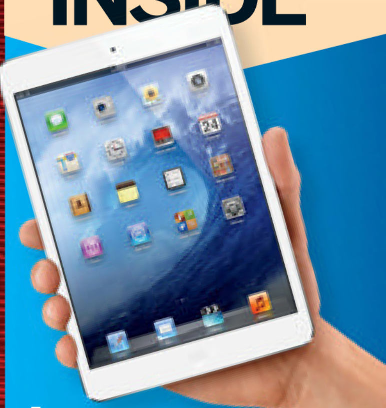
THE MAGAZINE THAT FEEDS MINDS

HOW IT WORKS

SCIENCE ENVIRONMENT TECHNOLOGY HISTORY SPACE ™

INSIDE



iPAD MINI
HOW APPLE MADE ITS TABLET EVEN SMALLER

25 FACTS ABOUT EARTHQUAKES
Your top tectonic questions answered by our experts

EXPLORING THE OUTER PLANETS
How space probes are uncovering the farthest reaches of the Solar System

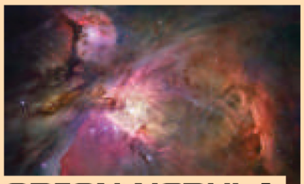
INDUSTRIAL REVOLUTION
HOW THE STEAM AGE CHANGED THE WORLD

- Mass production
- Steam power
- Global travel
- Electricity
- Pioneering inventions & more

EDISON

BRUNEL

AMPHIBIOUS VEHICLES
How cars, planes and even tanks are made seaworthy



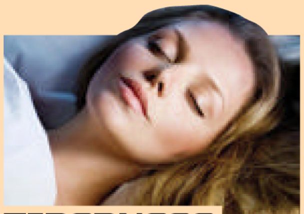
ORION NEBULA
Why is this star cloud visible to the naked eye?

+LEARN ABOUT
- LIGHT & COLOUR
- HOOVER DAM
- HARD DRIVES
- ICE RINKS
- PENGUINS
- OVARIES

www.howitworksdaily.com

ip IMAGINE PUBLISHING
ISSUE 41 £3.99
41 >
9 772041 732004

PLANTS
How do flowers create scent to attract insects?



TIREDNESS
How does your body tell you when to go to sleep?

HOW IT WORKS

ISSUE 41

WELCOME

The magazine that feeds minds!

Get in touch

Have YOU got a question you want answered by the How It Works team? Get in touch via...

HowItWorksMagazine
howitworks@imagine-publishing.co.uk
www.howitworksdaily.com
@HowItWorksmag

WEBSITE

APP

BOOKAZINES

eBOOK

FEED YOUR MIND

This issue we celebrate THE most significant era of technological and scientific advancement. A time during which our planet witnessed a concentration of innovation and engineering mastery the likes of which had never been seen before. It's difficult to imagine a world in which steam power and electricity never existed, nor a time when crossing the Atlantic would have equated to a perilous voyage of discovery and yet before the Industrial Revolution these things just weren't possible. But with the rise of the machines and the progression of science came a new dawn of prosperity and knowledge.

We explore not only how all the key inventions and contraptions worked, but also take a look at the main people ringing the changes. Find out about the pre-eminent engineer Isambard Kingdom Brunel, learn how great minds like Thomas Edison innovated, and ask where we would be if James Watt hadn't reinvented the steam engine. As you can see from this issue's specially commissioned cover illustration, in this edition of the magazine we're celebrating a rather special time for science and tech – the golden age of how things worked.

Enjoy the issue.

Helen

Helen Laidlaw
Editor

Meet the team…

Dave
Ed in Chief
As a big Bond fan, I couldn't wait to dive into the article about amphibious vehicles – I just wish I had one now!

Robert
Features Editor
Writing the feature on the Industrial Revolution was a real pleasure. I'd love to have seen 1851's Great Exhibition.

Ben
Features Editor
To think one day soon we'll be looking beyond our Solar System thanks to space probes is mind-boggling.

Adam
Senior Sub Editor
Having been in Japan when the 2011 earthquake struck, it was fascinating to read about the science behind it.

The sections

The huge amount of info in each issue of How It Works is organised into these sections:

HISTORY
SCIENCE
ENVIRONMENT
SPACE
TRANSPORT
TECHNOLOGY

CONTENTS

The magazine that feeds minds!

MEET THE EXPERTS

Find out more about the writers in this month's edition of How It Works...

Luis Villazon
Super-thin TV screens

This issue How It Works regular Luis takes you on a virtual trip behind the glass in our Technology feature looking at the thinnest OLED TV screens in the world and how they differ from other televisions.

Vivienne Raper
25 Earth-shattering facts

Looking at everything from tsunamis to quakes in outer space, geophysicist Vivienne reveals the answers to all your tricky tectonic quandaries in this issue's big feature on earthquakes.

Freddie Harrison
iPad mini

Hot on the heels of the iPhone 5 we examined last issue, Apple expert Freddie, from iCreate magazine, is tearing apart the new pint-sized iPad and revealing how it hasn't compromised on performance.

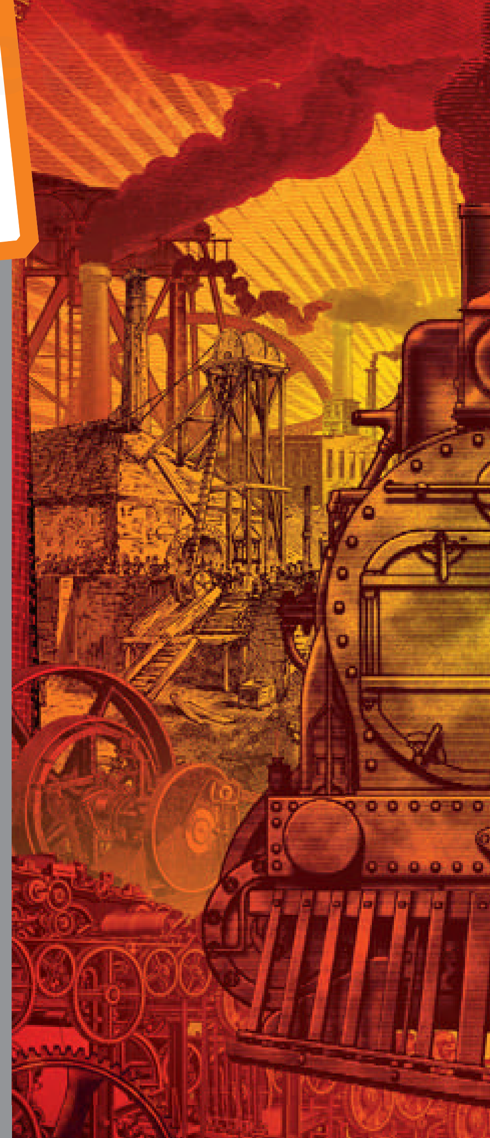
Dave Roos
Amphibious vehicles

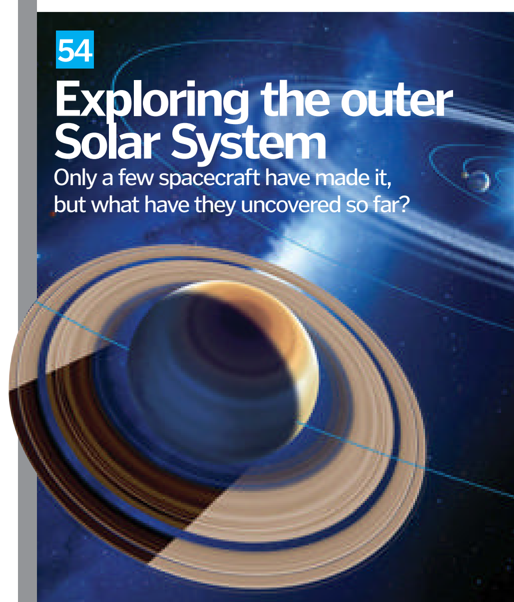
From the armoured tank that thinks it's a boat to the James Bond-like car that thinks it's a submarine, Dave's feature in Transport explains how even land-loving vehicles can traverse the seven seas.

Alexandra Cheung
Light and colour

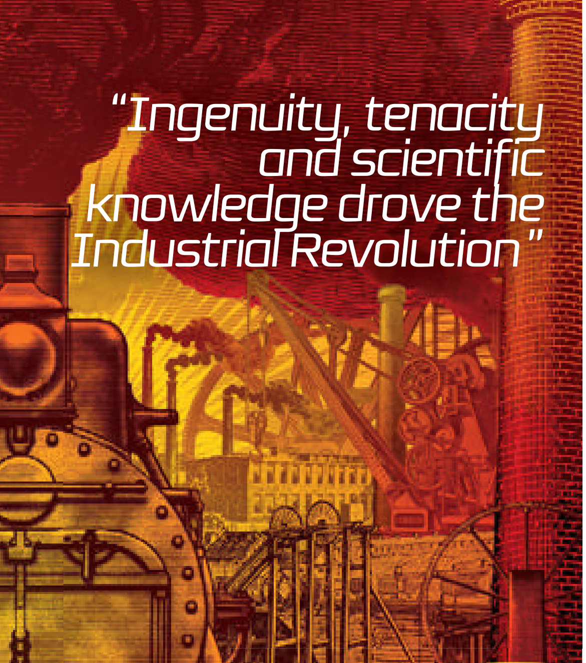
Her knowledge and skills with science communication are unmatched and this month Alex makes complex science simple again in this physics article exploring the unique relationship between light and colour.

Why was Apple's iPad made even smaller?
Go to page 29 to find out!

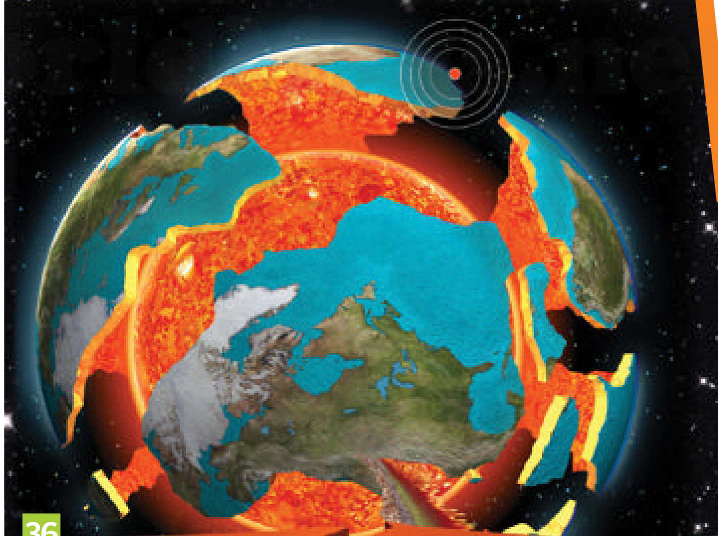




WWW.HOWITWORKSDAILY.COM



"Ingenuity, tenacity and scientific knowledge drove the Industrial Revolution"



REGULARS

Happy birthday, ISS!

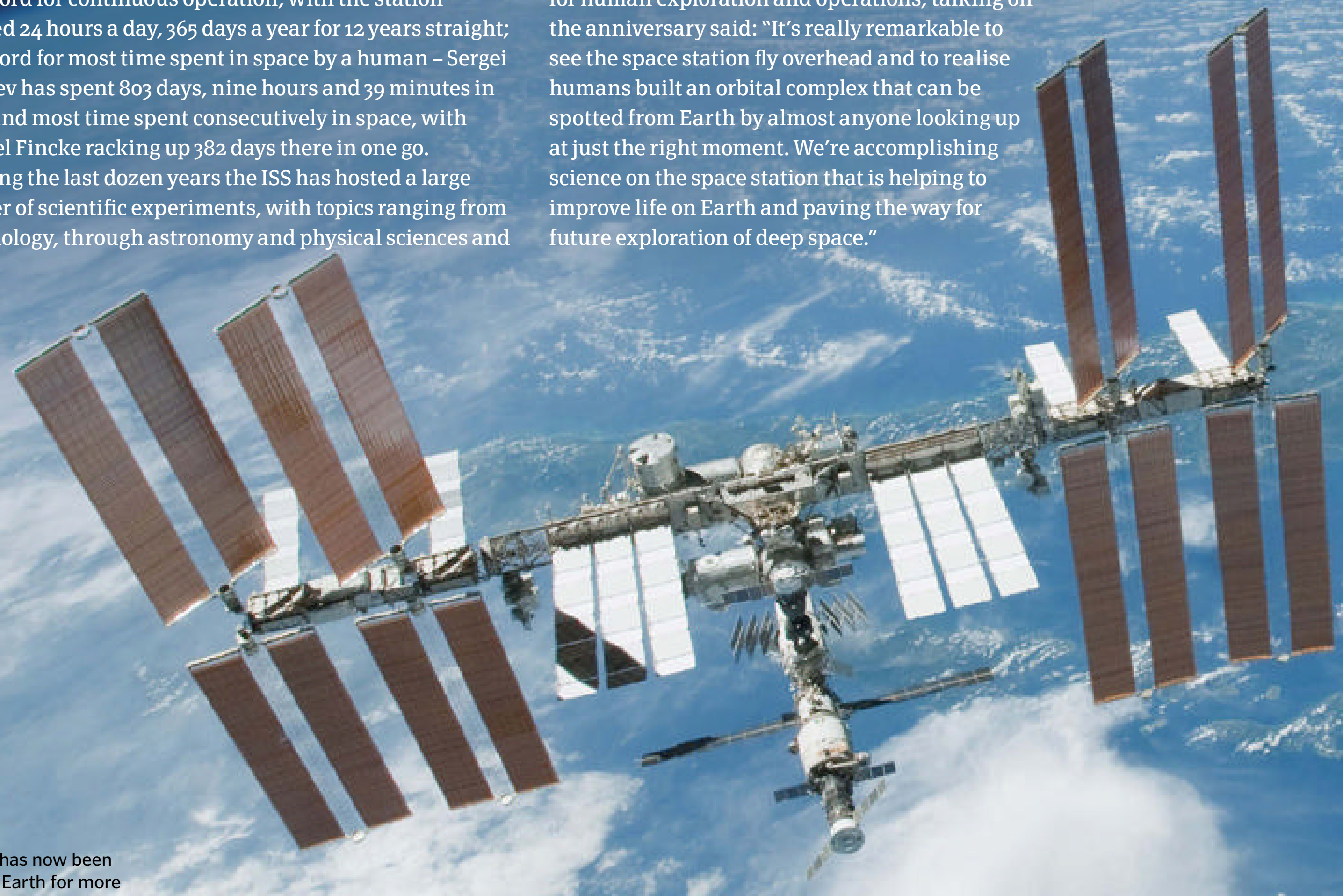
The International Space Station has made history again, becoming the oldest operational station in orbit around Earth

The International Space Station (ISS) has turned 12 years old, passing its birthday on 2 November 2012. The milestone confirms it as the oldest operational space station around Earth, with over 4,380 days passing since the first expedition officially boarded.

A global effort drawing together the expertise of five space agencies, the ISS has broken, or contributed to, numerous records during its time in space. These include the record for continuous operation, with the station manned 24 hours a day, 365 days a year for 12 years straight; the record for most time spent in space by a human – Sergei Krikalev has spent 803 days, nine hours and 39 minutes in orbit; and most time spent consecutively in space, with Michael Fincke racking up 382 days there in one go.

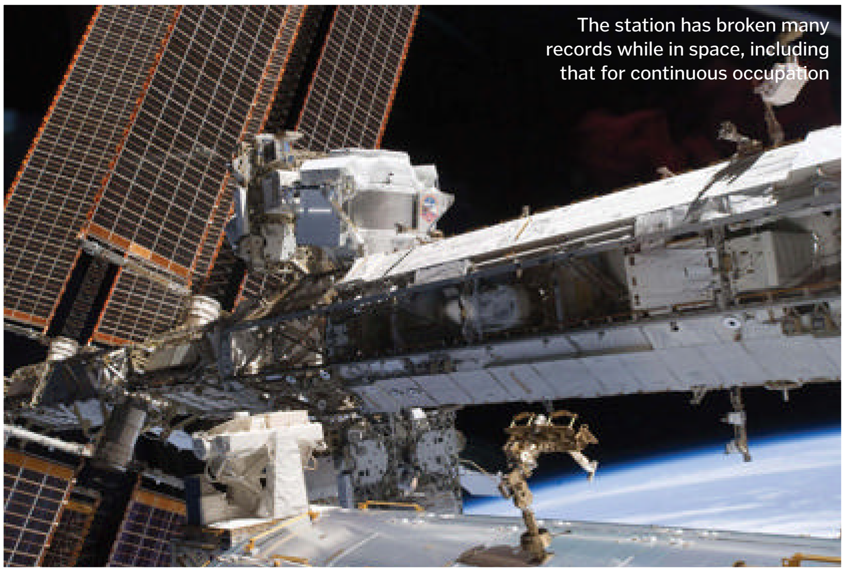
During the last dozen years the ISS has hosted a large number of scientific experiments, with topics ranging from astrobiology, through astronomy and physical sciences and on to meteorology and life sciences. As a celebration of the station's birthday NASA has announced a new Spot The Station service that sends notifications (such as text messages and emails) to astronomers, informing them when the ISS is going to be visible in their region. Looking to the future the ISS is scheduled to remain in operation until 2020 at the earliest, with a possible extension to 2028.

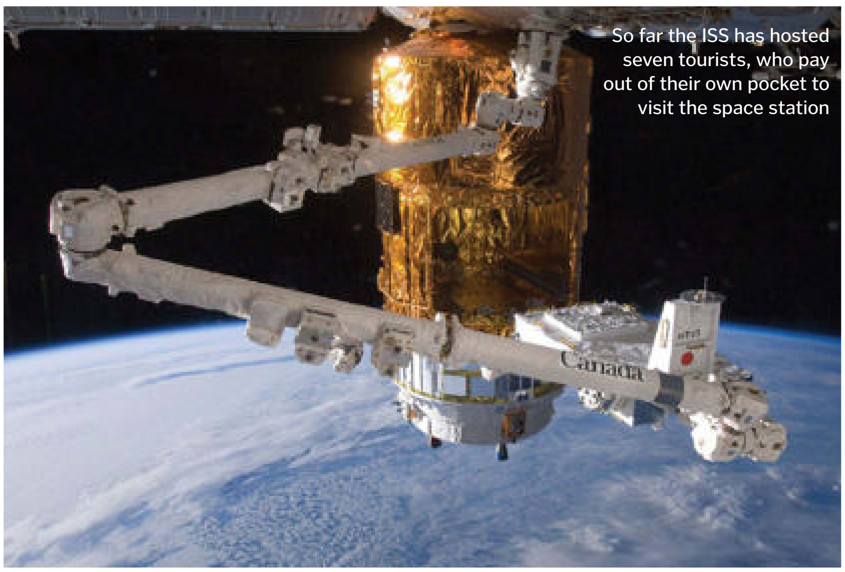
William Gerstenmaier, NASA's associate administrator for human exploration and operations, talking on the anniversary said: "It's really remarkable to see the space station fly overhead and to realise humans built an orbital complex that can be spotted from Earth by almost anyone looking up at just the right moment. We're accomplishing science on the space station that is helping to improve life on Earth and paving the way for future exploration of deep space."



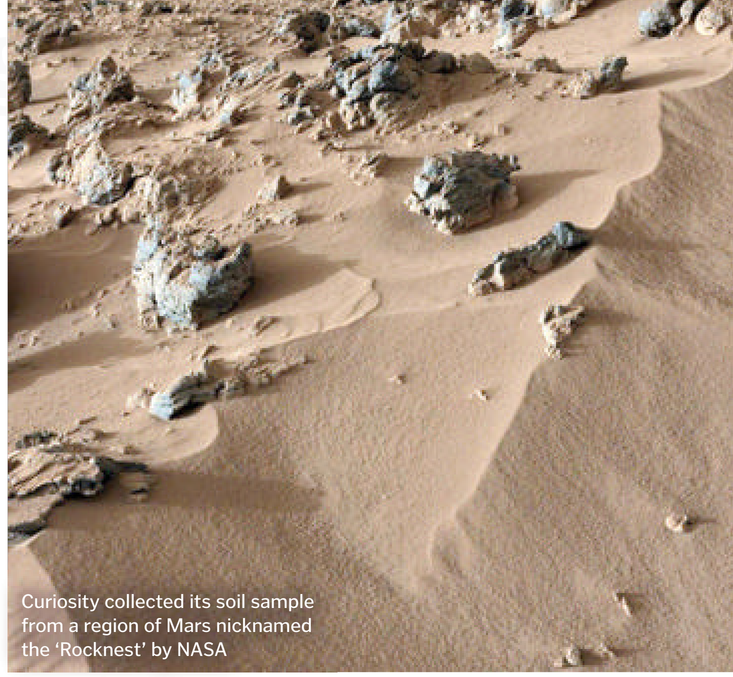
The ISS has now been orbiting Earth for more than 4,380 days

"We're accomplishing science on the space station that is helping to improve life on Earth"


The station has broken many records while in space, including that for continuous occupation


So far the ISS has hosted seven tourists, who pay out of their own pocket to visit the space station


The original crew of the ISS who boarded the craft as Expedition 1 back in November 2000


Curiosity collected its soil sample from a region of Mars nicknamed the 'Rocknest' by NASA

Martian soil is like Hawaii's

Curiosity reveals the Red Planet has similar origins to the Aloha State

Mars's soil has been revealed to be akin to that of Hawaii. The Curiosity rover's CheMin instrument exposed the soil's composition by filtering fine particles of material and firing X-rays at them – a process that showed much of it was weathered basaltic rock and volcanic dust. The similarity in composition to Hawaii's earth indicates that at one time Mars was heavily volcanic. Speaking on the data, David Bish, the co-investigator on CheMin, said: "So far, the materials Curiosity has analysed are consistent with our initial ideas of the deposits, recording a transition through time from a wet to dry environment. The ancient rocks, such as the conglomerates, suggest flowing water, while the minerals in the younger soil are consistent with limited interaction with water."

The next stage of the process will see Curiosity transfer the soil sample to its Sample Analysis at Mars (SAM) instrument suite, which will look for the presence of organic materials. It is hoped that the results will help to confirm whether life ever existed on the Red Planet.

Deadly disease threatens UK woodlands

Ash dieback, the result of an invasive species of fungus recently found in England, is threatening to destroy Britain's 80 million ash trees. The exact origin of the fungus Chalara fraxinea that gradually causes ash trees to blacken and die, is unknown, but it's being blamed on a tree import system that is 'chaotic'. Ash dieback is now known to have been the cause of the destruction of many ash trees in Poland in 1992, although this was only formally recognised in 2006. Chalara fraxinea is closely related to another pathogen, which feeds on dead ash leaves. A free app called AshTag can now be downloaded and used to upload photographs of suspect trees to a location where an expert can examine them, so the spread of the disease can be tracked.

> "The Supercharger network is a game-changer for electric vehicles"

Electric vehicles get a power-up

A revolutionary new charging system allows Tesla Motors cars to be topped up for free in minutes

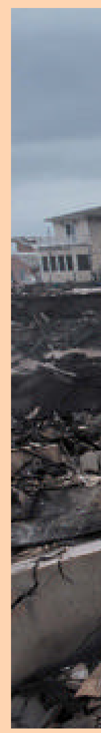
Tesla Motors has unveiled a secretly constructed network of advanced charging stations which has been dubbed 'Supercharger'. These stations enable Tesla-brand electric vehicles to be charged significantly quicker than conventional systems, with a 90-kilowatt connector hooking up directly to the vehicles' batteries.

The connector means electricity can enter the battery four and a half times faster than in existing systems, allowing the Tesla Model S to be half-charged in 30 minutes; half a charge equates to 240 kilometres (150 miles) of range. This compares favourably to current 240-volt, ten-kilowatt outlets, which only deliver 26 kilometres (16 miles) per 30-minute charge.

What is most advanced about the network is how it is fed electricity, with a solar carport system generating more electricity annually than it uses; this means the system can actually transfer some of its sunlight-generated power back to the electricity grid.

Speaking on its launch, Tesla Motors CEO, Elon Musk, said: "The Supercharger network is a game-changer for electric vehicles, providing long-distance travel that has a level of convenience equivalent to gasoline cars for all practical purposes. However, by making electric long-distance travel at no cost – an impossibility for gasoline cars – Tesla is demonstrating just how fundamentally better electric transport can be."

Hurricane Sandy origins revealed



The origins of Hurricane Sandy, one of the most costly superstorms ever, have been revealed by meteorologists. The storm caused over $20 billion (£12.5 billion) worth of damage and claimed more than 50 lives.

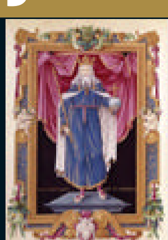
Classified as a post-tropical cyclone, Sandy caused wide-scale destruction to buildings, left over 7.4 million properties without power and led to the cancellation of some 15,000 flights as intense wind, rain and ocean surges battered the north-east US states on the Atlantic. The storm formed from an area of low pressure (a tropical wave) on 22 October in the western Caribbean before strengthening due to organised convection, low wind shear and warm waters.

Tropical waves are a type of atmospheric trough, an elongated area of low air pressure that moves east to west across the tropics. They are typically characterised by their high humidity and destabilised atmosphere – factors that usually produce severe thunderstorms. Sandy's winds peaked at 145 kilometres (90 miles) per hour, with a wind diameter of 1,850 kilometres (1,150 miles). While a mass clean-up operation is now underway, many homes are still without power and some public transport isn't fully operational.

This day in history

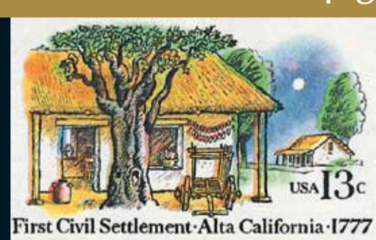
29 November: How It Works issue 41 goes on sale, but what

800 CE
Ungodly crimes
King of the Franks Charles I arrives in Rome to investigate alleged crimes by Pope Leo III.

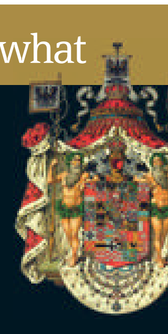


1394
Capital idea
Korean king Yi Seong-gye moves the capital city from Kaesong to Hanyang (which is modern-day Seoul).

1777
San José
The city of San José is founded, becoming the first civilian settlement in Alta California.



1850
Surrender
The Punctation of Olmütz is signed, leading to Prussia surrendering to the Austrian Empire.



'Youthful' ancient stars uncovered

The Hubble Space Telescope has found stars that seem to defy the ageing process

Looking into globular cluster NGC 6362, which is around 25,000 light years from Earth, the Hubble telescope recently spotted something unexpected: a group of stars around twice the age of our Sun, which look much younger. They are being dubbed 'blue stragglers' because stars generally become redder as they get older, yet these have the colour of young stars despite their age. It's suspected that because of the high concentration of stars in this region of space, collisions between stars and the transfer of material between binary pairs gives them extra fuel. This ultimately makes the blue stragglers heat up and shifts their emitted light to the opposite end of the visible spectrum – that is, from red to blue.

The coastal community of Breezy Point, Far Rockaway, was devastated by the superstorm

President Obama and New Jersey Governor Chris Christie talk with residents of Brigantine

Gray's beaked whale, a similar-looking species that the spade-toothed beaked whales were initially mistaken for

Earth's rarest whale is found

Two whale skeletons confirm a new member of the cetacean family

The world's rarest whale – the spade-toothed beaked whale – has been retroactively discovered by researchers in New Zealand and the USA. The pair of skeletons were correctly identified in a lab recently after conservation workers found the bodies of a 5.2-metre (17-foot) whale and her calf washed up on a beach in New Zealand two years ago. At the time they were misidentified as a more common species – Gray's beaked whale – before being buried deep in the sand. It's only after samples were examined by the University of Auckland in routine tests that the research team made the exciting discovery, before returning to the beach to exhume the entire remains.

In the past, only fragments of skull have ever been found that pointed to the existence of this creature: one piece in New Zealand in 1872, one discovered in the Fifties and another off the Chilean coast in 1986. The marine mammal had never been seen whole until now – let alone alive.

It's hoped that the team might be able to use the skeletons to re-create the muscles and tissues of the spade-toothed beaked whales, perhaps revealing how they live and why they have proved such an elusive species.

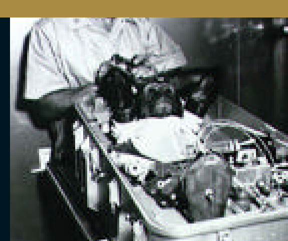
else happened on this day in history?

1877
Phonograph
Thomas Edison demonstrates his phonograph for the first time.

1929
Fly like a Byrd
US Rear Admiral Richard Byrd becomes the first person to fly over the South Pole.

1944
Baby blues
The first human surgery to correct blue baby syndrome is performed.

1961
Space chimp
Enos, a chimpanzee, is launched into space. The spacecraft orbits Earth twice and then splashes down just off Puerto Rico.

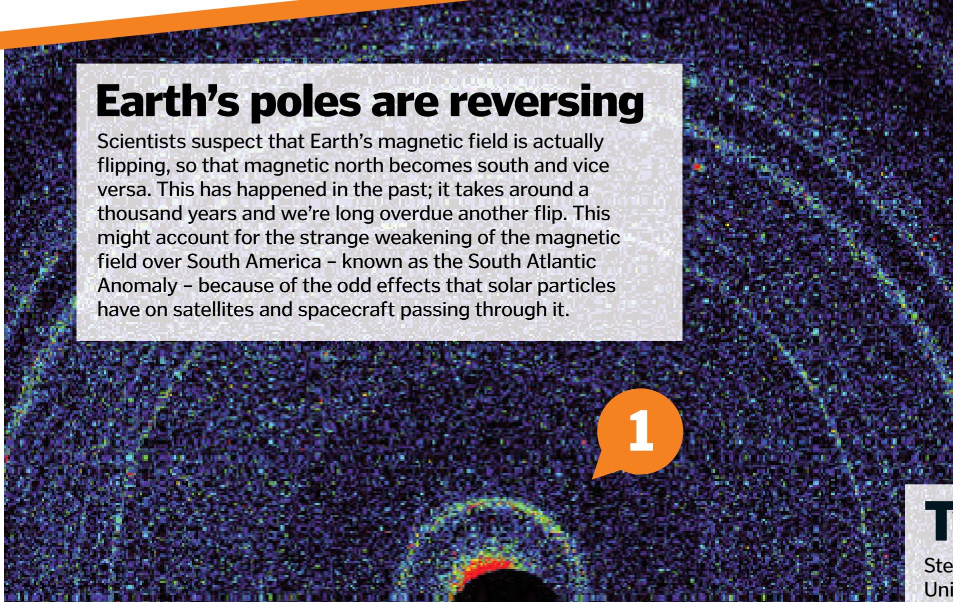


1972
Pong
Atari announces the release of *Pong*, the first commercially successful videogame.

2007
Antillean quake
A 7.4-magnitude earthquake rocks the northern coast of Martinique.

10 COOL THINGS WE LEARNED THIS MONTH

AMAZING TOPICAL FACTS...

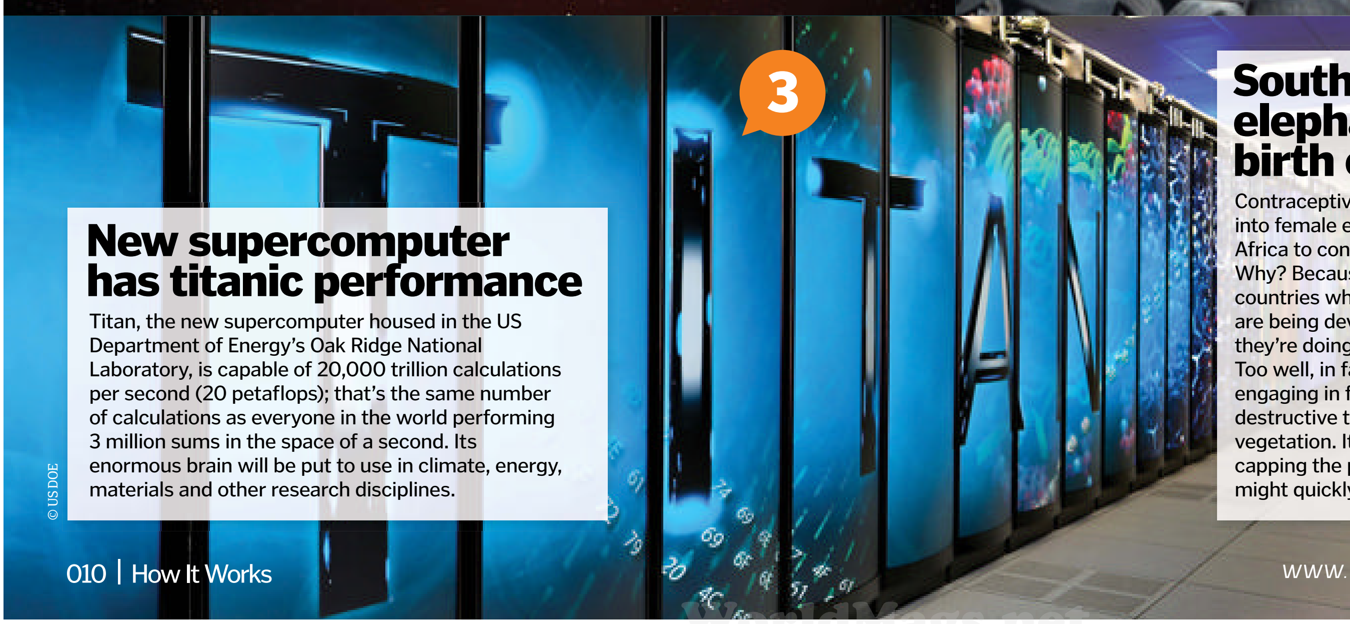


1 Earth's poles are reversing

Scientists suspect that Earth's magnetic field is actually flipping, so that magnetic north becomes south and vice versa. This has happened in the past; it takes around a thousand years and we're long overdue another flip. This might account for the strange weakening of the magnetic field over South America – known as the South Atlantic Anomaly – because of the odd effects that solar particles have on satellites and spacecraft passing through it.

2 Superman's home world has been 'discovered'

DC Comics has hired astrophysicist Neil deGrasse Tyson to determine the most likely location of Superman's home planet, Krypton, in the universe – and he has supposedly found it. It's orbiting the red dwarf star LHS 2520, about 27 light years from Earth, in the southern constellation Corvus (the Crow). The details have been published in the new Superman book, *Star Light, Star Bright*.



© US DOE

3 New supercomputer has titanic performance

Titan, the new supercomputer housed in the US Department of Energy's Oak Ridge National Laboratory, is capable of 20,000 trillion calculations per second (20 petaflops); that's the same number of calculations as everyone in the world performing 3 million sums in the space of a second. Its enormous brain will be put to use in climate, energy, materials and other research disciplines.

4 Gold doesn't have to be gold

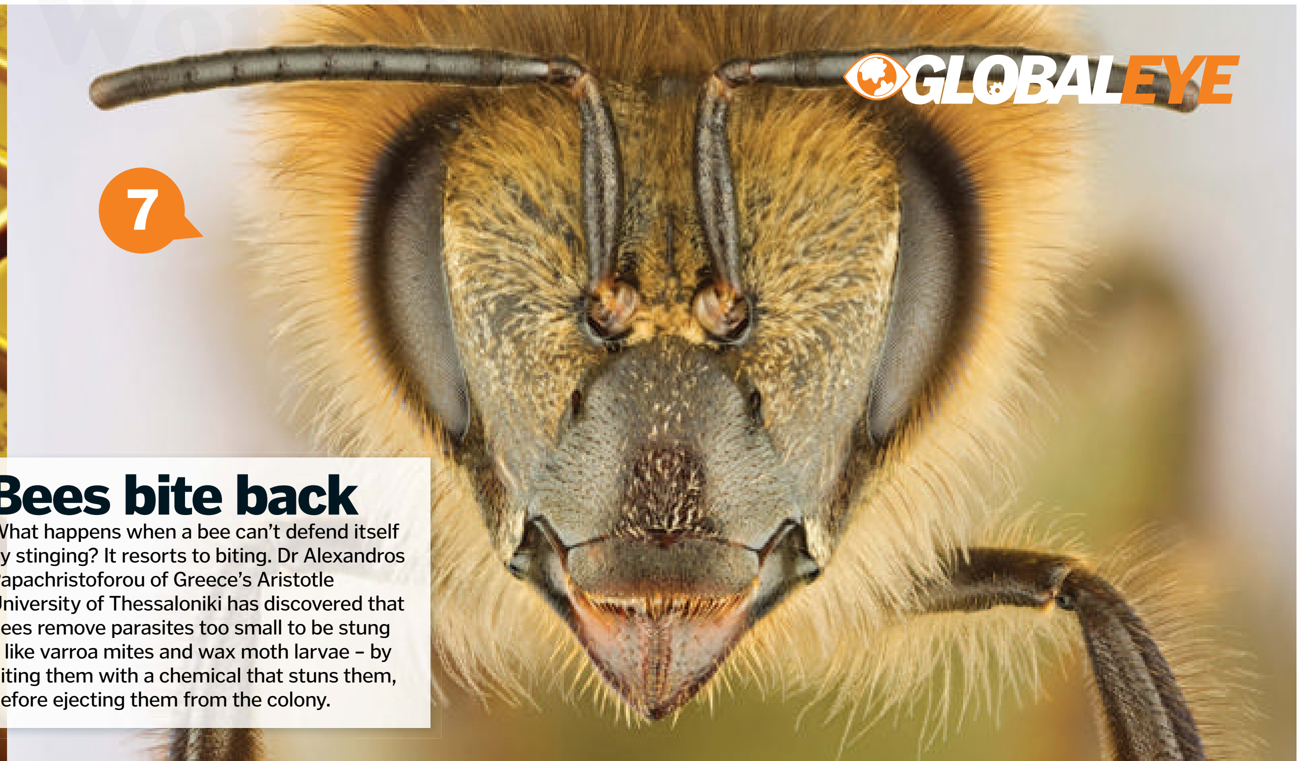
Scientists at the University of Southampton, UK, have found a way of changing the colour of gold. By embossing tiny patterns onto the surface with an ion beam milling system, it changes the way that the metal absorbs or reflects light. With patterns just 100 nanometres in width, the colour of gold can be altered to any shade in the visible spectrum.

5 Tyres may stop hurricanes

Stephen Salter, emeritus professor of engineering design at Edinburgh University, has devised a way of weakening tropical storms using old car tyres. Backed by Microsoft billionaires Bill Gates and Nathan Myhrvold, his patent is for a system that lashes thousands of tyres together. Each one suspends long tubes that mix deep water with warm surface water, cooling it below the 26.5-degree-Celsius (79.7-degree-Fahrenheit) critical temperature at which hurricanes form.

South African elephants use birth control

Contraceptive darts are being shot into female elephants in South Africa to control their population. Why? Because, unlike other African countries where elephant numbers are being devastated by poachers, they're doing well in South Africa. Too well, in fact, with over 20,000 engaging in feeding patterns destructive to local trees and vegetation. It's argued that without capping the population, damage might quickly spiral out of control.



7

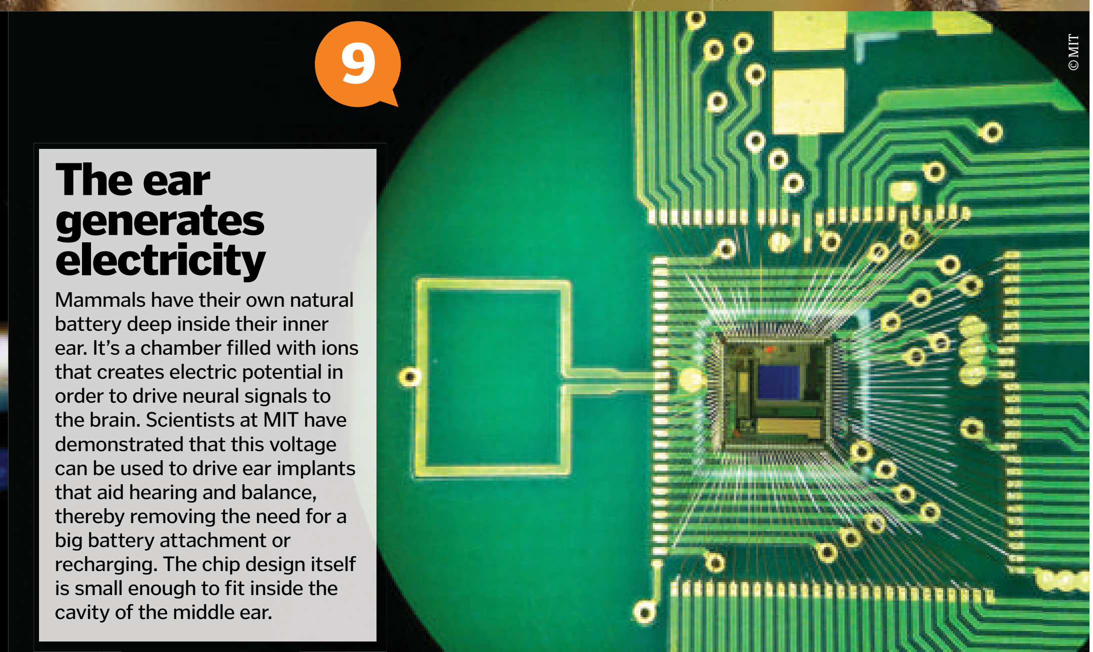
Bees bite back

What happens when a bee can't defend itself by stinging? It resorts to biting. Dr Alexandros Papachristoforou of Greece's Aristotle University of Thessaloniki has discovered that bees remove parasites too small to be stung – like varroa mites and wax moth larvae – by biting them with a chemical that stuns them, before ejecting them from the colony.

8

Paintball guns could deflect asteroids

MIT graduate Sung Wook Paek has published a paper detailing a strategy for dealing with asteroids that threaten Earth: shoot them with paintballs. The idea is that the paintballs impacting would begin to send the asteroid off course over time, while the white paint spread on its surface could double its photon reflectivity (albedo) of sunlight, helping to further steer it away from a terrestrial impact.



9

The ear generates electricity

Mammals have their own natural battery deep inside their inner ear. It's a chamber filled with ions that creates electric potential in order to drive neural signals to the brain. Scientists at MIT have demonstrated that this voltage can be used to drive ear implants that aid hearing and balance, thereby removing the need for a big battery attachment or recharging. The chip design itself is small enough to fit inside the cavity of the middle ear.

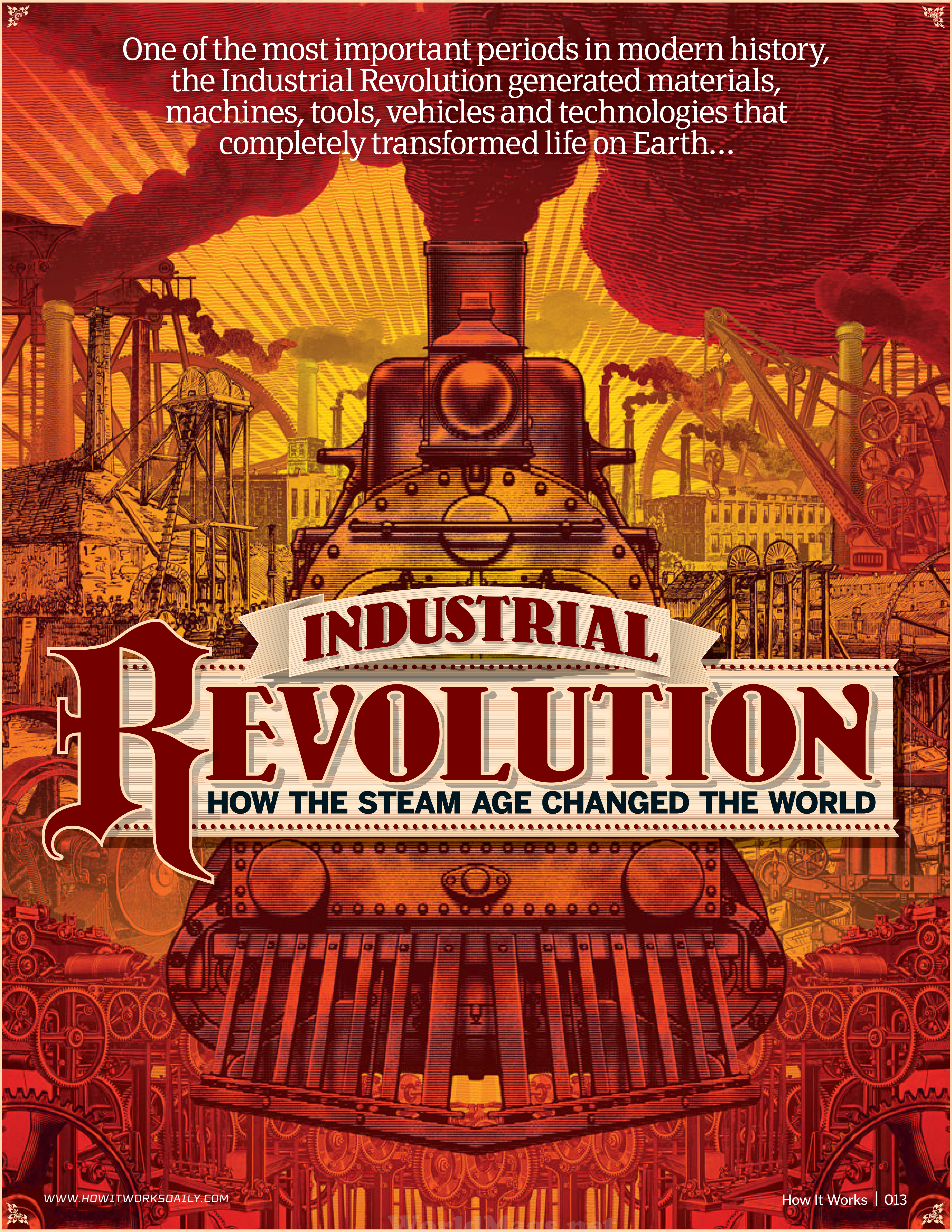
6

10

Exoplanets can be resurrected

Exoplanet Fomalhaut b was announced in 2008 as a rare planet three times the size of Jupiter orbiting the brightest star in Piscis Austrinus, but was later dismissed by a study suggesting it was a big cloud of dust. Using data from Hubble though, the theory that Fomalhaut b is actually a massive planet was revived recently, as scientists determined the speed and direction it was moving in are consistent with the idea that the planet's huge gravity is affecting the dust ring it moves within.

One of the most important periods in modern history, the Industrial Revolution generated materials, machines, tools, vehicles and technologies that completely transformed life on Earth…



INDUSTRIAL REVOLUTION

HOW THE STEAM AGE CHANGED THE WORLD

The Industrial Revolution might have ended over a century ago, but it's still relevant today as it embodies many of humanity's greatest characteristics. Traits that in a world of rapidly dwindling fossil fuels, fragile national economies and ever-increasing populations are going to be crucial in tackling the problems that lie ahead. Ingenuity, tenacity and scientific knowledge drove the Industrial Revolution and created a better world for the billions of people alive today. That noble ability to enrich the lives of future generations is something worth celebrating.

THE STEAM AGE

It's a common misconception that steam is visible. The characteristic white mist that we see rising from a boiling kettle or the cooling tower of a power station is, in fact, haphazard clouds of water droplets forming through the condensation of steam in the cooler air. Indeed, if steam was simply a mist of water droplets and nothing more, it wouldn't be anywhere near as exciting as we're about to reveal.

No, true steam – generated when water molecules receive an energy excess great enough to break down their bonds – is of interest due to the massive growth in volume brought about by its phase change. This expansion clocks in at 1,700 times the volume of its liquid state (water) – a factor of 30,600:18. As such, a single mole of water – a mole of a substance is the mass of the material in grams that is numerically equal to its molecular mass – is 18 grams. However, at standard temperature and pressure, that mole expands to fill a volume of 22.4 litres when vaporised. Conversely, the same factor is attributable to the reversed state change (ie condensation).

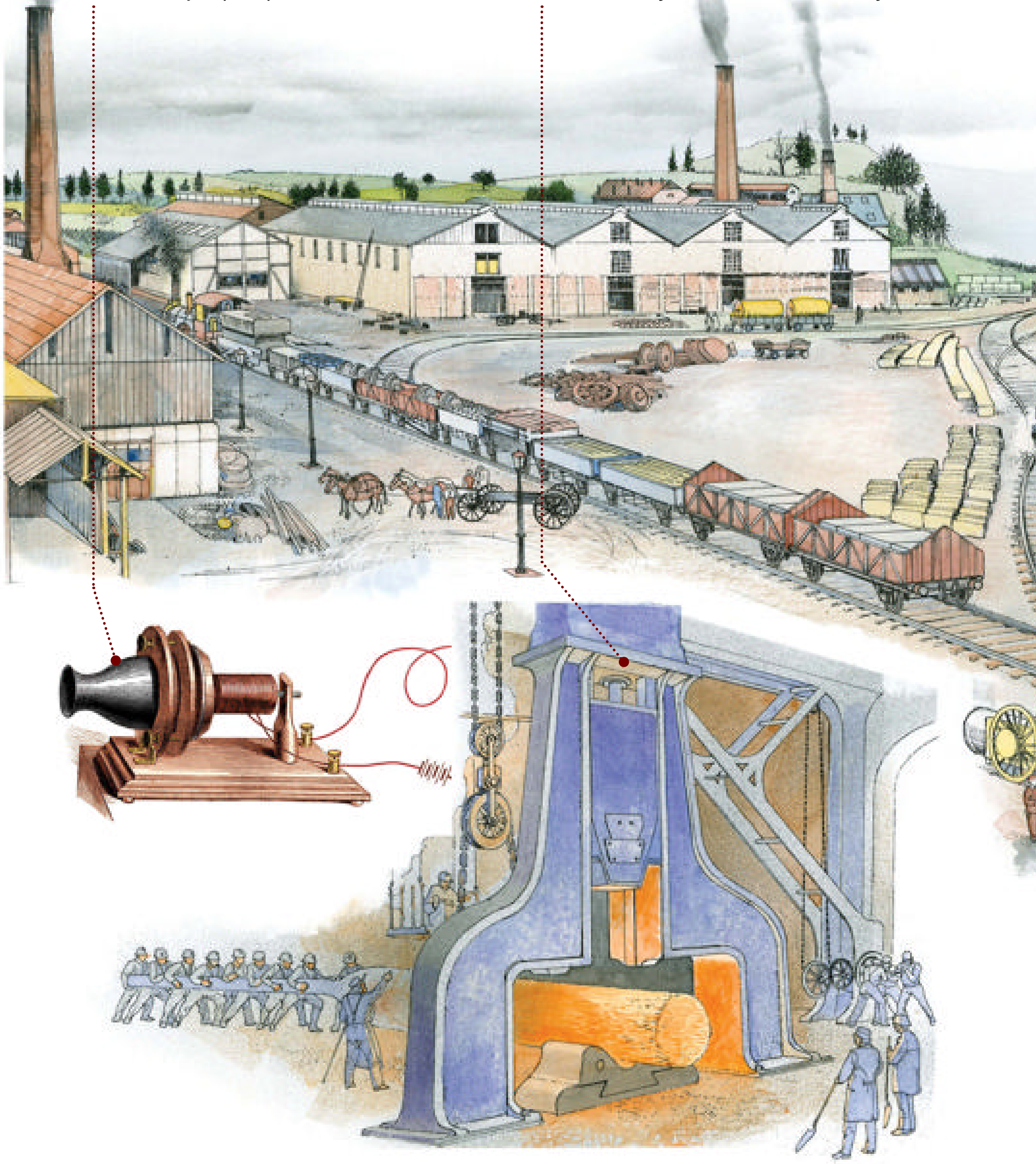
This process is far from merely a scientific curiosity. It is fundamental to understanding how arguably the biggest social, industrial and economic upheaval the world has ever witnessed came to bear over a period of 200 years. That upheaval was the Industrial Revolution and that simple, invisible, beautiful expansion of volume was the driving factor of the steam engine – one of the most important inventions ever created and the machine that essentially built the modern world. ▶

Industrial Revolution at a glance

Discover how our special feature is broken down by scanning this illustration

Inventions & curiosities (pg 22-23)
Embodied in the character of the 100,000-exhibit Great Exhibition of 1851, the limits of not only what was possible but what could be imagined by scientists and engineers exploded, creating the forebears of many of our modern machines and appliances. From the electric induction motor to the telephone, here we look at but a few of these remarkable – and sometimes just plain peculiar – innovations.

