NEW

THE MAGAZINE THAT FEEDS MINDS

HOW IT WORKS™

SCIENCE · ENVIRONMENT · TECHNOLOGY · TRANSPORT · HISTORY · SPACE

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Heart-stopping secrets of the world's wildest rides

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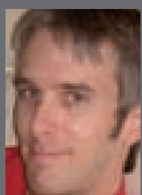
"FEED YOUR MIND!"

Meet the experts

"Written by experts to be enjoyed by everyone" is how we like to roll, so meet the people that work so hard to bring you each issue…

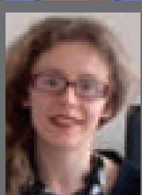


Nick Parkin
Weapons of the Wild West

Nick has a Masters in oceanography and philosophy of mind. He's no cowboy but he was quick on the draw when it came to writing about the weapons of the Wild West this issue.

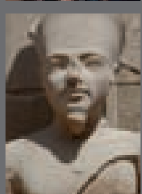
Aneel Bhangu
Heart bypass

Aneel is a trainee colorectal surgeon in Birmingham, training in both cancer surgery and care of emergency and trauma patients. He is also the author of three medical textbooks.



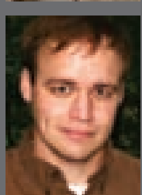
Vivienne Raper
Geysers

Vivienne is our go-to gal for earth sciences, she gained her PHD by studying polar ice-fields with lasers and radar. This issue we asked her to explain geysers and the results can be seen on page 36.



Dr Bridget McDermott
Greek warships

Ancient military technology is the specialist subject for our resident history expert so she was right at home with her assignment on the Trireme, the warship that helped build the mighty Greek empire.



Tom Harris
Human nervous system

A familiar face who has been with us since issue 1, Tom was one of the original writers at howstuffworks.com where he headed up an award-winning content team.

With thanks to

How It Works would like to thank the following companies and organisations for their help in creating this issue

sciencemuseum, REUTERS, Google, DK, NASA, 2010 International Year of Biodiversity

The sections explained

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

ENVIRONMENT
The natural world explained

HISTORY
Questions answered on how things worked in the past

TRANSPORT
Be it road, rail, air or sea you'll find out about it here

TECHNOLOGY
The wonders of modern gadgetry and engineering explained

SCIENCE
Explaining the applications of science in the contemporary world

SPACE
From exploration to the solar system to deep space

Editor's pick

It's tricky trying to pick a favourite from so many cool topics but my choice this issue comes from the History section. It's the 70th anniversary of the Battle of Britain so head to page 74 to discover the machines and tactics that defeated the Luftwaffe back in 1940.

What you're saying about How It Works

Just wanted to say – on behalf of the team – how much we love the magazine! – **James Walshe, Kerrang! Radio & Q Radio**

I would also like to say that your magazine is simply AWESOME!!! And I mean like WHOAAA!!!!! – **Miguel Reyes**

Thanks for putting together such a great mag, keep it up. – **Jennifer Ford**

Loved the mega yachts feature! – **Dave Carstairs**

Welcome to How It Works issue 9, and the newest and most accessible science and technology magazine is back with another helping of nutritious entertainment to feed knowledge-hungry minds everywhere.

Editing this magazine could be described as something of a roller coaster, a particularly exciting one with many more highs than lows, and maybe it was the experience of the last eight issues that led us to offer the in-depth explanation of the white-knuckle rides that can be found on page 14. If you've ever wondered just how you're being propelled around a track at breakneck speeds the answers lie just a few page turns away.

Speed is a recurring theme this issue and while out-of-control buses carrying bombs aren't quite within our remit, the world land speed record is definitely right up our salt-flat. While the actual record attempts are a few years away yet we thought it was high time to take a look at the contenders who hope to break the awesome 1,000mph limit and their amazing vehicles, so get up to speed on page 54.

If roller coasters and rocket cars don't offer enough blokey excitement then we've raised the stakes even further with a rundown of the five most explosive substances on earth, an explanation of the Apache gunship helicopter and a look at why volcanoes erupt. For less testosterone-fuelled information, you can also find out how our nervous systems react, why the tower at Pisa leans and how mankind is searching for new Earths.

Dave Harfield
Editor in Chief

HOW IT WORKS

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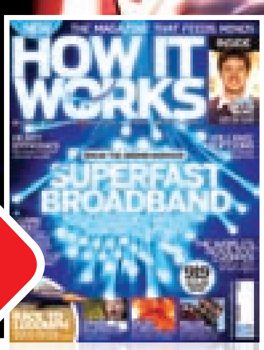

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Because enquiring minds want to know…

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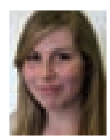
Experts from the National Science Museum and the International Year of Biodiversity

Dr Robert Bloomfield
Director IYB-UK
With a PhD in Genetics, Bob leads the panel of experts from International Year of Biodiversity.

Dan Plane
Science Museum Explainer
Dan performs shows at the museum about subjects as varied as structures, bubbles and blood.



Dominique Sleet
Science Museum Explainer
Dominique studied Natural Sciences before becoming a museum explainer.

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GLOBAL EYE NEWS

A fresh look at the world

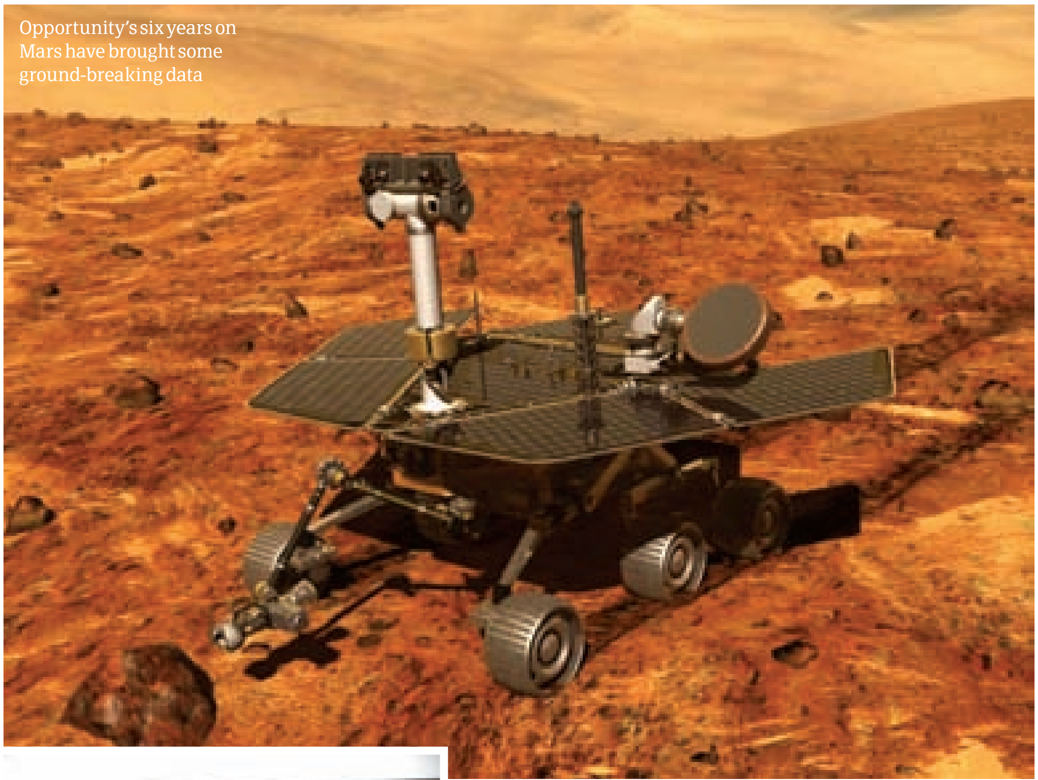
Opportunity breaks Mars record

NASA bot exceeds record for longest mission on Mars

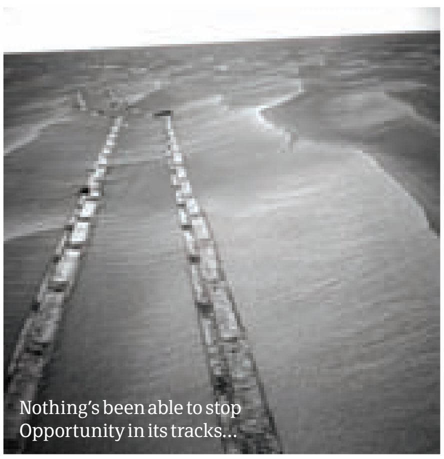
On 20 May NASA's Mars Exploration Rover (MER) Opportunity, one of two research robots sent to the red planet in 2003, became the longest successful Martian mission. The last surface mission to Mars to last this long was NASA's stationary lander the Viking 1, which spent six years and 116 days on the surface between 1976 and 1982.

Although the other MER, Spirit, began work on the planet before the record-breaking Opportunity, Spirit has been out of action since becoming lodged on difficult terrain a year ago and full communication has been lost since 22 March this year when her batteries finally went flat. However, if and when solar panels can recharge her batteries, in turn enabling the rover to resume comms and research, Spirit's mission will automatically take over as the longest on record. Although the recharging of batteries is entirely dependent on their tilt towards the limited winter sun, NASA scientists are hopeful that the rover's normal service could resume. "Opportunity, and likely Spirit, surpassing the Viking 1 Lander longevity record is truly remarkable, considering these rovers were designed for only a 90-day mission on the surface of Mars," said MERs' project manager John Callas.

The work carried out by the rovers has been invaluable to our understanding of Mars. For instance, evidence of clay minerals support the idea that water once flowed over the surface. And according to Steve Squyres, the principal investigator for Opportunity and Spirit, "the clay minerals… speak to a time when the chemistry was much friendlier to life than the environments that formed the minerals Opportunity has seen so far. We want to get there to learn their context. Was there flowing water? Were there steam vents? Hot springs? We want to find out." And if these rovers continue to exceed all expectations there's every chance we will.



Opportunity's six years on Mars have brought some ground-breaking data

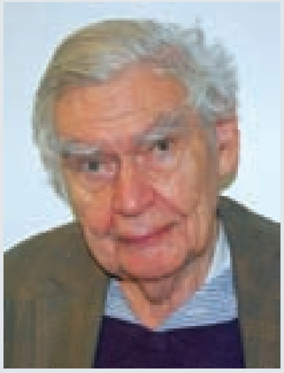


Nothing's been able to stop Opportunity in its tracks…

NASA hopes Spirit will once again become functional

All images © NASA

We say goodbye

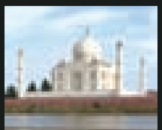


Sadly, after contributing to issue 7's article on optical illusions, Professor Richard Gregory passed away on 17 May at the age of 87. Gregory, who was Emeritus Professor of Neuropsychology at the University of Bristol, was respected world wide for his work in the field, with his writing, lecturing and public speaking unparalleled over the past 60 years. **How It Works** would like to thank him again for the expert guidance he lent to us when researching the optical illusions article.

This day in history

17 June: How It Works issue 9 goes on sale, but what else happened on this day in history?

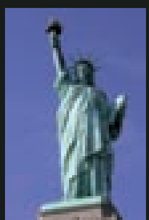
1631 Mumtaz Mahal, the wife of Mughal emporer Shah Jahan dies during childbirth. The Taj Mahal is a dedication to her.



1714 French astronomer César-Francois Cassini de Thury, grandson of Giovanni Domenico Cassini, is born.

1775 British troops battle the American Continental Army during the famous Battle of Bunker Hill during the American Revolutionary War.

1885 A 151-foot tall gift from France, the globally iconic Statue of Liberty arrives in New York City.



© syncardia.com

Heart in a bag

The Freedom Driver has enabled the first American with a totally artificial heart to leave hospital

No ordinary backpack – the Freedom Driver is a pioneering piece of kit

An artificial heart recipient has become the first American to be fitted with a battery-driven device that supports his prosthetic heart. 12 years ago 43-year-old Charles Okeke's own heart was irreversibly damaged by a blood clot. He received a transplant, which, ten years later, his body rejected. Unable to receive a second transplant, Okeke spent two years in hospital attached to a life-saving 400lbs machine.

To enable Okeke to leave hospital and regain his freedom while he awaits a donor heart, a more portable alternative was required, and thanks to SynCardia Systems' Freedom Driver, Okeke has now left his hospital ward and returned home. Okeke is the first American to trial the Freedom Driver, which is connected to his artificial heart by tubes. The device, which has now been approved by the FDA, weighs just 13.5 pounds and can fit into either a backpack or shoulder bag. It's powered by two batteries but can also be plugged into a wall or car socket. A display screen also reveals the user's beats per minute, fill volume and cardiac output.

While Okeke's doctors maintain that if he doesn't find a suitable donor he could use the Freedom Driver for the rest of his life, the device currently costs $125,000 with yearly maintenance costs of around $18,000, so the system certainly doesn't come cheap. Still, you can't put a price on freedom.

Clear skies ahead

A super-green plane designed by MIT burns 70 per cent less fuel

The Double Bubble gets its name from the extra-wide fuselage that resembles two bubbles stuck together

© MIT/Aurora Flight Sciences

A team of developers run by MIT have designed a commercial plane that uses 70 per cent less fuel than today's airliners.

The team pitched the design to NASA in a bid to win a contract to develop and evaluate concepts for cleaner aircraft over the next 25 years. The D series 'Double Bubble' takes the traditional tube-and-wing fuselage but adds a second tube for extra space and lift. The engines use a technique called Boundary Layer Ingestion, which takes in slow-moving air in the wake of the fuselage. Slimmer wings and a smaller tail also help reduce the amount of drag and fuel burned. D series planes could replace Boeing's domestic flights 737s. With the go-ahead and funding from NASA, MIT could change the shape of air travel by 2035.

1898 The birthday of artist MC Escher, whose many optical illusions – such as never-ending staircases – confuddled audiences everywhere. To learn about the secrets of optical illusions, why not revisit issue 7 where we have four pages on the subject.

1939 In Versailles, murderer Eugen Weidmann becomes the last person to be publicly beheaded in France.

1958 Playland's flagship attraction the Wooden Roller Coaster opened today in 1958. For all you need to know about roller coasters, turn to page 14 of this very issue.

1972 Five members of the White House are arrested at 2:30am for attempting to bug the Democratic National Committee's HQ at the Watergate hotel and office complex.

1974 An IRA bomb explodes at the Houses of Parliament damaging the government building's Westminster Hall and injuring 11 people.

MONTH IN FACTS

Short, concentrated bursts of facts and figures from the last month in news

2,307 days

■ The Opportunity rover surpassed the Viking 1 Lander's Mars mission longevity record of 2,307 days on 20 May 2010.

"I know we've made a bunch of mistakes, but my hope at the end of this is that the service ends up in a better place"

■ Facebook cofounder Mark Zuckerberg confirms the social networking site's privacy settings will receive a major an overhaul.

50

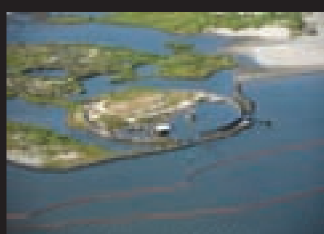
■ The ESA's Ariane 5 heavy-lift launch vehicle made its 50th flight when it launched from French Guiana on 21 May.

We spend almost a day online every month

■ The UK Online Measurement company's research shows British internet users spend 22 hours 15 minutes online every month.

$500 million

■ BP is funding research up to the value of $500 million towards studying the impact of the oil spill in the Gulf of Mexico.



© BP

Apple vs Flash cont.

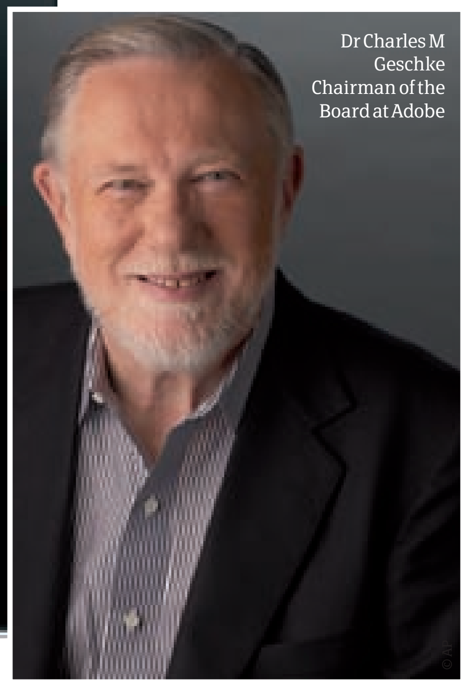
Two weeks after Apple CEO Steve Jobs openly attacked Adobe over the proprietary nature of its Flash technology – a multimedia platform that is used to add animation, video and interactivity to webpages – its cofounders hit back with an open letter of their own and a very targeted advertisement campaign.

Currently, Adobe Flash is banned on Apple's iPod, iPhone and iPad due to, as commented by Jobs, poor performance and security issues when translated to run on touch-screen smartphones and handheld devices. Jobs, commenting on the reliability, security and performance of Flash said that, "Flash is the number one reason why Macs crash and we don't want to reduce the reliability and security of our iPhones, iPods and iPads by adding Flash. We have routinely asked Adobe to show us Flash performing well on a mobile device [and] we think it will eventually ship, but we're glad we didn't hold our breath."

Firing back, however, Adobe founders Chuck Geschke and John Warnock responded to Jobs saying: "No company – no matter how big or how creative – should dictate what you can create, how you create it, or what you can experience on the web. We believe that Apple, by taking the approach [to ban Flash], has taken a step that could undermine this next chapter of the web – the chapter in which mobile devices outnumber computers, any individual can be a publisher, and content is accessed anywhere and at any time."

The Apple iPad. Could it be the ultimate Flash-killer?

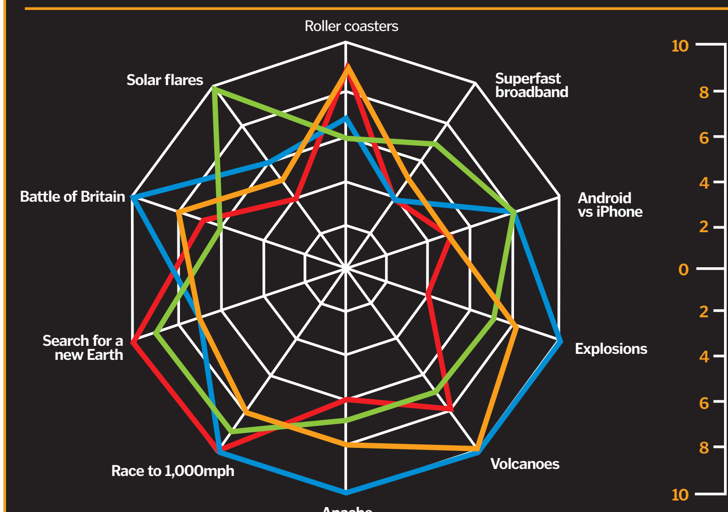
After an open letter from Steve Jobs was released by Apple, Adobe launches advertising campaign and reacts with counter statement



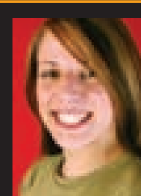
Dr Charles M Geschke
Chairman of the Board at Adobe

THE EXCITE-O-METER!

What's on the radar of excitement? Take a look at this visual guide to what the team love most this issue…



Dave
Ed in Chief
On a personal level, this is one of the most exciting issues we've done. I love the Battle Of Britain feature and the Apache AH-64D Longbow cutaway is amazing. I'm also really pleased with the feature on the world land speed record and the race to 1,000mph.



Helen
Deputy Editor
The world is moving faster in so many ways and issue 9 is testament to this. From the fast-paced thrills of roller coasters to advances in broadband speeds, and of course the race to break the 1,000mph record I'm loving the speedy features this issue.

Rob
Staff Writer
I love it when humans push the boundaries of what was thought impossible just because they can, stepping forth into unknown territory and risking it all in the name of progress. For that reason the race to 1,000mph has to win it for me this issue.

Jon
Senior Sub Editor
For me, nothing displays the incredible power of the natural world quite like a volcano. As we've seen recently, they can bring countries to a standstill, and are a spectacular sight to behold. They've also given us some great films, such as *Dante's Peak*…

AND THE VERDICT IS…

Rob's excitedness seems to have gone nuclear this month with a massive ten-point jump over last issue. And while Helen's excitement dipped, Dave got excited by pretty much everything in the issue!

The Lockheed P38 Lightning was used extensively by the Americans during the Second World War

©Tighar / Barcroft media

Lost fighter plane to be salvaged

After 60 years submerged under sand off the coast of Britain, a Lockheed P38 Lightning lost during World War II is to be saved

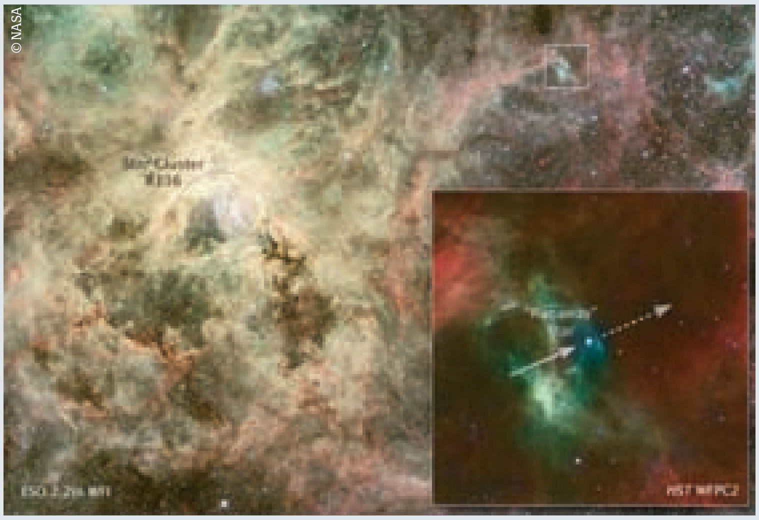
The International Group for Historic Aircraft Recovery (TIGHAR), a group who discovered a rare World War II plane buried under sand and sea on a UK beach, are to shortly raise it from its current resting place. The Lockheed P38 Lightning – an American-built fighter bomber – was lost during training exercises in the late Forties where its engines cut-out and had been long-presumed lost.

The TIGHAR team have announced that they plan to raise the P38 from its watery grave by using a state-of-the-art technique involving submerging the aircraft in an electrified solution. This will prevent the plane – which is highly rusted – from breaking and disintegrating into dust when it is finally moved.

When finally removed from its current location – which is being kept secret from the general public to prevent looting and potential damage, as well as the potential dangers its intact fuel tanks might have – it is to be gifted to the British Museum, where it will be on public display.

Star ejected from cluster at massive speed

A star in the distant 30 Doradus nebula that is 90 times more massive than our own Sun has been ejected from its stellar nursery at 250,000mph



© NASA

Right now a massive runaway star is careering away from its stellar nursery at more than 250,000mph. The star is only 1-2 million years old and NASA scientists believe it may have travelled up to 375 light-years from its suspected birthplace of R136.

Nolan Walborn of the Space Telescope Science Institute in Baltimore and a member of the COS team that observed the runaway star commented: "These results are of great interest because such dynamical processes in very dense, massive clusters have been predicted theoretically for some time, but this is the first direct observation of the process in such a region."

"It is generally accepted that R136 is sufficiently young that the cluster's most massive stars have not yet exploded as supernovae," said Danny Lennon of the Space Telescope Science Institute.

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HOW IT WORKS TV

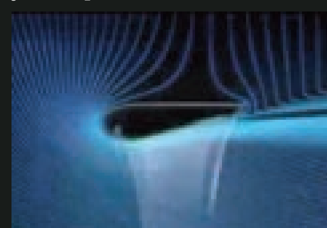
The How It Works site is regularly updated with the web's most amazing videos

Atlantis docks for the last time

Due to NASA's retirement of the Space Shuttle programme, Atlantis makes its last ever visit to the ISS.

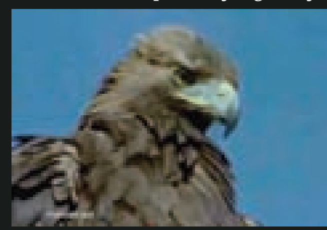
Air Multiplier technology

Following on from our feature on Dyson's new bladeless fan last month, this quick video shows you the process in real-time.



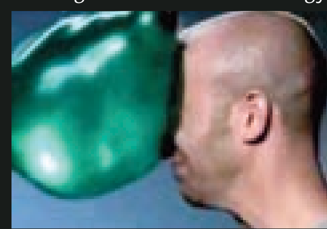
Golden Eagle hunts

Watch as a Golden Eagle hunts goats by dragging them off the high cliffs they inhabit, before picking the carcasses up and flying away.



Slow-motion water balloon face explosion

Enjoy the results of a water balloon and man's face meeting with a great deal of kinetic energy.



GLOBAL EYE INTERVIEW

A fresh look at the world

Dr Wong is a man on a mission

Dr Yan Wong

Putting science theories to the test in the hip BBC show *Bang Goes The Theory,* scientist and Oxford-educated author Dr Yan Wong spoke to us about how and why he thinks making science fun and applying its use to the real world is so important

> "Anything involving magnets seems magical – try dropping one down a copper or aluminium pipe: that amazes me every time I see it"

How It Works: Please tell us a little about your role in *Bang Goes The Theory* and what you want to pass on to viewers.

Yan Wong: Well, I'm naturally quite a chatty person, and I'm also quite curious about anything and everything. I guess that's why I have the role in the series of finding members of the public and discussing some of the science behind things that they see and do. It's a brilliant role to have, because awakening that curiosity in people just makes everything so much more interesting. That's really what I'd like to pass on: the idea that investigating the world around us is one of the most stimulating things that you can do as a human.

HIW: You've become a very popular face on the science education scene. You describe yourself as a 'boffin', what does this term mean to you?

YW: I think I said that other people might describe me as a boffin. I don't really think about what to call myself. I'm just me! The word 'boffin' to me conjures up that clichéd image of someone in a white lab coat, or absentmindedly scribbling down equations. But I actually think it's a mistake to think of scientists like that. They are just everyday people who have the immense good fortune to be paid to think about – and play with – the world around them.

HIW: Which of your many exciting experiments on *Bang Goes The Theory* has been your favourite to pass on to viewers? And which has been the scariest – how do you manage to avoid the slightly more hazardous experiments?

YW: For the simple ones you can try at home, I like those that seem almost magic. I have recently filmed one on how to supercool water – that's pretty stunning. And anything involving magnets seems magical – try dropping one down a copper or aluminium pipe: that amazes me every time I see it. Actually, I only found out rather recently that electromagnetism is a fantastic simple demonstration of the special theory of relativity. On the other hand, ferromagnetism (like you get in a permanent magnet) is a lot more complicated, and I'm not sure I have properly grasped it yet; but that's great – more chance for me to enjoy trying to understand it.

Amusingly, I did manage to slice into my thumb with a knife just before going into a shark tank to talk about snorkels. But they were only small, well-fed sharks, and it's a bit of a myth about blood being particularly important: I'm told they can detect all sorts of bodily excretions (sweat etc) too. I'm actually slightly disappointed that I haven't had the chance to do any really scary or hazardous experiments. Fingers crossed for the next series.

HIW: In an interview you mentioned two particular teachers that encouraged your curiosity in biology. How did these individuals inspire you, and have you ever had the opportunity to say thank you?

YW: My GCSE teacher made the class figure things out for themselves, rather than referring to a textbook all the time. My main A-level teacher gave up a lot of his time to push me beyond the limits of the syllabus, forcing me to understand the subject, rather than just memorise what was needed for the exam. I did return to thank them after my undergraduate degree, and it's funny you should mention it now, because I'm in the process of contacting them again now.

HIW: You say you'd like to "stamp your mark" on the world around you, do you plan to do this as a continuation of the show and sharing your love for science and your knack for inspiring others to learn, or do you have plans for more research and self-discovery for yourself which you can then pass down to new generations?

YW: Both, I hope! I'd certainly like to keep mentally active with a lot more research than I'm managing to do at the moment. That might improve when my young daughter starts going to school. At the moment I do quite a lot of the child care – which I enjoy too.

HIW: We're hoping you're a fan of gadgets, and if so is there one particular gadget or piece of kit that you wouldn't like to live your daily life without?

YW: I'm afraid that I might disappoint you, as I'm not a real gadget freak. I do use my laptop a lot – too much probably. It's a cliché, but the internet really has revolutionised human knowledge, and that's what science is all about. Since I don't have a car, my bikes are pretty indispensable too.

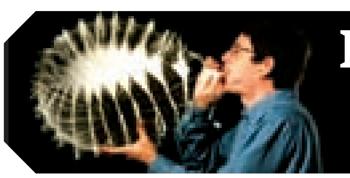
HIW: What is next on your to-do list?

YW: Right now: going to pick up my daughter and taking her to my parents' house in London, where I'll try to fix my mum's garden trellis! In the long term – more TV experience, writing an introduction to statistics, and getting more involved in interesting research.

HIW: And finally, are you the brainiest member of *Bang Goes The Theory*?

YW: I think most people have about the same amount of raw neurological processing power. When it's channelled by education in certain ways it's seen as brainy, but I'm not really sure it's a very useful classification. So I don't usually think of anyone as more or less brainy than anyone else.

A new way of toasting Ryvita



DR YAN WONG FACTS

Protégé
As an undergraduate at Oxford University, Yan studied under the famous British science writer Richard Dawkins.

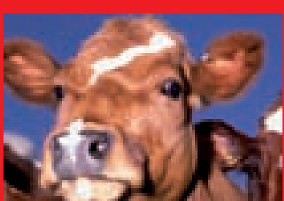
It's complicated…
An evolutionary biologist, Yan gained a PhD in computational and mathematical modelling of self-incompatibility systems in plants – as far as we understand this relates to learning about the theories of plant evolution and reproduction.

Author
For three years Yan worked as a researcher and co-author on Richard Dawkins' book about evolutionary biology *The Ancestor's Tale*, which was published in 2004.

Teacher
Yan has lectured on a number of subjects including evolution, genetics and ecology at Leeds University.

This month in Technology

Thrill-seekers should check out our guide to roller coasters and how they get our hearts pounding. Meanwhile, those demanding highly efficient download speeds should also take a look at our superfast broadband article to find out how this side of the communications industry is developing. We also pitted iPhone versus Nexus in the ultimate smartphone showdown, took a look at milking machines, and discovered what makes bulletproof glass so tough.



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TECHNOLOGY

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22 Superfast broadband

Oblivion is one of Alton Towers' main attractions

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1. Corkscrew
Among the most famous roller coaster elements – trains enter the corkscrew and are twisted through 360° to emerge travelling in a different direction.

3. Zero gravity roll
Riders experience 0g – gravity is cancelled out by opposing forces so there is a feeling of weightlessness. It is often felt on uphill 360° twists.

6. Train
Two or more cars linked up are called a train. The position of the car in a train dictates the effects on the riders.

5. Brake run
These are sections of track, usually at the end, that incorporate a braking device to slow the roller coaster. These can be skids, a fin on the car or, more recently, magnetic eddy current brakes.

7. Dive loop
A dive loop is a type of roller coaster inversion wher the track twists upwards and to the side, and then dives toward the ground in a half-vertical loop

Roller coasters

They strike fear into many, but we still love them! Here, we detail the engineering achievement that is the roller coaster

Some of the world's most forward-looking engineering is actually in operation right now, in the unexpected setting of the world's theme parks. From the pioneering 18th Century 'Russian Mountains', people have been hooked on the frightful thrill of a roller coaster – and ever since, the challenge has been to make an even bigger, even better, even more terrifying one.

Today, they incorporate solutions that are at the leading edge of scientific development. This means they are able to accelerate as fast as a drag racer and let passengers experience G-forces way in excess of a Formula 1 race car.

They do all this in complete safety, having passed the very strictest engineering standards. People travel for miles to ride on the latest roller coaster – they'll even cross continents just to experience the latest thrill. But why? Here, we explain all…

5 TOP FACTS
MOST THRILLING ROLLER COASTERS

1 Ferrari World, Abu Dhabi
This will be the world's fastest roller coaster when it opens later this year – it will hit a top speed of nearly 150mph and riders will even have to wear safety goggles.

2 Kingda Ka, New Jersey
This 'Strata coaster' is the daddy of all roller coasters. It holds the record for tallest (456ft), biggest drop (418ft) and is also the fastest currently operating coaster.

3 Steel Dragon 2000, Nagashima, Japan
For sheer length of thrill, this one tops the lot with a running length of 8,133ft. Here's hoping you don't discover you hate it after the first twist…

4 Colossus, Thorpe Park, UK
A combination of loop, double corkscrew, heartline roll, cobra roll and quad heartline roll hand this ride the record for number of inversions.

5 Ring Racer, Nurburgring, Germany
Running parallel to the famed German racetrack, this goes from 0-135mph in 2.5 seconds! That's way beyond any road car.

DID YOU KNOW? American LaMarcus Adna Thompson is considered the 'father of the roller coaster'


Smile for the camera…

How roller coasters roll

Roller coaster trains are unpowered. They rely on an initial application of acceleration force, then combine stored potential energy and gravitational forces to continue along the track. This is why they rise and fall as they twist and turn.

There are various methods of launching a roller coaster. Traditionally, a lift hill is used – the train is pulled up a steep section of track. It is released at the top, where gravity transfers potential energy into kinetic energy, accelerating the train. Launches can be via a chain lift that locks onto the underneath of the train, or a motorised drive tyre system, or a simple cable lift. There is also the catapult launch lift: the train is accelerated very fast by an engine or a dropped weight.

Newer roller coasters use motors for launching. These generate intense acceleration on a flat section of track. Linear induction motors use electromagnetic force to pull the train along the track. They are very controllable with modern electronics. Some rides now have induction motors at points along the track, negating the need to store all the energy at the lift hill – giving designers more opportunities to create new sensations. Hydraulic launch systems are also starting to become more popular.

Careful calculation means a roller coaster releases roughly enough energy to complete the course. At the end, a brake run halts the train – this compensates for different velocities caused by varying forces due to changing passenger loads.

Anatomy of a roller coaster

Roller coasters comprise many elements, each with its own specific physical characteristics. Designers give a ride character by applying an understanding of physics to build up a sequence of thrills. These are all interrelated and mean the experience of every ride is exciting and unique.

Computer models can analyse the forces that will be produced by each twist and turn, ensuring they are kept within specific boundaries. Roller coasters may look like a random snake of track, but the reality is years of scientific calculations to provide just the right effects.


The Stealth ride at Tower Park isn't for the faint-hearted

"Because of frictional and other losses, each subsequent incline will be shorter than the one before"

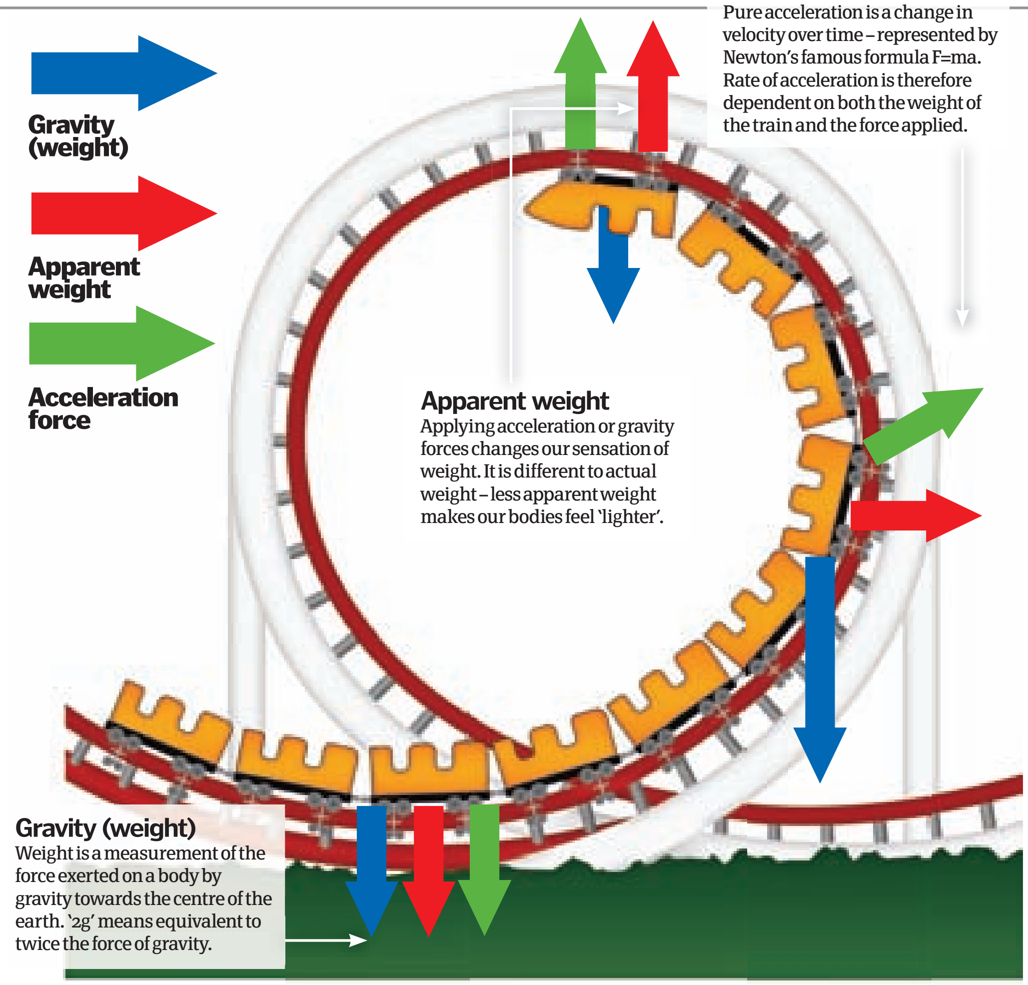
The physics of the ride

The science that gets roller coasters going

All roller coasters begin with an acceleration force. This is to overcome inertia – the resistance to change in velocity. It is quantified by the mass of the train, which depends on the individual load. Full trains will have more inertia than unladen ones. However, by applying more force during acceleration, they also store more potential energy to offset this. Designers work to reduce other sources of inertia such as friction-reducing low rolling resistance wheels.

The aim of acceleration is to store sufficient potential energy at the top of the crest for transferral into driving kinetic energy to take the train to the next ascent. Because of frictional and other losses, each subsequent incline will be shorter than the one before – not all the kinetic energy can be recovered into potential energy.

Gravity is fundamental to roller coasters – designers manipulate the effect of attraction between two masses to subject strong forces on the body. Weightlessness, for example, is caused by centrifugal forces cancelling out gravity forces. Centrifugal force feels like an outward force away from the centre of rotation when turning a corner. It's as if the body is being pressed down into the train, but is actually the reverse: an external force is being supplied by the train towards the centre of rotation.



Acceleration force
Pure acceleration is a change in velocity over time – represented by Newton's famous formula F=ma. Rate of acceleration is therefore dependent on both the weight of the train and the force applied.

Apparent weight
Applying acceleration or gravity forces changes our sensation of weight. It is different to actual weight – less apparent weight makes our bodies feel 'lighter'.

Gravity (weight)
Weight is a measurement of the force exerted on a body by gravity towards the centre of the earth. '2g' means equivalent to twice the force of gravity.

Need for speed
The roller coaster is accelerated to the ground faster than gravity – this causes negative G-force that presses you back into the seat.

G makes it great

The aim of a roller coaster is to subject forces on the body people do not normally experience. These have to be within safe medical limits, and to do this designers consider physiology. The body is more able to tolerate vertical forces rather than horizontal ones. This is particularly the case for compression forces. Many roller coasters therefore compress passengers firmly into their seats, with forces up to +6g, but won't let them 'float' out too severely – the effects of a negative 2g force will still be strongly felt!

An intolerance of side forces is why many roller coaster corners are banked. This reduces the G-forces on passengers to around 1.5g, helping protect necks. It is unable to deal with high side forces so careful consideration must be given here to not injure people.

Overall, though, a roller coaster is the only thing this side of a race car or space shuttle where you can feel what such incredible forces are like. Are your body and your constitution up to it?

Summit approach
The approach to a summit appears to be about to launch you into the air as no track is visible in front!

Loop
Serious G-force is felt during the loop, along with disorientation as the track disappears over your head.

FASTEST 149.1mph TALLEST 456ft LONGEST 8,133ft
BIGGEST DROP 418ft MOST INVERSIONS 10 DROP ANGLE 97

DID YOU KNOW? A human intolerance to side forces is why many corners and bends are banked

Train to retain

Keeping you on the right track

Roller coaster trains themselves are quite simple – they are not powered so do not have to account for drive mechanisms. They do, however, have to incorporate a method of picking up drive from the roller coaster itself – either through connection to a launch track or chain lift, or via power from induction motors.

There is much redundancy built into the connection between train and track. There are a series of wheels which run on the sides and underneath of the track as well as the usual top-running wheels. Side wheels drive it and wheels below stop it moving up off the track. The top wheels carry the load of the passengers. In combination, the wheels lock the train securely on the track.

Train carriages are connected by a flexible joint that securely attaches despite the extreme angles, twists and turns that can occur between the two trains. Carriages themselves are usually steel structures, with classic roller coasters using wooden trains.

Side wheels
Wheels to the side and wheels below prevent the train from being derailed.

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Top wheels
The wheels above the track support the weight of the passengers.

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Learn more

The Roller Coaster Database is a great source of top stats (**http://rcdb.com/**). Fan sites include Ultimate Roller Coaster (**http://www.ultimateroller coaster.com/**) and ThrillNetwork (**http://www.thrillnetwork.com/**). Discovery also airs special programmes on roller coasters and has a great roller coaster builder resource on its website (**http://dsc.discovery.com/games/coasters/interactive.html**). The industry body's IAAPA (**http://www.iaapa.org/**) and BlooLoop (**http://www.blooloop.com/index.aspx**) provides news for the theme park industry.

Feeling hot?
The twists of Thorpe Park's Nemesis Inferno demand over-the-shoulder restraints.

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Belts for the fans

Two types of restraint are common – lap bars and over-shoulder restraints. Older roller coasters use lap bars – floor-mounted padded bars that swing down above the passenger's legs and lock at either side of the carriage. This double locking means if one side fails, the other will still restrain people. Roller coaster connoisseurs like them for the greater freedom but they are not as safe.

Most roller coasters now use over-shoulder bars. These are U-shaped padded bars that swing down to lock over the passengers' shoulders. They hold securely and also mean occupants cannot fly out of their seat: an essential for inversion rides. Secondary strap belts are often fitted too – for redundancy, and for measurement: they're sized to fit the largest allowed person, no larger!

Hold on tight
Colossus is the UK's only quadruple corkscrew.

