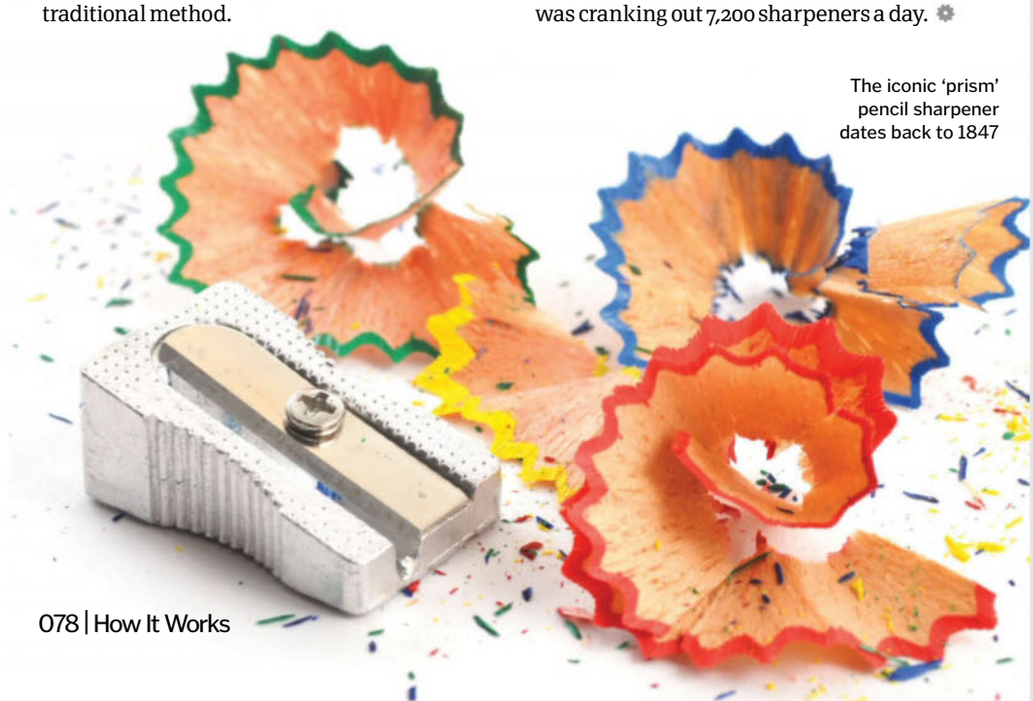
Discover the French engineers and the American tycoon behind the pencil sharpener

Although the exact origins of the pencil are uncertain, its growing popularity demanded a far less time-consuming and far more precise method of sharpening it than to slash away with a knife.

The first attempt came in 1828 from French mathematician Bernard Lassimone, who placed two blades at 90 degree angles on a block of wood, but this method of grinding down the pencil to a point wasn't any faster than the traditional method.

The mechanism we're familiar with today came in 1847 from another Frenchman, Therry des Estwaux, who invented a cone-shaped device with a single blade that when turned would neatly and evenly shave away at the pencil on all sides.

The French may have paved the way, but it was America that made waves. In the 1850s, US inventor Walter K Foster mass-produced a similar cone design and by 1857 his company was cranking out 7,200 sharpeners a day.



The iconic 'prism' pencil sharpener dates back to 1847

5 gruesome facts about ancient dentistry

Many ancient civilisations' solutions to toothache could be truly stomach-churning

1 Slow drill
The Indus Valley civilisation of modern-day India, Afghanistan and Pakistan would slowly and painfully drain the pus from an infected tooth using a bow drill, which was turned by a taut piece of string.

2 Tooth worms
The Sumerians – as well as many other ancient civilisations – believed tooth worms ate away at teeth, causing the holes we now recognise as tooth decay. Some dentists yanked out nerves thinking they were worms.

3 Roman ritual
Roman philosopher Pliny the Elder wrote that burning a wolf's head or a pig's trotters and popping the ashes in your mouth would sooth toothache. Amulets made from bone would also keep the pain away.

4 Mouse to mouth
Ancient Egyptians believed that slicing a dead mouse in half and placing it on the teeth or gums while it was still warm would cure toothache. They also made primitive replacements for lost teeth with shells or wood.

5 Winning smile
The Mayans of Central America and southern North America gave their teeth cosmetic upgrades, carving lines into them, drilling holes, filing notches or attaching gems.

A Mayan skull showing teeth decorated with jade

The Gothic chapel of Sainte-Chapelle

Built for King Louis IX, this church displays the finest example of Gothic stained glass

The Sainte-Chapelle, or 'Holy Chapel', was commissioned by King Louis IX of France more than 770 years ago. The reason? To house his most prized possessions – what was believed to be the authentic 'crown of thorns' worn by Jesus Christ at his crucifixion, as well as fragments of the Holy Cross. The king did not want these relics to become lost or separated, so he decided to buy them and build an appropriately elaborate church to display them in.

It is a truly stunning example of medieval architecture; nothing like this had ever been constructed before in history. The fact it was built between around 1241 and 1248 is even more incredible considering the Notre Dame took more than 200 years to build from 1163. The church walls act essentially as window frames for the 15 immense stained glass panels. The stained glass mainly depicts famous *Bible* stories, including parts from the *Old Testament* such as *Genesis* and *Exodus*. Also shown is the history of the holy relics, from their discovery by Saint Helen to their eventual arrival in the French Kingdom. Restorations of the stained glass in the 19th century remained faithful to the original designs, and further work is underway today in order to protect the glass from deterioration for years to come.

When we think of medieval architecture, many of us will automatically think of dark, dingy buildings. The Sainte-Chapelle defies this preconception, with a majestic design that shows off the power of light, embracing it to create a truly breathtaking church.

Church spire
This has been replaced on numerous occasions; one spire was destroyed during the French Revolution.

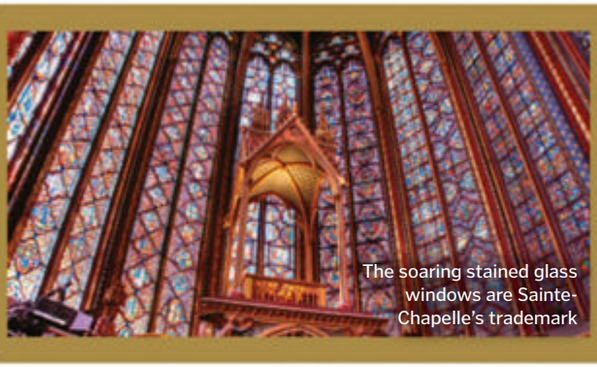
Engineering breakthrough
The thin walls between each glass panel were able to support the considerable weight by directing it toward their base.

Stained glass
Each window group has four lancets, with three rose windows above them.

Rose window
The inclusion of this window is characteristic of Gothic architecture, seen in many cathedrals of this age in northern France.