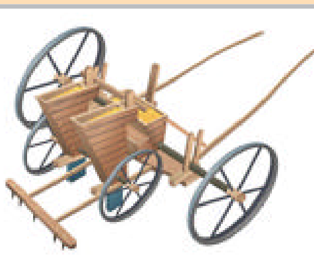
Manufacture & industry (pg 18-19)
From the heavy-duty forging of iron with gargantuan steam hammers, through the fast and efficient creation of steel in Bessemer converters and on to the mechanical finesse imparted by spinning frames and cotton engines, a vast host of mechanical marvels were created through the 18th and 19th centuries. Here we explore some of the most notable and reveal how they affect our lives to this day.



KEY DATES OF THE STEAM AGE

Chart some of the most game-changing inventions, developments and discoveries over 200 years

1701
Tull's seed drill
Jethro Tull's seed drill embodies the shift from an agrarian economy to one dominated by urban industry and machine manufacture.



1712
Newcomen engine
Thomas Newcomen's engine is an early glimpse into the possibilities of steam power. It's used mainly to drain mines of water, but will later be adapted to do much more.

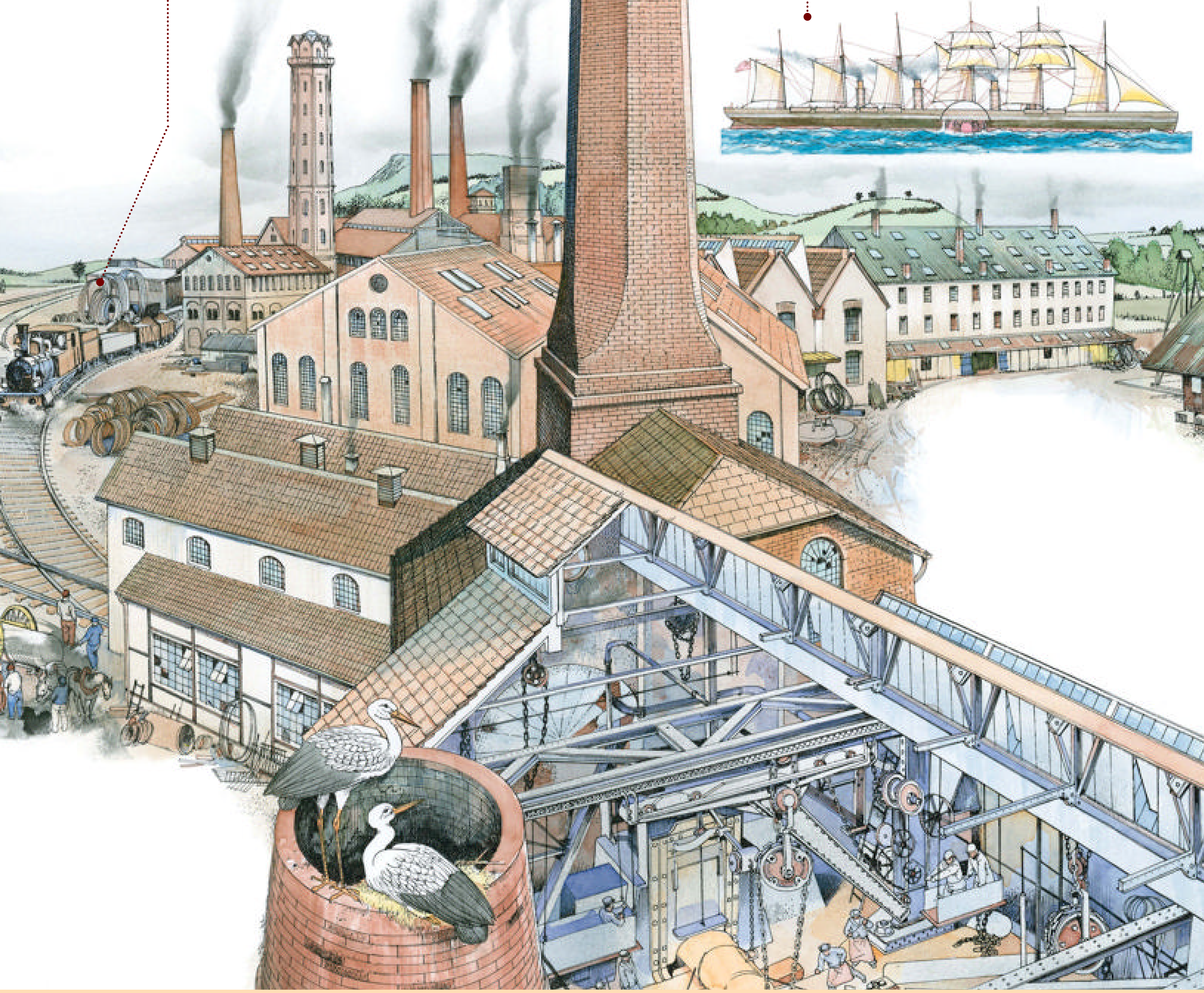
1733
Flying shuttle
The invention of the flying shuttle in the mid-18th century allows for a much larger-scale weaving of fabrics. It is eventually automated in machine looms.

Materials & energy (pg 16-17)

Raw materials not only literally fuelled the Industrial Revolution but also allowed the construction of landscape-changing structures, the latter connecting people like never before and the former acting as a catalyst for rapid industrial expansion. In this section we look at some of the key inventions and advances in infrastructure that laid a roadmap for the transformation of nations.

Vehicles & transport (pg 20-21)

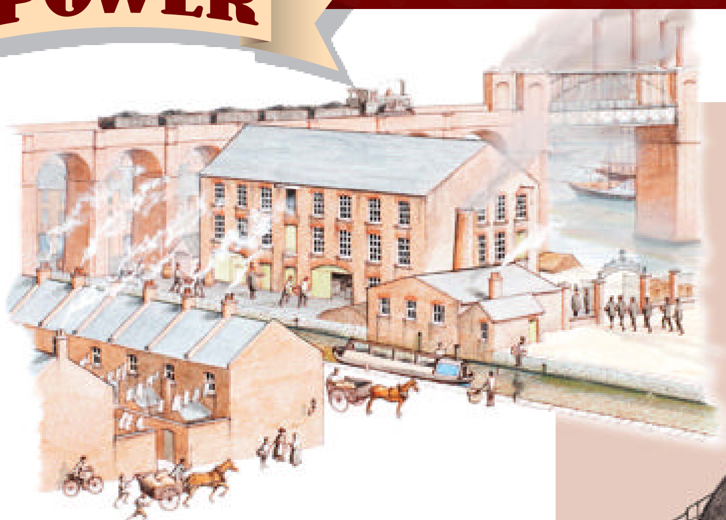
With brand-new energy sources and engines being produced at a furious rate, the dream-like possibilities of what they could be made to power ploughed like a pneumatic drill into the scientific and engineering communities. From French airships to American steamboats and British steam trains, the Industrial Revolution produced many new modes of transport. Here we look at a selection of the major game-changers.



1764
Spinning jenny
This spinning machine reduces the amount of work needed to produce yarn, allowing for multiple spools to be created at once, increasing efficiency.

1772
Bridgewater Canal
The successful completion of the Bridgewater Canal in north-west England kicks off the rapid expansion of a canal network throughout the UK.

1775
Watt steam engine
James Watt's engine markedly improves on Newcomen's design from 60 years earlier, using steam at a pressure just above atmospheric to drive a piston.



INDUSTRIES TRANSFORMED

The invention of the steam engine and its practical implementation in the beam engines of the early-18th century was the catalyst. By mechanising and automating the excavation of mines, not only could raw materials – such as coal and ores – be harvested in immense quantities, but the process could be executed at a speed simply infeasible for manual labourers. Soon, the rapidly increasing availability of coal and raw building materials allowed ever-more complex machines to be invented, housed in greatly upscaled industrial buildings like factories.

Everything was affected. From agriculture through to metal working and construction, and on to the textile industry, the fuel surplus enabled more and more steam engines to be built, which in turn allowed more and more machines and processes to be automated. Workers who had till then found themselves confined to their area of birth were released from this geo-economic prison by roads, bridges, plus quicker and cheaper transport.

This expansion – not just industrially but socially and commercially – essentially led to the collapse of the existing social structure, with a wider distribution of wealth generating extra tiers within a nation's class system. It also led to the creation of modern industrial cities, with many industries increasingly bound by a mutual reliance on each other's trade and, importantly, the machines and power source (steam produced by coal) that, year by year, was becoming the norm. ▶

1712 The beam engine

This invention allowed mines to be cleared of water mechanically, so coal and ores could be excavated quicker than ever before

The beam engine was used to draw out water from mines, as well as to pump water into canals. The engine consisted of a large wooden frame into which a pivoted overhead beam was used to apply force generated by a vertical piston and transfer that movement to a pump rod.

The piston's movement was driven by a coal-heated boiler, which generated steam and fed it into the piston's cylinder. When the piston was at its apex – moving the beam and dropping the pump rod – the cylinder was injected with cold water, creating condensation and eventually a vacuum, thereby drawing the piston down and raising the pump rod again in a cycle. Early beam engines (eg Newcomen's) were quite inefficient due to their lack of a separate condenser.

A beam engine displayed at the 1876 Centennial Exhibition in Philadelphia

KEY PLAYERS

BRUNEL

Isambard Kingdom Brunel

Nationality: English

Role: Structural engineer

Born: 1806

Died: 1859

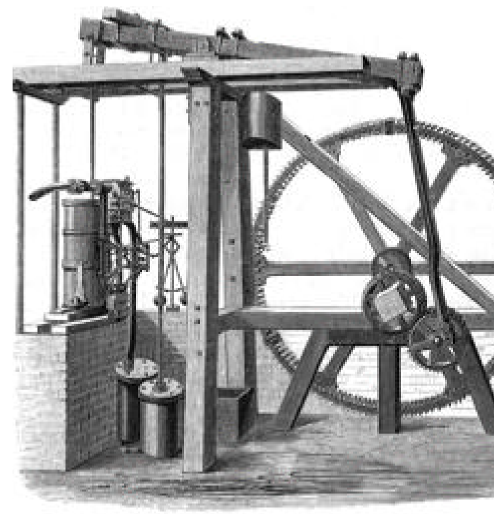
Known for: Thames Tunnel, Clifton Suspension Bridge, Great Western Railway

Responsible for the creation of bridges, tunnels, dockyards, railways and steamships, Brunel was one of the foremost mechanical and civil engineers of the era. Historical accounts frequently cite his excellent ability to generate innovative solutions to both structural and mechanical problems.

1775 Watt's steam engine

James Watt brought steam to the masses, allowing industries to upscale and automate their operations

The Watt steam engine made two critical improvements to existing models. The first was the addition of a separate condenser cylinder alongside the main piston cylinder. This meant that the majority of condensation – and therefore vacuum creation – took place outside the heated drum. This allowed the main piston cylinder to remain at a temperature where water could quickly be pressurised. The second improvement was the introduction of an extra steam valve. The added valve increased the power of the engine as it capped and inserted low-pressure steam into the upper part of the main piston cylinder. This sped up vacuum creation, increasing the piston's downstroke power and, as a result, its actions per minute.



1779
Spinning mule

English inventor Samuel Crompton's mule combines the spinning jenny and the water frame to fully automate the weaving process for the first time, ushering in a new era for the textiles industry.

1785
Power loom

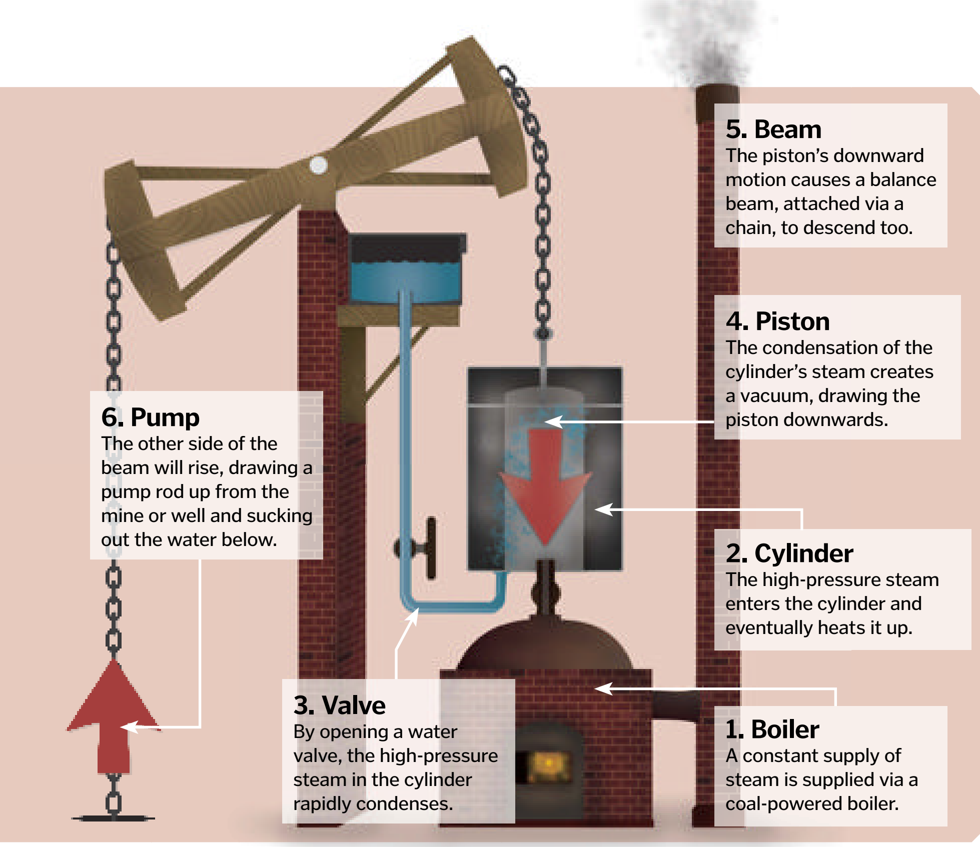
Edmund Cartwright refines his power loom, a mechanised device powered by a line shaft that rapidly increases the speed of operation.

1793
Cotton gin

American Eli Whitney invents the cotton engine, a machine that quickly separates cotton seeds from their fibres.

1801
Puffing Devil

British engineer Richard Trevithick demonstrates a steam-powered car – the Puffing Devil – and drives it up Camborne Hill, Cornwall. It can only travel short distances though.

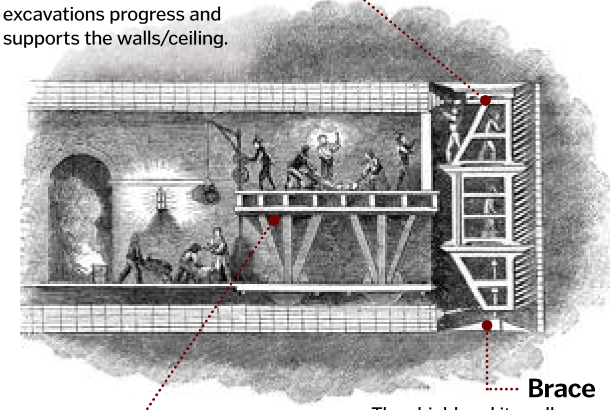


1843 The Thames Tunnel

The first tunnel to be built under a navigable river, this was one of Brunel's engineering milestones

The Thames Tunnel introduced the tunnelling shield. This consisted of three iron frames mounted on top of one another like an open-backed bookcase. This structure was placed against the area of earth that needed to be excavated and then workers proceeded to dig in its cavities, removing soil in sections. Once the distance of the cavities had been excavated, it was shunted forward by a series of screw braces. This meant that at each stage of the dig the shield supported the walls and ceiling, allowing time for masonry reinforcements to be installed.

Shield
Essentially an iron scaffold structure, it shunts forward as excavations progress and supports the walls/ceiling.



Brace
The shield and its cells are moved by screw braces that can be released when the tunnel has been reinforced with bricks.

Gantry
A wheeled wooden gantry acts as a platform for workers to stand on to reach the tunnel roof. It follows in the path of the shield.

1800 The voltaic pile

The world's first electric battery, made by Alessandro Volta, led to a boom in electrochemical power supplies and the discovery of electrolysis

The voltaic pile was a set of individual electrochemical cells placed in a stack separated by an electrolyte, such as pasteboard soaked in brine. When both ends of the tower were connected with wire, it generated an electric current. The pile produced a charge due to molecular reactions, involving each zinc disc being partially dissolved by the acidic brine disc, leading to zinc atoms losing two electrons each. The zinc atoms became ions, passing into the brine disc and coming into contact with a silver or copper disc on the other side, where their lost electrons were replaced. This generated excess electrons within the zinc disc that would travel through the cell and replace the electrons stolen by the zinc atoms from the silver disc. This continuous flow of electrons created a steady current, which had eluded scientists for many years.

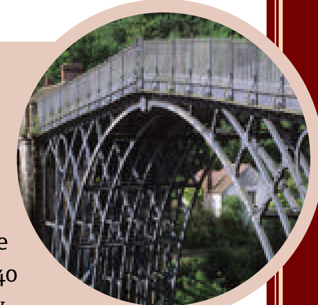
Copper disc
As the ions reach the copper disc they steal electrons, returning into atoms. The zinc disc's remaining electrons then pass through the cells.

Pasteboard disc
Zinc ions pass through the acidic pasteboard disc as it acts as a crude electrolyte.

Zinc disc
The zinc disc's surface is slightly dissolved by the pasteboard disc's brine, causing zinc atoms to lose electrons and turn into ions.

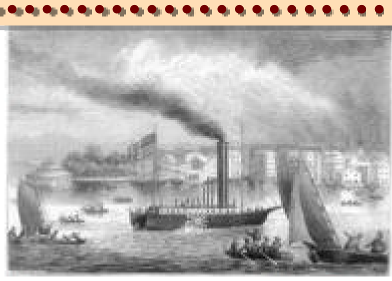
1779 Iron Bridge

The first-ever arch bridge to be made purely from cast iron

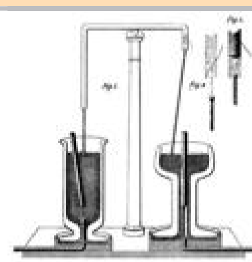


The Iron Bridge, in Shropshire, UK, consists of 482 main iron castings, which were forged at the Bedlam Furnaces 500 metres (1,640 feet) downstream and shipped by reinforced barges to the site. The construction of the huge iron components was made possible by improvements to furnace, moulding and pressing equipment, with many parts needing to be heavily bowed, such as the structure's five parallel arch frames. After a complex assembly process, the road surface was finished with clay and blast furnace slag.

1807
Clermont steamboat
Following success with his Nautilus submarine, American engineer Robert Fulton sets up the world's first commercially successful steamship service with the Clermont steamship, operating around New York.



1821
Electromagnetic rotation
English scientist Michael Faraday demonstrates electromagnetic rotation – the principle of the electric motor. Ten years later, he will discover electromagnetic induction.



1825
Thames Tunnel
Isambard Kingdom Brunel begins work on the first under-river tunnel ever to be attempted – the Thames Tunnel (see above for more details). It is completed in 1843.

RISE OF THE MACHINES

The Industrial Revolution saw machines put centre stage due to their ability to perform tasks at a literally inhuman rate. Manual workers found they were no longer craftspeople, but operators of steam hammers, water frames, power looms and more. They operated many of these steam-powered devices in factories – a new system of production also born in this period.

Prior to the 1700s the majority of industries were 'cottage industries', with small groups of craftspeople taking part in heavily localised operations producing limited goods. Taking the textiles industry as an example, wool and cotton fibres were spun by hand into yarn and weavers turned them into bespoke items for a select few wealthy clients. However, with the advent of spinning frames and mechanised looms, these craftspeople were drawn together in a factory setting, with items created en masse. Due to the removal of hands-on skill in many of their roles, more untrained workers could be hired.

The scale of the integration of industrial machinery can't be overstated. Every level of the textiles industry was transformed, with cotton engines allowing fibres to be separated from seeds rapidly, spinning frames enabling those fibres to be spun into yarn on a massive scale, and power looms driven by vast drive shafts allowing cloth to be weaved with unprecedented efficiency.

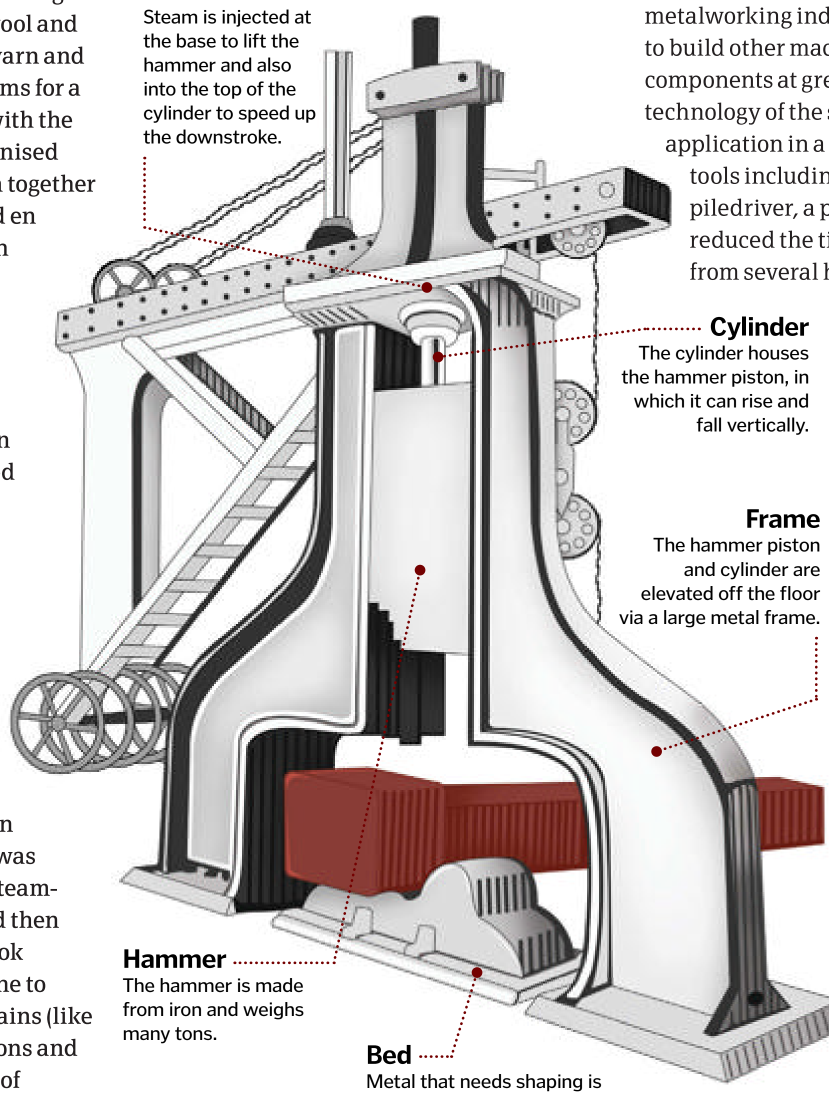
While the first half of the Industrial Revolution, circa 1700-1830, was characterised by stationary steam-powered machines, the second half (circa 1830-1900) saw an explosion in machines that moved. It was kick-started by Richard Trevithick's steam-powered locomotive and carriage, and then refined by a series of inventors who took mobile applications of the steam engine to another level. Soon steam-powered trains (like Stephenson's rocket), carriages, balloons and ships were opening up the possibility of long-distance travel across the globe. ▶

1839 The steam hammer

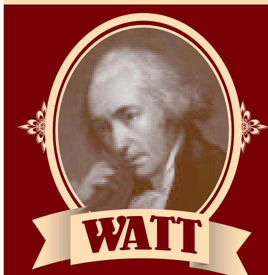
One of the many machine tools invented during the Industrial Revolution, James Nasmyth's steam hammer took forging to a whole other level

The steam hammer was essentially a power hammer, as used today to shape forgings, but it was driven by a steam engine. It comprised a hammer-like piston within a cylinder positioned vertically in an iron frame. The central hammer piston was driven upwards by injecting high-pressure steam into the cylinder's base, which was supplied by an adjacent coal boiler. Once the hammer had been raised, the metal that needed forging was placed underneath on an iron bed. The steam at the bottom of the cylinder was then ejected rapidly via a condenser, creating a vacuum that, combined with gravity, caused the hammer to drop quickly onto the metal, shaping it as desired. Later, the drop speed of the hammer was further increased by injecting high-pressure steam into the top of the cylinder at the same time.

Despite its simple operation, the steam hammer gained huge traction in the metalworking industry, allowing machines to build other machines, structures and components at great speed. In addition, the technology of the steam hammer also saw application in a range of other mechanised tools including the first automatic piledriver, a piece of engineering that reduced the time it took to install piles from several hours to just minutes.



KEY PLAYERS



James Watt

Nationality: Scottish

Role: Mechanical engineer

Born: 1736

Died: 1819

Known for: Watt steam engine, Soho Foundry, International System of Units (SI)

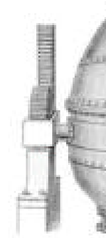
Watt's steam engine was a cornerstone of the Industrial Revolution, transforming the feasibility of employing steam as an energy source. The power gain, improved efficiency and low running costs that Watt engines delivered allowed for rapid expansion in the mining, metalworking and fabric industries to name just a few.

1834
Analytical engine
The English inventor and mathematician Charles Babbage begins work on the analytical engine, which is a mechanical forerunner of the modern computer.

1837
Morse code
The electrical telegraph is improved by Samuel Morse (right). Morse code, however, is developed by his assistant Alfred Vail.

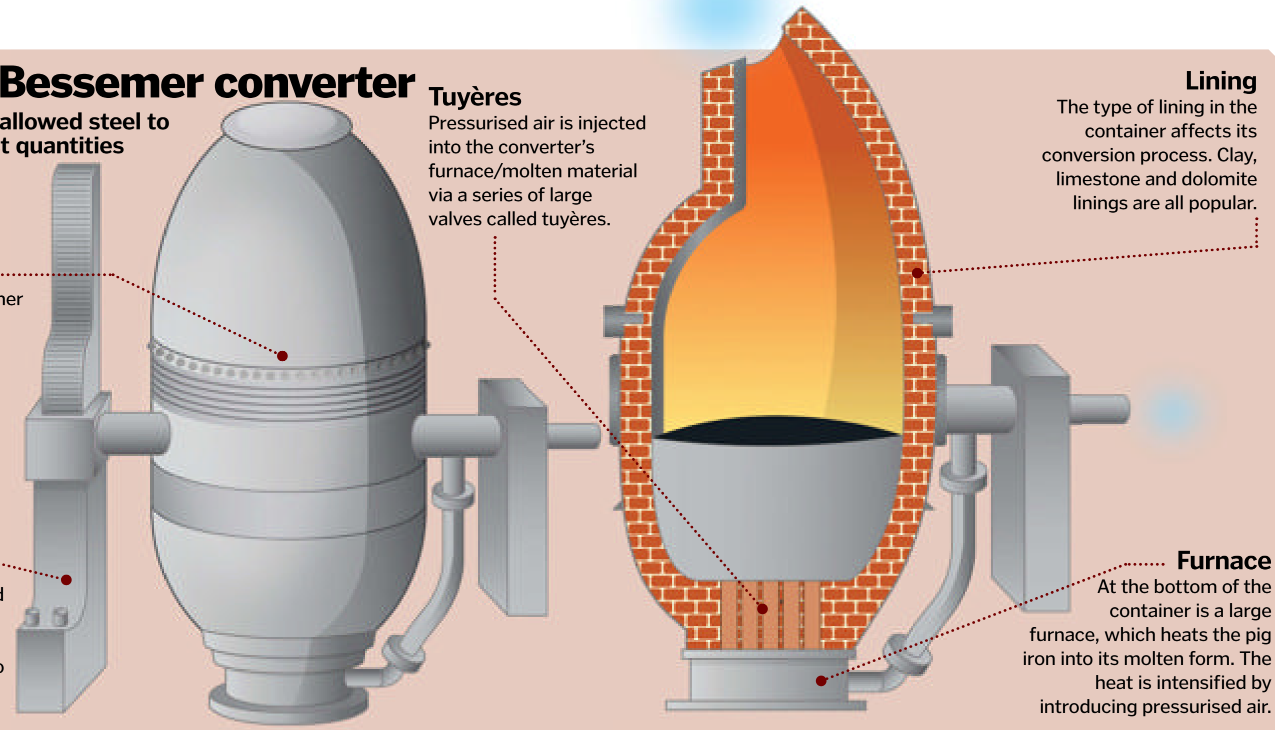
1851
Singer sewing machine
The first practical, mass-produced sewing machine is invented by the Singer Sewing Machine Company in New Jersey, USA. It is still making machines to this day.

1856
Bessemer converter
Henry Bessemer invents the Bessemer converter, a process allowing the mass production of steel from pig iron, described in more depth opposite.



1856 The Bessemer converter

The invention that allowed steel to be produced in vast quantities

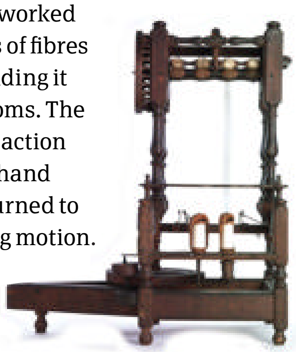


The Bessemer converter was a machine and surrounding process that involved the removal of impurities from pig iron (a type of iron with a high carbon content) and its conversion into steel – a material that had historically been costly and time consuming to manufacture. The key principle behind its operation was the removal of impurities such as silicon, manganese and carbon through oxidation, turning the brittle, largely unusable pig iron into very useful steel. The oxidation of impurities occurred in a Bessemer converter, a large egg-shaped container in which the iron was melted. The solid iron was inserted through a hole at the top and heated from the bottom. Once the converter had melted the pig iron, pressurised air was injected through and across the liquid metal, forcing the unwanted silicates to react with oxygen and convert into gas and/or solid oxides (ie slag). Once the oxidation process had taken place, the usable molten steel could be poured out from the container directly by tipping it on a central pivot – the container was suspended off the ground by a pair of large struts – while the slag could be skimmed off the surface for reuse or disposal. The steel was emptied into large moulds, where it could be set into a wide range of products.

1768 The spinning frame

Over the 18th century, spinning technology went through a great metamorphosis that would revolutionise the textiles industry

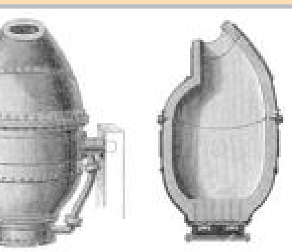
The spinning jenny, the original spinning frame made by James Hargreaves in 1764, worked by twisting bundles of fibres into thread and winding it onto spindles for looms. The jenny's mechanical action was generated by a hand crank, which was turned to produce the twisting motion. In 1768 Richard Arkwright's spinning frame hugely improved the speed at which thread could be produced. It was enhanced again by Arkwright's water frame. The latter worked largely the same way as the previous spinning frame, but the power for the mechanical parts came from a water wheel rather than a manual crank. This greatly reduced the number of workers needed to make thread.



1793 The cotton gin

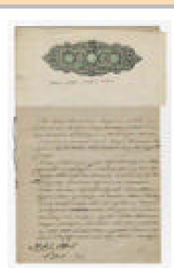
Saving thousands of hours of manual labour, this machine turned the cotton industry on its head

The cotton gin – short for cotton engine – consisted of a small wooden box-frame in which a wooden cylinder was surrounded by a spiked metal mesh. On the outside of the frame, the cylinder was attached to a hand crank that, when rotated, would cause the cylinder to spin. The rotating motion picked up raw cotton balls from a hopper and pulled them through the metal mesh, drawing the cotton lint into thin fibres and collecting the seeds at the same time.



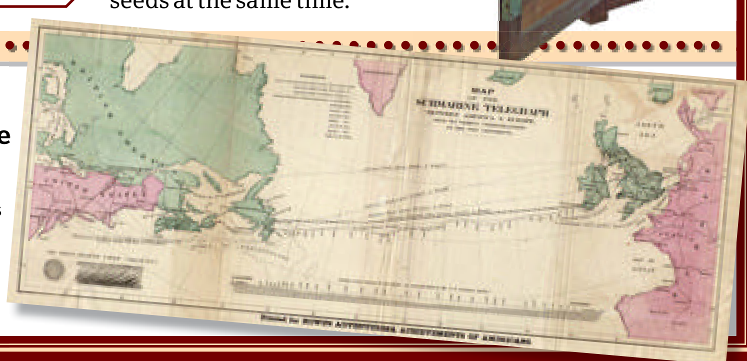
1864
Dynamite

Swede Alfred Nobel invents the explosive substance dynamite, for use in mining.



1866
Transatlantic cable

After several failed attempts, the first permanent cable to cross the Atlantic Ocean is completed, speeding up communication between the UK and the USA.



DRIVE TOWARDS GLOBAL TRAVEL

Beginning in the UK but soon spreading throughout Europe, America and many other parts of the world, these new mobile machines led to the creation of vast new transport networks. New roads were constructed to accommodate carriages, new railroads built to carry steam trains laden with food, coal and produce, new canals were built on a grand scale between major industrial cities, and new laws were passed to allow inventors to trial machines that could fly for miles in the skies, or cruise silently beneath the ocean waves. These advances expanded the availability of labour, raw materials and products massively, and drew people together like never before.

Of course the age of steam and steam-powered inventions couldn't last for long in the enlightened, driven mindset it had indirectly spawned. The rise of science and engineering culturally, as well as the increasing knowledge of material science, led to the creation of new forms of energy and explosive new prime movers. The electric battery was invented and the electric motor was derived from it; before the close of the 19th century the internal combustion engine had fired up, driven by the development of petrol and diesel.

These new power sources took mechanical engineering to another level, allowing devices such as the incandescent lamp, phonograph, electrical telegraph, telephone, automobile and aeroplane to not just be invented, but produced and implemented across the globe on a scale that was almost inconceivable.

The expansion was unstoppable and, by the end of the 19th century, most western countries were all but unrecognisable from the nations they had been at the turn of the 18th. Cities were packed with machines, vehicles, businesses, people and, crucially – indeed, the greatest legacy of the entire movement – knowledge on a truly industrial scale. It was a newfound general level of understanding that would see the world transform through the 20th century into the one we live in today. So, you see, we weren't exaggerating when we said steam really is quite interesting… ▶

1829 Stephenson's Rocket

Although not the first steam train to be built during the Industrial Revolution, Stephenson's Rocket incorporated lots of advanced technology into one vehicle

The father and son made Stephenson's Rocket was such a success as it drew together five key innovations. The first innovation was a single pair of driving wheels with a small carrying axle behind which allowed the weight of the coupling rods to be significantly reduced. In addition, as 2.5 tons of the Rocket's total 4.2-ton weight was positioned over the forward driving wheels, the second axle could be smaller – again cutting weight. This reduction improved speed and efficiency, the latter bolstered by the Rocket's use of a multi-tube boiler array. By installing 25 copper fire tubes instead of a single large tube to carry exhaust gases from the firebox to the chimney, a much bigger area of hot piping was created, and consequently more steam. The integration of a blastpipe aided the extra steam generated by feeding exhaust steam from the train's cylinders into a smokebox beneath its chimney; this boosted the intensity at which air was drawn through the system. This increase in raw steam power was bolstered by the separation of the enlarged copper firebox from the boiler. The final major innovation on the Rocket was the positioning of its two cylinders at a close to horizontal angle. By arranging the cylinders this way – with their pistons powering a pair of drive wheels – the train was able to eradicate an uneven swaying motion which had been a big problem on previous vehicles.

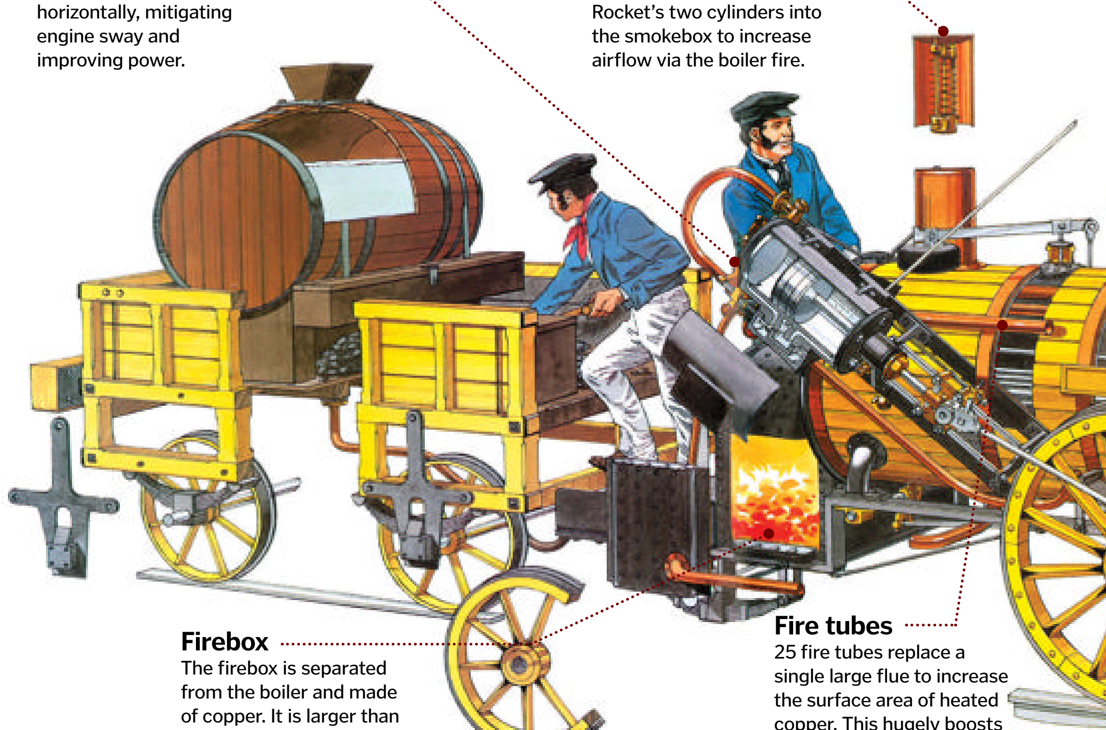
The statistics…

Stephenson's Rocket

Built:	1829
Wheel arrangement:	0-2-2
Weight:	4,230kg (9,325lb)
Fuel:	Coke
Boiler pressure:	3.5kg/cm² (50psi)
Cylinders:	2
Top speed:	47km/h (29mph)

Cylinder
The Rocket's cylinders are mounted almost horizontally, mitigating engine sway and improving power.

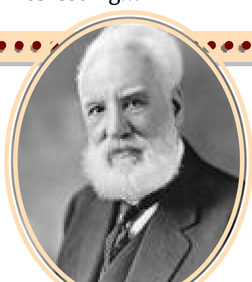
Blastpipe
The blastpipe discharges exhaust steam from the Rocket's two cylinders into the smokebox to increase airflow via the boiler fire.



Firebox
The firebox is separated from the boiler and made of copper. It is larger than previous examples too.

Fire tubes
25 fire tubes replace a single large flue to increase the surface area of heated copper. This hugely boosts steam generation.

1876
Bell telephone
Scottish-born engineer Alexander Graham Bell invents the telephone, improving on a water transmitter system which was pioneered by American Elisha Gray.



1877
Edison phonograph
The world's first phonograph is invented by Thomas Edison, allowing for the recording and reproduction of audio for the first time.

1880
Incandescent lamp
Although there are a number of earlier attempts Thomas Edison patents the first commercial incandescent lamp that will become the precursor to modern-day light bulbs.

KEY PLAYERS

STEPHENSON

George Stephenson

Nationality: English

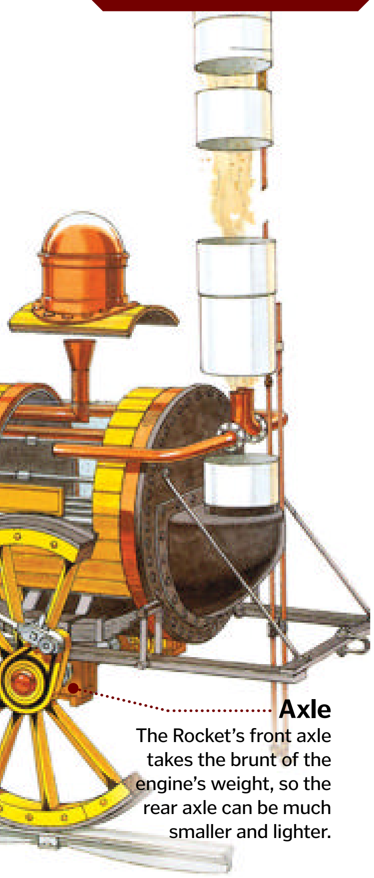
Role: Civil engineer

Born: 1781

Died: 1848

Known for: Stephenson's Rocket, safety lamps

Engineer George Stephenson not only invented the world's first public railway line that used solely steam locomotives, but also played the main role in making the Rocket steam train, miners' safety lamps and skew arch bridges. He is sometimes called the 'Father of Railways'.

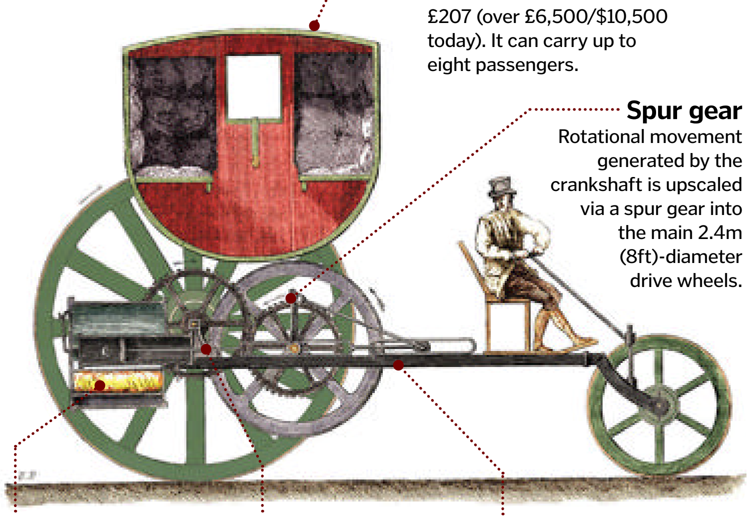


1803 The London Steam Carriage

The world's first self-propelled, passenger-carrying vehicle introduced the possibility of horseless travel

Replacing horses as a means of power required the carriage to be raised from its traditional position near the ground in order to accommodate the engine and gearing. The engine used high-pressure steam to drive a single cylinder and piston, which in turn powered a crankshaft. The linear motion produced by the piston was converted by the crankshaft into rotational motion and transferred into a spur gear, which turned the axle of the driving wheels. On top of this, the crankshaft powered the engine's steam cocks, force pump and firebox bellows as well.

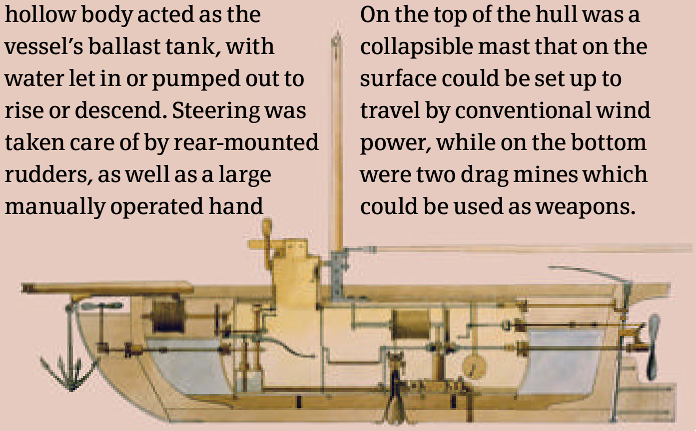
Unique to the design was the addition of a forked piston rod, which effectively closed the gap between the piston head and crankshaft. Another innovation was the use of a valve gear, allowing for the carriage's flywheel to be scaled down, improving efficiency and top speed.



1800 The Nautilus submarine

The inspiration for Jules Verne's famous fictional sub, Robert Fulton's Nautilus was the first practical submarine to be built

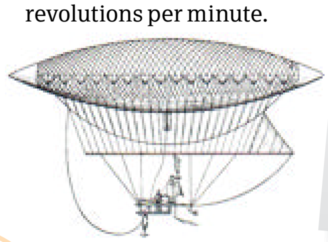
The Nautilus consisted of an ellipsoid tube of iron ribs covered by a series of riveted copper sheets; it measured 6.5 metres (21.3 feet) in length. The hollow body acted as the vessel's ballast tank, with water let in or pumped out to rise or descend. Steering was taken care of by rear-mounted rudders, as well as a large manually operated hand crank. This crank was directly connected to an external screw propeller, which gave a top speed of 3.2-4.8 kilometres (two to three miles) per hour. On the top of the hull was a collapsible mast that on the surface could be set up to travel by conventional wind power, while on the bottom were two drag mines which could be used as weapons.



1852 The Giffard dirigible

Discover the first-ever airship to be powered by a steam engine

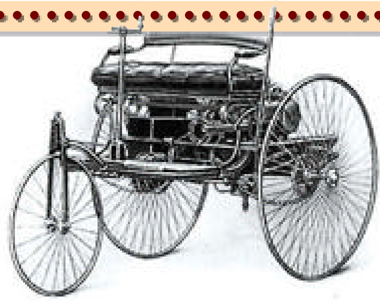
The 1852 Giffard dirigible consisted of a 44-metre (144-foot)-long hydrogen balloon that was encircled by a rope matrix. From the matrix hung a single metal pole which supported a gondola. The gondola was installed with a steam engine capable of producing just 2.2 kilowatts (three horsepower) that could turn the dirigible's large, gondola-mounted propeller at around 110 revolutions per minute.



Henri Giffard's airship cruising over Paris, France, in 1878

1885
Benz Motorwagen

Karl Benz's Patent-Motorwagen is developed and becomes the world's first commercially sold, mass-produced car, 23 years before Henry Ford releases his Model T.



1892
Diesel engine

German engineer Rudolf Diesel invents the diesel engine, which centres around the principle of fuel compression.

1895
Lumière cinematograph

What will become the first practical and successful motion-picture film camera is created, kick-starting the cinema industry.

INVENTING THE FUTURE

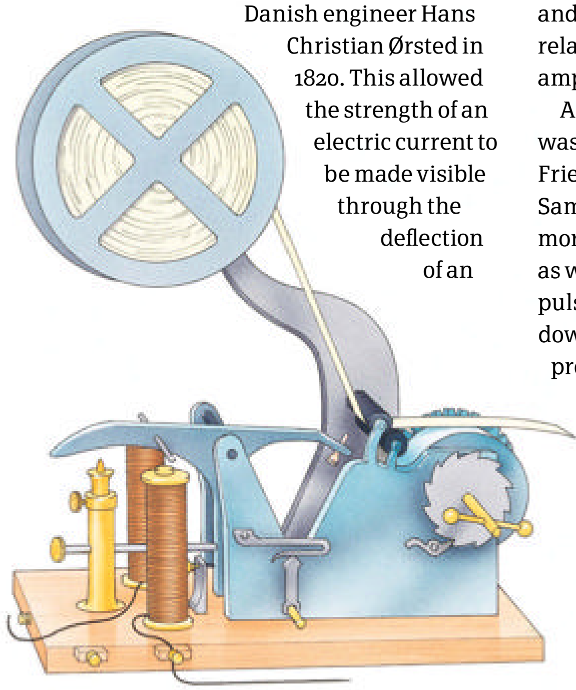
While the first half of the Industrial Revolution saw widespread changes to manufacturing and factory processes, the second built on that solid base, spawning a variety of world-changing inventions. The scope and purpose of these inventions was different to anything before, exploiting the newfound scientific understanding of physics and chemistry to create devices that would benefit people's day-to-day lives. Here are some of the most notable...

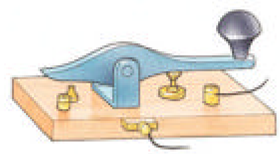
1833 Electrical telegraph

Radically changing the way that people communicated, the electrical telegraph helped connect the world like never before

The electrical telegraph was developed over a period of 40 years and worked by drawing together three key innovations. The first of these was the invention of the galvanometer by Danish engineer Hans Christian Ørsted in 1820. This allowed the strength of an electric current to be made visible through the deflection of an electric needle. The second innovation was the electromagnet, a device that provided a process for multiplying the magnetic force generated by a small electric current. The third and final innovation was the invention of the relay system in 1835, which could drastically amplify the strength of a signal.

Although the first electrical telegraph system was created by German scientists Karl Friedrich Gauss and Wilhelm Weber in 1833, Samuel Morse and Alfred Vail created a much more sophisticated telegraph four years later, as well as Morse code – a system of sending pulses of electrical current at different lengths down a network of metal cables. This led to the proliferation of long-distance communication throughout the USA and eventually the whole world, with the first successful transatlantic cable laid in 1866.





1887 Induction motor

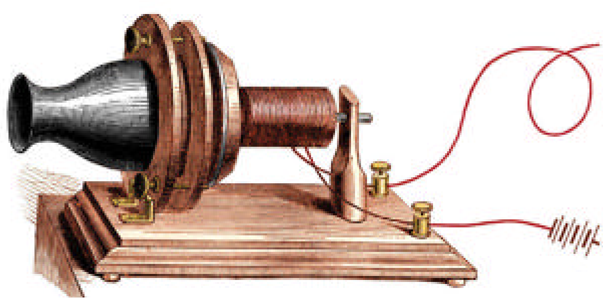
With this device, Tesla took previous electric motors to a whole new level

Prior to Nikola Tesla's invention of the polyphase induction motor, traditional dynamos had used a stationary stator to provide a constant magnetic field through which a set of rotating windings would turn. However, by reversing this process – so that the stator magnets rotated, rather than the rotor (windings) – current could be induced to flow through the latter with far greater efficiency. This was achieved by Tesla in 1887 with a two-phase induction motor that featured a rotating stator with two pairs of magnets – one pair for each two phases of alternating current (AC).