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"The polycarbonate layer behind it forces the glass to shatter internally rather than outwards"

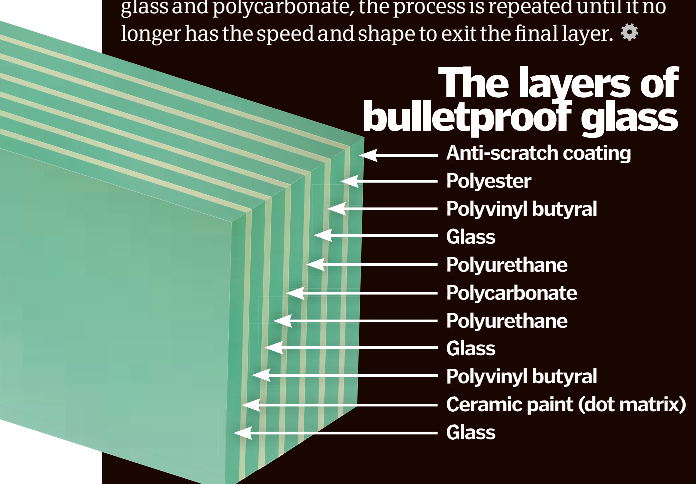
Bulletproof glass explained

Shattering the science behind what makes the breakable unbreakable

Bullet-resistant glass works by absorbing a bullet's kinetic (movement) energy and dissipating it across a larger area. Multiple layers of toughened glass are reinforced with alternated layers of polycarbonate – a tough but flexible transparent plastic which retains the see-through properties of glass. As a bullet strikes the first glass layer, the polycarbonate layer behind it forces the glass to shatter internally rather than outwards.

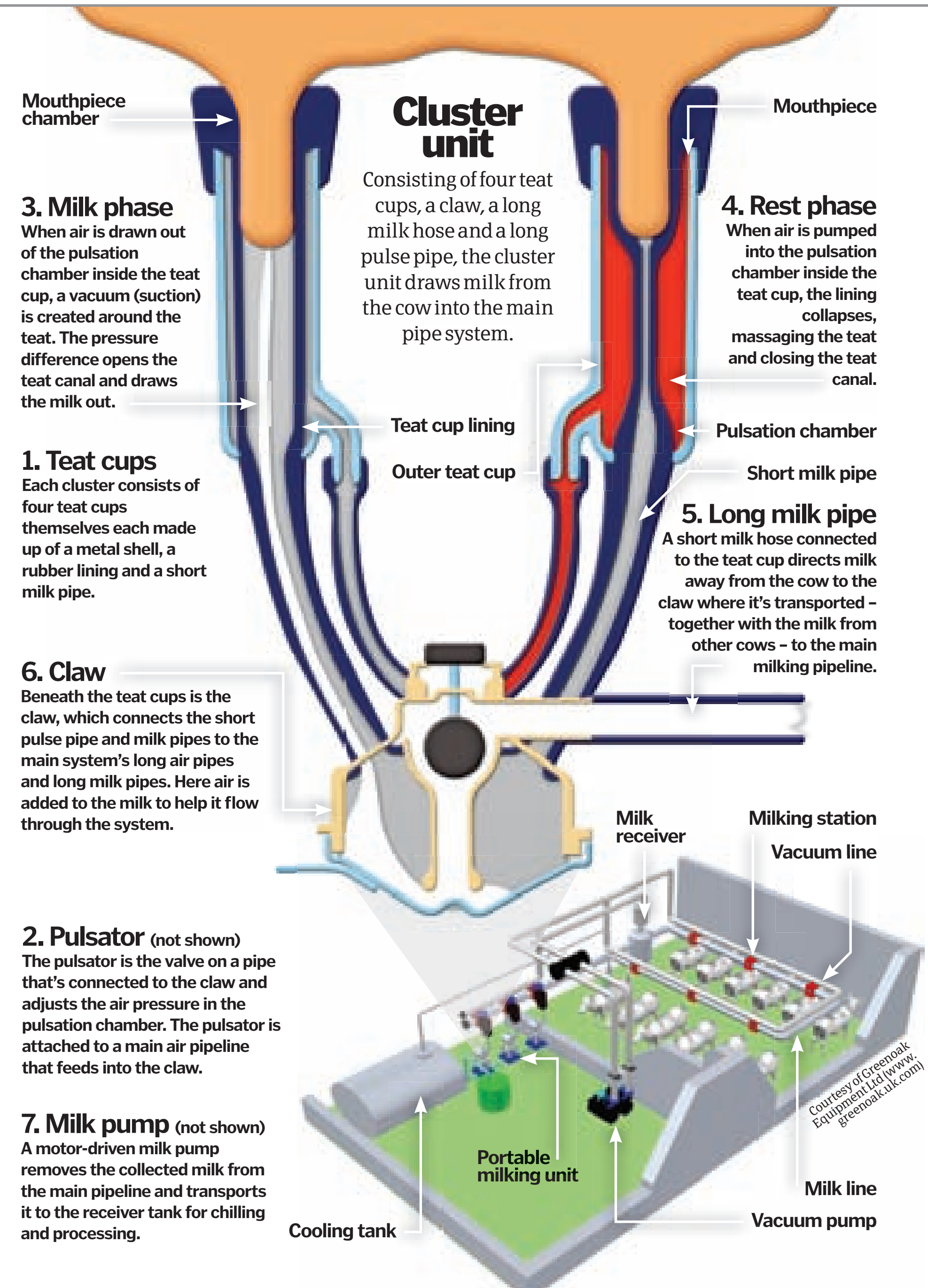
This process absorbs some of the bullet's kinetic energy. The high velocity impact also flattens the bullet's head. Imagine trying to pierce through a sheet of cotton with the top end of a pencil. It would be very difficult compared to using the sharp pointed end. The same principle applies here. The flat-headed bullet struggles to penetrate the layer of polycarbonate. As the bullet travels through each layer of glass and polycarbonate, the process is repeated until it no longer has the speed and shape to exit the final layer.

The layers of bulletproof glass



DID YOU KNOW?

One-way bullet-resistant glass is often used in military situations. While protecting against incoming bullets, shots can still be returned unaffected.



Milking machines

How to get milk from a cow

The milk is extracted using a vacuum applied to the cow's teats. Milk stored in the udder is drawn into a system of pipes leading to a receiver tank where the milk is collected before being passed to the cooling tank.

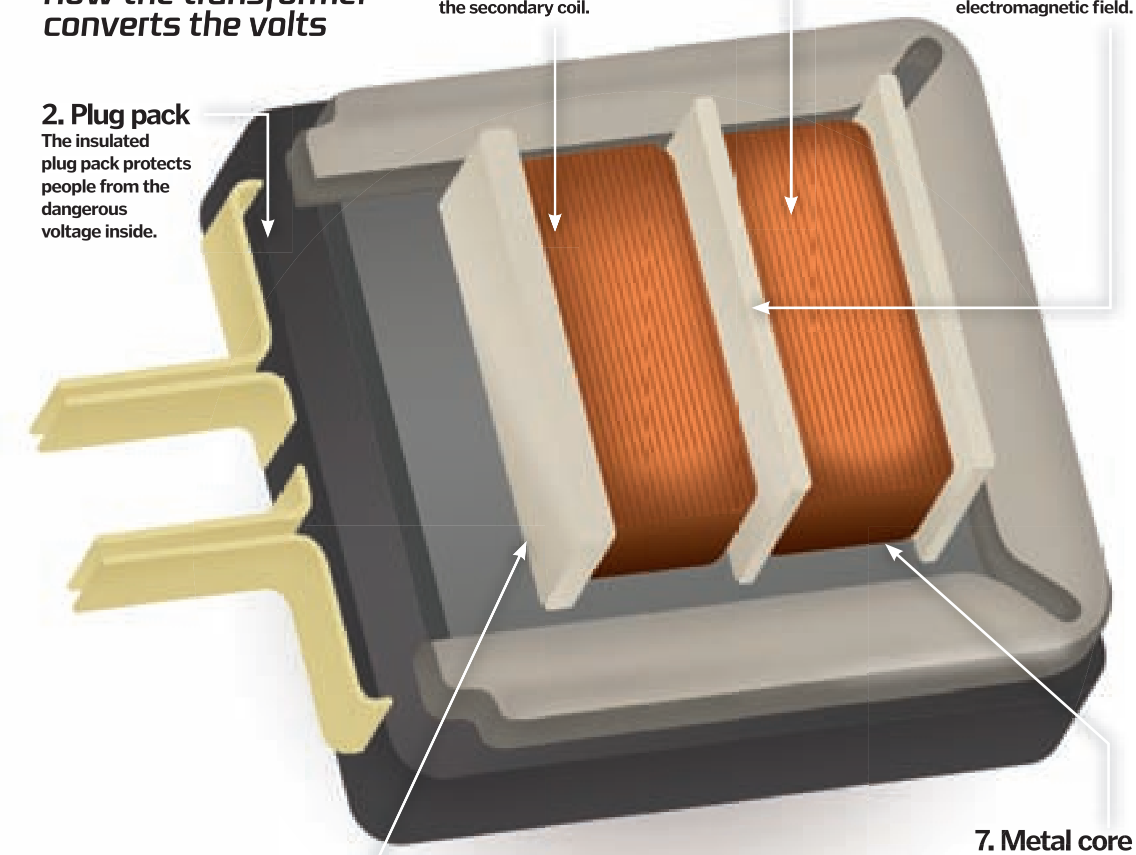
A 'cluster' of four teat cups – each consisting of a stainless steel shell, a flexible rubber lining and a short pulse pipe – are attached to the teats. Between the outer shell and lining is a pulsation chamber that collapses with the addition of air from a pulsator. When the chamber is devoid of air (milk phase) a vacuum is created, which gently draws milk from the teat. When the chamber is filled with air (rest phase) the lining of the teat cup collapses and massages the teat. Continued repetition of these phases not only aids milk production by mimicking the action of a suckling calf, it also promotes blood circulation.

To help the milk flow away through the pipeline, once out of the cow the milk is mixed with air added by a claw – the claw connects the teat cups to the milk and pulse tubes.

DID YOU KNOW? *Touch-sensitive lamps that change brightness per touch work by rapidly switching the bulb on and off*

Inside a powercube

How the transformer converts the volts



How powercube transformers work

How 240 volts is converted into a safe power supply for home gadgets

Look around your home and you will probably find several transformers connected to laptops, charging phones and powering alarm clocks. Transformers convert relatively high domestic voltages into lower voltages suitable for home appliances.

Inside is a single core of metal. Wrapped around it are two separate coils of wire – a primary coil and a secondary coil. The primary coil receives the 110-240 volt mains alternating current (AC) power supply. This generates an electromagnetic field. An electromagnetic field will always generate an electric current in a wire within its proximity – a process called electromagnetic induction.

The primary coil's electromagnetic field induces an electric current of a lower voltage in the secondary coil. How much lower depends on the ratio of turns between each coil. If the primary coil had 1,000 turns and the secondary coil had 500 turns, the output voltage would be halved. Finally, two diodes convert the output into direct current (DC) for use in home appliances.

Here's one that we broke earlier!

How do touch-sensitive lamps work?

How your body's own conductivity can light up a room

Everything, including people, has a certain level of capacitance; the ability to retain an electrical charge. In standby mode, the lamp's circuitry sends a weak electrical current to its external metal layer until its capacitance is full. This flow of current remains a constant value until a person touches the metal surface. The human body can conduct electricity quite well so electrons freely flow from the lamp's surface into his or her body.

As a result, the capacitance is increased and a higher current is required to electrify both the lamp and the person. A circuit detects the increase in current and sends a signal to a 'binary flip flop' switch. This 'flips' its output signal between off and on each time the lamp is tapped, switching the bulb off and on. The 'flip flop' switch 'remembers' the last status of the bulb so it can react accordingly after each touch.

"Android is clearly heavily influenced by the iPhone"

iPhone vs Android

Google's Android and Apple's iPhone are taking mobile phones into evermore exciting areas. But what are their differences, and which is the best?

When Apple unveiled the iPhone in 2007 little did anyone know just how revolutionary it would be. Three years on and the device has established itself as perhaps the most defining electronic gadget of its generation, and it has a whole new troop of big-name rivals looking to get a slice of the market. Biggest among these is the Android OS. An OS (operating system) is the software on a computer that manages the way different programs use its hardware. Android is just such an operating system and similar to how Windows fulfils this task on a PC, Android manages the tasks on a smartphone. Developed by internet search giant Google, the OS recently surpassed iPhone sales for the very first time in the US.

Android is heavily influenced by the iPhone – its user interface is built around touch screen input, but it has significant differences too. The key to the iPhone is its apps – tiny programs that can add almost unlimited functionality to the phone. While Android has apps there aren't as many (around 50,000 compared to the near 200,000 for iPhone). Instead Android is a more web-based OS, using an always-on internet connection over 3G or Wi-Fi to constantly download data from the web, from Facebook updates to sports scores. Instead of having its data confined to individual apps it supports widgets, tiny icons that go on the home screen and display the data held within its associated app. A widget for the BBC News app, for example, shows a constant stream of news headlines as soon as you turn your phone on. It makes the Android OS feel like a very dynamic system.

The Statistics

Apple iPhone

Dimensions: 115mm x 62mm x 12.3mm
Weight: 135g (n/a without battery)
Display: 3.5-inch touch screen
Processor/speed: 600MHz
Camera: 3.2MP
Memory: 256MB RAM
Ports: iPhone connector
Battery: N/A
Extras: GPS and compass, accelerometer, iTunes store

iPhone explained

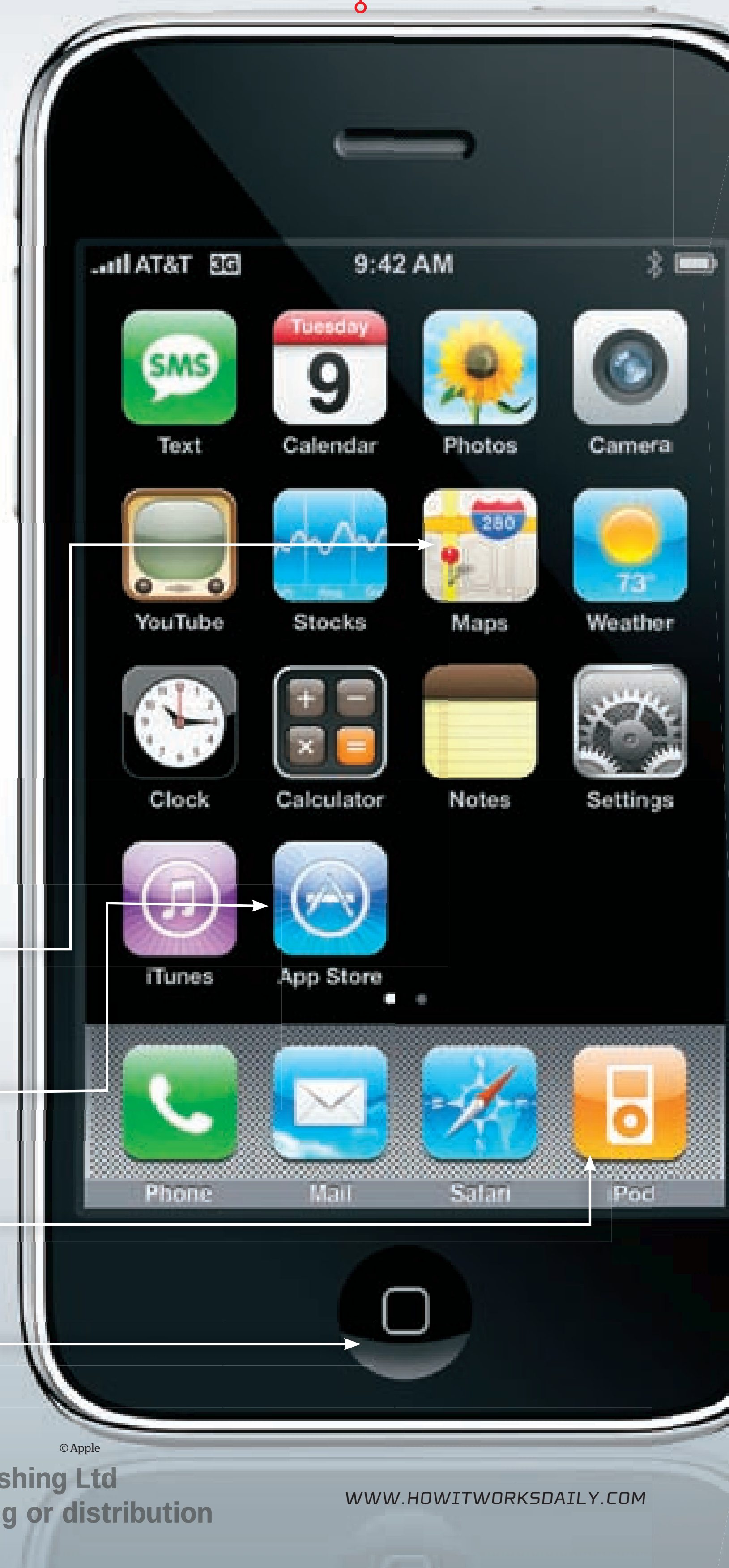
Needing no introduction, the iPhone's success lies in functionality and simple design. Its hardware makes it one of the fastest handhelds available today with 600MHz of processing power and 256MB of RAM in the latest 3GS model

Maps
Like Android the iPhone has Google Maps installed, although it doesn't have the same turn-by-turn navigation that Google-based devices have.

Apps
The iPhone has well over 150,000 apps available in the App Store, covering just about every function you could imagine a phone doing – and a few more besides!

iPod
The iPod is at the heart of the iPhone experience. It is as powerful and seamless as any dedicated iPod, and backed by up to 32GB of storage.

Home
The only button on the front of the iPhone has multiple functions assigned to it. Tap once to return to the home screen, or tap twice to uncover other app-specific functions.



© Apple

Head to Head ANDROID PHONES

FASTEST

1. HTC Desire
Powered by a 1GHz processor, this rather impressive Android-based smartphone is as capable as a desktop PC from only a few years ago.

CHEAPEST

2. T-Mobile Pulse Mini
The Pulse Mini runs the Android OS, but is priced at just £99 on a pay as you go deal in the UK. Perfect for smartphone newcomers.

NEWEST

3. HTC Evo 4G
This is where the smartphone is heading: four-inch screen, super-fast 4G network connectivity – an incredibly powerful device coming to the States soon.

DID YOU KNOW? Current 3G smartphones are able to download data at up to 7.2Mbps over a phone network

© Google

The Statistics

Nexus One

Dimensions: 119mm x 59.8mm x 11.5mm
Weight: 130g (100g without battery)
Display: 3.7-inch touch screen
Processor/speed: 1GHz Snapdragon processor
Camera: Five megapixels, auto focus, LED flash, location tagging from AGPS receiver
Memory: 512MB Flash, 4GB microSD card (expandable to 32GB)
Ports: 3.5mm stereo headphone jack with four contacts for inline voice and remote control
Battery: Removable 1400mAh
Extras: GPS and compass, accelerometer, light sensor that changes screen brightness to conserve power, personalised laser engraving (up to 50 characters on the back of the phone)

Nexus One explained

Released in January, the Nexus One is an Android-powered smartphone from Google. It features a 1GHz processor and a five megapixel camera. It's available on T-Mobile and AT&T networks in the US and Vodafone in the UK

Search
Google's own search engine is inevitably a key feature of the Android OS, opening its results in the desktop-quality web browser.

Satnav
In the US and the UK Google's popular Google Maps application also provides full, free turn-by-turn satellite navigation, along with voice directions.

Widgets
Widgets show a summary of what a full app is doing – giving previews of weather, news, emails and any other data-based activities.

Gmail
The Nexus One Gmail app provides the full Google Mail experience. It uses a push service, meaning your mails are 'pushed' to your phone as soon as they are sent, much like text messages.

Buyer's guide

Which OS is right for you?

While the iPhone OS is only available on iPhone devices from Apple, Android OS comes in many different forms including in popular handsets such as the HTC Desire, Motorola DROID, and Sony Ericsson Xperia X10. As a result, when choosing to buy one or the other it is not simply a case of either Android or iPhone, but between the different Android handsets as well. They all look pretty much the same – rectangular in shape with a large screen and minimal buttons on the front, although a couple of Android handsets also come with slide-out Qwerty keyboards that make typing much easier. This is often seen as a must-have for those wishing to use the phone for work. What the iPhone offers ahead of Android is the full iPod experience, with seamless integration with iTunes delivering the easiest and quickest way of getting music and videos onto any phone.

LOOKING FOR Great music performance
GO FOR: iPhone

LOOKING FOR Free satnav
GO FOR: Nexus

LOOKING FOR Loads of apps
GO FOR: iPhone

LOOKING FOR Ease of use
GO FOR: iPhone

LOOKING FOR Social networking
GO FOR: Nexus

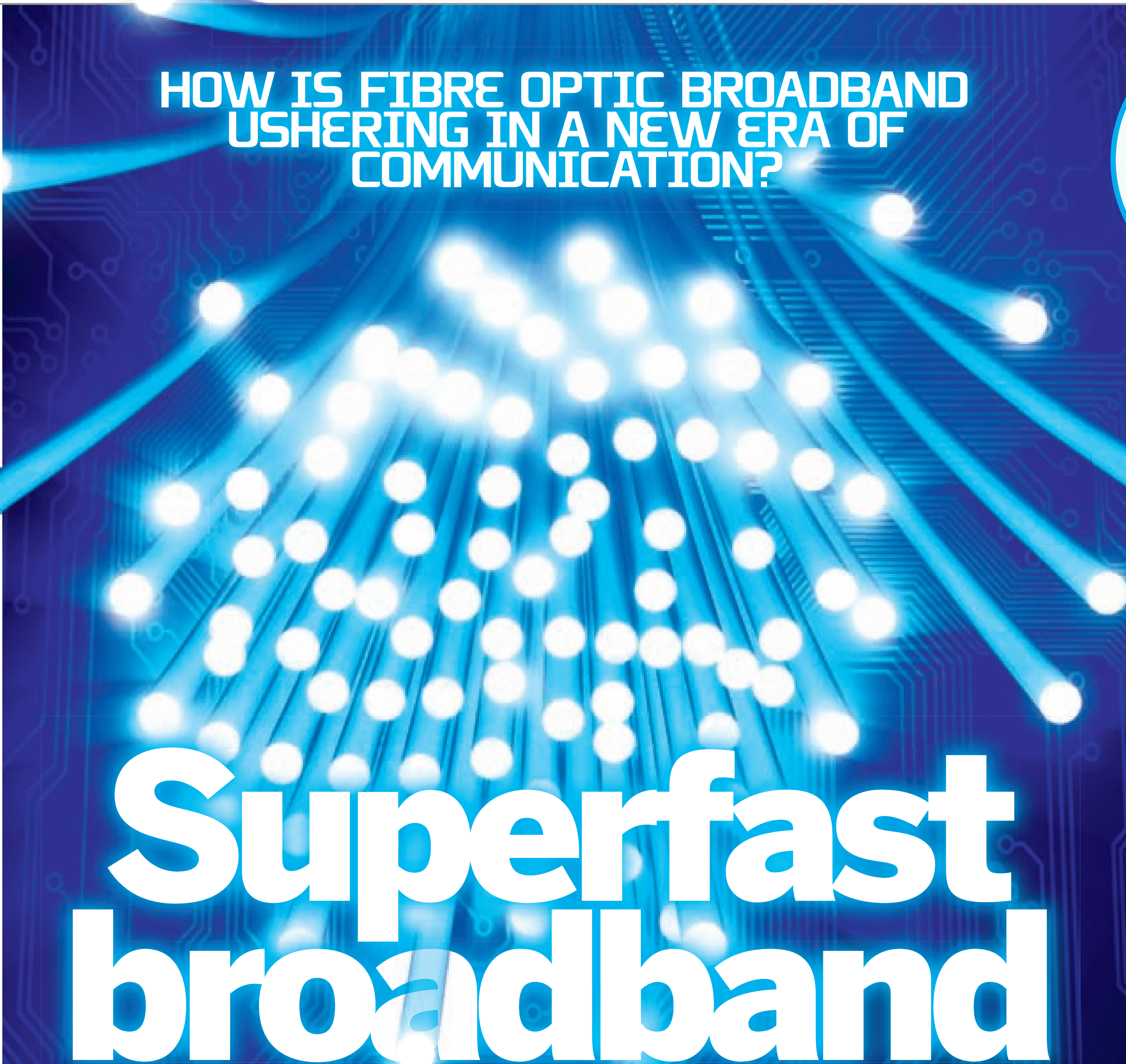
LOOKING FOR Powerful web browsing
GO FOR: Nexus

Verdict...

The iPhone certainly comes out on top in relation to the number of apps available and general entertainment, but for the mobile web Android is the way to go.

Learn more

Smartphone Essentials is a monthly magazine dedicated to the latest in the world of mobile devices. With a strong focus on iPhone and Android, the mag is the best place to discover the latest apps and accessories (**www.smartphonedaily.co.uk**).



HOW IS FIBRE OPTIC BROADBAND USHERING IN A NEW ERA OF COMMUNICATION?

Superfast broadband

Remember dial-up internet? Most of us do and it's not so very long ago that speeds of 56K were considered fast when it came to accessing the delights of the world wide web. And while it may have been fine for checking GeoCities pages and bulletin boards, as our demands and uses of the internet became more complex so higher speeds became more necessary, can you imagine using iTunes or YouTube on a 56K modem? Neither could the service providers who now vie for our attention, trying to find the balance between faster connections and lower prices.

Currently the fastest speed on offer in the UK and US and most of Europe lie somewhere between 2MB and 10MB while China, South Korea and Japan lead the way in 'fibre-to-the-home' broadband lines. However many western nations such as America, Sweden and Romania are following close behind. Over the next few pages we'll be explaining fibre optics, the amazing technology behind the new generation of internet connections, so read on to find out just how it works, where you can find it and why some countries are faster than others.

5 TOP FACTS INTERNET

WWW
1 The man credited with inventing the internet is Sir Tim Berners-Lee, a British computer scientist and professor at the Massachusetts Institute of Technology.

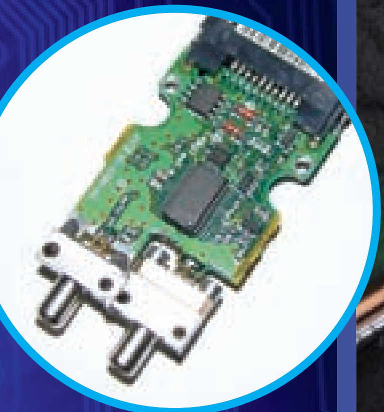
Dominant
2 The prevalent language of communication on the internet is English, followed by Chinese and Spanish. This is despite 42 per cent of total users being based in Asia.

Modal
3 Currently, in the UK the fastest commercial fibre optic line broadband connection is an 'up to 50MB' connection. The lines are available in selected areas only.

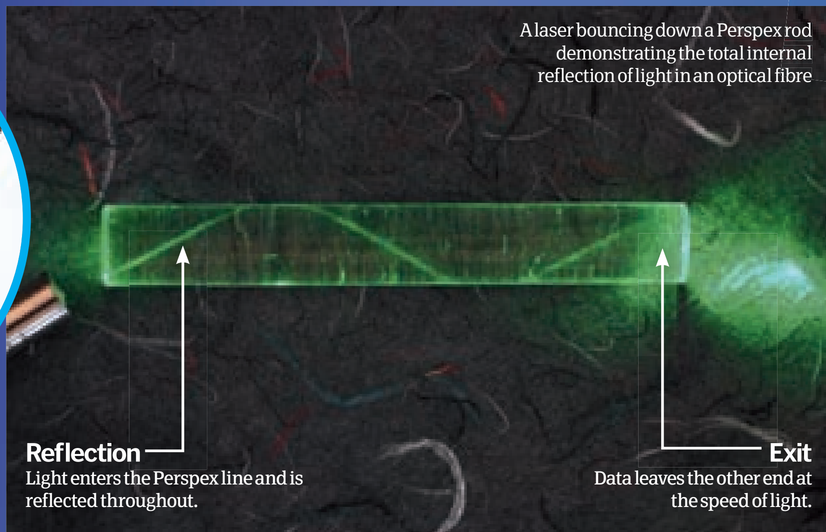
VIP
4 The first switched telephone network arrived in Britain in 1879 when The Telephone Company Ltd opened its first exchange in London. It served just eight subscribers.

Victorian
5 Many copper-based communication lines in the UK can trace their origins back to Victorian and Edwardian times, especially in built-up areas around major cities.

DID YOU KNOW? Currently all new undersea cables are made of optical fibres



A standard transceiver used to send and receive data



A laser bouncing down a Perspex rod demonstrating the total internal reflection of light in an optical fibre

Superfast broadband explained

The brand new breed of superfast broadband connections is made possible by switching from copper telephone wires to new fibre optic cables. Fibre optic broadband essentially works by transmitting data as pulses of light from an exchange throughout an optical fibre – a cable consisting of a light-carrying glass core, light-reflecting cladding (to ensure total light retention) and protective buffer coating – before then receiving and decoding that information at the far end with a transceiver.

A fibre optic line is an excellent medium for communication purposes as it holds numerous advantageous properties over the existing copper-based wiring networks. Most notable is its long-distance data delivery speed, a factor made possible because light propagates through fibre with little attenuation and, obviously, at the speed of light. Further, each fibre optic cable can carry many independent channels of information, each using a different wavelength of light, so the sheer amount of data is increased also.

Broadband now

In most countries, broadband is delivered down copper telephone wire, which suffers from speed, range and breadth restrictions. The wire, which is prevalent across most networks, often dates from the early 20th or even late 19th Century and carries information through electric pulses. This is problematic in terms of maintaining speed at long ranges as all electrical transmissions are subject to high electrical resistance, and information effectiveness is compromised. In addition, electrical transmission lines suffer when tightly packed from crosstalk – a phenomenon by which a signal transmitted on one circuit or channel of a transmission system creates an undesired effect in another circuit or channel. In short, the system is an ageing one, unable to meet today's demands.

Delivery

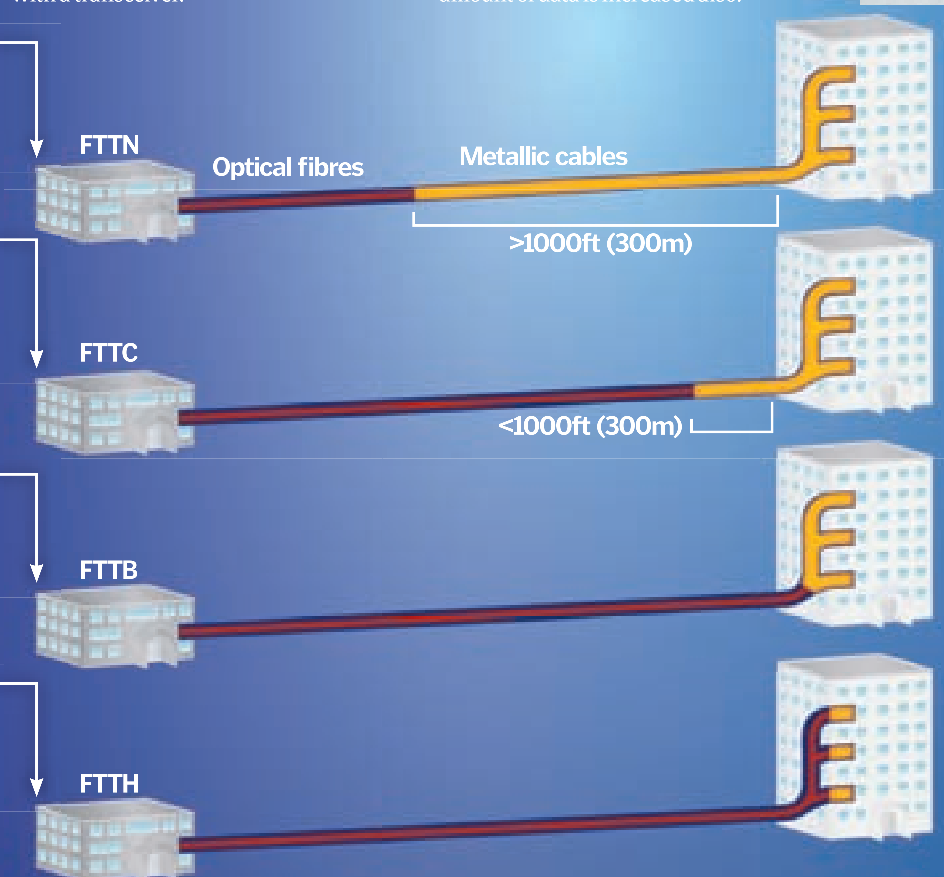
A diagram illustrating how broadband architectures vary depending on the distance between the optical fibre end-point, existing copper-based network and the user. The building on the left is the communications exchange; that on the right is representative of one of the buildings served by it.

FTTN
(Fibre-to-the-node)
Optical fibre is terminated at a node multiple miles from the user's residence, with the connection from it to the premises being copper-based.

FTTC
(Fibre-to-the-cabinet)
Similar to FTTN, this configuration sees any optical fibre terminated at a street cabinet closer to the user's house. The connection from it, though, is still copper.

FTTB
(Fibre-to-the-building)
Used in apartment and office blocks, this sees the optical cable stop at the boundary of the structure, the final connection being delivered by other means.

FTTH
(Fibre-to-the-home)
Here an optical fibre line enters the user's premises like a regular copper connection. No copper connections are necessary in the 'last mile' and speed is vastly increased.



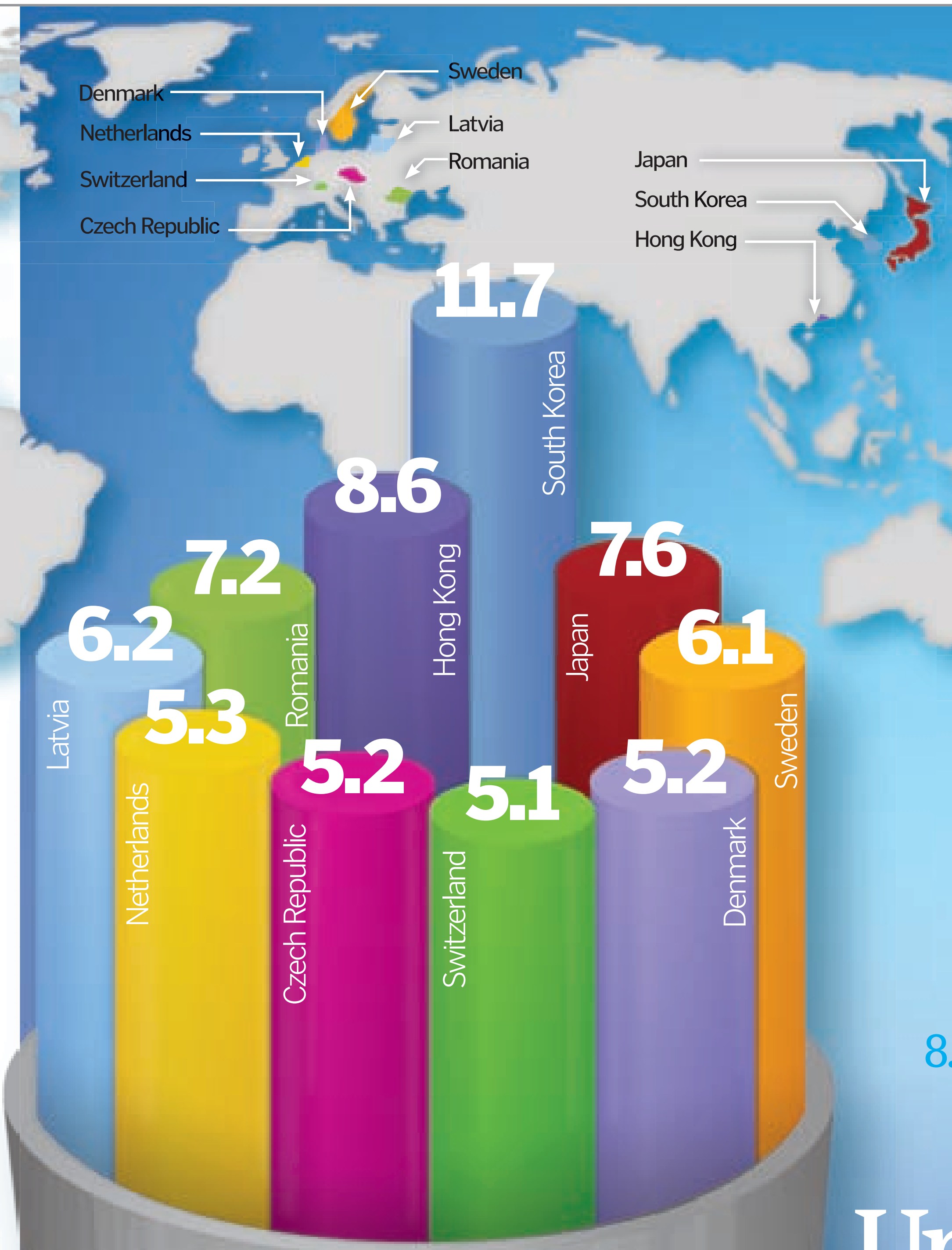
The last mile

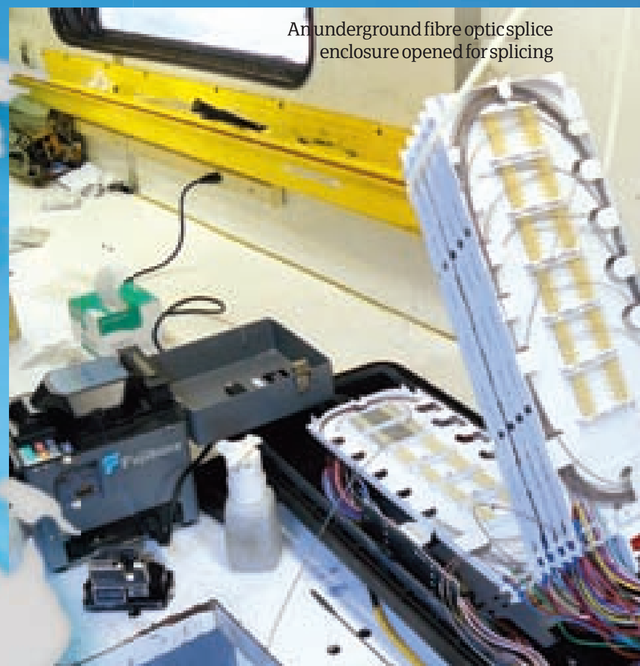
The term 'the last mile' refers to the final leg of delivering broadband communications from a provider to a user. In reality, the last mile may in fact be considerably further than a mile, with many miles separating the two. This is because at this late stage any main cable must be fanned out and split to service numerous separate clients, often living far apart. This is time-consuming and carries a large expense, however, if the 'last mile' is too great a distance, then the cable infrastructure is rendered useless as it cannot sustain information flow due to speed loss.

To address these connectivity issues many operators share and splice networks to reach customers, with cabling varying in type and length depending on where the user is based. This has the obvious drawback that while initially a line from a provider may be fibre optic (carrying data faster and further with less speed loss), at the users' end, in the 'last mile', it may be fanned out onto an old, pre-existing copper line, which as aforementioned in this article, sustains high-speeds poorly, especially over large distances.

Superfast broadband

"More and more countries are rolling-out extensive optical networks"





An underground fibre optic splice enclosure opened for splicing

1. South Korea – 11.7 Mbps
2. Hong Kong – 8.6 Mbps
3. Japan – 7.6 Mbps
4. Romania – 7.2 Mbps
5. Latvia – 6.2 Mbps
6. Sweden – 6.1 Mbps
7. Netherlands – 5.3 Mbps
8. Czech Republic – 5.2 Mbps
9. Denmark – 5.2 Mbps
10. Switzerland – 5.1 Mbps

THE TOP 10 REGIONS WITH THE FASTEST AVERAGE SPEED

22 United States of America

26 Great Britain

*The United States is ranked 22nd, with the average broadband connection speed of 3.8Mbps, while Britain is ranked even lower at 26th with an average of 3.5Mbps

DID YOU KNOW? The government of Estonia passed a law declaring internet access a fundamental human right of its citizenry


© Dhaluza

Why are some countries faster than others?

If you've been looking at the speeds on offer in Asian countries and experiencing an extreme case of broadband envy then you might be wondering just why the services on offer in South Korea, Hong Kong and even Sweden are better than those in the US or UK. Part of the answer lies in financial outlay; Japan, South Korea and Sweden have all made significant investment in fibre optic networks.

Urban density plays its part in the disparity too. Much of the population in South Korea live in very dense apartment complexes. Most of the superfast broadband service has been delivered by fibre optic connections into the basements of buildings like these, then to the individual apartments by fast DSL. So while the fastest broadband connection in the world currently resides in the UK (see below) this is unlikely to see domestic role-out soon due to the prohibitive nature of upgrading the existing network.

The fastest broadband in the world

From the 20 March 2010, the title of world's fastest broadband supplier was awarded to Virgin Media after it demonstrated its 200Mbps service trials at Earls Court, London. That speed is four times faster than its current top-end 50Mbps connection and twice that of the already reported 100Mbps connection due at the end of 2010. Virgin achieved this record speed by using the DOCSIS 3 (Data Over Cable Service Interface Specification) international telecommunications standard that allows for high-speed data transfer over an existing hybrid fibre coaxial infrastructure. Despite the epic speed, the service is not currently commercially available, however, and an early estimate has put it being introduced, depending on demand, in mid 2012.

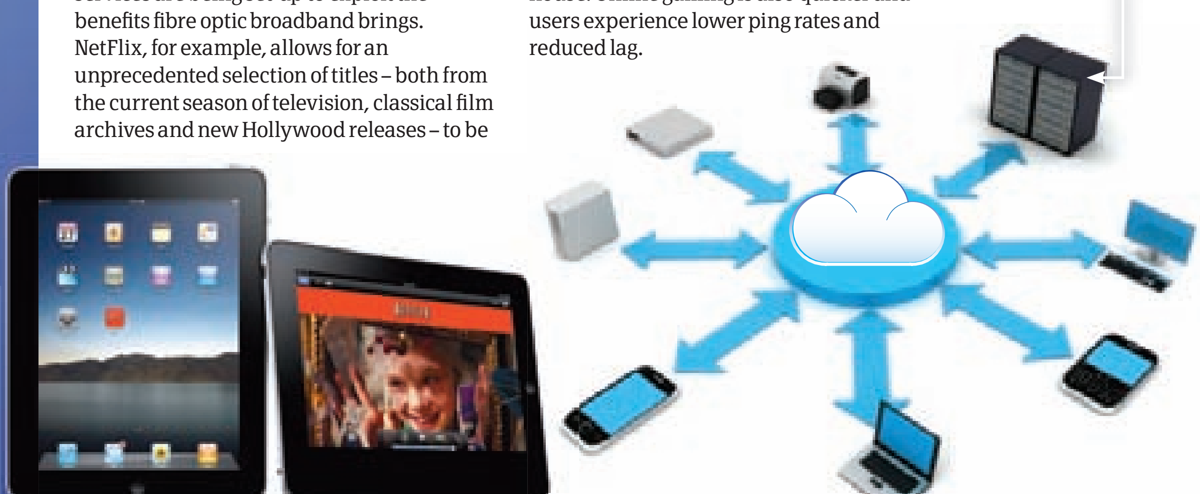
Top five fastest places for broadband

What can superfast broadband be used for?