Stained glass preservation
Recently, an innovative layer of protective glass has been applied to many of the stained glass windows.

Lower chapel
This functioned as the parish church, serving everyone who resided in the royal palace.



The soaring stained glass windows are Sainte-Chapelle's trademark

Producing stained glass

Making stained glass to a high standard is much easier now than it would have been during the Sainte-Chapelle's construction in the 13th century. Throughout this period, glass factories were located in areas with a good supply of silica such as sand, an essential ingredient for the mix. The overall process was much the same then as it is today; first you mix the silica, potash and lime along with a metallic oxide, which provides the colour. This could be copper oxide, which can produce blue, green or ruby colours depending on the conditions. These ingredients are then heated in a furnace to around 1,371 degrees Celsius (2,500 degrees Fahrenheit), creating molten glass. This stage was problematic in medieval times, as creating this heat with the techniques available was a lengthy process and hard to maintain. The molten glass can then be rolled into thin sheets and left to cool before cutting to the desired size.

BRAIN DUMP

Because enquiring minds need to know...

Want answers?

Send your questions to...

How It Works magazine @HowItWorksmag

howitworks@imagine-publishing.co.uk

MEET THE EXPERTS

Who's answering your questions this month?

Luis Villazon

Luis has a degree in zoology from Oxford Uni and another in real-time computing. He builds steampunk gizmos and electronic gadgets, and his articles about science, tech and nature have been published around the world.

Laura Mears

Laura studied biomedical science at King's College London and has a masters from Cambridge. She escaped the lab to pursue a career in science communication and also develops educational video games.

Alexandra Cheung

Having earned degrees from the University of Nottingham as well as Imperial College, Alex has worked at many a prestigious institution around the world, including CERN, London's Science Museum and the Institute of Physics.

Sarah Bankes

Sarah has a degree in English and has been a writer and editor for more than a decade. Fascinated by the world in which we live, she enjoys writing about anything from science and technology to history and nature.

Shanna Freeman

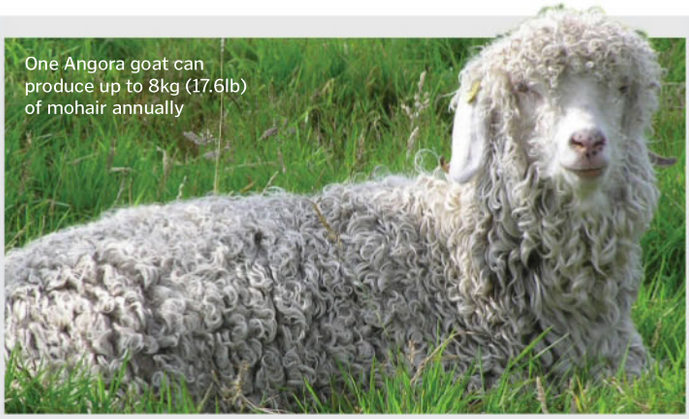
Shanna describes herself as somebody who knows a little bit about a lot of different things. That's what comes of writing about everything from space travel to how cheese is made. She finds her job comes in very handy for quizzes!

The Moon's surface is a very inhospitable environment

How long could a stranded astronaut survive on the Moon?

Kim Hamilton

■ How long a stranded astronaut could survive on the Moon would depend very much on the supplies they had with them, particularly oxygen. While the average human can survive for a few weeks without food and about three days without water, just 16 minutes of oxygen deprivation typically leads to irreparable damage to the brain and ultimately death within 30 minutes. The longest Moon mission to date was Apollo 17, during which astronauts spent 75 hours on the lunar surface. Had their lander been unable to return into orbit, they would only have had enough oxygen to last them a few days. If we return to the Moon for a longer mission, astronauts may extract water and oxygen by melting ice hidden deep inside the Moon's craters, allowing them to survive for much longer. **AC**



One Angora goat can produce up to 8kg (17.6lb) of mohair annually

What is mohair?

Kerry Foster

Mohair is a silky, luxurious textile produced from Angora goats. After shearing, the hair is spun into yarn, then knitted, crocheted, or woven onto a cotton backing. The name 'mohair' likely comes from the Arabic 'mukhayyar,' referring to a cloth made of goat hair. Mohair is a popular fabric because it can be easily dyed and is wrinkle resistant, flame resistant, and moisture resistant. It's also very durable and warm while being light. Mohair was so highly prized in Turkey that export of both the fabric and goats was restricted until the 1820s. **SF**

Why do mockingbirds mimic other birds?

Daniel Jessop

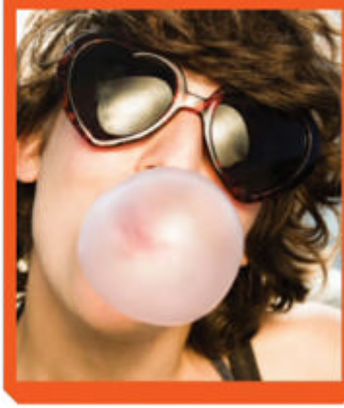
Mockingbirds are masters of mimicry – they've been caught imitating not just other birds, but also car alarms and bells, as well as other animals such as frogs and crickets. The mockingbird's gift for mimicry is actually critical to its survival. Variations in the singing of male mockingbirds are linked to the hormonal changes necessary to get the reproductive systems of both sexes ready for mating. If a male mockingbird has a wide repertoire, he conveys to females that he has an established territory and good survival skills. If you followed a male mockingbird for an entire mating season, you might record as many as 400 distinct songs. **SF**

The northern mockingbird is one of 17 mockingbird species

FASCINATING FACTS

Gum doesn't stay in your body for long

Assuming it is smaller than two centimetres (0.8 inches) in diameter, anything you swallow, including chewing gum, should pass through your stomach and into your small intestine within a couple of hours.



Why do you get a runny nose when you have a cold?

Joseph Newell

The common cold is most often caused by a type of virus called a rhinovirus, which mainly infects the cells that line the nose. The virus itself does very little damage, but the body mounts a strong immune response, which is responsible for the symptoms. Within 24 hours, your immune system is activated and white blood cells known as neutrophils are brought in to fight the infection. The virus triggers the release of a cascade of inflammatory mediators, which increase mucus production and cause the blood vessels in your nose to become leaky, and the extra mucus mixed with the extra fluid makes your nose run. **LM**

Talk to Siri and it will talk back, using your name

How does Apple's Siri know who I am?

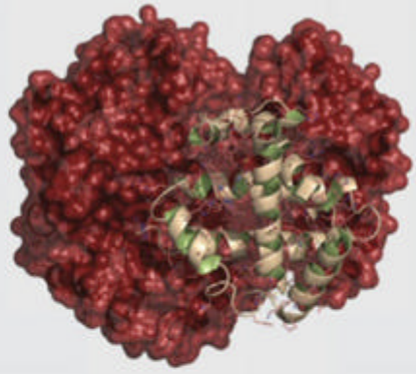
Freddie Stevens

Siri won't automatically know who you are. It's clever, but it's not that clever! You have to tell it who you are, but you only need to do this once, and it stores the details. Go into Settings and then General, then select Siri from the list. Scroll down to My Info and then enter your details. When you next talk to Siri, it should address you by name. It also uses your personal information to tailor answers to your circumstances. For example, if you ask what the weather is like, it will give you the local forecast. **SB**

Why do we need protein?