1876 Bell's telephone

Alexander Graham Bell's telephone brought acoustic telegraphy to the masses, allowing people to talk to one another over great distances

Alexander Graham Bell's original telephone, patented in 1876, worked by converting sound into an electrical signal via a 'liquid transmitter'. This process centred around directing sound through a receiver and onto a thin membrane stretched over a drum. On the outside of the membrane a cork with a needle attached to a battery extended to a cup filled with sulphuric acid and a metal contact. When sound waves hit the membrane, it caused vibrations, varying the strength of the current passing between the needle and the contact. This created a varying strength electric signal that travelled down a wire to a receiver, where through a reversed process, the sounds were re-created. While not the only person to make a telephone at this time, Bell was the first to transfer his invention into a commercial product with a supporting network of exchanges and switchboards, etc.



1901 Marconi radio

Long-distance radio transmission becomes a reality with the invention of the radio telegraph and the radio by Italian Guglielmo Marconi.

1903 Wright Flyer

The Wright brothers launch their Wright Flyer – the first aeroplane to make a successful powered flight.

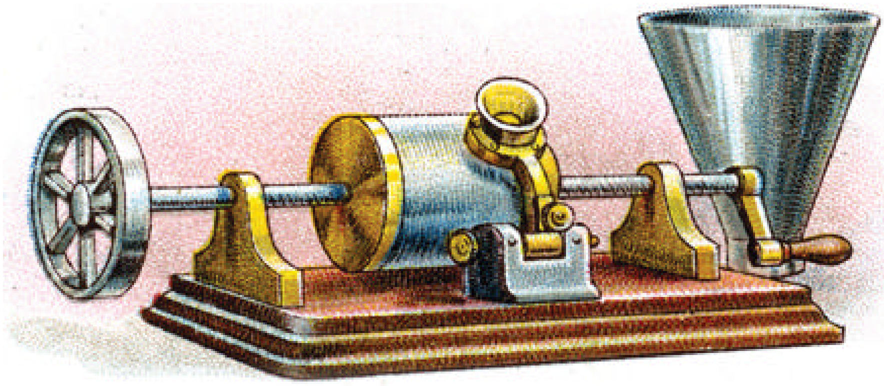
1908 Ford Model T

Henry Ford introduces the production line and uses it to mass produce his now legendary Model T car.

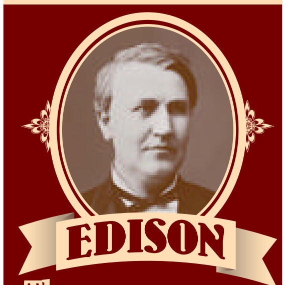
1877 Edison's phonograph

An invention that resonates deeply today, Edison's 1877 phonograph ushered in an era of recordable and reproducible audio – the forebear of modern music players

The Edison cylinder phonograph was the first device in history that could mechanically record and then reproduce audio. It worked by receiving sounds through a brass mouthpiece and relaying them through a diaphragm to make it vibrate. The diaphragm's vibration caused a connected stylus to make indentations on a tinfoil-wrapped, rotating drum. Once the tinfoil drum had been covered with indentations, the received audio could be played back by passing a second stylus over them, making a second diaphragm vibrate to re-create the recorded sounds. The phonograph would eventually lead to the invention of the gramophone and disc-based storage, with LP (long-play) records becoming the dominant form of audio data storage until magnetic tape, which didn't emerge until the late-1920s.



KEY PLAYERS



Thomas Alva Edison

Nationality: American

Role: Inventor

Born: 1847

Died: 1931

Known for: Carbon telephone transmitter, incandescent lamp, phonograph

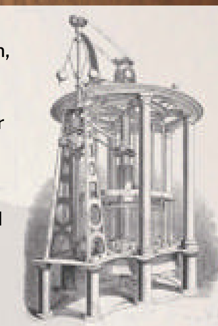
The US inventor and astute businessman produced many devices still around today. As well as inventions, he created a new system of electricity generation and distribution.

FOCUS ON THE GREAT EXHIBITION

1851's Great Exhibition typified the Industrial Revolution, showcasing a range of inventions and curiosities in a celebration of human ingenuity. **HIW** looks at just a few of the exhibits and where they came from…

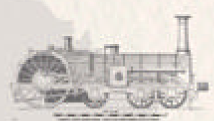
Double turbine

Made by Fromont & Son, the double turbine offered many benefits over the standard water wheel. It featured 'no accelerating gear', a drive shaft capable of a velocity of 100, 150 and 200 revolutions per minute and a one-piece propeller 'that does not require repairing'.



Express engine

Displayed by the English South Eastern Railway Company, the express engine was a steam train with its engine suspended across three load-bearing struts. This allowed the weight to be evenly distributed over all wheels, granting a much smoother ride.



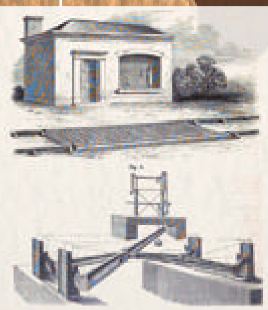
The Great Exhibition of 1851 was held at London's Crystal Palace

Fire engine

Created by GJ Perry, this fire engine evolved the standard side-to-side pumping mechanism of contemporary engines with a large, end-to-end one. This increased the engine stroke from 20cm (8in) to 41cm (16in) and needed fewer firefighters to operate.

Weighing machine

Shown by Henry Pooley & Son, this device allowed a train's gross weight and rail impact to be measured while still on the track. It advertised an accuracy 'equal to that of the beam and scales' and an 'economy of labour, space and cost' improvement of roughly 50 per cent.



Indian howdah

Not everything at the Great Exhibition was a mechanical device. This Indian howdah (carriage) and elephant came courtesy of an Indian rajah and demonstrated the elaborate fixings needed to strap it securely to an elephant's back.

Domestic TVs are growing to cinematic proportions, but hand in hand some clever tech means they're getting ever thinner too. In the same vein, discover how Apple has shrunk its iPad and, on a much grander scale, see how the Hoover Dam was built.

28 Shark repellant

29 iPad mini

32 Hoover Dam

LEARN MORE

Ultra-slim OLED screens

HIW reveals the crash-diet technology that makes the latest TV displays so incredibly thin

Most mid-range TVs and computer monitors today are called LED displays, but this is an inaccurate shorthand. The LED, or light-emitting diode, is just the light source. An array of LEDs sits behind the picture, or around the edges with special diffusers, to illuminate the image. The pixels themselves are still generated by an old-fashioned liquid crystal display (LCD). This is because traditional semiconductor LEDs are much too big to work as individual screen pixels in an average TV.

Organic LED (OLED) technology is different. The organic chemicals that generate the light can be produced in very thin films. So thin, in fact, that they can actually be printed into the screen matrix using a machine like an inkjet printer – except that it prints pixels instead of ink dots. The limitation on how small you can make the pixels depends not on the size of the OLEDs themselves, but on how tightly you can pack together the grid of transistors to switch them on and off. This is the same grid that LCD screens use, so the manufacturing process already exists. OLED screens have the same pixel resolution as LCDs, however they are drastically thinner. Not only are the OLED pixels themselves thinner, but you don't need to allow room for a backlight; the OLEDs are their own light source.

These two factors mean that OLED screens are up to a third of the thickness of today's slimmest TVs. Early OLED displays suffered from relatively short life spans – especially in the blue pixels – but new organic molecules that produce brighter, truer colours and last far longer are being developed. As far as TVs go, the future isn't just bright – it's ultra-thin too.

An organic diet

How do organic LEDs manage to be so much thinner than other displays?

HEAD 2 HEAD

SVELTE TVS

1. THIN

Sony KDL-40NX713
One of the thinnest of the current generation of LED backlit screens, this Sony TV is just 32 millimetres (1.3 inches) deep.

2. THINNER

Samsung ES9500
Samsung's debut 140-centimetre (55-inch) OLED screen has a razor-thin profile of 7.6 millimetres (0.3 inches).

3. THINNEST

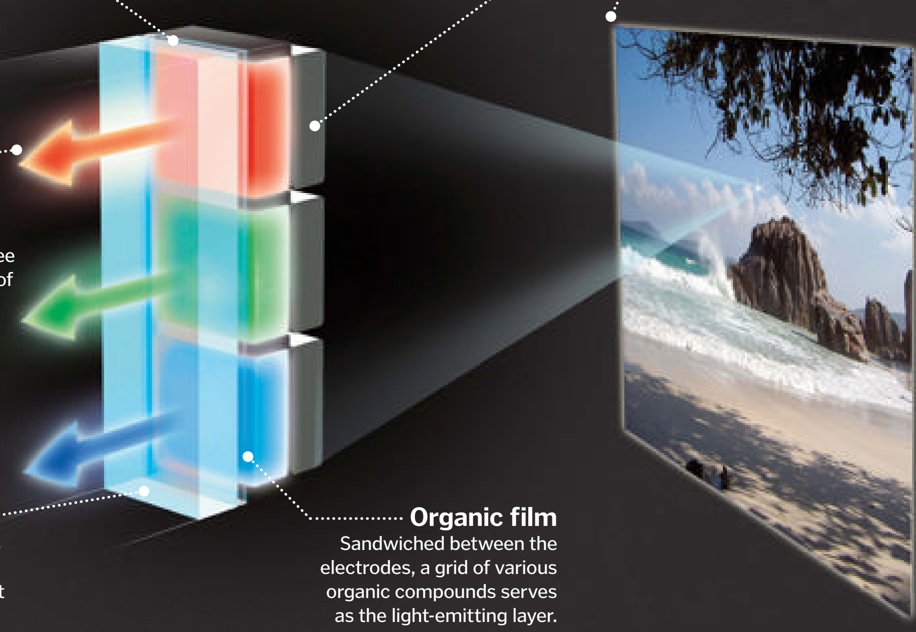
LG EM970V
LG wins with a screen just four millimetres (0.2 inches) deep. Both this and the Samsung ES9500 will be on sale at some point in 2013.

DID YOU KNOW? *OLED screens can display up to 100,000 fps, compared with 60-480 fps for LCD displays*

LG's EM970V is currently the world's largest and slimmest OLED television

Thinner and twistier

Most OLED displays are made by depositing the different layers on a sheet of glass that forms the front of the screen. But if you swap the glass for a plastic, like PET, you can make OLED screens that are even thinner, and flexible enough to wrap around a pencil. It's a bit more complicated than that, obviously, because the electronics that control the OLED pixels have to be flexible as well. The organic molecules themselves also degrade when exposed to air and moisture so a flexible screen must be very tightly sealed. Nevertheless flexible screen technology opens up the possibility of manufacturing displays in a continuous roll, with the components 'printed' directly onto the plastic like an inkjet printer. And soon, quantum-dot (QD) displays – which use nanocrystals of cadmium selenide instead of organic polymers – will make it even easier to print the thinnest, most flexible displays yet.



TV tech translated

Cathode ray tube (CRT)

Old-style TVs use a heavy glass vacuum tube chamber. Electrons are generated at one end by heating a metal filament – just like a light bulb. Electromagnets accelerate and steer the beam of electrons (cathode rays) so that they strike a grid of phosphor dots which causes them to glow.

Liquid crystal display (LCD)

Liquid crystals change the polarisation of light passing through them. Pixels are activated or deactivated by rotating the liquid crystal molecules with an electric field. A polaroid filter at the front blocks out all the light shining through the pixels, except the ones that have been rotated correctly.

Organic light-emitting diode (OLED)

Certain organic compounds and polymers will emit light when you run an electric current through them. Sandwiching a layer of this compound between two electrodes enables you to turn them on and off. Different materials illuminate in different colours.

Plasma display panel (PDP)

Each pixel is essentially a tiny fluorescent light bulb. A low-pressure mixture of xenon and neon gases is ionised to a plasma by an electric field and the colliding gas atoms emit a small amount of ultraviolet light. This strikes a fluorescent coating at the front to convert the UV into visible light.

"The needle drags a loop of thread to the other side of the fabric, where a hook grabs it"

How do sewing machines work?

Ever wondered how a sewing machine can stitch fabric so quickly yet precisely? HIW reveals all now

Modern sewing machines do the job of a highly skilled tailor in a fraction of the time. Before they were invented in the late-18th century, the fine stitching that we take for granted on our everyday clothes today would have only been available to the wealthiest members of society.

There are several basic methods of stitching that various models employ, but the loop stitch is the most common. This works by passing a needle tied with thread through both pieces of fabric and out the other side, then back again. When stitching manually this involves passing the needle to the other hand and turning it around to go back, which is too elaborate for a machine to perform, and also unnecessary.

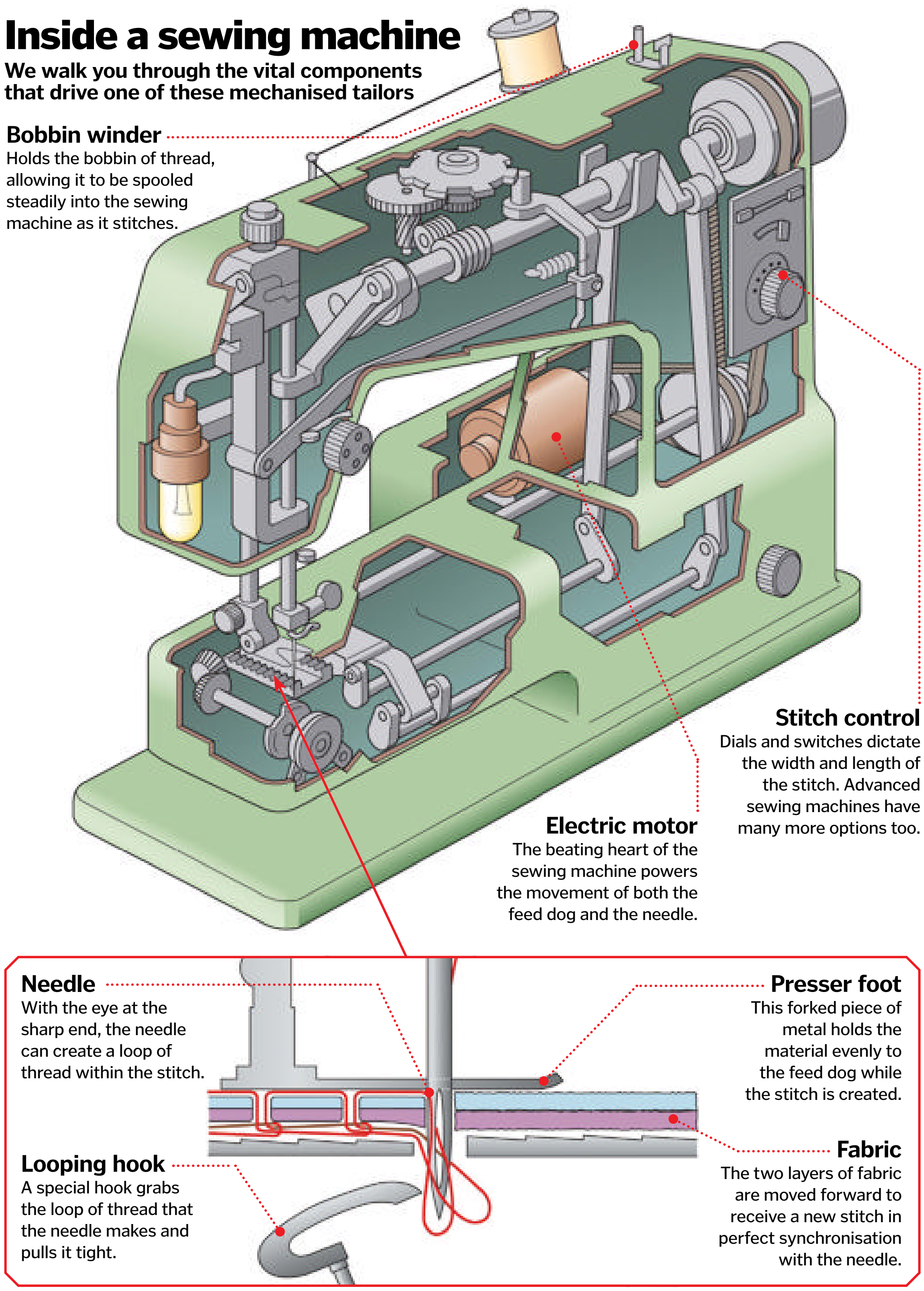
Instead a sewing machine uses two parts: a needle and a looping hook. The machine needle passes only partway through the material with the eye at the sharp end rather than the blunt end like its handheld equivalent. As it's moving through the fabric, the needle drags a loop of thread to the other side, where a hook grabs it and either loops the thread around itself or around a separate piece of thread. The needle then retracts and the thread is drawn tight, fastening the fabric together.

What is the feed dog?

Inside an electric sewing machine is a sophisticated series of gears and shafts that all connect to a single motor. One part of the motor controls a crank that pulls the needle bar up and down, plus a thread-tightening arm, which creates a slack loop and then tightens it to form the stitch. The other vital part of the sewing machine that the motor controls is the feed dog. This is the belt that steadily and evenly moves the fabric forward in synchronisation with the needle to create a new stitch. The feed dog is pressed up against the fabric where it rolls forward, shifting the material a short, consistent distance before dropping down again to release it. The entire process of feed dog, needle bar and thread-tightening arm is entirely driven by the motor, which in turn is controlled by a pressure-sensitive footplate operated by the user.

Inside a sewing machine

We walk you through the vital components that drive one of these mechanised tailors



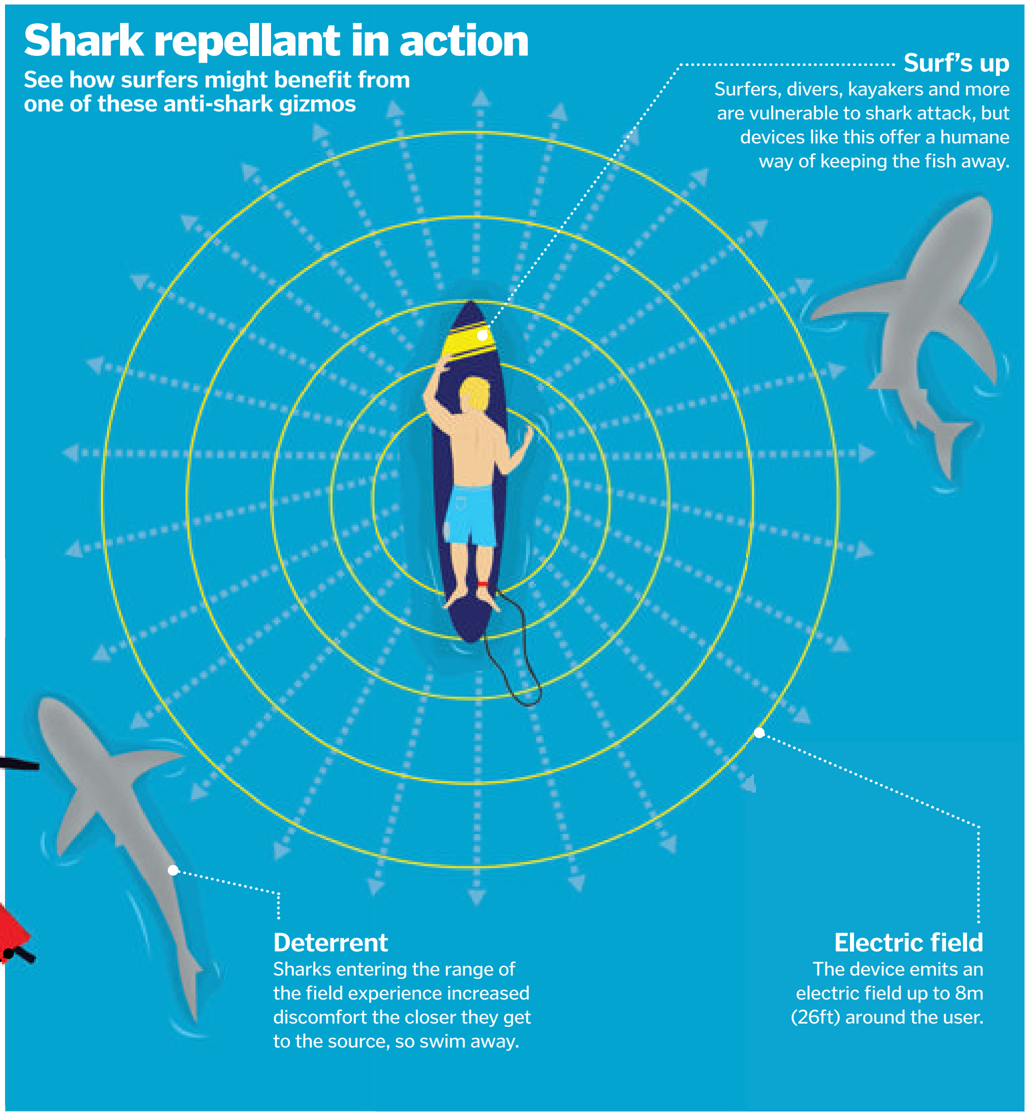
"One of the most effective repellants exploits the electric sensitivity of the shark's ampullae of Lorenzini"

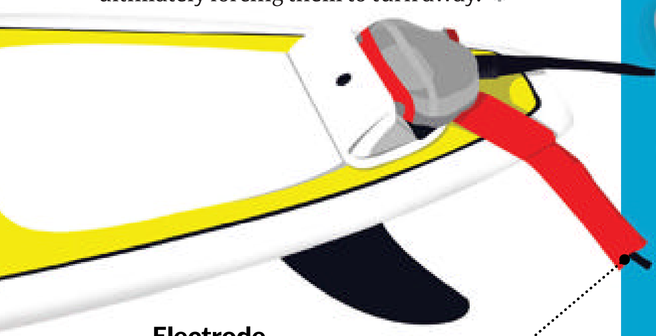
What is shark repellant?

Learn about the clever technology being developed to keep sharks at bay

Shark repellant technology is still a work in progress to some extent, but there are two main proven methods to keep sharks at bay. These predatory fish will stay well clear of other dead sharks when they smell them, and scientists have isolated the chemical source of the odour to several compounds, like copper sulphate. There are also examples of prey taking advantage of the shark's sensitivity to certain smells, such as the Moses sole, which produces a soap-like substance called pardaxin that sharks hate.

One of the most effective repellants so far, though, exploits the electric sensitivity of the ampullae of Lorenzini on the shark's nose, which it uses to detect prey and navigate. The device creates a local elliptical electric field that employs a particular waveform that all sharks are sensitive to. This causes uncomfortable (but not harmful) spasms in their snouts that intensify the closer they move to the source, ultimately forcing them to turn away.





1. LIGHTEST

iPad mini
Although made out of aluminium (compared to the Nexus 7 and Kindle Fire which are built out of plastic), the iPad mini weighs significantly less.

2. FASTEST

Google Nexus 7
The Nexus 7's Tegra 3 processor has more cores and a faster clock speed than any of its rivals. This means pages are quick to load and games glitch-free.

3. WIDEST

Kindle Fire HD
Despite having the same screen as the Nexus 7, the Kindle Fire HD from Amazon is the widest of the three major miniature tablets on the market.

DID YOU KNOW? *On a Retina-standard display individual pixels aren't visible at a normal operating distance*

Inside the iPad mini

We take a look at what makes Apple's scaled-down tablet tick

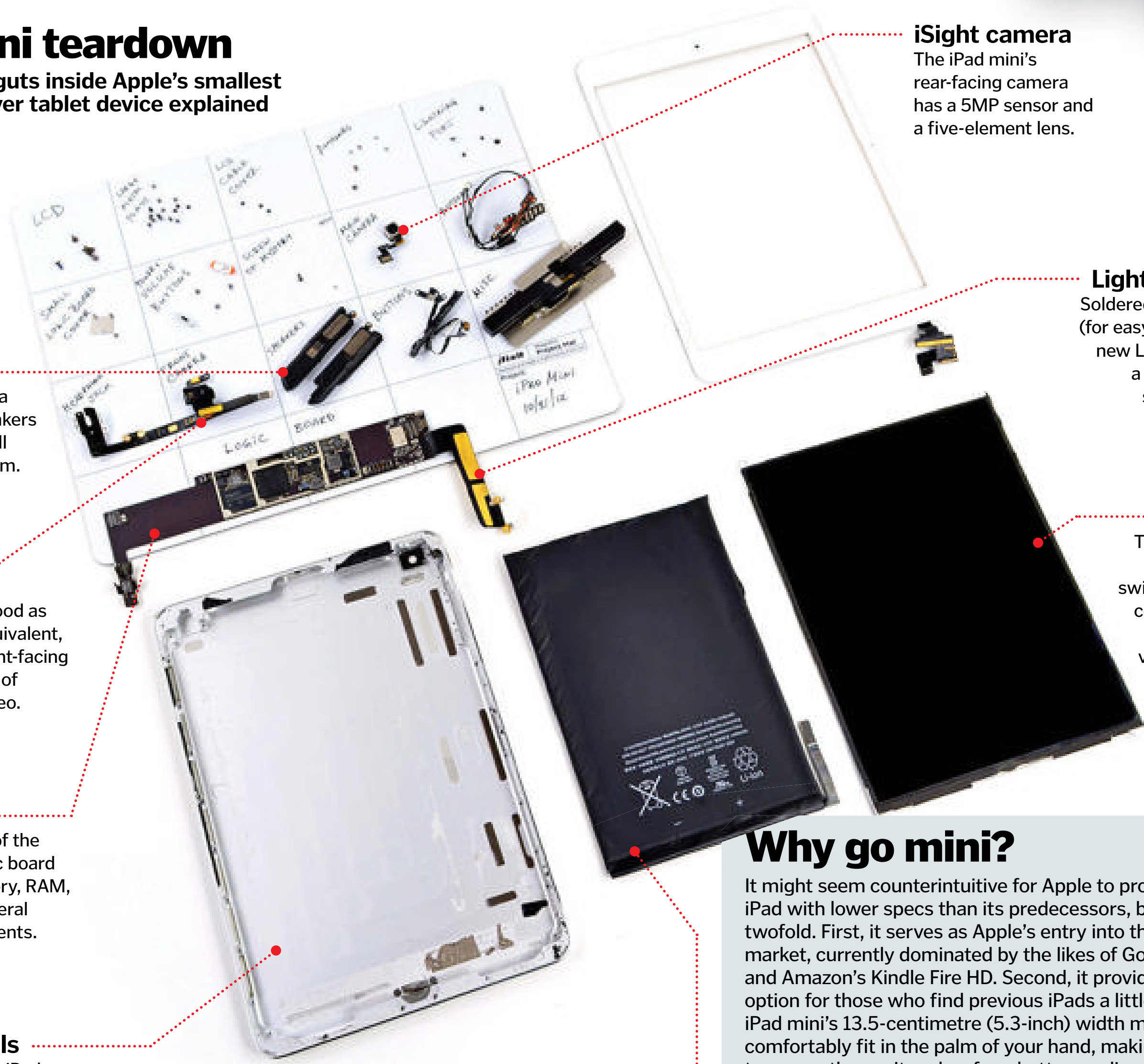
After months of speculation and leaked parts, Apple unveiled the iPad mini on 23 October 2012. As the name indicates, it's significantly smaller than the previous four generations of the iPad lineup, sporting a 20-centimetre (7.9-inch) display (diagonal). It's also 23 per cent thinner, with a depth of 7.2 millimetres (0.3 inches) and lighter too, weighing in at just 308 grams (10.9 ounces).

Despite being significantly smaller, Apple has still managed to pack in the same dual-core A5 processing chip used in the original iPad, iPhone 4 and fourth-generation iPod touch, 512MB of RAM and up to 64GB of flash memory. This gives the iPad mini enough power to run Apple's latest mobile operating system: iOS 6.

In order to fit everything into such a small form factor, a few compromises on specs have been made. Unlike the third and fourth-generation iPads, the screen has a resolution of 1,024 x 768 pixels – the same as the iPad 2, which means it doesn't have enough pixels per inch to be considered a Retina display. The battery is also a lot smaller, but will still apparently provide up to ten hours of internet browsing, video or music playback.

iPad mini teardown

The technical guts inside Apple's smallest and lightest-ever tablet device explained



iSight camera
The iPad mini's rear-facing camera has a 5MP sensor and a five-element lens.

Lightning connector
Soldered onto the logic board (for easy assembly) is Apple's new Lightning connection – a smaller connector for syncing and charging.

Speakers
The iPad mini has a pair of stereo speakers packed into a small space at the bottom.

Display
The LED-backlit display uses IPS (in-plane switching) technology so colours look vivid, even when the screen is viewed at wide angles.

FaceTime HD camera
Although not as good as the rear-facing equivalent, the iPad mini's front-facing camera is capable of shooting 720p video.

Logic board
The nerve centre of the iPad mini, the logic board contains its memory, RAM, processor and several other key components.

Build materials
Apple has built the iPad mini like many of its products out of aluminium and glass – both of these materials have good environmental credentials.

Battery
The 16.3Whr cell has a much lower capacity than other iPads, but will still last for up to ten hours.

Why go mini?

It might seem counterintuitive for Apple to produce a smaller iPad with lower specs than its predecessors, but its purpose is twofold. First, it serves as Apple's entry into the smaller tablet market, currently dominated by the likes of Google's Nexus 7 and Amazon's Kindle Fire HD. Second, it provides another option for those who find previous iPads a little unwieldy. The iPad mini's 13.5-centimetre (5.3-inch) width means it will comfortably fit in the palm of your hand, making it much easier to use on the go. It makes for a better reading experience using apps like iBooks, with the screen width much more akin to a paperback book. Also, as the 20-centimetre (7.9-inch) display shares the same resolution as the iPad 2, app developers won't have to redesign applications to work with the mini.

"SSDs are built very much like the USB flash drives that have become popular over the last decade"

How do wireless speakers work?

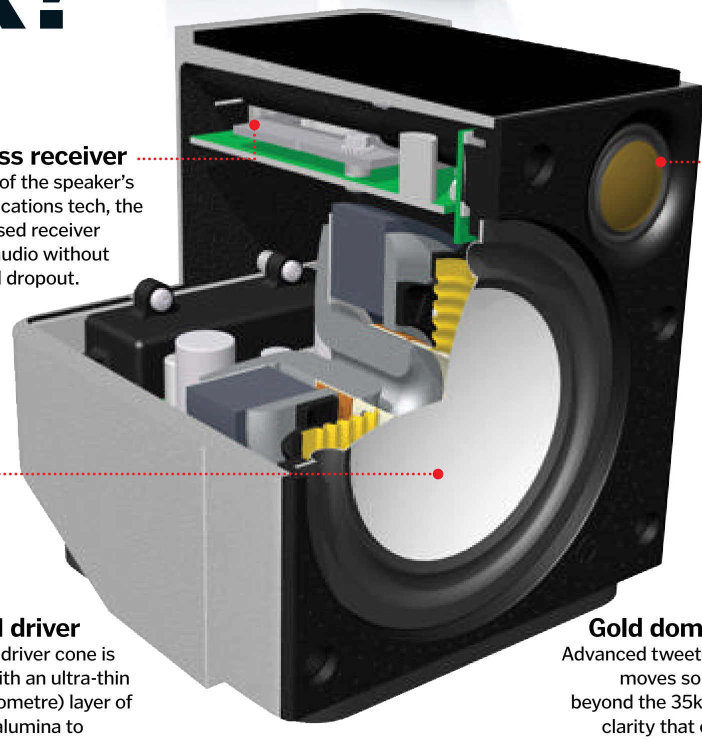
Discover the inner workings of a modern wireless speaker system

Wireless speakers combine the same basic techniques that the first speakers and wireless devices were based upon. So what makes modern wireless speakers stand out? Well, today's systems employ a transmission protocol called SKAA – a hi-fi audio standard that uses a portable device as the sound source that can be connected to any wireless gadget with SKAA support. Today, the 2.4GHz radio wavelength is a very crowded frequency as it's such a high-quality audio band, so SKAA makes use of a patented protocol to avoid conflicts with any other devices.

Of course, speakers themselves have been refined in many ways over the years too. Alloy tweeters are now geometrically designed using computer software to find the optimum shape, then coated with ceramic and anodised with gold: this improves high-frequency sound output. Elsewhere, the main drivers are made out of the same light yet rigid material originally developed for jet engines, which ensures it is highly resistant to flexion, or bending; this also reduces audio distortion at higher audio outputs.

Explore the WS100

We examine a wireless speaker from the inside out



Wireless receiver
The core of the speaker's communications tech, the SKAA-based receiver delivers audio without noise and dropout.

C-CAM driver
The alloy driver cone is coated with an ultra-thin (50-micrometre) layer of ceramic alumina to dissipate heat.

Gold dome C-CAM
Advanced tweeter modelling moves sound breakup beyond the 35kHz range for clarity that extends way beyond human hearing.

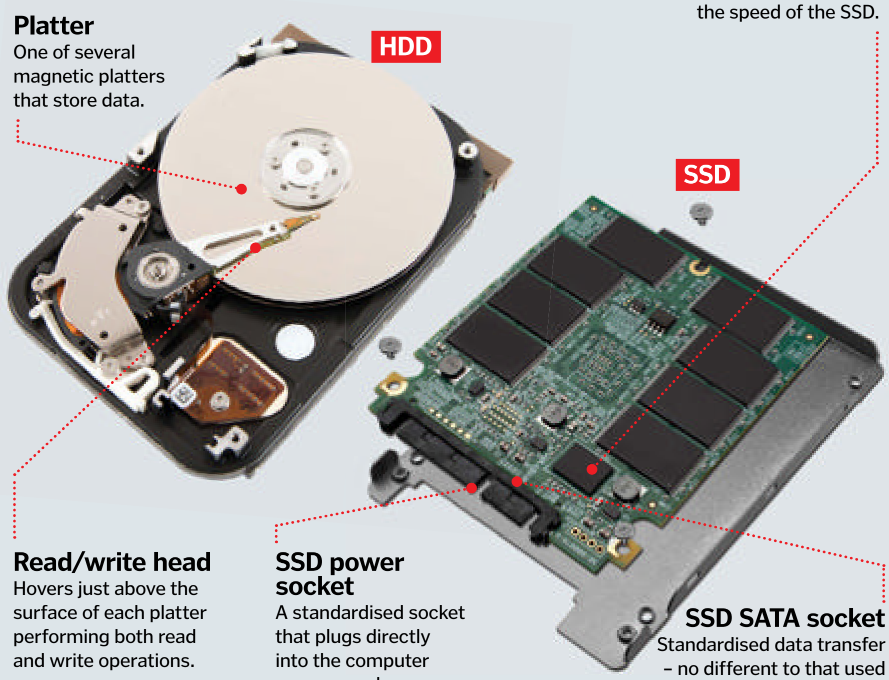
Disk drives demystified

Why are solid-state drives superseding hard-disk drives?

Hard-disk drives (HDDs) have been around since IBM conceived of the need for extra computer storage in 1956. A hard disk uses magnetised platters made of aluminium, ceramics or even glass to store data. These are typically rotated at 5,400 or 7,200 revolutions per minute for drives in home PCs. An arm that hovers just above the platters reads data from and writes data to the disk. SSDs, meanwhile, are built very much like the USB flash drives that have become popular over the last decade. There are no moving parts in an SSD, which helps it to access data significantly faster. SSDs use a type of memory called NAND, which is non-volatile: instead of writing a magnetic pattern to a ceramic substrate, it stores data as an electrical signal that it retains even after the computer is switched off. Each SSD features a small processor called a controller, which performs the same role as the read/write arm of an HDD.

Comparing the drives

Take a closer look at the key differences between these electronic storage devices



Platter
One of several magnetic platters that store data.

Controller
Reads and writes to the drive's memory chips, ultimately determining the speed of the SSD.

Read/write head
Hovers just above the surface of each platter performing both read and write operations.

SSD power socket
A standardised socket that plugs directly into the computer power supply.

SSD SATA socket
Standardised data transfer – no different to that used by modern-day HDDs.

"The Hoover Dam was the largest in the world requiring over 3.3 million cubic metres of concrete to build"

Hoover Dam construction

It was one of the most ambitious projects in the world, but how was the Hoover Dam constructed?

In the early-20th century, the lower region of the Colorado River was considered as a site for flood control and potential source of hydroelectric power for the growing demands of western US states. What would be known as the Hoover Dam was authorised by President Calvin Coolidge in 1928 and construction began by building conglomerate Six Companies in March 1931.

At the time the Hoover Dam was the largest in the world requiring over 3.3 million cubic metres (118 million cubic feet) of concrete to build, including the power station.

Before the dam could be built, foundations had to be laid and over 1.3 million cubic metres (48 million cubic feet) of loose rock and sediment were removed from the bottom of the Colorado River to reach stable bedrock. The foundation was reinforced with a grout curtain and the canyon walls were similarly stabilised by drilling holes up to 46 metres (150 feet) deep into them and filling cavities with more grout. Chief engineer John Savage had decided it would be an arch-gravity dam, which combines the main features of two different types of dam: the arch part is a concave face that leans towards the water, deflecting some of the pressure onto the canyon walls, while the gravity part of the design is the enormous weight of the dam that thickens considerably from the top (13.7 metres/45 feet) to the bottom (201 metres/660 feet). This helps to resist the immense force that the Colorado River can generate with its 5.5 million-ton weight.

To help dissipate the heat generated by all this concrete setting, around 950 kilometres (590 miles) of steel piping delivered water cooled by the dam's dedicated ammonia refrigeration plant through the 230 concrete blocks that make up the structure. Without this active cooling system in place, all that concrete would still be setting today!

Diverting the Colorado River

Constructing the Hoover Dam would have been impossible with the Colorado River still flowing through Black Canyon. So, the builder endeavoured to divert the course of the river. Four tunnels with a combined length of over five kilometres (three miles) were dug into the canyon walls and around the dam site. The river was diverted into these tunnels by blocking its natural course with rubble as well as detonating a hole in a cofferdam – a temporary enclosure that stopped the river draining into the diversion tunnels. This was only performed for the two tunnels on the Arizona side of the canyon. The two drainage tunnels on the Nevada side were held in reserve for the higher waters in spring and summer.

Hoover Dam structure

How It Works explores one of the world's greatest engineering feats

Lake Mead
At maximum capacity, the lake on the upstream side of the dam can yield 219,700kg/m² (45,000lb/ft²) of force at its base.

Spillway inlet
Overflow from Lake Mead drains downstream via these inlets. They've been used only twice since the dam was built.

KEY DATES
HOOVER DAM

1928
A dam in Black Canyon is authorised by Congress and Six Companies wins the contract.

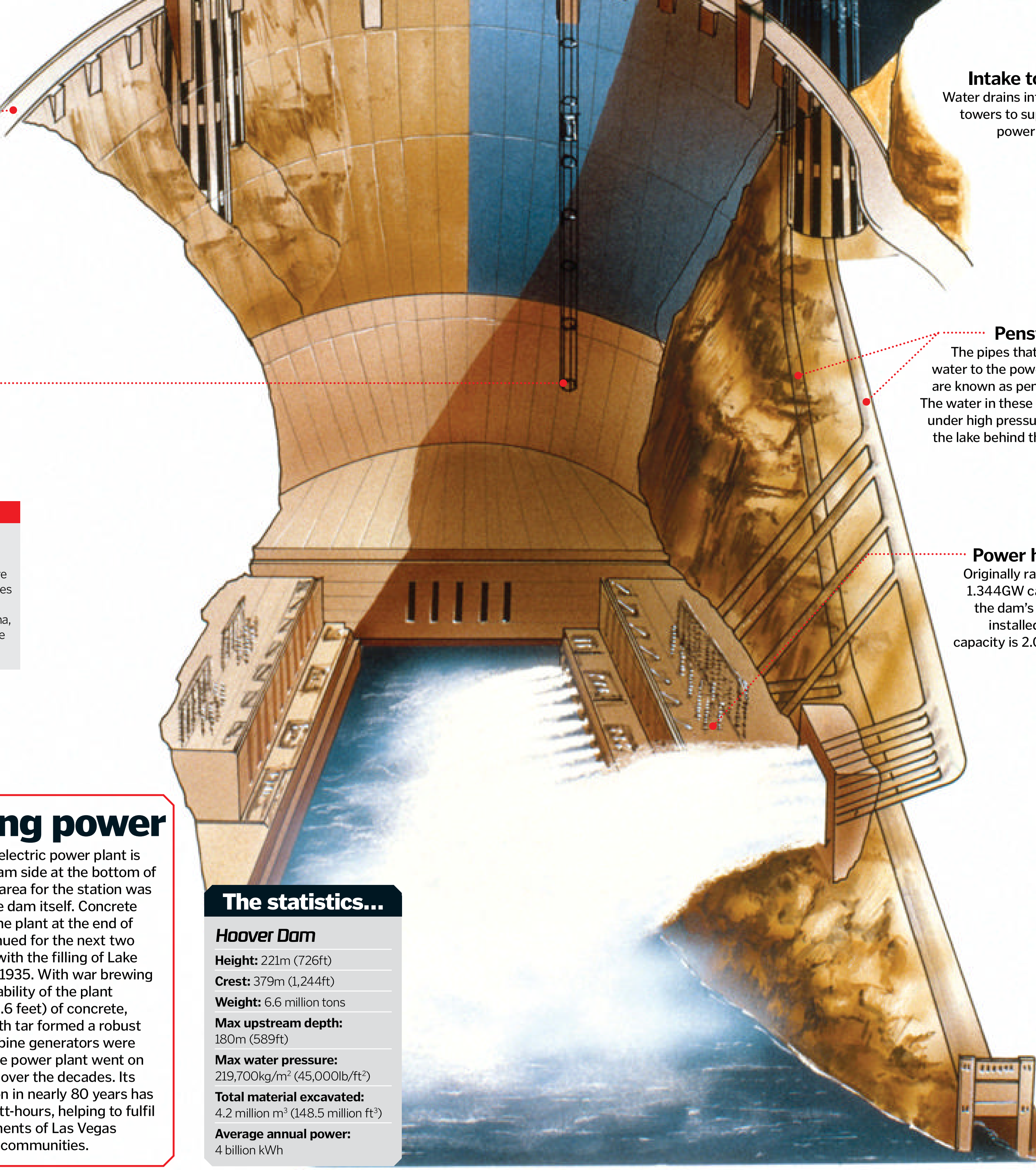
1935
President Roosevelt (right) formally opens the dam on 30 September to a crowd of 10,000.

1947
The 'Boulder Dam' name is removed and the House of Congress bestows the name 'Hoover Dam' instead.

1961
The last of the 17 turbines is installed into the power station, bringing it up to full capacity.

1983
The 1983 floods see the Hoover Dam use its spillways for only the second time (the first being a 1941 test).

DID YOU KNOW? *The Hoover Dam was initially called Boulder Dam, as Boulder Canyon was the original site location*



Intake towers
Water drains into these towers to supply the power station.

Penstocks
The pipes that deliver water to the power plant are known as penstocks. The water in these pipes is under high pressure from the lake behind the dam.

Power house
Originally rated at a 1.344GW capacity, the dam's current installed power capacity is 2.078GW.

Highway
For many years the top of the Hoover Dam served as a public highway between Nevada and Arizona until the Hoover Dam Bypass was opened in 2010.

Elevator
An elevator takes tourists down a 152m (500ft) shaft to the base of the dam to the power plant.

Learn more

Go to **www.howitworksdaily.com** for some fascinating facts on megastructures, a look at five of the most impressive structures built on Earth by humankind, including: the Great Wall of China, the Mirny Mine in Russia and the Three Gorges Dam, China.

Generating power

The Hoover Dam's hydroelectric power plant is located on the downstream side at the bottom of the dam. Excavating the area for the station was finished in 1933, after the dam itself. Concrete began to be poured for the plant at the end of the same year and continued for the next two years, even overlapping with the filling of Lake Mead behind the dam in 1935. With war brewing in Europe and the vulnerability of the plant considered, 1.1 metres (3.6 feet) of concrete, rock and steel topped with tar formed a robust ceiling. Three Francis turbine generators were installed in 1937 when the power plant went on line, with 14 more added over the decades. Its average power generation in nearly 80 years has been around four terawatt-hours, helping to fulfil the huge power requirements of Las Vegas among other west coast communities.

The statistics...

Hoover Dam

Height: 221m (726ft)

Crest: 379m (1,244ft)

Weight: 6.6 million tons

Max upstream depth: 180m (589ft)

Max water pressure: 219,700kg/m^2 (45,000lb/ft^2)

Total material excavated: 4.2 million m^3 (148.5 million ft^3)

Average annual power: 4 billion kWh

categories explained: Animals, Climate, Geography, Geology, Plants, General

It can be all too easy to think of the ground as something solid and unchanging… But in fact this rocky mass with a molten core that we call home is forever shifting and re-forming with epic results, as we see here. Also learn about the chemistry of a flower's aroma and the life cycle of emperor penguins in the bitter Antarctic.

40 Flower scent

40 Belt of Venus

42 Emperor penguins

LEARN MORE

25 EARTH SHATTERING FACTS

Can earthquakes make days shorter? Are there quakes elsewhere in space? Find out now…

The earthquake and tsunami that devastated north-east Japan in March 2011 demonstrate the terrifying power of these natural phenomena. Almost 16,000 people died and more than a million buildings wholly or partly collapsed.

A year after the event, 330,000 people were still living in hotels or in other temporary accommodation, unable to return home. A further 3,000 people were still listed as missing. The gigantic tsunami waves spawned by the earthquake inundated the power supply and cooling of three reactors at the Fukushima Daiichi power station. The subsequent nuclear accident – the worst since Chernobyl – caused worldwide panic.

Earthquakes are unstoppable and strike with little or no warning, but we know a growing amount about how they work. Scientists have developed networks of sensors for monitoring ground movements, changes in groundwater and magnetic fields, which may indicate an impending quake. Engineers, meanwhile, have created new forms of architecture to resist earthquakes when they do strike. So without further ado, let's learn some earth-shattering facts…

5 TOP FACTS QUAKE PROOFING

Cloaking device
1 A 'cloak' of concentric plastic rings could protect future buildings from quakes. Waves of vibrations would be diverted in an arc around the building, saving it from damage.

Get braced
2 Engineers strengthen buildings against twisting forces by building around a skeleton of diagonal crossbeams, vertical shear walls and steel frames.

Steeling up
3 Buildings made of structural steel or reinforced with steel beams are less brittle than unreinforced brick or concrete buildings, and can flex when swayed by an earthquake.

Rubber feet
4 The building sits on lead-rubber cylinders, bearings or springs. These sway horizontally when a quake hits to reduce the sideways movement of the structure.

Symmetry
5 Box-shaped buildings are more resistant than irregular-shaped ones, which twist as they shake. Each wing of an L or T-shaped building may vibrate separately, increasing damage.

DID YOU KNOW? *Antarctica gets icequakes, a kind of earthquake that occurs in the ice sheet*

3. What is Earth's crust made of?

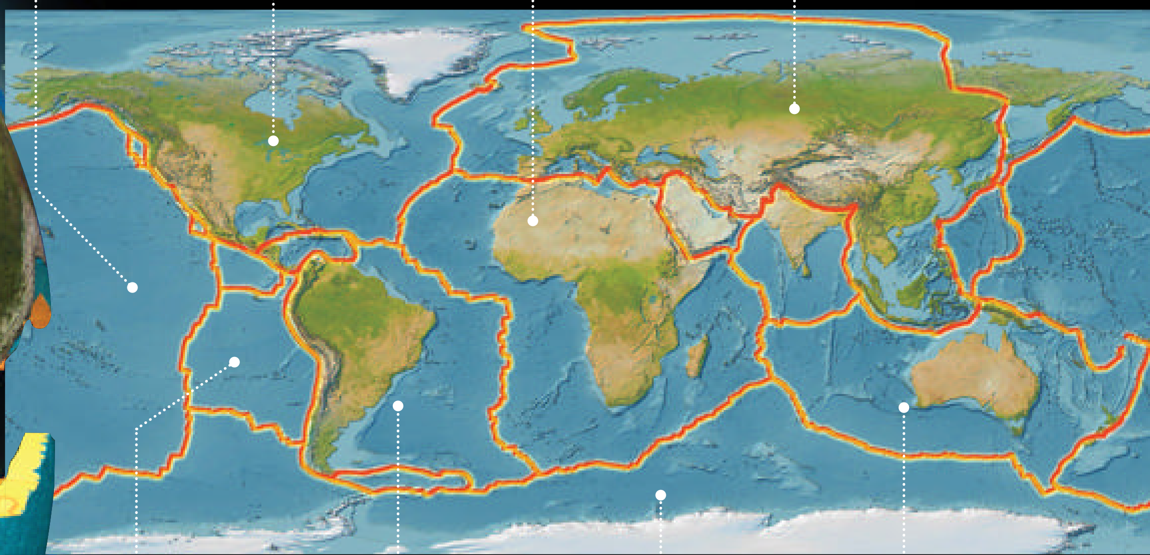
The crust consists of rock broken into moving slabs, called plates. These plates float on the denser rocks of the mantle, a sticky layer lying between the planet's core and the crust. Granite is the commonest rock in the crust that makes up Earth's continents. This continental crust is an average 35 kilometres (22 miles) thick, deepest beneath mountain ranges. Ocean floor crust is thinner – on average six kilometres (four miles) – and mainly made of denser volcanic rocks, such as basalt. Granite is 75 per cent oxygen and silicon. Basalt is denser as the silicon is contaminated with heavier elements like iron.

Pacific Plate
Earth's biggest plate is among the fastest moving, travelling north-west some seven centimetres (three inches) annually.

North American Plate
The continent of North America and some of the Atlantic Ocean floor sit on this plate.

African Plate
This plate carrying the African continent carries some of the world's most ancient crust – up to 3.6 billion years old.

Eurasian Plate
The Himalayas, Earth's highest mountain range, is rising as the Indian Plate thrusts beneath the Eurasian Plate.

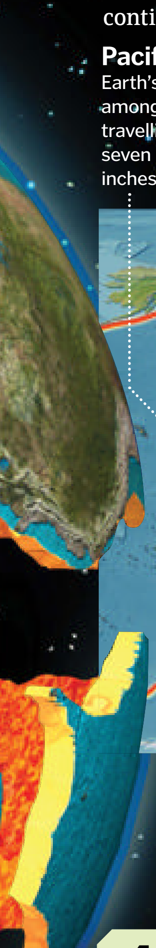


Nazca Plate
The Nazca Plate located off South America's west coast is one of several smaller plates.

South American Plate
The collision of South America with the Nazca Plate is lifting up the Andes, our planet's longest mountain range.

Antarctic Plate
Until 45 million years ago, the Antarctic Plate was joined to the Australian Plate.

Indo-Australian Plate
The Indo-Australian Plate may be splitting apart to form separate Indian and Australian Plates.



4. Did the 2011 quake in Japan shorten the days on Earth?

Yes, but you're unlikely to notice. Every day is now 1.8 microseconds shorter, according to NASA. The Japan earthquake made Earth spin slightly faster by changing its rotation around an imaginary line called the figure axis. The Earth's mass is balanced around the figure axis, and it wobbles as it spins. That wobble naturally changes one metre (3.3 feet) a year due to moving glaciers and ocean currents. The 2011 Tohoku earthquake moved the ocean bed near Japan as much as 16 metres (53 feet) vertically and 50 metres (164 feet) horizontally – that's the equivalent horizontal distance to an Olympic swimming pool! The shifting ocean bed increased Earth's wobble around the figure axis by 17 centimetres (6.7 inches). As the wobble grew, Earth sped up its rotation. It's the same principle as when a figure skater pulls their arms closer to their body in order to spin faster.