New devices are making the most of increased bandwidth

Cloud computing, online gaming, digital downloads and live streaming of television and films are but a selection of the possible services fibre optic broadband can be utilised for. Indeed, already a host of applications and services are being set-up to exploit the benefits fibre optic broadband brings. NetFlix, for example, allows for an unprecedented selection of titles – both from the current season of television, classical film archives and new Hollywood releases – to be instantly streamed live over the internet with no waiting or downloading. Gaming services like Steam allow for titles to be bought online, then downloaded and played instantly without the buyer ever needing to leave the house. Online gaming is also quicker and users experience lower ping rates and reduced lag.

Cloud computing
Where content is stored online and accessed remotely from hardware devices – will be advanced with widespread superfast broadband.



This month in Science

It's a well established rule in Hollywood that the cool guys in movies never look at explosions. They just walk away from them while lighting a cigarette, cocking a handgun or putting on sunglasses. Individuals who aren't in the movies or aren't particularly cool usually love looking at a good explosion so if you fall into this category turn to page 32 and find out why things blow up. We've also compiled a list of the most explosive substances on Earth for your information and enjoyment.

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Your nervous system

Lovely as you may be, you are really just an organisation of not especially talented cells

Like any organisation, your success depends on communication between your individual members. In a sense, you actually are this communication, since it is the magic that makes you a single, clever creature. Your built-in communications network, known as the nervous system, perceives the outside world, keeps all body parts working in harmony, and forms the thoughts and memories that make you unique.

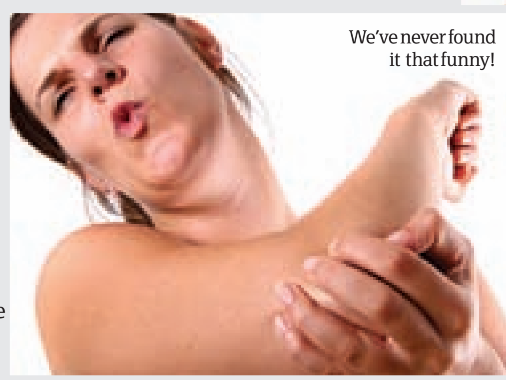
The nervous system comprises hundreds of billions of specialised cells called neurons. A typical neuron consists of a compact cell body, protruding filaments called dendrites, and a long single fibre called an axon. The axon can transmit signals to other neurons and to muscle cells, while the dendrite can receive signals from other neurons and sensory cells. A neuron's axon may extend across the brain or body and branch off hundreds of times.

When something excites a neuron, the cell body will send an electrical charge down the length of an axon, triggering axon terminals to release chemicals called neurotransmitters. These neurotransmitters can travel to receptors on dendrites of an adjoining neuron, across a small gap called a synapse. Depending on the type of neurotransmitter and receptor, the signal may excite the adjoining neuron to fire an electrical charge down its own axon, or the signal may inhibit the neuron from firing. The complex connections and signal patterns among the hundreds of billions of neurons in your brain form thoughts, memories and all other mental activities.

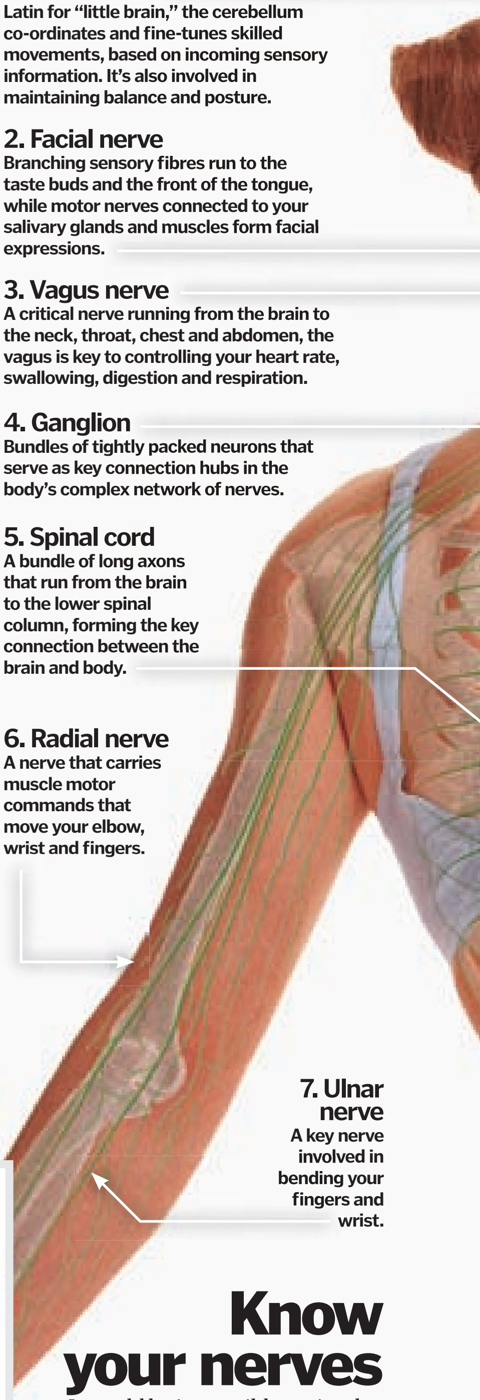
Similarly, axons that extend out from your brain and spinal column into your body can release neurotransmitters to trigger muscle movement and organ activity. This is how your brain controls the rest of your body. Neurons also carry signals from the body back to the brain. You perceive sights, sounds, smells and taste when sensory cells in your eyes, mouth, nose and ears excite nearby neurons. The neurons send an electrical signal up to the brain, which interprets them. Sensory neurons near your skin and other parts of the body fire an electric signal in response to pressure, which your brain perceives as the sense of touch.

Hitting a nerve: the not so funny bone

Most of the larger nerves in your body are insulated by muscle, bones and tissue. The big exception is the ulnar nerve, which runs down your arm, by way of your elbow. The nerve carries motor commands to your ring and pinkie fingers and relays sensory information back to the central nervous system. If you bang your elbow, the humerus bone bumps the nerve, jarring the axons inside, which your brain interprets as a tingling sensation.



We've never found it that funny!



1. Cerebellum
Latin for "little brain," the cerebellum co-ordinates and fine-tunes skilled movements, based on incoming sensory information. It's also involved in maintaining balance and posture.

2. Facial nerve
Branching sensory fibres run to the taste buds and the front of the tongue, while motor nerves connected to your salivary glands and muscles form facial expressions.

3. Vagus nerve
A critical nerve running from the brain to the neck, throat, chest and abdomen, the vagus is key to controlling your heart rate, swallowing, digestion and respiration.

4. Ganglion
Bundles of tightly packed neurons that serve as key connection hubs in the body's complex network of nerves.

5. Spinal cord
A bundle of long axons that run from the brain to the lower spinal column, forming the key connection between the brain and body.

6. Radial nerve
A nerve that carries muscle motor commands that move your elbow, wrist and fingers.

7. Ulnar nerve
A key nerve involved in bending your fingers and wrist.

Know your nerves

It would be impossible to give due credit to all the interconnected neurons, nerves, and supporting cells that make up your nervous system, but we can point out some of the most valuable players…

5 TOP FACTS NERVOUS SYSTEM

World's largest neuron
1 The giant squid axon, which is almost a metre long and can be up to a millimetre thick, helps propel a squid forward (it propelled early nervous system research too).

No nervous system
2 Sponges are the only multi-cellular animals without neurons. They don't really do much, so they don't actually have much need for a nervous system.

Getting a head
3 Most animals have evolved cephalisation, an efficient clustering of neural structures (usually a brain) near sensors and feeding organs at one end of the body (a head).

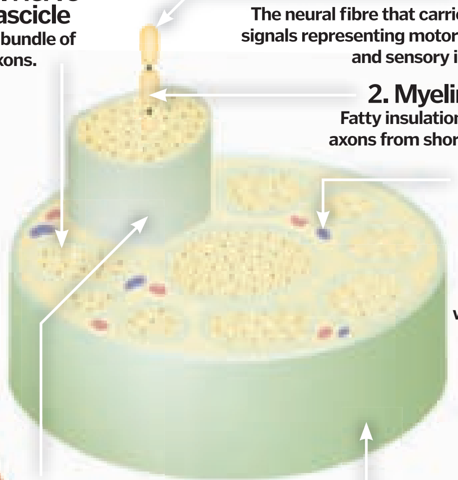
Gotta sing!
4 During the spring, a flood of testosterone greatly expands the song areas of a male bird's brain so it is able to handle complex mating calls.

Conscious breathers
5 For whales and dolphins, breathing isn't part of the automatic nervous system. They have to do it consciously, which means they can never go to sleep completely.

DID YOU KNOW? *Laid out flat and end-to-end, all the nerves in your body would wrap 2½ times around the planet*

Anatomy of a nerve

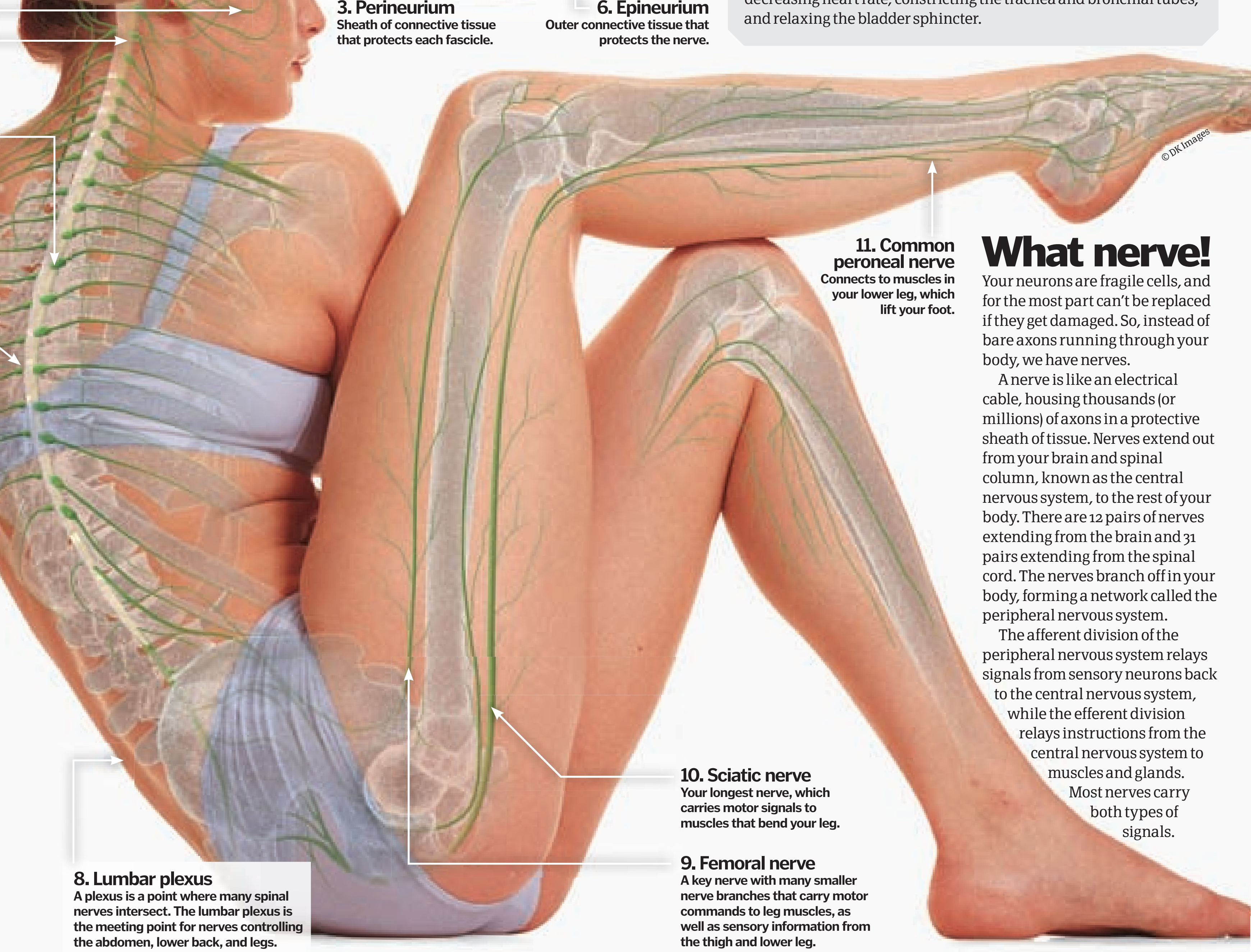
Nerves are sturdy enough to protect your sensitive axons from damage, but flexible enough to snake around your body parts…



Your built-in autopilot

Your automatic nervous system (ANS) works behind the scenes to keep your body running smoothly. The ANS is part of your peripheral nervous system, made up of sensory nerve fibres that constantly relay information about the state of your body and the motor nerves that relay commands from the brain and spinal cord to various glands, the involuntary smooth muscles in organs and blood vessels, and the cardiac muscles that control your heart.

The ANS' chief function is homeostasis – adjusting bodily processes to maintain internal stability. The ANS does this through two opposing, yet complimentary sub-systems: the sympathetic division and parasympathetic division. The sympathetic division is like the accelerator in your car. The motor neurons excite your body, by increasing your heart rate and producing stress hormones, among other things. The parasympathetic division is like the brakes. The motor neurons can relax your body, by doing things like decreasing heart rate, constricting the trachea and bronchial tubes, and relaxing the bladder sphincter.



What nerve!

Your neurons are fragile cells, and for the most part can't be replaced if they get damaged. So, instead of bare axons running through your body, we have nerves.

A nerve is like an electrical cable, housing thousands (or millions) of axons in a protective sheath of tissue. Nerves extend out from your brain and spinal column, known as the central nervous system, to the rest of your body. There are 12 pairs of nerves extending from the brain and 31 pairs extending from the spinal cord. The nerves branch off in your body, forming a network called the peripheral nervous system.

The afferent division of the peripheral nervous system relays signals from sensory neurons back to the central nervous system, while the efferent division relays instructions from the central nervous system to muscles and glands. Most nerves carry both types of signals.

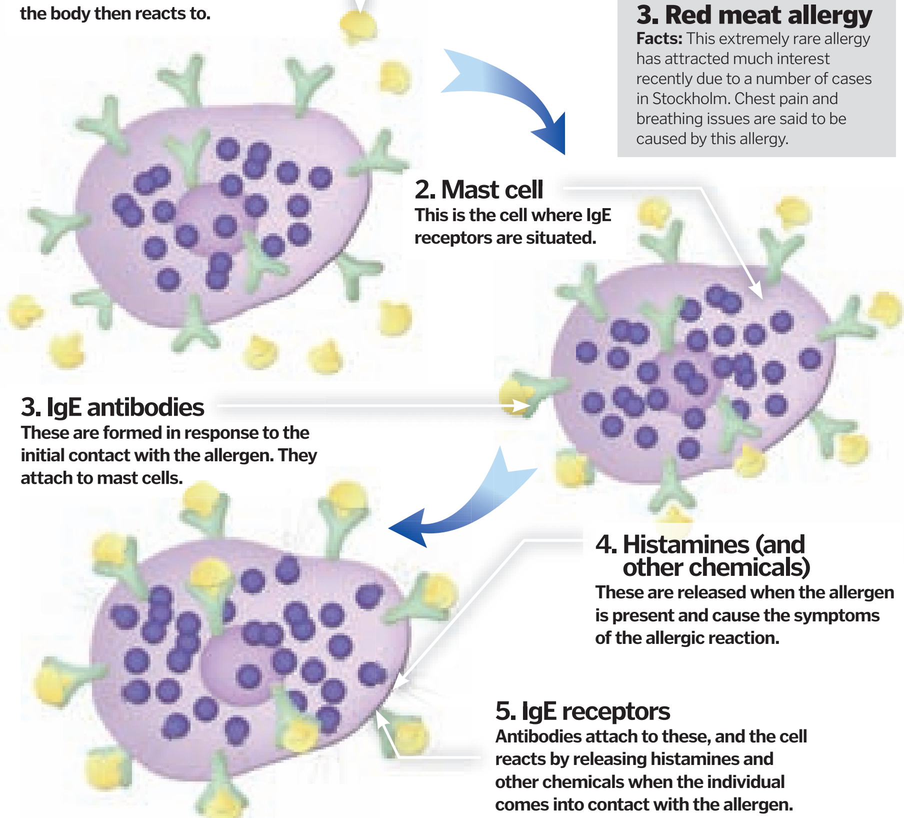
“Ultimately, placebos will not cure physical conditions”

How do allergies affect us?

Hay fever is seen to be becoming more common, but how and why do allergens cause our bodies to react?

Allergic reactions occur in response to specific environmental stimuli (called allergens), such as pollen, dust, bee stings and food, and the reaction displayed in individuals is normally due to an immune system disorder. Most allergies are mild, but some can be severe and even fatal depending on the reaction and treatment received following exposure to the allergen.

Allergies are actually caused by the immune system being hypersensitive to elements within the environment, rather than – as many people suppose – it being under active. Large numbers of antibodies are produced in response to the allergen, which then cause an over-reaction in the immune system when the individual next comes into contact with the allergen – so creating the allergic reaction.



Head to Head
ALLERGIES

MOST COMMON

1. Allergic rhinitis (hay fever)

Facts: This common allergy is a reaction to pollens and other airborne particles. It causes sneezing and itchiness of the eyes.

COMMON

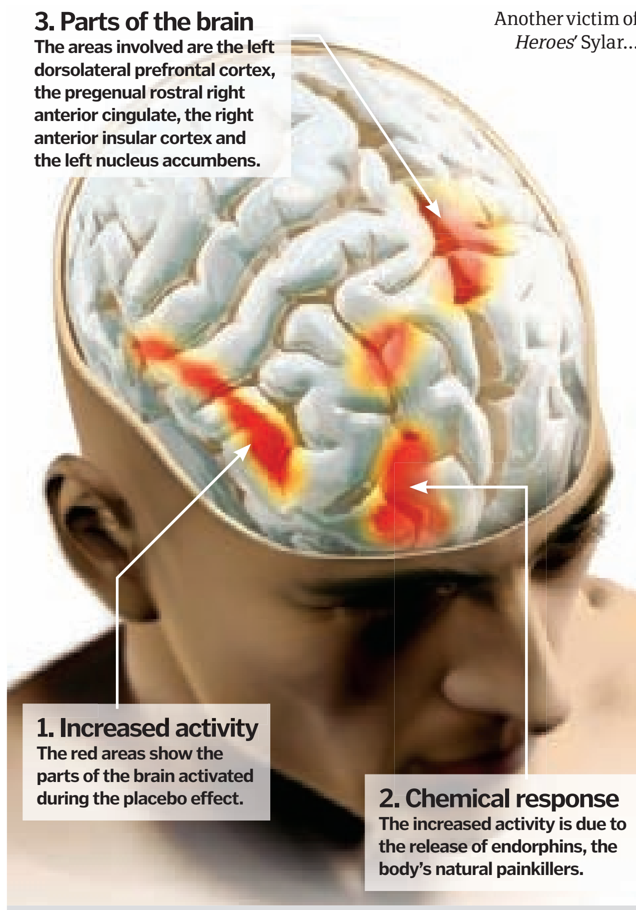
2. Peanut allergy

Facts: This food allergy can cause a range of reactions from rashes and mild swelling to causing the throat to close, potentially suffocating the individual.

RARE

3. Red meat allergy

Facts: This extremely rare allergy has attracted much interest recently due to a number of cases in Stockholm. Chest pain and breathing issues are said to be caused by this allergy.



Another victim of *Heroes*’ Sylar…

Placebos – do they work?

What are placebos, how do they actually work, and can they really cure disease?

The placebo effect occurs when a patient with a condition responds positively to a treatment that doesn’t have any medical value. It is thought to alleviate conditions due to the patient believing they are being treated, and psychologically they start to feel better.

It is thought that the improvements often seen with placebos might be due to conditioned responses (for example, taking medicines makes you feel better, therefore you feel better because you’re taking medicine). However, sceptics commonly state that the so-called placebo effect is actually only seen because patients want to please the doctors or testers, and that in truth placebos have no effect at all.

Ultimately, placebos will not cure physical conditions – they can only affect the individual’s mental state, which may be seen to then aid physical and mental recovery. With some patients and some illnesses, a placebo is potentially a very powerful mental and psychological tool for use in a number of cases, but often is not a valid replacement for treatment.

5 TOP FACTS HEART BYPASS

Risk scores
1 Using complex mathematical models, each individual patient is given a risk of dying from the operation, allowing them to make a decision about how risky the operation is.

How much does it cost?
2 The op is free on the NHS but in the private sector it would cost £16,000-£20,000 ($23,300-$29,000). The price varies with the risks and if it's the first surgery or a re-do.

How much blood?
3 On average, the heart beats 70 times per minute (about 100,000 times per day) which pumps five litres of blood per minute. Five per cent flows through the coronary arteries.

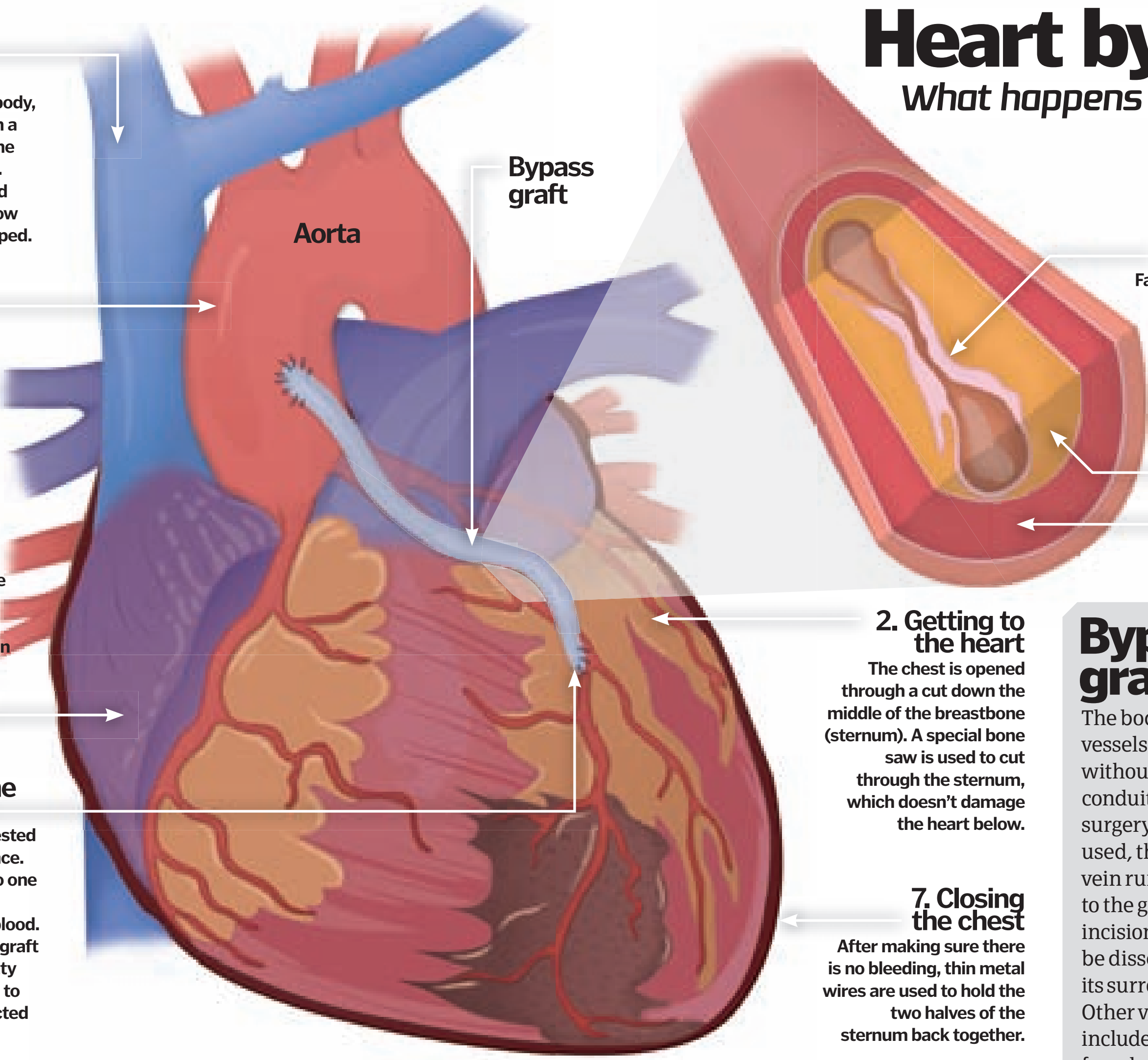
Beating heart bypass
4 A bypass can be performed without stopping the heart, using a special retractor. In a few places, surgery has been performed this way on patients who are awake.

New techniques
5 New techniques include using mini-incisions into the chest and also the use of robots. Small cameras are also used to harvest the new vessels for the bypass grafts.

DID YOU KNOW? *The heart has four separate chambers, four valves to control blood flow and two main coronary arteries*

Heart bypass

What happens in surgery?



3. Bypassing the heart
Blood is removed by pumping it out of the body, oxygen is added to it in a bypass machine and the blood pumped back in. This allows oxygenated blood to continually flow while the heart is stopped.

4. Stopping the heart
The aorta, the main vessel out of the heart, is clamped. The heart is then cooled and stopped using a potassium-rich solution.

6. Restarting the heart
Once the new vessels have been secured, the aorta is unclamped which washes the potassium-rich solution from the heart. The patient is warmed and the heart restarts.

5. Attaching the new vessels
The new vessels are tested and then sewn into place. The opening is sewn to one of the large arteries carrying oxygen-rich blood. The end of the bypass graft is sewn beyond the fatty plaque, allowing blood to freely flow to the affected heart muscles.

1. The problem
Fatty plaques narrow and eventually block the coronary arteries, preventing oxygen-rich blood flowing to the heart muscle.

2. Getting to the heart
The chest is opened through a cut down the middle of the breastbone (sternum). A special bone saw is used to cut through the sternum, which doesn't damage the heart below.

7. Closing the chest
After making sure there is no bleeding, thin metal wires are used to hold the two halves of the sternum back together.

How heart bypasses work

When too little blood is getting to the muscles of the heart, a surgeon can bypass the blockages using the body's own vessels

Although the heart pumps oxygenated blood around the body, the heart's muscular walls need their own blood supply. Oxygen-rich blood is delivered to these tissues via small vessels on its surface – the coronary arteries. These arteries can get narrowed or blocked up with cholesterol causing fatty plaques which slow blood flow. At times of exercise, not enough blood gets to the heart muscles, leading to pain due to lack of oxygen – angina. If a vessel becomes completely blocked, no blood gets through, causing a heart attack where the heart muscle dies.

The first way to treat this type of coronary artery disease is with medicines. Secondly, angioplasty can be used, where narrowings within the arteries are stretched using a balloon, with or without placing a stent to keep the vessel open. Finally, a heart bypass operation is an option for some patients.

The surgeon uses healthy vessels from other parts of the patient's body to bypass the blockage, allowing a new route for blood to flow. This delivers higher volumes of the oxygen-rich blood to the heart muscles beyond the blockage, preventing the pain.

Most bypasses are performed by stopping the heart and using a heart-lung bypass machine to deliver oxygenated blood to the body. The new vessels are then sewn into place.

Bypass grafts

The body has certain vessels which it can do without, and these act as conduits for bypass surgery. Commonly used, the long saphenous vein runs from the ankle to the groin. A shallow incision allows the vein to be dissected away from its surrounding tissue. Other vessels often used include small arteries from behind the rib cage (internal mammary artery) or the arms (radial artery).

Stopping the heart

Cardiopulmonary bypass (where a machine takes over the heart's pumping action and the gas exchange function of the lungs) is established to provide oxygenated blood to the rest of the body. Next, the heart is stopped. This is achieved using a potassium-rich solution, pumped down the coronary arteries. This stops the heart contracting. The surgeon can now carefully attach the fresh vessels to bypass the blockages.

Why do people get frostbite?

A common hazard for polar explorers and climbers, severe frostbite can cause the loss of fingers or toes

Severe consequences
Second-degree frostbite can cause the skin to blister, although it will heal after a month or so. More severe frostbite can result in the extremities being amputated.

Frostbite is damage caused when body tissues freeze in subzero temperatures. The fingers, face and toes – the extremities – are most commonly affected. The body keeps the essential organs warm by narrowing blood vessels in the extremities, sending blood deeper into the body. Frostbite starts if little warm blood reaches the extremities for a long time. Ice crystals can form and kill cells. When blood vessels damaged by ice crystals widen to keep the extremities working, blood can leak out or clot, killing more cells.

Frostbite is treated by slowly warming the affected area to prevent further, irreversible damage. Severely frostbitten tissue may have to be amputated. Frostbite can happen to anyone, but climbers, skiers and others who spend long periods outdoors are especially susceptible.

"Severely frostbitten tissue may have to be amputated"

White hot
1 Dazzling white flames are on average three times the temperature of their much more standard red counterparts, and can reach a rather scorching 1,500°C.

Collateral damage
2 Despite only claiming a recorded six deaths, the Fire of London in 1666 consumed more than 13,200 houses, 87 parish churches and St. Paul's Cathedral.

Flash! Aha!
3 The temperature where an ignitable liquid vaporises to form an ignitable mixture in air is called its flash point. At this point, the vapour can cease to burn as well once ignited.

Zero-G
4 In zero gravity flames become spherical and blue, and burn more efficiently. This is due to decreased convection and an increased amount of soot being completely oxidised.

Troy Story
5 Fire has always been used for its destructive capabilities, including in Homer's account of the Siege of Troy by Greek soldiers, who snuck into Troy before burning it to the ground.

DID YOU KNOW? The typical temperature of a lit cigarette's main body is 550°C


Bambi's life was just going down in flames…

How does fire work?

What is fire and what are the chemical processes that underlie it?

Fire is the result of the rapid oxidisation of a material undertaking the chemical process of combustion, a sequence of exothermic chemical reactions between fuel and an oxidant. This process releases heat, light and various by-products such as soot and ash. If the flame – the visible portion of the fire – reaches a temperature hot enough to ionise its gases, plasma may also be produced in the process.

To best understand the chemical processes that underlie fire, it is best to view the process as a tetrahedron. The fire tetrahedron, comprising of the four elements you need in order for fire – oxygen, heat, fuel and a chain reaction – helps visualise the processes involved.

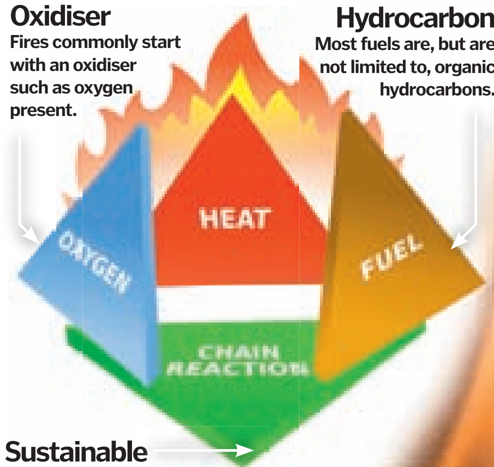
All fires, if they are to be maintained, require the aforementioned four elements, starting with a combustible fuel (wood, for example) then adding an oxidiser to it (such as oxygen) before then exposing it to a source of heat greater than that of the fuel/oxidiser's flash point (the point where it will ignite in air), and ending with a chain reaction of continuous combustion. Take any one of these factors away and fire simply cannot exist and will choke and be extinguished. A good example of this in practise can be seen in the retardant chemical Halon, which when exposed to a fire, slows the combustion's chemical reactions to the point where a chain reaction cannot be maintained and the fire ultimately ceases to burn.

Without this type of hindrance however, in a combustion reaction a compound (usually types of organic hydrocarbons) reacts with an oxidising element, such as hydrogen, before causing and propagating a chain reaction that, provided the input variables don't change, will stabilise itself and burn continuously emitting a flame.

The visible flame of any fire is the mixture of reacting gases and solids emitting both light and heat. This light is caused when excess energy is released through transient intermediate reactions in the burning process and it can lead to a variety of differing flame colours depending on its black body (an idealised object that absorbs and re-emits radiation in a characteristic pattern called a spectrum) radiation as well as its spectral band. The dominant colour of a flame changes with its temperature and – in general – the clearer the flame the hotter and more efficient its combustion and chemical processes are.


A small campfire is fuelled by an abundance of combustible material – in this case twigs and branches

© Marcus Oba



Oxidiser Fires commonly start with an oxidiser such as oxygen present.

Hydrocarbon Most fuels are, but are not limited to, organic hydrocarbons.

Sustainable Fires can only be maintained when the combustion process releases further heat energy.

“Low-angle high-velocity shards can shred human tissue, render vehicle armour and level structures”

EXPLOSIVES

Man has created many different types of explosives over the past 1,000 years, deploying them in warfare, industry and society

Explosions are characterised by three factors: a rapid increase in volume, the generation of high temperatures and an extreme release of energy. In addition to this, every explosion generates a shock wave that varies depending on the explosive substance's detonation velocity.

The four main properties of explosions are force, velocity, heat and fragmentation. The force of any explosion is the physical impact it has on its immediate environment, something often increased through a warhead's shaped charge. An explosion's force when magnified in a shaped charge can gauge impact craters, tear through the armour of military vehicles and puncture buildings.

An explosive's detonation velocity is the rapidity of the expansion of its volume (gases mainly) post detonation. Typically, the greater the detonation velocity the higher up the relative effectiveness (RE) table the explosive is placed, with a direct correlation between velocity, pressure and generated heat. So, generally, the greater the velocity the greater the heat and damage produced.

Heat, generated by and also the cause of an explosion's high-pressures, is its ability to liberate its exothermic material's elements at a certain temperature. Coal, for example, is very good at liberating its material's elements at a high temperature in an exothermic reaction, albeit at such a slow rate that it cannot be used as an explosive (why we use it for fires). Nitroglycerin (the chemical base of explosives such as dynamite) produces five times less heat as coal but has the necessary rapidity in liberation for an explosion to be caused.

Finally, almost all explosions are subject to fragmentation – the accumulation and projection of particles as a result of its detonation. Fragmentation is proportional to the explosion's generated shock waves and detonation velocity, with supersonic shock waves (those travelling faster then the speed of sound) producing considerably more fragmentation than subsonic varieties. Fragmentation increases an explosion's potency ten-fold as low-angle high-velocity shards can shred human tissue, render vehicle armour and level structures.

The history of explosives

Chart the rise of man-made explosives over the centuries

800AD

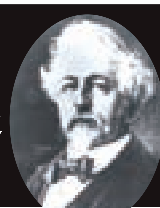
Ancient Chinese: The ancient Chinese are credited with the creation of early explosives – which were crude black powders – used in rockets and fireworks.

1300AD

European gunpowder: By the 1300s, the knowledge of the East had reached Europe and a new era of explosive warfare ensued, relegating suits of medieval armour to museums.

1846AD

Nitroglycerine: More powerful than black powder, nitroglycerine paved the way for the creation of dynamite and other explosives.



5 TOP FACTS EXPLOSIVES

Gunpowder plot
1 In 1605, Guy Fawkes attempted to blow up the House of Lords with 36 barrels of gunpowder. He failed, however in a re-enactment in 2005, a replica House was destroyed.

Dr Dolittle
2 Sir Ranulph Fiennes was expelled from the SAS for attempting to blow up a damn in protest of Hollywood's *Doctor Dolittle* film recording in the village of Castle Coomb.

RE
3 The power of military explosions is measured by its relative effectiveness factor (RE). TNT is the base for all scores, which has an RE factor of 1.00.

Melting
4 TNT melts at 80°C (176°F), far below the temperature at which it spontaneously detonates, allowing it to be easily poured and combined with other explosives.

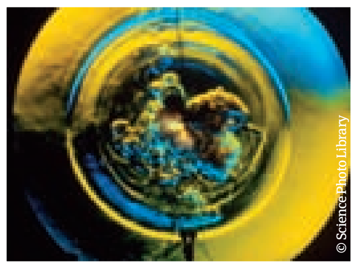
Impact
5 The explosive C-4 has a massive detonation velocity of 8,040m/s (18,000mph). This is due to its 91 per cent RDX (an explosive nitroamine) make-up.

DID YOU KNOW? Despite octanitrocubane's massive explosive power, it is shock-insensitive and not easily detonated

This Schlieren photograph shows a reconstruction of a bomb exploding beneath the passenger seat of an aircraft. Notice how the blast generates circular shock waves of heat and light energy that radiate vertically within the cabin

© Science Photo Library

A Schlieren photograph of a firecracker explosion detailing the cloud of gas, particles and blast wave that are generated



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Why are explosions deadly?

Capable of breaking the physical threshold of human tissue, explosions claim many lives

Explosions are deadly for a variety of reasons. The basis of any explosion is the rapid burning and decomposition of a material, a process that creates a large amount of heat, pressure and gas in a short amount of time. All these factors can have an effect on humans, as their physical thresholds to withstand the various forces and chemicals in play is easily broken. For example, the heat generated by an explosion of HMX (a nitroamine high explosive) reaches thousands of degrees Celsius in a matter of seconds, something that the skin of a human – which would be subjected to third-degree burns – could not withstand, with the skin tissues and structures being destroyed.

The force and velocity of the detonation is equally as deadly. The shock wave created by an explosion carries tremendous amounts of energy and can easily project objects of such light weight hundreds of feet. Fragmentation – the shattering of explosive casing and material in an explosion's immediate vicinity – too, in supersonic explosions, can cause severing and puncturing to human tissue. In addition, the force of any explosion is often increased if it is a consequence of the detonation of an explosive device. This is because many warheads, mortars, rockets, shells and bombs have shaped charges, as demonstrated in the example of C-4, a type of plastic explosive based on cyclotrimethylene-trinitramine (RDX). C-4 is deadly as it can be moulded into various shapes to increase its destructive potential.

Gunpowder

Since its invention by the ancient Chinese, gunpowder has been one of the most used explosives on Earth

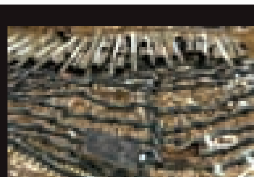
Gunpowder, unlike other modern explosives, is classified as a low explosive – an explosive that undertakes subsonic combustion – as it deflagrates slowly. For this reason, despite its creation over 1,000 years ago, it was still used as the explosive mechanism in guns all over the world up until the 20th Century, providing enough energy to propel a bullet out of a muzzle, but not enough to break the weapon and injure the user (of course, backfires and jams lead to bad injuries).

Modern rifle cartridges – the combination of a bullet, case, powder and primer – such as the one fired in the accompanying image, use smokeless powders (they are not actually smokeless, however, just considerably less so than conventional black powder), as their combustion efficiency is greatly increased, allowing rounds to be fired with less explosive. Further, smokeless powder does not leave heavy fouling (unwanted residue materials) within the weapon, allowing for semi and full automatic rifles to operate cleanly and efficiently.

This image shows the shock waves from the passage of the supersonic bullet and the muzzle blast, as well as a white cloud of propellant gas

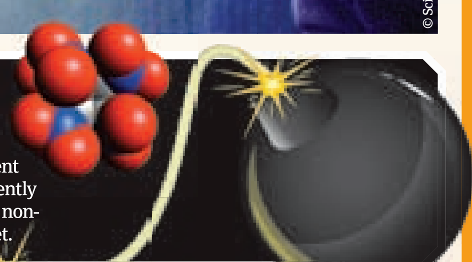
© Science Photo Library

1863AD
Trinitrotoluene: Trinitrotoluene or TNT for short, was created by German chemist Joseph Wilbrand in 1863. It is now used as the modern benchmark for all other explosives.



1950AD
C-4: A common type of plastic explosive due to its easy handling, C-4 is based on the explosive RDX and provides massive, yet refined, damage.

2000AD
Octanitrocubane: With performance roughly 25 per cent greater than HMX, this is currently considered the most powerful non-nuclear explosive on the planet.



“HMX is only used for specialist military purposes, such as a nuclear bomb detonator”

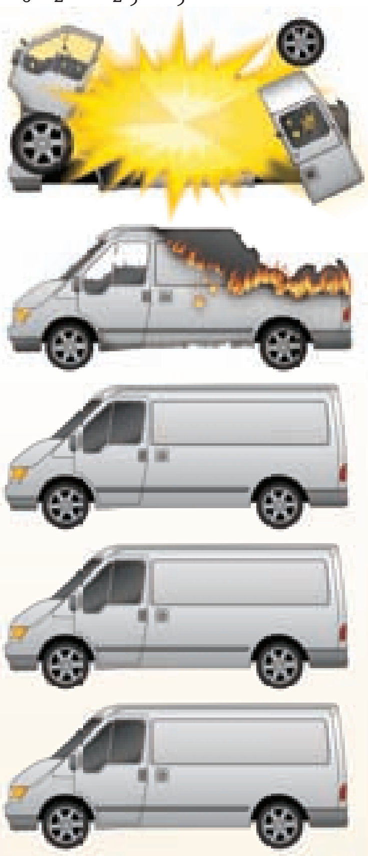
You were only supposed to blow the doors off!

Trinitrotoluene

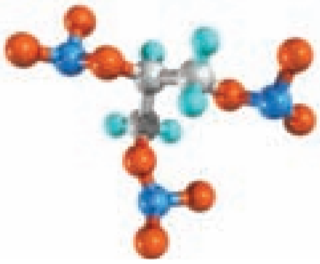
The first real breakthrough for explosives post gunpowder, trinitrotoluene is one of the most commonly used explosives on Earth. It was formed in 1863 and has an RE factor of 1.00.

Molecular formula:

$C_6H_2(NO_2)_3CH_3$



1.5/5
Small explosion. Detonation velocity of 6,900m/s.