Jo Waldorf

Proteins form the molecular machinery that makes the human body work, from the structure of our muscles, skin and bones, to the digestive enzymes that break down our food. They are made from long chains, folded into three-dimensional structures, and are constructed using around 20 different building blocks known as amino acids. All living things use the same 20 or so amino acids, so we are able to use the proteins from plants and animals as a source for the building blocks we need to construct our own bodies. However, unlike fat and carbohydrate, the human body cannot store excess protein, so we need to eat it every day in order ensure a steady supply of the amino acids we need for growth and repair. The liver is able to convert some amino acids into others, but around eight of them are known as 'essential' and can only be obtained from our diets. **LM**



This protein, called haemoglobin, is responsible for transporting oxygen in the blood

BRAIN DUMP

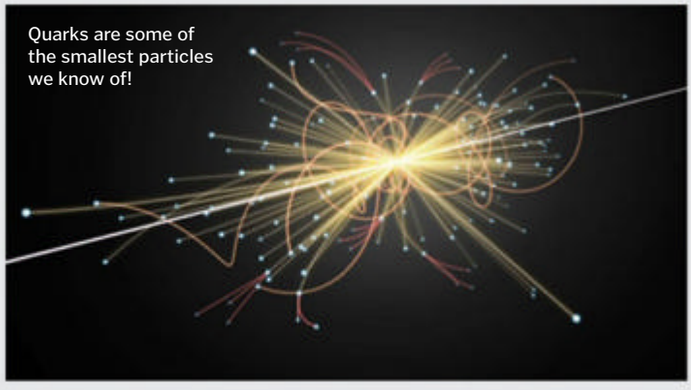
Among birds, the males are most often the biggest show-offs

Why are jungle birds more colourful than others?

Danielle Yeoman

Birds' bright plumage and beaks are nearly always there to attract mates. In most species only the male is brightly coloured and this is central to understanding how these colours evolved. Being colourful makes you more visible to predators, so a bright male has to be especially good at outwitting and outflying danger. A female chooses colourful males because they demonstrate how fit and healthy they must be to have survived that long. All her offspring, male and female, benefit from his superior genes and only the gaudy male offspring have to put up with the extra attention from predators.

In dense forest environments, there are enough places to hide that predators can't catch every single bird of paradise, so the mating advantage of bright colours is completely worth it. In more exposed environments, predation is a bigger immediate concern, so there it's more advantageous for both sexes to be camouflaged. **LV**



Quarks are some of the smallest particles we know of!

What is the smallest thing in the universe?

Yadira Martinez

The concept of size breaks down at the tiniest scales, but scientists think the smallest possible size for anything in the universe is the Planck length, about a millionth of a billionth of a billionth of a billionth of a centimetre across! **LV**

FASCINATING FACTS

The boat is almost a million years old

Palaeontologists believe modern man's ancestor Homo erectus built the first boats, using them to colonise the Indonesian island of Flores some 800,000 years ago.

Buckingham Palace is 312 years old

Buckingham Palace was built by John Sheffield, Duke of Buckingham, in 1703 as Buckingham House. King George III bought the house for Queen Charlotte in 1761, and after enlargements and remodelling it became the official royal residence in 1837.

OK is an American slang term

OK originates from the deliberately misspelt slang term 'orl korrekt' instead of 'all correct', used in the US in the 1830s. It's one of the many abbreviations used at the time that has survived to the modern day.

How does a camera's autofocus know when something is in focus?

Matt Lathan

There are two mirrors in an SLR camera, and you can change the orientation of these using the focus ring. A display inside the viewfinder allows you to see when the images from the two mirrors line up. Two electronic sensors are used to look at the views from the two mirrors. A computer chip inside the camera then takes the two images from the sensors and compares the pattern of light and dark to find where they overlap and therefore the distance of the object. The computer then tells the focus ring to turn to the right distance, focusing on the object. **SB**

Why do identical twins have different fingerprints?

Victoria White

Identical twins form when a single fertilised egg splits in two during the early stages of embryonic development, and as a result, the siblings share exactly the same genetic information. However, our bodies are shaped not only by our genes, but also by our environment, and although the twins share the same womb, their environments are subtly different. Each developing twin is in a different position, and experience slight variations in pressure and contact with amniotic fluid as they grow. One might have a longer umbilical cord than the other, and one might receive more oxygen or nutrients. Fingerprints develop during the second trimester of pregnancy, and these small differences add up to produce noticeably different fingerprints. **LM**

Some wasps don't look anything like bees at all

What's the difference between a bumblebee and a wasp?

Hannah King

Let's start with the similarities. Bumblebees and wasps are both flying insects belonging to the order Hymenoptera. And they are both yellow and black. That's basically it. Bumblebees are a group of about 250 species which are all members of a single genus, Bombus, they live in small social groups of 50 to 400 and they eat nectar and pollen. Wasps are a much larger group of 30,000 loosely related species. Nearly all of them are solitary predators that lay their eggs in the body of another insect. Only about a thousand wasp species are social and live in colonies, but these are the ones we tend to see most often. **LV**

Why are deserts so hot?

Ollie Gibson

Deserts contain almost no moisture, meaning the temperature can rise and drop very quickly, although not all deserts are hot. It takes much more energy to heat water than air, so in humid conditions, a lot of the Sun's energy is used to warm the water in the air and the ground. But when the Sun shines on a desert, all of its energy goes into heating the air and the ground itself, allowing them to grow extremely hot. However, most deserts cool dramatically overnight as there is not moisture present to retain heat. Many deserts form in subtropical regions, but there are also cold deserts at the poles. **AC**

Iran's Lut Desert is one of the hottest places on Earth

BRAIN DUMP

Basking in the sun is like morning coffee for an iguana

Why do lizards like to bask in the sun?

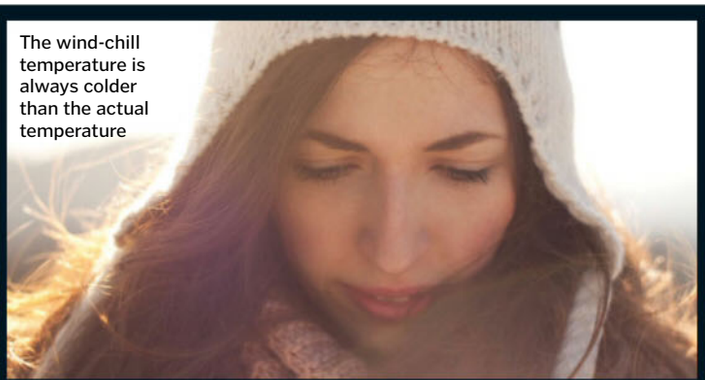
Gary Miller

Lizards are covered with scales, which are very good at preventing moisture loss, but pretty bad at keeping in body heat. Because of this, lizards and other reptiles don't try to maintain such a fixed internal body temperature as birds and mammals do. At night their body temperature drops, so in the morning they bask on a rock until the Sun has warmed them up enough for their metabolism to operate efficiently. This strategy restricts most reptiles to warmer countries, but it also allows them to get by with much less food than mammals. For example, some crocodiles can go for a year without eating. **LV**

Why are my feet always cold?