5. What is the shadow zone of an earthquake?

A shadow zone is the location on the Earth's surface at an angle of 104-140 degrees from a quake's origin that doesn't receive any S-waves or direct P-waves. S and P-waves are seismic waves that can travel through the ground. Seismic waves are shockwaves created when a fault suddenly moves. The shadow zone occurs as S-waves can't pass through the Earth's liquid outer core, while P-waves are refracted by the liquid core.

6. Where is the quake capital?

Around 90 per cent of earthquakes occur on the so-called Ring of Fire, a belt of seismic activity surrounding the Pacific Plate. The Ring of Fire is a massive subduction zone where the Pacific Plate collides with and slides beneath several other crustal plates. Most earthquakes are measured in Japan, which lies on the Ring of Fire at the junction of the Pacific, Philippine, Eurasian and Okhotsk Plates. Japan has a dense earthquake-monitoring network, which means scientists can detect even small quakes. The volcanic island chain of Indonesia probably experiences the most earthquakes based on landmass, however it has fewer instruments for measuring them.

7. Are earthquakes more likely to occur in the morning? No

8 What are tremors?

A tremor is simply another word for an earthquake. It's also another word for the vibrations you experience when a quake hits. The earth trembles because movement energy is released in an earthquake, causing the ground to vibrate.

9 How can scientists tell how far away an earthquake occurred?

Scientists use a seismometer to record earthquake waves called P and S-waves. P-waves travel faster than S-waves and can pass through liquids. By measuring the delay between the P and S-waves arriving, they can calculate the distance the waves travelled.

10 What's the earliest recorded major earthquake in history?

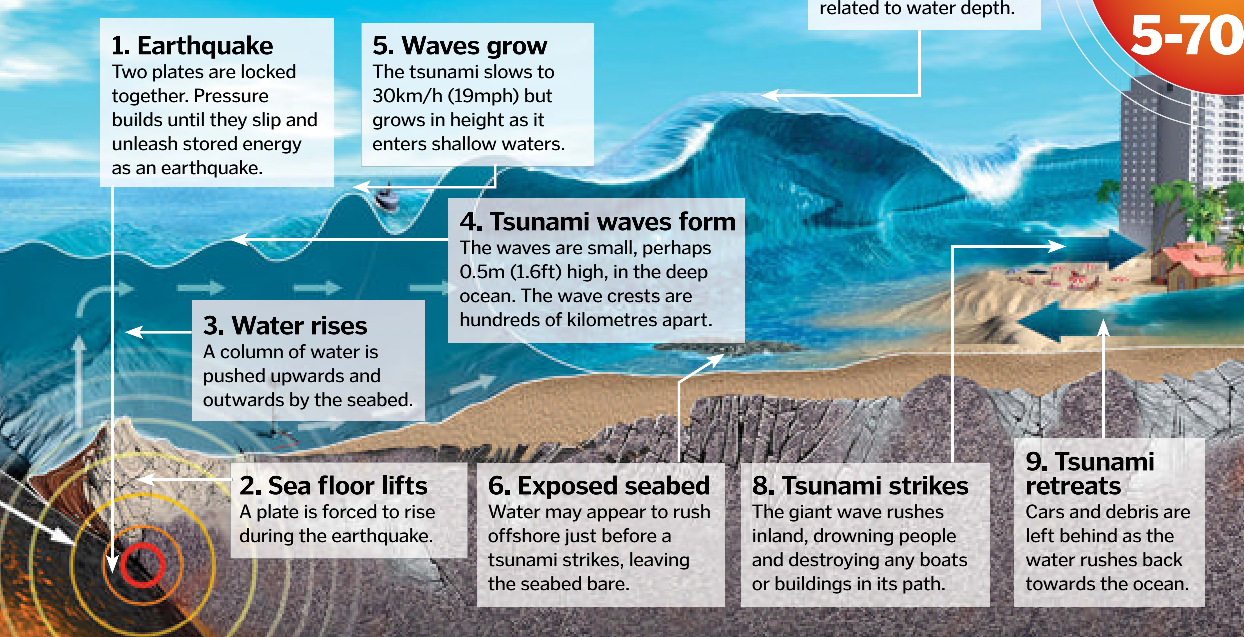
The first earthquake described was in China in 1177 BCE. By the 17th century, descriptions of the effects of earthquakes were published worldwide, although of course these accounts were often exaggerated and less detailed than data recorded today.

11 What do the lines on a seismometer reading represent?

The wiggly lines on a seismogram represent the waves recorded. The first big wiggles are P-waves. The second set of wiggles are S-waves. If the latter are absent, the quake happened on the other side of the planet.

"Seismometers on the Moon detected tidal 'moonquakes' caused by the pull of the Earth's gravity"

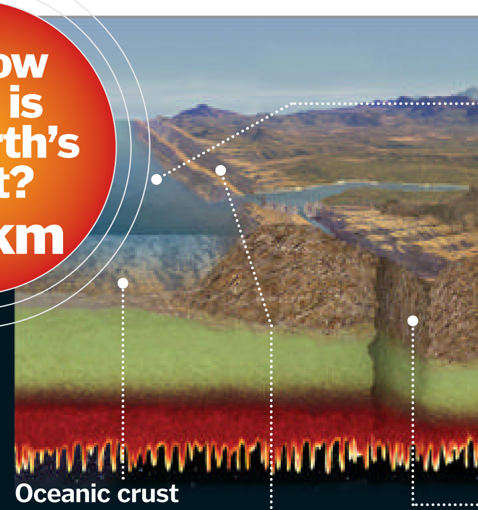
12. Why do quakes at sea lead to tsunamis?



Earthquakes trigger tsunamis by generating ripples, similar to the effect of sloshing water in a glass. Tsunamis are giant waves, which can cross oceans at speeds similar to jet aircraft, up to 700 kilometres (435 miles) per hour, and reach heights of 20 metres (66 feet) as they hit the coast. They sweep inland faster than running speed, carrying away people and buildings alike. For example, the 2004 Indian Ocean tsunami claimed 300,000 lives and made nearly 2 million more homeless.

15. How thick is the Earth's crust?

5-70km



Oceanic crust
The Pacific Plate is mainly oceanic crust, which is younger and thinner than continental crust – about 5-10km (3-6mi) thick.

San Andreas Fault
The San Andreas is a strike-slip fault created by the Pacific and North American Plates sliding past each other.

16. How many quakes occur each year?

500,000

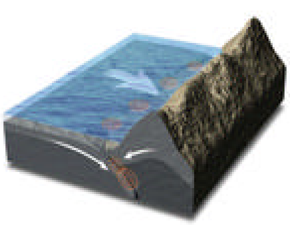
13. Are there different types of earthquake?

Strike-slip fault

Roads can be sheared apart along strike-slip faults. They're straight cracks in the crust where two plates are sliding horizontally past each other. Every time a section of the fault moves, an earthquake occurs.

Normal fault

Earth's brittle crust becomes fractured along fault lines. Quakes occur along a normal fault when the two sides move apart. Rock slabs sitting above the fault slide down in the direction the plates are moving, like at the Mid-Atlantic Ridge.



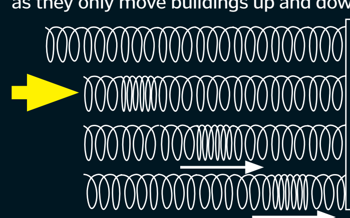
Thrust fault

The 2011 Tohoku quake ruptured a thrust fault in a subduction zone. These zones are associated with Earth's most violent quakes as oceanic crust grinds beneath continental crust, creating great friction. Huge stresses can build here and release the same energy as a thousand hydrogen bombs!

14. How do P and S-waves move?

Primary (compressional) waves

P-waves are the fastest waves created by an earthquake. They travel through the Earth's interior and can pass through both solid and molten rock. They shake the ground back and forth – like a Slinky – in their travel direction, but do little damage as they only move buildings up and down.



Secondary (shear) waves

S-waves lag behind P-waves as they travel 1.7 times slower and can only pass through solid rock. However they do more damage because they're bigger and shake the ground vertically *and* horizontally.

17. Do earthquakes happen off Earth?

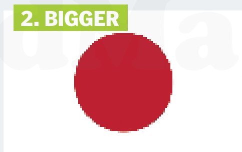
There's evidence of 'marsquakes' on Mars as well as quakes on Venus. Several moons of Jupiter and Titan – a moon of Saturn – also show signs of quakes. Seismometers on the Moon detected tidal 'moonquakes' caused by the pull of the Earth's gravity, vibrations from meteorite impacts and tremors caused by the Moon's cold crust warming after the two-week lunar night.

HEAD 2 HEAD BIGGEST QUAKES

1. BIG

Shaanxi, China, 1556 (mag 8.0)
Around 830,000 people died in this quake, which flattened city walls and was felt 800 kilometres (500 miles) away.

2. BIGGER

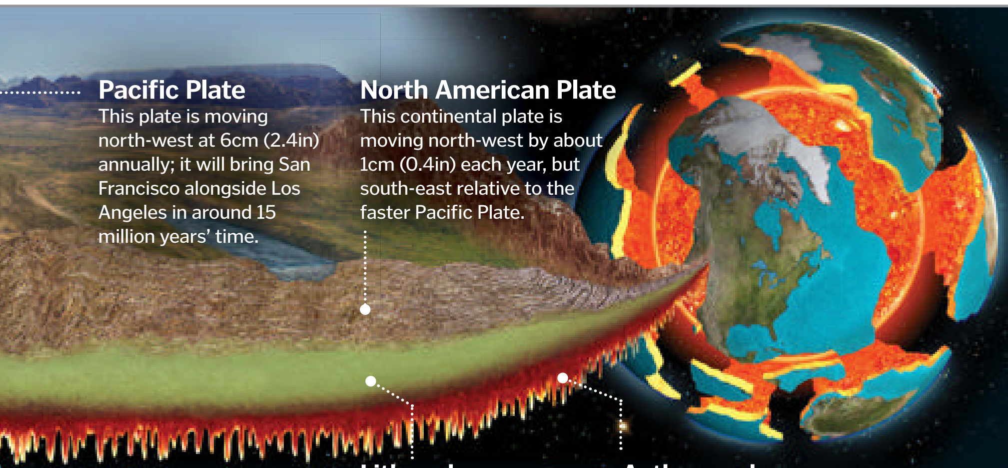


Tohoku, Japan, 2011 (mag 9.0)
Japan's biggest recorded earthquake killed 15,853 people, collapsed 129,874 buildings and triggered a global nuclear crisis.

3. BIGGEST

Valdivia, Chile, 1960 (mag 9.5)
The most powerful quake ever left 2 million people homeless and spawned a tsunami affecting Hawaii, Japan and the Philippines.

DID YOU KNOW? Tidal waves and tsunamis are not the same; the former is brought on by gravitational, not seismic, activity



18. Why is the San Andreas Fault prone to large quakes?

Longer faults have larger earthquakes, which explains why the strike-slip San Andreas Fault has had several quakes over magnitude 7. The San Andreas Fault extends 1,300 kilometres (800 miles) along the coast of California. When a fault ruptures, it 'unzips' along its length. Each section of the fault releases energy – the longer the fault, the more energy released and so the bigger the quake. Scientists believe the San Andreas Fault is overdue for a potential magnitude 8.1 earthquake over a 547-kilometre (340-mile) length. The southern segment has stayed static for more than a century, allowing enormous stresses to build.

19. Could Africa ever be split from Europe by an earthquake?

The Eurasian and African Plates are not splitting apart; they're actually moving towards each other at about one centimetre (0.4 inches) each year. In the future, it's possible that the Eurasian Plate may begin to slide beneath the African Plate. Even if the plates were moving apart, you'd need a mega-quake to yank Africa away from Europe in one go. There is no known fault long enough to create a mega-quake above magnitude 10. The most powerful earthquake in history was magnitude 9.5.

20. How many people jumping would it take to re-create the same reading as the Tohoku earthquake?

You'd need a million times Earth's population, all jumping at once, to generate the energy released by the March 2011 Tohoku quake. How do you calculate that? You assume Earth's population is 10 billion and each person generates 200 joules of energy by jumping 0.3 metres (0.98 feet).

23 Can animals predict quakes?

There's little evidence for whether animals can predict earthquakes, but many stories exist of odd behaviour. These include hibernating snakes fleeing their burrows in China in 1975, a month before the Haicheng quake.

24 Where is the safest place to be during an earthquake?

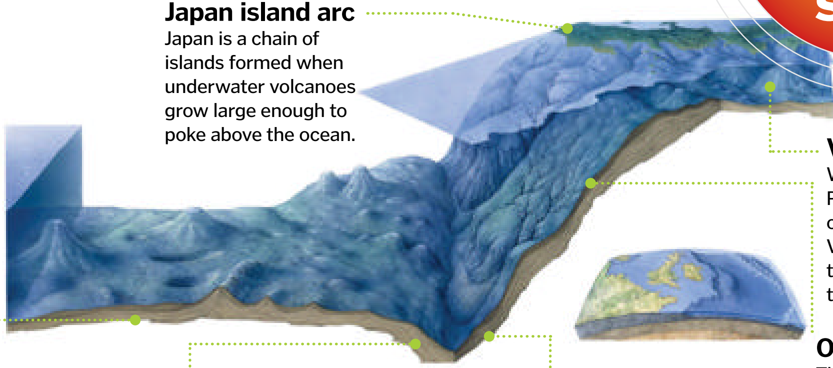
The safest place inside is underneath a sturdy table, away from light fittings and windows. The safest place outside is out in the open away from any buildings and electricity cables.

25 If I were stood on a beach during an earthquake would I sink?

Perhaps, but it's unlikely you would drown. During an earthquake, wet sand or soil can behave like quicksand – a process called liquefaction. A quake vibrates the sand, separating the grains so that they flow like a liquid. It's extremely unusual and even then people will rarely sink below their chests during liquefaction as they will float.

21. How did the Japan Trench form?

A 390-kilometre (242-mile) stretch of the Japan Trench is associated with Japan's 2011 Tohoku earthquake. The trench is a vast chasm in Earth's crust at the junction between the Pacific Plate and tiny Okhotsk Plate beneath Japan. The Pacific Plate is moving westwards and diving beneath the Okhotsk. Friction between the two plates causes them to lock together and pressure to build. Sudden slippages release the tension in a violent burst of energy.



22. How long do quakes last?

10-30 secs

Belt of Venus

What is this naturally occurring atmospheric phenomenon that makes the sky blush?

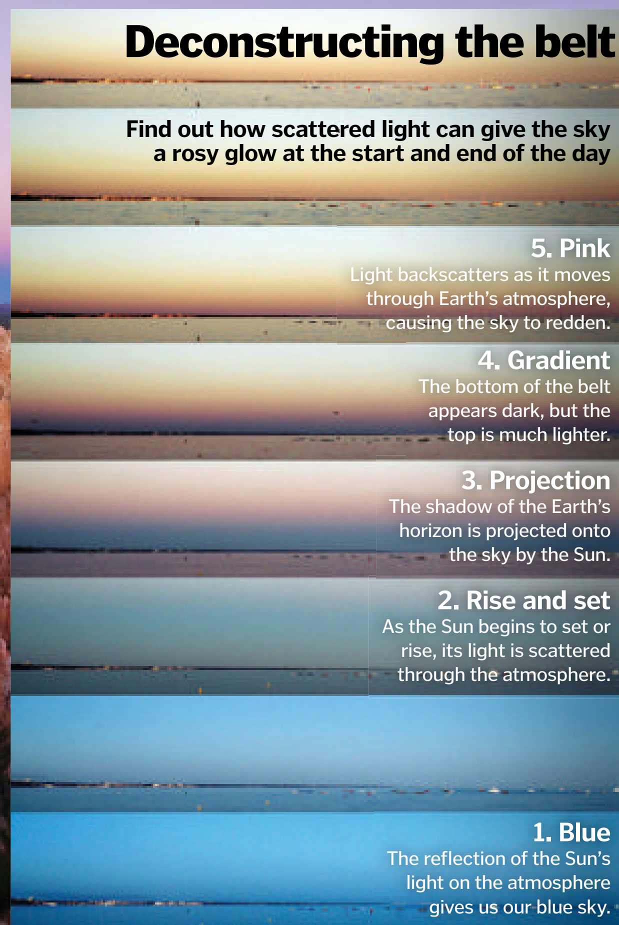
We are used to seeing glorious sunsets and sunrises, but on the opposite horizon to the Sun a little-known atmospheric phenomenon called the Belt of Venus – named after the Roman goddess of love – can be witnessed, offering equally stunning views.

As the Sun sets or rises its light moves through the atmosphere and casts a shadow of the Earth onto the sky. For a setting Sun, as the light moves downwards, this shadow appears to get closer and closer to the horizon until the Sun disappears from view completely and the sky is left black. For a rising Sun, however, the opposite is true until the shadow dissipates and the sky appears entirely blue.

The dark band of the Earth's shadow at dusk and dawn often has a light pink arch above it, known as the Belt of Venus. It extends about 10-20 degrees up from the horizon, acting as a boundary between the shadow and the sky. The effect is due to the reddened sunlight being backscattered in the atmosphere, which produces the rosy glow.

Deconstructing the belt

Find out how scattered light can give the sky a rosy glow at the start and end of the day



5. Pink Light backscatters as it moves through Earth's atmosphere, causing the sky to redden.

4. Gradient The bottom of the belt appears dark, but the top is much lighter.

3. Projection The shadow of the Earth's horizon is projected onto the sky by the Sun.

2. Rise and set As the Sun begins to set or rise, its light is scattered through the atmosphere.

1. Blue The reflection of the Sun's light on the atmosphere gives us our blue sky.

Why do flowers smell?

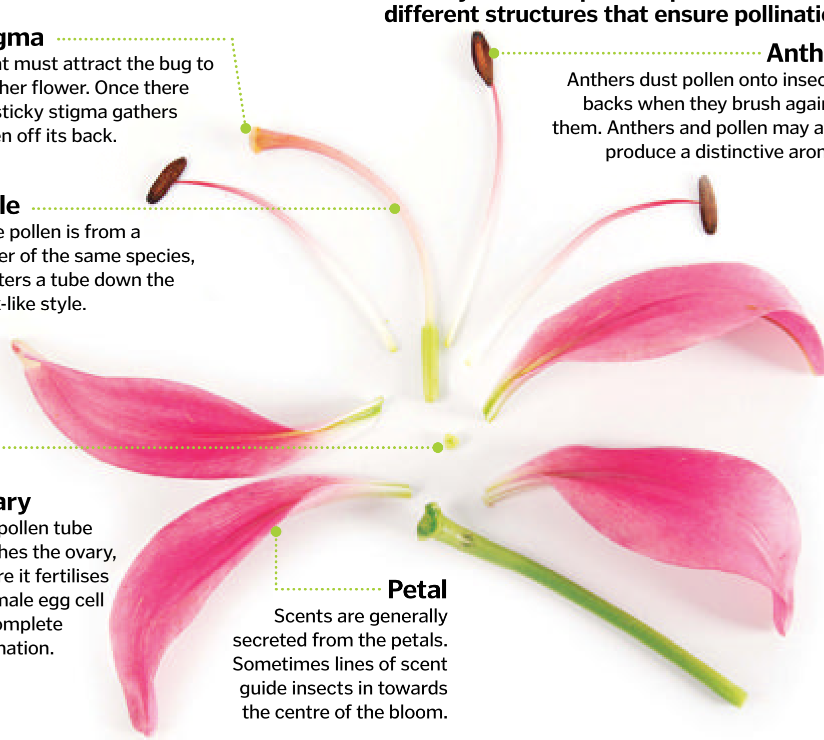
Scents take a lot of effort to make, but they ensure the next generation

Flowers have just one biological role: to guarantee pollination. Many showy blooms are pollinated by insects, attracted by a flower's bright colours and the reward of energy-rich pollen or nectar. But flowers must also lure insects from farther afield – enter, scent.

The aroma of some flowers contains up to 100 different chemicals. These are modified from chemicals in leaves which deter grazing animals, but are manufactured within the flower. Warm weather stimulates their release – just when bugs are most active. Characteristic scents encourage insects to visit other flowers of the same species and so transfer pollen between them. The blooms of evening primrose and night-scented stock release their sweet aroma in the evening, attracting nocturnal moths. These moths only visit other night-scented flowers, thus reducing pollen wastage. Some species have 'stinky' flowers, which only attract carrion-seeking insects. The clove scent of one Bulbophyllum orchid is so particular that it lures just one species of fly, thus ensuring efficient pollen transfer.

The role of scent

This lily has been picked apart to show the different structures that ensure pollination



Stigma Scent must attract the bug to another flower. Once there the sticky stigma gathers pollen off its back.

Anther Anthers dust pollen onto insects' backs when they brush against them. Anthers and pollen may also produce a distinctive aroma.

Style If the pollen is from a flower of the same species, it enters a tube down the stalk-like style.

Ovary The pollen tube reaches the ovary, where it fertilises a female egg cell to complete pollination.

Petal Scents are generally secreted from the petals. Sometimes lines of scent guide insects in towards the centre of the bloom.

biOrb LIFE 60 litre

Scan here to go to www.biorb.co.uk

"The best gifts are enjoyed long after they're opened"

Give them a biOrb aquarium this Christmas and they'll love it for years to come

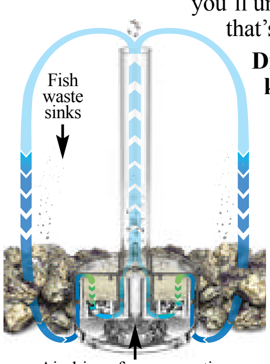
Finally, an aquarium that's easy to look after. biOrbs have built-in lighting and simple filtration that really works. See the whole range at www.biorb.co.uk

First, the truth about aquarium filters

Many traditional aquariums have a filter on the side, but that's crazy because fish waste sinks. biOrbs have a filter at the bottom of the aquarium. Put simply, a biOrb filter works where there is most to filter.

And in case you're wondering, they're easy to change. It really only takes a few seconds to do.

biOrbs also have air pumped up through the base of the tank making all the water 100% oxygenated, which is great for fish.



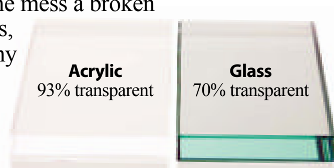
Air driven for oxygenation

Tested in Germany by experts

The world renowned University of Veterinary Medicine in Hannover conducted scientific tests on a biOrb. In their results they said, "Fish in the biOrbs were very calm and fed well".

Why they're made from acrylic instead of glass

Acrylic is ten times stronger than glass. If you've ever seen the mess a broken glass aquarium makes, you'll understand why that's important.



Did you know it's also quite a bit clearer?

Acrylic has a transparency rate of 93% but glass only allows 70% of light through.

Owners have told us...
"We love it, it's like watching fish in high definition"

Mother Nature works for you

This is ceramic media. It's in every biOrb. Amazingly, because of its honeycomb shape a few handfuls provides a surface area about the size of a football pitch. Good bacteria live here. Too small to be seen with the naked eye, this bacteria lives on fish waste. This helps to keep your aquarium healthy.

All you'll need to get started is included

Light, Pump, Filter and step-by-step instructions. Just sit back and enjoy the magic of keeping fish. What's more, every biOrb is backed by a 12 month guarantee.

If you've ever thought you'd like an aquarium, but were put off by all the work, then a biOrb is for you. They're simple to set up and easy to look after. See them all at www.biorb.co.uk

The biOrb LIFE aquarium shown has automatic day & night lighting.

Ask about biOrb at your local aquatics store or buy online at **www.biorb.co.uk**

biOrb®

> "While pretty much all other Antarctic wildlife heads for milder climes, the emperor penguins stick it out"

Life cycle of the emperor penguin

Discover the incredible endurance of Earth's biggest penguins and how they survive the bitter Antarctic

While the northern hemisphere experiences winter between December and February, winter in the Antarctic takes place between June and August. One of the only creatures to endure the -30-degree-Celsius (-22-degree-Fahrenheit) temperatures and 160-kilometre (100-mile)-per-hour winds of Antarctica's harsh winters is the emperor penguin. The stalwart males in particular spend the entire winter in the unforgiving landscape of the frozen continent's exposed open ice.

While pretty much all other Antarctic wildlife heads for milder climes, the emperor penguins stick it out. The reason they do this is so that the new chicks will be fully fledged in midsummer when survival rates are much higher.

It's a treacherous 12 months in the life of an emperor penguin, but their resilience and dedication to caring for a single precious egg for months on end is simply extraordinary.

The statistics…

Emperor penguin

Type: Bird

Genus: Aptenodytes

Diet: Carnivore, eg fish, squid

Average life span in the wild: 15-20 years

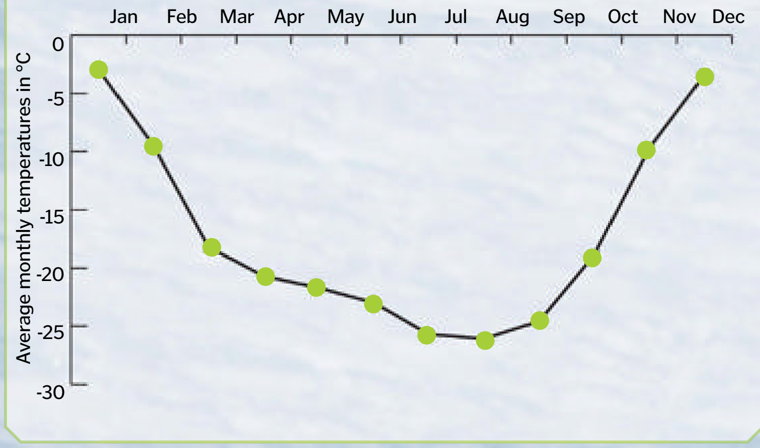
Height: Up to 130cm (51in)

Weight: 25-45kg (55-100lb)

The emperor penguin is the tallest and heaviest of all living penguin species and is endemic to Antarctica

It's cold out there…

Home to the lowest temperature ever recorded at the Earth's surface, Antarctica can get seriously chilly during winter

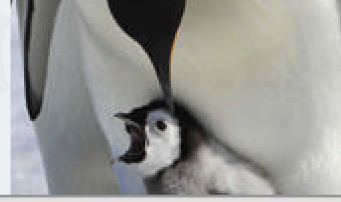


STRANGE BUT TRUE

STAY-AT-HOME DAD

Male emperor penguins possess the ability to...

A Lay eggs **B** Multitask **C** Produce milk



Answer:
If the chicks hatch before the females have returned home from feeding, the male emperor penguin can actually sustain the chicks with crop milk – a substance that consists of protein and fat which is secreted in the oesophagus.

DID YOU KNOW? *The emperor penguin is the world's deepest-diving bird, able to plunge 565m (1,850ft) underwater!*

A year with the emperors

What goes on over the course of 12 months in a community of the planet's biggest penguins?

1 Feeding: January-February
At the start of the year, the adult emperor penguins head out to sea to feast and make the most of the more accessible food in the summer months.

2 Winter draws in: March
Temperatures begin to plummet from March, and over the coming months the region will be battered by freezing winds and bitterly cold temperatures.

3 Home to breed: April
The male and female emperors return from feeding and make their way to the breeding grounds in the south. Despite the fact that a colony can contain anywhere up to 12,000 pairs about 15 per cent of couples hook up with their mates from the previous year.

4 Breeding: May
After mating, the female emperor penguins lay a single egg, which they immediately leave in the safe hands (or perhaps more accurately the 'safe feet') of their male partner. With the absence of a nest the male rests the egg on his feet beneath an insulating flap of warm, feathery skin.

5 Females feed: May
With the egg safely in the care of the males at the breeding ground the females then embark on a treacherous expedition back out to sea. They can trek around 80-160 kilometres (50-100 miles) to the edge of the ice pack in search of vital food.

6 Incubating: June-July
For nine long weeks each male alone will protect his egg in his brood pouch. During this time he will have nothing to eat and conditions on the ice will grow increasingly hostile. To conserve heat, the fathers huddle in a tightly packed group. Once the penguins on the inside of the huddle have warmed up they will migrate to the outer edge to give other penguins a chance to thaw out. It's a bit like a penguin conveyor belt.

7 Hatching: August
In August – usually before the females return home from feeding – the chicks will begin to hatch. To reduce the number of breakages, emperor penguin eggs have an extra-thick shell, which accounts for over one-sixth of the egg's weight, and it can take several days for the chick to break through. Once hatched the young penguin will maintain its position beneath the flap of skin above the adult's feet. Any unlucky chicks that fall out of the brood pouch are likely to perish within minutes because of the sub-zero temperatures.

8 Females return: September
With their stomachs full the female penguins return to the nesting ground just after the chicks have hatched. Their unique calls help them to locate their mates among the throngs of penguins. Upon being reunited with their young family they will regurgitate a meal stored in their bellies for their chicks.

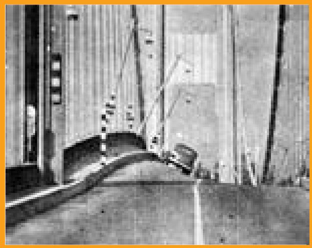
9 Males feed: September
Relieved of their chick-sitting duties the male emperors head to sea to forage for themselves. Having shed up to half their body weight they are very hungry indeed. The parents then take it in turns to head off in search of food.

10 Crèches: October-November
As winter begins to subside the growing chicks will leave the warmth of their parents' brood pouches after about seven weeks. Their downy feathers will moult and their coats will eventually toughen up to form a waterproof covering. To stay warm the chicks huddle in small groups called crèches.

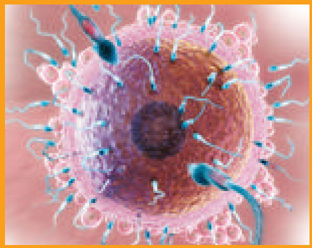
11 Fledged: December
The warmer weather melts the pack ice so that it breaks up, effectively bringing the sea closer to the colony. Fully fledged chicks will now rejoin their parents and take their first dip.

It can be quite a hard thing to get your head around, but essentially, without light, there would be no colour – learn about this complex relationship now. We also look at the hormone that tells us when we're tired, why vibrations can tear apart bridges and the role ovaries play in the female body.

49 Melatonin



50 Resonance



52 Ovaries

LEARN MORE

Light &

We take our multicoloured world for granted, but life would be much duller if it wasn't for a trick of the light

Red

Red can't be seen underwater. Water absorbs longer wavelengths of light, so once you get beyond about ten metres (33 feet), red light is almost entirely filtered out. The colour provides great camouflage for certain sealife and divers sometimes notice their blood looks dark green if they cut themselves!

What about pink?

There's no pink in the spectrum of visible light. While the colours of the rainbow each correspond to a band of wavelengths of light, there is no 'pink' wavelength. What our brains interpret as pink is actually a mixture of red and blue light waves.

Orange

In nature, yellow and orange are often produced by the carotenoid pigment. As their name suggests, carotenoids are found in large quantities in carrots, but also egg yolks and autumn leaves. While it's not true that eating carrots will improve your vision, your body converts some carotenoids into vitamin A, which is a must for healthy eyes.

Yellow

Astronomers classify stars according to their colour, which matches their surface temperature. Our Sun is a yellow (or G-type) star, meaning that its surface temperature is around 5,500 degrees Celsius (10,000 degrees Fahrenheit). Stars remain in this class for around 10 billion years, so our Sun still has a good 4-5 billion years left.

5 TOP FACTS
COLOUR TRIVIA

Seeing red
1 Like a large number of animals, bulls are colour blind and can't see red. So it's a common misconception that a matador's red cloth is what gets a charging bull wound up.

Sticky light
2 Try ripping a piece of sticky tape off the roll in the dark. This separates positive and negative electrical charges – when they recombine, it creates a flash of blueish light.

Slow sparkle
3 Want to slow light down? It travels at its slowest inside a diamond. Even then, it still manages a fairly impressive 124,000 kilometres (77,000 miles) per second!

Whiter than white
4 Ever seen white clothes glow under a UV light? Laundry detergents contain optical brighteners, which emit blue light under UV to stop your whites from looking yellow.

How many colours?
5 By measuring our eyes' top performances, scientists have estimated that we can distinguish up to 10 million colours, though thankfully we don't have names for them all!

DID YOU KNOW? 90 per cent of deep-sea creatures have bioluminescent properties, emitting light using photophores

colour

Violet

Mauveine was the first synthetic dye, discovered by British chemist William Henry Perkin in 1856. Until then, the colour purple had been laborious and expensive to create from natural sources, with its basic ingredient being mucus from certain molluscs. Perkin's vivid violet dye made him very wealthy.

Blue

On a sunny day, the sky is a brilliant shade of blue. This colour comes from gas molecules in the atmosphere, which scatter mostly short blue wavelengths of light. The same effect can be observed by astronauts orbiting the Earth, who see a faint halo of blue around our planet.

Green

Why are plant leaves green? Plants use a pigment called chlorophyll to convert the Sun's light into energy. Chlorophyll absorbs red and blue light (possibly due to some ancient evolutionary advantage), and therefore reflects mostly light in the yellow and green parts of the spectrum; this is what gives plants their lush, verdant tones.

We all know what light is on a basic level, but its true nature has fascinated scientists from Ancient Greek times right up until the present day. Visible light (in other words, the light our eyes can perceive) is electromagnetic (EM) radiation – a type of energy which travels as a wave. Waves are disturbances which travel through space and, more specifically, EM waves are waves where the disturbances are changes in the electric and magnetic fields.

The light we see is just a tiny sliver of the EM spectrum, though, which encompasses the full range of wavelengths that electromagnetic waves can occupy. Other wavelengths of EM radiation include radio waves, ultraviolet, microwaves and X-rays, to name just a few.

But that's just half the story. While light's behaviour can often be understood by thinking of it as a wave, some of its properties only make sense when considering it to be a stream of particles – called photons. Confused yet? Physicists reconcile these conflicting observations by considering light to be both a particle *and* a wave – a concept which goes by the name of wave-particle duality. To avoid the headaches, it's easiest to think of light as a wave for most purposes.

Light on our planet comes mostly from the Sun. The Sun's blistering heat causes it to incandesce, or glow (just like the embers of a bonfire), emitting energy as light, which then travels some 149 million kilometres (93 million miles) to reach us. The same principle allows the filament in an old-fashioned incandescent light bulb to brighten up our homes.

Our eyes are sensitive to light of wavelengths between about 390 and 750 nanometres. Each 'colour' that we perceive corresponds to a band of wavelengths. Our brains interpret the shortest visible wavelengths as violet and the longest as red, thus giving rise to the terms ultraviolet (UV) and infrared (IR) for the invisible wavelengths lying just beyond the visible spectrum. While we tend to describe the rainbow as having seven colours, in reality it is a continuum of different shades.

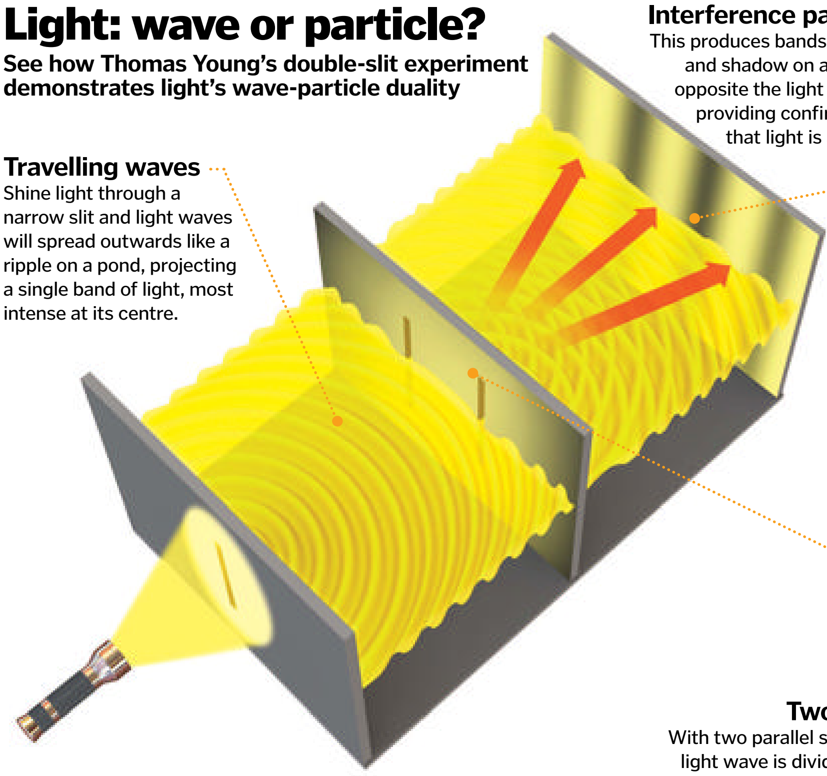
Though colours may seem very real to us, they are just our brains' way of interpreting this narrow band of EM radiation. Other animals see a completely different range of colours to us – and there are many variations in how humans see colour too.

Ever wondered why white isn't part of the rainbow? As Isaac Newton demonstrated when he shone the Sun's light through a prism, white ▶

"Chemical compounds called pigments are responsible for the majority of the colours we see in nature"

Light: wave or particle?

See how Thomas Young's double-slit experiment demonstrates light's wave-particle duality



Travelling waves
Shine light through a narrow slit and light waves will spread outwards like a ripple on a pond, projecting a single band of light, most intense at its centre.

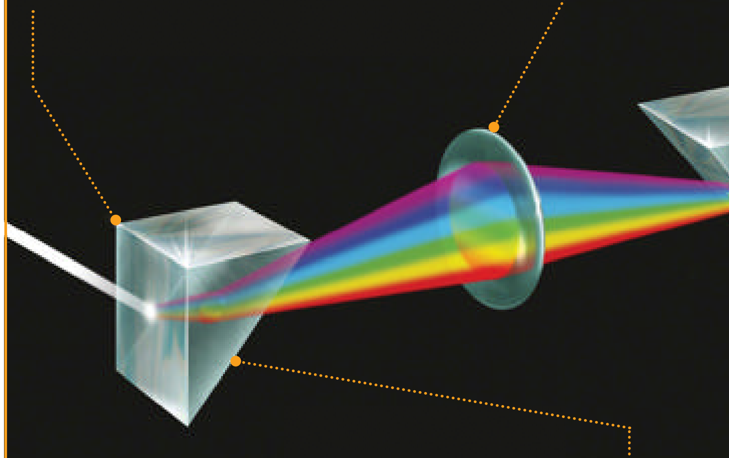
Interference pattern
This produces bands of light and shadow on a screen opposite the light source, providing confirmation that light is a wave.

Two slits
With two parallel slits, the light wave is divided into two wavefronts spreading out side by side. Where two waves meet, they interfere with each other – reinforcing or cancelling each other out.

In conclusion...
So what would happen if you fired photons one by one through the slits? In fact an identical interference pattern would slowly emerge. Crazy as it seems, this is evidence that an individual photon can interfere with itself. In other words, light can simultaneously act like a wave and a particle.

The colour spectrum

In 1665, Isaac Newton set out to prove that white light is made up of the full spectrum of colours...



1. White light
By making a hole in his window shutter, Newton isolated a narrow beam of sunlight. He then used a prism to refract the light.

2. Revealing the rainbow
Since different wavelengths of light are refracted to varying degrees (eg violet refracts the most and red the least), the prism splits the white light into its constituent colours.

▶ light is actually made of the full spectrum of colours combined. When light waves hit an object they can be reflected, absorbed or transmitted. These interactions transform plain old white light to draw out the multitude of colours that we witness every day.

When you 'see' an object, what you are actually seeing is the light that it reflects. Reflection occurs when light hits a surface and the light waves bounce off it. Say you are looking at an apple. Light hits the apple and rebounds off it in all directions; this is called scattering. Some of this reflected light reaches your eyes, feeding your brain information on what the apple looks like.

If everything around us reflected the full spectrum of the Sun's white light perfectly, we'd see the world in shades of black and white. Instead, almost everything transforms white light in some way, creating everything from brilliant blues to murky browns.

Chemical compounds called pigments are responsible for the majority of the colours we see in nature. Pigments absorb certain wavelengths of light and so reflect only a portion of the visible spectrum – these reflected wavelengths are what we detect with our eyes and perceive as colour. A red apple, for example, absorbs green and blue wavelengths of light, reflecting mainly red light.

Many pigments are present in rocks and minerals, but living things like animals, plants and insects also make pigments of their own. Humans, for instance, produce a type of pigment called melanin, which is responsible for the full range of skin tones, as well as eye and hair colours, found throughout the human race. And while a few hundred years ago artists had to rely on natural pigments to create the colours on their paint palettes, synthetic pigments mean we can now adorn our houses, clothes and fingernails with just about any colour under the Sun.

When you mix different pigments in paint, you are actually combining the wavelengths they absorb. So if you mix cyan (blue) paint, which absorbs red and green light, with yellow paint, which absorbs blue light, you get a colour which absorbs red and blue light and reflects green light – in other words, green.

Pigments are just one of the mechanisms splashing colour into our world though. Another is refraction, which allows spectacular colours to be separated out of plain old white light. Light travels at different speeds depending on the medium it is passing through. Glass or water, for example, enforce much lower speed limits on light than air. When two different materials are in contact, light travelling through is forced to slam on the brakes. The change in speed as it passes from one medium to the other causes the beam of light to bend. This, in a nutshell, is refraction.

If you were to put a plastic straw into a glass of water and look at it from the side, it appears as though the straw is bent where the liquid meets the air. This is because light travels approximately 30 per cent more slowly through water than it does air. If you wear glasses or contact lenses you can thank refraction for helping you bring the world into focus.

What does this have to do with colours? Different wavelengths of light are refracted at slightly different angles, splitting white light into its component colours. Even minuscule

1. SHINY

Jewel beetle
With some 15,000 species found all over the world, beetles from the Buprestidae family display some dazzling metallic colours on their shell.

2. SHINIER

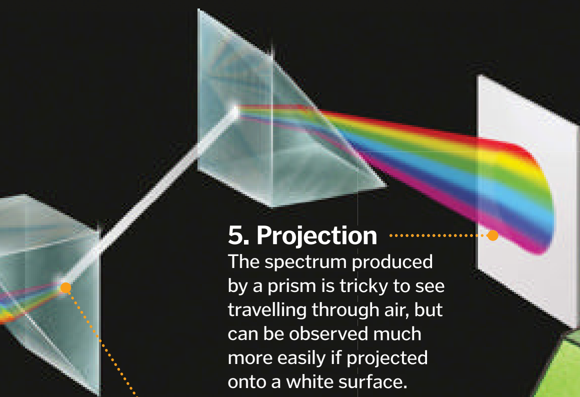
Morpho butterfly
Often described as the strongest colour in nature, the Morpho butterfly's mesmerising wings reflect up to 70 per cent of light.

3. SHINIEST

Pollia condensata
This tiny African berry, aka the marble berry, packs an amazing punch, reflecting more light than any other living organism.

DID YOU KNOW? *Isaac Newton once poked a needle around his eyeball to prove pressure and colour perception were related!*

3. Focusing light
A convex lens focuses the spreading spectrum of colours, allowing the light to converge on the surface of the second prism.



5. Projection
The spectrum produced by a prism is tricky to see travelling through air, but can be observed much more easily if projected onto a white surface.

4. Recombining the rainbow
Passing through the second prism, the opposite effect occurs and the colours are recombined into white light by the process of refraction.

droplets of water can refract light, painting rainbows in the sky. Refraction is also what gives diamonds their multicoloured sparkle.

If you've ever looked at soap bubbles up close, you'll have seen the myriad colours on the surface. The technical term for this is iridescence, and it happens because light waves can interfere with one another when they cross paths. A bubble is, in essence, a very thin sheet of water sandwiched between two layers of soap molecules. When light hits the top surface of the bubble, some of it bounces off and the rest is transmitted down to the bottom surface, where it too is reflected, merging with the light reflected by the top surface.

Having travelled slightly farther, the light waves reflected from the bottom surface are now out of phase with those reflected from the top surface. When they meet, these two waves interfere with each other, amplifying certain wavelengths and dulling others. The result: vibrant colours that change depending on the angle from which you view them. The same effect can be seen on the underside of a CD or in some of nature's shiniest creatures.

The speed of light

Travelling through a vacuum, light zips along at just under 300,000 kilometres (just over 186,000 miles) per second. Almost all particles in our universe contend with the Higgs field, which interacts with them to give them mass. Photons – the particles which make up light – are the exception. They don't interact with the Higgs field and therefore possess no mass. This means that no energy is required to change their velocity and there is no limit to their speed. So why is 300,000 kilometres (186,000 miles) per second the cutoff? This is simply a fundamental property of our universe, a constant set in stone when the cosmos came into being.

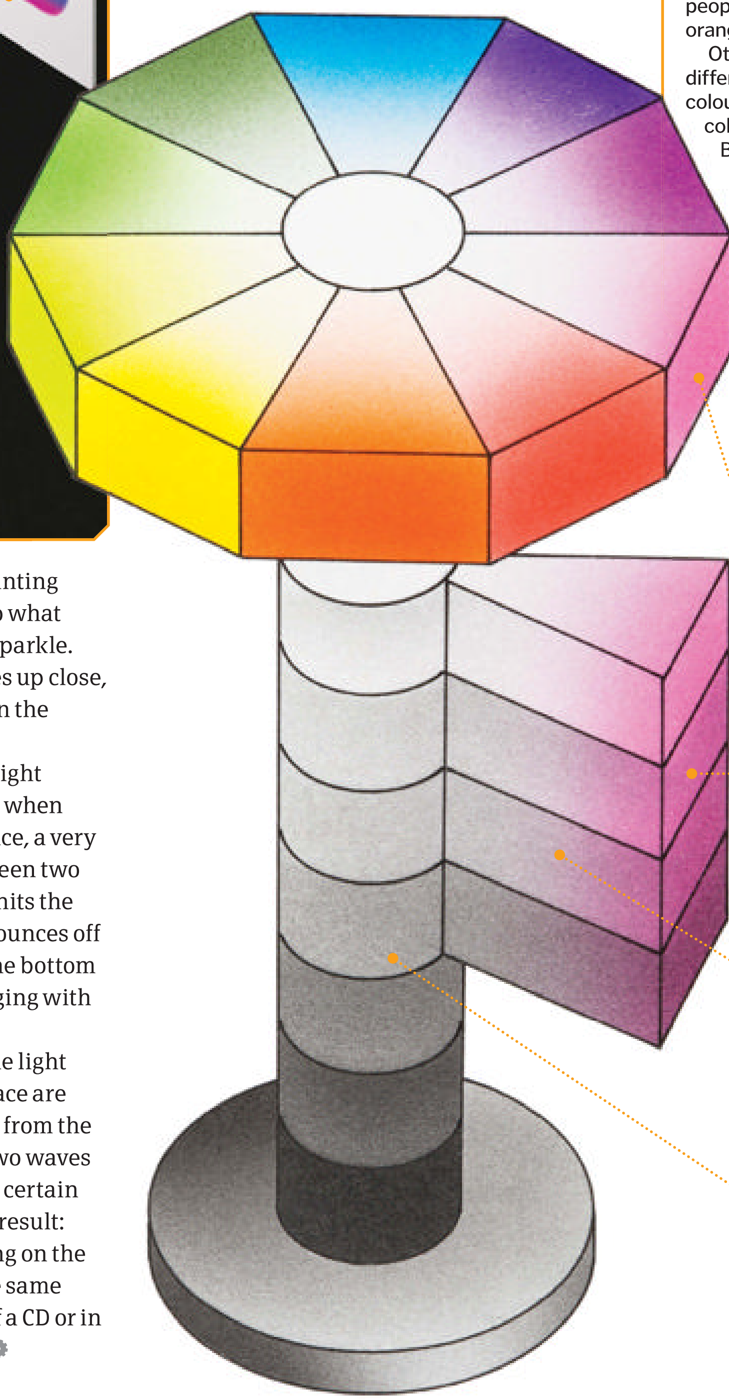
How do we perceive colour?

The retinas of our eyes have three types of light receptors called cone cells. They respond to light in bands of wavelengths centred around red, green and blue. Each colour we see produces a different combination of responses from these cone cells, allowing our brains to tell millions of different colours apart.

Some people, however, have faulty cone cells, causing colour blindness. In people with red-green colour blindness, the green cone cells are mutated, making colours shift towards the red end of the spectrum. As a result, these people have trouble distinguishing shades of red, orange, yellow and green.

Other people's brains are wired slightly differently, leading them to strongly associate colours with numbers or letters, or even see colours when they hear certain sounds. Play Beethoven's symphony to someone with sound-colour synaesthesia and the music will trigger visual fireworks.

Beyond these extreme variations in our perceptions of colour, it's quite possible that everybody experiences colour in subtly different ways.



Classifying colour

Albert Munsell's colour tree gives us an objective way of describing colours, splitting them into three dimensions: hue, value and chroma

Hue
Hue is what we commonly mean when we say 'colour'. It is measured on a circular scale, ranging from red to purple.

Naming a colour
Finally, a colour is named by listing its hue, value and chroma. This shade of pink would be called something like 5RP 4/10.

Chroma
Chroma is a measure of how intense a colour is. Pastel colours are at the centre, with brilliant colours on the outside.

Value
Value describes how light or dark a colour is. It is represented vertically, with white found at the top and black at the bottom.

5 TOP FACTS
COLD TREATMENT

Evidence
1 The risks and benefits of hypothermic surgery are based on evidence from the most rigorous test available in the medical field – the randomised controlled trial (RCT).

Nothing new
2 Before high-level evidence emerged, therapeutic hypothermia was known to have been used in ancient times and various wars, albeit with mixed success.

Further benefits
3 In patients who survive cardiac arrest following heart attacks, hypothermic cooling of the body can improve functional outcome and also help avert brain damage.

Protecting babies
4 Induced hypothermia can also help babies who are starved of oxygen following difficult births, a condition medically known as hypoxic-ischemic encephalopathy (HIE).

On target
5 Modern techniques can cool the body to within 0.1 degrees Celsius of the target temperature. Gradual re-warming can also be carried out at a specific rate.