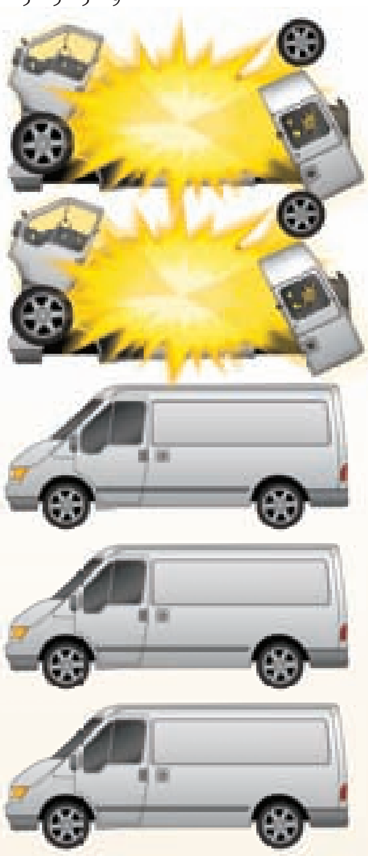


Dynamite

Based on nitroglycerin, dynamite has 60 per cent greater energy density than TNT. It was created in 1867 by renowned German chemist Alfred Nobel and has an RE factor of 1.50.

Molecular formula:

$C_3H_5N_3O_9$



2/5
Modest explosion. Detonation velocity of 7,700m/s.

C-4

Based on the explosive RDX, C-4 is the most famous plastic explosive used today. It is easily moulded into any shape (excellent for shaped charges) and has a high detonation velocity. It has an RE factor of 1.34.

Molecular formula:

$C_3H_6N_6O_6$

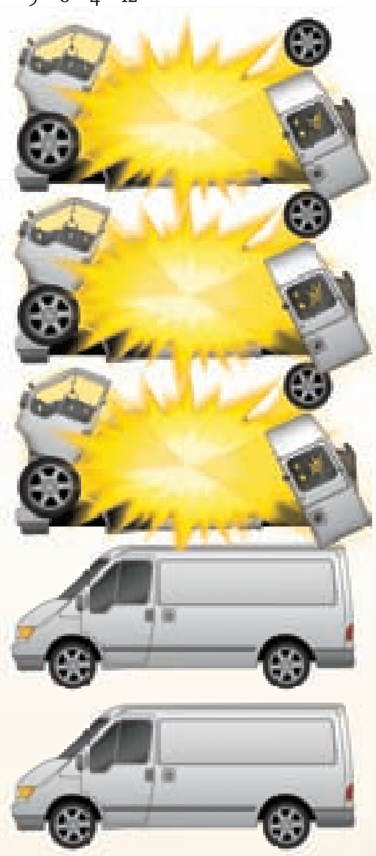
2.5/5
Large explosion. Detonation velocity of 8,040m/s.

Semtex

Another brand of plastic explosives used mainly in commercial and industrial applications, Semtex is a mix of RDX and PETN. It is brick-orange in colour and has an RE factor of 1.66.

Molecular formula:

$C_5H_8N_4O_{12}$



3/5
Great explosion. Detonation velocity of 8,420m/s.

BIG

1. Grand Slam
A British evolution of the T-12, the Grand Slam was a 10,000kg earthquake bomb used to eliminate strategic targets during World War II.

BIGGER

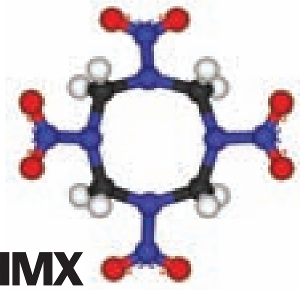
2. T-12
Designed by the US, the T-12 was a bomb employed to create an earthquake effect. It had a thick nose section so it could penetrate deep into the Earth.

BIGGEST

3. GBU-43/B
The Mother of All Bombs (MOAB) is a bomb developed by the US. It has a blast yield of 11 tons of mixed RDX, TNT and powdered aluminium.

DID YOU KNOW? In 1910 TNT was exempted from the UK's Explosives Act 1875 due to its large shock insensitivity

An Italian Job-style visual guide to the six most powerful non-nuclear explosives on the planet

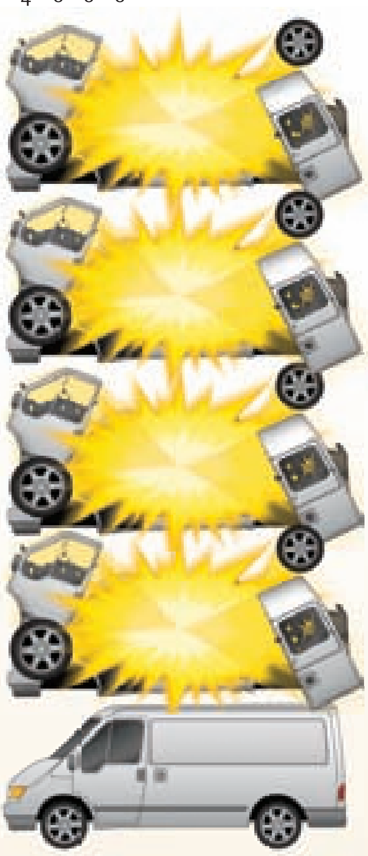


HMX

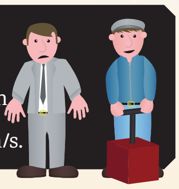
Related to RDX but much more explosive, HMX is a nitroamine high explosive. Difficult to manufacture, it is only used for specialist military purposes, such as a nuclear bomb detonator. It has an RE factor of 1.70.

Molecular formula:

$C_4H_8N_8O_8$



4/5
Massive explosion. Detonation velocity of 9,100 m/s.

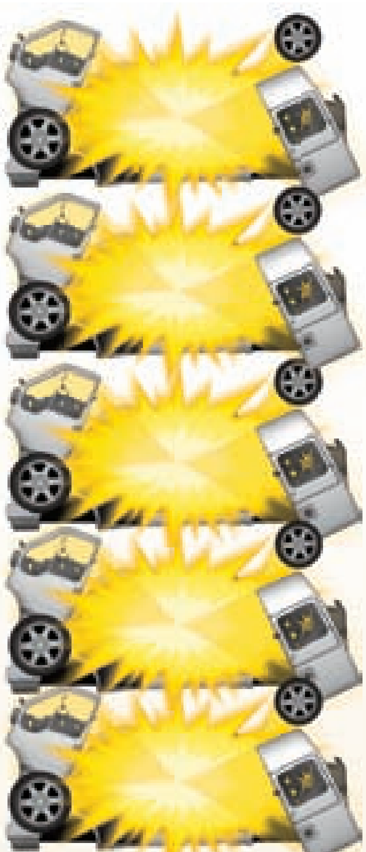


Octanitrocubane

The most explosive chemical structure on Earth, Octanitrocubane has 25 per cent greater performance than HMX. It was synthesised at the University of Chicago in 1999 and has an RE factor of 2.70.

Molecular formula:

$C_8(NO_2)_8$



5/5
Epic explosion. Detonation velocity of 10,100 m/s.

Explosions in nature

Explosions are not always man-made, with many natural examples visible over the Earth and in space

Organic – Many explosions are caused by plants and trees when subjected to hot and volatile conditions. For example, the Eucalyptus tree – which is predominantly found in Australia, New Guinea and Indonesia – is often prone to spontaneous combustion in periods of sustained heat and dry conditions. This is caused by the tree's high oil content (ie Eucalyptus oil) that rises above the bush as vapour when heated sufficiently creating a characteristic haze in dense forested areas. This oil, in both liquid and vapour forms, is incredibly flammable and if environmental pressure and heat reach critical levels, is prone to combust suddenly. This factor is severely exacerbated when a forest fire passes into Eucalyptus-heavy areas, as the resulting explosions and general flammability of the tree's bark carries and generates fire quickly.

Volcanic – Maybe the most obvious example of a natural explosion, volcanoes cause explosions when magma, which has risen to the Earth's surface, releases large amounts of accumulated dissolved gases into the atmosphere. This reduction in pressure above ground causes the gas to be separated from the magma and rapidly increase in volume, sending massive clouds of volcanic dust and particles spiralling into the atmosphere. Further, if a volcano's resulting magma flow reaches a water source, such as the ocean, then further steam-based explosions may be caused when the high-temperature flow meets the cold water, rupturing sections of coastline.

Stellar – The largest natural explosion currently known in the universe is that of a supernova, the resulting explosion that follows a dying star. Supernova explosions are ridiculously powerful and send the remnants of the star's material screaming out through space at a velocity up to 30,000km/s – that is ten per cent the speed of light – in a vast shock wave. Supernovas can be caused in a variety of different ways, however the most common is when the core of an aging star ceases to generate nuclear fusion, collapsing in on itself under the effects of gravity and expelling its outer layers as it releases its gravitational potential energy. During its short explosion (due to its size this would last several weeks or months) the amount of radiation of a supernova can total the entire amount it has ever radiated over its whole life span.

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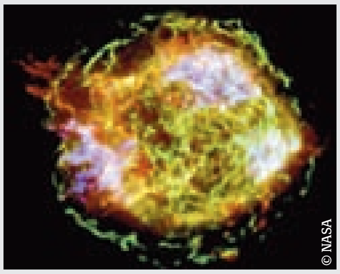
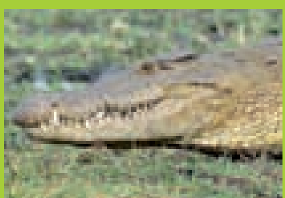


© NASA

This month in **Environment**

Anyone who was stuck abroad for a week or two while the Icelandic volcano Eyjafjallajökull endlessly spewed ash into the air might find our main Environment feature of added interest this month. We take a look at volcanic eruptions and the awesome power that lies just beneath the Earth's surface.



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Geysers

What drives these spectacular fountains of superheated water and steam?

Geysers form when water is superheated by volcanic activity underground, but can't move freely as it circulates towards the surface. Instead, pressure builds up until the water explodes upwards in a giant gush.

Since water needs to encounter hot rock, some geyser fields are found above upwellings of hot rock from deep within the Earth. Others are found near crustal plate boundaries where there is volcanic activity and broken, fractured rock. Rivers, snow or rainwater trickling through the Earth can provide a constant source of water.

Most geysers form where there's a silica-rich rock known as rhyolite. Rising hot water dissolves the silica in the rhyolite and carries it upwards through natural pipes in the rock where it's then deposited as a rock called geyserite. The silica seals the pipe against water pressure and narrows its walls.

Every geyser has a different plumbing and reservoir system, but there are two main types. 'Cone' or 'column' geysers like Old Faithful erupt in a steady column from a beehive-shaped nozzle of geyserite. They tend to have one reservoir of water with a single pipe leading from it to the surface. 'Fountain' or 'pool' geysers erupt from a large pool of water in a series of powerful bursts. They are thought to have a reservoir fed by two water sources – descending shallow, cold water and hot water rising from below.

As geysers need a rare combination of geological conditions to form, they're found in just a handful of places. There are around 50 geyser fields worldwide and most have just a few geysers. The biggest – Yellowstone, USA – has almost half the world's geysers.

Head to Head GEYSERS

TALLEST

1. Steamboat Geyser, Yellowstone
Major eruptions can shoot a column of water and steam over 300 feet (90m) into the air.

BEST-KNOWN

2. Old Faithful, Yellowstone
It 'faithfully' erupts every hour or so for up to five minutes, attracting thousands of onlookers every day.

BIGGEST EVER

3. Waimangu Geyser, New Zealand
The largest geyser ever recorded, Waimangu had super-eruptions up to 1,509 feet (460m).

DID YOU KNOW? Yellowstone's geysers sit above one of Earth's largest active volcanoes

How geysers work

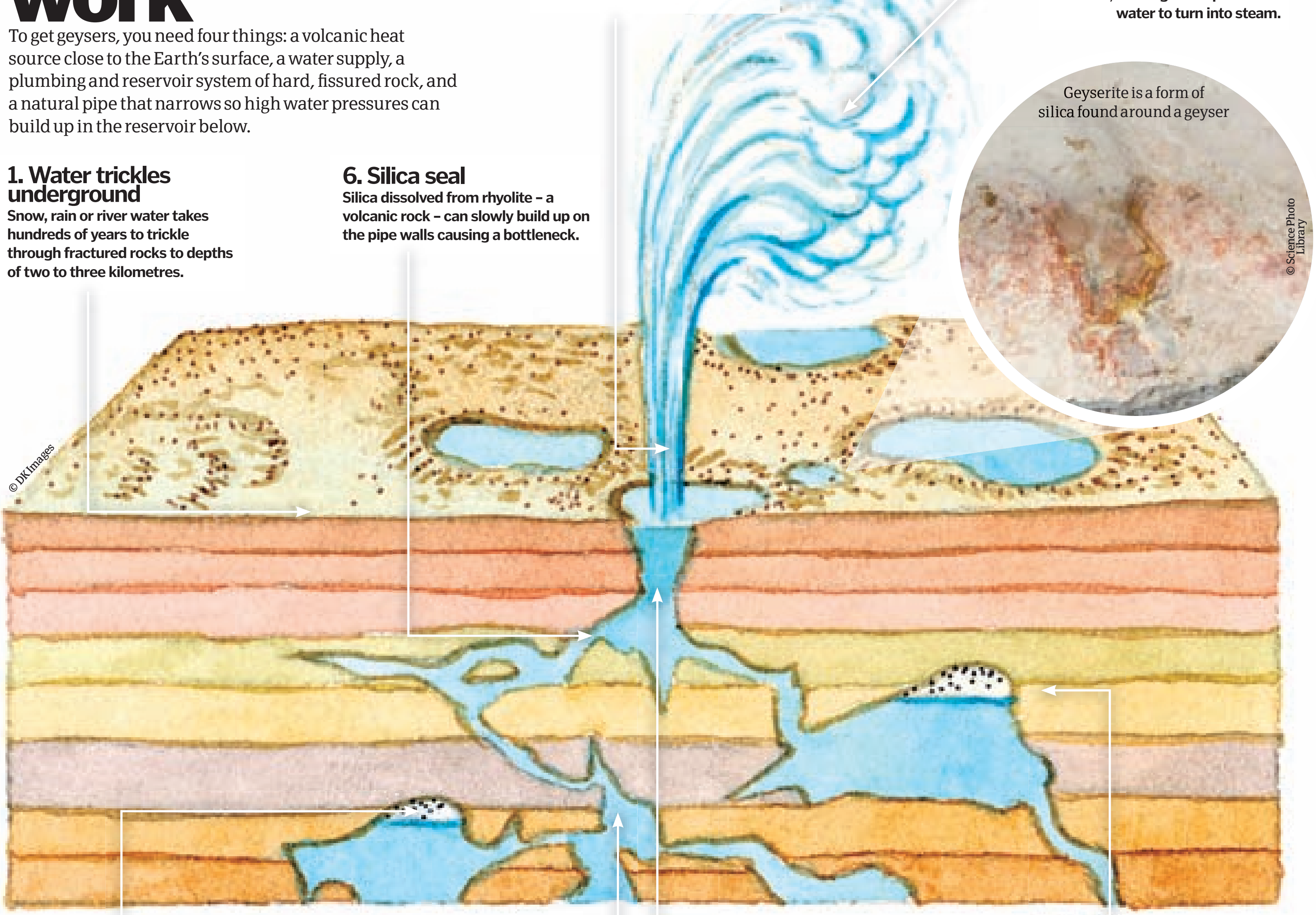
To get geysers, you need four things: a volcanic heat source close to the Earth's surface, a water supply, a plumbing and reservoir system of hard, fissured rock, and a natural pipe that narrows so high water pressures can build up in the reservoir below.

1. Water trickles underground
Snow, rain or river water takes hundreds of years to trickle through fractured rocks to depths of two to three kilometres.

6. Silica seal
Silica dissolved from rhyolite – a volcanic rock – can slowly build up on the pipe walls causing a bottleneck.

7. A sudden rush
Water pressure mounts below the bottleneck until it can overcome the weight of overlying, colder water and rush to the surface.

8. Sky-high water
The colder water above the superheated water is thrown up into the air as a jet. The pressure lifts, causing the superheated water to turn into steam.



Geyserite is a form of silica found around a geyser

3. Superheated water
The water is heated to very high temperatures, but it can't boil because of the pressure of the overlying water and rock. This is called superheating.

4. Plumbing system
The heated water circulates upwards via a complex, natural system of underground pipes and passages. As it does, the overlying pressure lessens and it can expand and boil.

5. High-pressure area
For a geyser to form, there must be a tight spot in the underground pipe system. This acts like a giant pressure cooker.

2. Hot rocks
The water comes in contact with hot rocks surrounding partially molten rock lying only a few kilometres below the Earth's surface.

ON THE MAP

The world's biggest geyser fields
1 Yellowstone National Park, US
2 Kamchatka Peninsula, Siberia
3 Taupo Volcanic Zone, New Zealand
4 El Tatio Geysers, Chile
5 Iceland
6 Umnak Island, Alaska

Hot and steamy

Geysers aren't the only hydrothermal features on Earth. Mudpots, hot springs, fumaroles and hydrothermal vents can also form when water is heated underground. However, unlike geysers, the heated water flows freely to the surface rather than erupting in a jet.

Where lots of water reaches the surface, hot springs form. Bacteria living in the hot water can give hot springs like Grand Prismatic Spring vivid, beautiful colours. Fumaroles – or steam vents – form where all the water is boiled away before reaching the surface. Hydrothermal vents or 'smokers' are like hot springs, but they form in the deep ocean near ridges and rifts.

"The strongest bite of any known creature, producing a force of around 5,000 pounds per square inch"

Earthworms

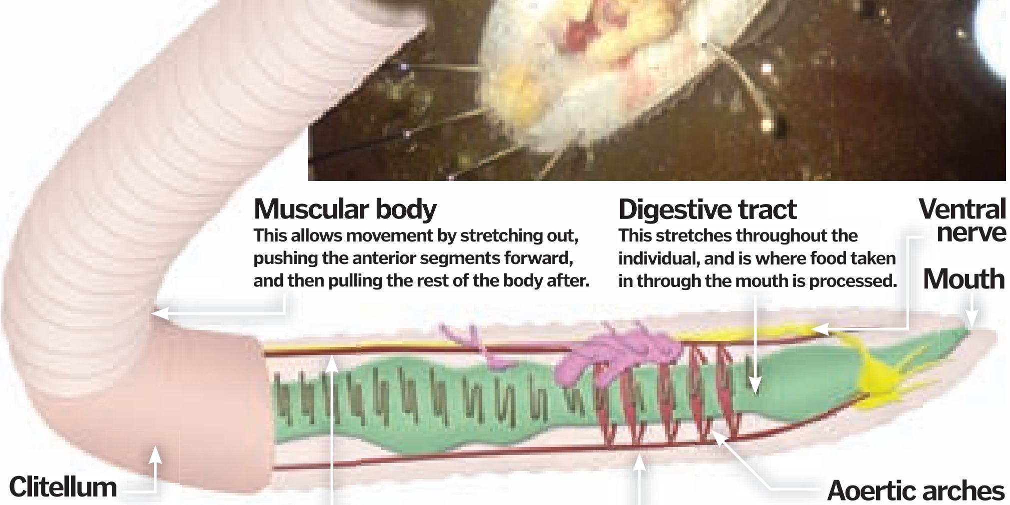
Worms are well known to us, often spotted in back gardens across the country – but more importantly, can they actually survive if they are cut in two?

Earthworms need moisture to survive and consequently commonly live underground in damp soil. They are cylindrical in shape, and their body structure is surprisingly simple with a muscular outside body that lines their digestive tract and circulatory system.

This circulatory system is very simple, with only two blood vessels (the dorsal and the ventral) which run between the anterior and posterior of the creature, with blood being pumped by aoertic arches in the case of the ventral vessel, or moved back to the anterior by the dorsal vessel contracting. However, although simple, earthworms do display distinct segments, which are more specialised towards the anterior (head). Consequently, segments situated further back in the body can be regenerated in many cases, but it is dependant on the type of species and the actual extent of damage.

Earthworms are also hermaphrodites, holding both male and female sexual organs, however they commonly mate and then store the other individual's sperm for reproduction.

Anatomy 101
Upon dissecting an earthworm it's easy to see the digestive tract wrapped in aoertic arches, transporting blood down the body.



Crocodile jaw

Why do crocodiles have the strongest bite of any creature known, yet are not able to open their jaw if we place an elastic band around it?

A crocodile has the strongest bite of any known creature, producing a force of around 5,000 pounds per square inch. The muscles that control this bite down have evolved and developed to be extraordinarily strong, and alongside relative speed over short distances on land and the immensely sharp teeth that crocodiles prominently display, this forms an immense weapon for the crocodiles to successfully hunt within a competitive environment.

However, although the jaw muscles used to snap the jaw shut are well developed, the muscles used to open the jaw are considerably weaker, so much so that if the jaw is taped shut or a large rubber band is put around it, the muscles are not strong enough to push up against the force created by these.


He hasn't lost a game of snap yet!

5 TOP FACTS AVALANCHES

The thick of it

1 A large avalanche might release up to 300,000 cubic yards of snow, which is equivalent to something like 20 football pitches covered with ten feet of snow.

The white killer

2 Each year, avalanches kill around 150 people – the victims are usually males in their twenties who are experienced mountaineers or skiers more likely to take risks.

Fresh snow = bad news

3 A snow-faring adventurer is most likely to witness an impressive avalanche during or just after a storm that has deposited around 30cm of fresh snow.

Breath of life

4 If caught under an avalanche, wait for the slide to stop and then use your hands to clear an area in which to breathe, then punch a fist upwards and outwards.

Intentional avalanches

5 When a lot of snow builds on a slope where an avalanche is likely, small avalanches are intentionally triggered using explosives to prevent one potentially deadly slide.

DID YOU KNOW? *A noise cannot trigger an avalanche; it's a myth – a plot device fabricated for films*

Avalanche!

What causes these often deadly snow slides?

Although the potential for an avalanche is present wherever you find a mass of snow on a slope, there are three main types of avalanche each dependent on several conditions: the type of snow in the snowpack, the temperature, wind, the steepness and orientation of the slope, and vegetation (or anchors).

1. Trigger

This disturbance is where the avalanche begins to fracture and it tends to be high up the slope but can still occur anywhere on a mountain. 90 per cent of fatal avalanches are triggered by the victims.

2. Starting zone

The starting zone is the section of the avalanche path at which the avalanche is released sending unsecured snow downhill. It normally occurs on a steep slope of between 30 and 50 per cent.

The avalanche path

This consists of the starting zone, the track and the run-out zone.

3. Track

The track is the main path down which an avalanche flows. The snow will either slide down as a sheet or concentrated in gullies. Towards the bottom of a track you may well see large piles of snow, boulders and tree remains.

4. Run-out (debris toe)

As the slope flattens out – or meets another slope – the avalanche will come to rest. This area is the run-out and consists of a pile of snow and debris picked up along the run. Any unfortunate victims would likely be found in this area of deposition. The very end of the deposited snow is referred to as the avalanche toe.

Main types of avalanches

Dry (80mph)

Occurring below freezing, dry avalanches are usually triggered by loading from new snow or blowing snow. These high-speed slides consist of air and powdery snow, beginning at a single point and gathering speed and mass. As it moves downhill, pressure builds ahead of the mass of snow, creating a powerful blast of air capable of destroying most things in its path.

Slab (60-80mph)

The most common – not to mention deadly – type of avalanche occurs when a layer of compacted snow overlies softer snow. When the weaker snow can no longer support the snow above – or if a passing skier adds to the weight – the hard layer (usually 30-80cm) will fracture like a pane of glass and slide away. If a victim is in the middle of the slab, they are unlikely to survive.

Wet (10-30mph)

Wet avalanches move slower than their drier relatives and occur as a result of rain or warmer weather melting the snow. Rain or humidity softens the snowpack, breaking the bonds between water molecules. Although wet avalanches are slower and don't feature a dust cloud, they are still highly destructive, capable of dragging boulders and even trees down the mountainside.

© Science Photo Library

Interview

We spoke to **Cam Campbell**, public avalanche forecaster for the Canadian Avalanche Centre, to find out more

How It Works: What are the most common avalanche triggers?

Cam Campbell: The most common triggers for all types of avalanches are natural; [including] loading from new snow, rain or blowing snow, rapid warming of the snowpack from an increase in air temperature or intense solar radiation, falling cornices, or other natural snowpack stressors. [...] Most fatal avalanches are human-triggered by the victim or someone in their party.

HIW: How and why are avalanches sometimes triggered intentionally?

CC: [Avalanches are triggered intentionally] to reduce the threat of future uncontrolled avalanches. Any time an avalanche is intentionally triggered, strict procedures, such as access closures and spotters are in place to ensure nobody will be adversely affected. Ski resorts or commercial backcountry operations often stabilise slopes by triggering avalanches before opening to the public. Intentional triggering can be achieved safely through remote-controlled explosives well away from the avalanche path, or hand- or helicopter-deployed explosives above the path.

Survival tips

The top ten survival tips for mountaineers and skiers

- ✔ Take avalanche safety course
- ✔ Read avalanche bulletin
- ✔ Choose route or terrain appropriate for conditions
- ✔ Carry and practise using safety gear (transceiver, shovel and probe)
- ✔ Never travel alone
- ✔ Avoid common trigger points such as convexities, thin areas, or below protruding rocks or trees
- ✔ Travel on avalanche prone slopes one person at a time and spot from safe locations
- ✔ If caught do everything in your power to escape the flowing mass
- ✔ If burial is imminent, create an air pocket in front of your face with hands and arms
- ✔ If buried, remain calm and await rescue

"The waterspout can carry items over large distances until it reaches land"

Hummingbirds

Like a cross between bird and insect, the hummingbird can beat its wings up to 80 times every second, but how?

Hummingbirds are tiny fliers that can flap their wings extremely fast – so fast in fact that they can hover. Not only that, the hummingbird can also fly up, down, sideways, backwards, and even upside down. The reason they can achieve such exceptional flight patterns is that they can rotate their wings in a circle, creating power on the upstroke as well as the downstroke. Hummingbirds use their unique 'hands', which are long bones at the end of their arms that support the wing. The wing itself is flexible at the shoulder but not at the wrist, helping the bird beat them fast without any bending.

5 TOP FACTS HUMMINGBIRDS

1 Variety
There are around 330 different species of hummingbird – and most are found in central and southern America.

2 A busy day!
The average hummingbird can flit from bloom to bloom and pollinate up to 2,000 flowers in a period of 24 hours.

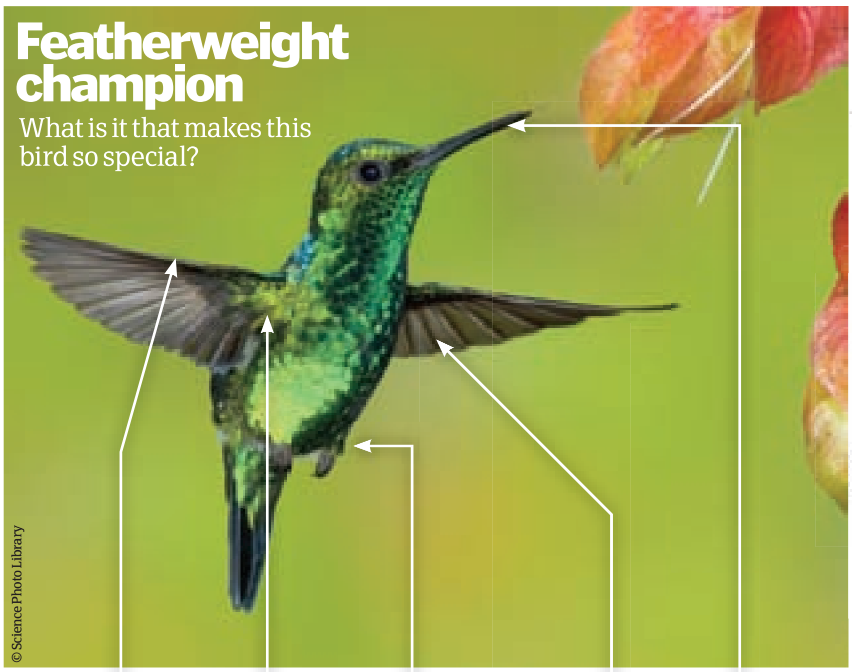
3 Heart of the matter
Just like humans, hummingbird hearts have four chambers, enabling very efficient oxygen transport. The hummingbird's heart can beat at 500 beats per minute (at rest!).

4 Fast flappers
Small hummingbirds can beat their wings 40-80 times per second, larger species 20-30 times and the giant hummingbird beats its wings as 'few' as ten times a second.

5 Feeling peckish?
Hummingbirds have the fastest metabolism of any other creature and so consume up to three times their own weight each day. Time between feeds can be just ten minutes.

Featherweight champion

What is it that makes this bird so special?



© Science Photo Library

Hands
These very long bones support the main wing feathers and allow the bird to beat its wings extremely quickly without having to bend the wings.

Feathers
Hummingbirds have a huge number of iridescent feathers but no down. Their tail feathers act as a paddle for steering while airborne.

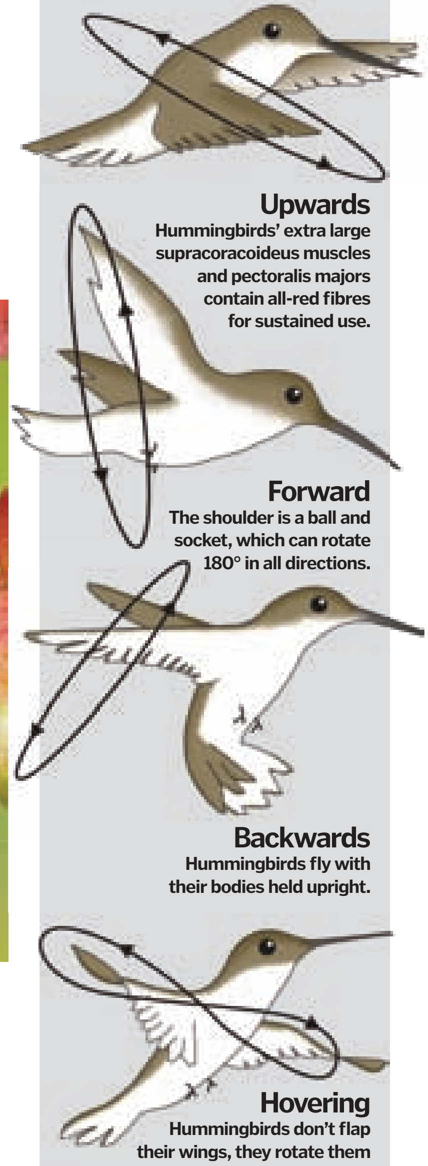
Feet
Hummingbirds do have feet, which they use for perching and scratching, but they cannot use them for walking – they fly literally everywhere.

Wings
Hummingbirds have short 'upper arms' and their elbow and wrist joints don't move. The shoulder joint can rotate 180˚ and move in all directions.

Bill
Hummingbirds feed on sweet nectar that they industriously collect through their especially long tapered bills and straw-like, hairy tongues.

Flight patterns

Hummingbird anatomy enables unique flight



Upwards
Hummingbirds' extra large supracoracoideus muscles and pectoralis majors contain all-red fibres for sustained use.

Forward
The shoulder is a ball and socket, which can rotate 180° in all directions.

Backwards
Hummingbirds fly with their bodies held upright.

Hovering
Hummingbirds don't flap their wings, they rotate them using their unique hands.

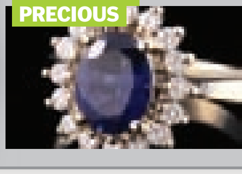
Raining fish and frogs

What is the meteorological phenomenon that causes animals and other objects to rain from the sky?

A waterspout is a kind of whirlwind that often forms over a large body of water during a thunderstorm. At the heart of the waterspout is a tunnel of low-pressure, which results in a vortex capable of sucking up not only water but also lightweight creatures near the surface. And because the waterspout is crossing water not land the animals collected tend to be fish and amphibious animals – not to mention other non-organic objects. The waterspout can carry these items over large distances until it reaches land. At this point the wind loses energy and releases the contents of the waterspout over the land – occasionally as a dramatic bombardment of fish or frogs.

Forget cats and dogs, it's fish and frogs!

PRECIOUS



1. Sapphire

Sapphires are commoner and cheaper than other precious stones. As with many gemstones, modern heat treatment can improve inferior sapphires.

MORE PRECIOUS

2. Emerald

Emeralds are rare because they require chromium deposited near a hydrothermal vent. This means that few emeralds are flawless.

MOST PRECIOUS

3. Ruby

Ruby is expensive because few large, deep red stones are actually found. Chromium reddens rubies, but also cracks them as they grow.

DID YOU KNOW? *The Black Prince's Ruby and Timur Ruby in the British Crown Jewels are a red gemstone called spinel*

1. Table (top)
This is the largest facet on a cut gemstone.

2. Crown (short side)
The crown is the top part of the gemstone that sits above the girdle.

5. Culet
A tiny flat facet that gemstone-cutters sometimes add at the bottom of a gemstone's pavilion.

4. Pavilion
The bottom part of the gemstone, below the girdle.

3. Girdle
The outer edge or the widest part of the gemstone forming a band around the stone.

Rubies, sapphires and emeralds

Their colour and scarcity make these beautiful gemstones a byword for love and luxury

Rubies, sapphires and emeralds are among the world's most beautiful, rare and valuable gemstones. Along with diamonds, they are called the precious stones. But amazingly, they are formed by crystal growth – the same process that creates table salt or snowflakes.

When any fluid cools, chemicals dissolved in it can be deposited in a regular structure – a crystal. Precious stones are crystals formed under heat and pressure in the Earth. They're rare because exactly the right chemicals must be present.

Coveted since antiquity, it wasn't until the 18th Century that people realised rubies and sapphires are crystals of the same chemical compound – aluminium oxide – called corundum. Ruby is corundum coloured red by traces of chromium. Sapphires can be any colour, except red, and are coloured by iron, titanium and other elements. They are formed when materials rich in aluminium and with little silicon and magnesium undergo heat and pressure, perhaps as continents crash together and mountains form.

Emeralds are made of a mineral called beryl – beryllium aluminium silicate. The bright grass green colour comes from traces of chromium and vanadium. They are often formed when chemicals are dissolved by water placed under intense heat and pressure by geological activity.

ON THE MAP

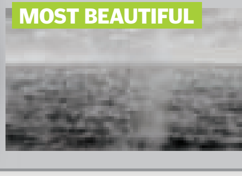
Where to find precious stones

Most rubies and sapphires are mined from river deposits. They're concentrated in placer deposits – heavy sediments left behind when a river slowed suddenly and could no longer carry them. Placers form at the base of slopes or in natural hollows. Famous sapphire and ruby deposits are found in Burma **(1)**, Sri Lanka **(2)** and Thailand **(3)**. In antiquity, emeralds were mined in "Cleopatra's Mines" in Egypt **(4)**. But today these deposits yield only poor-quality emeralds. Since the Spanish conquered South America, emeralds have famously been mined near Muzo, Chivor and Coscuez in Colombia **(5)**. Emeralds are found in Austria **(6)**, Russia **(7)** and several other countries too.

Valuing a precious stone

Four 'Cs' determine a gemstone's cost: colour, cut, carats and clarity. Gems are more expensive if they have an intense colour and no gas bubbles, liquids or other minerals trapped inside. The skill of the craftsperson who shaped a gem also affects its value: cuts are rated by their precision and how they enhance the gem's sparkle. The carat is a measure of the cut gem's weight – larger gems are rarer and more valuable.

MOST BEAUTIFUL



1. Steam fog

When a quantity of cold air flows over warmer water, the warm air next to the water rises, cools and gives it the appearance of steam.

MOST DANGEROUS

2. Haze

Fine particle pollution can cause breathing difficulties, skin, eye and throat irritation or even heart attacks in susceptible people.

MOST COMMON

3. Radiation fog

The UK's commonest fog forms on clear, still winter and autumn nights when the ground loses heat and then cools the overlying air.

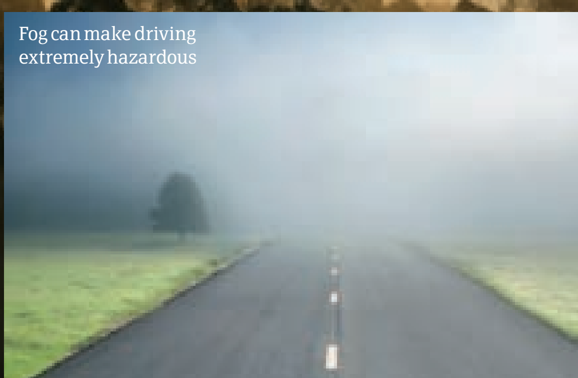
DID YOU KNOW? Fog is classified as reducing visibility to less than 1km, whereas mist reduces visibility from 1-2km

What are fog, mist and haze?

Discover how fog lets you walk through the clouds without leaving the ground

Fog and mist are ground-level clouds: they are formed of airborne water droplets. Fog is denser than mist – it prevents you seeing further than 1km ahead. In mist, you can see between one and 2km. Haze also makes the air less clear. But unlike mist and fog, it's caused by airborne particles of soot, salt or dust.

Fog and mist form when moist air near the ground cools enough that condensation occurs. Condensation is the mechanism that mists a mirror when you breathe on it. Air contains water vapour – the warmer the air, the more vapour it can hold. When the warm air in your breath hits the colder mirror, it cools. The vapour the air can no longer hold condenses out, ie water droplets form on the mirror's surface. Haze particles can be a precursor to fog because, in fog, water droplets form on particles in the air.



Fog can make driving extremely hazardous

© Milazinkova 2009

DID YOU KNOW?

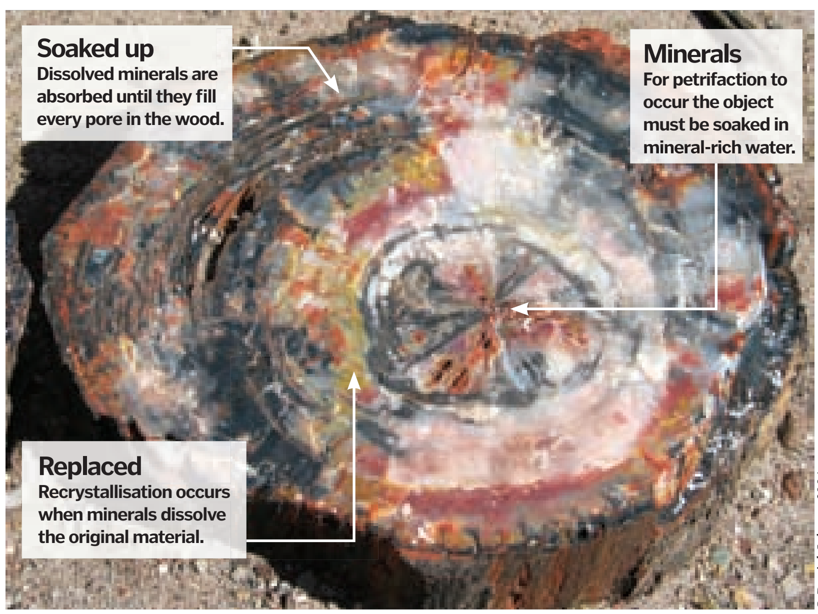
The 'Asian brown cloud' is a wintertime pollution haze over parts of Asia. It's big enough to see from space.

Petrifaction

What causes organic matter to turn to stone?

Petrifaction is a process of fossilisation that sees the solid remains of animals or plants turn to stone. The process occurs when organic matter is saturated in mineral-rich water – usually silica or the more soluble calcium carbonate. To prevent, say, a log from being decayed by bacteria, it must be sealed off from oxygen. Then, over time the log will soak up dissolved minerals until they either fill every pore in the wood (known as permineralisation) or completely dissolve the original material and replace it with minerals (recrystallisation).

Petrified forests around the world – such as the Petrified Forest National Park in Arizona – are full of fossilised trees from the Triassic period approximately 200 million years ago, but the length of time it takes for an organic object to petrify depends on such factors as pH and temperature and could take as little as 100 years.



© Daniel Schwen 2004

Volcanoes explained

Around the world, sleeping giants lie in wait for their 15 megatons of fame

Imagine the Earth as a giant ripe orange. Beneath the thin, dimpled peel is a thick layer of pulp and juice, 90 per cent of it liquid. The Earth's peel is called the lithosphere, a fragile crust of rock – 75-150km thick – that floats on a massive sea of impossibly hot, semi-fluid magma that extends 5,000km below the surface.

When German meteorologist Alfred Wegener first proposed his theory of "continental drift" back in 1912, people thought he was crazy. How could a colossal hunk of solid rock such as Asia or Africa possibly drift? As we now know, the continents are indeed solid, but they are fragmented into seven major plates and seven minor plates that eternally jostle for position like buoys on troubled water.

The engines that power this perpetual tectonic dance are giant convection currents in the Earth's molten mantle that slowly push magma upward and outward. Wherever rising magma manages to break through the thin lithosphere, it's called volcanism, but the vast majority of volcanoes aren't the explosive, violent variety. Instead, they are slow-bubbling cauldrons along a 60,000km underwater seam called the mid-ocean ridge.

The mid-ocean ridge is like an open, oozing wound in the crust where two oceanic plates diverge. The plates are pulled away from each other by the slow and steady convection currents and the gap between them is constantly refilled by thousands of unknown, unnamed underwater volcanoes. As this underwater lava cools, it creates new ocean floor covering 60 per cent of the Earth's surface.

Forget the orange analogy and think of the Earth's crust like a giant moving walkway in an airport. The walkway emerges from below the floor, travels a set distance and then rolls back underground. The divergent plate boundaries along the mid-ocean ridge are where the Earth's "moving walkway" begins. The diverging plates are carried along this magma conveyor belt – travelling only three to four centimetres per year – until they meet a plate moving in the other direction.

When two plates converge, something has to give. An incredible 90 per cent of earthquakes occur along convergent plate boundaries and so do the world's biggest and deadliest volcanoes. The prime example is the Ring of Fire, the unbroken string of seismic and volcanic activity that encircles the Pacific Ocean. The Ring of Fire is a giant subduction zone, where oceanic plates "dive" below continental plates and are melted back into magma in the blazing hot forge of the mantle.

Ocean sediment holds tons of water, carbon dioxide, sodium and potassium. When oceanic crust enters the blast furnace of the mantle, these sea-borne elements lower the melting point of surrounding rock, forming a gaseous, yet viscous magma that rises quickly toward the surface. If the rising magma reaches an obstacle – an impenetrable thick layer of solid rock – it pools below the surface, building increased pressure as more gaseous, volatile molten materials push up from below.