Ian Wallace

Cold feet are typically caused by reduced blood circulation. When your body is cold, it constricts your blood vessels, reducing blood flow to your skin in order to conserve heat around your internal organs. In some people this reaction, called vasoconstriction, is triggered even at relatively warm temperatures, leading to cold feet and hands. Cold extremities are quite common in cooler weather and are unlikely to indicate a medical condition. However, if they go white you may be suffering from Raynaud's phenomenon, a condition where arteries cut off almost all circulation to hands and feet in cold temperatures. **AC**



The wind-chill temperature is always colder than the actual temperature

What does 'wind chill' mean?

Brenda Li

The Met Office states wind chill is the 'feels-like' temperature. It's a perceived decrease in air temperature felt on exposed skin. The actual temperature might be five degrees Celsius (41 degrees Fahrenheit), but it feels more like zero degrees Celsius (32 degrees Fahrenheit). This is because any surface, including skin, loses heat through conduction, convection and radiation. The rate of convection depends on the difference in temperature between the skin and its surroundings. Convection from the skin heats the surrounding air and an insulating boundary layer of warm air forms against the skin. However, moving air, such as a breeze, disrupts this layer, and cooler air replaces the warm air against the skin so we feel colder. **SB**

Why do computers tell you to 'eject' USB drives?

Derek Elliot

Because some operating systems use 'write caching'. This is where the computer pretends your file has been saved immediately, but the changes are in fact just stored in working memory, and only copied to the disk in the background when things are less busy. If you pull the USB drive out while there are still write commands waiting in the cache, you could lose data. This is only a problem if you yank the USB drive out within a few seconds of your last save, and it doesn't apply to modern Windows computers anyway, because write caching is turned off for USB drives by default. **LV**

Fingertips wrinkle in the bath because the blood vessels under the skin constrict

Why do fingers and toes wrinkle in water?

Alex Parker

After a long soak in a hot bath, your fingers and toes often become wrinkled, and many people incorrectly assume this is because the water has soaked into their skin, making it swell. However, an experiment performed in the 1930s showed this strange phenomenon only occurs if the nerves feeding the fingertips are functioning properly, and it is now known that the wrinkle response is actually caused by blood vessels under the skin constricting.

Car tyres have a tread that helps to channel water away from the surface, enabling them to grip to the road in bad weather, and some scientists think we might gain a similar advantage when our fingers and toes wrinkle up in the wet. **LM**

Noise-cancelling headphones cancel out surrounding sounds without interfering with the music you want to hear

How do noise-cancelling headphones work?

Michael Bird

All sound, whether music or general background noise that interferes with our music, is compression and rarefaction of the air around us. Noise-cancelling headphones work thanks to the materials they are made of, which block out unwanted noise. Passive noise-cancelling headphones, such as circumaural headphones, maximise noise-filtering properties by being packed full of sound-absorbing material, such as high-density foam. This makes them heavy, but blocks out interfering noise, such as that of an engine. Active noise-cancelling headphones go a step further and actually erase lower-frequency sound waves. They contain a tiny microphone that listens to the ambient noise. Their internal electronics measure this and create a noise-cancelling wave that is 180 degrees out of phase with the intruding waves, or ambient noise. This wave cancels out the annoying 'surrounding' sounds without erasing the audio that you want to hear through the headphones. These headphones can reduce noise by a further 20 decibels. **SB**

Why does my eye sometimes twitch?

Derek Elliot

Involuntary contractions in the muscles around the eyes are caused by minor malfunctioning of the surrounding nerves and muscles, often brought on by tiredness, stress, or caffeine intake. For instance, stress and caffeine both cause your body to produce epinephrine (adrenaline), a molecule that prepares your heart and muscles for action. In this state of heightened arousal, muscle contractions are more likely to be triggered involuntarily. These twitches can also be caused by fatigue or even eye strain from the overuse of screens or not wearing glasses if you need them. Eye twitches – technically known as blepharospasm – are usually harmless, almost always disappearing of their own accord. **AC**

Why are eggs egg-shaped?

Cody Morgan

Eggs have evolved to be egg-shaped – known as an asymmetrical tapered oval – for a few reasons. The shape makes it easier for the hens to lay the eggs, as their cloacae (the vent through which hens pass eggs, as well as waste) muscles find more surface area on the tapered end. An egg's shape also makes it less likely to roll out of the nest, because it will make a circular path when it rolls. Finally, the shape also means more eggs can fit into the nest and that they can fit snugly together to stay warm. **SF**

How does antibacterial soap work?

William Tucker

Antibacterial soaps are cleaning products that contain agents designed to kill or slow the growth of microorganisms, in order to prevent the spread of bacterial contamination. One of the most common antimicrobial ingredients in antibacterial soaps is triclosan. Originally used in hospital settings only, triclosan is found today in the majority of liquid antibacterial soaps on the market. In commercial products, triclosan essentially kills bacteria by stopping the growth of its cell membranes. Although antibacterial soaps are in wide use, they've become controversial in recent years. Some researchers believe they haven't been proven to be any more effective in reducing bacteria than properly washing with regular soap and water. Antibacterials have also been accused of contributing to the rise in antibiotic-resistant bacteria, potentially causing devastating health problems. Because of this, regulatory agencies are taking a closer look at antibacterial soaps and other products. **SF**

New Brain Dump is here!

Don't miss issue 24 of **Brain Dump**, the digital sister magazine to **How It Works**, when it lands on the virtual newsstand on 1 May. You'll discover whether goldfish have short memories, why clouds are white, what those packets of silica gel really do and more! Each issue is packed with amazing images and loads more trivia snippets for you to get stuck into, giving you the knowledge hit you need without having to lug an encyclopaedia around! Download the new issue of **Brain Dump** on the first day of every month from iTunes or Google Play. If you have a burning question, you can ask at **www.facebook.com/BraindumpMag** or Twitter – the handle is **@BrainDumpMag**.

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Running technology

Whether you're a fun runner or a marathon man, the latest running tech has a lot to offer

The thought of running may send shivers down the spines of some, but for many it's a regular, fun activity that keeps them fit and healthy. There is a vast array of sports technology available on the market, and running is no exception. These brilliant accessories will keep you logging the miles for longer.