DID YOU KNOW? *Melatonin is available in a tablet to help people with disturbed sleep cycles, such as insomniacs*

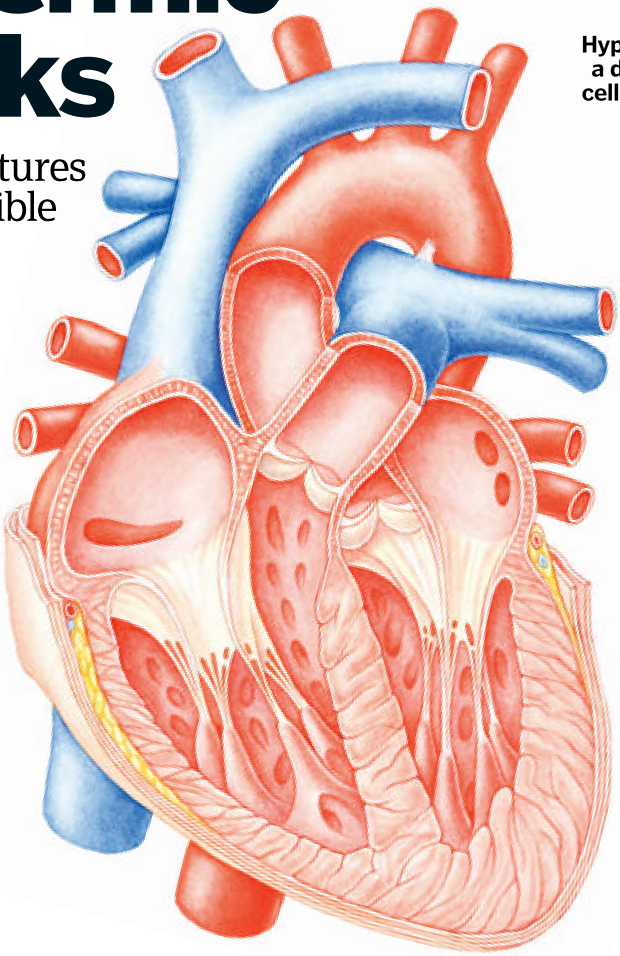
How hypothermic surgery works

Cooling the body to extreme temperatures makes cutting-edge procedures possible

During cardiac surgery, the heart sometimes needs to be stopped to allow surgeons to perform delicate procedures, such as replacing valves. If left uncorrected, the subsequent lack of oxygen supply would lead to brain damage within minutes. Cardiopulmonary bypass can overcome most of these effects, although it is technically not possible in all patients.

Hypothermic cardiac surgery can now be used to overcome these limitations. The body is cooled from its normal 37 degrees Celsius (98.6 degrees Fahrenheit) to as low as 24 degrees Celsius (75.2 degrees Fahrenheit). Cold saline solutions are infused into the bloodstream via the major vessels and the heart is surrounded by ice. This stabilises cell membranes and reduces the metabolic rate. Once cool enough, the heart is stopped using a potassium-rich solution. In this reduced oxygen-dependent state, the body can temporarily survive without the heart beating.

When surgery is completed, the potassium solution is rinsed out and the body re-warmed before the heart is restarted. Hypothermic cooling isn't without its risks, however; there is a chance that once a procedure is finished and the body re-warmed, the heart might not restart.



Super-cold surgery step-by-step

Hypothermic surgery requires a deep understanding of how cells work at a molecular level

1. Cooling
Using cold saline solutions infused into the circulation and ice placed around the heart, the body's core temperature is reduced.

2. Cardioplegia
A potassium-rich solution is used to paralyse the heart muscles – a process known as cardioplegia.

3. Cell membrane
The cold temperature stabilises ion transfer across cell membranes in the body, protecting them from the low-oxygen state.

4. Warming up
Once surgery is done, the body is re-warmed slowly. The cells start to re-function as oxygen returns to them.

5. Jump-start
The crucial moment comes when defibrillators are placed against the heart's muscular wall and an electrical current is used to shock it back to a beating state.

How does melatonin help us sleep?

Falling asleep and waking up are complex processes, which couldn't happen without a certain hormone

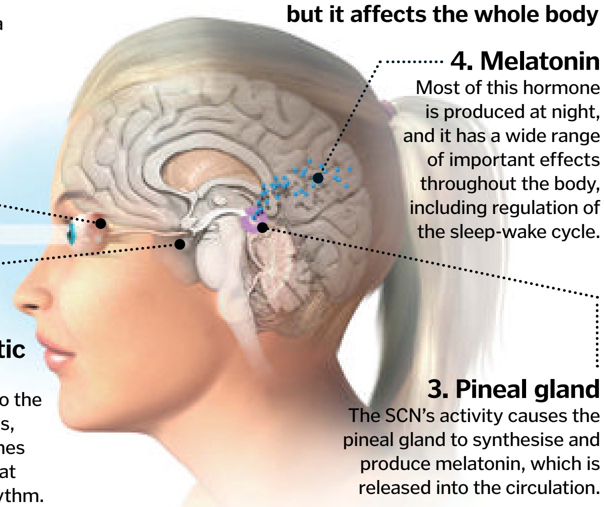
Melatonin is a natural hormone found in plants and animals. It is vital to regulating a variety of bodily functions that we rarely think about unless they go wrong. These include sleep-wake cycles, dreaming, maintaining the immune system and regulating ageing.

In humans, melatonin is made in the pineal gland, located near the centre of the brain. Its chemical form is N-acetyl-5-methoxytryptamine, and once produced it is released directly into the bloodstream. The pineal gland produces melatonin during the night, typically in response to darkness detected by the eyes. Melatonin reduces alertness, induces drowsiness and drops the body temperature; all this helps us to drop off. During the day, melatonin production dramatically declines so that we stay alert. This 24-hour cycle is referred to as the circadian rhythm.

Making melatonin

Melatonin is made in the brain but it affects the whole body

1. Photoreceptors
Changes in light levels are detected by the retina, which produces a photopigment called melanopsin that sends signals to the brain.



2. Suprachiasmatic nucleus (SCN)
These signals are sent to the suprachiasmatic nucleus, which produces hormones and electrical signals that govern the circadian rhythm.

3. Pineal gland
The SCN's activity causes the pineal gland to synthesise and produce melatonin, which is released into the circulation.

4. Melatonin
Most of this hormone is produced at night, and it has a wide range of important effects throughout the body, including regulation of the sleep-wake cycle.

"The world's largest tuned mass damper is a 660-ton pendulum in the Taipei 101 tower in Taiwan"

How can resonance collapse bridges?

How It Works finds out why a little shaking can cause such epic destruction

Many bridges and buildings have fallen down due to the effects of resonance – or to be more precise, mechanical resonance. This is the susceptibility of a structure to respond at an increased amplitude when the frequency of its oscillations matches its natural frequency of vibration. In other words, this means that if a structure begins to vibrate in a violent manner, it's liable to fail mechanically and this can quickly lead to its total destruction.

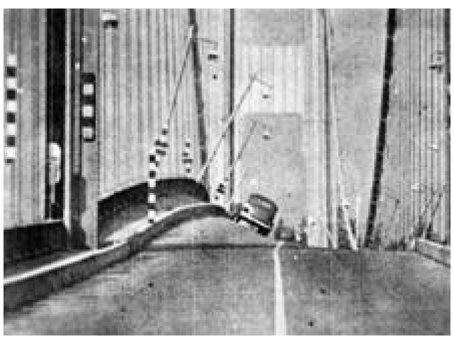
Structures like bridges can start to oscillate – ie vibrate at a regular rate – for many reasons. Indeed, environmental factors like traffic, a high footfall or powerful machinery can all trigger vibrations. If these vibrations happen to occur at a system's resonance frequency, then oscillation generates excitation at an atomic level, where more and more energy is stored. When this stored energy exceeds an object's load limit, it will lose structural integrity.

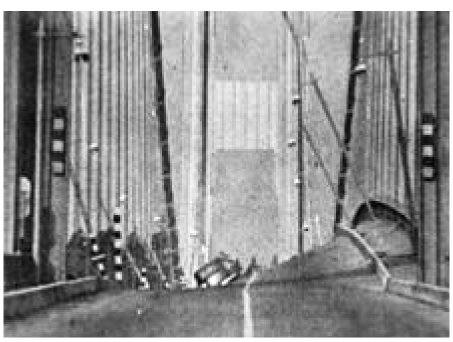
One of the most famous examples of a resonance disaster is the 1940 Tacoma Narrows Bridge collapse in Washington, USA. This came about not simply as a result of mechanical resonance, but also aeroelastic flutter – a process that occurs when complex, varying oscillations are caused by passing winds. This flutter only intensifies typical vibrations, heightening their amplification, which makes building structures that are capable of resisting these forces even more difficult.

The effects of resonance are countered by installing tuned mass dampers, or harmonic absorbers. These devices specialise in moving in opposition to the resonance frequency oscillations in a structure using springs, fluid or pendulums. The world's largest tuned mass damper is a 660-ton pendulum in the Taipei 101 tower in Taiwan. This colossal, £2.5-million ($4-million) steel pendulum is found in the centre of the building from floor 87 to 91 and sways in opposition to the movement caused by high winds. Incredibly, the damper reduces overall movement by up to 40 per cent.

Tacoma Narrows Bridge in focus

As these pictures show, the degree of torsional twist that the roadway experienced was phenomenal. This is clearly demonstrated by the position of the stranded car in each image.





London's Millennium Bridge

The London Millennium Bridge is a more recent example of the effects of resonance and how it can be generated by a wide variety of factors. The bridge, which was seen to be wobbling not long after its opening in 2000, demonstrated a form of positive feedback – a synchronous lateral excitation to its structure. This was caused by the natural swaying motion of people walking across it – typically 2,000 pedestrians were on the bridge at any one time – with small sideways oscillations generated by people's steps exaggerating and reinforcing existing motion. This resulted in a pronounced wobbling effect and the bridge was shut down later that year. Engineers had to counter the resonance-induced swaying effect by installing 37 fluid-viscous, energy-dissipating dampers to mitigate the horizontal movement and 52 tuned mass dampers to limit vertical movement. This refitting cost about £5 million ($8 million) and took over a year.

© Getty; SPL

"Every month an egg is released from one of the ovaries into the fallopian tube where its fate will be decided"

How do ovaries work?

The development and release of an egg in the female of the species is a remarkable process

A major part of the female reproductive system, a woman's ovaries are the two oval-shaped, egg-storing glands which are located either side of her uterus (womb).

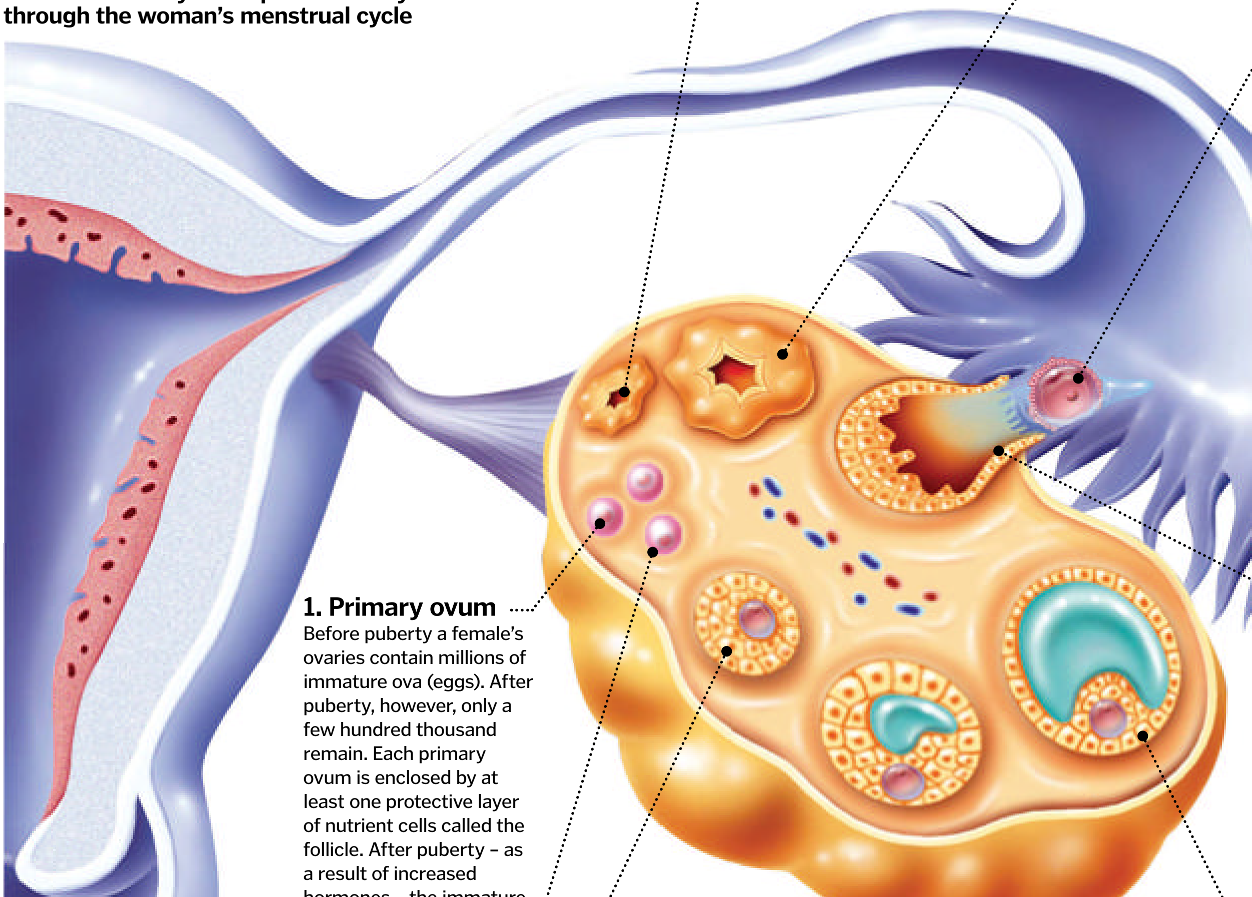
Every month an egg is released from one of the ovaries into the adjoining fallopian tube where its fate will be decided. The egg will either travel along the tube to the uterus where it will be shed with the rest of the uterine lining during menstruation, or it will become fertilised in the fallopian tube first.

If it is fertilised by a sperm cell in the fallopian tube, the egg stands a chance of being implanted into the wall of the uterus where it can develop into a foetus.

Each of the ovaries is connected to the uterus by a fallopian tube.

Egg development and release

Ovulation usually takes place halfway through the woman's menstrual cycle

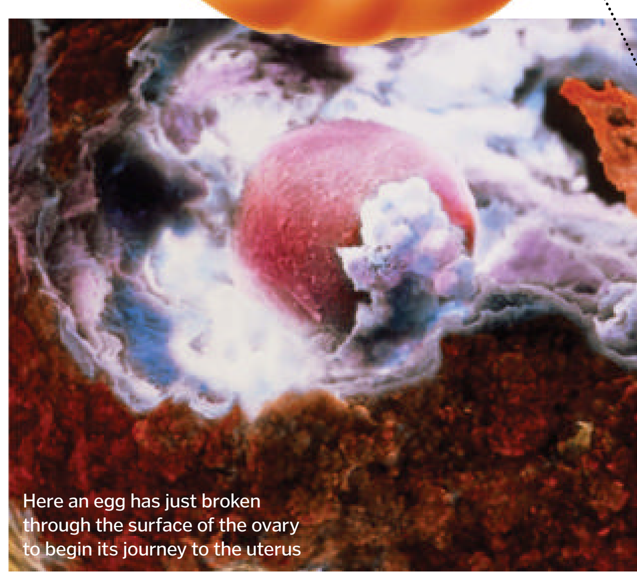


8. Corpus albicans
If the egg continues to the uterus unfertilised, the remnants of the corpus luteum will shrink and die, leaving the scar-tissue corpus albicans.

1. Primary ovum
Before puberty a female's ovaries contain millions of immature ova (eggs). After puberty, however, only a few hundred thousand remain. Each primary ovum is enclosed by at least one protective layer of nutrient cells called the follicle. After puberty – as a result of increased hormones – the immature eggs begin to ripen.

2. Primary follicle
Each month, before the female begins to ovulate, the pituitary gland in the brain produces follicle-stimulating hormone (FSH), which causes a number of the primary ova to start to mature and produce oestrogen.

3. Secondary follicle
Over the course of the month the follicle grows until it becomes fully mature.

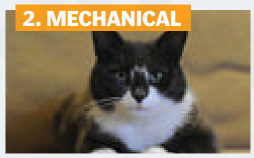


Here an egg has just broken through the surface of the ovary to begin its journey to the uterus

1. VEGETABLE

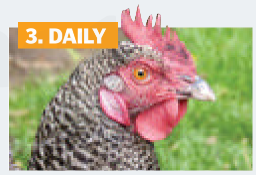
Flowers
It's not all about animals. A flower's ovary is part of the reproductive organ that contains ovules that form compartments full of reproductive cells.

2. MECHANICAL



Cats
The male cat's penis has backward-pointing spines that scrape the female's vagina after mating. This triggers ovulation when the female is in heat.

3. DAILY



Chickens
Induced by sunlight, a hen ovulates daily, releasing one egg from its ovary in the morning. The egg is layered with calcite to form a hard shell.

DID YOU KNOW? *Baby girls are born with millions of eggs already developing in their ovaries*

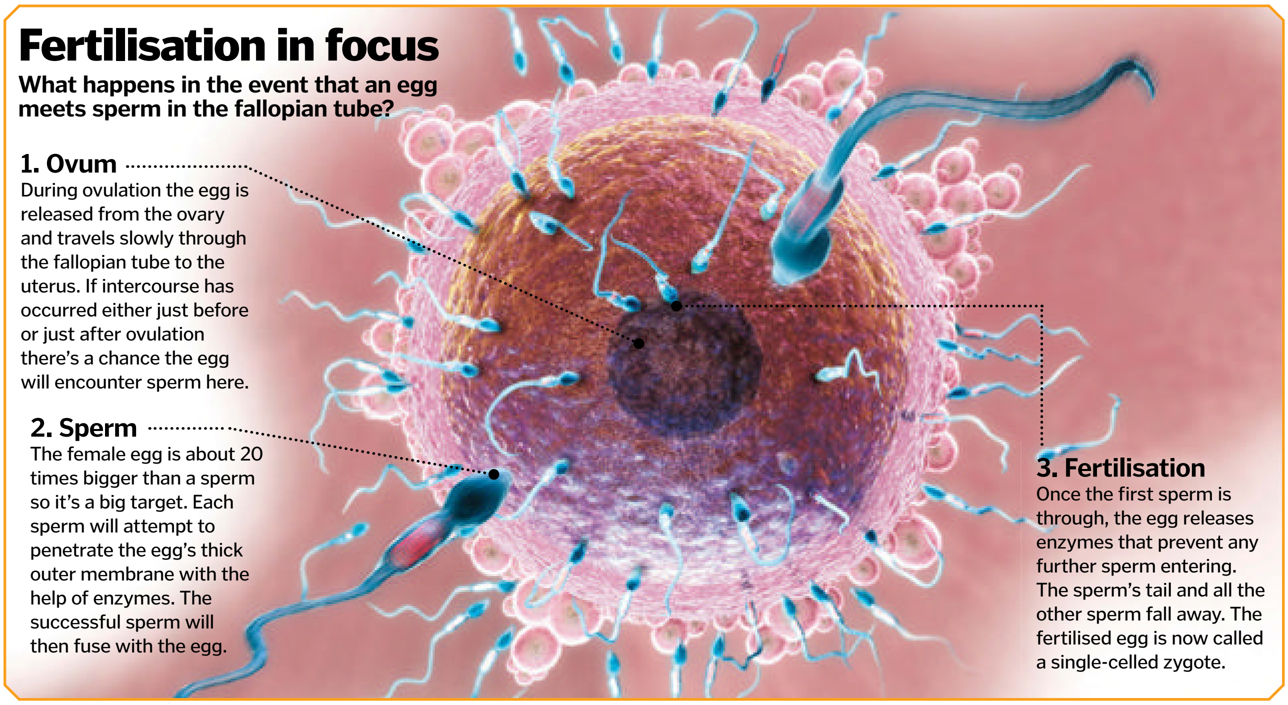
7. Corpus luteum
The now-empty mature egg follicle becomes the corpus luteum. This produces the progesterone that causes the uterus lining (endometrium) to thicken in preparation to receive any egg that may be fertilised. If the egg is not fertilised it will be shed during menstruation.

6. Released egg
When the egg is ready to be released it is helped into the fallopian tube by a fringe-like structure called the fimbria, which swells in response to changes in hormone levels just before ovulation. Fimbriae are covered in tiny hairs called cilia, which guide the egg through the fallopian tube towards the uterus.

5. Rupturing follicle
The LH-stimulated egg ruptures the follicle and breaks through the ovary's surface (germinal epithelium) into the fallopian tube. All the other stimulated follicles will then disintegrate. After ovulation oestrogen and LH levels decrease and the body starts to produce much more progesterone.

4. Mature follicle
Fully developed eggs are contained in the fluid-filled structure of the mature follicles. While several follicles will have begun to mature, just one will relocate itself near the surface of the ovary to break out. Mature follicles produce oestrogen, which increases the level of luteinising hormone (LH) and sets off ovulation.

Fertilisation in focus
What happens in the event that an egg meets sperm in the fallopian tube?



1. Ovum
During ovulation the egg is released from the ovary and travels slowly through the fallopian tube to the uterus. If intercourse has occurred either just before or just after ovulation there's a chance the egg will encounter sperm here.

2. Sperm
The female egg is about 20 times bigger than a sperm so it's a big target. Each sperm will attempt to penetrate the egg's thick outer membrane with the help of enzymes. The successful sperm will then fuse with the egg.

3. Fertilisation
Once the first sperm is through, the egg releases enzymes that prevent any further sperm entering. The sperm's tail and all the other sperm fall away. The fertilised egg is now called a single-celled zygote.

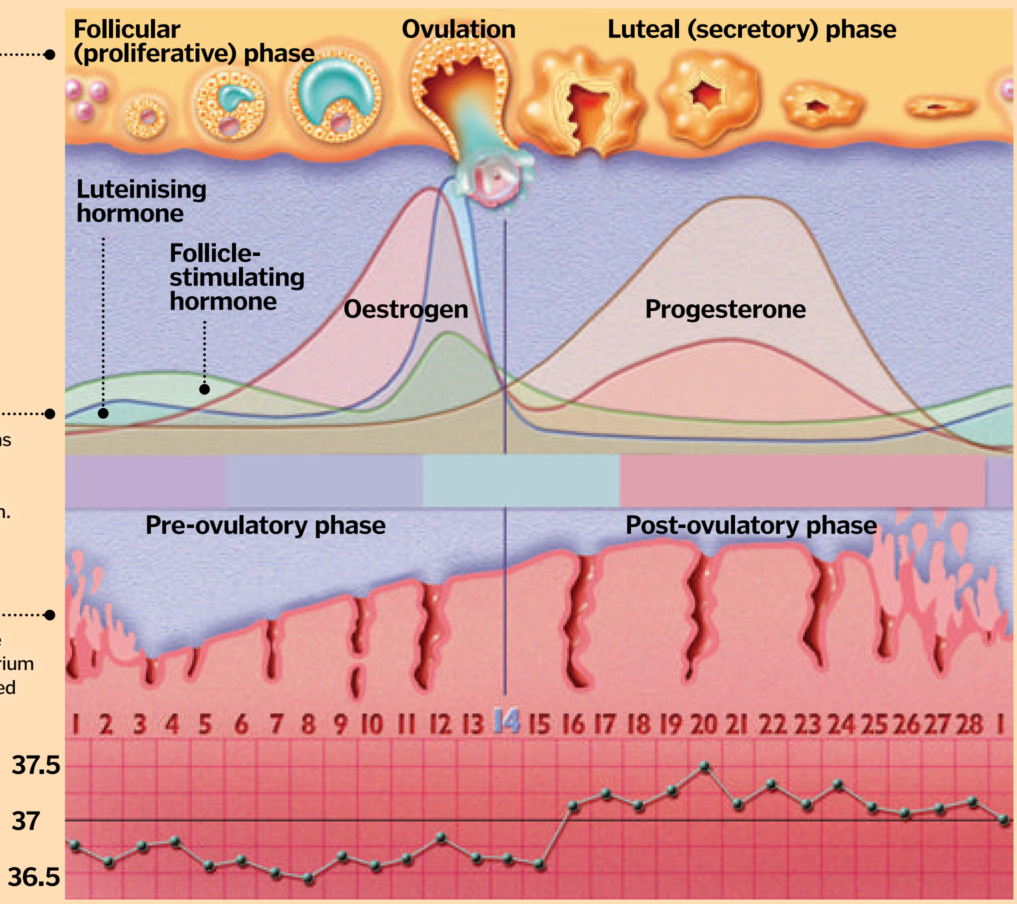
Menstruation and the body
This cycle starts from the first day of menstruation and lasts for between 28 and 32 days; ovulation occurs around day 14

Ovarian cycle
This reveals the development of the follicles throughout the woman's monthly cycle.

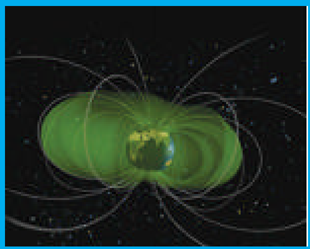
Hormonal cycle
Here you can see variations in the levels of pituitary and ovarian hormone production over the month.

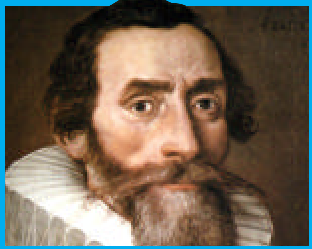
Uterine cycle
This shows changes in the thickness of the endometrium and at which point it is shed during menstruation.

Temperature
This curve shows how progesterone slightly increases the female's basal body temperature.



Billions of miles lie between the Sun and the edges of the Solar System and across this vast distance there is a great distinction between the inner and outer regions. Here we focus on the probes shining a light on the outer Solar System. Also find out why plasma helps to protect Earth and how Johannes Kepler revolutionised astronomy.

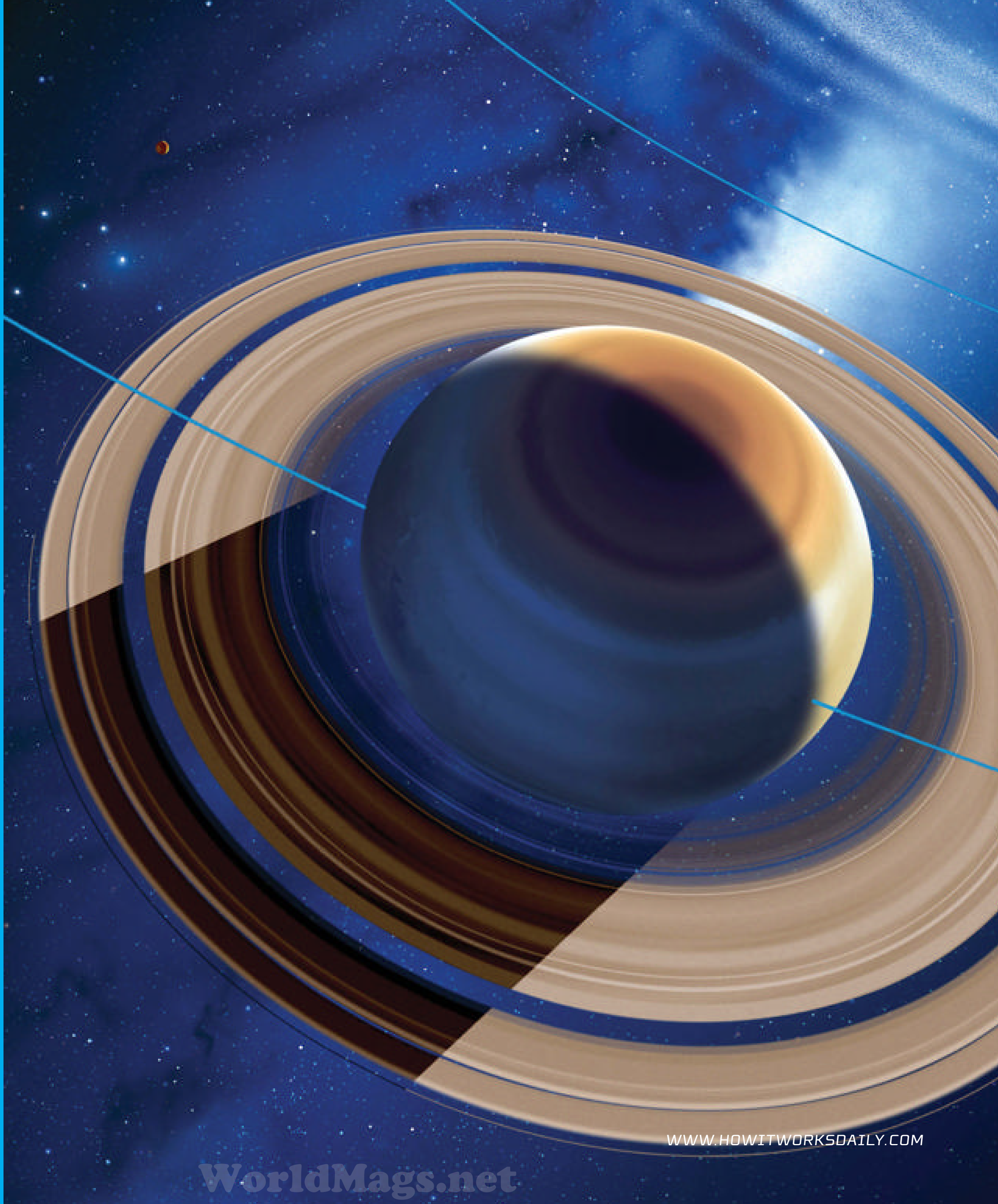




LEARN MORE

Exploring the

Only a handful of spacecraft have ventured to the farthest reaches of our Solar System, but what did they find when they got there?



MISSION COST	$3.27bn	PHOTOS TAKEN TO DATE	300,000	NAMED SATURNIAN MOONS PASSED	53
YEAR OF TITAN'S DISCOVERY	1655	LENGTH OF CASSINI'S WIRES	12km	DATA CAPTURED	300GB

DID YOU KNOW? *It takes almost 90 minutes for radio signals from Saturn to reach us on Earth*

outer Solar System

On 14 January 2005, the world got its first proper look of Titan. A spray of yellow stones on a sandy backdrop extending into a hazy sky, it could easily have been mistaken for a sepia-toned photograph from a desert, taken back in the Sixties. It's not what most people would expect a land of liquid methane lakes, water-ice rocks and an average daytime temperature of -179 degrees Celsius (-290 degrees Fahrenheit) to look like.

This was our first closeup of anything in the outer Solar System, however. Previously we had nothing but giant telescopes or passing probes taking photos of the four planets and their many moons but often from millions of miles away. The ESA's Huygens probe, piggybacking NASA's Cassini spacecraft, had plunged through Titan's dense nitrogen and methane clouds that had veiled its surface from our prying eyes ever since its discovery, down to the rocky ground below. Because its relay, Cassini, was moving out of range at the rate of five metres (16 feet) a second, Huygens was only designed for 30 minutes of data acquisition in mind, even though it continued to transmit data for just over an hour and a half.

Though Cassini is revealing unprecedented detail about Saturn, we're still scraping the surface of what we can learn about this gas giant – and there's still a black hole of knowledge to be filled in about the outer Solar System in general. We've managed to visit Mars, Venus and the planets on our galactic doorstep within the Asteroid Belt with all manner of spacecraft, but our cosmic 'backyard' is still wild and unexplored. Historically, the farther beyond Mars we look, the fewer probes we see making the huge journey to the strange celestial bodies that dwell far from the warmth of the Sun. Jupiter has had six successful flybys by separate spacecraft and one orbiter (Galileo) while Saturn has had three flybys and one orbiter (Cassini). Uranus and Neptune have only ever had a fleeting visit by the Voyager 2 probe, while dwarf planet Pluto (about 5.9 billion kilometres/3.7 billion miles from the Sun) is yet to get its own closeup, but New Horizons is set to reach it in 2015.

Saturn being the current planet on NASA's 'Grand Tour' of the outer planets, Cassini is getting a lot of attention at the moment. Its primary mission was to study Saturn and its satellites in close proximity, but in the seven-year journey to the sixth planet from the Sun, it collected a staggering amount of data simply flying past planets it was using to carry out a gravitational assist. Venus, Earth and the Moon got a slew of calibration shots to add to their portfolios as their gravity was used to propel Cassini towards Saturn. Jupiter was analysed in greater detail, photographed 26,000 ▶

"Pioneer 11 is on a course that will see it pass one of the stars in the Aquila constellation in 4 million years' time"

times in Cassini's six-month Jovian flyby. It added to the bounty of information gathered by the Galileo orbiter in its eight-year mission that concluded in 2003, along with the Galileo probe that sacrificed itself in the name of astronomy by plummeting into the vice-like pressures beneath Jupiter's gaseous surface.

Although all contact has now been lost with the Pioneer 10 spacecraft that launched in 1972, its mission to fly by Jupiter was a success at a time when landing on the Moon was still fresh in everyone's mind. It took 500 photos of the behemoth before moving on to the chilly outer fringes of our Solar System, gathering data until its power failed in 2003 at a distance of 12 billion kilometres (7.5 billion miles) from Earth.

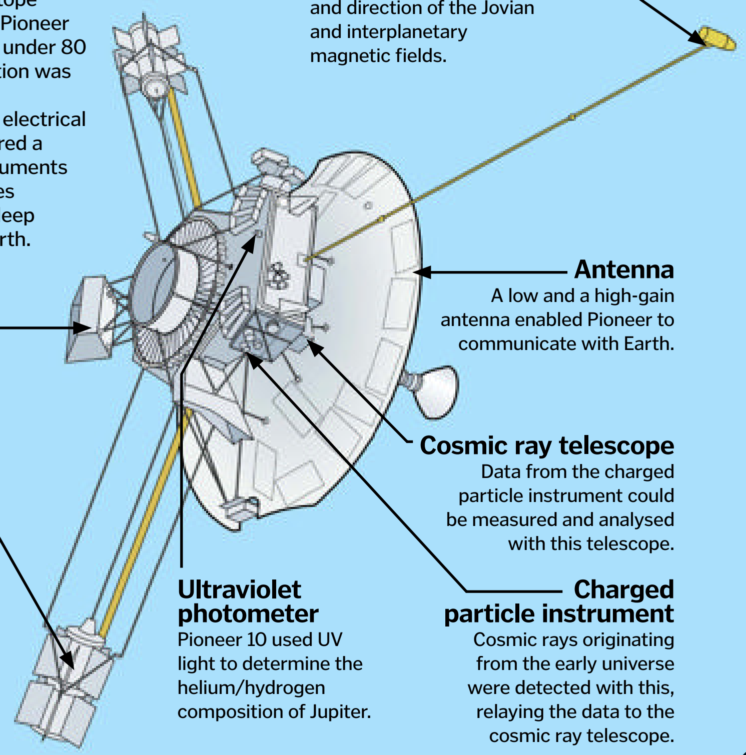
Pioneer 11, which has performed flybys of both Jupiter and Saturn, has suffered from similar technical issues (in this case with its radio) and is lost in the outer Solar System on an extrasolar course that will see it pass one of the stars in the Aquila constellation in around 4 million years' time. Similarly, Voyager 2 is bordering on the farthest reaches of the Sun's influence, having flown by Jupiter, Saturn, Uranus and Neptune in the Seventies and Eighties. In contrast, both Voyager 1 and 2 are, amazingly, still fully functional and in regular communication with NASA headquarters.

Cassini entered Saturn's orbit on 30 June 2004, seven years after its launch. The next four years of its initial mission it spent scanning Saturn's surface, its rings and its moons to gain an unprecedented understanding of the Saturnian system. Its primary objective was completed in 2008 and, with nearly a decade of life left in Cassini, NASA embarked on the two-year extended Equinox mission in which the craft orbited Saturn another 60 times with 36 flybys of its moons, including 26 close encounters with Titan. Cassini's current extended mission – Solstice – began on 12 October 2010 and will end in 2017, just in time for the summer solstice of Saturn's 29-year orbit in its northern hemisphere.

Probably the most famous of all probes, though, is Voyager 1. It actually launched a month after Voyager 2 but because of Voyager 2's more convoluted trajectory, it passed its older sibling as the farthest man-made object from Earth and is on track to be the first man-made object to exit the Solar System into interstellar space. On its path to extrasolar glory, it has examined Jupiter, Saturn and its biggest moon Titan, providing the first detailed images of all three of these celestial bodies.

Pioneer 10's technology

Powered by a lump of plutonium-238 isotope inside four radioisotope thermoelectric generators, Pioneer 10 should have been at just under 80 per cent when communication was lost in 2003, due to rapid deterioration of several key electrical points on the craft. It powered a load-out that included instruments for gathering and sometimes processing raw data from deep space to be sent back to Earth.



Magnetometer
Held out by a boom arm, this measured the strength and direction of the Jovian and interplanetary magnetic fields.

Asteroid-meteoroid detector sensor
Always on the hunt for interesting objects, Pioneer 10 could track anything from motes of dust to passing asteroids.

Antenna
A low and a high-gain antenna enabled Pioneer to communicate with Earth.

Cosmic ray telescope
Data from the charged particle instrument could be measured and analysed with this telescope.

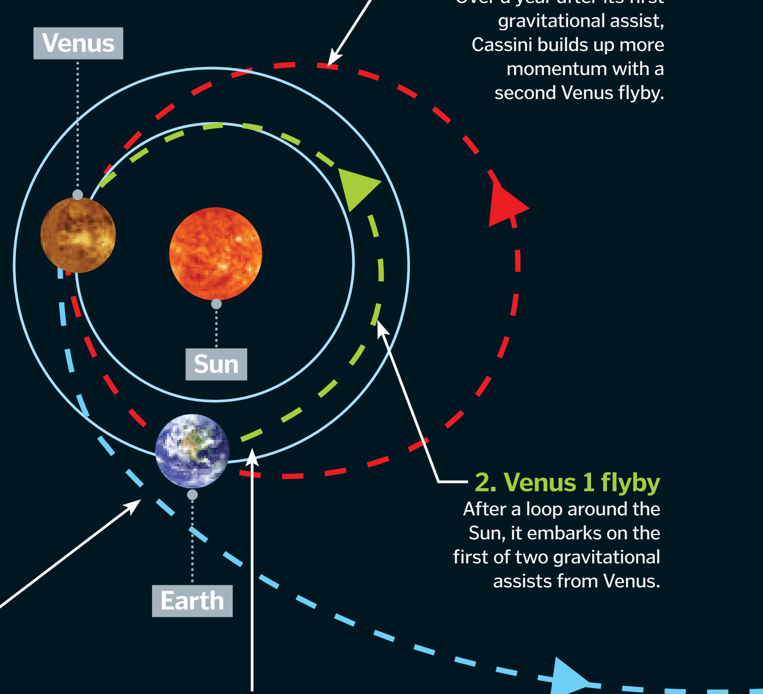
MMRTGs
Pioneer 10 used multi-mission radioisotope thermoelectric generators to power its systems. Each of the four MMRTGs harnessed heat from 4.8kg (10.6lb) of plutonium-238 to produce electricity and could be used in both an atmosphere or a vacuum.

Ultraviolet photometer
Pioneer 10 used UV light to determine the helium/hydrogen composition of Jupiter.

Charged particle instrument
Cosmic rays originating from the early universe were detected with this, relaying the data to the cosmic ray telescope.

What are gravitational assists?

Sending a probe directly to the outer planets by pointing the spacecraft in the right direction and blasting away can cost a prohibitive amount of fuel. Instead, using well-found techniques, NASA can calculate a trajectory that uses the gravity of the inner planets to 'slingshot' the craft in an increasingly wider orbit. With this added velocity, they are able to shoot off on course for a journey beyond the Asteroid Belt. In this diagram, we reveal how the Cassini-Huygens craft used gravity assists to get to Saturn…



3. Venus 2 flyby
Over a year after its first gravitational assist, Cassini builds up more momentum with a second Venus flyby.

2. Venus 1 flyby
After a loop around the Sun, it embarks on the first of two gravitational assists from Venus.

4. Earth flyby
The probe bids farewell to its home world as Earth gives it the momentum it needs to leave the inner Solar System.

1. Cassini launch
The Cassini-Huygens launches from Earth on the back of a Titan IVB/ Centaur booster.

1. BRIGHTEST

Enceladus
This cold moon (-201 degrees Celsius/-330 degrees Fahrenheit) is covered in water-ice, reflecting nearly 100 per cent of sunlight.

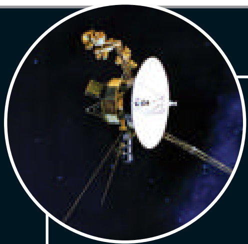
2. WEIRDEST

Iapetus
Even NASA thinks that this moon is odd. One side is jet-black and the other white; and while it looks like it should have a 16-hour day, in fact it's 79 Earth days long!

3. SPONGIEST

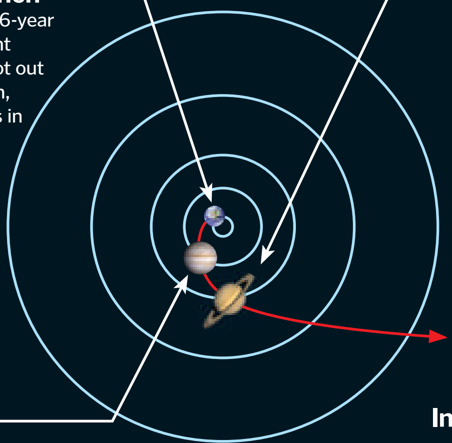
Hyperion
This oddly shaped moon is the largest irregular-shaped satellite ever to be observed in space. Its pockmarked surface lends it a spongy appearance.

DID YOU KNOW? *One of Cassini's cameras is so sensitive that it can take clear pictures of a coin 4km (2.5mi) away!*



Voyagers' journey to the edge of the Solar System

Compare the routes of Voyager 1 and Voyager 2 and discover how they have managed to get so far…



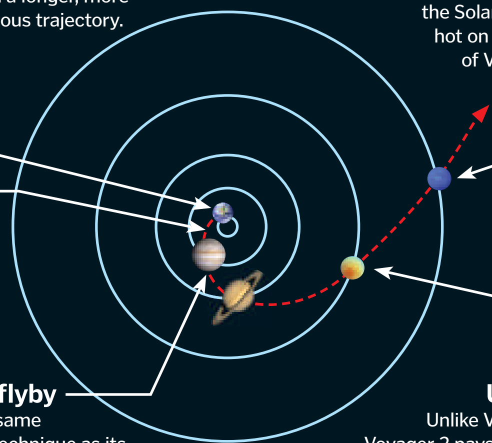
Voyager 1 launch
Exploiting a rare 176-year planetary alignment window to slingshot out of the Solar System, Voyager 1 launches in September 1977.

Saturn flyby
Over a year after the Jupiter encounter and Voyager 1 uses the gravity of Saturn to propel itself on.

Jupiter flyby
Voyager 1 says a brief hello to Jupiter in March 1979.

Voyager 1

Interstellar space
Voyager 1 is propelled onward on a trajectory that will take it directly out of the Solar System.



Voyager 2 launch
Voyager 2 launches the month before Voyager 1 but on a longer, more circuitous trajectory.

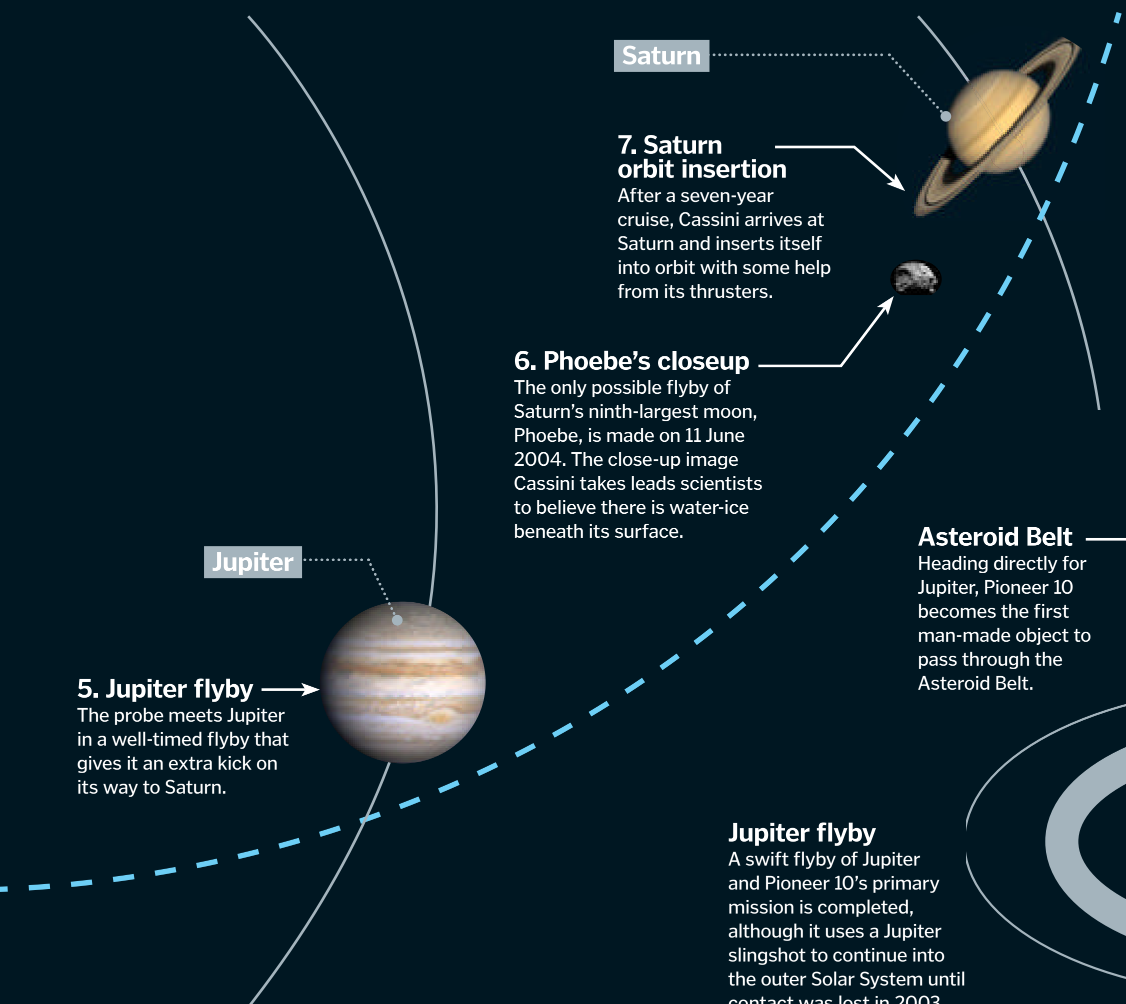
Neptune
Its final, fleeting visit is to Neptune before Voyager 2 makes its way out of the Solar System, hot on the heels of Voyager 1.

Spacecraft overtake
Voyager 2 is overtaken as Voyager 1 takes a more direct route onward.

Jupiter flyby
Using the same slingshot technique as its sibling, Voyager 2 takes advantage of Jupiter's gravity to push itself on.

Voyager 2

Uranus
Unlike Voyager 1, Voyager 2 pays a visit to Uranus having swung around Saturn for another assist.



7. Saturn orbit insertion
After a seven-year cruise, Cassini arrives at Saturn and inserts itself into orbit with some help from its thrusters.

6. Phoebe's closeup
The only possible flyby of Saturn's ninth-largest moon, Phoebe, is made on 11 June 2004. The close-up image Cassini takes leads scientists to believe there is water-ice beneath its surface.

5. Jupiter flyby
The probe meets Jupiter in a well-timed flyby that gives it an extra kick on its way to Saturn.

Testing Einstein

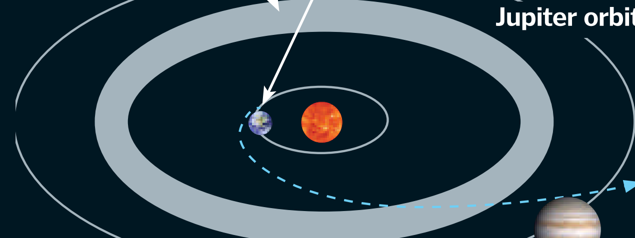
One of the tasks Voyager performed was to put Einstein's theory of general relativity to the test – specifically the curvature of space-time. The idea is that a massive body like the Sun would increase the distance radio waves have to travel as its gravity greatly distorts space-time. Radio waves were beamed from Voyager to Earth and back, resulting in a measured frequency shift as the radio waves passed by the Sun. The experiment has also been performed by the Mars Viking programme and Cassini, and all three experiments produced the same results – totally supporting Einstein's theory.

Pioneer 10's route

Where has this probe travelled since it launched and what has it seen?

Asteroid Belt
Heading directly for Jupiter, Pioneer 10 becomes the first man-made object to pass through the Asteroid Belt.

Moon
11 hours after launch, Pioneer 10 reaches the Moon.



Jupiter orbit

Jupiter flyby
A swift flyby of Jupiter and Pioneer 10's primary mission is completed, although it uses a Jupiter slingshot to continue into the outer Solar System until contact was lost in 2003.

> "The nebula's composition makes it ideal for a stellar nursery, as proven by the imaging of over 3,000 stars"

The Orion Nebula

Made up of thousands of stars, Messier 42 is one of the most beautiful and well studied of celestial phenomena

The Orion Nebula, aka Messier 42, situated to the south of Orion's Belt in the constellation of Orion, is one of the brightest diffuse examples ever captured by astronomers. Colossal in scale and packed with thousands of stars of all ages, the nebula is atypical, vividly demonstrating the many processes involved in star creation.

The Orion Nebula consists of a dense mix of clouds of neutral gas and dust, star clusters, ionised volumes of gas and reflection nebulas (clouds of interstellar dust that reflect light from nearby stars). Structurally, the nebula forms a slightly off-spherical cloud of these various celestial features, with a sharp density gradient emanating from its core to its rim.

Temperatures inside the nebula range from 10,000 Kelvin (9,727 degrees Celsius/17,540 degrees Fahrenheit) in its central regions, to a fraction of that in its periphery. In addition, a wide range of velocities are apparent within its structure, with relative movements falling at 35,405 kilometres (22,000 miles) per hour, and local movements reaching up to 177,000 kilometres (110,000 miles) per hour.

The nebula's composition makes it an ideal region for a stellar nursery, as proven by the imaging of over 3,000 stars of all ages by the Hubble Space Telescope. Indeed, only recently did NASA image a series of 150 protoplanetary discs within Messier 42 – each of which is a potential starting point for a solar system.

THE STATS
MESSIER 42

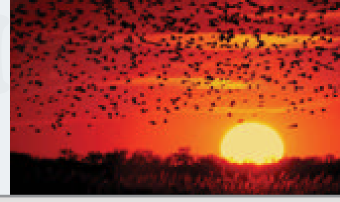
DISTANCE FROM EARTH	1,500LY	WIDTH	24LY	SOLAR MASSES	2,000
CONSTELLATION	Orion	NUMBER OF STARS	~3,000	FIRST IMAGED	1880

DID YOU KNOW? *The Orion Nebula is so big that it's visible with the naked eye from Earth*

STRANGE BUT TRUE
AVIAN AID

How do birds make use of Earth's plasmasphere?

A To navigate **B** To breathe **C** To watch TV



Answer:
Birds have an amazing ability that allows them to use Earth's magnetic field to help them fly. Their upper beaks have a series of nerves containing iron, which they use as a built-in magnetometer to orientate themselves, particularly on long journeys.

DID YOU KNOW? *Singly ionised helium constitutes around 20 per cent of the plasma in our planet's plasmasphere*

How does plasma help to protect Earth?