And then one day – boom! All it takes is a weak point in the cap of rock holding back the magma. On Mount St. Helens, a landslide cleared a swath of rock from the north flank of the mountain, lowering the downward pressure on the boiling pot of magma below. The result was an explosion that produced a monstrous pyroclastic surge – a wall of searing hot fluidised gas, debris and ash – that vaporised everything within a 500-square-kilometre area.

Some of the most famous and infamous eruptions came from subduction zone volcanoes ▶

"90 per cent of earthquakes occur along convergent plate boundaries and so do the world's biggest and deadliest volcanoes"

5 TOP FACTS VOLCANIC ERUPTONS

How many active?
1 There is some disagreement on what makes a volcano "active" but 1,510 volcanoes have erupted in the last 10,000 years. There are many more volcanoes on the sea bed.

Biggest in the world?
2 The biggest volcano in the world is Mauna Loa in Hawaii. Its whole volume is about 80,000 cubic kilometres. Its most recent eruption occurred on 24 March 1984.

Can they do good?
3 Volcanic slopes left after an eruption are very steep, so rare and delicate plants and animals can set up home there and be protected. Volcanic ash is very good for soil.

Eyjafjallajökull
4 The Icelandic volcano that caused so much disruption to European flights, the crater of the volcano measures 1.8 miles to 2.5 miles across (three to four kilometres).

Largest in the solar system
5 In the wider solar system, Mars is believed to hold the honour of housing the largest volcano – the 17-mile tall Olympus Mons. More on this next issue.

DID YOU KNOW? *The loudest noise in history was the eruption of Krakatoa in 1883, a 180dB explosion heard 3,500km away*

© Science Photo Library

Why volcanic eruptions can spark lightning

The mesmerising lightning storms that danced among the ash clouds of Iceland's Eyjafjallajökull volcano were caused by the same conditions that trigger regular thunderstorms. High in the black clouds of a rainstorm, hail and water droplets whirl and collide, freeing large amounts of electrons. Newly charged positive ions congregate in the upper portion of the clouds while the negative particles drift downward. When the charge separation becomes too great, a spark of lightning releases the pent-up energy, bringing the system back to equilibrium.

In a volcanic lightning storm, the same principles are at work. In this case, the colliding particles include ash, water and even hail. Electrical fields form within the ash cloud and the frequent and eye-popping lightning strikes (often in vivid purple and orange colours) resolve the charge separations. Another ingredient of volcanic lightning is electrically charged silica particles that are blown airborne from deep in the earth.

© Science Photo Library

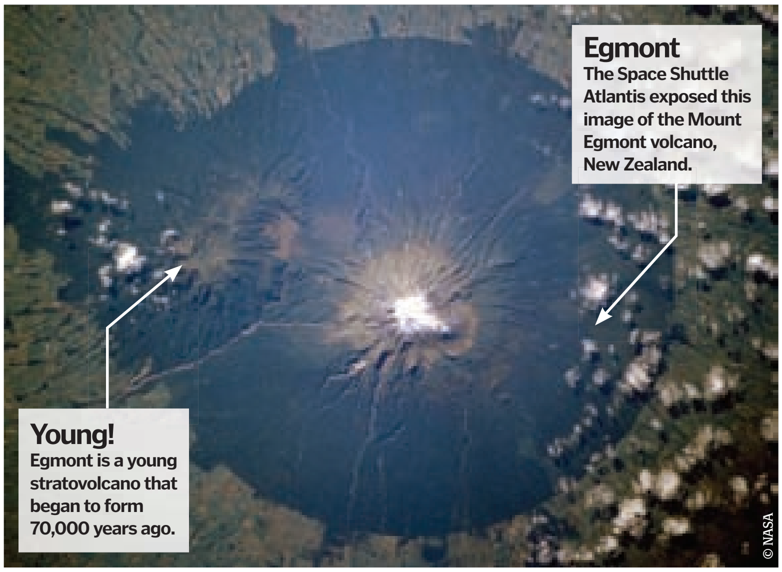
"Pyroclastic surges travelling 150 km/h can obliterate a city in seconds"

along the Ring of Fire: Tambora in Indonesia, Pinatubo in the Phillipines, Gagxanul in Guatemala, Mount Pelée in Martinique, the list of killer volcanoes goes on. In fact, 400 of the world's 500 known active volcanoes occur along subduction boundaries.

But not all famous volcanoes are of the subduction variety. The volcanoes of the Hawaiian Islands are an example of something called hot spot volcanism. Think back to those powerful convection currents in the mantle that push magma upward toward the crust. In certain 'hot spots' around the entire planet, convection currents are able to ooze magma to the surface with very little resistance.

Picture the hot spot under the Hawaiian Islands as a giant tube of toothpaste. Squeeze the tube and the little dollop of paste becomes the first Hawaiian Island, Kauai. Now keep the tube in the same place while the ocean plate travels a few hundred kilometres northwest. Squeeze the tube again and you've created the second island, Oahu. Hawaii, the Big Island, is still sitting over that magma pump, fuelling magnificent, slow-boiling eruptions that are literally building the island.

The intensity and duration of a volcanic eruption depends mostly on the consistency of the magma rising to the surface and the obstacles preventing the magma from reaching the surface. Subduction volcanoes are so ear-poppingly explosive because the magma fuelling them is loaded with gas bubbles and silica from sea floor sediments. The high silica content makes the magma more viscous, preventing gas bubbles from easily escaping. The result is like shaking a bottle of soda. When that pressure is released – pop!



Egmont
The Space Shuttle Atlantis exposed this image of the Mount Egmont volcano, New Zealand.

Young!
Egmont is a young stratovolcano that began to form 70,000 years ago.

© NASA

The hot spot volcanoes of Hawaii, on the other hand, feature highly fluid magma formed from basaltic rock with low silica content. The 'watery' quality of Hawaiian magma allows gas to escape easily. After an initial, relatively calm eruption, Hawaiian volcanoes spew fountains of lava forming large river-like flows that creep slowly to the sea.

The Hawaiian volcanoes Mauna Loa, Kilauea and Mauna Kea are the most closely studied volcanoes in the world, which is why different varieties of lava are classified with Hawaiian names. Pahoehoe is a highly fluid basaltic lava that cools with a smooth, ropy surface. A'a is a thicker lava carrying large chunks of pyroclastic debris like lava blocks and bombs. The result is a slow, jagged flow that cools with a very rough-looking texture.

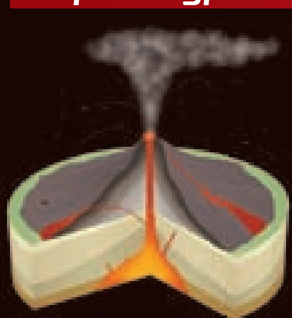
© U.S. Geological Survey/photo by Cyrus Read

Lava flow crossing a road during volcanic activity on Reunion, an island in the Indian Ocean

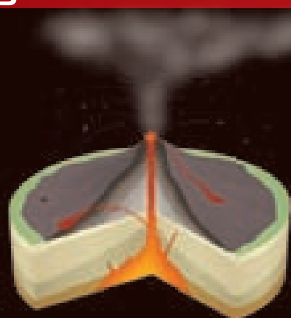
Types of volcanic eruption

Oozing, bubbling, spraying, fountaining, splattering, exploding! When magma reaches the surface, it's sure to be a memorable event. Check out the many different kinds of volcanic eruptions.

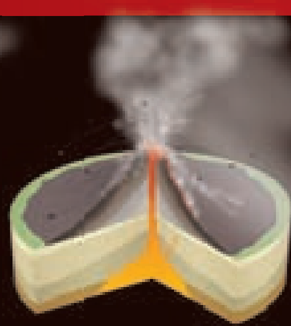
Eruption type: Magmatic



Strombolian
Huge gas bubbles rise and explode at the surface, shooting fast-cooling projectiles like lava bombs, glassy spatter and ash.



Vulcanian
Caused by the sudden release of a lava plug, these violent bursts of lava can send molten material several kilometres in the air.

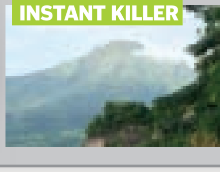


Pelean
Incredibly deadly, a towering wall of rock, debris and lava pour down the slope of a volcano at speeds upwards of 150km/h.

Hawaiian
The classic Kilauea-style eruption is where highly fluid lava 'fountains' spurt upward from long, narrow fissures or vents.

Head to Head
DEADLY ERUPTIONS

INSTANT KILLER



1. Mount Pelée

On 8 May 1902, a pyroclastic flow travelling at a rate of 160km/h incinerated the town of Saint-Pierre, Martinique, killing all but two of its 28,000 residents.

WORLD CHANGER

© NASA

2. Tambora

The largest eruption in recorded history, this Indonesian volcano's 1815 eruption took at least 71,000 lives, approximately 11,000 of those directly from the eruption.

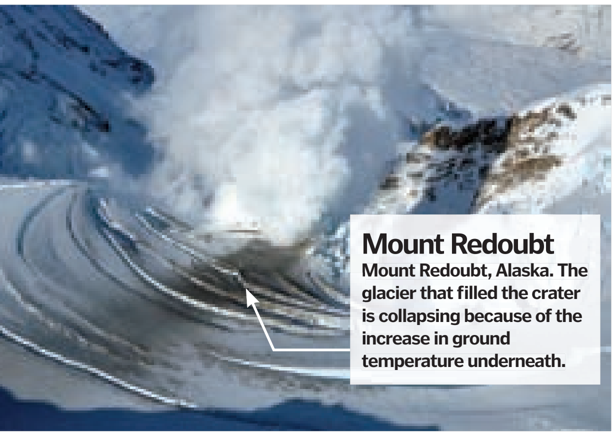
SUPERVOLCANO

© NASA

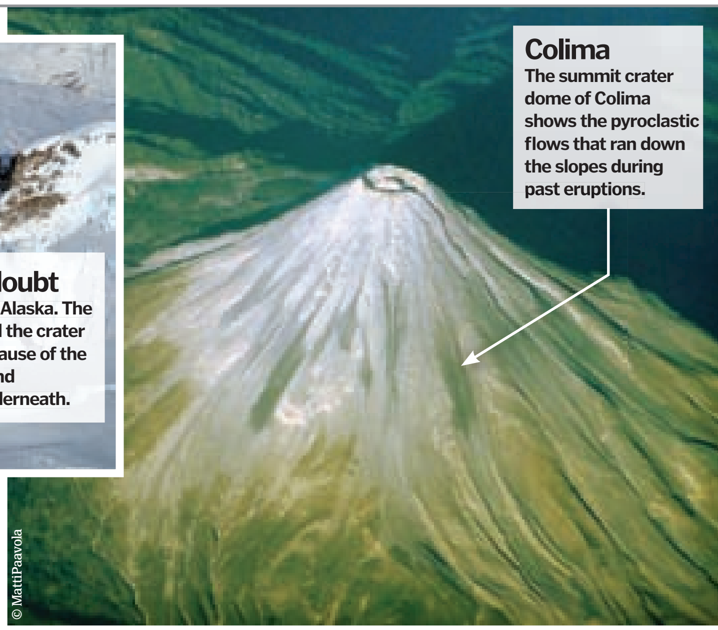
3. Yellowstone caldera

Over 500,000 years ago, an eruption 1,000 times as powerful as Mt St Helens blew the lid off of the western US, creating the Yellowstone caldera.

DID YOU KNOW? The ash from the 1815 eruption of Tambora created a "year without summer" as far away as New York



Mount Redoubt
Mount Redoubt, Alaska. The glacier that filled the crater is collapsing because of the increase in ground temperature underneath.



Colima
The summit crater dome of Colima shows the pyroclastic flows that ran down the slopes during past eruptions.

© MattiPaavola

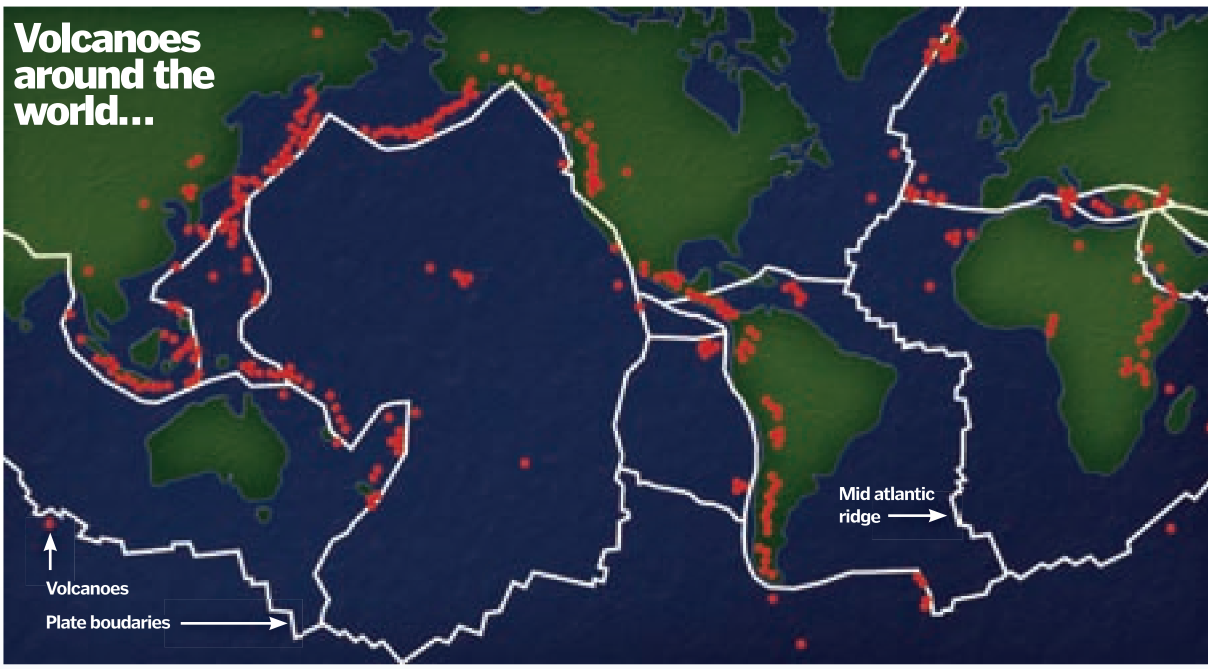
A colourful stromboli eruption

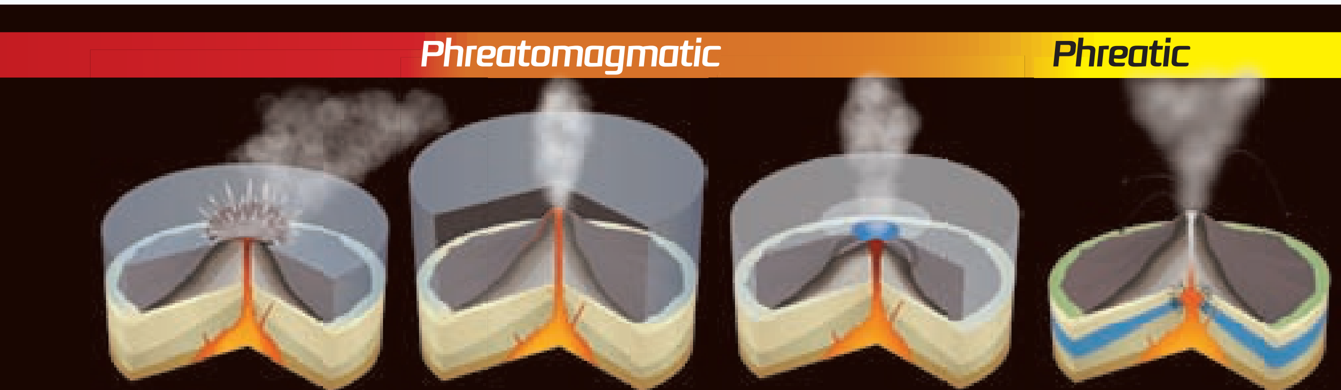
© Wolfgang Meyer

When a lava flow meets water, you get some lovely rounded formations called pillow lava, but if freshly emerging magma meets water, the results are far more explosive. A phreatic or 'steam blast' eruption discharges large rock fragments and ash, but little lava. The monstrous ash cloud that grounded flights across Europe for weeks was the product of magma meeting glacial ice. The ash from such an eruption isn't the soft, fluffy stuff that gets in your eyes when you have a campfire. Volcanic ash particles are hard, jagged fragments of rock, minerals and glass that can be up to 2mm in diameter.

The effect of a large-scale volcanic eruption is both local and global, immediate and long-term. Pyroclastic surges travelling 150km/h can obliterate an entire city in a matter of seconds, while a massive ash storm can block the Sun's rays so thoroughly that the Earth's surface temperature lowers for months, if not years. The 1815 eruption of Tambora in Indonesia spewed so much ash into the global atmosphere that it created a "year without a summer", complete with June snow storms in New York.

© Science Photo Library





Surtseyan
When a boiling underwater volcano breaks the ocean surface, the result is an explosive hydromagmatic reaction.

Submarine
Over 75 per cent of the magma that reaches the surface originates along the mid-ocean ridges that circle the planet.

Subglacial
When magma surfaces underneath a sheet of glacial ice, the combination can trigger a lahar, a mud and debris flow.

Phreatic
When emerging magma meets a body of water, the superheated water instantly vaporises, creating a monumental 'steam blast'.

Learn more

In the Discovery Channel's online video archives, you can watch 20 informative video clips from TV documentaries such as *Ultimate Guide To Volcanoes*, including rare footage of a pyroclastic flow **http://dsc.discovery.com/videos/volcano-video**.

For a video featuring our old friend Professor Iain Stewart (interviewed back in issue 6), check out **HIWTV** for a clip from NatGeo, which reveals how volcanoes brought Earth out of the Ice Age.

This month in **Transport**

Very much a testosterone-based Transport section this month. Cast your eyes to the right for an amazing breakdown of one of the deadliest aircraft in the skies today, and find out just what makes it such a formidable beast. Alternatively you could read up on the contenders for the land speed world record and find out what a 1,000mph car looks like. More sedate topics include hybrid buses, a look at the Wankel rotary engine and a closer examination of spark plugs.

50 Spark plugs

51 Hybrid drive buses

54 Race for 1,000mph

TRANSPORT

48 Apache Longbow
50 Spark plugs
51 Hybrid buses
53 Wankel rotary engine
54 Race for 1,000mph

AH-64D Ap

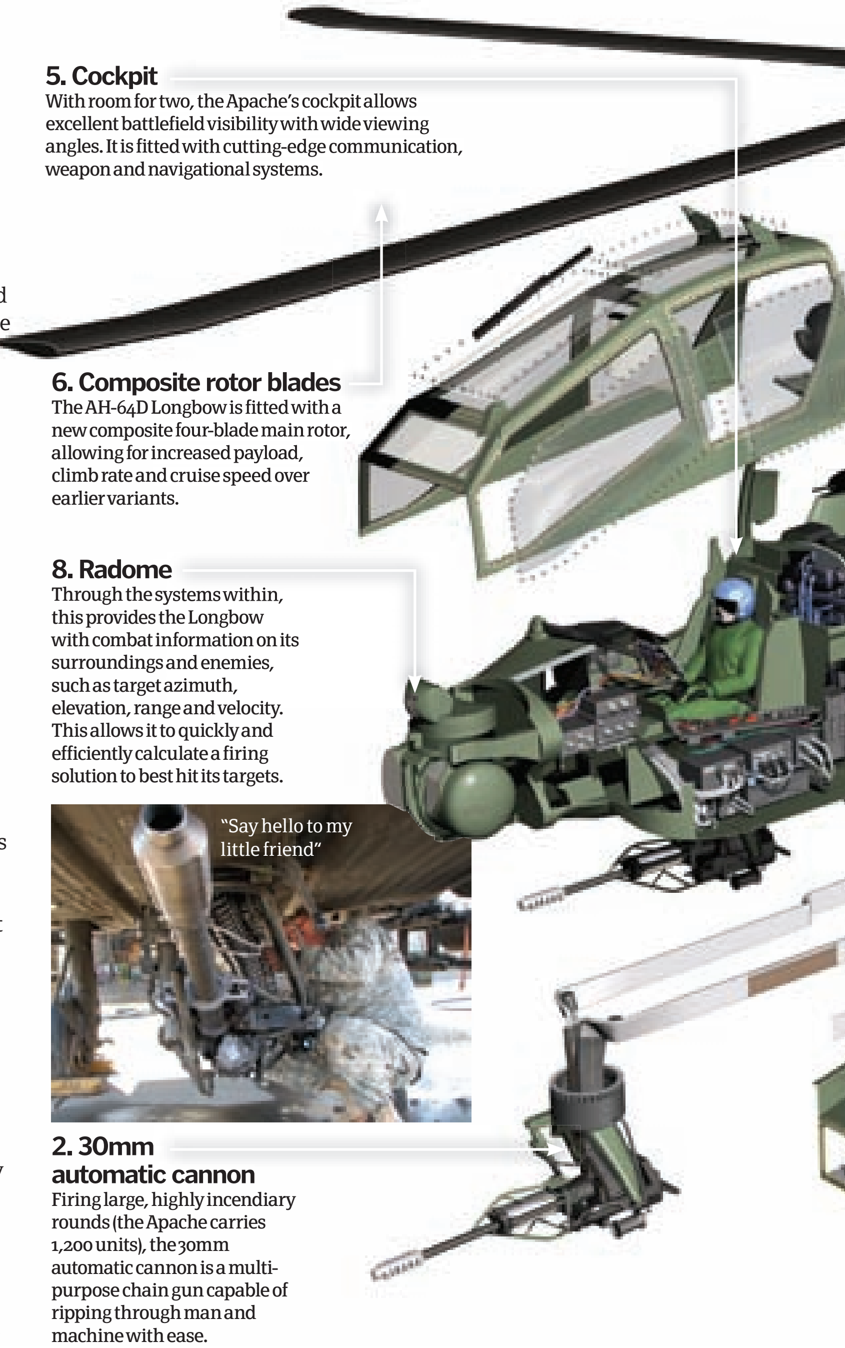
The latest iteration of the combat-tested Apache gunship, the AH-64D Longbow is a powerhouse of performance, bringing massive damage and flexibility to the theatre of war

Emerging as the next generation of multi-mission attack helicopter, the AH-64D Apache Longbow is changing the face of warfare today. Currently in operation in Iraq and Afghanistan, and used by armed forces all over the world, its military performance is well-recognised and has proved itself both combat-ready and reliable over the last 13 years of service.

The AH-64D Apache Longbow is the latest iteration of the Apache class of gunship as produced by Boeing. Differentiating it from earlier models, the AH-64D Longbow is now fitted with a fire-control radar above its four-blade composite main rotor. This allows it longer-range weapons accuracy, cloaked object detection (both moving and stationary), classification and threat-prioritisation of up to 128 targets in less than 60 seconds and greater situational awareness, real-time management of the combat arena and digital transmission of target locations.

Married to these advanced systems is an armament to make the most armoured target rethink their strategy. Topping this list of destruction is the Apache's Hellfire missiles – dedicated laser-guided anti-armour missiles that make short work of tanks, bunkers and artillery. The Longbow is also fitted with a brace of 70mm rockets, which can be fired off in quick succession and provide awesome power and flexibility when up against numerous targets. Lastly, mounted on its underside is the AH-64D's 30mm M230 chain gun. Holding 1,200 30mm high-incendiary rounds, and controlled remotely by the pilot through his helmet – allowing hands-free targeting and tracking – the M230 chain gun is capable of laying down a phenomenal amount of damage and is ideal for clearing enemy soldiers on the ground.

As of 2008 onwards, the AH-64D has also been upgraded to include increased digitisation, a joint tactical radio system, enhanced engines and drive systems, capability to control UAVs (unmanned aerial vehicles) – which have been used extensively in the Iraq and Afghanistan wars – and improved landing gear. Currently, the Apache AH-64D Longbow is operated by America, Egypt, Greece, Israel, Japan, Kuwait, Netherlands, China, Singapore and the United Arab Emirates, with many other countries operating earlier variants.



5. Cockpit
With room for two, the Apache's cockpit allows excellent battlefield visibility with wide viewing angles. It is fitted with cutting-edge communication, weapon and navigational systems.

6. Composite rotor blades
The AH-64D Longbow is fitted with a new composite four-blade main rotor, allowing for increased payload, climb rate and cruise speed over earlier variants.

8. Radome
Through the systems within, this provides the Longbow with combat information on its surroundings and enemies, such as target azimuth, elevation, range and velocity. This allows it to quickly and efficiently calculate a firing solution to best hit its targets.

"Say hello to my little friend"

2. 30mm automatic cannon
Firing large, highly incendiary rounds (the Apache carries 1,200 units), the 30mm automatic cannon is a multi-purpose chain gun capable of ripping through man and machine with ease.

MOST FUTURISTIC
1. Blue Thunder
A troubled Vietnam war veteran and pilot is forced to battle baddies and the government to stop the 'Blue Thunder' attack helicopter being used for evil deeds.

CHEESIEST
2. Fire Birds
Fresh out of the Apache Air Combat School, gifted but arrogant pilot Nicholas Cage must take down a South American drugs cartel.

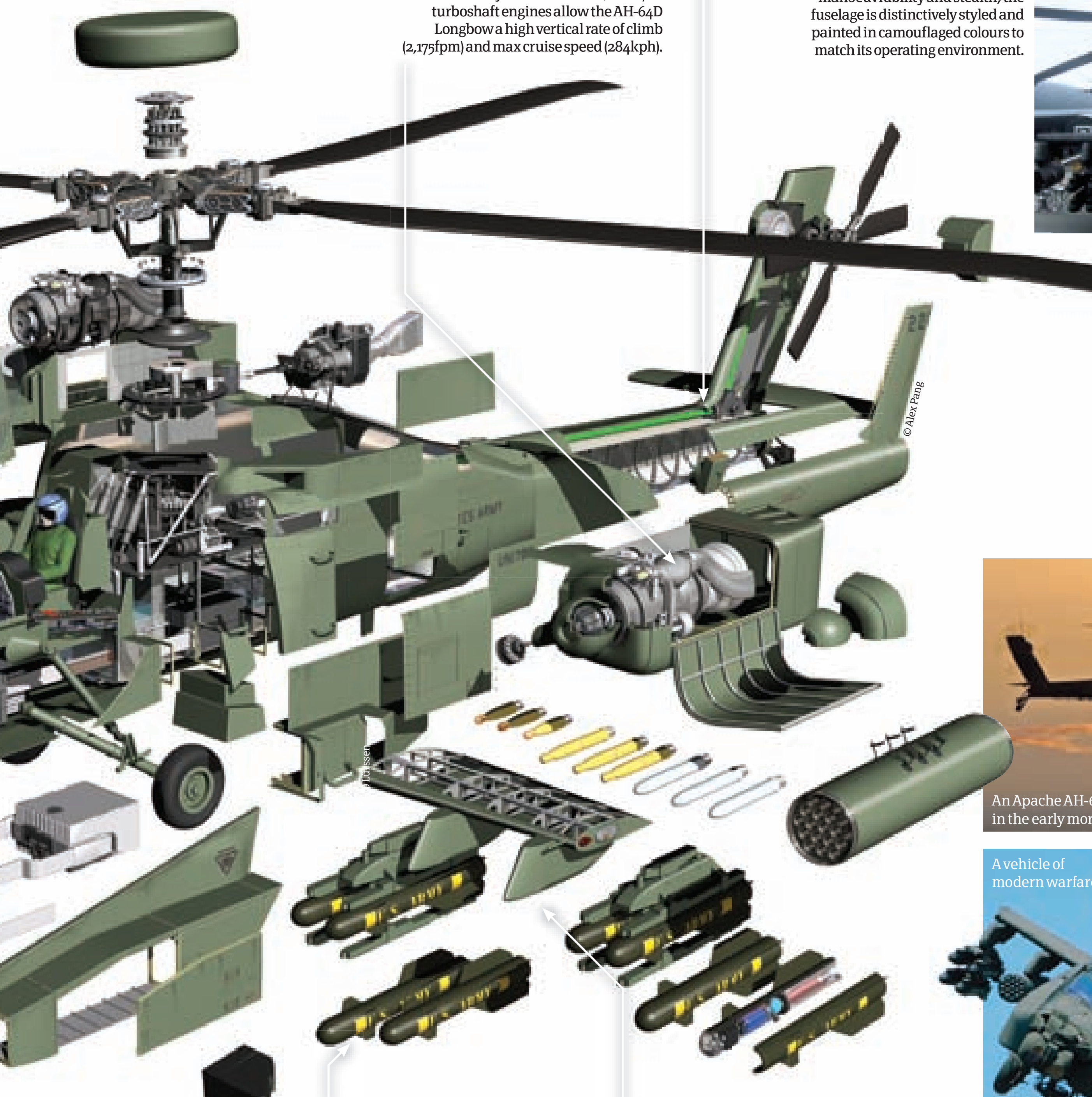
MOST UNBELIEVABLE
3. Airwolf
A renegade pilot steals a helicopter capable of flying halfway around the world on one tank and with a top speed that allows it to outrun jet planes. The TV show ran for 79 episodes!

DID YOU KNOW? *The AH-64A was first given the Apache name in late 1981, and went into full-scale production a year later*

ache Longbow

1. T700-GE-701C engines
Produced by General Electric, the T700 turboshaft engines allow the AH-64D Longbow a high vertical rate of climb (2,175fpm) and max cruise speed (284kph).

7. Fuselage
Designed for lightness, manoeuvrability and stealth, the fuselage is distinctively styled and painted in camouflaged colours to match its operating environment.



The Statistics

AH-64D Apache Longbow

Length: 58.17ft (17.73m)
Height: 15.24ft (4.64m)
Engine:
Twin turboshaft T700-GE-701C
Max speed: 284kph
Cost: $15.4 million
Number produced:
1,174 (Feb 2010)
Armament:
Hellfire missiles, 70mm rockets, 30mm M230 chain gun


An Apache AH-64 fires flares in the early morning


A vehicle of modern warfare

3. Laser-guided Hellfire missiles
Multi-platform and multi-target, these laser-guided modular missiles are excellent at taking down enemy armour and structures.

4. 70mm explosive rockets
Fast firing 2.75-inch rockets allow the Apache to support ground troops in any assault, destroying enemy soldiers, strongholds and vehicles.

"The spark plug has a tough life"

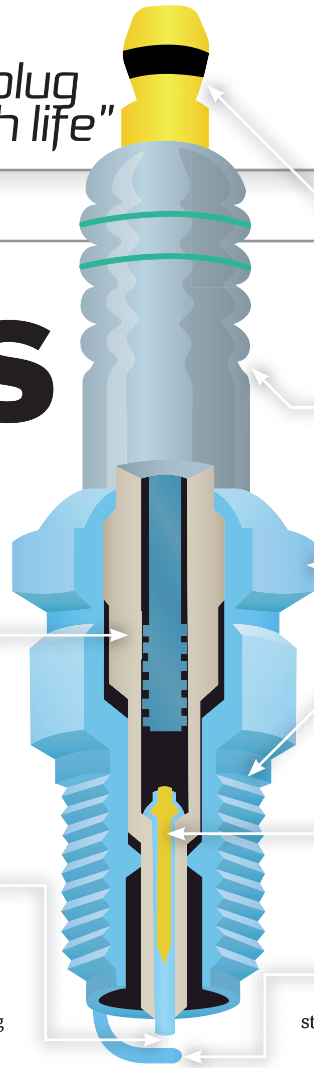
Spark plugs

These little detonators set off mini explosions and are at the heart of almost every petrol engine

Petrol-powered internal combustion engines rely on a mix of air and petrol exploding, and the resulting force pushing a piston down. This happens many times a second – and each explosion has to be ignited somehow.

This is done by creating an electrical spark inside the cylinder, at just the right moment and in just the right place. A high voltage (typically 25,000 volts) arcs across a gap between two metal electrodes to create the spark. These electrodes are contained within a spark plug, that can easily be removed from the engine for maintenance or replacement. There's usually one spark plug per cylinder, although some engines have twin plugs per cylinder.

Little has changed since its invention in the mid-19th Century, and the spark plug has a tough life. It has to withstand very high temperatures, contain high voltages, survive repeated electrical arcing, contend with petrol and carbon deposits and act as a seal to the high pressures inside the cylinder. Finally, though, its ability to cope with all this fails and the plug is thrown away and replaced with a new one.



5 TOP FACTS HYBRID TRANSPORT

Railpower Technologies Corp. crane
1 A Vancouver firm has designed a hybrid diesel-electric crane for unloading ships; energy used to lift containers is regained when they're lowered.

Toyota Prius
2 Probably the most famous hybrid, Toyota introduced the world to hybrid motoring with the Prius. The latest version boasts some of the lowest CO_2 emissions of any car.

Autorail à Grande Capacité
3 This hybrid-electric train runs in France. This is dual-mode, so can run using both diesel-electric drive, and electric energy from a DC motor.

Boeing 737-800
4 Boeing has designed a fuel cell/lithium-ion hybrid to power an electric motor driving a traditional propeller. The fuel cell powers the plane during cruising.

Hybrid submarine
5 Diesel-electric submarines run on battery power when they are submerged, and these batteries are then recharged by the diesel motor when it resurfaces.

DID YOU KNOW? HybriDrive allows future green-fuel technologies to be installed to further its eco credentials

Hybrid bus

All Images © 2010 BAE Systems

30% greener and with the potential to become fully zero-emission, the hybrid double-decker has arrived

The hybrid bus has been in New York since 1998 and the fleet has covered over 150 million miles. Now, aided by a £30m British Government grant, it's coming to the UK. The Enviro400 bus will be key to delivering 300 hybrid buses to UK roads, starting this summer.

It looks like any other double-decker. The key components of the HybriDrive technology – starter-generator, electric drive motor, propulsion control system and lithium-ion energy storage batteries – is integrated into the bus structure; electric power connected by cables allows such remote placement.

Electronics form the heart of BAE's HybriDrive system. Power management of electrical energy is controlled by a propulsion system by the engine. Using fast and flexible multiplex CAN wiring and extensive on-board diagnostics, it can link all components and distribute 320kW of electricity.

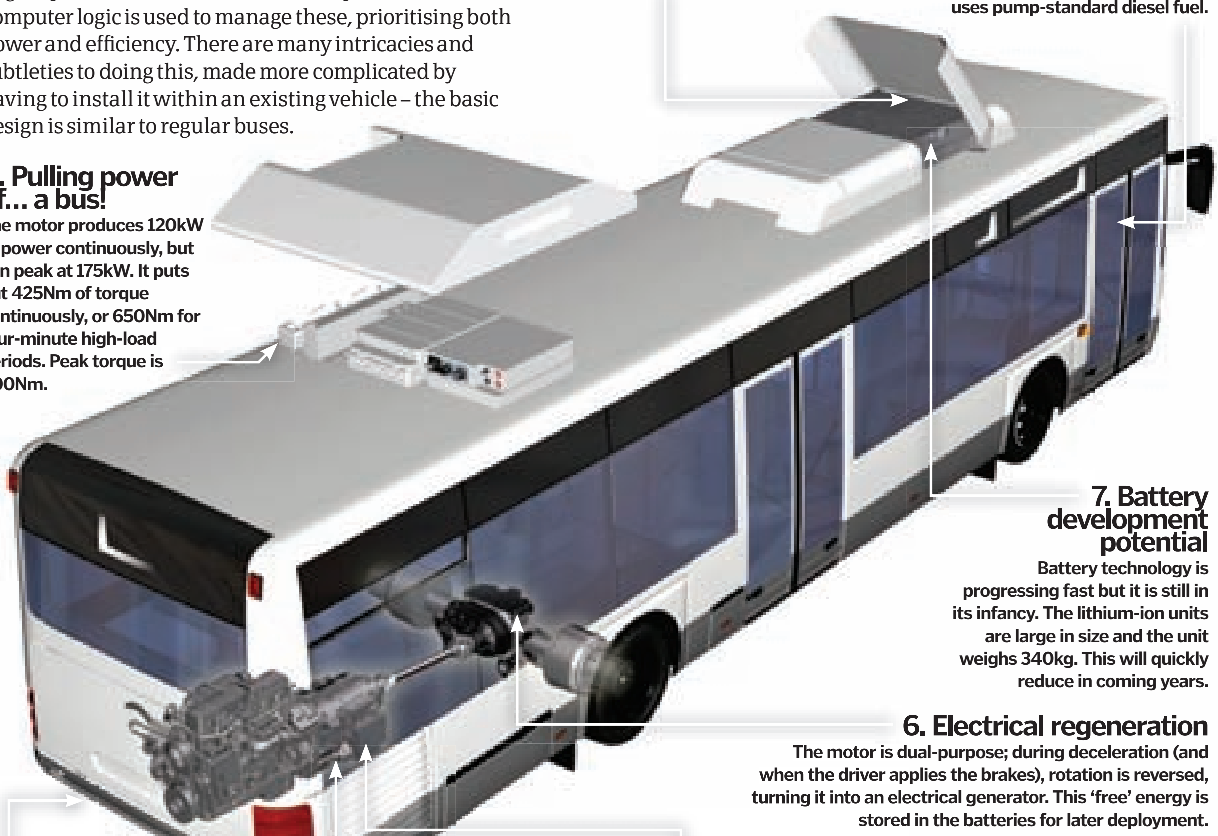
145kW of electrical energy is produced by a generator attached to the diesel engine. It also functions as a starter motor, meaning the diesel automatically switches off when stationery, yet is rapidly restarted. Surveys show traffic in city centres can spend 30 per cent of the time stationary.

An electric air conditioning compressor draws no engine power and can run on energy from regenerative braking. Acceleration is smooth due to the fact there's no gearbox – the electric motor drives the wheels directly. Any excess energy not used for driving is stored in a lithium-ion energy storage system, for a 'boost' during demanding acceleration. Under braking, the motor turns into an electrical regeneration system, further charging the batteries.

Hydrogen fuel cells will eventually replace the diesel engine, making this a true zero-emission bus capable of running independently of fossil fuels.

Computer power catches the bus

The BAE Systems HybriDrive technology is a combination of five components: a high-efficiency diesel engine plus four electrical-control components. Computer logic is used to manage these, prioritising both power and efficiency. There are many intricacies and subtleties to doing this, made more complicated by having to install it within an existing vehicle – the basic design is similar to regular buses.



4. Pulling power of… a bus!
The motor produces 120kW of power continuously, but can peak at 175kW. It puts out 425Nm of torque continuously, or 650Nm for four-minute high-load periods. Peak torque is 900Nm.

5. Lithium-ion batteries
Batteries are nanophosphate lithium-ion units. Nanotechnology cures low electrical conductivity issues, and phosphate is safe and produces a high current.

8. Little change for the driver
Few new driving techniques are needed to operate the HybriDrive bus. The stationary engine cut-off is fully automatic and the driver is presented with familiar vehicle controls. It also uses pump-standard diesel fuel.

7. Battery development potential
Battery technology is progressing fast but it is still in its infancy. The lithium-ion units are large in size and the unit weighs 340kg. This will quickly reduce in coming years.

6. Electrical regeneration
The motor is dual-purpose; during deceleration (and when the driver applies the brakes), rotation is reversed, turning it into an electrical generator. This 'free' energy is stored in the batteries for later deployment.

1. Exhaust
Urea from a separate chemical tank is injected into exhaust gases. This bonds to particulates in the exhaust, reducing nitrogen oxide emissions.

2. Fuel cell future
As the engine is independent of the road wheels, it is easy to replace in the future.

3. Super-efficient engine
By running in its optimum speed range, the engine is up to 70 per cent more efficient than a conventional engine that runs over a wide range. The capacity is also half the size of a normal bus.

Hybrid power

BAE HybriDrive buses are hybrid machines propelled by electric drive. Energy is produced by a downsized 4.5-litre diesel engine. Operating separate to the wheels, engine turnover speed can be independently controlled: it can run in its 'sweet spot' where the max pulling power is at peak efficiency. The generator converts this mechanical rotation into electrical energy to drive the propulsion motor. For this, it uses a permanent magnet system, which is efficient but very large (the unit weights 135kg here).

The rotation of the diesel engine turns a shaft linked to the generator. On the shaft are permanent magnets, within two rotors. When rotated, magnetic flux passes from one rotor to the other through a stator. This moving flux produces electrical power. Coils are mounted on the stator, and through these electricity is harvested.

Head to Head WANKEL-ENGINED CARS

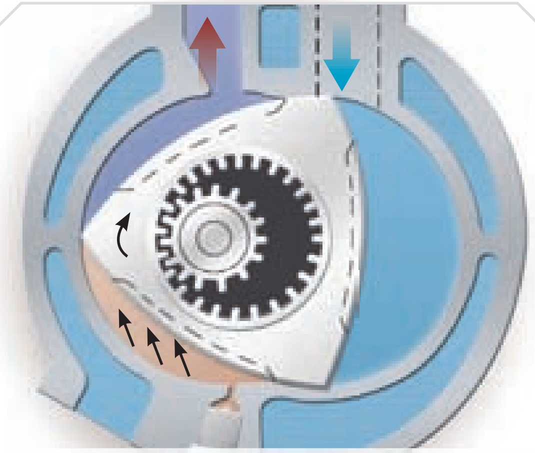
1. Mazda 787B
1991 Le Mans winner that produced 700bhp from a non-turbocharged 2622cc Wankel engine. The only Japanese car to win the historic 24-hour race.

2. Mazda RX-8
Today's only production Wankel-engined car, the RX-8 produces 230bhp, hits 62mph in 6.4 seconds and has a top speed of 146mph.

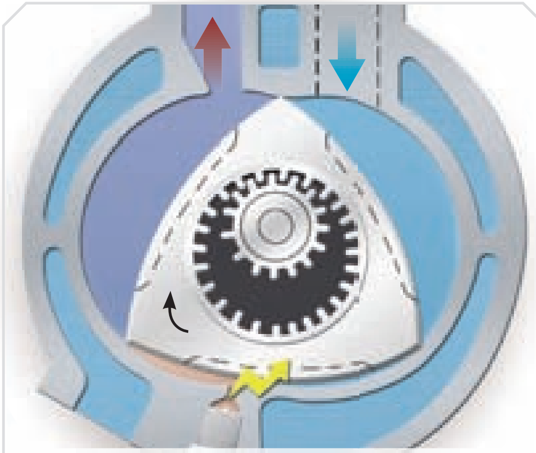
3. NSU Spider
This was the first production car to use a Wankel engine, back in 1964. The 50bhp engine was mounted in the back of the open-top car.