Checklist

- ✔ Running trainers
- ✔ Headphones
- ✔ Socks
- ✔ Hydration pack
- ✔ Cap
- ✔ Smartwatch

Hidden bladder
The bladder sits in its own compartment, separate from the main storage, so you can access it without emptying the backpack.

LED visibility
The LED lights are a great addition, ensuring you are highly visible.

Fit clip functionality
The fit clip and cable design adjusts for optimal fit, securely holding the headphones in place without reducing comfort.

Socially fit
With the help of Garmin Connect, you can review, replay and share your workouts online for free.

1 Salomon Agile 12 Set Running Backpack

£79.99 / $119.99

www.sportsshoes.com

This 12-litre (3.2-gallon) pack is designed for trail running. It contains a 1.5-litre (0.4-gallon) bladder to keep you hydrated on longer runs; great for the coming warm weather. It manages to spread its weight evenly when you wear it, which makes it very comfortable to use. The multiple tassels that hang off it can be annoying when you run, however, and would benefit from being tidied up.

Verdict: ●●●●○

2 Salomon Night Cap

£35 / $35

www.salomon.com

The Night Cap from Salomon is ideal for anyone who enjoys a run after dark or early in the morning. It fits comfortably on the head and is nice and lightweight. The three integrated LED lights on the back ensure that you will be visible to motorists at all times. The only drawback is the price.

Verdict: ●●●○○

3 Jabra Sport Wireless+

£79.99 / $99.99

www.amazon.co.uk

These clever headphones won't fall out as you run, thanks to the strap and fit clip, which secure them in place. This simple strap design performs very well and is much more comfortable to wear than headphones with a rigid headband. Three months' free Endomondo premium (a personal trainer in your pocket) is also a big plus. The headphones sound good, and for the price, they are tough to beat.

Verdict: ●●●●●

4 Garmin Forerunner 210 Watch

£179.99 / $249.99

www.garmin.com

The Forerunner 210 from Garmin is an essential accessory for any serious runner. It occasionally finds difficulty in connecting with a satellite (taking up to two minutes), but once connected it stays locked on. It copes well whether you're doing a pace run or interval training. The option of the added heartrate monitor is also welcome. If you are looking for analysis during and after your run, the Forerunner 210 will provide the answers.

Verdict: ●●●●○

Adaptive BioMoGo DNA
This technology helps the shoe to provide adaptive cushioning depending on the owner's running style.

EXTRAS

More fit stuff to keep you running

BOOK

The Art of Running Faster

£13.99 / $19.95
www.amazon.com
Going out for a run is one thing, but improving your technique, training and speed is another. This book aims to help those who are looking to do more than just keep fit with a spot of jogging; it endeavours to help improve its readers' overall running ability.

APP

Nike+ Running

Free
iTunes / Google Play
This clever app from Nike works on road, trail or treadmill runs, accurately recording all features of your run including pace and distance travelled. It even lets you load a "Power Song" for when you need extra encouragement to keep going.

WEBSITE

runnersworld.co.uk

Runner's World has an abundance of great information for runners, whether you're interested in the latest gear or in finding out where you can compete. It even has injury clinics and forums to discuss running.

Sticky rubber outsole
The shoe's outsole is composed of a durable, tacky rubber, allowing for excellent traction on any surface.

5 Brooks PureConnect 4

£100 / $100
www.milletsports.co.uk
The PureConnect 4 from Brooks is designed as a lightweight running shoe. They test exceptionally well, feeling more like an extension of the body rather than a new, alien running shoe. They instantly feel fast, enabling nimble movement from the off. They also perform very well on hills. Overall these shoes are very good; and are worth the money if you're a serious runner.
Verdict: ●●●●○

6 New Balance Minimus Zero Trail v2

£80 / $109.99
www.newbalance.co.uk
The Minimus Zero Trail v2 shoes are designed for those who want to leave the monotony of the road and hit the trails. The extra large lugs on the soles provide exceptional traction, spaced wide enough so that stones and dirt don't clog them up. New Balance shoes come up quite small, so try them on before you buy.
Verdict: ●●●●○

7 1000 Mile Breeze socks

£11.99 / $17.95
www.1000mile.co.uk
If you're of the opinion that all socks are basically the same, the 1000 Mile Breeze socks may well change your mind. The Breeze model is truly brilliant at keeping your feet feeling fresh while running; the difference between wearing these and a traditional sock is drastic. Even if you're still sceptical, at such a reasonable price they are worth trying.
Verdict: ●●●●○

Padded heels and toes
The padding at the heels and toes provides excellent shock absorption and additional comfort for the user.

GROUP TEST

Putting products through their paces

Sat navs

Find your way from A to B with these clever car devices

Points of interest
Scroll through lists of nearby popular locations to find somewhere to go.

Voice packs
Download novelty voices onto your TomTom to get directions from Yoda or Homer Simpson.

Bluetooth compatible
Sync the device with your smartphone to make and take hands-free calls while driving.

1 Garmin nüvi 2599LMT-D

£179.99 / $269.99

www.garmin.com

The sleek Garmin sat nav blends in nicely with your car dashboard and can be used horizontally or vertically depending on your personal preference. It comes loaded with detailed maps and Garmin's Digital Traffic software, with regular free updates at no extra cost and plenty of other features for your money.

It's quick and simple to set up using the bright and responsive touchscreen display, or you can give voice commands for hands-free operation. Finding nearby points of interest (POI) is easy thanks to information on popular locations sourced from Foursquare. If you connect to the free Smartphone Link app on your phone, you can even check in, find more information about the POI and, after your visit, get help finding where you parked your car.

Instructions are clear and on-screen animations show you what lane to be in when approaching a junction and how far it is until the next service station, and the verbal commands give you simple directions based on recognisable landmarks, so you don't need to worry about having to squint looking for street names.

Verdict:

2 TomTom Go 5000

£259.99 (approx $390)

www.tomtom.com

The curvaceous TomTom sat nav may be the most expensive on test, but it does come with lots of handy features. As well as a lifetime supply of maps and TomTom traffic info, it also includes a SIM card with unlimited data, giving you real-time traffic and weather updates to help plan your route. Speed-camera information is also provided, but at an extra cost, and you can report new cameras you come across with a simple tap of a button.

While driving, an on-screen sidebar counts down the distance to upcoming petrol stations and speed cameras, with coloured alerts to indicate your own speed. Lane guidance is also provided when approaching junctions, while 3D maps show nearby buildings and landmarks so you know exactly where you are.

Searching for your desired destination is fast, as the responsive display instantly shows a list of locations when you start typing. You can also give voice commands, which proved very efficient during our test, or input coordinates if you want to be really specific.

Verdict:

3 Binatone U605

£54.99 (approx $82)

www.amazon.co.uk

The budget-bracket Binatone has a huge 15-centimetre (six-inch) screen, which can obstruct your windscreen view a little. However, it does provide a clear map display, with large buttons and on-screen instructions. The device feels a little cheaply made and even the supplied stand is a little unstable, but it's suitable for its lower price point.