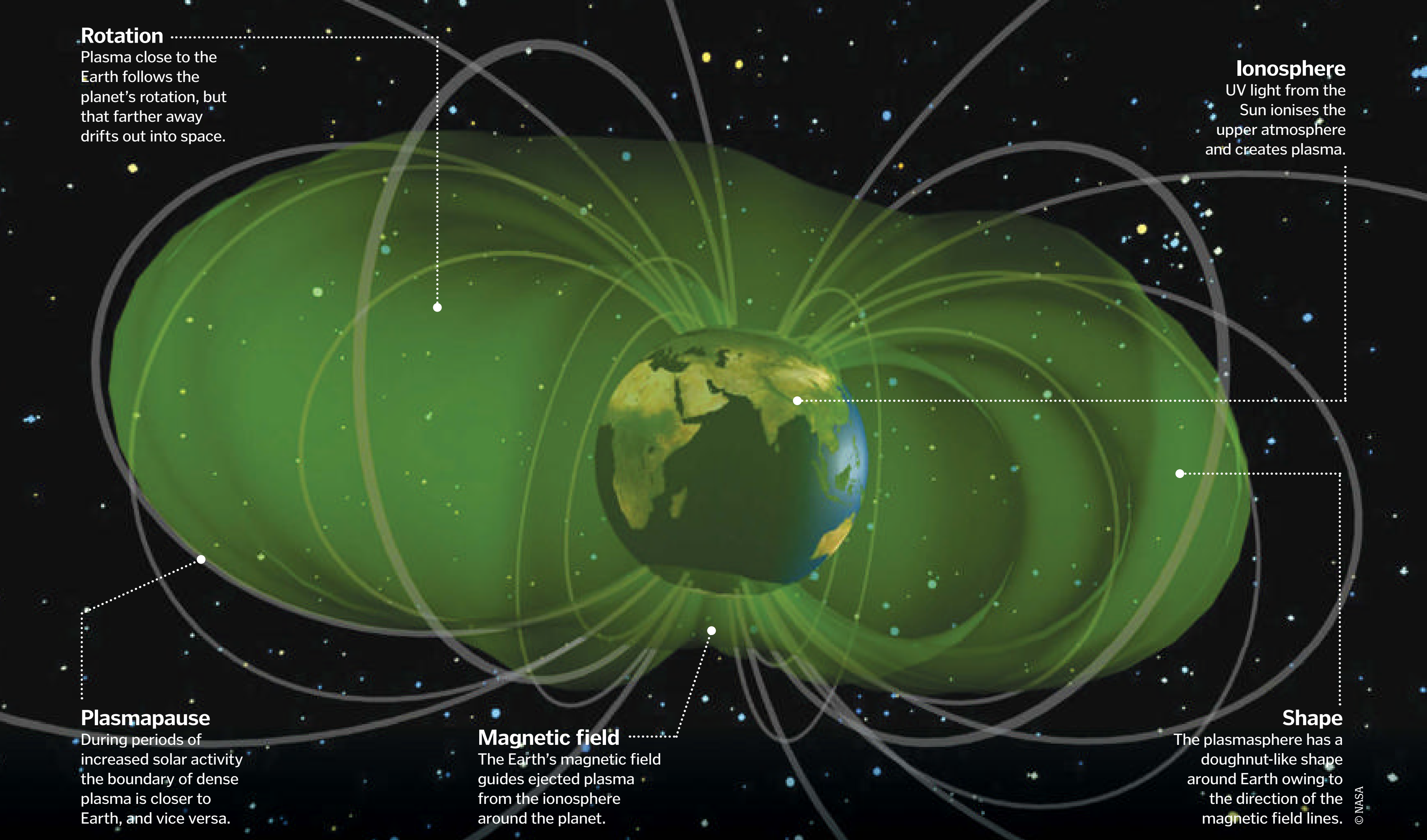
Learn about the densest region of plasma surrounding our planet

Our planet's magnetic field interacts with solar wind released from the Sun's corona to form a protective magnetosphere – an area of charged particles that continually zip around Earth. Within this magnetosphere, above the ionosphere in the upper atmosphere, is the plasmasphere.

While electrically charged gas, known as plasma, is found throughout the magnetosphere (and indeed the entire universe), the coldest and densest plasma around Earth is located in the plasmasphere. It is formed by the outflow of plasma from the ionosphere being held in a somewhat stable position by our world's magnetic field lines, creating a balance of pressure. The plasma co-rotates with the Earth, but it's also lost into space where its density decreases. Essentially this means that the plasmasphere is constantly shifting and being replenished. The area of plasma shrinks and grows during periods of increased and decreased solar activity, respectively. While the plasmasphere itself doesn't do much to protect Earth from the Sun, the leaking of plasma into the magnetosphere does contribute to our planet's protective outer shell. This shields us from cosmic rays and UV radiation among other things.

What is Earth's plasmasphere?

We look at the main characteristics of this doughnut-shaped cloud of charged gas



Johannes Kepler

Kepler's cosmological model which shows the relative distances of the planets from the Sun

Often overshadowed by Galileo, Kepler was one of the most important figures in the fields of astronomy and physics ever

Johannes Kepler was a German mathematician and astronomer who, despite being less well known than scientists like Galileo, played a pivotal role in the founding of modern astronomy.

Today, Kepler is best remembered for his three laws of planetary motion (see 'The big idea' boxout), as well as his seminal texts on the orbit of Mars, the shape and formation of planets and the ratification of a Sun-centred model of the Solar System – first posited by Renaissance astronomer Nicolaus Copernicus.

Kepler was born on 27 December 1571 in the free imperial city of Weil der Stadt, near to modern-day Stuttgart. One of his first encounters with astronomy came when he was six, observing the Great Comet of 1577. This was followed three years on with a lunar eclipse, which he later recalled greatly inspired him.

Kepler stayed in touch with astronomy throughout his schooling, retaining his interest during his time at the University of Tübingen. It was at Tübingen where his superb mathematical abilities became evident and he soon gained a reputation as a skilful astronomer and astrologer (in this era, these disciplines were considered the same thing).

Around this time he gained a mentor – Michael Maestlin – and began learning both the Ptolemaic system of planetary motion (which was Earth centred) and also the Copernican system, which was new and revolutionary and controversially placed the Sun at the heart of our Solar System.

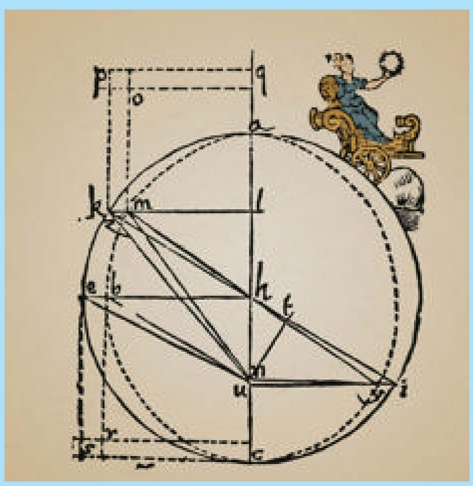
At the age of 23 Kepler started teaching mathematics and astronomy at the University of Graz. It was during his time here that he published the first defence of the Copernican system, his *Mysterium Cosmographicum*. The text was not widely read, but it firmly established Kepler as one of the foremost astronomers of the age, as it largely modernised and honed Copernicus's theories.

In 1600 Kepler met someone who would become a key colleague in the formulation of his three laws: Danish nobleman Tycho Brahe, who was building a new observatory. Here he

The big idea

Despite the underlying reasons being discredited by modern-day astronomers, Kepler's three laws of planetary motion are still considered an accurate description of the movement of any planet or satellite in space. The three laws are as follows: first, the orbit of every planet is an ellipse with the Sun at one of the two foci. Second, a line joining a planet and the Sun sweeps out equal areas during equal intervals of time. And third, the square of the orbital period of a planet is directly proportional to the cube of the semi-major axis of its orbit.

These three laws were revolutionary in the early-17th century as they demonstrated that the Sun was at the centre of the Solar System (which was considered the universe in Kepler's day) rather than Earth. This laid down the foundation for the important works of Isaac Newton a century later, such as his universal law of gravitation.



A life's work

A journey through the big moments in Kepler's life

1571
Johannes Kepler is born on 27 December in Weil der Stadt, Württemberg, south-west Germany.

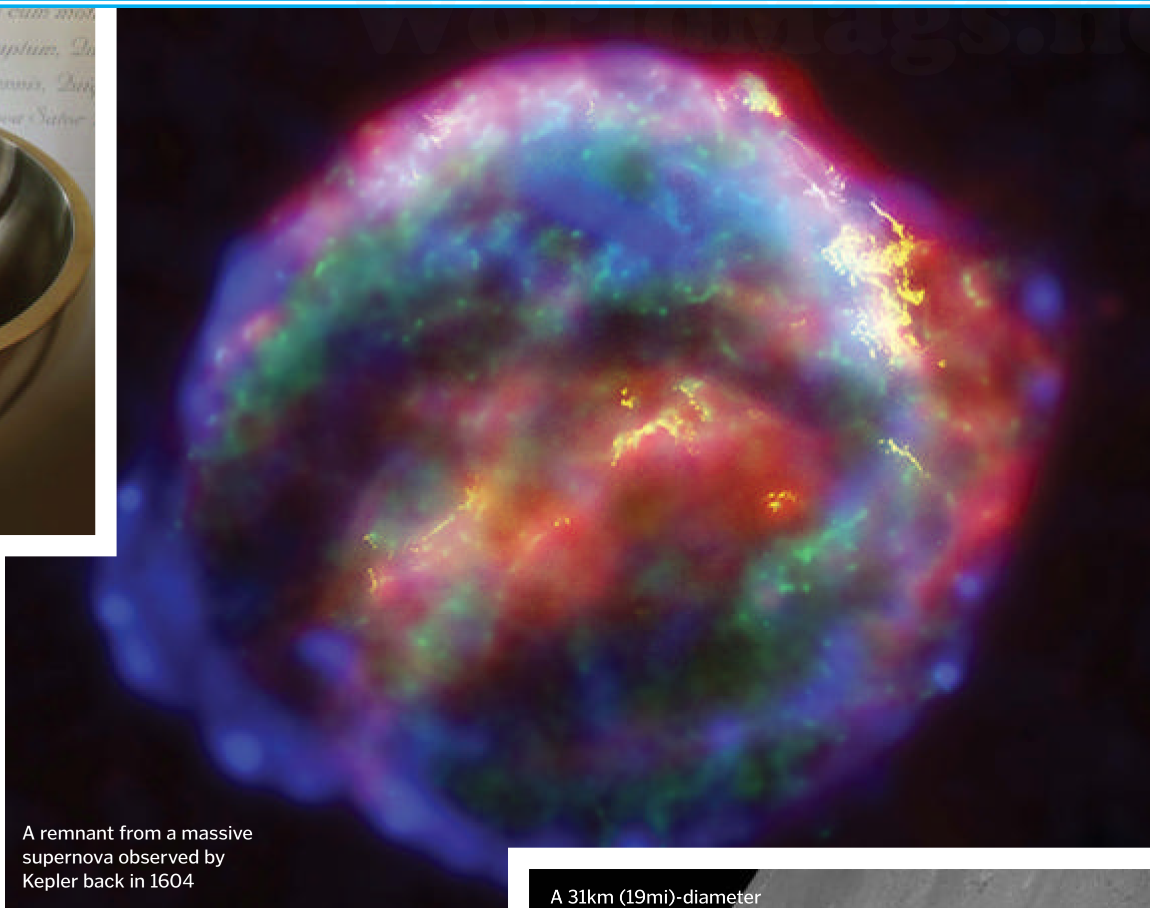
1577
Although a sickly child, viewing the Great Comet of 1577 is a turning point that will inspire his career.

1589
At 18 he enrols at the University of Tübingen's stift (the theological seminary).

1594
He starts teaching mathematics at the University of Graz but is dismissed in 1600.

1596
Publishes *Mysterium Cosmographicum*, developing the Copernican theory of heliocentrism.

1600
Moves to Prague to work with Danish astronomer Tycho Brahe, who dies the following year.

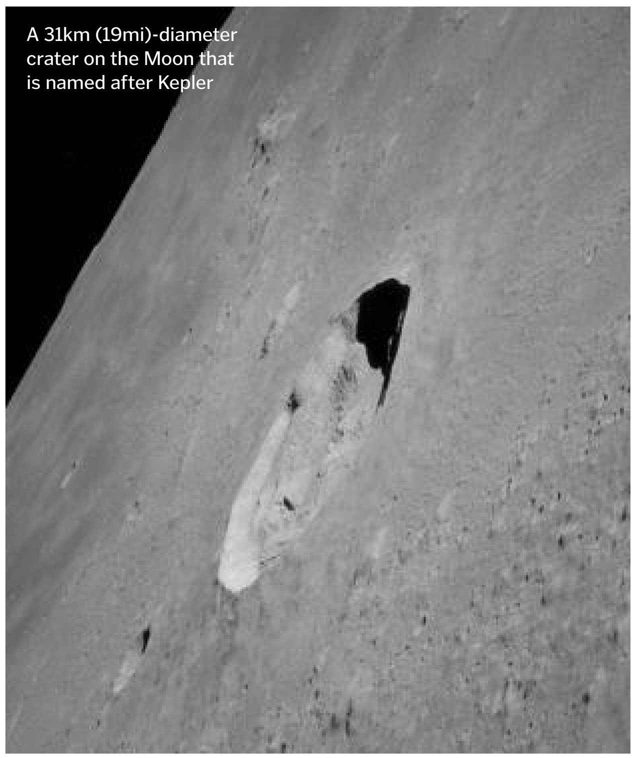


A remnant from a massive supernova observed by Kepler back in 1604

wished to utilise Brahe's extensive observations of Mars to run a test to back up his evolution of the Sun-centred Copernican system. Following Brahe's untimely death in 1601, he succeeded him in becoming imperial mathematician to Emperor Rudolf II, a time in which he published works on optics and techniques for observing stars and planets, as well as his landmark 1609 text *A New Astronomy*, in which he introduced the first two of his three laws of planetary motion.

After the death of the emperor in 1612, Kepler moved to Linz. It was here, seven years later, that he published *Harmonices Mundi*, a text that while filled with much erroneous material as determined by modern science, did include his third and final law of planetary motion. He later completed a comprehensive star catalogue and planetary table started with Brahe in 1600.

Kepler died on 15 November 1630 in Regensburg, Germany. Despite his impressive work, his three laws were not immediately accepted by the astronomical community, with notable figures such as Galileo and René Descartes ignoring them. It was not until the late-17th century that astronomers like Isaac Newton started to adopt them.



A 31km (19mi)-diameter crater on the Moon that is named after Kepler

Top 5 facts: Johannes Kepler

1 Family
Johannes Kepler and his first wife, Barbara Müller, had five children in total. However, the first two – named Heinrich and Susanna – both died in infancy. The following three survived. He married a second time in 1613.

2 Banishment
Kepler's belief in a Sun-centred Solar System – along with his deep-rooted Protestantism – saw him banished from the Austrian, heavily Catholic city of Graz in August 1600.

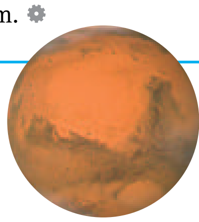
3 Supernova
Kepler was the first astronomer to observe the SN 1604 star go supernova in October 1604. Two years later he described it in detail in his text *De Stella Nova*.

4 Rejection
When Kepler published two of his three laws in his groundbreaking work *Astronomia Nova* at first he was ridiculed and ignored by the majority of the scientific establishment, including Galileo Galilei.

5 Mountains
In New Zealand's Fiordland National Park there's a mountain range named after Kepler in tribute to his extensive contributions to the field of astronomy.

"Kepler is best remembered for his three laws of planetary motion and seminal texts on the ratification of a Sun-centred Solar System"

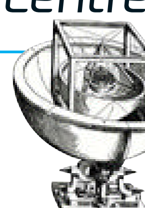
1601
Kepler is appointed Emperor Rudolf II's imperial mathematician in Brahe's stead.



1609
Two of Kepler's three laws of planetary motion are published in *Astronomia Nova*, based largely on the movements of Mars.

1611
In the wake of Galileo's success, Kepler puts forward a new design for a telescope with two convex lenses.

1612
Kepler returns to his hometown to defend his mother, a healer, against charges of witchcraft.

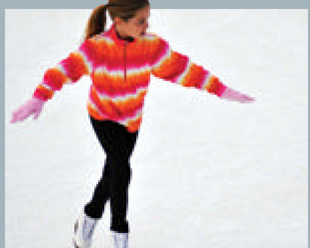


1621
Publishes *Epitome Astronomiae*, which is a compilation of all his other work on heliocentrism.

1624
As per Brahe's dying wish, Kepler completes an astronomical table that is far more accurate than previous models.

1630
Johannes Kepler dies in Regensburg on the way to collect a debt, aged 58.

Whether it's flying boats or submersible cars, there's something inspiring about vehicles that can segue from one terrain to another; here we look at some of today's most advanced. Also find out how an ice rink is built, why the Coyote HMT is always ready for action and how tiny tractors can tow jumbo jets.



LEARN MORE

Amphibious vehicles

HIW explores the cutting-edge vehicles able to jump between land, water and air as a result of some innovative engineering

The dream of a fully functional amphibious vehicle dates back to the mid-1700s, when an Italian prince drove a modified land/water coach into the Tyrrhenian Sea. Despite the odd universal desire to drive our cars into the nearest lake, only the Amphicar, a steel beauty with stylish tailfins, achieved anything close to commercial success, selling 4,500 units in the Sixties.

Other 'amphibians' have had greater success – namely amphibious aircraft. That's because a simple amphibious plane or helicopter can be made by adding sturdy floats to a pair of landing skids. But amphibious land/water vehicles face many more obstacles, because the engineering rules of the water are often in direct conflict with the rules of the land.

For example, a high-speed watercraft needs to break the plane of the water to reduce drag. Picture the wide, hydrodynamic shape of a speedboat hull, which lifts the nose of the boat up and out of the water. The body of a sports car, on the other hand, needs to be low and flat to reduce drag and safely hug the road during sharp turns. So how do you engineer the body of a vehicle that can navigate both surf and turf with ease and speed?

Modern amphibious vehicles have several key advantages over earlier models. Materials, for example. The Amphicar was pure steel, which not only rusts and corrodes, but

The statistics...

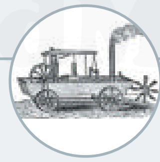
Quadski

Crew: 1
Length: 3.2m (10.5ft)
Width: 1.6m (5.2ft)
Height: 1.4m (4.6ft)
Weight: 535kg (1,180lb)
Max land speed: 72km/h (45mph)
Max water speed: 72km/h (45mph)

KEY DATES
VERSATILE VEHICLES

1750 Italian prince and scientist Raimondo di Sangro invents an internally propelled amphibious carriage.

1804 Oliver Evans builds the Orukter Amphibolos (right), a 20-ton amphibious, steam-powered dredger.



1870s Steam-powered alligator tugs gain popularity in the North American logging industry.

1961 After many commercial attempts, the German Amphicar (right) sells 4,500 units worldwide.

1977 An underwater Lotus Esprit in *The Spy Who Loved Me* inspires the CEO of Rinspeed to set up shop.

DID YOU KNOW? In 2012, DARPA decided to crowdsource a new design for the military's AAV with a grand prize of $2m (£1.24m)

makes it heavy as a rock. To keep a steel craft afloat, you need a lot of water displacement, which demands a bulky body that looks odd on the road. Today's amphibious cars and ATVs are built from composite material – a strong and lightweight blend of plastics and fibre. These lighter bodies sit higher in the water and require less speed to break the plane.

Propulsion is another huge obstacle. Earlier motorised amphibious vehicles relied on propellers for thrust. Propeller blades had to be small in order to ride high enough on the road to avoid damage, and small propellers provide less thrust. Modern amphibians have switched to water jet propulsion systems with no moving parts outside the craft. Water jets take in water through a hole in the bottom of the hull and use power from the engine to turn a centrifugal pump to build up pressure. The pressurised water is then forced through a nozzle in the rear, providing forward thrust.

The military has always been a great supporter of amphibious vehicles, with landing craft, troop movers and jeeps playing critical strategic roles since World War II. With continued military funding and engineering breakthroughs, we might see a commercially viable amphibious car sooner than you think.

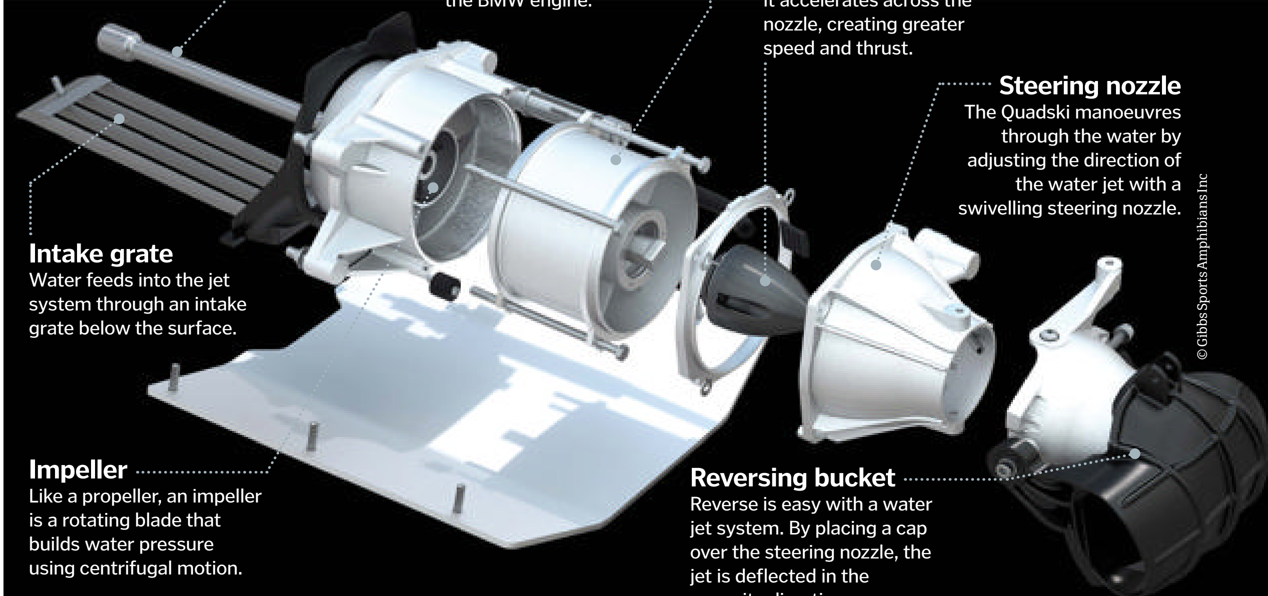
Gibbs Sports Quadski

A quadbike that goes from turf to surf in just five seconds

The Quadski is an amphibious transformer, switching from ATV to jet-ski at the push of a button. The quick-change act centres on the wheels, which fully retract in five seconds thanks to two zippy servomotors. On land, the Quadski looks and rides exactly like a quadbike. For mud-chewing trail rides, the Quadski is powered by the same 130-kilowatt (175-horsepower), 1.3-litre motorcycle engine that supercharges BMW's high-performance racing line. For safety reasons, the engine is capped at 60 kilowatts (80 horsepower) on land, reaching a maximum 72 kilometres (45 miles) per hour. But the real magic is seeing this lightweight ATV move from land to water. Previous amphibian car concepts were literally dead in the water, slogging slow and low. The Quadski, however, leaps out of the water using the full 130 kilowatts (175 horsepower) to pump water through its jet propulsion system. By riding high on the surface on its fibreglass hull, the Quadski can match its maximum land speed on the water.

Jet propulsion up close

The Quadski's compact water jet system delivers serious thrust



> "The hull of the speedboat-looking Dornier Seastar is made entirely of corrosion-proof composite material"

Rinspeed sQuba

A James Bond fantasy car brought to life

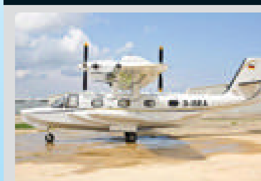
Rinspeed CEO Frank Rinderknecht had dreamt about an underwater 'flying' car since seeing *The Spy Who Loved Me* in 1977. 007's swimming car was the direct inspiration for the sQuba, a modified Lotus Elise with three battery-powered electric motors and oxygen masks. When the aluminium-bodied, watertight Lotus drives into a lake, it floats. With the flick of a switch, power is diverted to two propellers and two water jets to reach a leisurely surface cruising speed of 5.9 kilometres (3.7 miles) per hour. Getting the sQuba to dive requires driver and passenger to open doors and windows to flood the cabin. To travel at the maximum depth of ten metres (33 feet), the driver must use the water jets. On land, the zero-emissions sQuba can rocket from 0-80 kilometres (0-50 miles) per hour in 5.1 seconds, but maxes out at just 2.9 kilometres (1.8 miles) per hour when underwater.

Dornier Seastar

Land, sea and air: this flying boat has got it all covered

A conventional seaplane is nothing more than a Cessna outfitted with floats. Exposed to seawater, metal seaplanes corrode quickly and require constant maintenance. And without landing gear, they're as waterbound as a tuna. The hull of the speedboat-looking Dornier Seastar, meanwhile, is made entirely of corrosion-proof composite material. For terrestrial destinations, landing gear lowers from the hull. The wide boat hull keeps the craft stable on the water, as does the in-line arrangement of the twin turboprop engines positioned directly over the cabin. The push-pull action of the two propellers can see the Seastar take off – with up to 12 passengers – after just 760 metres (2,500 feet) and reach a maximum air speed of 180 knots (333 kilometres/207 miles per hour). Short takeoffs and landings are aided by two sets of curved sponsons – side projections that add stability to a vessel's hull – located near the middle of the Seastar.

The statistics…



Seastar

Crew: 2
Wingspan: 17.6m (58ft)
Length: 12.5m (41ft)
Height: 4.8m (15.9ft)
Empty weight: 3,289kg (7,250lb)
Max speed: 333km/h (207mph)
Max altitude: 4,572m (15,000ft)

Boat mode
The Seastar is a boat that flies – rather than a plane that floats – so it sits low and steady in the water on its V-shaped hull.

Breaking the plane
Two sets of sponsons make the hull wider under the wings. The sponsons act almost as hydrofoils to raise the hull when moving.

Liftoff
With the nose of the hull out of the water, drag is greatly reduced, so the Seastar can reach takeoff speed in 760m (2,500ft).

Gaining altitude
The push-pull configuration of the twin turboprop engine results in huge thrust so the Seastar can climb 396m (1,300ft) per minute.

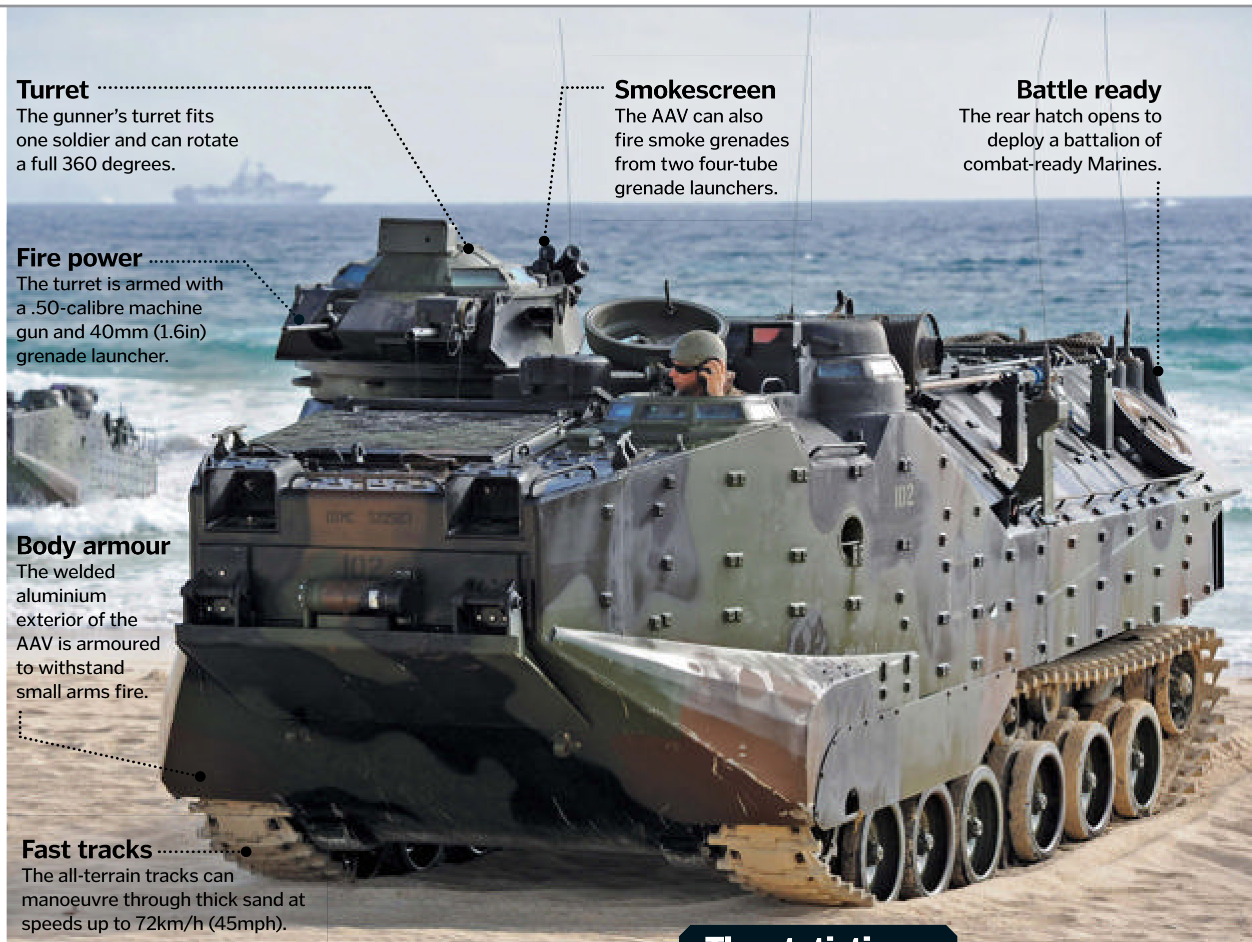
Water landing
The sponsons double up as 'water wings'. As the Seastar touches down, the sponsons create just enough drag to slow it.

DID YOU KNOW? Sir Richard Branson has proposed an amphibious limo service for Virgin Airlines' first-class passengers

The statistics...

sQuba

- **Crew:** 2
- **Length:** 3.7m (12.4ft)
- **Width:** 1.9m (6.3ft)
- **Height:** 1.1m (3.6ft)
- **Empty weight:** 920kg (2,028lb)
- **Max land speed:** 120km/h (75mph)
- **Max underwater speed:** 2.9km/h (1.8mph)



Amphibious Assault Vehicle

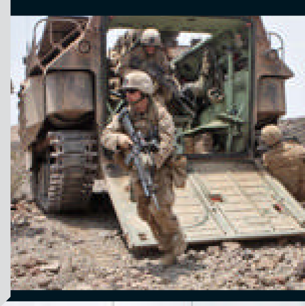
The first to land and the first to fight

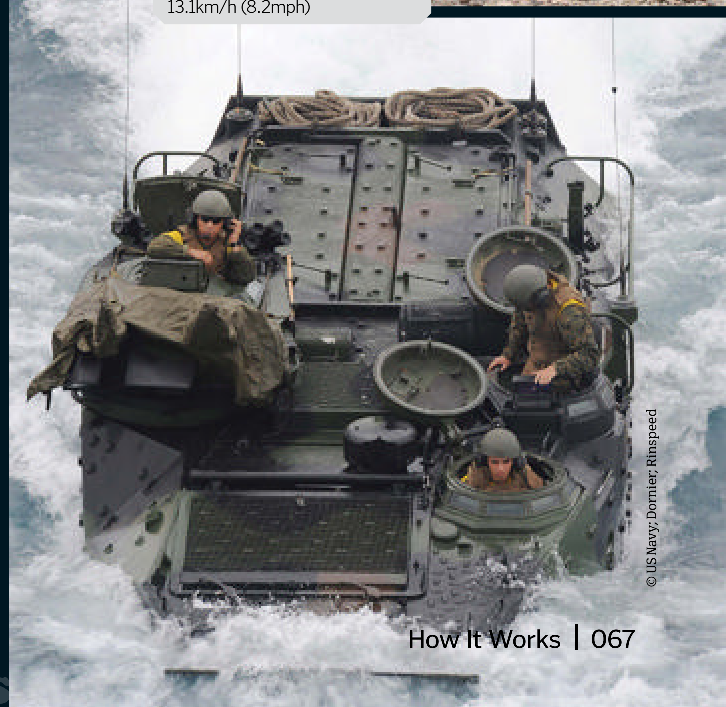
Owned by the US Marine Corps, the Amphibious Assault Vehicle (AAV) is a ship-to-shore troop transporter and fully armed combat vehicle. The AAV weighs close to 30 tons and can carry 21 combat-ready Marines and a crew of three. The amphibious tanks launch from the sea-level well decks of assault ships and roar through the water at ten knots (18.5 kilometres/11.5 miles per hour) powered by two rear water jets. The jets are mixed-flow, reversible pumps that propel 52,990 litres (14,000 gallons) of water per minute. In addition to the jets, the AAV gets some propulsion from its spinning tracks. The AAV rides low in the water and can fire its .50-calibre machine gun and 40-millimetre (1.6-inch) grenade launcher on both land or sea. It makes a seamless transition from ocean to shore and carries enough fuel to haul 4,535 kilograms (10,000 pounds) of cargo as far as 480 kilometres (300 miles) inland.

The statistics...

Amphibious Assault Vehicle

- **Crew:** 3
- **Length:** 7.9m (26ft)
- **Width:** 3.3m (10.8ft)
- **Height:** 3.3m (10.8ft)
- **Weight:** 29.1 tons
- **Max land speed:** 72km/h (45mph)
- **Max water speed:** 13.1km/h (8.2mph)





162,000m²

WORLD'S BIGGEST ICE RINK

When the Rideau Canal Waterway in Ottawa, Canada, freezes over in winter it becomes bigger than 90 Olympic-sized ice hockey rinks.

DID YOU KNOW? *A degree or two can make the difference between a surface suitable for ice hockey or figure skating*

How are ice rinks built?

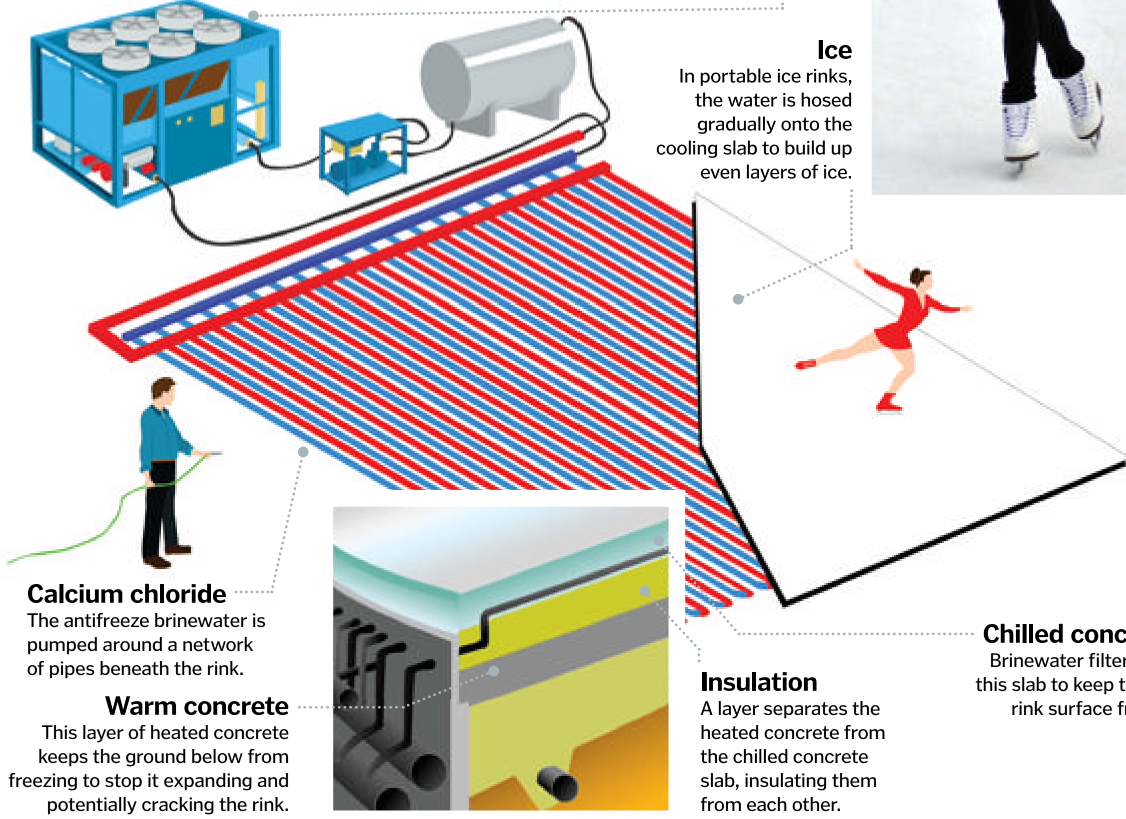
How do we re-create the perfect frozen surface to skate on indoors?

Making an ice rink is nowhere near as simple as freezing a pool of water, even though this sometimes works in nature. It can take up to a dozen separate stages depending on what the ice rink is going to be used for and what markings, if any, are going to be applied. Ice rinks use a similar technology to that of refrigerators except that, instead of directly cooling the ice until it freezes, a calcium chloride solution called brinewater is cooled to the required temperature – usually around -16 degrees Celsius (3.2 degrees Fahrenheit) and then pumped under the concrete floor of the rink. Beneath the cooling slab are an insulated layer and a heated layer that prevent the ground under the rink from freezing.

To form a suitable surface for a professional ice hockey game, for instance, up to 57,000 litres (15,000 gallons) of water are gradually pumped onto the concrete cooling slab and allowed to freeze in a series of smooth layers.

Ice rink breakdown

Learn about the technology that maintains an ice rink's glassy smooth surface

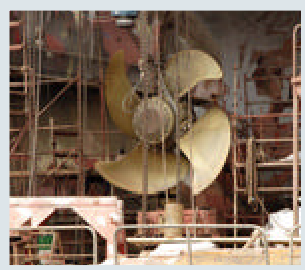


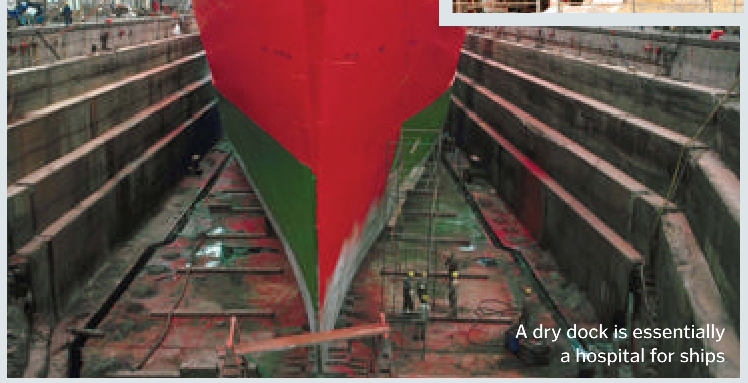
What happens in dry docks?

Why do shipbuilders use dry docks to construct and fix all manner of vessels?

A dry dock is exactly what it sounds like: a dock for ships, submarines and any aquatic vehicle, which is emptied of water. It's used to repair and build with easy access to the hull and underside, while the vessel is suspended off the bottom. Typically, the dry dock is flooded to the same level as the body of water it neighbours, like a canal lock, before the vessel is floated in and carefully positioned according to the docking plan. The dry dock gates then close and the water is pumped out, leaving the boat supported by a series of blocks. Once work has been completed the dock floods again, the gates open and the renovated vessel floats out.

Floating dry docks can take the place of the terrestrial variety where space on the land is limited or portable ship repair is required by the same company in remoter regions.





A dry dock is essentially a hospital for ships

THE STATS
EAGLE ETT-12

DRAWBAR PULL 54kN | DECK HEIGHT 109.2cm | TURNING RADIUS 355.6cm
TORQUE 284Nm | GROUND CLEARANCE 22.8cm | WEIGHT WITHOUT BATTERY 4,536kg

DID YOU KNOW? TaxiBot is a semi-robotic pushback tug which is controlled by the pilot from a plane's cockpit

How pushback tugs tow planes

Learn about the unique tractors which are powerful enough to transport jumbo jets around an airport

A pushback tug (a form of tractor) is a small and highly specialised vehicle used to tow aircraft to and from a gate, hangar or runway. 'Pushback' actually refers to the airport procedure, where the plane is moved by an external power source: many aircraft are perfectly capable of moving around under the power of their own jet engines (ie taxiing), but the resulting blast in close proximity to the terminal or other equipment could easily cause damage and disruption.

Pushback tugs have a significantly low profile to fit under the nose of the planes they tow. To generate the traction they require to pull today's commercial airliners (a fully laden Boeing 777 can weigh as much as 300,000 kilograms/660,000 pounds), ballast can be added to increase the vehicle's weight. Aircraft tugs operate using similar principles as other vehicles designed with towing in mind, such as farm tractors and, of course, tow trucks.

First, they have thick tyre walls to withstand the added pressure from the weight of the tug as well as inner tyre inflation. They also feature four-wheel drive engines, which are designed to generate a large amount of torque at low speeds to move an aircraft that can easily be ten times heavier or more.

Torque & traction

The principal forces that pushback tugs deal with when hauling huge aircraft are torque and traction. Torque is the force at which an object rotates about an axis (like the force at which the wheels of the tug rotate around their axle), while traction is the maximum friction that two surfaces can produce without slipping, such as the tyres of the tug on the tarmac. The two are related when it comes to pushback tugs towing planes: tugs don't need to pull the entire weight of the aircraft – they just need to get them rolling. They do this by overcoming the friction between the tarmac and the aircraft tyres using a great deal of both torque and traction.

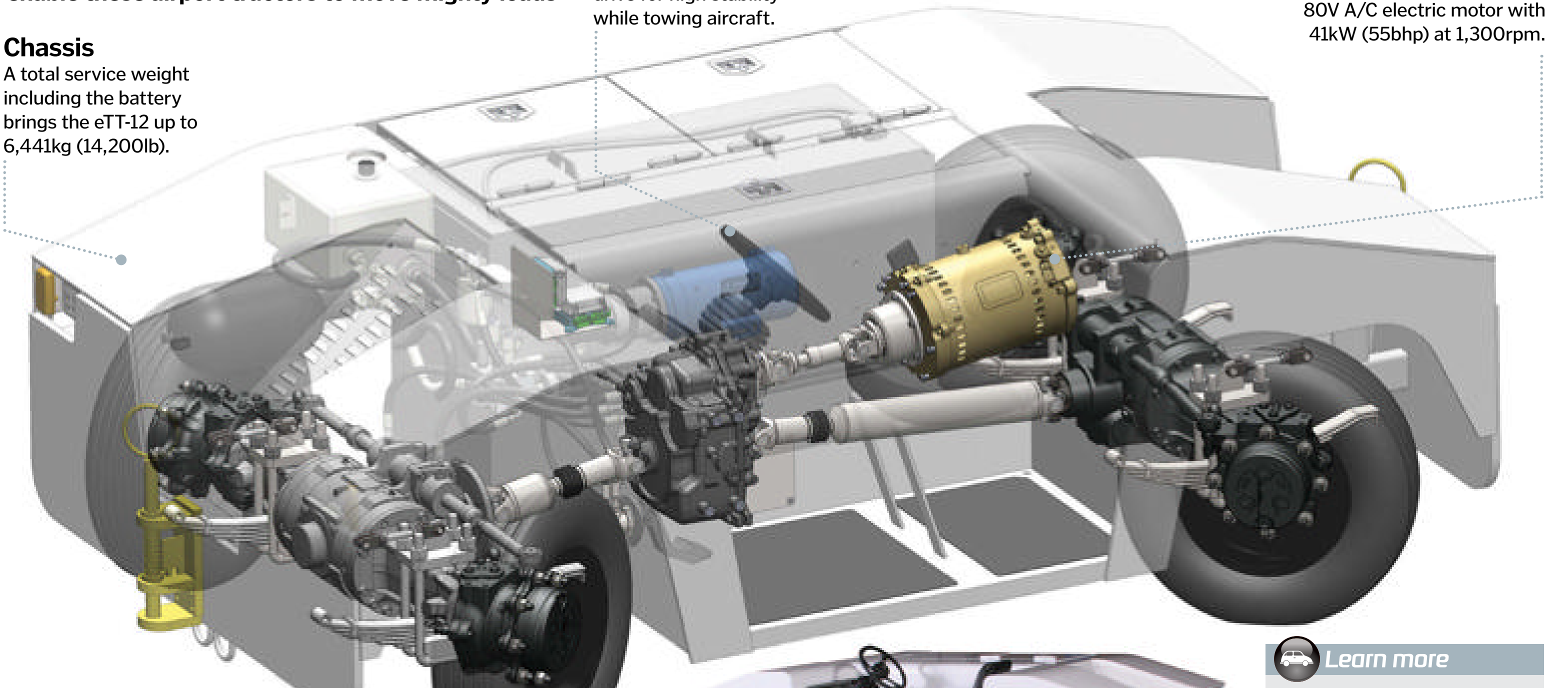
Pushback tug engineering

Explore the main components of an eTT-12 which enable these airport tractors to move mighty loads

Steering
Steering is hydraulic boosted and four-wheel drive for high stability while towing aircraft.

Motor
The tug is granted an unloaded top speed of 19km/h (12mph) from an 80V A/C electric motor with 41kW (55bhp) at 1,300rpm.

Chassis
A total service weight including the battery brings the eTT-12 up to 6,441kg (14,200lb).



Wheels
Two front and two rear wheels help provide a maximum towing capacity of 58,967kg (130,000lb).

Learn more
Pushback tugs are used across the aviation industry. Originally manufactured by the airliner companies themselves, a new industry has sprung up around this type of vehicle. Check out www.eagletugs.com for more.

> "To cope with different battle areas and situations, the Coyote can be installed with a range of features"

The Supacat Coyote

We investigate the tough tactical support vehicle that's armoured to the teeth and ready to tackle any terrain


The Coyote can be fitted with a range of extras, from smoke grenade launchers to IR lights and a self-recovery winch

The Supacat Coyote is based on the High Mobility Transporter (HMT) platform developed by the Supacat company based in Honiton, Devon, UK, which it produces under licence with US advanced technology and defence manufacturer Lockheed Martin.

The HMT's unique air suspension system enables the 6x6 drive Coyote to be a highly mobile battlefield vehicle across all manner of terrain. Its main role is to support long-range operations for its sister HMT 400 Jackal vehicles and to transport troops, equipment and supplies.

By any standards the Coyote is big, at seven metres (23 feet) long, two metres (6.7 feet) wide and with an adjustable height of 1.9-2.4 metres (6.2-8 feet). It has a kerb weight including fuel and armour of 6,600 kilograms (14,550 pounds) and can carry a 3,900-kilogram (8,600-pound) payload.

A Cummins 6.7-litre turbocharged diesel engine gives it a top speed of 120 kilometres (75 miles) per hour and a range of 700 kilometres (435 miles), so that it can easily carry and tow supplies and equipment where necessary throughout a sizable battlezone. Further, it can deal with one-metre (3.3-foot)-deep water obstacles and 60 per cent gradients.

Since the HMT 600 is an open-top vehicle, even the best armoured protection makes it vulnerable to mines or sustained attacks. For this reason, it relies mostly on firepower and mobility to deal with enemy forces.

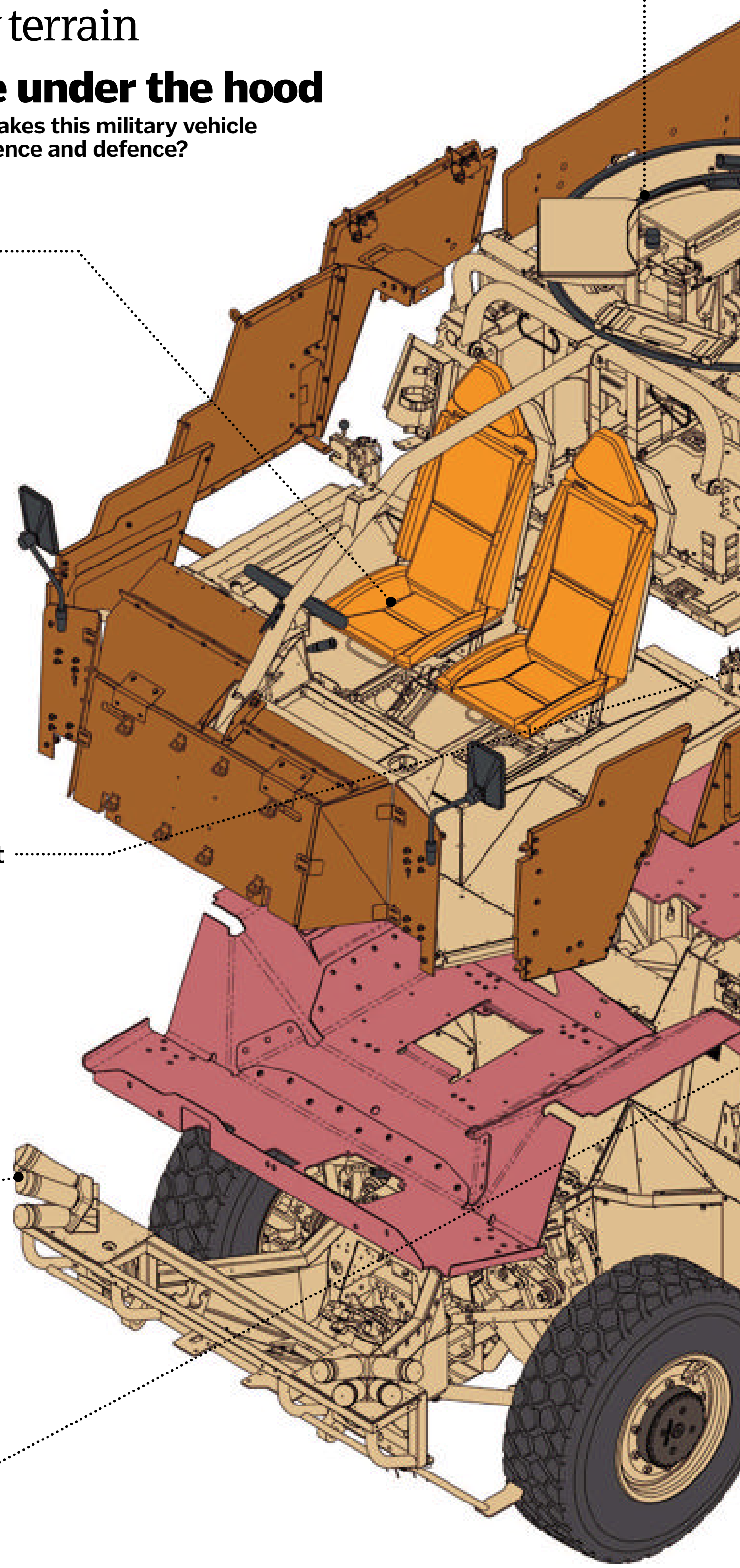
To cope with different battle areas and situations the Coyote can be installed with a range of cutting-edge features from blast and ballistic protection kits, run-flat tyres, a self-recovery winch, weapon mounts for machine guns, smoke grenade launchers and infrared lights.

Surprisingly, it is a relatively easy vehicle to drive as it has very light power steering, sensitive hydraulic brakes and the HMT air suspension system that ensures it's a smooth ride.