DID YOU KNOW? Felix Wankel developed his engine while working at German car maker NSU, which evolved into Audi

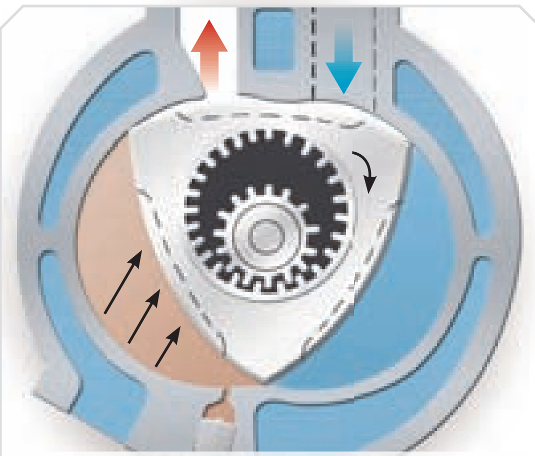
The combustion cycle



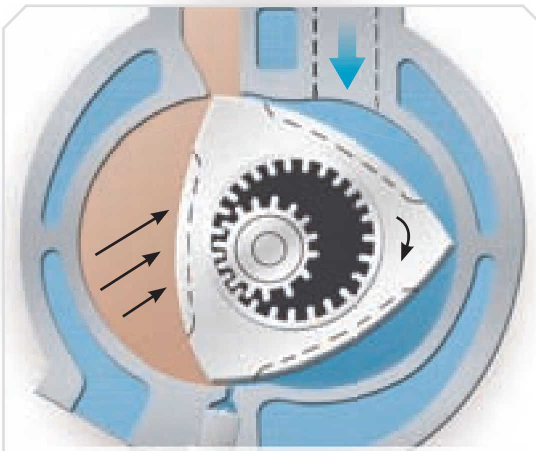
1. Intake
When the top-most rotor tip just passes the intake port, air and fuel is drawn into what will become the combustion chamber. As the rotor continues to turn, the inlet port is sealed off and the air/fuel mixture is compressed.



2. Compression
As the chamber with the air/fuel in reaches the spark plug (there are often two), the mixture is fully compressed and ready to be ignited by the spark, which takes place as shown on the diagram.



3. Combustion
The resulting explosion causes an expansion of gases which pushes the rotor around, therefore creating power that is transferred to the transmission and can propel the vehicle forward.



4. Exhaust
Finally, the exhaust port is opened as the rotor tip passes it, and the spent gases are forced out of it, as the exhaust chamber reduces in size. Note that the next stage of the cycle is already in progress.

Where you'll find a Wankel

Although there have been various cars with rotary engines over the years, only Mazda has continued to embrace and develop the technology, with its RX-8 sports car being its current Wankel-engined car. Mazda has also had considerable success in motorsport with rotary engines.

Wankel engines have been used in aircraft since back in the Sixties and are becoming increasingly popular for aviation use. As well as being potentially safer, they are also more compact (useful when one is mounted at the nose of a plane) and tend to be quieter, which is also an important consideration in today's environmentally aware world.

Small Wankel engines with capacities of around 50cc are used in model aeroplanes. Smaller still, are micro Wankel engines used in micromachines. These are as small as 1mm in diameter and have a capacity of just 0.1cc.

At the other end of the scale, massive 41-litre Wankel engines are used for driving compressors for pumping gas along pipelines.

The cylinderless engine

The Wankel engine uses a rotary design in place of pistons and cylinders. It's more efficient but remains a quirky solution

Despite a name guaranteed to make schoolboys snigger, the Wankel engine is a seriously clever invention.

Devised by German engineer Felix Wankel in the Fifties, it gets rid of the usual complexities of pistons, cylinders, connecting rods and such like, and replaces them with a three-sided symmetrical rotor that spins inside a specially shaped housing. The design is such that the three tips of the rotor are always in contact with the walls of the housing. This effectively makes separate chambers within the housing, in which the stages of combustion take place.

A Wankel engine is smaller, lighter and has less parts than a regular, conventional piston engine. It is also generally smoother, as there are no pistons flying up and down. What's more, in the event of any kind of mechanical failure, it is less likely to seize up and fail suddenly – an very important consideration for aircraft.

On the downside, engineers have struggled to maintain good seals between the rotor tips and housing, with leakages making the engine less efficient. Because of this, a Wankel engine can be expensive to produce and its applications have remained limited. Furthermore, fuel consumption tends to be higher than with a piston engine.

> "Predicted resistances from drag are extreme and increase in proportion to velocity squared"

The race to 1,000mph

So fast that they will transcend the speed of sound, three rocket cars are pushing the limits of conventional physics in their bids to reach the Holy Grail of motoring

Forget the Bugatti Veyron, this is where the real speed lies. Awesome conglomerations of engineering prowess, mathematical accuracy, split-second reactions, chiselled experience and cutting-edge design theory – brought together in one of man's latest and greatest challenges; to take a land vehicle to the fabled 1,000mph.

And what a challenge it will be. At this speed everything counts: aerodynamic principles that are watertight on paper crumble under the pressure that physics has on current technology, predicted resistances from drag are extreme and increase in proportion to velocity squared, jet engines are subject to untested speeds at altitudes they were never meant to operate in, and the risk of cataclysmic combustion of fuel reserves is far from improbable.

Despite this, however, three teams from the far-flung corners of the Earth are currently building rival vehicles to undertake this very mission, to make the impossible, possible. British, Australian and American, they combine specialists in aerodynamics, engineering, mathematics and physics, and between them have decades of experience in breaking man-made barriers. We take a look at these teams and the vehicles that will transport them beyond the limit that they said could never be broken.

5 TOP FACTS SPEED

Historic

1 The first land speed record was set by Count Gaston de Chasseloup-Laubat in Yveslines, France, on 18 December 1898 at – for the time – a rather dizzying 39mph.

Mach 1

2 The speed of sound is 761mph (1,224kph), which in aviation terms is referred to as Mach 1. To achieve low Earth orbit you'd need to be travelling at the equivalent of Mach 25.4.

Blink

3 At the speed of sound you are travelling at 340.3 metres per second, the equivalent of three times the length of Manchester United's Old Trafford football pitch.

Phileas Fogg

4 The circumference of the Earth is 24,901 miles. At 1,000 miles per hour you could travel around it in little more than 24 hours… not bad for a day's work.

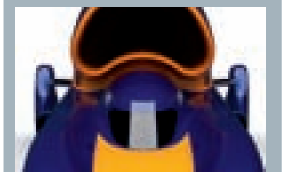
Runway

5 To accomplish a 1,000mph record-breaking attempt, a runway area of over 14 miles is necessary, with a massive ten miles needed purely for braking.

DID YOU KNOW? The current world land speed record is held by the ThrustSSC at a speed of 763.035mph

The Statistics

Bloodhound SSC



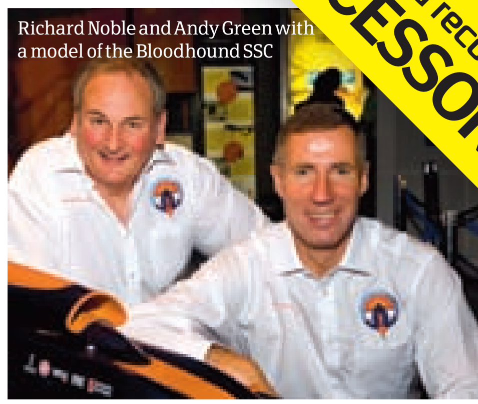
Engine: 1 x MCT V12 800bhp, 1 x Falcon HTP rocket, 1 x Eurojet EJ200
Length: 12.8m (42ft)
Width: 6.4m (21ft)
Weight: 6,422kg (14,160lb)
Max speed: 1,050mph+

Bloodhound SSC

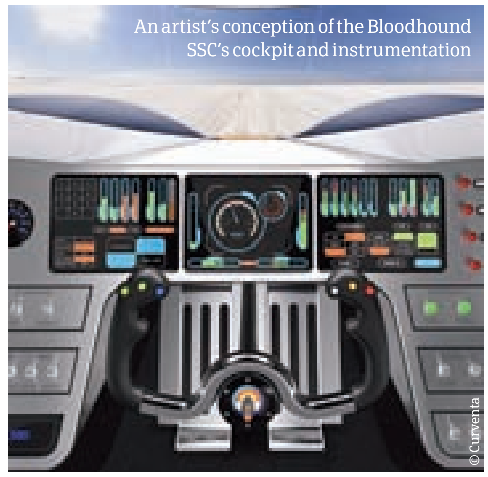
World land speed record: SUCCESSOR

The current world land speed records holders, the British-based SSC team hope to rewrite their own legacy with their new Bloodhound rocket car

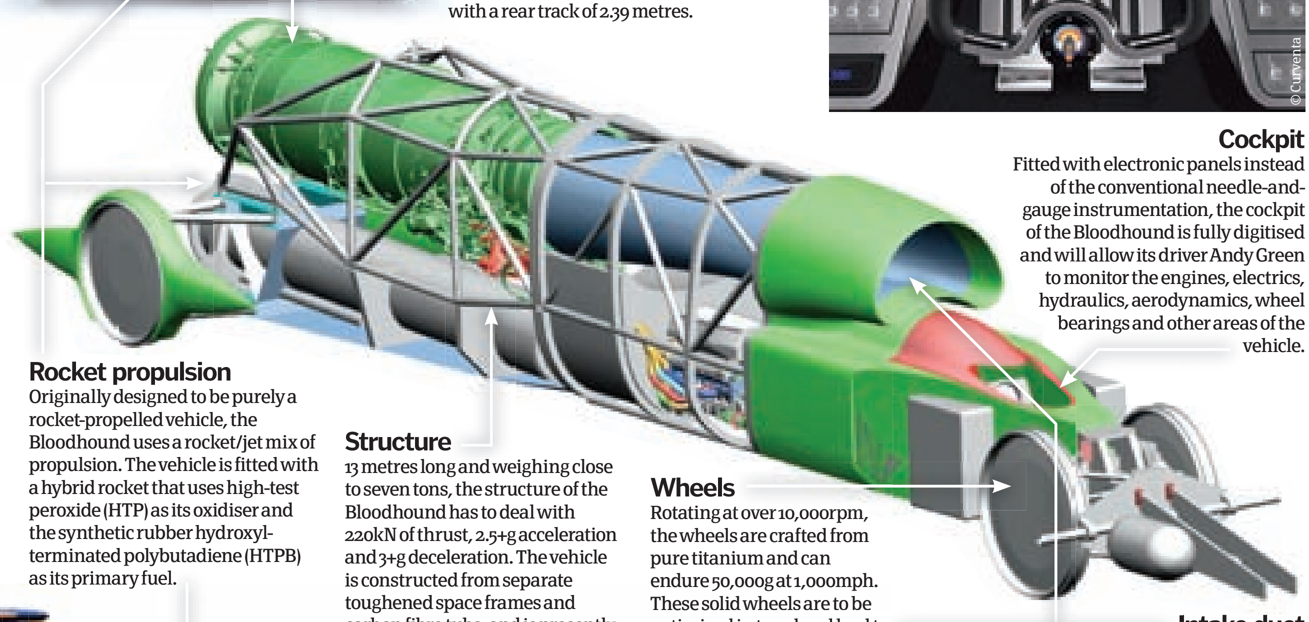
When the ThrustSSC broke the sound barrier back in 1997 on its way to an unprecedented world land speed record of 763mph, many commentators said that it would never be beaten, that the limitations of physics and human technology had topped out. But then again, they had said that before. The Bloodhound world land speed record challenger is the latest design from the SSC team, who despite holding the record, intend to topple it spectacularly with a 1,000mph run, cementing their position in the history books. We take a look inside the Bloodhound to see what makes it so special and how it will top 1,000mph.



Richard Noble and Andy Green with a model of the Bloodhound SSC



An artist's conception of the Bloodhound SSC's cockpit and instrumentation



Jet propulsion
Half the thrust of the Bloodhound is provided by a Eurojet EJ200, a sophisticated military turbofan normally found in the engine bay of a Eurofighter Typhoon combat aircraft. The engine has a highly sophisticated engine control and health monitoring system, which will put the engine into a safe mode if checks fail.

Suspension
Essential for handling and stability, the suspension has 100mm of bump and droop travel to observe any undulations in the Earth's surface. Currently, the vehicle is fitted with a double wishbone front suspension, with a front track of one metre, and a double wishbone rear suspension, with a rear track of 2.39 metres.

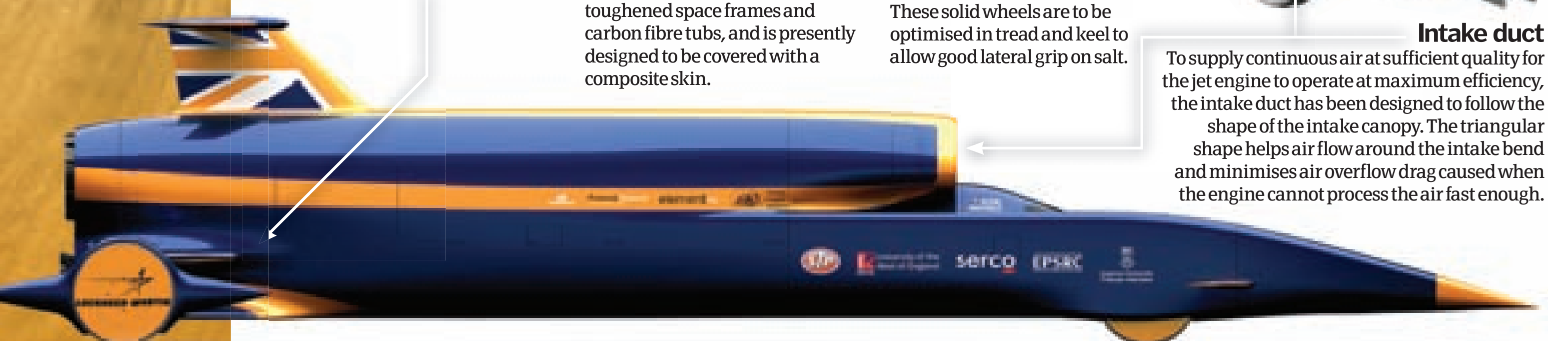
Cockpit
Fitted with electronic panels instead of the conventional needle-and-gauge instrumentation, the cockpit of the Bloodhound is fully digitised and will allow its driver Andy Green to monitor the engines, electrics, hydraulics, aerodynamics, wheel bearings and other areas of the vehicle.

Rocket propulsion
Originally designed to be purely a rocket-propelled vehicle, the Bloodhound uses a rocket/jet mix of propulsion. The vehicle is fitted with a hybrid rocket that uses high-test peroxide (HTP) as its oxidiser and the synthetic rubber hydroxyl-terminated polybutadiene (HTPB) as its primary fuel.

Structure
13 metres long and weighing close to seven tons, the structure of the Bloodhound has to deal with 220kN of thrust, 2.5+g acceleration and 3+g deceleration. The vehicle is constructed from separate toughened space frames and carbon fibre tubs, and is presently designed to be covered with a composite skin.

Wheels
Rotating at over 10,000rpm, the wheels are crafted from pure titanium and can endure 50,000g at 1,000mph. These solid wheels are to be optimised in tread and keel to allow good lateral grip on salt.

Intake duct
To supply continuous air at sufficient quality for the jet engine to operate at maximum efficiency, the intake duct has been designed to follow the shape of the intake canopy. The triangular shape helps air flow around the intake bend and minimises air overflow drag caused when the engine cannot process the air fast enough.



"Four rocket engines deliver a staggering 62,000 pounds of thrust"

World land speed record: CHALLENGER

Aussie Invader 5R

Built by the current Australian land speed record holder, the Aussie Invader 5R has been ten years in the making and is a serious contender for the 1,000mph crown

Interview

How It Works talks to the driver of the Aussie Invader 5R **Rosco McGlashan**

How It Works: What was the catalyst to initiate the Aussie Invader 5R project?

Rosco McGlashan: The 5R project was started to build the world's most powerful and fastest car, the catalyst came from 45 years of blood, sweat and tears of breaking records.

HIW: The Invader team already hold the Australian land speed record, could you tell us about the record-breaking attempt?

RM: We attempted the Aussie LSR previously held by Donald Campbell at 403mph (647kph) back in 1994. We lifted the record to 500mph (802kph) but went on to crash the car in the following year. In 1996 we ran a peak one way speed of 643mph, however we never had the right conditions to run our race.

HIW: With the 5R you are looking to break the 1,000mph barrier, how difficult is that going to be?

RM: Yes, it will be difficult. The last record attempt we undertook was impossible for a small dedicated team to achieve using an all-volunteer team working in a shed. This new attempt is unthinkable, the same conditions but an older team trying to fund development from more sponsors.

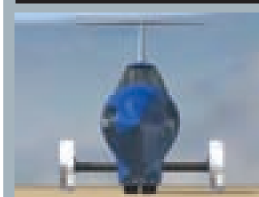
HIW: With teams from across the globe competing in the race to 1,000mph, are there certain design features on the 5R that you think will pip them to the post?

RM: The 5R is the perfect car for the LSR: brute power, no moving parts (for the engine systems) and simplicity. The car is designed around a purpose-built central mainframe and the on-board pressure vessels use the wall of the mainframe for strength. The mainframe uses PVs for strength and rigidness.

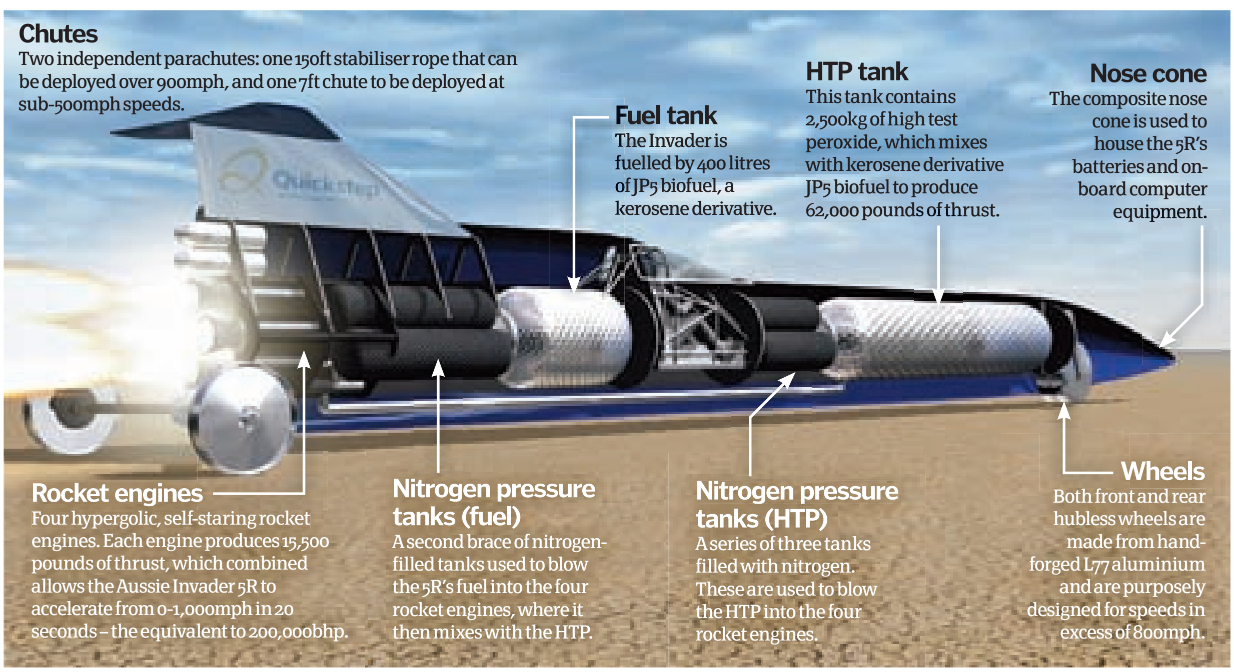
Rosco McGlashan, known round the world as 'The Rocket Man', is attempting his biggest challenge to date. Helped with his team of dedicated volunteers – a team that currently holds the Australian land speed record of 643mph – the 1,000mph barrier, the ultimate land speed challenge, is set squarely in his sights with the Aussie Invader 5R. Weighing over eight tons fully fuelled and powered with four rocket engines that together deliver a staggering 62,000 pounds of thrust (the equivalent of 200,000bhp), the 5R is set to propel McGlashan to 1,000mph in just under 20 seconds. How It Works contacted McGlashan and the 5R's team to see how keeping things simple will ensure victory in the greatest race of all.


Pete Taylor, member of the Invader's team, works on the initial mould for the 5R's canopy

The Statistics
Aussie Invader 5R



Engine: 4 x HTP rocket (62,000 pounds of thrust)
Length: 18.0m (58.5ft)
Height: 3m (10ft)
Weight: 6,363kg (14,000lb)
Max speed: 1,000mph+



AIR

1. SR-71 Blackbird
The SR-71 has held the record as the fastest air breathing manned aircraft in the world since 1976. Its speed is rated as Mach 3+.

LAND

2. ThrustSSC
Holds the current world land speed record, reaching an impressive 763mph on 15 October 1997 in the Black Rock desert, Nevada.

WATER

3. XSR48
Capable of a ferocious maximum speed of 90 knots, the XSR48 sports the acceleration of a supercar but on water instead of on land.

DID YOU KNOW? The North American Eagle is named after the Bald Eagle, a bird of prey with an average body size of 80cm

World land speed record: WILDCARD

North American Eagle

Hot on the tail of the Bloodhound and the Aussie Invader 5R, a team of dedicated Americans are working to readjust the balance of power with their own 800+ mph challenger, the North American Eagle

The Statistics

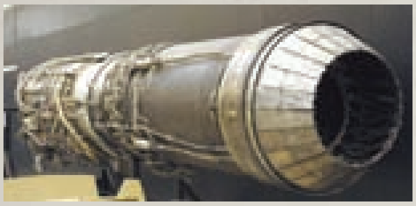
North American Eagle

Engine: 1 x GE J79 Turbojet (52,000 hp)
Length: 17.07m (56.0ft)
Height: 4m (13ft)
Weight: 5,900kg (13,000lb)
Max speed: 808mph+

© Rachel Shadle

Chassis
The chassis of the Eagle is taken from a F-104A-10 Starfighter.

Wheels
The Eagle has 100 per cent aluminium wheels.



Engine
The engine is a modified General Electric J79 turbojet.

Powered by a General Electric variation of its J79 turbojet engine, and built around the chassis of an F-104A-10 Starfighter, a third land speed challenger is emerging from the USA. The North American Eagle is a joint project between an experienced group of American and Canadian engineers, pilots and mechanics to break the current world land speed record of 763mph. Their goal is 1,300km/h (808mph), a speed that has never yet been achieved on Earth.

Taking the Eagle to 800+ miles per hour is driver Ed Shadle – a project manager at IBM – and his team of experienced and hard-working volunteers. The NAE project has attracted quite a crop too, with bearing engineering and airframe mechanics from Boeing, a jet engine specialist from Fort St. John, an owner of a hi-tech machine shop and various other members with piloting experience.

Currently, the Eagle is participating in a steady and calculated series of test runs and system refinements – a must when taking a vehicle supersonic – and so far has managed to top 400 miles per hour. Unfortunately, due to the nature of the North American Eagle project – a group made up purely of volunteers and reliant largely on sponsorship monies to progress the project – exact dates for faster runs are presently not possible due to the massive financial outlay required for any land speed attempt.

Further, many questions remain unanswered, as this is unknown territory for mankind. These include: will the Eagle's bearings handle the weight loading and revolutions per minute at such epic speeds, can the aluminium-alloy wheels withstand the tremendous centrifugal force, what about the Eagle's effect on the Earth's surface with its shockwave and acoustical absorption, and will Ed Shadle be able to control such a machine safely?

Despite this ,however, the North American Eagle is considerably more advanced in its project life span than either of its contemporaries and, providing they can acquire the requisite funds, are the closest to setting a new world land speed record. That will make Ed Shadle the fastest man on the planet and a first for the NAE team. Whether they can top their current target of 808mph and close in on the elusive 1,000mph is yet to be seen.

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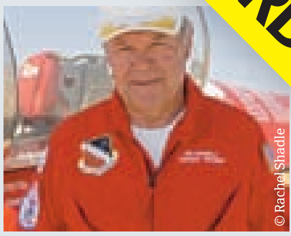

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Interview

How It Works talks to the driver of the North American Eagle **Ed Shadle**

HIW: So far, what has been the biggest challenge you have faced on the project?

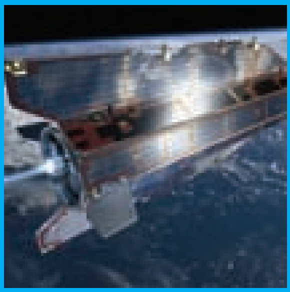
Ed Shadle: The biggest challenge the project has faced is financing and logistics. While several sponsors have come on board to support by providing equipment or donating consultation, the most elusive to acquire has been a financial backer that is willing to risk up-front capital for the rewards which come with such a high-risk venture. Despite such restraints, the team has pressed on, frequently spending their funds to conduct test sessions.

HIW: With the NAE you are looking to break the 800mph barrier, yet rival teams are aiming for 1,000mph. Could the NAE close in on that speed?

ES: The two rival teams, or contenders, have come along many years after the NAE project began. When it started in 1998, the owners felt that 800mph was the next appropriate level at which to set a goal for reaching. While the NAE could potentially get close to the other teams' goal, it would take a massive infusion of capital and testing to assure that it would be safe to attempt such a speed.

HIW: How important will the record be to the NAE team? And how long do you feel your record will stand?

ES: The importance of getting the land speed record for the NAE team will be equivalent to having successfully gone to the moon and back. As for how long a record of 800mph will stand depends entirely on how quickly the Bloodhound SSC or Aussie Invader 5R projects get through necessary testing to go beyond that speed.



This month in **Space**

If you were a fan of the excellent sci-fi drama that was *Battlestar Galactica* then you're probably familiar with the search for Earth. While we can't promise Cylons or Vipers, we can tell you how our own Earth-bound scientists are searching the surrounding star systems for a planet similar to our own. The area is relatively small but new planets are being discovered all the time and the search for one that could support life continues apace. Find out more by heading over to page 64.

61 Io: The volcanic moon

62 Solar flares

64 Search for a new Earth

SPACE

58 Mercury
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64 Search for a new Earth

Mercury

Compared to the other planets, we know relatively little about the smallest planet in our solar system

Although we've been observing Mercury from Earth for thousands of years, its close proximity to the Sun – about 58 million kilometres, on average – has made it difficult for astronomers to learn much about the planet. The Hubble Space Telescope cannot observe it, because turning that close towards the Sun would damage the telescope's instruments. Most of what we know came from the 1975 Mariner 10 space probe's fly-by.

With the naked eye, Mercury can only be seen at dawn or dusk, depending on the time of year (unless there is a solar eclipse). This is due to the Sun's glare. Mercury can also be seen as a small black spot moving across the Sun at intervals of seven, 13 and 33 years. This is known as a transit of Mercury across the Sun and occurs when the planet comes between the Earth and the Sun.

Mercury has the shortest year of any planet at 88 Earth days. It also orbits around the Sun faster than any other planet, which is why it was named after the speedy Roman messenger god. Conversely, Mercury has the longest day of any planet due to its slow rotation. Because it revolves so quickly around the Sun, yet only rotates on its axis once every 59 Earth days, the time between sunrises on Mercury lasts 176 Earth days. Mercury also has the most eccentric, or stretched-out, elliptical orbit. Like our Moon, Mercury can be observed going through apparent changes in its shape and size called phases.

Inside Mercury

A cross-section of the smallest planet in our solar system

Atmosphere

Mercury has a very thin, almost airless atmosphere. At one time it was believed that the planet didn't have an atmosphere at all, but it does contain small concentrations of the gases helium, hydrogen and oxygen as well as calcium, potassium and sodium. Because of Mercury's size, it does not have a strong enough gravitational pull to keep a stable atmosphere. It is constantly being lost and replenished via solar wind, impacts and radioactive decay of elements in the crust.

1 Heavily cratered surface
Although telescopes had revealed that Mercury looked much like our moon, the nearly 10,000 images recorded by Mariner 10 confirmed that it had a heavily cratered surface.

2 Lobate scarps
Mariner 10's images showed that Mercury was also covered in curved cliffs called lobate scarps, which formed when the planet's core cooled and shrank.

3 Ultraviolet radiation
Mariner 10 recorded large amounts of ultraviolet radiation near Mercury. It was eventually determined to come from a nearby star called 31 Crateris.

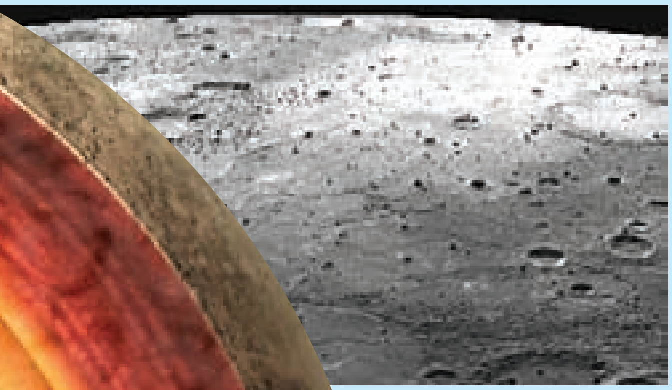
4 Magnetic field
The Mariner 10 space probe's instruments picked up a magnetic field on Mercury, which is rather similar to Earth's own magnetic field.

5 Exosphere
Mercury has an atmosphere like the exosphere on Earth – the upper layer of our planet's atmosphere. Its lightness and low density allows molecules to escape into space.

DID YOU KNOW? Ancient Greeks believed that Mercury was two planets: one called Hermes and one called Apollo

Terrestrial planet

Like Earth, Mercury is a rocky planet. It comprises about 70 per cent metal and 30 per cent silicate materials. Because Mercury is so dense – almost as dense as Earth, although it's much smaller – it probably has a very large, iron-rich core. Scientists believe that Mercury's core makes up almost half of the planet's total volume and three-fourths of its total radius. It also contains more molten iron than any other major planet in the solar system. The core is estimated to have a radius of about 1,800 kilometres, with a mantle about 600 kilometres thick and a crust about 300 kilometres thick. There are a few potential explanations for this large core. Mercury may have had a more substantial crust and mantle that were stripped away by high temperatures and solar wind from the Sun, or it could have been hit by a still-forming planet called a planetesimal.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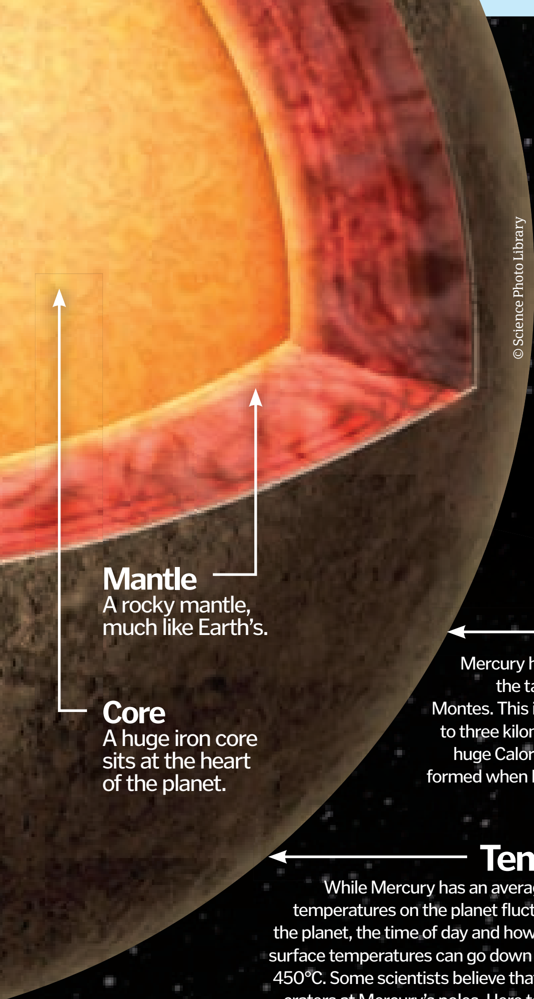
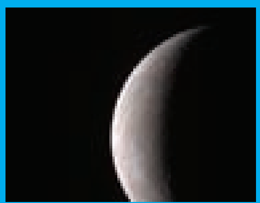


The Statistics
Mercury



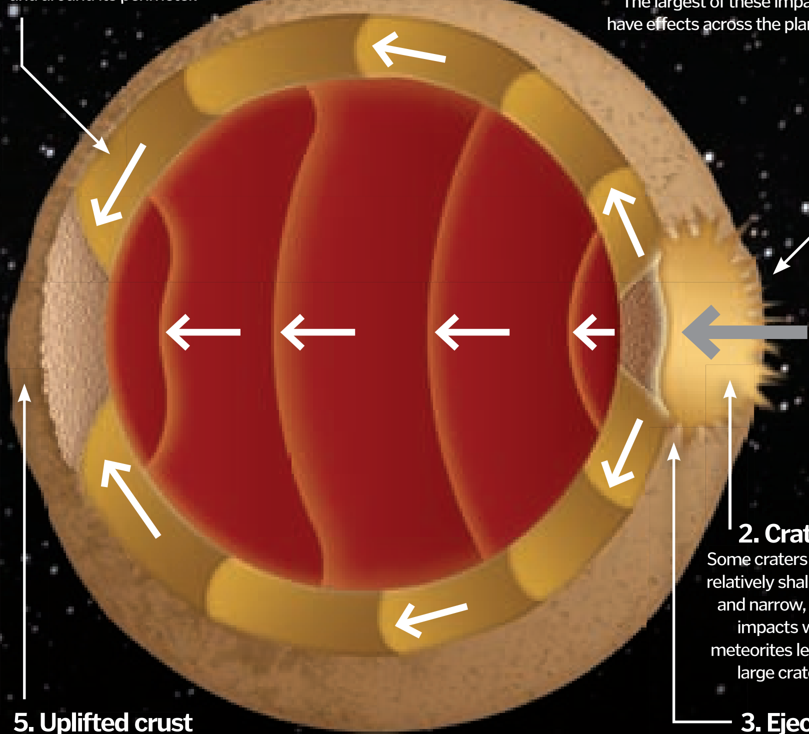
Diameter: 4,879 kilometres
Mass: 3.3022×10^{23} kilograms
Density: 5.427 grams per cubic centimetre
Average surface temperature: 179°C
Average distance from the Sun: 57,910,000 kilometres
Surface gravity: 0.38 g

Caloris Montes
Mercury has several mountains known as montes, the tallest and largest of which are the Caloris Montes. This is a series of circular mountain ranges up to three kilometres in height located on the rim of the huge Caloris Basin. The Caloris Montes are massifs, formed when Mercury's crust flexed and fractured due to impact.

Temperature extremes
While Mercury has an average surface temperature of around 179°C, temperatures on the planet fluctuate wildly depending on the location on the planet, the time of day and how close it is to the Sun in its orbit. At night, surface temperatures can go down to -170°C. During the day, they can reach 450°C. Some scientists believe that ice may exist under the surface of deep craters at Mercury's poles. Here temperatures are below average because sunlight cannot penetrate.

Moon-like surface

The surface of Mercury looks much like the surface of our moon. The largest crater on Mercury is the Caloris Basin at 1,300 kilometres across. The impact caused lava eruptions and shockwaves that formed hills and furrows around the basin. Mercury also has two different types of plains. The smooth plains were likely formed by lava flows, while inter-crater plains may have been formed by lava or by impacts. The most unusual features are the wrinkles and folds across its plains and craters, caused by the cooling and contraction of the planet's core.



1. Meteorite impact
Mercury has been continually hit with comets and meteorites. The largest of these impacts have effects across the planet.

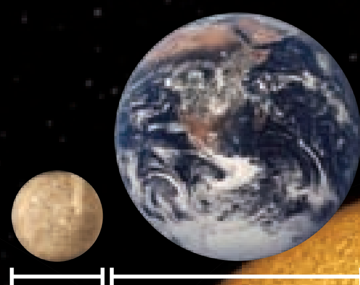
2. Crater
Some craters are relatively shallow and narrow, but impacts with meteorites leave large craters.

3. Ejecta
Impacts force debris high into the air on Mercury. Falling debris settles around the crater, creating an ejecta blanket.

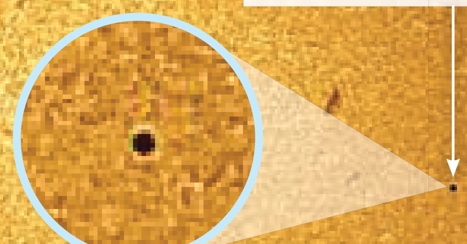
4. Shockwaves
Impacts with large meteorites actually send shockwaves through the core of the planet and around its perimeter.

5. Uplifted crust
The shockwaves force the rocky mantle to buckle upwards through the crust, forming mountains.

Sizes…
Mercury's diameter is two-fifths that of the Earth, and its mass is slightly less than Earth's.



The transit of Mercury
Every seven, 13 and 33 years, Mercury can be seen as a black spot moving across the Sun.



> "True solar time is based on the apparent motion of the Sun as we observe it"

Day and night, night and day

This seemingly simple phenomenon that we call night and day is anything but simple


© NASA

What we term 'night and day' is a phenomenon known as rotation. The Earth rotates around its axis, an imaginary line that extends from its North Pole to its South Pole, once every 24 hours. This axis of our planet is tipped at an angle of about 23.5 degrees from the vertical.

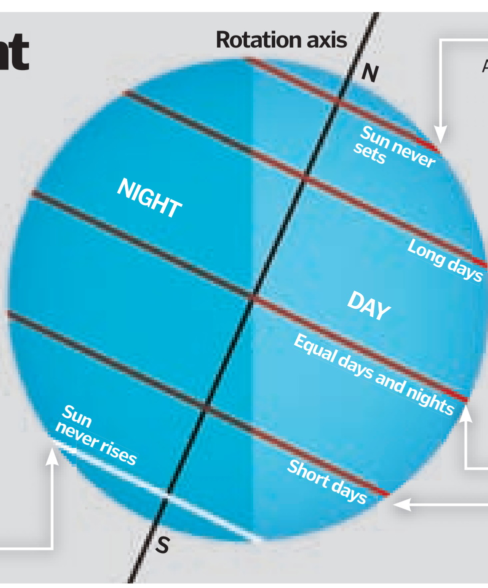
As the Earth rotates, the part of it illuminated by the Sun experiences daytime, while the dark part experiences night. When the Sun appears above the horizon in the east and sinks below it in west, we call this sunrise and sunset. But this is an illusion created by the Earth's counter-clockwise rotation – because of course the Sun isn't actually rising or sinking at all.

True solar time is based on the apparent motion of the Sun as we observe it, as with a sundial. This measurement varies from day to day because of the Earth's elliptical orbit – it rotates faster when closer to the Sun and slower when further away from it. The tilt of Earth's axis also means that true solar days are shorter at some times of the year and longer at others. A mean solar day is an average so that all of our days are of equal length. This is the time we use to set our clocks. Sidereal time takes into account how long it takes the Earth to rotate with respect to the apparent movement of the stars instead of the Sun. A sidereal day is about four minutes shorter than a mean solar day. Astronomers use sidereal time to determine the placement of the stars in the sky at any given time.

Although a rotation of the Earth takes 24 hours, that doesn't mean that daytime and nighttime are each 12 hours long. On average, nights are shorter than days. This is due to the Sun's apparent size in our sky as well as the way that our atmosphere refracts sunlight. The lengths of our days and nights depend on our location on the Earth's surface as well as the time of year.

Day and night explained

This image shows the Earth's axis is tilted towards the Sun during the summer, or northern solstice. This occurs around 21 June and changes the lengths of nights and days depending on where you live. The five major circles of latitude mark the shifts in length.



1. Arctic Circle
Above the Arctic Circle, the region around the North Pole experiences a 24-hour day of sunlight during the summer solstice.

2. Tropic of Cancer
During summer solstice, the area around the tropic of Cancer experiences much longer days than nights due to the extreme tilt of the Earth's axis towards the Sun.

3. Equator
The region around the equator is the only place on Earth where days and nights are generally the same length of time regardless of the time of year.

4. Tropic of Capricorn
Below the tropic of Capricorn, the region has much shorter days than nights.

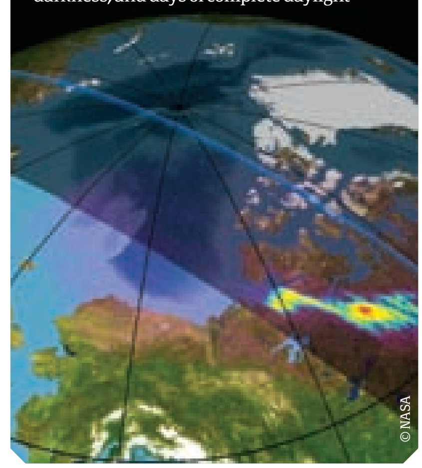
5. Antarctic Circle
The Antarctic Circle marks a region that experiences a 24-hour period, or "day", of darkness due to the summer solstice.

Days and nights around the world

Depending on the time of year and where you live, the length of days and nights can vary. These shifts occur during specific moments of the year known as equinoxes and solstices. The equinoxes occur around 20 March and again around 22 September. This is when the Earth's axis is tilted neither towards nor away from the Sun. Solstices occur around 21 June and 21 December, when the Earth's axis is most inclined either toward (in June) or away (in December) from the Sun.

Locations around the equator experience the most even night and day lengths, with increases in variation spreading outwards to the tropic of Cancer at the northernmost point and the tropic of Capricorn at the southernmost point. The differences are the most extreme at the poles. Once a year, the North Pole is tilted towards the Sun and experiences a day of 24 hours of sunlight. During this time, the South Pole has 24 hours of darkness. The reverse happens six months later.

The North Pole experiences days of complete darkness, and days of complete daylight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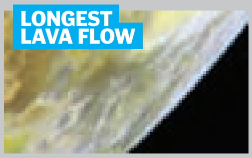
Head to Head IO'S VOLCANOES

LONGEST LASTING PLUME

1. Prometheus
The nearly 100-kilometre dust plume emanating from the Prometheus volcano is thought to have been continuously erupting since at least 1979.

LONGEST LAVA FLOW



2. Masubi Fluctus
Originating from the volcano Masubi, the Masubi Fluctus is an active lava flow more than 500 kilometres long.