Getting set up is a slow and laborious task, as you have to go through several menus before you can start navigating. The maps also take a while to load, it can be slow to find GPS signal and the touchscreen isn't the most responsive. Voice control is available for hands-free operation, though, and the verbal commands from the device are clear and informative.

Useful features including three-dimensional map views and lane guidance at junctions are included, but there is little in the way of traffic alerts, which can be found even on free smartphone apps. However, lifetime map updates and speed-camera alerts are available, and so the device should suffice for most drivers' basic needs.

Verdict:

BUDGET NAVIGATION

The sat navs that won't break the bank

TomTom Start 40

With prices starting from £99.99 / $119.99, TomTom's smaller-grade sat navs come with an easy-to-use interface, a lifetime supply of map updates, advanced lane guidance and quick search options.

Garmin nüvi 55

This easy-to-use 13cm (5in) sat nav still has plenty of useful features, such as lane guidance and speed camera warnings, but prices start from just £89.99 / $119.99.

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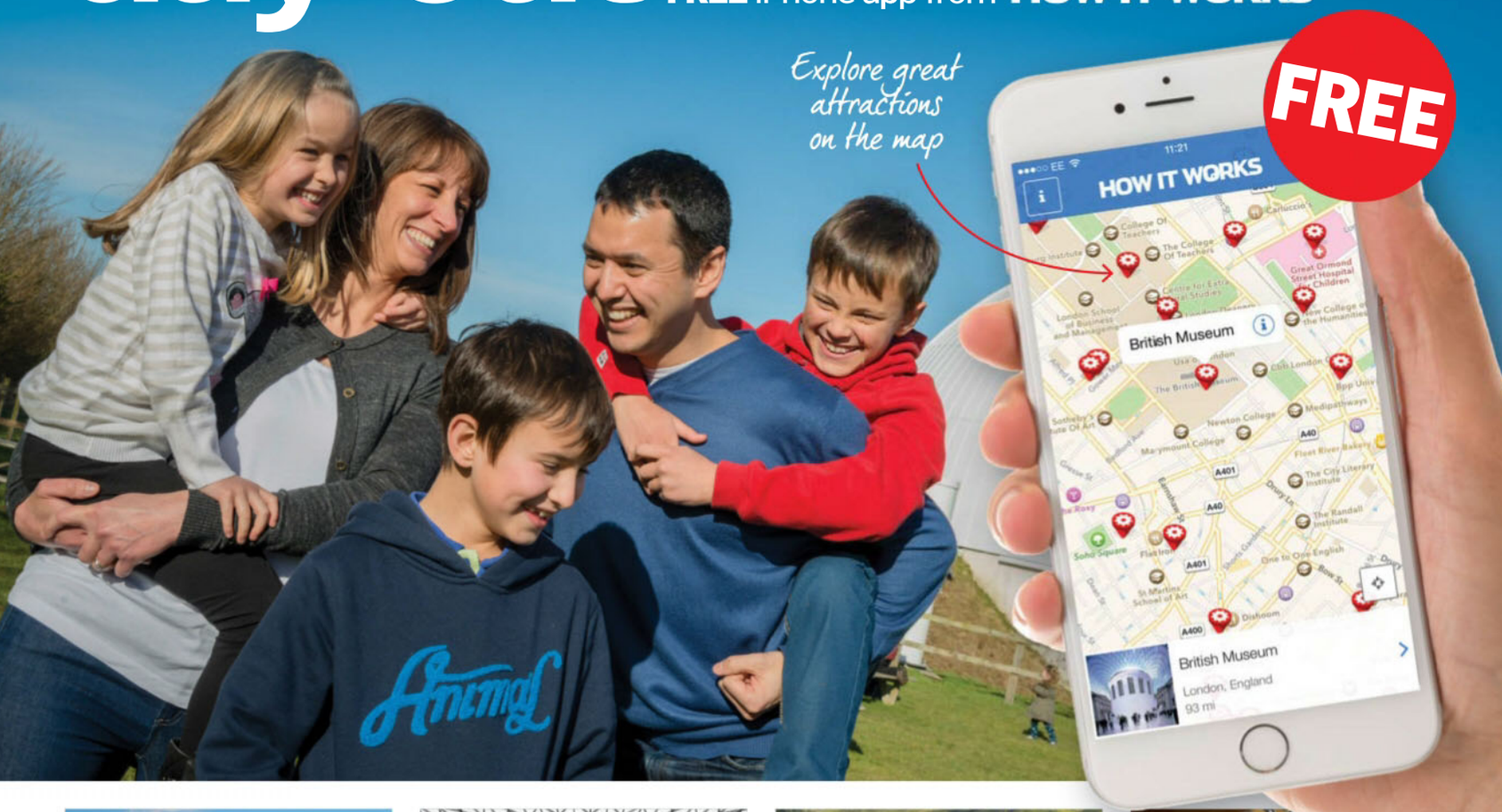


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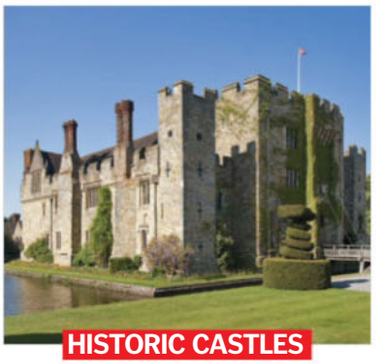
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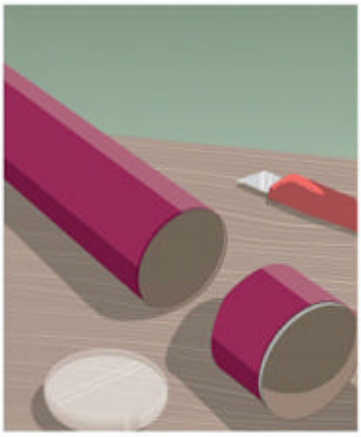
Make a pinhole camera

Turn an empty Pringles tube into a simple camera



1 Cut your tube

With the aid of a ruler, measure five centimetres (two inches) from the bottom of a crisp tube and mark this distance with a pen. Repeat this around the tube and then join up to marks so that you create a line that goes all the way around it. Carefully cut along this line, separating the tube into two separate pieces.

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

2 Make your pinhole

You then need to make a hole in the centre of your crisp tube's metal base. There are several techniques for achieving this; whichever one you choose needs to be able to create a very small, smooth hole. We recommend tapping a pin with a heavier object, but making sure to twist it as you push it through the metal, creating smooth edges. This pinhole is an example of a camera's aperture.

3 Design your viewing screen

Now to create your viewing screen, which acts as the film. Cut out a circle of waxed paper, making it slightly bigger than the tube's base, and tape it on top of the short part of the tube. The image you'll eventually see here will be inverted and reversed, as the light rays cross over when entering the camera. Reform your crisp can by taping the two pieces back together.