When there is a need to quickly deploy the Coyote, it can be transported by large military aircraft, such as the Lockheed C-130 Hercules.

The Coyote under the hood

What engineering makes this military vehicle a master of both offence and defence?



HEAD 2 HEAD ARMOURED VEHICLES

1. ICONIC

Humvee
Used by the US military since 1984, replacing the popular Jeep, it is powered by a 6.3-litre diesel engine and has optional armoured protection.

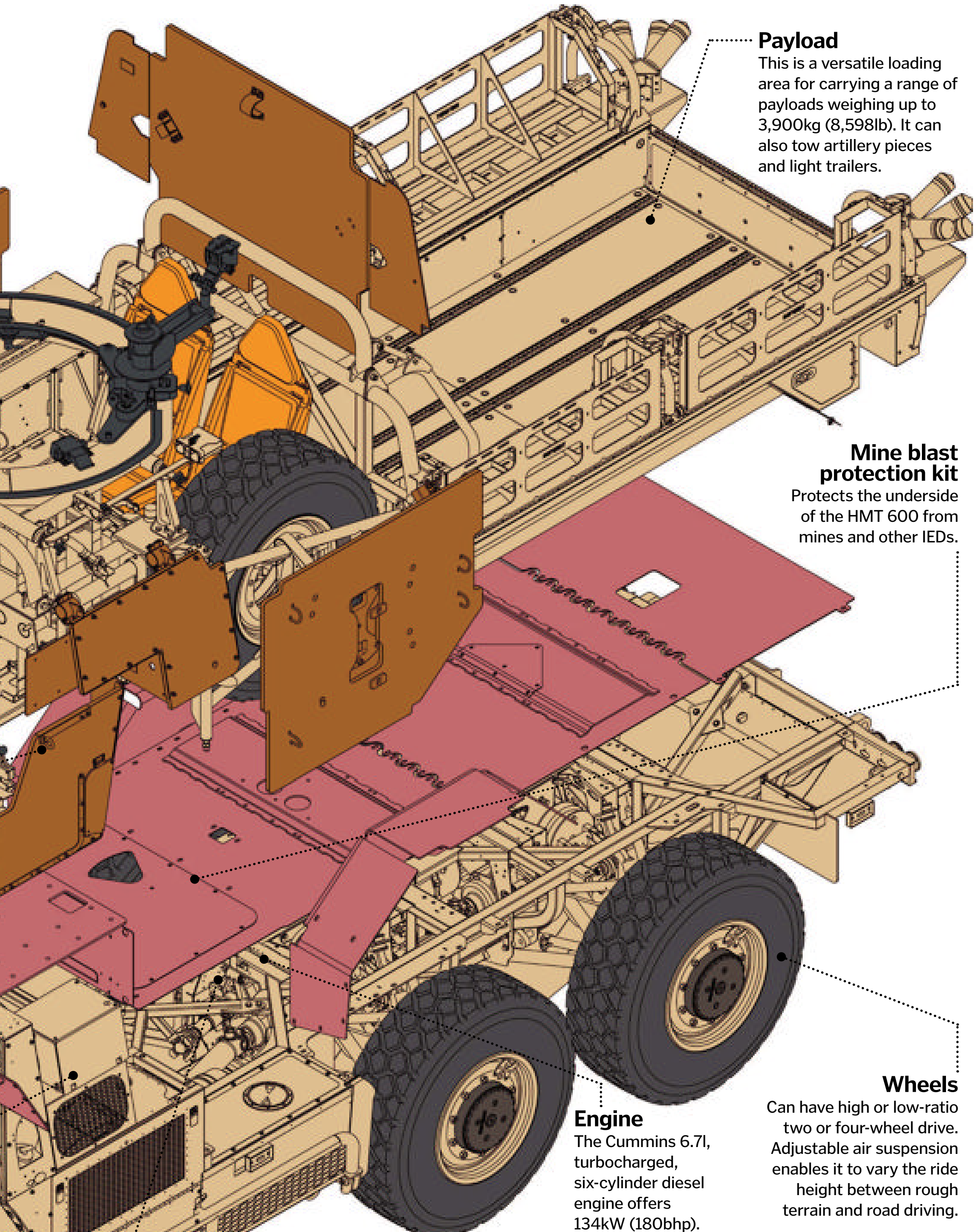
2. ROBUST

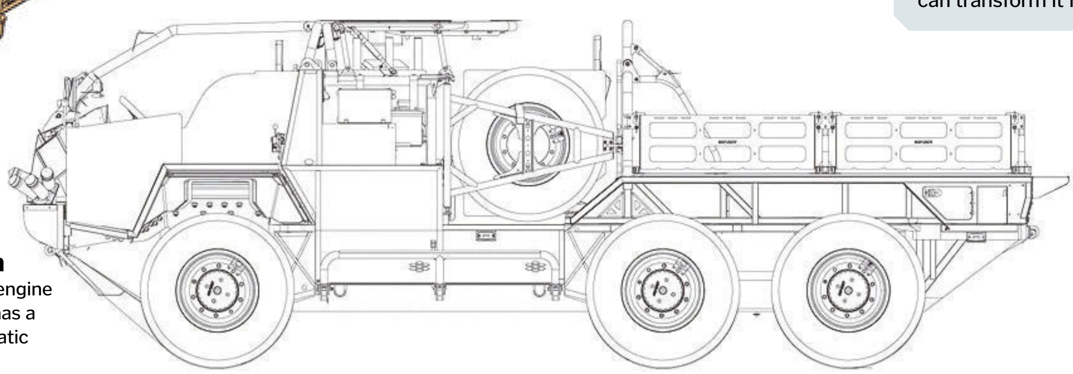
Cougar
This armoured vehicle has a V-shaped hull and armour plating to protect against mines. Options include a remote-control weapons system.

3. VERSATILE

Snatch Land Rover
Used in Northern Ireland in 1992, it can be vulnerable to mines, but is still a highly versatile vehicle for military and policing ops.

DID YOU KNOW? *Supacat has been developing vehicles for both the civilian and military spheres since 1981*





Armour in focus

Jankel Armouring Limited produces armoured protection for the Coyote in conjunction with Supacat. To deal with different situations and roles, the Coyote can be kitted out with modular solutions for mine and blast protection armour that can cope with the worst effects of roadside improvised explosive devices (IEDs), anti-tank mines and small arms fire.

The blast and mine protection kits comprise a mixture of composites and high-strength armoured steel and are in sections mounted to the bottom and sides of the vehicle. Their density, availability, thickness, cost and structural integrity are key parameters that define the overall survivability solution.

Coyotes also feature blast mitigation seats that have five-point harnesses, which can be fitted to the floor, rear or roof of the HMT. They are designed to deal with the initial impact of the explosion that blasts the vehicle into the air that would otherwise transfer life-threatening acceleration forces to the occupants, as well as the secondary effect of it slamming back to the ground. These powerful impacts are soaked up through its patented energy absorption system, which is optimised with weight adjustment technology and a rest mechanism.

All parts of the vehicle that might become detached in an explosion have been removed so they don't become secondary projectiles, while the footrests are isolated from the cab in order to protect the legs and feet of the crew.

The HMT family

The HMT concept originates from the Supacat's original All Terrain Mobility Platform (ATMP) from the early-Eighties. The ATMP is a six-wheel, turbocharged lightweight vehicle that can carry two people over rough ground or deep-water obstacles. It's used for transporting equipment, supplies and troops and can be adapted to carry 1,000 litres (220 gallons) of aviation fuel. It can also be fitted with a machine gun.

The 4x4 drive HMT 400 'Jackal' was introduced in 2004, based on Supacat's newly developed HMT vehicle platform that provides exceptional cross-country performance and versatility. Like the Coyote, it can be produced in a range of battlefield configurations that include blast protection armour and a variety of armaments. The HMT Extenda, meanwhile, can be configured as the four-wheel Jackal but, when needed, a modular, self-contained third axle unit can transform it into a six-wheel Coyote.

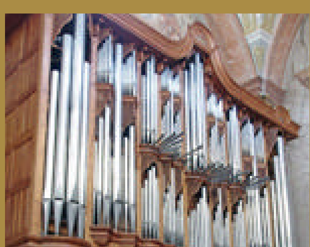
Learn more

Fancy owning your own Supacat Coyote? Well, unless you're very fortunate, they're probably a little beyond your budget. However you can get the next best thing – a scale Airfix model of the HMT 600 – from **www.airfix.com** for just £18.99 ($29.99).

Canterbury Cathedral has seen a lot of upheaval and violence over the centuries, including a very famous murder. Also learn about one of the most complex musical instruments, how crystal microphones project sound and why the Magna Carta was such a game-changer to the way England was ruled.

76 **Magna Carta**

76 **Piezoelectric mics**



78 **Church organs**

LEARN MORE

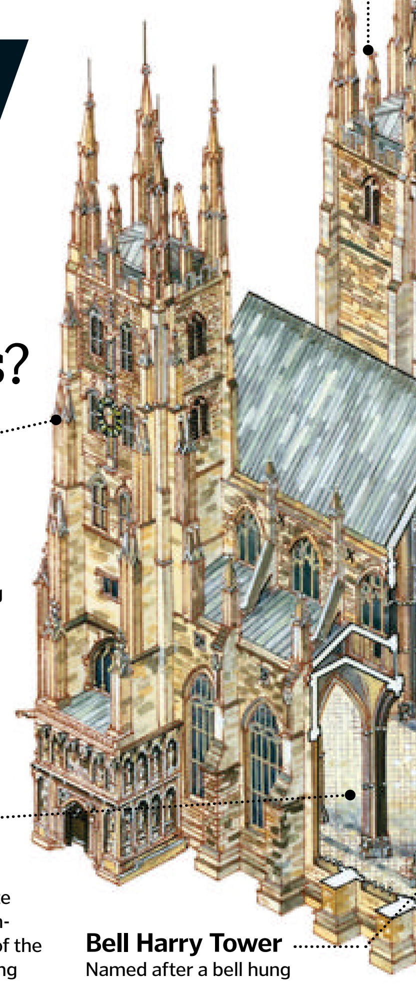
Inside Canterbury Cathedral

How has this incredible religious building evolved over the centuries?

At the cutting edge of history for over a thousand years, the Cathedral Church of Christ, or Canterbury Cathedral, stands in the north-west of the city. Said to be the oldest Christian place of worship still in use in England, it was originally established by St Augustine in 597 CE. The present cathedral is the third to stand on the site. The first was sacked by the Danes and the second destroyed by fire. The present building was started in the mid-12th century and was built to serve three major purposes: firstly as a metropolitan cathedral (the home church of an archbishop); secondly as a monastic church (for the use of monks); and, after Thomas Becket's murder in 1170, as a major pilgrimage destination.

Due to its multiple functions, the cathedral's interior is highly compartmentalised and its huge Norman crypt means the floor at the east end is nine metres (30 feet) higher than at the west. Throughout the Middle Ages, pilgrims flocked to the cathedral to visit the shrine of St Thomas 'the Martyr'. King Henry IV even chose to be buried on the north side of the shrine, as he had a particular devotion to the saint. Henry VIII, however, took against Becket's cult and ordered the shrine's destruction in 1538.

Most of the cathedral's medieval magnificence disappeared during the Reformation and it suffered further damage to its interior during the Commonwealth. It was only in the 19th century that restoration to the fabric began in earnest. Its outstanding beauty has always been recognised and it will forever be associated with Geoffrey Chaucer's *The Canterbury Tales*. Today the cathedral and its close constitute the largest and best-preserved monastic complex in the UK and it was made a UNESCO World Heritage Site in 1988.



Beyond Becket...

Aside from St Thomas Becket, Canterbury Cathedral contained the tombs and shrines of many other sainted archbishops. From St Augustine at the beginning of the 7th century to the Reformation in the 16th, 15 of Canterbury's primates were canonised. The most famous were St Dunstan, who oversaw the reform of the English Church in the 10th century, St Alphege who was martyred by the Danes at Greenwich and St Anselm, who developed the ontological argument for the existence of God. However, not all archbishops were saintly or even liked. Simon Sudbury was beheaded during the Peasants' Revolt for his association with the first poll tax, John Morton was best known for 'Morton's Fork' – the idea that those that pleaded poverty were in fact hiding their money, while Thomas Arundel supported the death penalty to combat heresy.

KEY DATES
CANTERBURY CATHEDRAL

1170
Archbishop (later Saint) Thomas Becket was murdered in the cathedral's north transept on 29 December.

1376
Edward of Woodstock, the 'Black Prince' (right), was buried on the south side of St Thomas's shrine.

1400
Manuel II Palaeologos, the only Byzantine emperor to ever set foot in England, visited the cathedral.

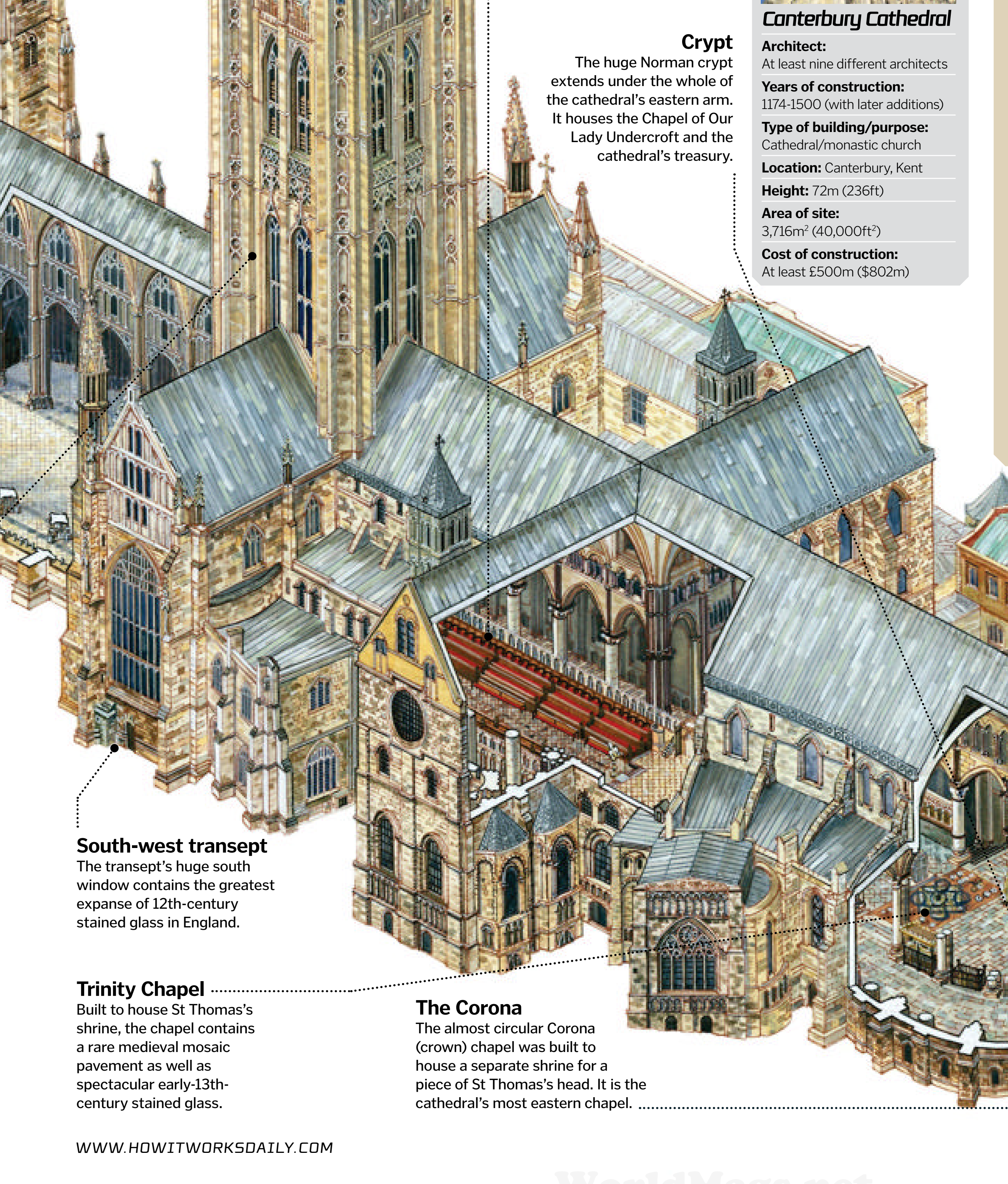
1540
The monastery attached to the cathedral was closed. A new body of clergy was formed (the chapter).

1982
On the first visit of a pope to Britain, John Paul II (right) prayed at Canterbury Cathedral.

DID YOU KNOW? The vaulting of the cathedral cloister features 864 individually carved medieval heraldic shields

Anatomy of the cathedral

Although a single structure, Canterbury Cathedral is composed of a number of distinct architectural elements



Choir
The cathedral choir was built on the grandest of scales to accommodate the cathedral priory's monks of which there were never fewer than 50 throughout the Middle Ages.

Crypt
The huge Norman crypt extends under the whole of the cathedral's eastern arm. It houses the Chapel of Our Lady Undercroft and the cathedral's treasury.

South-west transept
The transept's huge south window contains the greatest expanse of 12th-century stained glass in England.

Trinity Chapel
Built to house St Thomas's shrine, the chapel contains a rare medieval mosaic pavement as well as spectacular early-13th-century stained glass.

The Corona
The almost circular Corona (crown) chapel was built to house a separate shrine for a piece of St Thomas's head. It is the cathedral's most eastern chapel.

The statistics...

Canterbury Cathedral

Architect: At least nine different architects

Years of construction: 1174-1500 (with later additions)

Type of building/purpose: Cathedral/monastic church

Location: Canterbury, Kent

Height: 72m (236ft)

Area of site: 3,716m^2 (40,000ft^2)

Cost of construction: At least £500m ($802m)

Murder in the cathedral

Thomas Becket was a close friend of King Henry II. Raised to the archbishopric of Canterbury in 1162, Becket took his duties very seriously and often opposed the king. This led to exile in France for six years. When Becket returned trouble again flared. In a rage, Henry asked who would 'rid him of this turbulent priest'? Four barons took the king at his word, killing Becket on 29 December 1170. Canonised in 1173, the following year Henry II did penance for his crime. The gold shrine stood in the cathedral's Trinity Chapel, but it was destroyed on the orders of Henry VIII in 1538 and Becket's bones were lost.

"Crystals like Rochelle salt produce a proportionate voltage when pressure is applied"

Who wrote the Magna Carta?

Learn about this famous medieval document and how it has been preserved for 800 years

The Magna Carta, or Great Charter, is an English medieval document drawn up in 1215 by King John's barons in feudal times. The barons were tired of having a king who could punish according to whim and the Magna Carta was a document that sought to curtail this power and give every freeman (non-serf) certain rights.

King John signed the document, although his intent was simply to bring the barons over to his side, as civil war was brewing and Prince Louis of France was threatening to invade. He had no intention of honouring the document. But after King John's death in October 1216, the Magna Carta was copied and frequently used to show the sovereign was bound by law. Indeed, it has proved to be one of the most important civil rights movements in British history.

A 1297 copy of the Magna Carta has been preserved by the National Archives Conservation Lab by putting it in a case filled with the noble gas argon to prevent damage from oxidation. The case itself was hollowed out of a 15-centimetre (six-inch) block of aluminium in order to reduce creases through which the gas might leak.

Learn more

Salisbury Cathedral, England, has one of the four original copies of the 1215 Magna Carta on display in its Chapter House. You can read more about the document at www.salisburycathedral.org.uk.

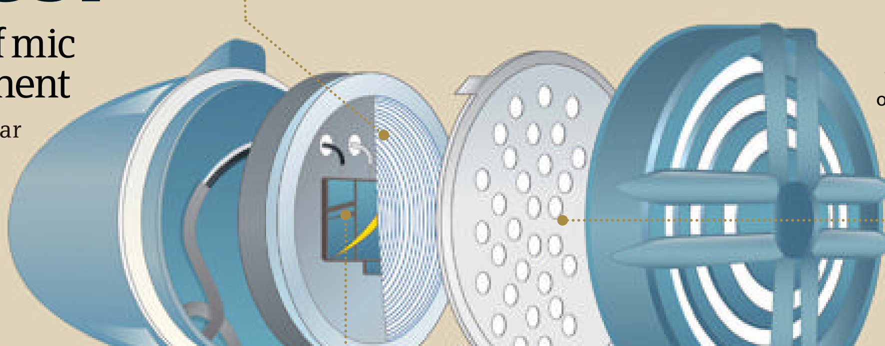
What are crystal microphones?

Look inside an early form of mic and discover its key component

Crystal microphones became popular in the Thirties and were based on a technology from decades earlier: the piezoelectric crystal. Alexander Nicolson first demonstrated the diversity of piezoelectric devices with inventions like microphones in 1919, using Rochelle salt. Crystals like Rochelle salt (potassium sodium tartrate) produce a proportionate voltage when pressure is applied. This is exploited in crystal microphones, where the piezoelectric crystal is attached to a diaphragm. When sound, such as a voice, vibrates the diaphragm, the crystal is deformed, producing a charge – an electric signal that can be amplified or recorded before being converted back into sound. The advantages of crystal microphones are that they are relatively cheap to manufacture and have a high output voltage resulting in good sound quality. However, they are fairly delicate devices and do not take well to rough handling or changes in heat and humidity.

Piezoelectric mic up close

How It Works takes a closer look at how natural minerals can be used to amplify our voices



Diaphragm
The diaphragm vibrates when sound waves hit its surface, applying pressure to the crystals.

Baffle
An acoustic trap called a baffle allows the sound to reach one side of the mechanism and also limits interference.

Crystals
Twin piezoelectric crystals are used as a transducer that, when depressed, acquire opposite charges on either side.

Cord
An insulated electrical cord carries the electric signal to a loudspeaker or recording device.

5 TOP FACTS: SUPACAT HMT400 JACKAL

- Designed to replace the WMIK the Jackal features better mobility, firepower and protection.
- Officially the Jackal is called the MWMIK (Mobility Weapon Mounted Installation Kit).
- It can be fitted in service with either a 12.7mm heavy machine gun or a 40mm grenade launcher.
- Both the Jackal and its six wheeled version the Coyote have served in Afghanistan to great effect.
- Capable of speeds of up to 50mph off road and 80mph on road the Jackal is a powerful machine.

AIRFIX® How it works

Scan this QR code with your smartphone to find out more!

The Jackal's primary armament is a 12.7mm heavy machine gun.

Attenuating seats absorb bomb blasts, protecting the crew.

The support armament for the Jackal is a 7.62mm general purpose machine gun.

1 metre ground clearance allows it to clear large obstacles.

Powered by a 6.7 litre engine the Jackal can reach speeds of 80mph.

SUPACAT HMT400 JACKAL - NEW TOOL

A05301 1:48 Scale Supacat HMT400 Jackal

Scan this QR code with your smartphone to find out more!

Part of the Airfix range of Operation Herrick Afghanistan kits.

Designed and developed by Supacat at their facility in Devon, England, the Jackal or MWMIK (Mobility Weapon-Mounted Installation Kit) is a wheeled, armoured vehicle used by the British Army. Its primary role is one of deep battlefield reconnaissance as well as rapid assault and convoy protection. In all of these roles, good mobility and visibility are paramount and it is in these areas that the Jackal excels.The Jackal has seen extensive use in Afghanistan where it has proved to be a very useful machine, becoming much loved by its crews.

HORNBY® A Hornby Product

www.airfix.com and all good retail stockists

AIRFIX CLUB – Join the **AIRFIX Club**

YouTube – www.youtube.com/officialairfix

www.twitter.com/airfix

www.facebook.com/officialairfix

Humbrol™ – www.humbrol.com

PROJECT AIRFIX – For schools and all youth organisations

HORNBY visitor centre

"A pipe organ typically has two or more keyboards – manuals – and a pedal board played by the feet"

How do pipe organs work?

Explore the inner workings of one of the largest and most complex musical instruments on the planet

The pipe organ is most commonly encountered in churches and concert halls, where they are used for the performance of sacred and secular music. Its origins can be traced back to Ancient Greece in the 3rd century BCE, but it wasn't until the 12th century CE that organs began to evolve into a complex instrument capable of producing different timbres. The world's oldest playable pipe organ is located in the Basilica of Valère in Sion, Switzerland, and was built around 1430.

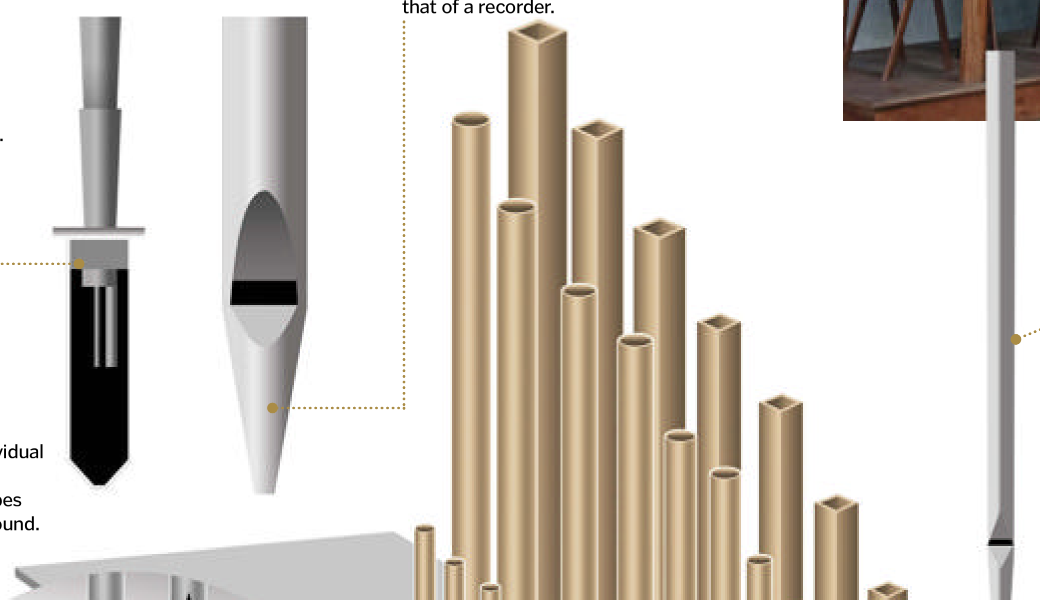
An organ produces sound by driving pressurised air (wind) through a series of pipes selected via a keyboard. As each pipe produces a single pitch, multiple pipes are required in sets (called ranks), each of which has a common timbre and volume. Most organs have many ranks of pipes of differing timbre, pitch and loudness that the organist can play in combination through the use of stops.

A pipe organ typically has two or more keyboards – manuals – played by the hands, and a pedal board played by the feet. The organ's continuous supply of wind produced by an electric blower enables it to sustain notes for as long as the corresponding keys are pressed. This is unlike a piano whose sound begins to fade immediately after the key is struck. The smallest portable pipe organs may have only one or two dozen pipes and a single manual, whereas the largest stationary organs may have over 30,000 pipes and seven manuals.

The Millennium Organ in Saint Mary of the Angels and Martyrs Basilica in Rome, Italy, was built by organ maker and restorer Barthèlèmy Formentelli

Internal organs

Despite widely varying in size, all pipe organs work around the same basic principles...



33,114

BIGGEST PIPE ORGAN

The Boardwalk Hall organ in New Jersey, USA, is not only the loudest in the world, producing 130 decibels at a one-metre (3.3-foot) distance, but also has the most pipes (over 33,000)!

DID YOU KNOW? *Pipe organs have been made out of many novel materials including bamboo, marble and even porcelain!*

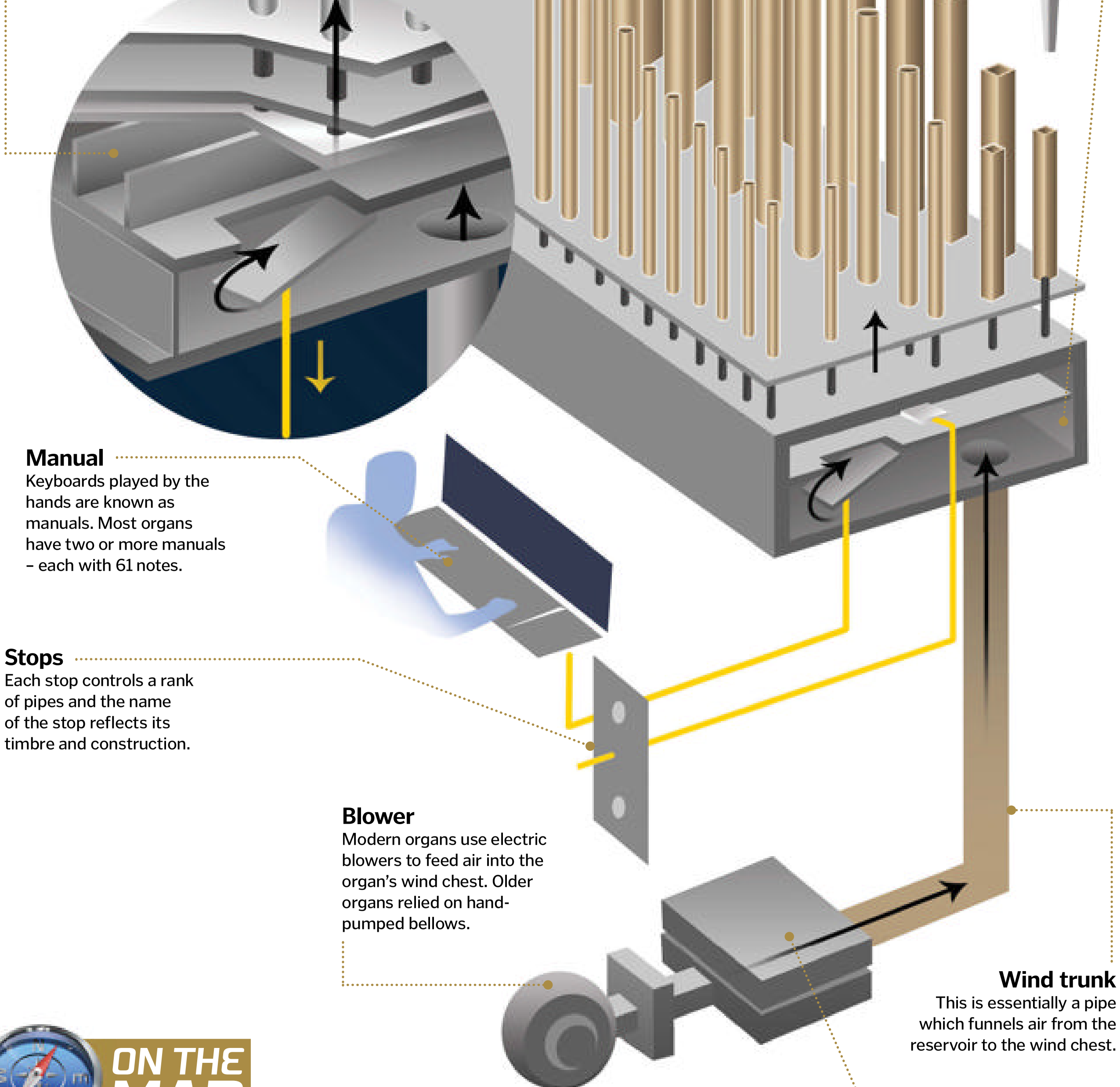
How does wind generate sound?

Sound is produced in a musical instrument, such as a clarinet or trumpet, by the movement of an enclosed column of air blowing through a reed; others require buzzing into a metal mouthpiece. Sounds are vibrations which are transmitted through the air as waves to be received by our ears. The frequency of a sound is given by the number of vibrations per second, measured in hertz. Humans can perceive only sounds with a frequency in the range of 0.02-20 kilohertz.

Most musical instruments produce sounds with frequencies of 27.5-4,186 hertz. If air for the energy waves to travel through is absent, such as in outer space, no sound is possible. When vibrations are fast, the ear will hear higher-pitched sounds; in comparison, slower sound waves create lower pitches.

An organ played by the sea…

The sea organ is a 70-metre (230-foot)-long architectural work-cum-experimental musical instrument located on the seafront of Zadar in Croatia. It is the world's first pipe organ 'played' by the sea. Stone steps on the quayside conceal 35 musically tuned polyethylene tubes and a resonating cavity, pierced by whistle openings on the steps. The movement of the sea pushes air through the tubes, into the cavity and out of the whistle openings and, depending on the size and velocity of the waves, different musical chords are produced. Seven successive groups of musical tubes are alternately tuned to two musically cognate chords of the diatonic major scale. The outcome of played tones and chords is a function of the random distribution of the wave energy to particular organ pipes. The waves thus create their very own 'music', a never-ending cycle of random harmonic sounds.



Manual
Keyboards played by the hands are known as manuals. Most organs have two or more manuals – each with 61 notes.

Stops
Each stop controls a rank of pipes and the name of the stop reflects its timbre and construction.

Blower
Modern organs use electric blowers to feed air into the organ's wind chest. Older organs relied on hand-pumped bellows.

Wind trunk
This is essentially a pipe which funnels air from the reservoir to the wind chest.

Reservoir
The electronic blower pumps air into the reservoir where it is pooled until required.

ON THE MAP

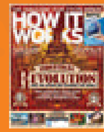
Giant pipe organs around the globe

1 Macy's Department Store, Philadelphia, USA
2 First Congregational Church, Los Angeles, USA
3 Milan Cathedral, Milan, Italy
4 Liverpool Cathedral, Liverpool, UK
5 Sydney Opera House, Sydney, Australia
6 National Concert Hall, Taipei, Taiwan


✓Android phone ✓Android tablet ✓Apple Mac ✓Windows PC
Save up to 40% off regular print prices
Download and enjoy over 20 great magazines on your favourite topics…
• Technology • Creativity
• Videogames • Sci-fi
• Science & knowledge
• Digital Photography
Enjoy great magazines on every device from one amazing website
Get your digital copies now at
www.greatdigitalmags.com

BRAIN DUMP

Because enquiring minds want to know...



Ask your questions

Send us your queries using one of the methods opposite and we'll get them answered

MEET THE EXPERTS

Who's answering your questions this month?

Luis Villazon

Luis has a degree in Zoology from Oxford University and another in Real-time Computing. He's been writing about science and tech since before the web. His science-fiction novel *A Jar Of Wasps* is published by Anarchy Books.

Giles Sparrow

Giles studied Astronomy at UCL and Science Communication at Imperial College, before embarking on a career in publishing. His latest book, published by Quercus, is *The Universe: In 100 Key Discoveries*.

Alexandra Cheung

With degrees from the University of Nottingham and Imperial College, Alex has worked for several scientific organisations including London's Science Museum, CERN and the Institute of Physics. She lives in Ho Chi Minh City, Vietnam.

Dave Roos

A freelance writer based in the USA, Dave has researched and written about every conceivable topic, from the history of baseball to the expansion of the universe. Among his many qualities are an insatiable curiosity and a passion for research.

Aneel Bhangu

Aneel is a training academic surgeon working in London. His main research interests include advanced cancers and medical statistics, with his clinical interests including planned surgery for rectal cancers and emergency surgery for trauma.

Why can tigers swim?

Terri Richardson

Most mammals can swim, including lions, leopards and cheetahs. Being able to swim is quite different from being able to swim *well* though. Most of the big cats tend to avoid water as they are adapted to hunt on land. Tigers, on the other hand, live in lush tropical jungles with lots of wide rivers. (The other big cat that swims well is the jaguar – another forest dweller.) Prey animals in forest environments don't form nice convenient herds, so tigers have to go looking for their food. Tigers can have territories as large as 100 square kilometres (37 square miles) and being able to swim across rivers is a big evolutionary advantage. Tigers can swim rivers as wide as seven kilometres (4.3 miles) across and might swim up to 29 kilometres (18 miles) per day as they patrol their territory.
Luis Villazon


'Make hay while the Sun shines' is a valuable piece of advice

How is hay made?

Matt Hooper

Hay is grass that has been cut, dried and baled, and is used as feed for animals like cows and horses which have limited or no access to open pasture. The first step is to seed and grow the grass. Tall, hardy varieties like ryegrass and Timothy grass are popular choices. Seeds can be sown by hand or by tractor-pulled mechanical seeders. The next step is to cut the grass, which depends on many factors, including the height of the crop, its moisture content, the maturity of its seeds or flowers and the chance of rain. Freshly cut grass needs several days of strong sunshine to dry completely in the field before it can be baled and stored. Moist grass will cause the bales to rot, making it inedible for most animals.
Dave Roos

What would happen if we didn't have the Moon any more?

Jenny Hornabrook

If we didn't have the Moon, the most obvious immediate effect would be that the tides would be much smaller, since our natural satellite's gravity accounts for roughly two-thirds of the tidal 'tug' on Earth's seas. This could have a big impact on life on our planet since there are some important species whose life cycles are synchronised with the tides. Even land-based creatures have behaviour patterns based on the changing brightness of the Moon in the night sky throughout the month. On a larger scale, though, the long-term consequences for Earth itself could be more dramatic. The Moon's gravity helps to stabilise our planet's rotation and keeps its axis tilted at a more or less constant 23 degrees, producing seasons that keep most parts of the world at moderate temperatures. Without the Moon, Earth might become like Mars, whose axis tips back and forth between 15 and 35 degrees over tens of thousands of years, carrying the planet from one climate extreme to another. As if that weren't bad enough, some astronomers believe the Moon also plays an important role in 'sweeping up' rogue asteroids and comets that would otherwise hit our world, so without it, we might suffer impacts much more frequently.
Giles Sparrow

Why is it easier to balance on a moving bike than on one that is stationary?

Matt Pryse

For a long time, scientists put a moving bicycle's stability down to the gyroscopic action of its wheels. Put simply, once in motion a spinning object likes to keep spinning in the same plane, meaning that bicycle wheels tend to stay upright. More recently, however, researchers have challenged this theory by building bikes with an extra wheel attached to the side, just off the ground. Spinning this additional wheel in the opposite direction to that of the bike's main wheels reduces or even cancels out the gyroscopic effect – but this had no noticeable impact on a cyclist's ability to balance.

Many scientists now believe that the small adjustments to steering made (often subconsciously) by cyclists can better explain a moving bike's stability. The faster you are going, the smaller the corrections that are needed to keep you balanced.
Alexandra Cheung

Is there any truth in the proverb: 'When wind blows from the east, the fish feed least'?

E Gould

It's likely that this expression originated in the UK on the east coast 500 or so years ago, where some fishermen suspected a trend whenever a cold easterly/north-easterly wind was blowing. Despite the onshore winds (which usually bring good fishing), poor catches led the fishermen to conclude that the fish simply weren't interested in taking their bait whenever an easterly blew in. This proverb has spread to other parts of the world where, in reality, myriad factors can result in poor fishing, including the time of year, tide, weather, bait used and coastal position. It's only your own experience of the area you fish in that will determine whether this saying holds true or not.
HIW

Who said Earth was round? Find out on page 84

BRAIN DUMP

Because en... ds
want to k...

Is antigravity a real thing?

Find out on page 85

Want answers?

Send us your questions using one of the methods opposite and we'll get them answered

Though food ultimately gives us energy, digesting it can be quite tiring in itself!

Why do we feel sleepy after eating?

Laura Sykes

After eating – particularly sugary foods – the pancreas produces insulin, which converts these sugars circulating in the bloodstream into the stored forms within cells. The increased level of insulin triggers the movement and action of tryptophan, which is an essential amino acid, within the brain. Essential amino acids can't be made by the body, and must be taken in from our diet.

Once in the brain, it leads to increased production of serotonin, a neurotransmitter that passes electrical signals between connecting neurons. Around 90 per cent of the body's serotonin is found in the abdomen, where it regulates intestinal movements. The remaining ten per cent is located in the brain. Serotonin has several functions, including control of mood and slumber; it has also been linked to depression and feelings of intimacy. Increased levels of serotonin stimulated following a sugary meal can thus lead to you feeling sleepy. But other factors may contribute to drowsiness after a meal. Particularly large meals take time to digest, meaning blood may be diverted away from other body areas to help with this. Further, if you are dehydrated during or after eating, this may exacerbate your lethargy.

Aneel Bhangu

While the stars in distant galaxies are quite easy to spot, planets are much more difficult to pinpoint

Who first discovered the world was round?

Audrey Le Pape

The idea that the Earth is spherical originated in Ancient Greece, and the oldest reliable sources credit Pythagoras from the 6th century BCE. For seafaring people who navigated by the stars, though, the proof of a spherical world was abundant throughout antiquity. As travellers sailed south, they saw constellations rising higher above the horizon. During a lunar eclipse, they could trace the circular shape of the Earth's shadow on the Moon. Not to mention ships returning to harbour: how else to explain why the tip of the mast was always the first bit to appear on the horizon? The first person to prove a spherical Earth was Portuguese explorer Ferdinand Magellan (left), whose expedition circumnavigated the globe in 1522, though sadly Magellan died before reaching the end.

Dave Roos

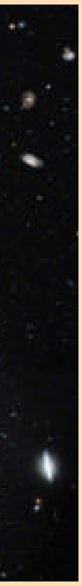
There's a lot of misinformation about hurricane preparation around; go to **www.ready.gov/hurricanes** for some top tips

Why are windows sucked out their frames in a hurricane?

Sam Jackson

This is actually a widespread myth related to both hurricanes and tornadoes. Windows damaged during extreme weather events are not 'sucked' out – rather, they are blown out. A common belief is that homeowners can reduce storm damage by opening their windows during heavy winds for two reasons: to equalise pressure and to give the wind an escape route. Both are fallacies, however. The best way to protect a home during high winds is to seal windows completely with heavy-duty hurricane shutters. Taping windows is ineffective, as is nailed-down plywood, unless it has been cut to fit and secured properly.

Dave Roos



If NASA can see galaxies 13 billion light years away, why can't they shoot closeups of planets in nearer galaxies?

Annie Dalby

There's an important difference between seeing things that are faint and seeing things that are small. The challenge with seeing distant galaxies is not so much a question of their size as it is their brightness, so if you have a large telescope with a big enough 'light grasp', a sensitive enough imaging system and a long enough exposure time, then you can detect light from some of the faintest and most distant objects in the cosmos.

Seeing planets around other stars is a different challenge that depends on a telescope's 'resolving power' – its ability to distinguish objects that have very little angular separation. Although larger telescopes do have better resolving power, there are limits (especially with Earth's atmosphere tending to make things blurry), and it's generally impossible with current technology to separate planets and their stars enough to ensure the faint planet is not drowned out in the light of the star.

Giles Sparrow

With waterproof plumage and special eyelids, birds are well equipped to fly even in heavy downpours

How can birds fly when it rains?

Charlie Eaton

Birds fly by forcing air downwards with their wings. On the upstroke, the feathers pivot to let the air pass through them, but on the downstroke they close – similar to a venetian blind – and push against the air. When it rains, the same principles apply. Strong winds and turbulent air during a storm can make it trickier to fly, but their feathers are quite waterproof and there is nothing inherent in the rain itself that prevents them flying. Birds even have 'windscreen wipers' in the form of a semi-transparent third eyelid that blinks sideways (known as a nictitating membrane) to keep their vision clear.

Luis Villazon

Does antigravity really exist?

Josh Cox

Antigravity is defined as an area which is free from gravity. If it existed, antigravity could make objects weightless or be used to propel spacecraft. Creating antigravity would mean shielding an area or a device from gravitational forces. According to general relativity, where gravity is the result of the geometry of space-time, this would simply be impossible. According to quantum theory, hypothetical particles called gravitons transmit gravitational forces. But given that we do not even know if these particles exist, destroying or controlling them seems more or less impossible. For now, scientists are therefore dubious that antigravity will ever exist anywhere but in the imaginations of science-fiction fans.

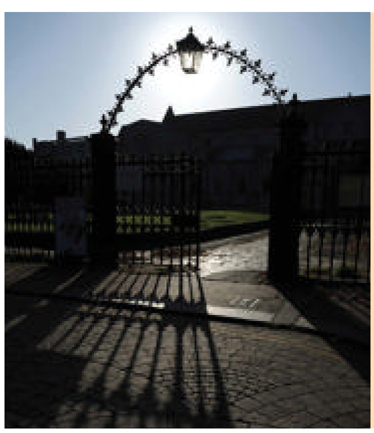
Alexandra Cheung

What are bone-conduction headphones?

Tom Lee

Ordinary headphones convert an oscillating electrical signal into movements of the speaker diaphragm. This makes the air vibrate and, in turn, your eardrums. The eardrum is connected to a set of three tiny bones that amplify the vibration onto a smaller eardrum called the oval window. But the oval window picks up vibrations from the skull too. When you hear yourself speaking, the sound reaches you through the air and also through your skull; that's why our own voices often sound weird when we hear a recording played back. Bone-conduction headphones use rubber speaker diaphragms that press directly on your head. Instead of vibrating the air and then your outer eardrum, they send vibrations directly into your skull. Your head resonates at different frequencies to your eardrum so the headphones must shift the frequencies to compensate. The result is music that sounds as if it's coming from inside your head!

Luis Villazon



What is the smallest thing with a shadow?

Vicky McTaggart

Shadows occur when visible light is blocked by an object, leaving a dark area on a surface opposite the source. As light travels as a wave, it bends slightly around objects (diffraction). Although the light is diffracted by only a few wavelengths, it means any object smaller than the light's wavelength will have no shadow. Visible light has a wavelength of 400-900 nanometres. So the tiniest thing to cast a shadow would have a diameter of about 400 nanometres – over 200 times finer than a hair.

Alexandra Cheung

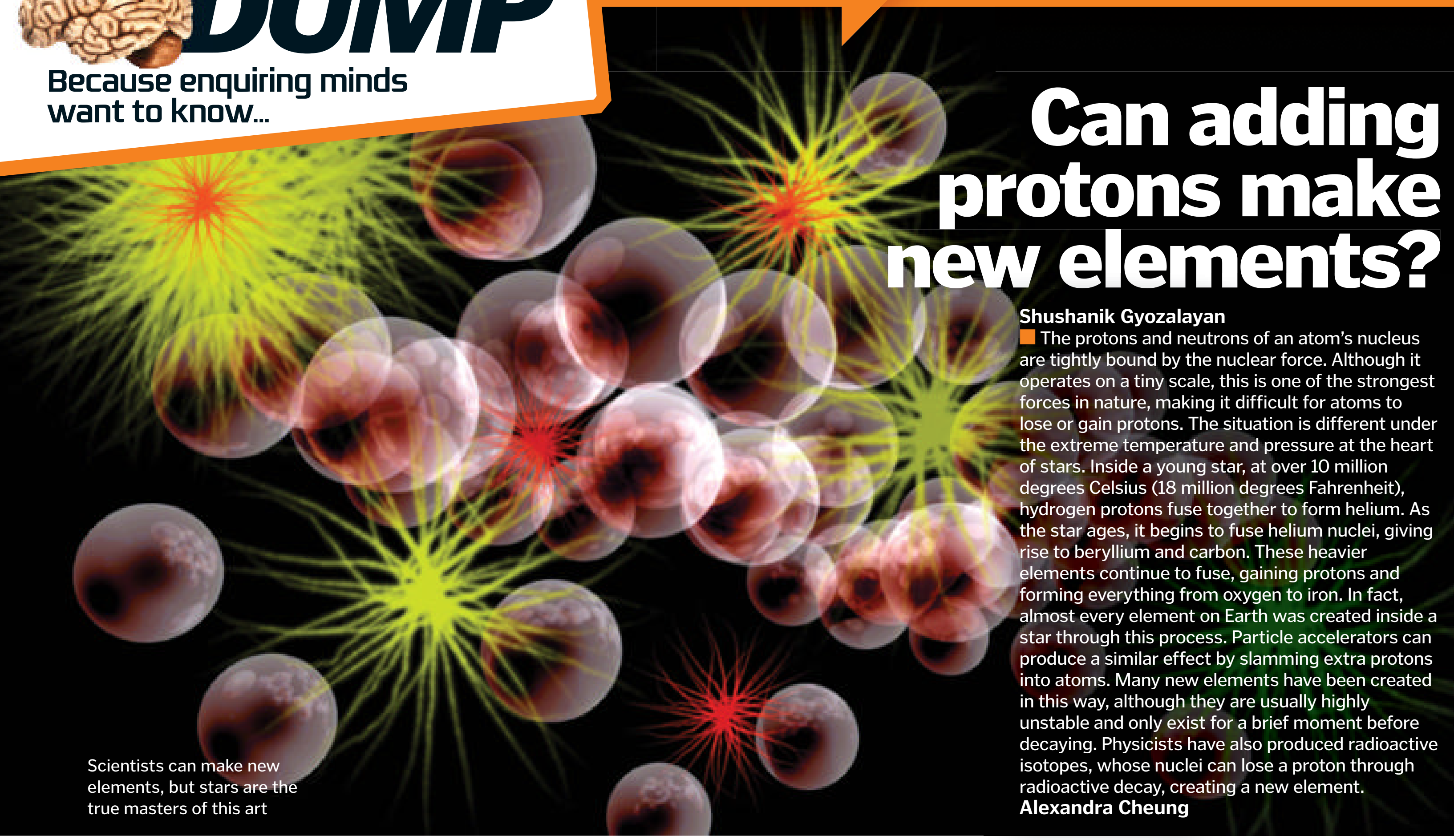
How are elements made? Find out on page 86

BRAIN DUMP

Because enquiring minds want to know…

How thick is opaque glass?
Find out on page 87

Want answers?
Send us your questions using one of the methods opposite and we'll get them answered



Scientists can make new elements, but stars are the true masters of this art

Can adding protons make new elements?

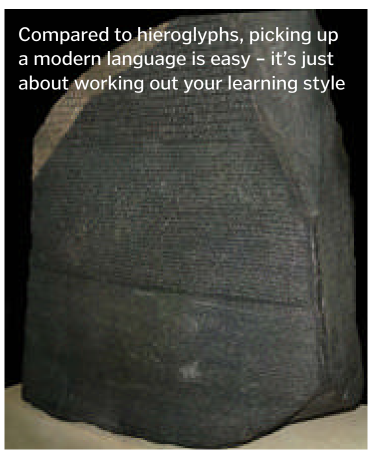
Shushanik Gyozalayan

The protons and neutrons of an atom's nucleus are tightly bound by the nuclear force. Although it operates on a tiny scale, this is one of the strongest forces in nature, making it difficult for atoms to lose or gain protons. The situation is different under the extreme temperature and pressure at the heart of stars. Inside a young star, at over 10 million degrees Celsius (18 million degrees Fahrenheit), hydrogen protons fuse together to form helium. As the star ages, it begins to fuse helium nuclei, giving rise to beryllium and carbon. These heavier elements continue to fuse, gaining protons and forming everything from oxygen to iron. In fact, almost every element on Earth was created inside a star through this process. Particle accelerators can produce a similar effect by slamming extra protons into atoms. Many new elements have been created in this way, although they are usually highly unstable and only exist for a brief moment before decaying. Physicists have also produced radioactive isotopes, whose nuclei can lose a proton through radioactive decay, creating a new element.
Alexandra Cheung

Are the prints on our toes identical to our fingerprints?