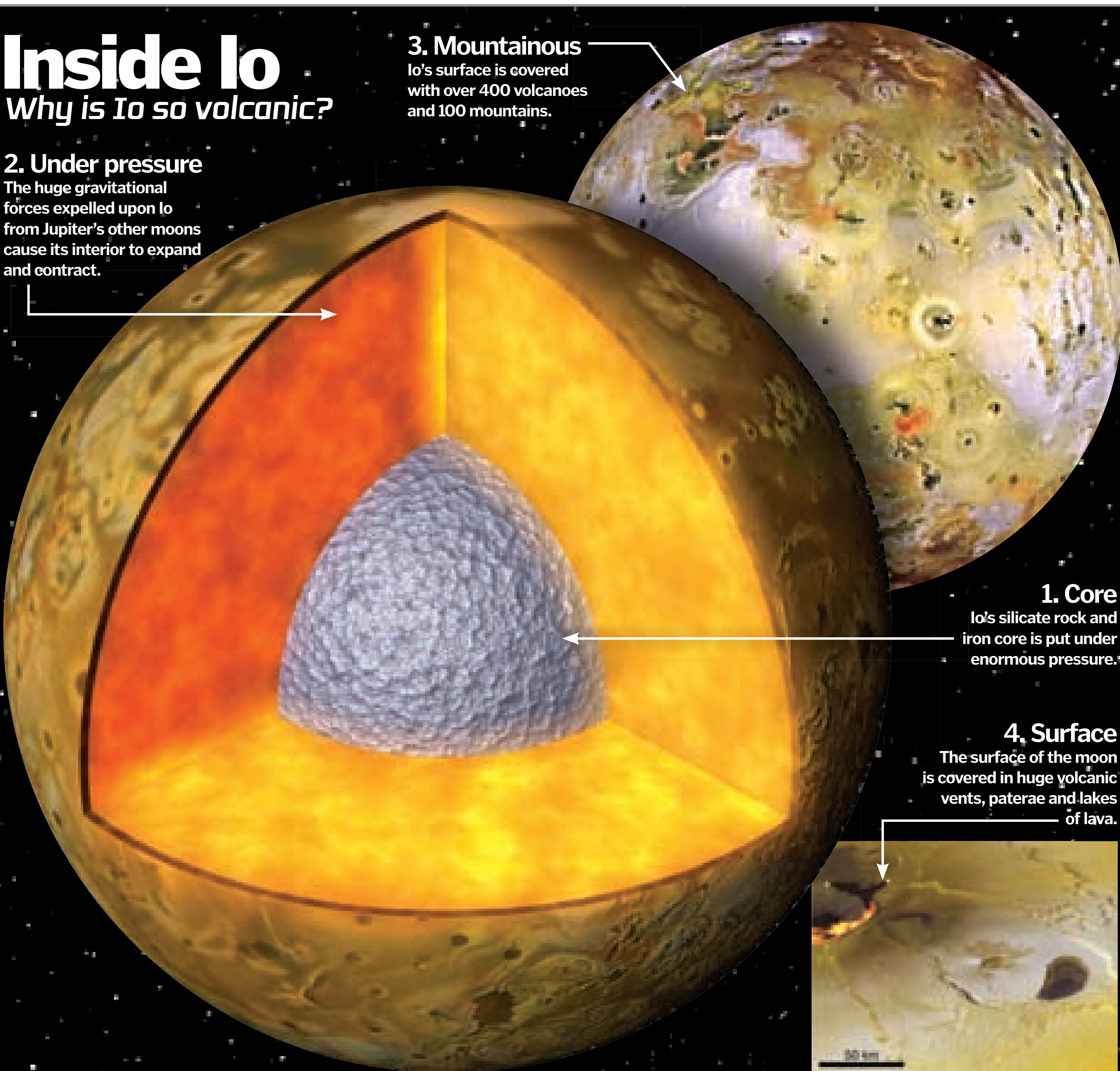
BIGGEST VOLCANO

3. Loki
Loki Patera is the biggest volcano depression on Io at more than 200 kilometres in diameter (126 miles).

DID YOU KNOW? *Io's volcanic activity was unknown until images were taken by the Voyager spacecraft in 1979*

Inside Io

Why is Io so volcanic?



Io: The volcanic moon

When it comes to the landscape on Jupiter's moon Io, the only real constant is change

We often think of moons in the context of Earth's moon – cold, quiet and devoid of activity. While Jupiter's moon Io is roughly the same size as Earth's moon, it couldn't be more different. Io's main feature is its volcanic activity. The moon is covered with more than 400 volcanoes, which constantly spew plumes of sulphur, sulphur dioxide and ash as high as 500 kilometres above its surface. Io is also covered with hundreds of kilometres of lava flows and lakes, massive volcanic depressions called paterae, and openings in its crust called volcanic vents. This non-stop activity gives Io a colourful surface that looks a lot like a pizza.

So what makes Io so unique? The answer is tides, but these tides are much stronger than those in Earth's oceans. Io experiences tidal heating thanks to the gravitational forces exerted upon it by Jupiter and three of its other moons: Europa, Ganymede and Callisto. Io is the innermost of these moons, so it's constantly in the centre of a tug-of-war between the planet and the other moons. These gravitational forces are so strong that they alternately compress and expand Io's interior, causing the surface to bulge in and out by as much as 100 kilometres. All of this force causes pressure and heat to build in Io's silicate rock and iron core, ultimately sending molten material spewing up through cracks in the crust.

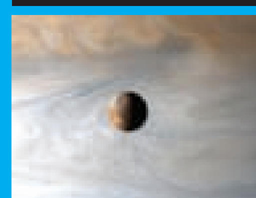
In addition to its numerous volcanic features, Io has more than 100 mountains, some of which are taller than Mount Everest's 8.84 kilometres. These mountains may be the result of the constant resurfacing of the moon's crust due to all of the volcanic activity. A build-up of volcanic material could cause the crust to fall into the mantle, pushing chunks of it up through faults and forming a mountain.

Jupiter's Galilean moons

Jupiter has 63 known moons, but its Galilean moons – Io, Europa, Ganymede and Callisto – are the four largest. Discovered by Galileo in 1620, the Galilean moons also rank among the biggest moons in the solar system. Io is known for its extreme volcanic activity as well as its unusual silicate rock and iron composition. Europa's the smallest of these moons, with a smooth surface of ice and water. It is thought to potentially harbour extraterrestrial life. Ganymede is the largest moon in the solar system, with a diameter wider than that of Mercury. Callisto is the second-largest Galilean moon, with a surface that is very old and covered in craters. Its largest crater, Valhalla, is 3,000 kilometres wide.

The Statistics

Io



Diameter: 3,636 kilometres
Mass: 8.93 x 10^{22} kilograms
Density: 3.5 grams per cubic centimetre
Average surface temperature: -143°C (130 Kelvin)
Core temperature: Estimated at up to 1,726°C (2,000 Kelvin)
Equatorial surface gravity: 0.183 g

> "The number and frequency of solar flares correlates to that of sunspots"

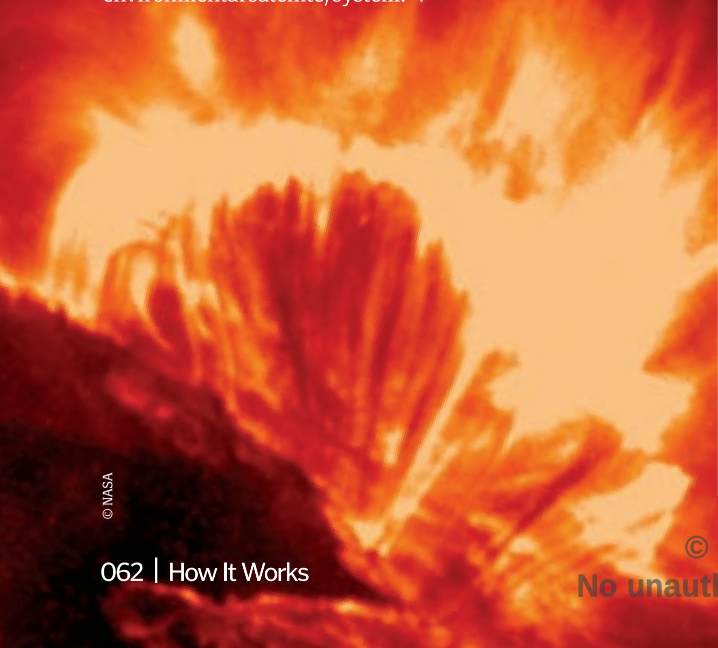
Solar flares

The largest explosions in the solar system explained

A solar flare is a sudden, high-energy explosion of energy that extends out to the Sun's corona, or outermost layer of atmosphere. They are caused by a build-up of magnetic energy and occur in areas of strong magnetic fields around the equator of the Sun. The number and frequency of solar flares correlates to that of sunspots. These temporary dark spots on the surface of the Sun mark areas of intense magnetic activity. During the solar cycle, the number of sunspots increases and they concentrate near the equator. The more sunspots there are, the more solar flares there are.

Solar flares happen in three stages, with each stage lasting as short as a few seconds or as long as a few hours depending on the strength of the flare. During the precursor stage, the energy begins to release in the form of lower-wavelength, or soft, x-rays. Next, electrons, protons and ions accelerate nearly to the speed of light during the impulsive stage. Plasma rapidly heats to anywhere from 10 million to as much as 100 million degrees Kelvin during the impulsive phase. A flare not only results in a visible flash of light, it also emits radiation across the electromagnetic spectrum at other wavelengths. These include gamma rays, radio waves and x-rays. The final stage is decay, in which soft x-rays are once again the only emissions detected.

Solar flares are classified on a scale of A, B, C, M or X, with each classification being ten times stronger than the previous one. Within each letter classification there is also a one to nine scale; an A2 flare is twice as strong as an A1 flare, for example. This depends on their peak x-ray flux measurement as determined by the GOES (geostationary operational environmental satellite) system.



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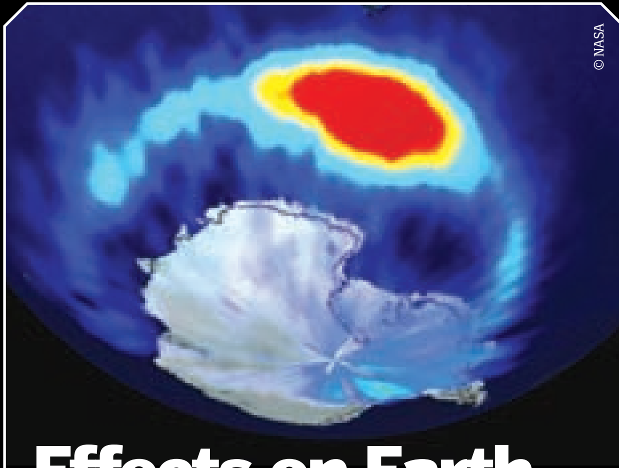

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Effects on Earth

The occurrence of a solar flare can have many different effects on Earth as well as on our space explorations. The hard x-rays emitted from a flare, as well as bursts of highly charged protons called proton storms, can do damage to both astronauts and spacecraft. Soft x-rays enter Earth's ionosphere and can disrupt radio communications. Ultraviolet radiation and x-rays also cause the outer atmosphere to heat up, creating a drag on satellites in low Earth orbit and reducing their life span.

Corona mass ejections (CMEs) often occur along with solar flares. These ejections of a large amount of plasma can disturb the Earth's entire magnetic field, known as a geomagnetic storm. Geomagnetic storms can damage satellites in high Earth orbit as well as power grids, leading to both communication and power outages.

5 TOP FACTS
BIGGEST SOLAR FLARES

1 04/11/03 X28+
This solar flare was observed by NASA's GOES satellite system and is the strongest solar flare recorded to date. It was not directed directly at Earth, but did cause some radio blackouts.

2 02/04/01 X20.0
This flare was the largest one observed for decades until 2003. It was observed by the Yohkoh spacecraft, which orbited the Sun from 1991 to 2001.

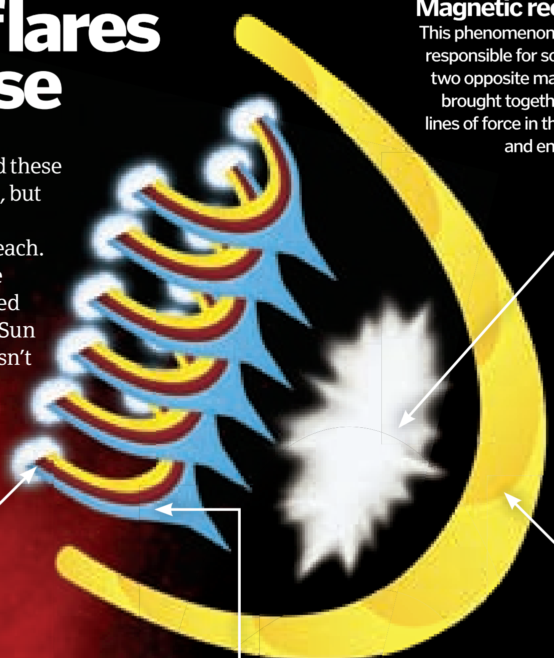
3 28/10/03 X17.2
This flare was observed by the SOHO (Solar and Heliospheric Observatory), a spacecraft currently orbiting the Sun. It had an associated coronal mass ejection.

4 07/09/05 X17
This flare blacked out high-frequency radio communications in both North and South America and caused numerous problems for air traffic controllers.

5 06/03/89 X15.0
This flare caused a geomagnetic storm that ultimately knocked out power to the entire Canadian province of Quebec.

Solar flares up close

Each solar flare has a unique structure, and these can be quite complex, but there are a few basic structures typical to each. Solar flares cannot be observed via the naked eye (and viewing the Sun this way at any time isn't advised), but are observed via electromagnetic emissions recorded by telescopes and spacecraft.



Magnetic reconnection
This phenomenon is thought to be responsible for solar flares. When two opposite magnetic fields are brought together, the magnetic lines of force in the Sun rearrange and energy is released.

Loop footpoints
Footpoints appear during the impulsive stage and are areas of electromagnetic emission. During the flare they appear to move due to the changing state of magnetic energy.

Post-flare loops
These hot magnetic loops remain on the surface of the Sun after a flare and are observable as white areas on soft x-rays.

Coronal mass ejection
Coronal mass ejections (CMEs) are powerful ejections of plasma that sometimes occur with strong solar flares, but can also occur during other types of solar activity.

5 TOP FACTS
CASSINI DISCOVERIES

New moons

1 Cassini's discovered seven new moons orbiting Saturn. Methone, Pallene and Polydeuces were discovered in 2004. The other three were found in gaps within Saturn's rings.

Water-ice on Enceladus

2 In 2008, Cassini observed water-ice spewing from the surface of Enceladus. These geysers shoot out so far from the tiny moon that they feed particles into Saturn's rings.

Earth-like Titan

3 Observations of Titan's surface show that it may look much like Earth did before the evolution of life. Titan has features such as mountains, volcanoes, rivers and dunes.

Ring rhythms

4 Cassini has discovered a rhythm to two of Saturn's rings. They contain evenly spaced lines of huge ice particles that look like ripples in a pond.

Let the hurricane roar

5 In 2006, the first hurricane seen on a planet other than Earth was found at Saturn's South Pole. It measured more than a colossal 8,000 kilometres wide.

DID YOU KNOW? Concerns about the damage to foreign relations helped the mission survive US budget cuts in 1992 and 1994

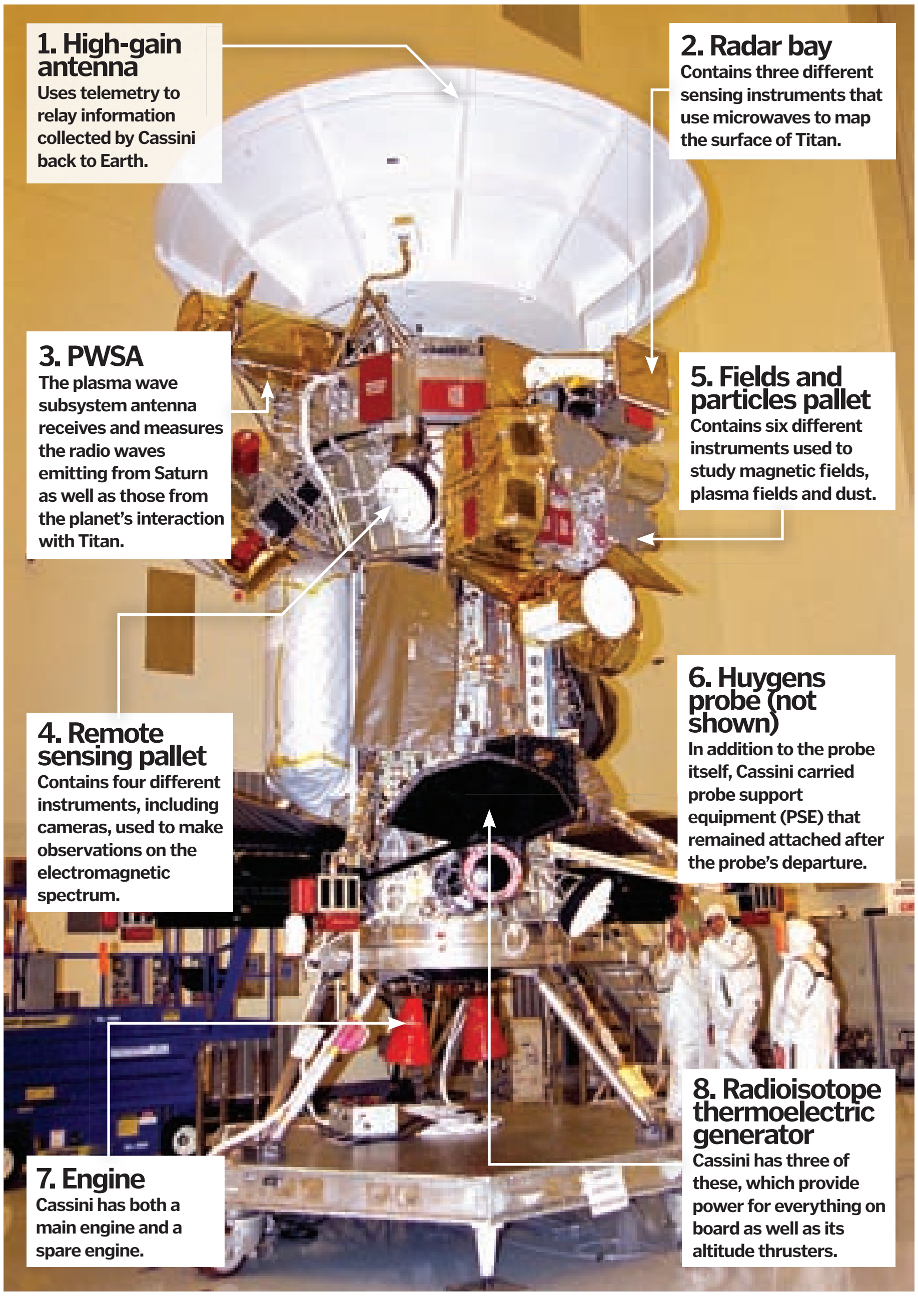
Cassini-Huygens

The mission launched in 1997 to explore Saturn and its many moons

Cassini-Huygens is an orbiting spacecraft resulting from collaboration among NASA, the European Space Agency and the Italian Space Agency (ASI). The spacecraft comprises two parts: the Cassini orbiter and the Huygens probe.

This spacecraft is the biggest and most elaborate interplanetary space probe ever built – partly due to the extensive technology needed to conduct more than 25 planned investigations during the mission. Cassini also had to be able to make the long, difficult journey to Saturn. It took over six years for Cassini to enter the planet's orbit. On the way to Saturn, Cassini conducted fly-bys of Earth's moon, the asteroid 2685 Masursky, Venus, as well as several of Jupiter's moons.

The Huygens probe landed on Titan and began transmitting data on 14 January 2005 while the Cassini orbiter continued on. The mission objectives included conducting studies of Saturn's atmosphere, magnetosphere and rings. The Cassini-Huygens mission was also intended to learn more about some of Saturn's satellites. This included studies of the atmosphere and surface of Titan and of the surface of Iapetus, Saturn's third-largest moon. While the original mission ended on 30 July 2008, NASA has extended it because the Cassini orbiter is still functioning and in good condition. Now renamed Cassini Equinox (which will change to Cassini Solstice), the mission is planned to continue until 2017.



The Statistics

Cassini-Huygens

Cassini orbiter weight: 2,125kg
Huygens probe weight: 320kg
Total dimensions: Seven metres high x four metres wide
Power: 885 watts
Launch: 15 October 1997
Cost: $3.27 billion

The complex Cassini

At nearly 6,000 kilograms at launch, the Cassini is the second-heaviest exploratory spacecraft built to date. It contains a massive number of components, housing more than 1,500 electronic parts and over 14km of cable. The Cassini also houses 12 different instruments, while the Hugyens probe housed six.

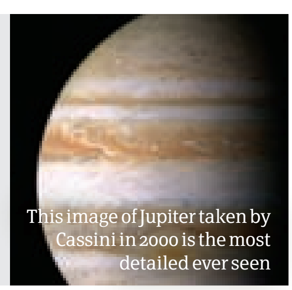
Learn more

For the latest info on the Cassini Equinox mission, check out the NASA website **saturn.jpl.nasa.gov**. NASA also has a DVD about the Cassini-Huygens mission called *Ring World*. A free podcast download is available at **http://tinyurl.com/36rjwf2**.

The Huygens probe

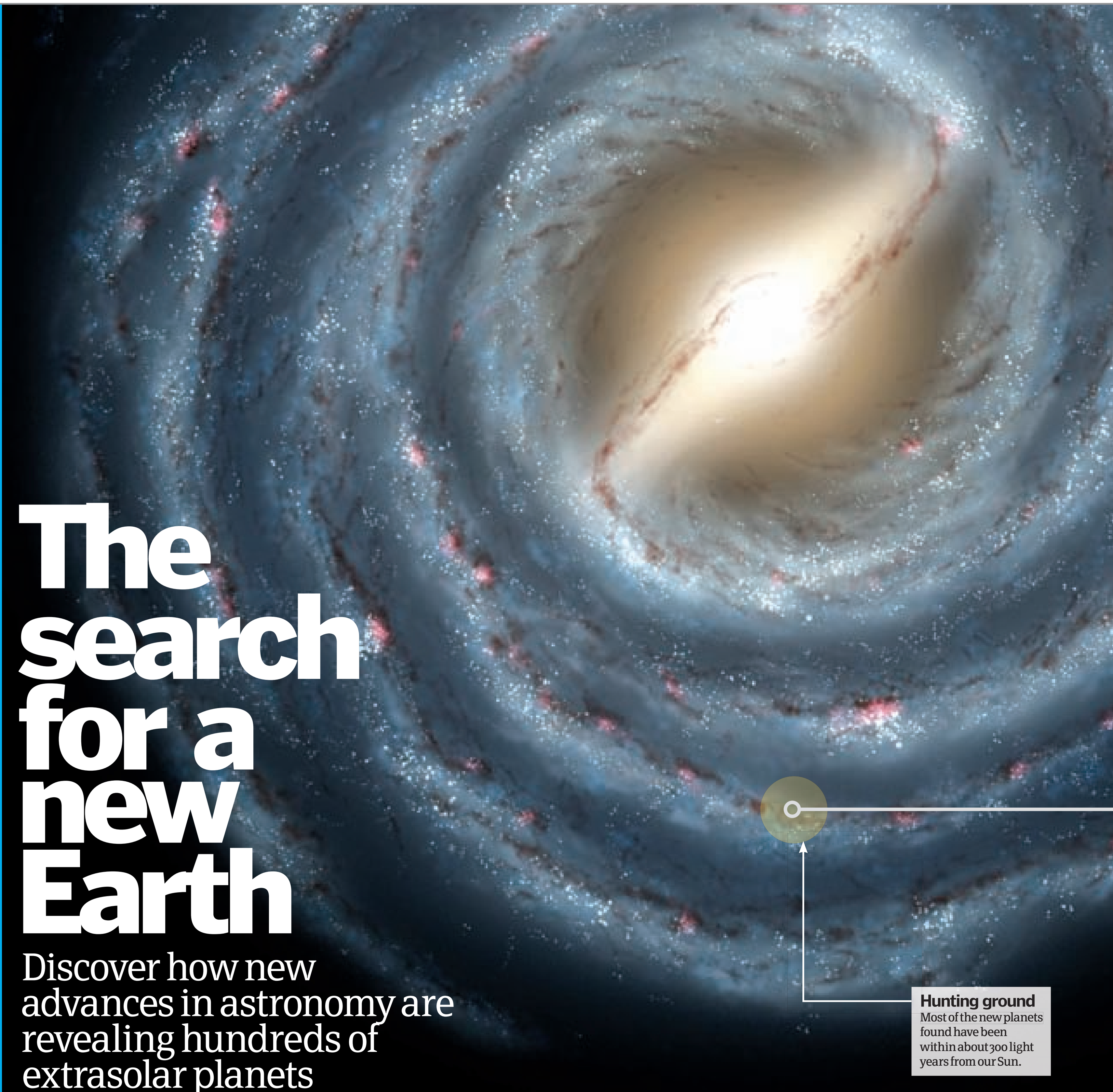
After separating from the Cassini orbiter, the Huygens probe descended via parachute and landed on the surface of Titan in what appears to be a floodplain covered with small chunks of ice. The main portion of the probe's mission was the descent itself, which took about three hours. As the probe passed down through the hazy atmosphere, it transmitted radio data to Cassini (which in turn relayed it to Earth) as well as nearly 300 images.

This mission revealed that Titan has a dense atmosphere comprising nearly 98 per cent nitrogen gas, with hazy clouds made of methane and ethane that rain down onto the surface. This atmosphere reflects back what little sunlight reaches the moon, contributing to its low average surface temperature of –179°C. The surface of Titan is covered with dunes along its equator, and both rough and smooth areas elsewhere. These were likely formed by lakes and rivers of liquid methane and ethane.



This image of Jupiter taken by Cassini in 2000 is the most detailed ever seen

"The answer will have huge implications for humanity"



Hunting ground Most of the new planets found have been within about 300 light years from our Sun.

The search for a new Earth

Discover how new advances in astronomy are revealing hundreds of extrasolar planets

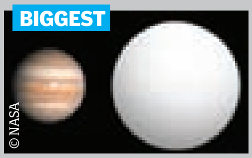
Since Galileo pointed a telescope at the heavens 400 years ago, the discovery of exoplanets beyond our own solar system is a goal astronomers have long cherished. Allied to this is the greater hope of finding Earth-like planets capable of supporting life. If it is proved we are alone in this universe, or share it with other life forms, the answer will have huge implications for humanity.

Earth-based techniques introduced in the Nineties, using interferometry and coronagraphy, finally proved that other star systems do have giant extrasolar planetary bodies orbiting them. The race to discover life-supporting Earth-sized planets, that are light years away, needs far greater precision and accuracy. To meet this challenge observatories throughout the world are constantly upgrading their technology, but the biggest hopes are pinned on telescopes launched into outer space.

DISCOVERED FIRST

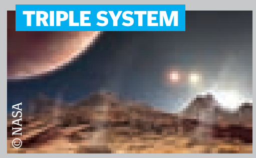
1. 51 Pegasi b
This extrasolar planet was detected in 1995 and named Bellerophon. It is a hot Jupiter-type planet, 50.1 light years away from us, in the Pegasus constellation.

BIGGEST



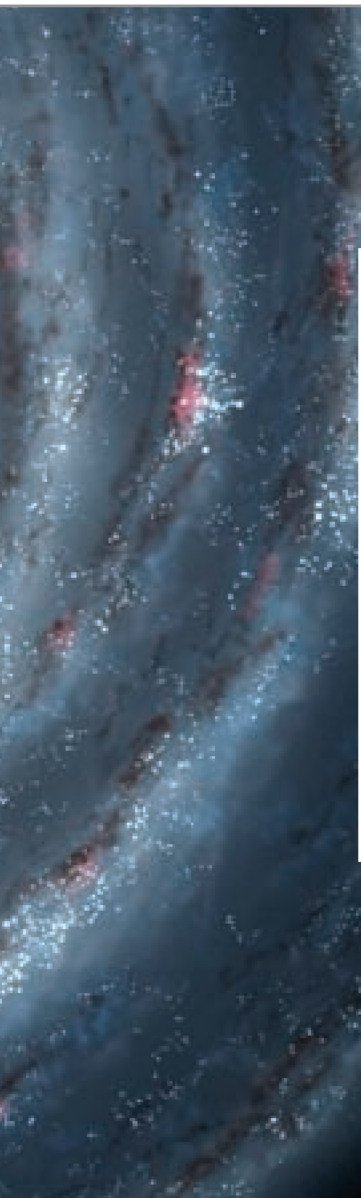
2. WASP-17
Discovered by the UK's super WASP (Wide Area Search for Planets), in August 2009. It is a gas giant twice the size of Jupiter.

TRIPLE SYSTEM



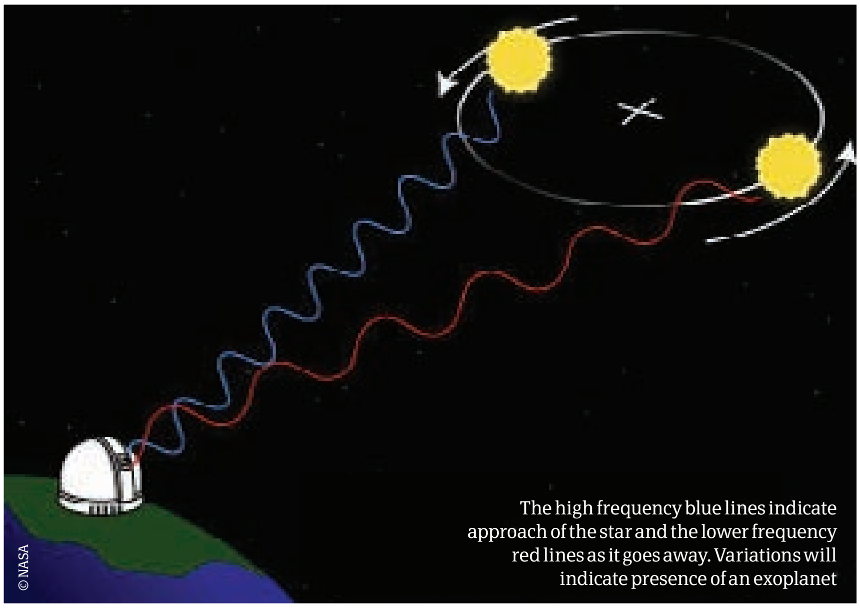
3. HD 188753 Ab
This hot Jupiter was the first to be discovered in a system with three suns. It is 149 light years away and was discovered by the Keck observatory back in 2005.

DID YOU KNOW? The search for exoplanets requires measurements that are fractions of an arcsecond



How are we looking?

Extrasolar planets are small, distant and hidden in the glare of their parent stars, unable to be seen directly by telescope. Astronomers use four main methods to infer their existence…



The high frequency blue lines indicate approach of the star and the lower frequency red lines as it goes away. Variations will indicate presence of an exoplanet

Doppler shift

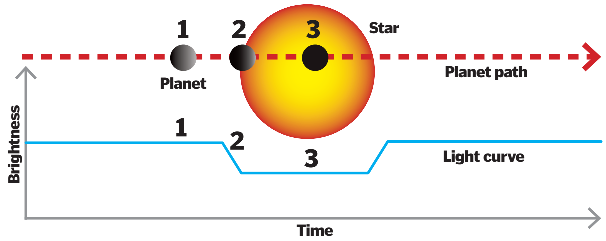
This is based on analysing the spectrum of the light from a star. The spectrum of a star is as individual to it as a fingerprint. When light is refracted through a prism, it creates a spectrum of violet, indigo, blue, green, yellow, orange and red light. A rainbow naturally produces this effect. The invisible electromagnetic radiation at either end of the spectrum, like x-rays and infrared, can also be analysed by astronomers.

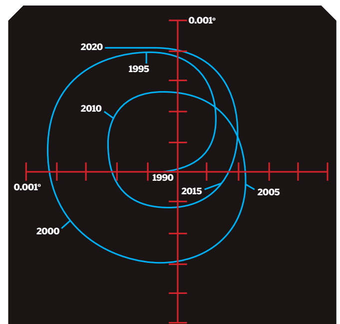
As a star moves towards us its light waves shift towards the higher-frequency blue end of the spectrum, and when it moves away they go to the lower frequency red end of the spectrum. This phenomenon is known as Doppler shift.

If a star has a nearby large planet, the two will orbit around a common centre of mass. The star will move faster around this centre of mass the bigger and closer the planet. This radial velocity can be measured, as the spectrum of the star will show correspondingly bigger colour shifts.

Transit method

As a planet passes (transits) in front of its parent star, it will cause the apparent brightness of the star to be reduced. During the transit, the spectrum of the light from the planet's atmosphere can be detected and analysed. Furthermore, when the Sun transits the planet the photometric intensity of the star can be compared with the data gathered during the planet's transit, enabling astronomers to calculate the temperature of the planet.



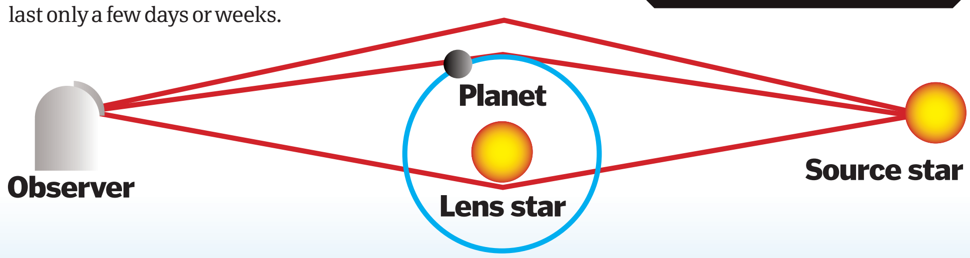


Astrometric measurement

The precise position of the star is recorded and plotted by telescope to detect the slight wobble of a star caused by radial velocity, implying the effects of a nearby planet. Astrometry is the earliest method of searching for exoplanets that dates back to the use of hand-plotted stars in the 18th Century.

Gravitational microlensing

This technique uses the lensing effect produced when one star is in alignment with another star. The gravitational field of the star nearest the observer magnifies the light from the star behind it, and if the foreground star has a planet, it will cause detectable variations in this lensing effect. Huge numbers of stars have to be monitored to discover these alignments that last only a few days or weeks.



Where are we looking?

The search for exoplanets is presently restricted to our own Milky Way spiral galaxy, which has a diameter of about 100,000 light years. This is mainly due to the various limitations on the technology and techniques used to seek them out.

Using astrometric and Doppler shift methods, the area of search is a range of from 100 to 300 light years. This can be extended by the transit method to 6,000 light years and using chronometry, as proposed for the TPF-C spacecraft, to 12,000 light years. Gravitational lensing can find extrasolar planets 25,000 light years away. As these techniques are refined, the search range is constantly being extended.

One theory is that the galaxy itself has a Goldilocks Zone, so that star systems in the spiral arms or too close to the centre of the galaxy would be too inhospitable for life-supporting planets. If this is true then Earth-like life-supporting exoplanets will be rarer to find.

Milky Way and Sun © NASA

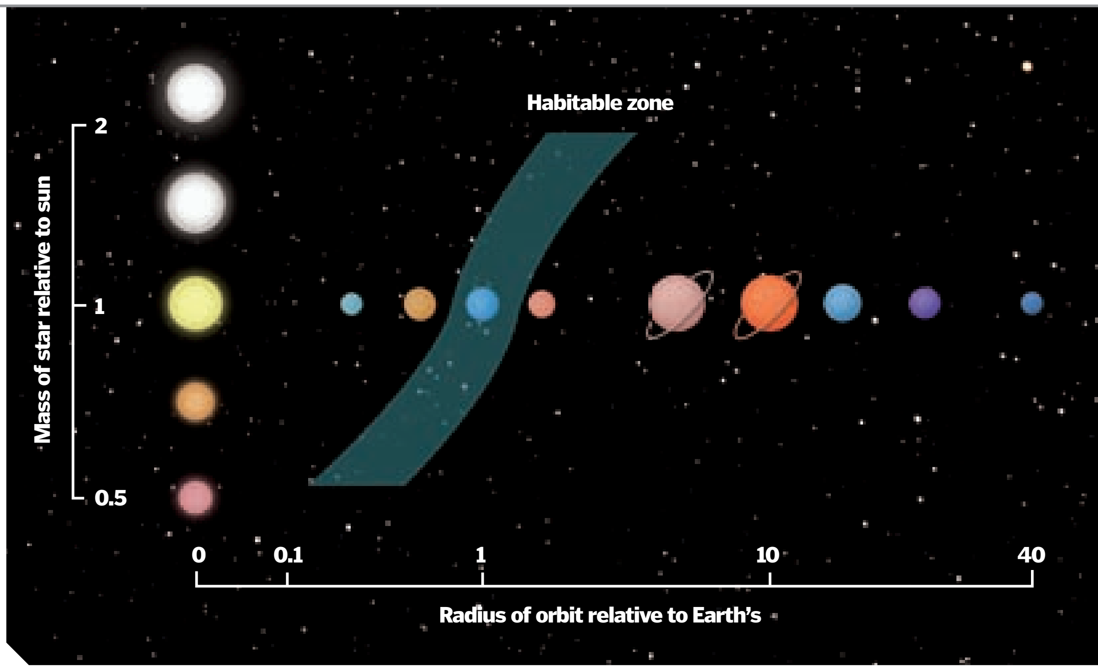
"This early data revealed five exoplanets, named Kepler 4b, 5b, 6b, 7b and 8b"

Goldilocks Zone

The simple system that explains why the Earth's position is perfect for us to survive

This term comes from the 'Goldilocks and the Three Bears' story. Goldilocks tested bowls of porridge to find out which one was not too hot or too cold. Earth is inside the Goldilocks Zone that is just right for habitation. If Earth was closer to the Sun, like Mercury and Venus, conditions are too hot for us. If we were further away, like Mars and beyond, conditions are too cold and arid.

Our Sun is a G-dwarf type star, for larger stars like A-dwarfs the habitable zone is further away, and for cooler stars like M-dwarfs the habitable zone is closer. Life is also dependent on the rotation, axial tilt and orbit of Earth that gives us our regular procession of days, seasons and years. If these factors were too extreme or irregular, the variations in temperature and effects on our climate and ecosystem would not be suitable for us.



What has been found?

Up to May 2010, 385 extrasolar planets have been discovered. So far not one Earth-sized planet has been found, the majority are hot Jupiters or gas giants. Hot Jupiters have a mass of between 110 to 430 times that of Earth. They are created beyond their parent star before establishing a close orbit around it. Their atmosphere consists of hydrogen and helium.

Other types of exoplanets are super Earths, which have a mass between that of Earth and Jupiter. So far about 30 of these have been detected. A good example is COROT-7 b, which was discovered in 2009 by the European COROT (Convection Rotation and planetary Transits) spacecraft. It resides 500 light years away in the Unicorn constellation, and orbits a Sun-like G-class star. Unfortunately, it orbits very close to its parent star and its surface could be as hot as 2,600°C. In addition, it orbits its star at the rate of 466,030mph; making Earth's 67,000mph look sluggish.

COROT found its ninth exoplanet in March 2010. Named COROT-9b it is a more temperate planet with a surface temperature of between -20 and 160°Celsius and has a steady 95-day orbit around its parent star. It is positioned in the Serpens constellation at a distance of a mere 1,500 light years.

Also in March 2010, HAT-P-14b was discovered 670 light years away in the Hercules constellation, and 235 light years away in the Andromeda constellation HAT-P-16b was reported in the same month. They are hot Jupiter exoplanets but there is a possibility of a smaller exoplanet near HAT-P-14b.

NASA's Kepler space telescope analysed 150,000 stars to detect any exoplanets using the transit method when it started operating in May 2009. This early data revealed five exoplanets, named Kepler 4b, 5b, 6b, 7b and 8b that were confirmed by ground-based observatories. All of them are in the Cygnus constellation and are hot Jupiter-type exoplanets. It has since obtained data from 156,000 stars that might reveal up to 400 more exoplanets, but it is not planning to release news on this until 2011.

An artist's impression of the COROT spacecraft

© NASA

BIGGEST TWIN

1. W. M. Keck Observatory

The Keck's twin 10m primary mirrors weigh 300 tons each. It is located on the top of an extinct volcano on Hawai'i Island.

NEW CONTENDER

2. Large Binocular Telescope (LBT)

Located on Mount Graham, Arizona, USA, it has twin 8.4-metre (27.6-foot) primary mirrors.

A FUTURE GIANT

3. European Extremely Large Telescope (E-ELT)

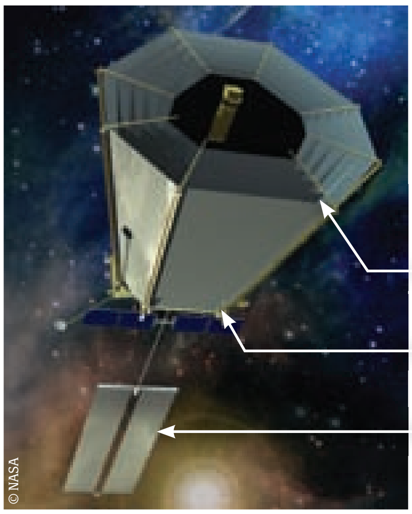
This will have a 42 metre mirror and is planned to search for Earth-like exoplanets in the Goldilocks Zone in 2018.

DID YOU KNOW? CoRoT-7 b orbits its star at a speed of 466,030mph

Future planet-finding missions

Space agencies have proposed the following spacecraft missions to study extrasolar planets

NASA's Terrestrial Planet Finder (TPF) Project



TPF Coronagraph

Solar coronagraphs were originally used with telescopes to block out the disc of the Sun to study its corona – this is hot plasma emitted by stellar bodies that travels millions of miles beyond its surface. Applied to the search for extrasolar planets the problem of blocking out the direct light of a star poses a much bigger problem. By isolating and studying the stellar corona, any planet within this area should be detected by the TPF-C spacecraft's telescope combined with coronagraph detection equipment.

Sunshade
The conical v-grooved sunshade fans out to insulate the telescope from the changing position of the Sun.

Primary mirror
Located at the base of the sunshade, the mirror is set at an angle to deflect its light to the top of the secondary mirror.

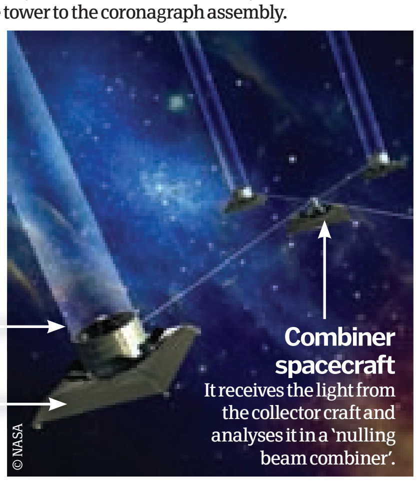
Secondary mirror tower
The smaller secondary mirror is mounted on top of this tower. The light from this and the primary mirror is reflected down the tower to the coronagraph assembly.