4 Make it 'light-tight'

A pinhole camera relies on the premise that the only light entering it is through the pinhole. This means light must be unable to penetrate the camera's body. To make it 'light-tight', wrap the camera in aluminium foil. It is worth wrapping the camera several times in foil to guarantee it blocks out all light, and taping it to the camera to ensure it stays intact.

5 Finishing touches

The final part of the camera requires a piece of thick black card. Roll the card into a cylinder and place it halfway into the top of the camera. This helps to shield the camera's eyepiece from any light, which will improve the visibility of the image the camera creates. To use your camera, simply place an object under a bright light and point the pinhole end at it. You will then see a colour image on the viewing screen within the camera.

In summary...

This experiment provides an excellent insight into a camera's origins, and can be carried out using readily available household materials. The images you see as you look through the camera will be upside down and back to front because of the way light travels through the tiny gap.

NEXT ISSUE
- Make pH paper
- Skim a stone on water

Create recycled paper

Take your unwanted mail and turn it into original handmade paper

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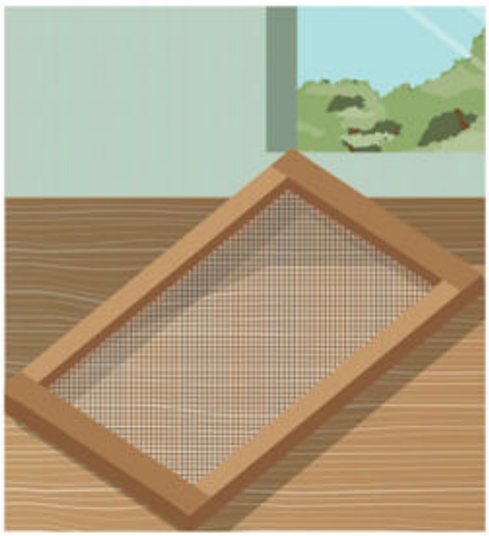
IF YOU'RE UNDER 18, MAKE SURE YOU HAVE AN ADULT WITH YOU



1 Make your deckle

The first step required to make your own paper is to construct a deckle, which functions to strain the paper pulp you will create in the next stage. Use staples or thumbtacks to fasten strong netting on one side of a wooden frame. Another potential deckle design involves stretching a piece of nylon stocking over a sturdy hoop, such as an embroidery hoop. This would also function well as a pulp strainer.

2 Form your pulp mix

Shred your paper into rough chunks; you'll need enough to fill your blender by half. Add warm water until the blender is full, and then blend until it forms a pulp, free from large chunks of paper. Blending helps break down the paper's cellulose fibres. Decant your pulp into a large plastic container and add another blenderful of warm water and mix, which helps bind the broken fibres. You can now add food colouring to create coloured paper.

3 Create your paper

Place your deckle into the plastic container with the screen submerged just below the pulp's surface, allowing an even collection of pulp on top of the screen. Remove the deckle and gently shake it to drain most of the water. A sponge can also be used to remove excess water. Carefully press a clean kitchen towel on the paper, pull it away from the screen and let it dry before peeling it from the towel. If the paper is too thin, add more pulp; if it is too thick, add more water.

In summary...

This fun experiment will require some trial and error to perfect, but it is an excellent way of making something interesting and handmade out of unwanted waste paper. Try adding some dried grass or thread into the pulp mix to give your paper an unusual texture.

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AMAZING PRIZE FOR NEXT ISSUE'S LETTER OF THE MONTH!

CHARGE YOUR TECHNOLOGY WITH SALT AND WATER

The myFC PowerTrekk 2.0 is a portable fuel cell that can power various devices using just water and an aluminium puck containing salt. It can charge your battery within a couple of hours!

Letter of the Month

Digital drug testing

Dear **HIW**,
Researchers at the Biomaterials Innovation Research Center in Boston, USA, have created a digital system that can replicate how organs react to drugs. It promises to speed up the testing of new drugs and see if an unknown substance could be toxic to humans. By connecting multiple 'digital organs' together the device can more accurately model real reactions produced by the human body. I'm curious to know why it is so expensive and why it takes so long to create?
Isobel Thornton

This really is a fascinating technological development, Isobel. Although much research into the effect of drugs has been carried out, the potential to test new drugs synthetically using a digital system opens the door for tests that can't be carried out on a human.

An example of this would be testing the effect of a combination of illicit drugs, as there is currently much interest into the additive effect caused by combining multiple substances, for example cannabis and alcohol. There are many reasons why technology such as this is so expensive to create. For it to be considered relevant and accurate within its field, any tech will need to be tested repeatedly. This requires numerous expensive resources, such as the latest laboratory facilities.

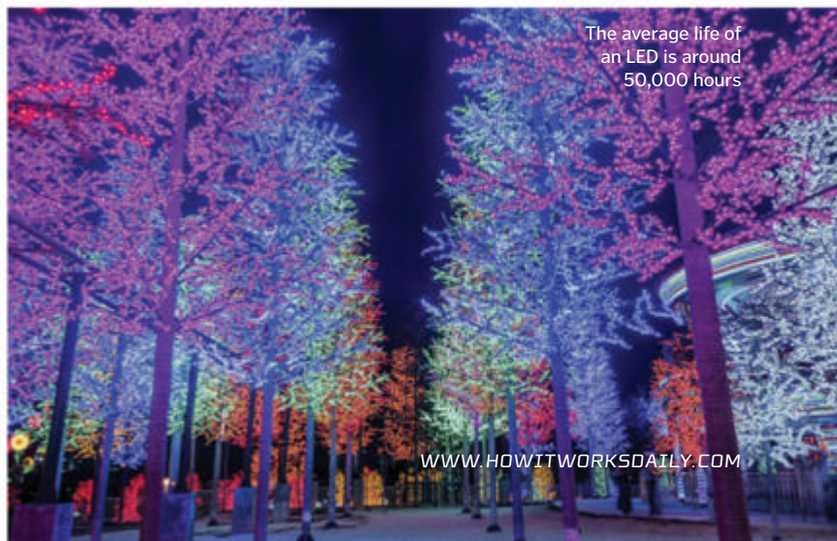
One resource that will definitely be needed is time. For this technology to gain scientific recognition, it will need to show it identifies the effects we know to occur with certain drugs that already exist. Only then will it be ready to test new drugs that are yet to be studied.