Jessica Hass (8)

Your fingerprints on each finger and each toe are different from all your other fingers and toes, and also totally unique to you. They are ridges and folds of skin, which help with improved sensation and, to a degree, better grip. Fingerprints are formed from three basic patterns – arches, loops and whorls – with many patterns being formed from combinations of these. Your actual fingerprints develop while you're still a foetus in your mother's uterus. The pressure on the fingertips, movement within the womb and thickness of the amniotic fluid surrounding the baby all affect the patterns that form. Although inherited genes will also dictate the pattern of the fingerprints, even identical twins have different prints due to the varying environmental exposure in the womb.
Aneel Bhangu



Compared to hieroglyphs, picking up a modern language is easy – it's just about working out your learning style

What's the best way to learn a language?

Josh Walker

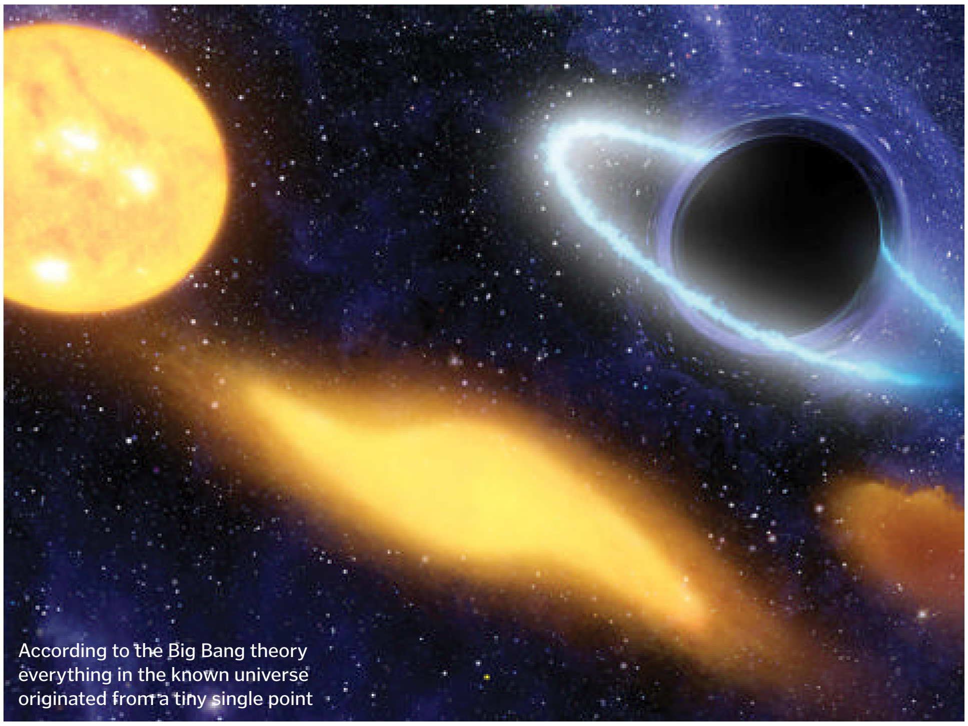
There has been vast research into people's differing learning styles; everyone learns in a slightly different way. However, it's generally agreed that immersion is the best way to learn a new tongue. This involves being completely surrounded by a language and culture, which is best achieved by living in a country where it's spoken. If this isn't possible, different people will learn well from formal courses, CDs, films or even just reading books.

There's a fierce debate over the best age to learn a language. The critical period hypothesis states that there is an ideal window in which to learn a second language, but experts disagree on whether this is at the youngest possible age or up until ten years old.
Aneel Bhangu

Is there any other planet that humans could inhabit?

Ben Battle

To be suitable for Earth-like life, an exoplanet must lie in its system's 'Goldilocks zone', where temperatures are not too hot or too cold for liquid water to persist on the surface. If water exists, this should lead to other Earth-like features and perhaps even life. Currently the most Earth-like exoplanet is thought to be Gliese 581g, an unconfirmed planet with 3.3 times Earth's mass, believed to orbit a feeble red dwarf star 22 light years from Earth. Whether the planet really exists is subject to further analysis but, if it does, it would have temperatures around -37 to -12 degrees Celsius (-35 to -10 degrees Fahrenheit). The most Earth-like planet around a Sun-like star is Kepler-22b (pictured), 620 light years away. Unlike Gliese 581g it's confirmed, but only part of Kepler-22b's orbit is known to pass through its star's habitable zone, so if it has an irregular orbit, temperature extremes could make it uninhabitable.
Giles Sparrow



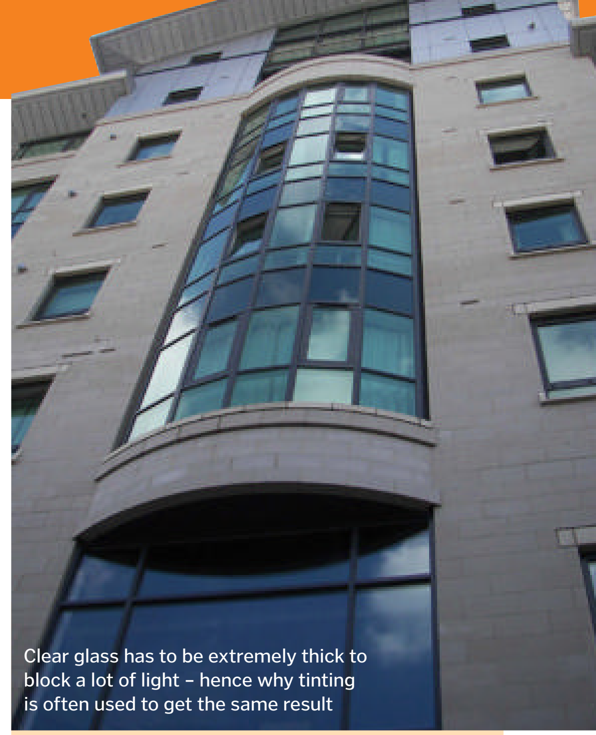
According to the Big Bang theory everything in the known universe originated from a tiny single point

Are black holes and the Big Bang part of the same thing?

Nick Kang

They are, to some degree, part of the same phenomenon. Both the Big Bang and black holes involve singularities – that is, strange points of infinite density and zero volume where the normal laws of physics as we know them cease to apply. In a black hole, the singularity is formed through the sudden collapse of a massive object – the core of a heavyweight star or gas clouds in the centre of a galaxy, for example. In the Big Bang, on the other hand, the singularity came first – it simply blinked into existence, bringing time and space as we understand them along with it. The explosion of this singularity to create all the matter in the cosmos is what we generally refer to as the Big Bang.

Giles Sparrow



Clear glass has to be extremely thick to block a lot of light – hence why tinting is often used to get the same result

How thick must glass be to become opaque?

Lester Leon-Lee

Glass absorbs different amounts of light at different wavelengths. For UV light it is already virtually opaque, but even for the visible part of the spectrum it isn't perfectly transparent. An ordinary three-millimetre (0.1-inch) sheet of window glass lets about 91 per cent of light pass. With six millimetres (0.2 inches), you'd only get 91 per cent of that 91 per cent – in other words, 83 per cent – and so on. If you were able to make a sheet of glass a metre (3.3 feet) thick, without introducing any impurities or imperfections, the amount of light making it all the way to the other side would be just 0.002 per cent, which is enough to make full daylight as dim as a moonlit night. However, it still wouldn't be totally opaque.

Luis Villazon

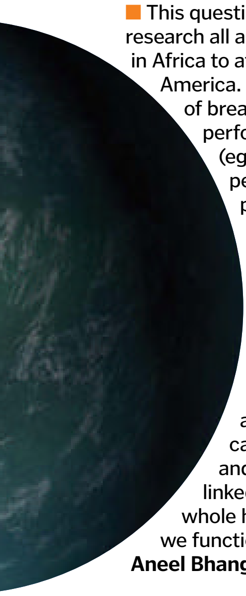
Does a big breakfast improve our daily performance?

Mo Bahar

This question has been the subject of extensive research all around the world, from schoolchildren in Africa to athletes in the United States of America. There is huge interest in the effects of breakfast on several types of performance, including cognitive function (eg learning, mood, concentration and performance in exams, etc) and physical function (eg performance of athletes, weight loss and cholesterol levels, etc). Despite positive reviews in the mass media, current research shows a mixed picture with a lack of compelling evidence either way.

There are strong associations between having breakfast (versus skipping it) and better performance, although these studies are not causative. This means that breakfast and performance cannot be directly linked as cause and effect; there are a whole host of other factors which affect how we function.

Aneel Bhangu



Whether it's a full fry-up or a more healthy bowl of cereal, the jury's out as to whether it enhances our performance

THE KNOWLEDGE

GAMES / BOOKS / GADGETS / TOYS

FOR CONNOISSEURS OF KIT AND SAVANTS OF STUFF

Vtriker Elite

Price: £69.99/$N/A
Get it from: www.vtriker.com

You know how scooters are fun? Well, double – no, triple that and you're approaching the kind of fun you can have on a Vtriker Elite. It works like most scooters (in other words, you push off with one leg and allow momentum to propel you forward), except there are *two* platforms upon which to place your feet, with a wheel at each end. Through a unique back wheel and spring design, squeezing your legs together as you go will convert some of the energy into forward momentum. That alone would amount to no more than a novel way of keeping your feet off the ground, but the way the Vtriker Elite is hinged allows for some stupendous slaloms, making it feel more like a drifting vehicle than a three-wheeled scooter. If you're buying for a child, get two, because you won't want to get off!

WS100 wireless speaker

Price: £249/$400
Get it from: www.monitoraudio.co.uk

The classic rule of thumb that's clearly not been lost on Monitor Audio is that if it's heavy, then it's expensive. If you were to pick up one half of the new WS100 wireless speaker pair (with both hands), you'd probably deduce that there would be little change left over from £250 – and you'd be right! These things weigh a ton, but they're undeniably sexy. The speaker cubes are finished in brushed aluminium and have an understated design that would blend right into a room if it weren't for the fact that these little things go loud. Retaining clarity at the top of its punchy 60W output is no mean feat for speakers this size and they can bring a whole new dimension to your favourite tunes. It's a really easy setup too – just pop the wireless dongle into a USB port and let your operating system do the work. You can even run up to four pairs of WS100 speakers on the same dongle, which – if you have the budget – can make for a funky party music system.

HOW IT WORKS

Potential energy

Elastic potential energy – energy stored as a result of deforming an elastic object – can come in many forms, but two of the most common are rubber bands and springs.

HOW IT WORKS

Chinese Zodiac

The Chinese Zodiac is based on a 12-year cycle, attributing an animal to each year. It's widely used in many far-eastern countries including China, Vietnam and Japan.

HOW IT WORKS

What is a DAC?

A digital-to-analogue converter (DAC) converts a binary digital signal into an analogue signal. Compressed MP3 digital audio needs converting to analogue to be heard properly.

Astronomy Photographer Of The Year

Price: £25/$39.95 **Get it from:** www.harpercollins.co.uk

When Hubble takes a photograph of an object in space, you expect it to be otherworldly, so it's hard to believe that the images in this hardback compilation weren't taken with equipment worth millions – or even by professional photographers. They were taken by amateurs with kit that's within the budget of anyone willing to invest a little in astrophotography. These mostly award-winning photographs make for an arresting series of galaxies, moons, planets and time-lapsed stars often juxtaposed against ephemeral man-made and natural objects down here on Earth.

Plantronics Voyager Legend headset

Price: £89.99/$99.99 **Get it from:** www.plantronics.com

For those who like to keep in touch but are constantly on the go, the Voyager Legend headset will allow you to get on without getting in the way. It uses a combination of a triple-microphone system and enhanced digital signal processing tech to deliver your voice effectively to the receiver even if you're bustling through a crowd or out on a windy running track. It will inform you when its seven hours of battery talk time is about to run out and it takes voice commands too, for a completely hands-free experience.

HOW IT WORKS

Astrophotography

Photographing objects in the night sky often goes hand-in-hand with amateur astronomy. One of the most effective setups includes a telescope that acts as the lens for the camera.

HOW IT WORKS

DSP explained

Digital signal processing in music systems is the on-chip mathematical manipulation of a signal that improves its quality, granting much better-sounding audio.

Maroo Drogo iPad case

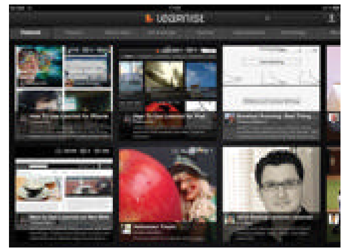
Price: £89.95/$99.99

Get it from: www.maroo.com

New for iPad 2 and its successor (though not iPad mini, mind) is Maroo's Drogo: an iPad case finished in plush leather and Chinese dragon embossing to celebrate (somewhat tardily) the 2012 Chinese new year. Protection for your iPad comes second only to the high quality of this case, with protective bumpers for the corners of your tablet and a well-padded enclosure. Smart magnet functionality and camera access come as standard – as does an eye-popping Apple price markup.

APPS OF THE MONTH

Brought to you by **Apps Magazine**, your essential guide to the best iPhone and iPad apps available on the Apple App Store



iPad: Learnist

Price: Free
Developer: Grockit
Version: 1.3
Size: 9.3MB
Rated: 12+

Learnist provides a space in which you can not only learn about a previously unknown subject, but also share your own knowledge by uploading 'Learnboards'. These masterclasses can be on any subject, and comprise webpages, images and even videos. Despite its DIY approach to study, the app has a sleek user interface, in which you click on tiles to select your topic of choice. If you're looking for something specific, there are also search options. Be aware that Learnboards can only be created on the iPhone version of the app.

Verdict: ★★★★☆

iPhone: LINE Brush

HOW IT WORKS EDITOR'S CHOICE AWARD

Price: Free
Developer: Naver Japan
Version: 1.1.0 **Size:** 13.4MB
Rated: 4+

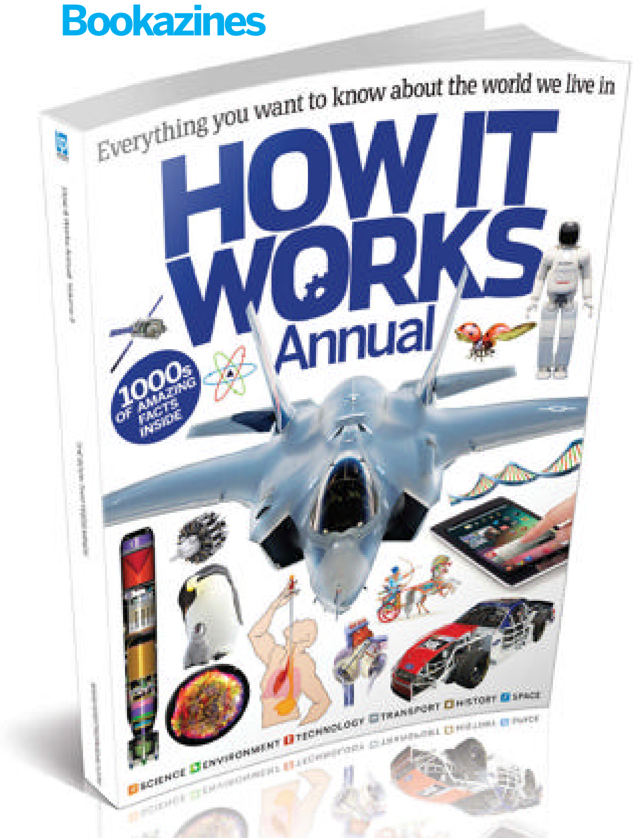
On first use, this bitmap painting app is deceptively simple, offering access to a wide range of digital brushes. Felt pens, watercolours, pencils, pastels and more enable users to either create an image from scratch or draw onto a photo. But in addition to the 27 brushes, it's the 15 Photoshop-style effect brushes that help elevate this app.

Verdict: ★★★★★

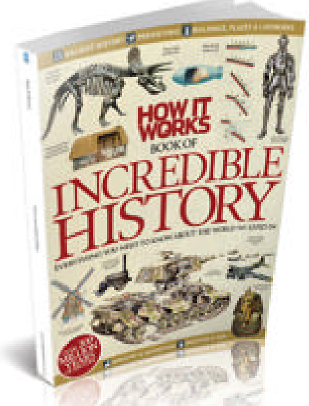
Expand your mind...

Bookazines and DVDs about science, technology, transport, space, history and the environment.

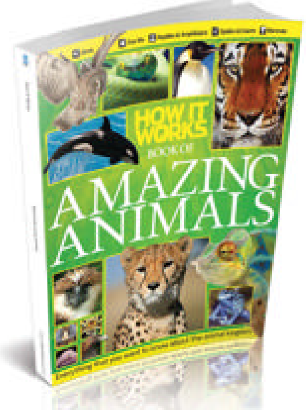
Bookazines



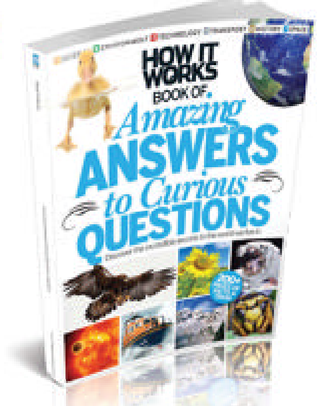
Annual Vol. 3
A fascinating facts about the world we live and is divided into six all-encompassing subject areas: the environment, science, technology, space, transport and history. Prepare to be amazed with detailed cutaway images, breathtaking photos and informative articles.
£9.99



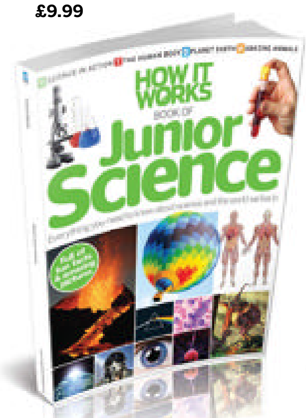
Book of Incredible History
Packed with fascinating facts, and covering over 200 million years of history, this book is the perfect guide to the world around us. From the dinosaurs to the Romans and the Battle of Hastings to the Battle of Britain.
£9.99



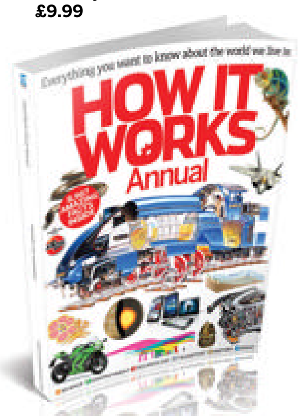
Book of Amazing Animals
Birds, sea life, reptiles and amphibians, spiders and insects, and mammals – all are explored and their natural talents explained. Beautifully illustrated diagrams detail everything from the tactics of a lion attack to the anatomy of a crocodile.
£9.99



Amazing Answers to Curious Questions
Packed with fascinating facts and answers to loads of life's intriguing anomalies. An encyclopaedia of knowledge in 212 pages is waiting for you to impress your friends with and expand your horizons.
£9.99



Book of Junior Science
The ultimate resource for budding scientists from the How it Works team. Explaining how the world around us works in a fun and easy-to-understand format, this book is the ideal tool to get kids interested in science and the world we live in.
£9.99



Annual Vol.2
Over 8,000 facts included! A section dedicated to the greatest inventions of all time, a look at the vehicles and designs that changed the world of transportation, fully illustrated guides and fantastic cutaways all written by experts to be understood by all.
£9.99

DVDs

How it Works eMag Vol. 2
Search, browse, read, print and enjoy every single article from issue 13-24 of How It Works magazine on one handy interactive DVD-ROM. If you're looking for a particular article, interview, news story or cutaway, this is a fully searchable disc.
£19.99

Become an ImagineShop customer and leave reviews of your favourite products.

10% OFF
all orders until 24 December!

Order online **imagineshop**.co.uk

IMAGINE PUBLISHING

@imagineshopuk
/imagineshopuk

MAGAZINES | BOOKS | DVDS | DOWNLOADS | GIFTS

GROUP TEST

PUTTING PRODUCTS THROUGH THEIR PACES

Telescopes

Which cutting-edge device offers the best view of the night sky?

PROS
✅ Easy to use; quick setup
CONS
❌ Not cheap; 8x batteries

PROS
✅ Powerful; simple to use
CONS
❌ A bit on the pricey side

PROS
✅ Good for deep space
CONS
❌ Awkward assembly

Celestron 80LCM

Price: £358/$N/A
Get it from: www.hama.co.uk

A complete newbie to the amateur astronomy scene might feel a little daunted by the idea of a computer stuck to the side of a telescope, but it's not as if NASA is handing over control of Hubble here! In fact, Celestron makes it very easy to set up and start spotting with its 80LCM refractor telescope. Even without any instructions the 80LCM is fairly simple to put together: attach the folding body to the legs, the motor and scope to the top, pop the optics on and you're ready to go… almost. While you are responsible for positioning the 80-millimetre (3.1-inch)-aperture telescope in a good spot with clear sky, the computer makes the fine adjustments. Key in the date, time and timezone, calibrate pointing at certain features in the sky, then let the computer do the rest. It's already programmed with a database of 4,000 celestial objects, so depending on your location and the time of year, you could be looking at the Andromeda galaxy or getting a closeup of Jupiter within an hour of setup.

Verdict: ★★★★☆

Celestron NexStar 127 SLT

Price: £359/$N/A
Get it from: www.sherwoods-photo.com

The other Celestron in our group is the NexStar 127 SLT, another variant on the standard telescope design called a Maksutov-Cassegrain, after its inventor Laurent Cassegrain and the Russian who adapted it, Dmitri Maksutov. Light enters this telescope in the same way it enters a reflector, hits the primary, concave mirror at the back and then hits a secondary convex mirror, which sends the light back along the body to a magnifying eyepiece. Like the 80LCM, this comes with a computer and motorised mount (that requires eight AA batteries), PC software and is very easy to operate using its SkyAlign system. It has the largest focal length in this roundup – 127 millimetres (five inches) – which, as a rule of thumb, makes for better image quality and, as it's a Maks-Cass, the telescope itself is also more compact. Although the computer is pre-programmed with 4,000 celestial objects, the software actually includes 10,000.

Verdict: ★★★★★

Visionary Saxon 4

Price: £209.99/$N/A
Get it from: www.opticalhardware.co.uk

The Saxon 4 doesn't look like a typical telescope. Its short body and lack of objective lens is because it's a reflector rather than a refractor. Instead of bending (refracting) light to a point of focus where it can be magnified, it uses a curved primary mirror in the back of the telescope to collect the light and reflect it onto a secondary mirror, which deflects it onto the eyepiece. Even though it has no computer to calibrate, it feels a lot more fiddly than the Celestron models to set up, with an array of knobs and dials to tweak and align. It does have one major advantage over any refractor, though: its 1,000-millimetre (39.4-inch) reflector lens means it can boast a much better deep-space performance, even if it does require painstaking efforts to find particularly distant objects working with the red dot finder. It's also a lot cheaper than the other two in this group test, putting it within the budget of most amateurs who want to jump in and take a peek beyond our Solar System.

Verdict: ★★★☆☆

HOW IT WORKS SUBSCRIPTION

☑ YES! I would like to subscribe to **How It Works**

Your details

Title________________ First name________________

Surname________________

Address________________

____

____

Postcode________________ Country________________

Telephone number________________

Mobile number________________

Email address________________

Please complete your email address to receive news and special offers from us

Direct Debit payment

☐ Yes! I would like to subscribe to **How It Works** magazine for £17.95 (saving 25%) every 6 issues plus receive a FREE book worth £9.99.

Instruction to your Bank or Building Society to pay by Direct Debit

Please fill in the form and send it to: Imagine Publishing Limited, 800 Guillat Avenue, Kent Science Park, Sittingbourne, Kent, ME9 8GU

Name and full postal address of your Bank or Building Society

To: The Manager ________ Bank/Building Society

Address

____

Postcode

Name(s) of account holder(s)

Branch sort code

Bank/Building Society account number

Originator's Identification Number

5 0 1 8 8 4

Reference Number

Instructions to your Bank or Building Society
Please pay Imagine Publishing Limited Direct Debits from the account detailed in this instruction subject to the safeguards assured by the Direct Debit guarantee. I understand that this instruction may remain with Imagine Publishing Limited and, if so, details will be passed on electronically to my Bank/Building Society

Signature(s)

Date

Banks and Building Societies may not accept Direct Debit instructions for some types of account

A6 instruction form

Payment details 13-ISSUE SUBSCRIPTION PLUS FREE BOOK

☐ UK – £41.00 (save 20%) ☐ Europe – £50.00 ☐ World – £60.00

Cheque

☐ I enclose a cheque for £________________

(made payable to Imagine Publishing Ltd)

Credit/Debit card

☐ Visa ☐ Mastercard ☐ Amex ☐ Maestro

Card number

Expiry date

Security number (last three digits on the strip at the back of the card)

Issue number (if Maestro)

Signed ________________

Date ________________

Code: PBF041

☐ Tick this box if you do not wish to receive any promotional material from Imagine Publishing Ltd

☐ Tick this box if you do not wish to receive promotional material from other companies

I would like my subscription to start from issue:

Return this form to: How It Works Subscriptions, 800 Guillat Avenue, Kent Science Park, Sittingbourne, Kent ME9 8GU or email it to **howitworks@servicehelpline.co.uk**.

***Terms & conditions**
This offer entitles all new UK and overseas subscribers to receive the **How It Works Book Of Incredible History** worth £9.99. UK DD subscribers will pay £17.95 every six issues. Subscribers can cancel this subscription at any time. New subscriptions will start from the next available issue. We publish 13 issues a year. Offer code PBF041 must be quoted to receive this special subscription price. Details of the direct debit guarantee are available upon request. This offer expires 28 February 2013. Stocks are limited and Imagine Publishing reserves the right to withdraw this offer at any time.

To manage your subscriber account visit www.imaginesubs.co.uk & enter your subscriber ID

3 EASY WAYS TO SUBSCRIBE

1. Online

www.imaginesubs.co.uk/hiw
and enter code PBF041

2. Telephone

0844 815 5944

Overseas: +44 (0) 1795 418680

3. Post or email

Please complete and post the form to:

How It Works Subscriptions
800 Guillat Avenue
Kent Science Park
Sittingbourne
ME9 8GU

Alternatively, you can scan and email the form to:
howitworks@servicehelpline.co.uk

USA readers See page 68 for our special offer

HOW TO…

Essential skills for surviving in the modern world delivered step by step

Want us to tell you how? All ideas welcome!

Facebook: How It Works
Twitter: @HowItWorksmag
Email: howitworks@imagine-publishing.co.uk
Web: www.howitworksdaily.com

Don't let your tasty jam go to waste because of dirty jars

Sterilise jam jars

The key to preserving preserves is ensuring your storage is spotless

1 Onto the tray
Heat the oven to no more than 180 degrees Celsius (350 degrees Fahrenheit; Gas Mark 4). Now get a baking tray, line it with baking parchment and place all your jars onto the tray. Make sure that none of the jars are touching one another.

2 Bake
Next you need to bake the jam jars for approximately 20 minutes. Once the jars have been heated remove them with oven gloves and place them onto a heatproof board or surface. Ensure that the surface is not cold – like marble – as this could lead to the glass cracking.

3 Fill and seal
Take your hot jam – the jam must be straight from the hob as otherwise the temperature difference may again shatter the glass – and spoon it into the jars. Once all the jam is inside, leave the jars for around 15 minutes so the preserve can settle and cool before sealing them tightly with caps.

Skim a stone

Learn the physics behind this timeless pastime in order to blow the competition out the water

1 The perfect pebble
The size and shape of your stone plays a vital role in the number of bounces achieved by a skim. The ideal stone should be as circular, smooth and flat as possible. This will help to reduce drag while in the air, as well as improving spin rate, angular stability and the lift reaction force as it hits the water.

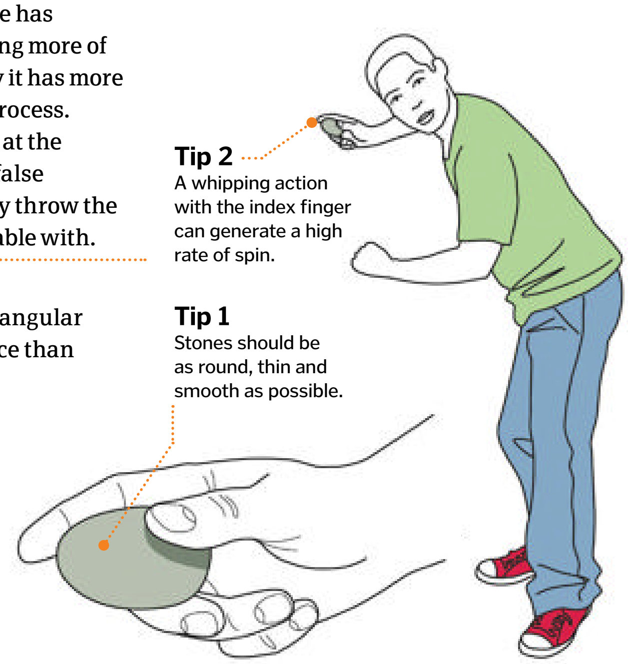
2 Position matters
The next thing to consider is the angle of incidence between the stone and the water's surface. This is pivotal as it will largely determine how much of the pebble breaks through the surface during the collision process – a factor that dictates the friction, lift and angular torque generated. Ideally, a low angle of incidence is ideal – ie as close to flat as possible without throwing on a parallel plane – while high angles generally lead to a poor result. The latter inevitably leads to angular destabilisation and limited perpendicular reaction force on contact so it sinks quickly.

3 Velocity
Once you've nailed your position, the next factor to consider is velocity. This is important to achieving a high number of bounces, but not as critical as most think. The stone has potential energy and, by converting more of this into kinetic energy, obviously it has more to release during the skimming process. However increasing throw power at the expense of other factors can be a false economy. As such, you should only throw the stone at a power you feel comfortable with.

4 Spin
It could be argued that spin (angular motion) is of far greater importance than velocity for achieving a high number of bounces. When a stone comes into contact with the water, the reaction force grants it a degree of torque, creating a potentially destabilising momentum – this can affect its angle of incidence and surface friction for subsequent bounces. With a high spin rate at the point of release, the pebble will have a much more stable touchdown on the water.

5 First contact
Unfortunately from here on in the stone's progress is out of the skimmer's hands. When the stone collides with the surface, a section of it will become immersed in the water, as determined by the angle of incidence and tilt. These factors, along with its velocity and angular momentum, determine how much is submerged, and consequently how much friction and lift are generated. As a general rule of thumb, a small amount of submersion leads to reduced friction with the water and enhanced lift, while greater submersion leads to high friction and little, if any, lift.

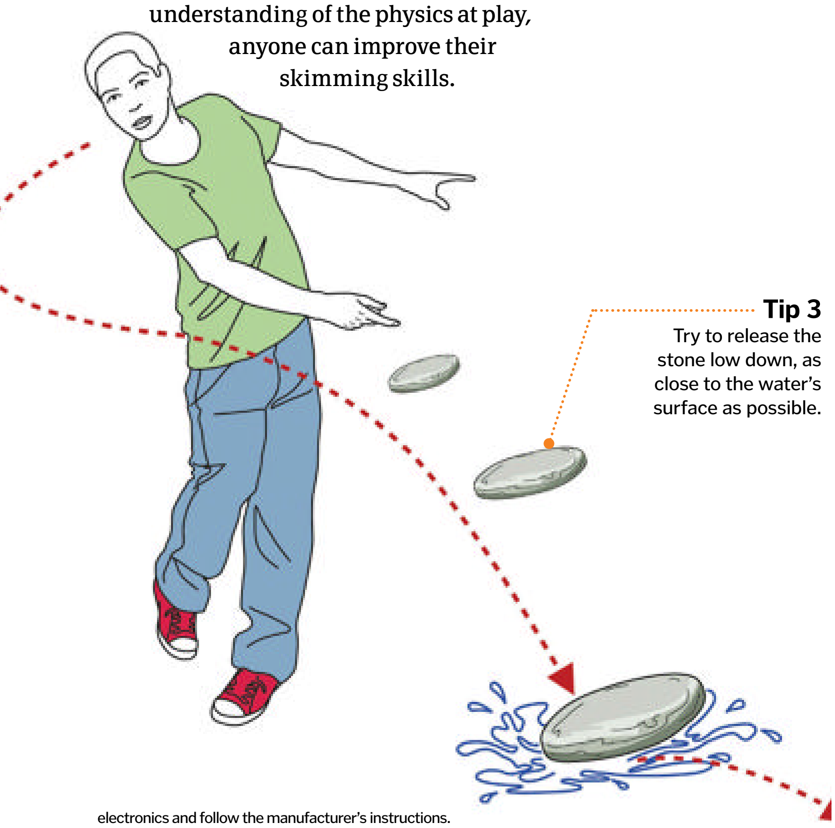
6 Energy dissipation
The previously mentioned properties of the water reaction force will lead to energy dissipation, slowing the stone's velocity and – in some cases – spin rate. Both of these, in partnership with any alteration in the stone's




Once you have got to grips with some of the science, skimming stones becomes a cinch

angle of incidence or tilt will lead to a different second contact and water reaction force. As you'd expect, the first contact is critical in determining the general success of additional bounces, with the pebble travelling shorter distances through the air and minimising the potential destabilising effects of wind.

7 Natural obstacles
Despite these steps outlining the core physical processes involved in skimming a stone, as well as some tips for improving your success rate, environmental factors – such as waves or high wind – will make achieving a lot of bounces much more of a challenge. That said, with a bit of luck and at least a basic understanding of the physics at play, anyone can improve their skimming skills.



© Thinkstock; Alamy

electronics and follow the manufacturer's instructions.

NEXT ISSUE
- Dive like a pro
- Build a snowman

TEST YOUR KNOWLEDGE

ENJOYED THIS ISSUE? WELL, WHY NOT TEST YOUR WELL-FED MIND WITH THIS QUICK QUIZ BASED ON THIS MONTH'S CONTENT?

1 Which US president opened the Hoover Dam in 1935?
A:

2 How many megabytes did IBM's first hard drive have?
A:

3 After the Japanese quake in 2011 a day is how many microseconds shorter?
A:

4 Which part of a flower secretes most of its scent?
A:

5 How far is the Orion Nebula from Earth in light years?
A:

6 What is the maximum towing capacity of the eTT-12 pushback tug?
A:

7 What size engine does the Supacat Coyote have?
A:

8 In which year was German astronomer Johannes Kepler born?
A:

9 What words did Henry II allegedly utter that led to Thomas Becket's murder?
A:

10 How many pipes does the Boardwalk Hall pipe organ have?
A:

ENTER ONLINE

at **www.howitworksdaily.com** and one lucky reader will win a model of the Supacat Coyote military vehicle, as explored on page 72 this issue

> ISSUE 40 ANSWERS
1. 720,000m^2 **2.** Dromos **3.** 0.2mg/cm^3 **4.** 1973 **5.** 661kg **6.** 1,490mph **7.** 3,100kg **8.** 1879 **9.** 1945 **10.** £415,000

INBOX

Feed your mind. Speak your mind

howitworks@imagine-publishing.co.uk @HowItWorksmag
www.howitworksdaily.com How It Works Magazine

Get in touch!

We enjoy reading your letters every month. So keep us entertained by sending in your questions and views on what you like or don't like about the mag.

FANTASTIC PRIZE FOR LETTER OF THE MONTH!

WOWee ONE™

WIN A WOWEE ONE PORTABLE SPEAKER

This issue's top letter wins a WOWee One Classic portable speaker. This turns any surface into a bass amplifier using gel technology, and is compatible with all iDevices and other mobile gadgets.

Jupiter's four Galilean moons – named after the forward-thinking astronomer who discovered them in 1610

Win! A WOWee One portable speaker

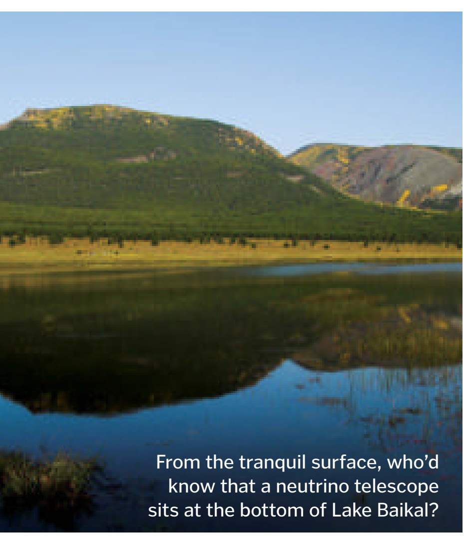
Letter of the Month

Still causing controversy…

Dear HIW

I received a copy of issue 19 recently and must say I quite enjoyed it. There is one statement though that I feel needs clarification/correction and that is on page 41, referring to Galileo and the Vatican: 'Galileo Galilei is… vilified by the Vatican for asserting that planets orbit the Sun and not Earth'. I think if you search deeper you will find that the Vatican did not oppose the theory that the planets revolve around the Sun rather than the Earth, but opposed Galileo's public claim that this was fact (the truth) when, in actual fact, he was unable to prove the theory. This further led him to make certain assertions related to the Bible that, of course, got him into hot water with the Church.
Ed Hausner

While our statement about Galileo was a tiny part of a much bigger feature on Mars, the point we were making was that while the Vatican did not outwardly oppose Galileo's claim, it did oppose anything that flew in the face of heliocentrism or, indeed, the status quo. It was only because Galileo (a subversive character at the time) had powerful friends and his finger on the pulse that he was able to fight his corner. Even when the Church did put him on trial for heresy, he was only sentenced to house arrest rather than the more severe punishments he might have received. Thanks for writing in about this interesting subject, Ed. If you want to read more about Galileo, he's covered in much more detail in issue 40.



From the tranquil surface, who'd know that a neutrino telescope sits at the bottom of Lake Baikal?

Deep thinking

Hey,

I really liked your article on Lake Baikal, the world's deepest lake [issue 40, page 26] and it's got me thinking that people are always looking in the ocean for the strangest and most interesting places, when there's plenty of other places just as fascinating on our own doorstep – especially if you live in southern Russia! Also, people should start looking under the icecaps in the Arctic and Antarctic – I bet there are some amazing things there!
Jason Rice

Fuel your mind

Hi HIW,

I purchased your magazine here in the US and have really enjoyed it. If you are curious, it sells for $10 – a little less than three gallons of gasoline, or the cost of a modest steak dinner for one. I would love a modest-cost subscription if one is available in the US. Speaking of gallons, in the States we would not measure engine displacement in gallons. We would use cubic inches or litres. Many of us really don't know how much a litre is, but we use it nonetheless. Older people like me remember a brief time when gasoline was sold by the litre, so we have an idea.
Matt Bruner

Measuring liquid volume in litres *and* gallons is standard practice in How It Works, so that as many people as possible can relate to our articles. However it's currently under review, partly for the reason you've put forward. As far as steak dinners are concerned, we can only dream of getting one for the equivalent of $10 (about £6) here in the UK!

Bonsai beasties

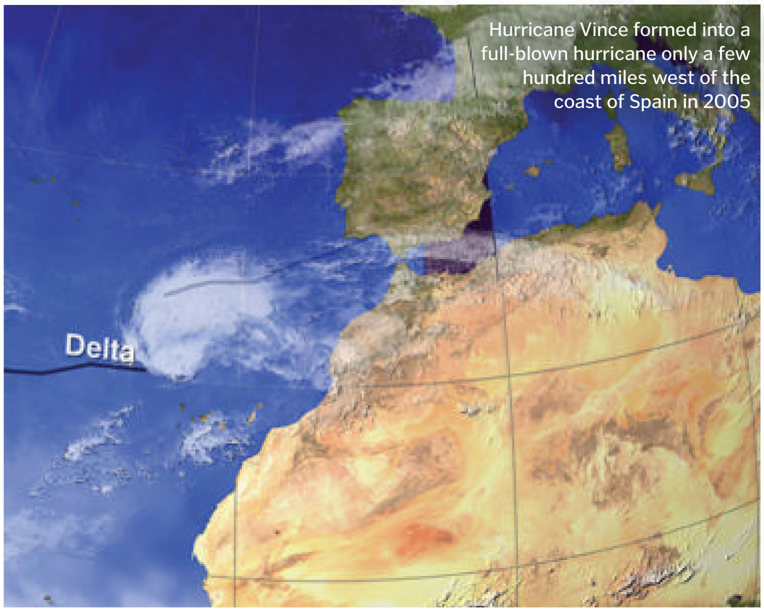
Hi,

I read in issue 39 [page 36] about bonsai trees and how you could make almost any tree the same size. I wondered if you could use the same method with animals? Like when we clone dinosaurs (possibly), we could make them small and quite harmless. HIW fever has spread through my school – everybody is subscribing!
Leon O Walker (11)

Vote for HIW!

Dear How It Works,

I'm writing on the day of the US presidential election, so by the time you



Hurricane Vince formed into a full-blown hurricane only a few hundred miles west of the coast of Spain in 2005

print this (wishful thinking!) we might have a new president of the USA. Anyway, I don't want to get all political about this letter – what I'm writing in to say is that whether Obama or Romney wins, they should make **How It Works** a compulsory read for science classes, or at least have a subscription for every high-school library. I love the way it's presented and written – I just wish my school books were as interesting!
Sasha Knowles

Not that How It Works should ever replace your school books, but we're very happy that you like reading our magazine, Sasha – we love making it too. You could always speak to your teachers about getting it into your school library. We like to think that How It Works is a great educational supplement whatever your age.

Blown away

I've been enjoying your article on 'Extreme weather' which appeared in issue 40 [page 14-21] – particularly the snippet you've got on Hurricane Vince. The idea that Europe nearly had a hurricane all of its own fascinates me, even if it was only a small one. In the UK we're lucky we seldom ever get anything worse than a bit of wind and rain. The power of a force 5 hurricane or a tornado touching down must be a terrifying thing to experience – let's hope that Europe remains a largely hurricane-free zone!
Chris Peroni

Jumping to conclusions

I was reading about the daredevil Felix Baumgartner [issue 40, page 8] and what I would really like to know is how much he got paid to make the jump? Especially with all that special kit on, it must have cost way more than your average skydive. My dad did one last month and it cost £200 for him to jump from just 4,600 metres [15,000 feet]!
Gavin Francis

What's happening on... Twitter?

We love to hear from **How It Works**' dedicated readers and followers, with all of your queries and comments about the magazine and the world of science, plus what you'd like to see explained in future issues. Here we select a few of the tweets that caught our eye over the last month.

Gary Mcnicol @IslayGaz
@HowItWorksmag
Got the new @HowItWorksmag today. Very topical with Hurricane Sandy in the news

Carleton Rutter @DaddyGamer5
@HowItWorksmag
Latest **HIW** has just arrived. Superb feature on my favourite natural science subject – extreme weather!

Becky John @becky0020
@HowItWorksmag
Received my lamp, many thanks!

Mike Simpson @wordsrmagic2me
@HowItWorksmag
Prescient cover story, given events on the east coast of the US #Issue40

Lennie Saggers @len27984
@HowItWorksmag
After just banging my finger I was wondering if you could tell me: why does it (seem to) hurt SO MUCH more when you're cold?

HOW IT WORKS

Imagine Publishing Ltd
Richmond House, 33 Richmond Hill
Bournemouth, Dorset, BH2 6EZ
+44 (0) 1202 586200
Web: www.imagine-publishing.co.uk
www.howitworksdaily.com
www.greatdigitalmags.com

Magazine team

Editor **Helen Laidlaw**
helen.laidlaw@imagine-publishing.co.uk
01202 586215

Editor in Chief **Dave Harfield**
Features Editor **Robert Jones**
Features Editor **Ben Biggs**
Senior Art Editor **Helen Harris**
Senior Sub Editor **Adam Millward**
Head of Publishing **Aaron Asadi**
Head of Design **Ross Andrews**

Contributors
Aneel Bhangu, Alexandra Cheung, Dani Dixon, Freddie Harrison, Tim Hopkinson-Ball, Peters & Zabransky, Vivienne Raper, Dave Roos, Michael Scott, Michael Simpson, Adam Smith, Giles Sparrow, Luis Villazon, Nigel Watson, Jon Wells

Cover images
Illustration by John Coulthart, iPad mini © Apple, Thinkstock, NASA, Rinspeed

Photography
Alamy, Corbis, DK Images, Dreamstime, Getty, NASA, Science Photo Library, Thinkstock, Wikimedia. All copyrights and trademarks are recognised and respected.

Advertising
Digital or printed media packs are available on request.

Head of Sales Hang Deretz
01202 586442
hang.deretz@imagine-publishing.co.uk

Account Manager Liz Tucker
01202 586431
liz.tucker@imagine-publishing.co.uk

International
How It Works is available for licensing. Contact the International department to discuss partnership opportunities.

Head of International Licensing Cathy Blackman
+44 (0) 1202 586401
licensing@imagine-publishing.co.uk

Subscriptions
Head of Subscriptions Lucy Nash
subscriptions@imagine-publishing.co.uk

For all subscription enquiries
0844 815 5944
Overseas +44 (0)1795 418680
Email: howitworks@servicehelpline.co.uk
13 issue subscription (UK) – £41
13 issue subscription (Europe) – £50
13 issue subscription (USA) – £50
13 issue subscription (ROW) – £60

Circulation
Head of Circulation Darren Pearce
01202 586200

Production
Production Director Jane Hawkins
01202 586200

Founders
Group Managing Director Damian Butt
Group Finance and Commercial Director Steven Boyd
Group Creative Director Mark Kendrick

Printing & Distribution
Wyndeham Heron, The Bentall Complex, Colchester Road, Heybridge, Maldon, Essex, CM9 4NW

Distributed in the UK & Eire by: Seymour Distribution, 2 East Poultry Avenue, London, EC1A 9PT 0207 429 4000

Distributed in Australia by: Gordon & Gotch, Equinox Centre, 18 Rodborough Road, Frenchs Forest, NSW 2086
+ 61 2 9972 8800

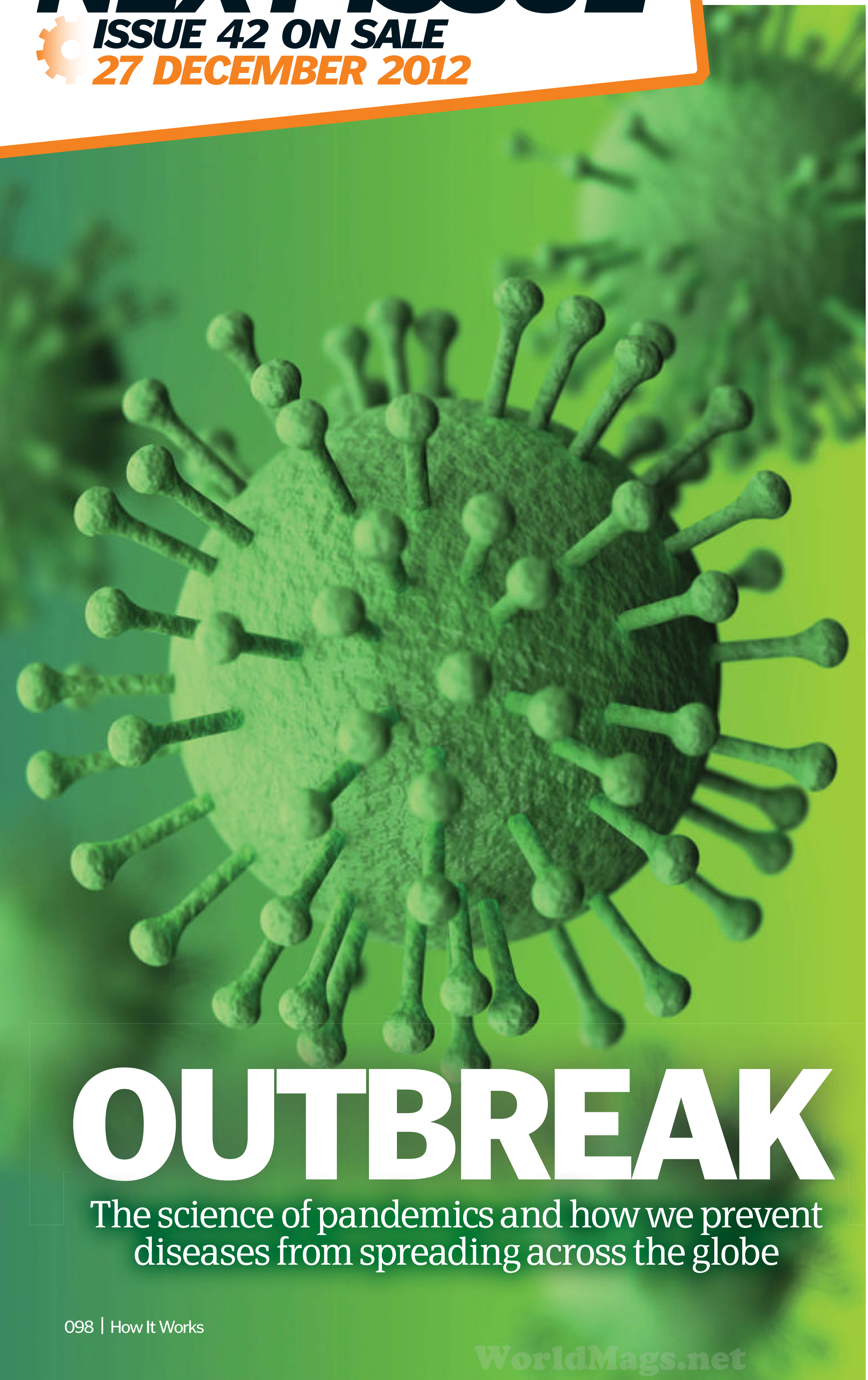
Distributed in the Rest of the World by: Marketforce, Blue Fin Building, 110 Southwark Street, London, SE1 0SU
0203 148 8105

ISSN 2041-7322

34,089
1 Jan – 30 Jun 2012
9,185 (digital)
1 Jan – 30 Jun 2012

NEXT ISSUE

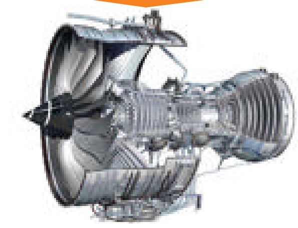
ISSUE 42 ON SALE 27 DECEMBER 2012



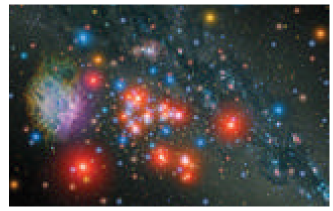
OUTBREAK

The science of pandemics and how we prevent diseases from spreading across the globe

ANSWERED NEXT ISSUE

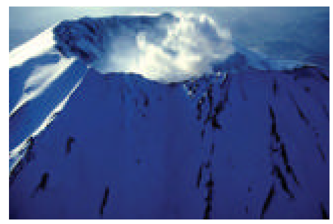


How do different types of jet engine work?

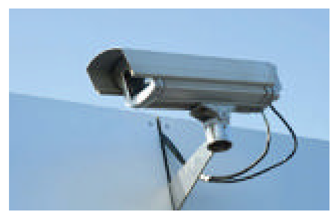


When does a galaxy become a supergalaxy?

How can a horse be trained to race faster?



Why did a volcano split Mount St Helens in two?



How do CCTV systems keep our cities safe?

+ LEARN ABOUT

- MARTIAN WEATHER
- WINDSURFING
- NEW HORIZONS
- MISTLETOE
- ISAAC NEWTON
- BLOOD-BRAIN BARRIER
- DENTIST DRILLS
- ANGKOR WAT
- WAR HAMMERS
- TYRANNOSAURUS REX
- FISSION VS FUSION