This technology aims to eradicate the need for animal drug testing

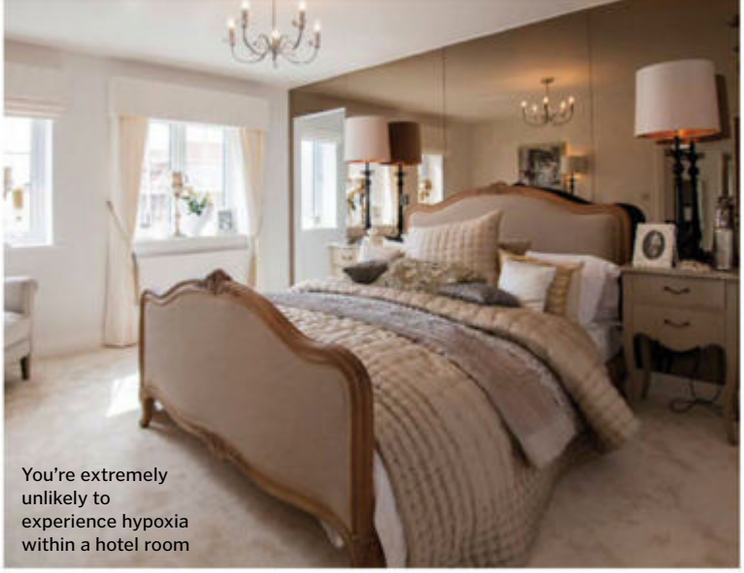
Multicoloured LEDs

Dear **HIW**,
I'm coming up to a fact-filled fourth year of **How It Works** and I have loved (and treasured) every single issue, keeping them all stacked in their own special drawer in my room! When designing my GCSE Electronics project I discovered you could get various types of multicoloured LEDs, and I was wondering how they worked? I understand the concept behind single-coloured LEDs and surely it cannot be the same? **How It Works**, you are the perfect people to ask. Hopefully you can help (and I can end up in your magazine).
Thanks,
Harry Buttle (age 15)

Thanks Harry! It is possible to have both a colour-changing LED and a multicoloured LED. Colour-changing LEDs operate by combining three small LEDs, which are controlled by a small computer. Multicoloured LEDs operate by a very interesting method. The semiconductor materials within the LED can be designed in such a way that they can limit the amount of energy capable of flowing through them. This has the effect of altering the colour of the light, which gives a multicoloured LED.



The average life of an LED is around 50,000 hours



You're extremely unlikely to experience hypoxia within a hotel room

Hotel-room hypoxia

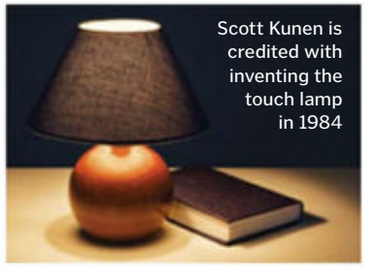
Dear **HIW**,
If I was in a hotel room where you cannot open the windows, the door has a good seal and the air-conditioning is switched off, would it be possible to use all the oxygen and contract hypoxia?
John Ray

Hypoxia can be defined as a low concentration of oxygen within the arterial blood and can occur when respiration is interrupted. This would require a completely airtight room, an extremely tall task. Air is amazingly good at findings its way through any gap, such as tiny cracks in walls. If we assume the room is airtight, the biggest danger is not a lack of oxygen, but carbon dioxide poisoning. The carbon dioxide we breathe out is 100 times the concentration found in the air. High carbon dioxide levels will lead to convulsions and eventually death.

"Colour-changing LEDs operate by combining three small LEDs, controlled by a small computer"

How touch lamps work

Dear **HIW**,
Touch lamps have always fascinated me, particularly how by just touching them you can turn them on. Can you tell me how they work?
William Tucker (14)



Scott Kunen is credited with inventing the touch lamp in 1984

Our bodies possess a number of different properties that can be used to manipulate touch technology. Most touch lamps use capacitance, which is an object's ability to hold on to electrons. When you make contact with a touch lamp, your body adds to the lamp's capacity. A larger number of electrons is required to fill both the person touching the lamp and the lamp itself, which is detected by the circuitry, and switches on the lamp.

What's happening on... Twitter?

We love to hear from **How It Works**' dedicated followers. Here we pick a few tweets that caught our eye this month...

treboreuk
@HowItWorksmag polar bears don't eat penguins... because they can't get the wrapper off

LATay18
Call me a nerd all you like but look what came! **@HowItWorksmag** volcanoes and earthquakes

librarynewhall
We've just started subscriptions to **@WorldAnimalsMag** and **@HowItWorksmag** – I think they will be VERY popular!

BarretCole
@HowItWorksmag #RichardHammond great interview <3 science of stupid

NorwichTony
@HowItWorksmag love How it Works it's so addictive

kazsugarman
Loving this month's **@HowItWorksmag** #brainfood

HeadPlants
@HowItWorksmag **@AboutHistoryMag** my children love these magazines, excellent, thank you :)

jdpjamesp
@HowItWorksmag Elephants are the only mammals, besides humans, to have chins.

LouiseWhittake6
@HowItWorksmag Chester Zoo is a great day out

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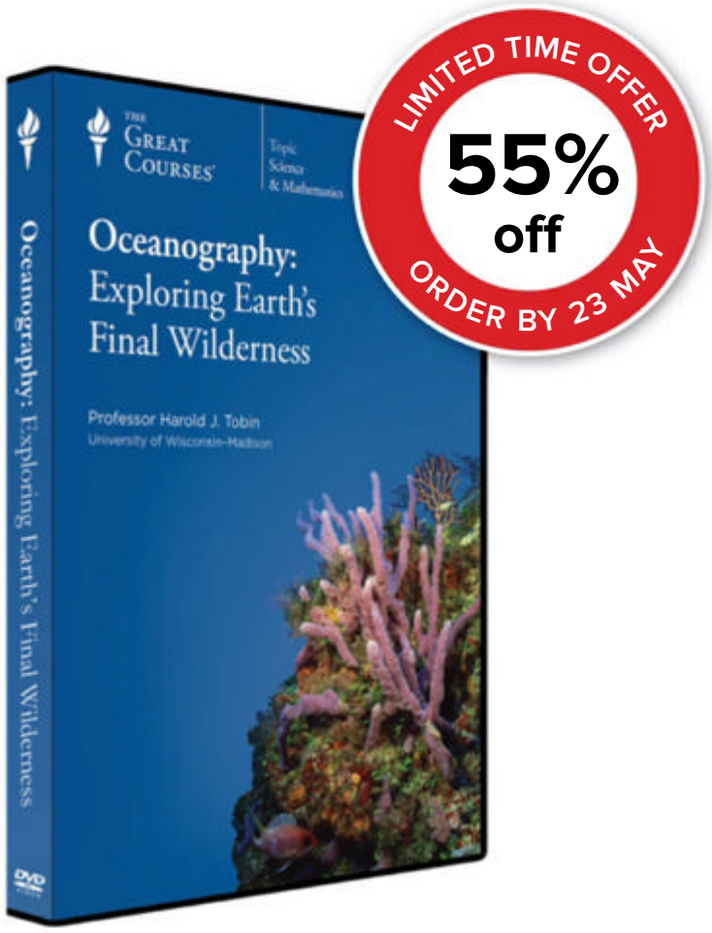

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