TPF Interferometer

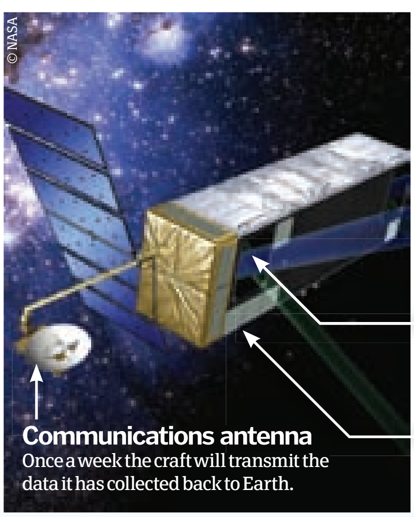
This TPF-I mission would employ a formation of five spacecraft. Four would each be equipped with a four-metre infrared telescope, and one spacecraft would receive the data from them and combine it. The interaction of the light waves from the telescopes produces interference that can be used to eliminate the glare of a star by a factor of 1 million. This so-called nulling technique allows the detection of any infrared emissions from planets near its parent star. The term interferometer is explained by the fact that it can also be used to measure the distance and angles of celestial objects.

Stray light baffles
Beams of light from the collector spacecraft telescopes travel along these 35-metre-long baffles to the combiner spacecraft.

Collector spacecraft
Each has a four-metre diameter telescope mirror shielded and cooled by a five-layer sunshade.



SIM Lite

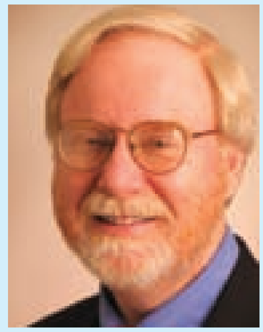


© European Southern Observatory, 2009

The SIM Lite spacecraft will take five and a half years to reach an orbit around the Sun at a distance of 82 million km from the Earth. Here it will search the Goldilocks Zones of 60 stars for Earth-sized planets at a distance of up to 33 light years away. To achieve this it employs sensitive interferometer equipment that can detect a star's wobble to an accuracy of 20 millionths of an arcsecond. These are incredibly small measurements; an arcsecond is 1/60th of an arcminute, which in turn is 1/60th of a degree. A star-tracking telescope is also carried by the craft to carry out astrometric calculations to compare and use with the inferometric data.

Collecting apertures
The twin mirrors of a six-metre baseline 'science' telescope have 50cm apertures at either end of the craft, and a 'guide' telescope with a 4.2 metre baseline has twin 30cm apertures.

Inside spacecraft
The images from the science and guide telescopes inside the spacecraft are sent to central beam combiners and analysed by inferometric equipment.



Interview
Wesley Traub
Chief scientist, NASA Navigator Program

We caught up with Wesly Traub, the chief scientist for NASA's Exoplanet Exploration Program, and the project scientist for the Terrestrial Planet Finder Coronagraph (TPF-C)

How It Works: What type of outer space missions are needed to find exoplanets?
Wesley Traub: An astrometric mission is needed to discover planets around our nearest neighbour stars. This mission could determine the orbital parameters of each planet and accurately measure its mass.

This is important because we need a list of planets that are close enough to Earth that we can measure their properties; nearest-neighbour planets are bright enough for us to measure, but more distant ones are not.

HIW: Will you be able to find evidence of Earth-type and even life on these planets?
WT: A visible spectroscopy mission is needed to look for biomarkers in the visible wavelength range. For an Earth-like planet these biomarkers include oxygen, ozone, water, an atmosphere at least as thick as the Earth's (via the blue colour of a blue sky, like ours), and possibly the enhanced reflection of red light from vegetation (grass, trees and plants, all of which look green to us but also reflect red light that we cannot see).

For a planet like the early Earth, you could see methane and carbon dioxide, in addition to the blue-sky effect. An infrared spectroscopy mission is needed to look for different biomarkers like carbon dioxide, ozone, and water. This mission could also measure the temperature of the planet, and its size. We need to look for these biomarkers in both wavelength ranges because together they give us a more complete picture than either one alone. For example, we can measure oxygen only in the visible spectrum, and temperature only in the infrared.

HIW: What is the most important objective for these missions?
WT: I think the most important thing would be to answer the question of whether there's life on other planets. I guess at heart I believe there are planets with life on them. I don't know about intelligent life. The usual argument is that there are billions of stars out there, and today we think the chances of planets being around each one of them are pretty high, which we didn't used to think. And we think that life formed very quickly, as soon as it was possible on Earth. But out of the billions of stars in our galaxy, we only have a chance of looking at about 200 stars that are nearby. The chances of intelligent life being there on one of those, right now, are pretty small.

HIW: Will TPF-I, TPF-C or SIM Lite go ahead?
WT: None of these missions have started development yet. Once the current suite of missions in development is completed, then an exoplanet mission may begin development. The earliest a mission of this type can be flown is towards the end of this decade.

Where on an Earth?

Exoplanet study has only been conducted over the past 15 years, and has already revealed completely different planetary bodies from those in our own solar system. Due to the limitations of our current technology, we have so far only found giant exoplanets. In future, we might discover rogue planets that do not orbit a parent star and exoplanets that are dominated by oceans, fields of ice, or boiling hot volcanic crusts like COROT-7b. None of these are likely to sustain life, as we know it, so the Holy Grail of this work is to find life-supporting Earth-type planets.

© NASA

Greek warships

This month in History

Delve into the History section and you'll discover the secrets of Forties' Battle of Britain and learn about the remarkable aircraft used in Germany's campaign against the English. There's also an evolution of the bicycle, revealing the origins of this still-popular mode of transport and its development. Ever wondered why the Tower of Pisa leans? Well, wonder no more as we have the answer on page 71. We also took a look at some of the deadly weapons used in Wild West America.

70 Bicycle evolution

71 Leaning Tower of Pisa

72 Weapons of the Wild West

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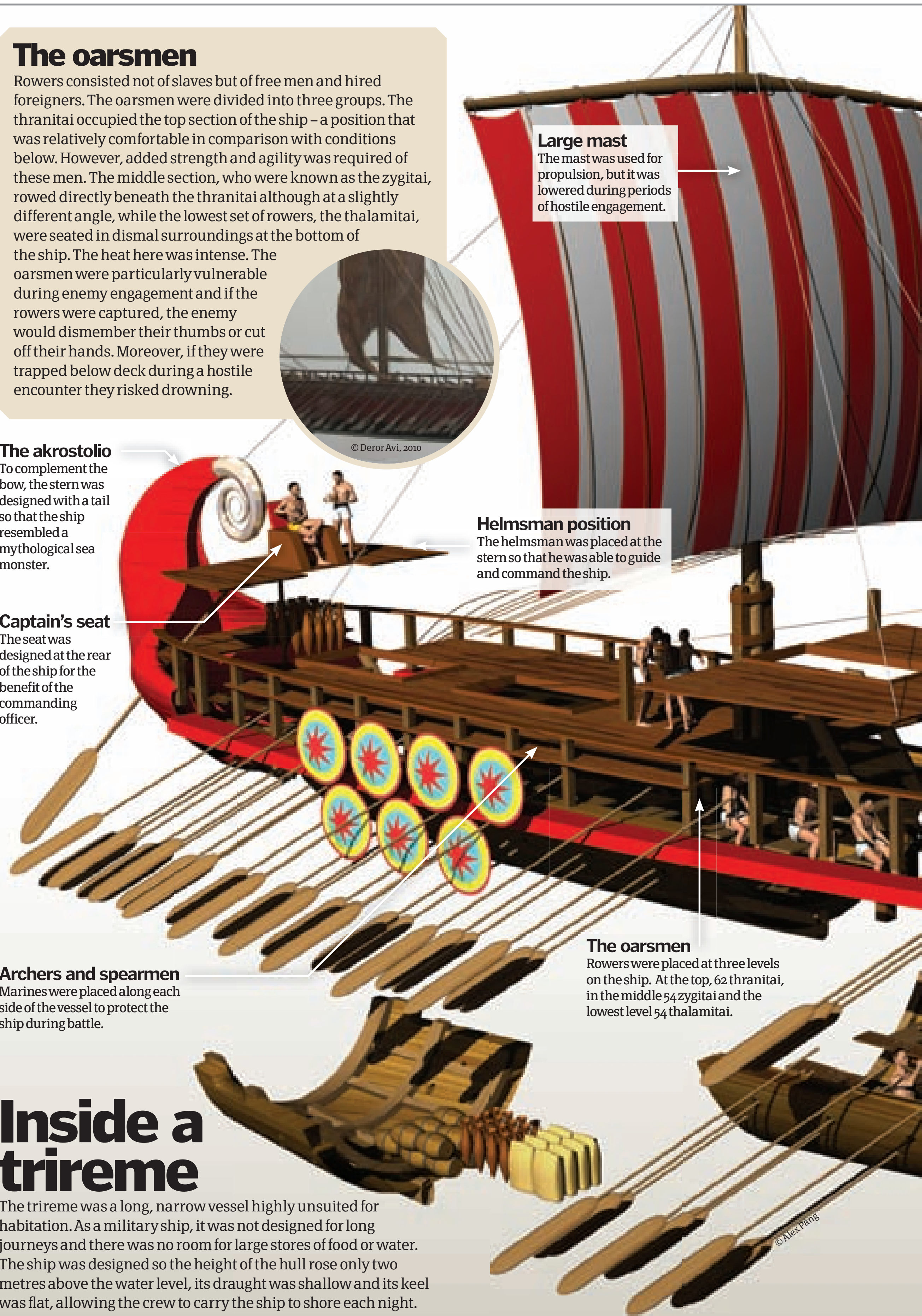
74 The Battle of Britain

The oarsmen

Rowers consisted not of slaves but of free men and hired foreigners. The oarsmen were divided into three groups. The thranitai occupied the top section of the ship – a position that was relatively comfortable in comparison with conditions below. However, added strength and agility was required of these men. The middle section, who were known as the zygitai, rowed directly beneath the thranitai although at a slightly different angle, while the lowest set of rowers, the thalamitai, were seated in dismal surroundings at the bottom of the ship. The heat here was intense. The oarsmen were particularly vulnerable during enemy engagement and if the rowers were captured, the enemy would dismember their thumbs or cut off their hands. Moreover, if they were trapped below deck during a hostile encounter they risked drowning.

© Deror Avi, 2010



Large mast
The mast was used for propulsion, but it was lowered during periods of hostile engagement.

The akrostolio
To complement the bow, the stern was designed with a tail so that the ship resembled a mythological sea monster.

Helmsman position
The helmsman was placed at the stern so that he was able to guide and command the ship.

Captain's seat
The seat was designed at the rear of the ship for the benefit of the commanding officer.

Archers and spearmen
Marines were placed along each side of the vessel to protect the ship during battle.

The oarsmen
Rowers were placed at three levels on the ship. At the top, 62 thranitai, in the middle 54 zygitai and the lowest level 54 thalamitai.

© Alex Pang

Inside a trireme

The trireme was a long, narrow vessel highly unsuited for habitation. As a military ship, it was not designed for long journeys and there was no room for large stores of food or water. The ship was designed so the height of the hull rose only two metres above the water level, its draught was shallow and its keel was flat, allowing the crew to carry the ship to shore each night.

LENGTH >35 metres METHOD OF SPEED CONTROL Flute players
SPACE BETWEEN OARSMEN 2 feet WEIGHT >45 tons ANCHOR Large stone

DID YOU KNOW? In 1987 scholars in Greece built a replica trireme called Olympias

Greek warships

Triremes – the ultimate fighting machines

First used in the 8th Century BC, the trireme was a state-of-the-art military machine. Fast and agile, triremes were designed to exert maximum power during military engagements. Both the Greeks and the Phoenicians employed these ships for military and trading purposes – its name is derived from its ability to seat three levels of rowers who were positioned on both sides of the vessel. Triremes played an essential role in the Persian wars becoming an important symbol of Athenian military capability. By the 5th Century BC these ships came to dominate the waters around the eastern Mediterranean.

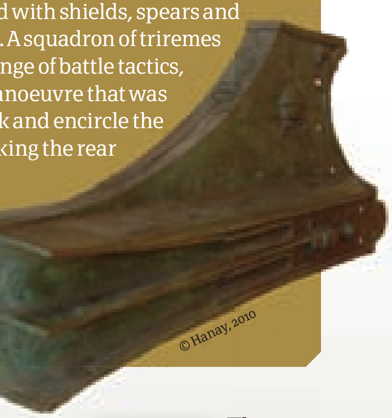
Construction of the triremes began with the hull. Later, the builders added wooden ribs in order to strengthen the vessel, these were reinforced with ropes that were fitted to the keel and stretched tightly over the timber. The ships were built with soft woods – namely pine and fir – while larch was employed for the interior of the vessel, the keel was made of oak.

The crew consisted of 200 men, this included rowers, a marine corp (comprising archers and spearmen) and a deck crew who were under the command of the helmsman. Due to its design the trireme was meant to undertake short, swift operations. At night, the ships would pull into harbour where the crew would collect fresh water and store it for the next stage of the journey.

Primary propulsion came from the oarsmen, this included one man per oar. While the ship was designed with two masts, its steering was actually controlled by two large paddles that were positioned at the stern. It is believed that the trireme could sail at six to eight knots; the distance it travelled depended entirely on the weather and its overall manpower. In favourable conditions, it was thought that the oarsmen were able to propel the ship 50 or 60 miles over a seven-hour period.

Battle tactics

Athenian military operations depended on their close-quarters battle tactics, namely the ramming and boarding of enemy ships. The ram of the trireme was built at the front of the ship creating a large metal horn. When the ship attacked it would come in from the stern and attempt to rupture the hull of the enemy ship. A small number of marines were placed on the deck of the ship. They would defend or attack, attempting to board the enemy vessel armed with shields, spears and archery equipment. A squadron of triremes employed a wide range of battle tactics, these included a manoeuvre that was designed to outflank and encircle the enemy before attacking the rear of their ship.



A ram on show at the Israeli National Maritime Museum

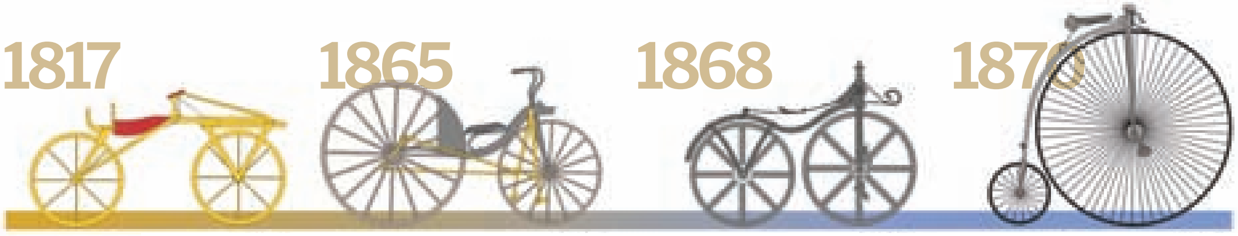
Why did the ancients give their ships female names?

There are many theories and no clear answers. Triremes, with only rare exceptions, were named after female deities or mythological figures. The Greeks named their ships after sea nymphs like Thetis or Charis or after women of legendary courage, such as Danae or Prokne. In ancient times the ship would also sail under a female figurehead that would guide or protect the vessel – before leaving port prayers and sacrifices were made to a goddess who was thought to safeguard the journey. The all-male crew may have associated their ship with the female shape and form – the boat, being a vessel of men, had clear female principles.

Learn more

For more information about these incredible ancient warships why not visit the Hellenic Navy webpage, which can be found at **www.hellenicnavy.gr**.

"The introduction of pedals on the velocipede kick-started the evolution of today's bicycle"

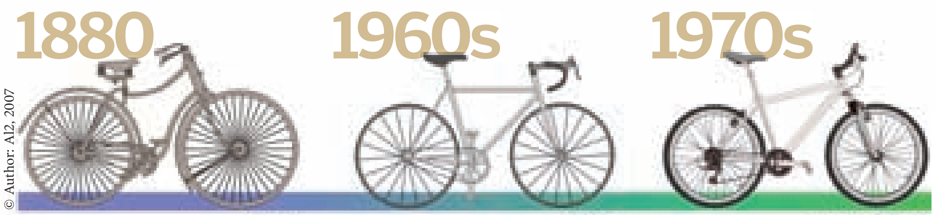


Walking machine
Invented by Baron von Drais in 1817. You sit in the middle of two similar sized wheels, and roll along by walking on the ground.

Velocipede
In 1865 crank-driven pedals were fitted on the front wheel of a walking machine-like bicycle. It was very bumpy to ride.

Pedal bicycle
Pierre Michaux formed a company that was the first to produce bicycles with pedals on a large scale.

High wheel
In 1870 came this machine. The rider sat above the large wheel, which had pedals on the front wheel to propel it forwards.



Safety bicycle
Stronger metal frames and the use of chains and gears made same-sized two wheeled bicycles more viable in the 1880s.

Racing bicycle
For maximum aerodynamic performance they feature lightweight frames, drop handlebars and fine gearing.

Mountain bike
Developed for off-track racing. To cope with rugged terrain they have either front or rear suspension.

Evolution of the bicycle

How we learnt to get on our bikes

The name bicycle was coined in 1869 but bicycle-like machines were built much earlier in this century. The walking machine of 1817 didn't have pedals, but did have a steerable handlebar and was used throughout Europe. In Britain they were known as 'hobby horses'.

Before pedals and chain drives, Kirkpatrick Macmillan invented a push rod system for propelling his bicycle. You had to push your feet up and downwards to drive the rear wheel. The introduction of pedals on the velocipede kick-started the evolution of today's bicycle.

One turn of the pedals equalled one turn of the bicycle wheel, making the rider pedal furiously to obtain any speed. To overcome this problem the high wheel bicycle had the pedals attached to a large wheel, so that the bicycle covered a far greater distance on one turn of the pedals.

By the end of the 19th Century tricycles and safety bicycles featured many new innovations; lighter steel-tubed frames, brakes, pneumatic tyres, metal-link chains that connected the pedals to a toothed sprocket on the rear wheel and gearing systems that employed several different sized sprockets to change the ease or difficulty of turning the pedals.

These technological innovations enabled urban dwellers to commute or travel to the countryside more efficiently and quickly. In particular, bicycles gave women far greater independence. In the Thirties, a combination of lower production costs and rising wages made bicycles much more affordable for the working classes and their recreational use began to increase.

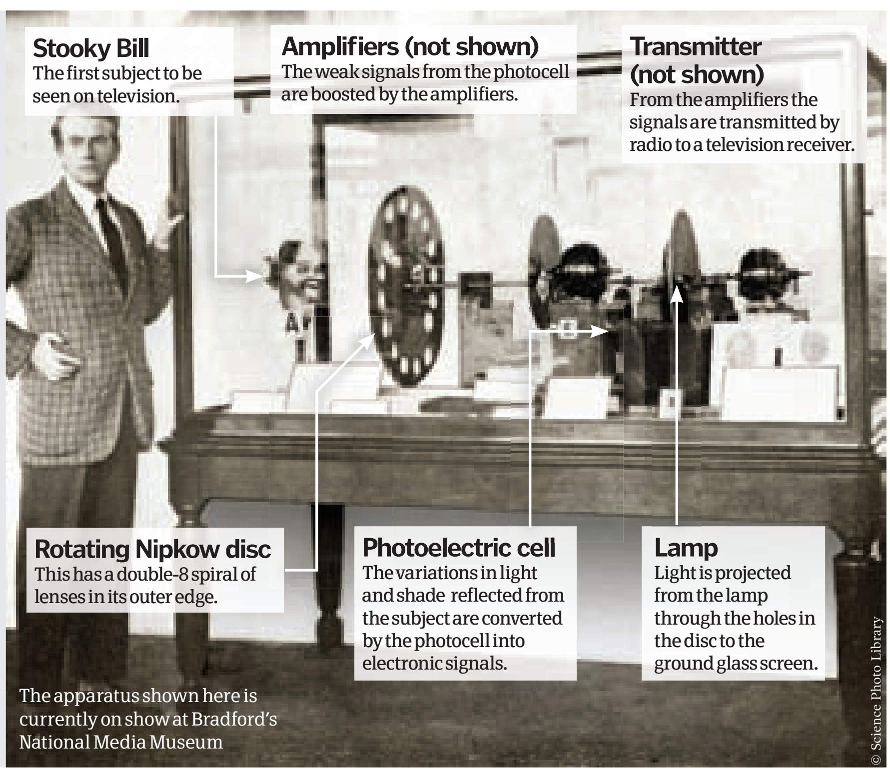
The first television

The start of the 'goggle box' invasion into our homes and minds

Scottish engineer John Logie Baird's breakthrough came on 2 October 1925 when he transmitted a greyscale image of the head of a ventriloquist's dummy called 'Stooky Bill'. Baird immediately replaced Bill with William Taynton who became the first person to appear on TV.

Elements of Baird's system used technology that had been developed during the 19th Century. It employs circular Nipkow discs to obtain 32 lines of vertically scanned images at a rate of five pictures per second. Baird's disc had a double-8 spiral of 16 lenses on the outer edge that corresponds to the 32 lines of the full television picture. Two rotations of the disc produce one complete television picture frame.

The light from the scanned subject is converted by a selenium photocell into electronic signals that are sent by radio waves to a receiver. Here, the signals trigger a neon tube to flash behind a spinning disc with holes on its edge. The light from the disc reproduces the transmitted pictures onto a ground glass screen.



Stooky Bill
The first subject to be seen on television.

Amplifiers (not shown)
The weak signals from the photocell are boosted by the amplifiers.

Transmitter (not shown)
From the amplifiers the signals are transmitted by radio to a television receiver.

Rotating Nipkow disc
This has a double-8 spiral of lenses in its outer edge.

Photoelectric cell
The variations in light and shade reflected from the subject are converted by the photocell into electronic signals.

Lamp
Light is projected from the lamp through the holes in the disc to the ground glass screen.

The apparatus shown here is currently on show at Bradford's National Media Museum

Head to Head THINGS THAT LEAN

1. Bad Frankenhausen
The church's spire inclines to one side. Leaning at 4.5 degrees the tilt is increasing at a rate of six centimetres each year.

2. The bell tower, at the church of San Nicola
Thought to be the product of the same architects, the bell tower of San Nicola is also tilting with the base currently secured.

3. Leaning Tower of Suurhusen
This late medieval steeple in East Frisia, Germany is the most tilted tower in the world according to the *Guinness Book Of Records*, at an angle of 5.19°.

DID YOU KNOW? *The name Pisa originates from the Greek word for 'marsh land'*

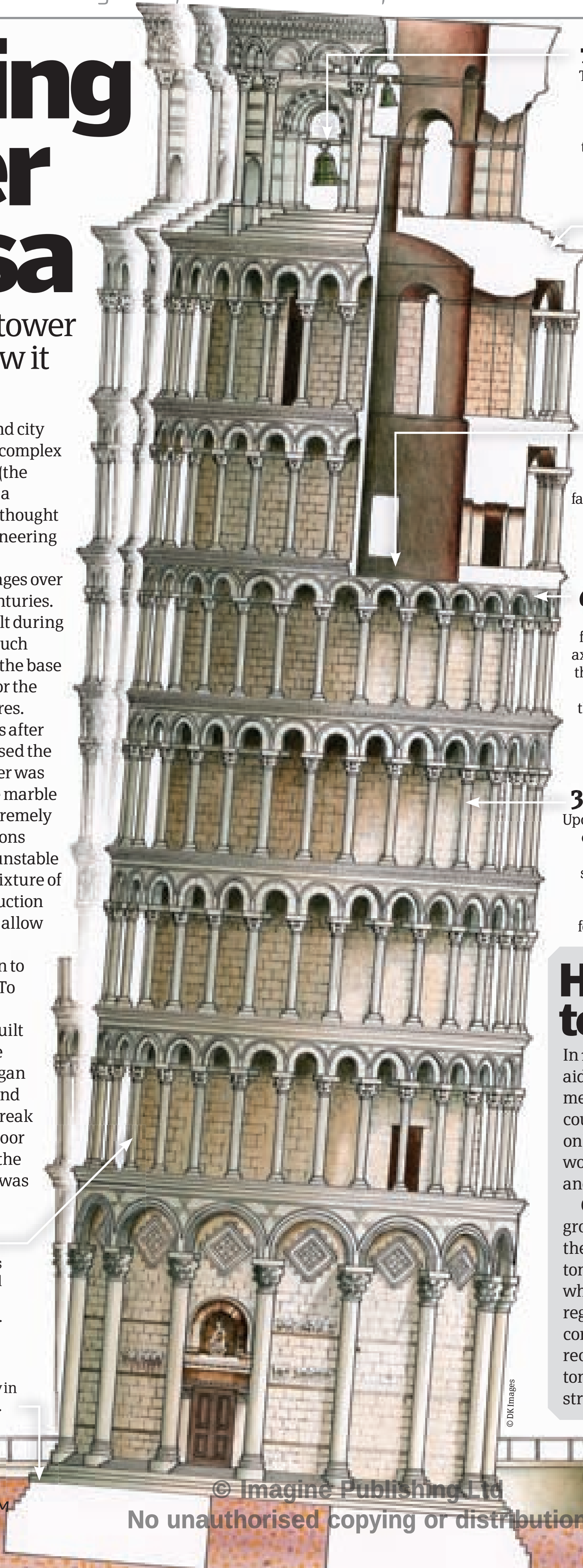
Leaning Tower of Pisa

Find out how the tower was made and how it went wrong…

The local architects and city officials designed the complex at Piazza dei Miracoli (the Square of Miracles) as a dedication to art, and as such it is thought the principles of science and engineering were not fully understood.

The tower was built in three stages over a period stretching nearly two centuries. The first part of the tower was built during a time of town prosperity and as such heavy white marble was used for the base and tower, with limestone used for the interior and exterior design features.

Disaster occurred just five years after work began, as the workers finalised the interior of the third floor. The tower was sinking because the weight of the marble building was too much for the extremely insufficient three-metre foundations which had been set in weak and unstable soil that contained a malleable mixture of clay, sand and rubble. The construction was halted for nearly a century to allow the soil to settle. In 1272 work recommenced as engineers began to build the tower's middle section. To compensate for the continuing problem of its lean, the workers built one side of the wall taller than the other. Subsequently the tower began to lean in the opposite direction and caused it to curve. War caused a break in construction and the seventh floor was not completed until 1319 and the eighth level, featuring the belfry, was finally added in 1372.


© DK Images

7. Bell tower
The Bell chamber was added in 1372. It features seven bells – one for each note of the musical scale. The largest of which was installed in 1655.

4. Shape
The tower has a cylindrical body encircled with arches and columns. The central body is a hollow shell which features an external wall of white and grey limestone.

5. Spiral staircase
The inner wall was fashioned from worked limestone and comprises a 296-step spiral staircase.

6. Curvature
In 1272 architects fashioned a corrective axial inclination where the walls on one side of the tower were taller than the other – giving the building its concave appearance.

3. Third floor
Upon reaching this level, engineers noticed the tower was starting to sink. The heavy white marble had become too heavy for the foundations set in soil.

2. First floor interior
Lining the inside the first floor is a series of arches in a typical Romanesque blind arcade style, intersected with columns displaying classical Corinthian capitals.

1. Foundations
Made of white marble the construction began in 1173 during a time of prosperity in Pisa thanks to the success of its military.

© Natalie Johnson

The Statistics

Leaning Tower of Pisa

Location: City of Pisa, Tuscany, Italy
Years of construction: 1173-1372
Length of construction: 199 years
Architect: There is still speculation as to who was the original architect but the following are credited as key architects involved with the construction: Diotisalvi, Guglielmo and Bonanno Pisano, Gherardo di Gherardo, Giovanni Pisano and Giovanni di Simone
Height – both high side / low side: The original height was 60 metres, today it is 56.67m on the highest side and 55.86m on the lowest
Type of building/purpose: Bell tower (campanile)
Angle of lean: 3.97 degrees
Weight of the tower: 14,700 tons
Number of steps: 296

How to stop the tower toppling…

In 1964 a desperate Italian Government requested aid to stop the tower from toppling. One of the first methods to be tested was to add 800 tons of lead counterweights to the raised end of the base, but this only added to its subsidence. With the problem worsening it was decided to close the tower in 1990 and remove the bells to relieve some of the weight.

Cables were cinched around the third level and grounded several hundred metres away to anchor the weight. Work began on removing some 38 cubic tons of soil from under the raised end of the base, which straightened the tower by 18 inches – regaining an angle last recorded in 1838. Ten years of corrective stabilisation followed and the tower reopened to the public in 2001. In 2008 another 70 tons of earth was excavated and for the first time the structure has officially stopped moving.

“The 1846 Walker Colt was the first large calibre rotating cylinder handgun”

Wild west w

The development of reliable, accurate pistols and rifles played a key part in how the west was won

During America’s frontier past, westward expansion meant settlers had to protect themselves and the land they had taken from Native Indian reprisals. Chief concern, the Comanche, could lose nine arrows in the time the Texans took to muzzle-load and fire a musket. The revolving cylinder pistol and lever-action repeating rifles marked the turning point in this battle. Of these, while the black powder .36 calibre 1851 Paterson Colt failed to unseat the mounted Comanche, the Walker Colt, adopted by the Texas Rangers in the 1850s, did not.

The Volcanic repeating rifle fired caseless ammunition known as a ‘rocket-ball’. The powder and primer was fused by a binding agent in the hollow rear of the bullet. Unlike the black powder handguns that used paper/cloth cartridges that were susceptible to moisture and so prone to misfire, the rocket-ball was waterproof. Unfortunately, the ammunition – despite its name – was grossly underpowered; it was usurped by the Henry and Winchester rifles of the 1860s.

By the 1870s revolvers benefited from enclosed metal-cased bullet cartridges, which meant all-weather shoot-outs. Their common centerfire rounds were compatible with many Winchester lever-action rifles, allowing the holder to alternate firearms with ease. These modern cartridges and later pistol designs gave rise to Colt’s game-changing Single Action Army 1873. The “Peacemaker” ushered in the typical pistol fighting genre with the line: “God didn’t create all men equal, Sam Colt did”.

Brothers in arms

The Clanton and McLaury clan’s defiance of Tombstone gun-carrying laws ended in a 15ft space of William Harwood’s lumberyard. From the OK Corral, Town Marshall Virgil Earp’s call to disarm could be heard; sparking the 19-year old Billy Clanton to draw against Wyatt and miss. The resulting firefight saw Morgan Earp’s reply hit Clanton twice in the chest. Wyatt’s .44 calibre Smith and Wesson turned on the stomach of Frank McLaury, while unarmed, his younger brother Tom and Ike Clanton tried to run. Ike escaped, but Tom McLaury was hit in the back by a shotgun loaned to Holliday. In just 30 seconds all but Ike from the cowboys were left dying, or dead.

Shooting from the hip

1. **Technique:** Draw pistol up, inches from holster; rotate wrist and lower elbow; move gun forward and up towards target; steady with supporting arm and fire!
2. **Weapon of choice:** Walker Colt’s weight did not lend itself to quick draw, unlike the SAA Peacemaker 1873.
3. **A good workman:** Considered by many the fastest, the Sundance Kid (1890s) would be more deadly, accurate, and quicker, because of his tools, than Jesse James (1870s) - but this didn’t factor in meanness or even a man’s will!
4. **The meanest:** John Wesley Hardin; with over 40 kills to his name was reputed to have killed a man simply for snoring!

Remington .44

A sturdier and more accurate competitor to the Colt

The Remington Army revolver was a large-framed .44 calibre, with an eight-inch barrel length. It had a six shot cylinder and an eight-inch octagonal barrel. Patented in 1858, it was the major competitor to the Colt .44 in the American Civil War, and many considered it to be more accurate than the Colt. The percussion model could be easily modified to accept cartridges prior to the introduction of the first Remington cartridge revolver in 1875. These percussion revolvers were capable of considerable power with muzzle velocities in the range of 550 to 1,000+ feet per second depending on the charge loaded by the shooter. It has been seen in many movies including *Pale Rider* and *The Good The Bad And The Ugly.*

Round bullets
The six chambers could be loaded by dropping in powder charge followed by a round or conical bullet.

Winchester Rifle

‘The Gun that won the West’

The Winchester 1866 succeeded the Henry rifle. Its ‘lever-action’ mechanism and distinctive side-loading gate allowed the shooter to eject spent cartridges and chamber new rounds from a sealed tubular magazine, all in one movement.

The rifling process, whereby spiral grooves are etched into the gun barrel, helped to impart spin on the passing bullet, enhancing its accuracy in flight.

The 1866 shot .44 rimfire cartridges while the 1873 and later designs chambered 0.44, 0.38 and 0.32 centerfire rounds; used by Colt, Remington and other revolvers. The replaceable primer located in the central base of the cartridge rather than built into the rim meant when struck and ignited the casing could be re-used; an advantage for large rifles where ammunition was expensive.

DID YOU KNOW?

Gunning for glory

The Winchester 1866, nicknamed 'Yellow Boy' due to its brass receiver, was no coward; the Winchester would come to be known as "the gun that won the west".

DID YOU KNOW? The gunfight near the OK Corral took place at approximately 3pm on Wednesday 26 October 1881

weaponry

Big gun!
The Remington Army revolver was a large-framed .44 calibre, with an eight-inch barrel length.

Percussion caps
After loading, placing a percussion cap at the rear of the cylinder readied the revolver for firing.

Brass trigger guard
This, along with the distinctive loading lever web, makes it easy to spot in movies.

Rifled barrel
Spiral grooves etched into the barrel imparted spin on the bullet, improving accuracy.

Lever action
This mechanism allowed a round to be ejected and a new one chambered in one movement.

Side gate
The loading gate on the side and integrated, round sealed magazine covered by a forestock.

Cylinder
Housing a cluster of six to ten barrels which were loaded by a hopper.

Crank
The Gatling Gun required an operator to crank, so it's not a true automatic.

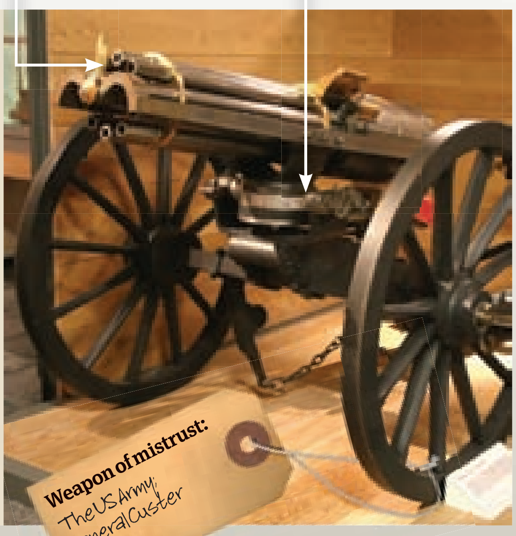
Gatling Gun

Slaughter... with the best of intentions

Gatling's aim was to reduce the need for large armies, and so exposure to battle. However, despite dispensing a murderous 400-1,200 0.45-1 calibre rounds/per min. this gun was initially unpopular. At 90lbs the US Army thought it too unwieldy for combat.

Its cylinder housed a cluster of six to ten barrels turned by a crank shaft; loaded upon rotation by a gravity-fed ammunition hopper. Each barrel had its own breech and a firing-pin mechanism aligned in a groove in the gun's body. As the barrel rotated the groove pulled the pin backwards, compressing its spring. As a cartridge fell into the breech of the barrel the firing-pin slid from the groove causing the pin to shoot forwards, contacting the cartridge and dispensing its round.

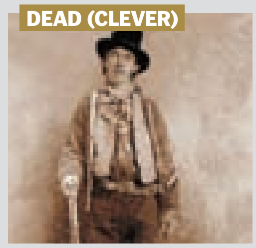
General Custer refused its use in his final fight at the Battle of Little Bighorn. It was only used late in the war against the North.



Head to Head
LAST MAN STANDING

More often than not gunfights were visceral spur-of-the-moment encounters sparked by disagreements and fuelled by drink that bore little relation to the honour and romantic idyll of quick-draw.

DEAD (CLEVER)

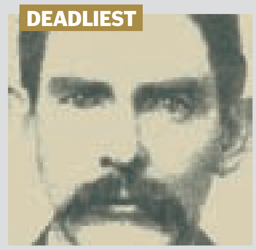


1. Billy the Kid
A renowned gunslinger he was not below tricking opponents to gain an advantage. On the wrong end of a battle of wits he was shot from the shadows by lawman Pat Garrett aged just 21.

DEADLIER

2. Wild Bill Hickok
Hickok killed more than 20 men during gunfights; he would reload his 1851 Colt black powder revolver every morning (even if it hadn't been used) to prevent moisture and a resulting misfire.

DEADLIEST



3. Doc Holliday
Wyatt Earp claimed Holliday was "the nerviest, fastest, deadliest man with a six-gun I ever saw!" Earp lived to the ripe age of 81. Enough said.

Learn more
For more information on the weapons that won the West, along with a detailed look at the history of arms and armour, the DK book *Weapon*, produced in association with the Royal Armouries Museum, is available from **www.amazon.co.uk**.

“Göring inherited a Luftwaffe of great numbers and experience”

Battle of Britain

70 years ago an epic conflict took place between allied and axis powers. It was one of the defining moments of World War II and changed the nature of armed conflict forever

The Battle of Britain was an exclusively aerial campaign between allied and axis forces which began in the summer of 1940 and culminated in May of 1941. The objective of the German-led aerial assault on Britain was to completely destroy the Royal Air Force (RAF) and render Fighter Command useless, so a planned land invasion of Britain could begin. The Luftwaffe (Germany's air force) was ordered by Hitler to drive the RAF from the skies in 'the shortest possible time', and led by notable First World War veteran fighter pilot Hermann Wilhelm Göring, the then Reich Minister of Aviation, what was to follow was a costly – in terms of human life and financially – battle of attrition.

At the head of Britain's defence was Hugh Dowding, the then Air Chief Marshal of the RAF and Fighter Command, which had been set up in 1936 to oversee and manage Britain's emerging modern air force. Fighter Command led its RAF-based defence of Britain from Bentley Priory, London, communicating with airfields, radar stations, pilots and other communications headquarters over the south east (where the majority of the battle took place) and other regions of the country. At his disposal was a well-ordered yet numerically inferior air force to that of the Germans, with many pilots lacking valuable experience.

Contrary to Dowding, Göring inherited a Luftwaffe of great numbers and experience, with many of its pilots having gained valuable flight experience in WWI. This allowed Göring and his commanders to launch large raids on Britain – one of the most notable being a 500-strong assault on 15 September 1940 – causing large damage to a wide variety of areas and military buildings as well as, by the end of the war, 43,000 civilian deaths. Despite Göring's leadership, his other commanders held differences of opinion in how the RAF should be toppled – a factor that Dowding also had to deal with among Britain's commanders in how to defend the country.

Despite their experience and numbers, Germany failed to gain air superiority over Britain and by the end of the Battle they had lost 1,152 aircraft and 1,144 crew, compared to Britain's losses of 1,085 aircraft and 446 crew. Retrospectively, this result was caused by a single piece of state-of-the-art technology, as we find out over the page.


A British air observer scans the skies for enemy bombers

Fighter Command

The men who led Britain's resistance

Name: Hugh Dowding
Rank: Air Chief Marshal
Description: An experienced officer, Dowding was set to retire shortly before WWII, only to be persuaded to stay on until the situation had stabilised. He is often credited as the mastermind behind Britain's success in the Battle of Britain.

Name: Keith Park
Rank: Air Vice Marshal
Description: In tactical command during the Battle of Britain, Park was in-charge of protecting London from attack. Flying a personalised Hurricane, Park held a reputation as a shrewd tactician.

Name: Trafford Leigh-Mallory
Rank: Air Officer Commanding
Description: The commander of 11 Group RAF had open disagreements with Park and Dowding over the tactics to counter the German threat. He was credited as creating the 'Big Wing' fighter formation to hunt German bombers.

Luftwaffe

The men who led the German attack

Name: Hermann Wilhelm Göring
Rank: Reich Minister of Aviation
Description: The last commander of legendary ace fighter pilot 'The Red Baron', Göring was responsible for German Luftwaffe. In his youth he had flown in the First World War and was respected by the Germans as a notable commander.

Name: Hugo Sperrle
Rank: General Field Marshal
Description: General Field Marshal of the Luftwaffe, Sperrle advised Hitler that the destruction of Britain's air force was key to winning the war. Air Fleet 3, which he commanded, played a major role in the battle but suffered heavy losses.

Name: Albert Kesselring
Rank: General Field Marshal
Description: Kesselring orchestrated combat in Poland, France and at the Battle of Britain. He is credited with the Coventry Blitz of November 1940 and won the respect of allied powers with his military accomplishments.

FAMOUS

1. Hawker Hurricane
The real hero, the Hurricane shot down more aircraft than either of its contemporaries and was the workhorse of the RAF.

MORE FAMOUS

2. Messerschmitt
Classed as heavy fighters, the Messerschmitt Bf 109E and Bf 110C were the Luftwaffe's main aerial threat and shot down many allied planes.

MOST FAMOUS

3. Spitfire
The most iconic fighter of World War Two, the Spitfire was a formidable opponent, packing firepower, flexibility and unparalleled dynamism.

DID YOU KNOW? The RAF lost 1,085 planes during the Battle of Britain, while the Luftwaffe lost 1,152

Battle map

Charting the key military bases, RAF and Luftwaffe headquarters, radar stations, and squadrons that partook in the Battle of Britain

Due to Germany's occupation of France, they could set up military bases at Calais and other coastal cities along the Channel. This put the German bombers in range of London and left the area to its south east (Kent) exposed to many attacks. Indeed, the majority of the Battle of Britain was fought over the south east of England and this led to the majority of Britain's air force bases being heavily used in the area. 11 Group RAF were responsible for protecting London and the south east, and they saw much action and suffered the bulk of the casualties during enemy attacks. As we see over the page, the careful and strategic use of the newly emerging technology of radar gave Britain valuable insight into the activities of approaching aircraft across the Channel, especially at night when countering German bombers in low-visibility situations.

A Spitfire flies over the south east of England

Heinkel He 111's running aircraft bombing raids over Kent during the Battle of Britain

Key:

- Fighter command bases
- Luftwaffe fighter bases
- Luftwaffe bomber bases
- RAF group boundaries
- Luftflotte boundaries
- Range of Messerschmitt BF 109
- Range of low-level radar
- Range of high-level radar

A selection of pilots from 303 Squadron walk away from their aircraft

"The main advantage that radar gave was the ability to launch intercepting attack aircraft at the right time"

How the battle was won

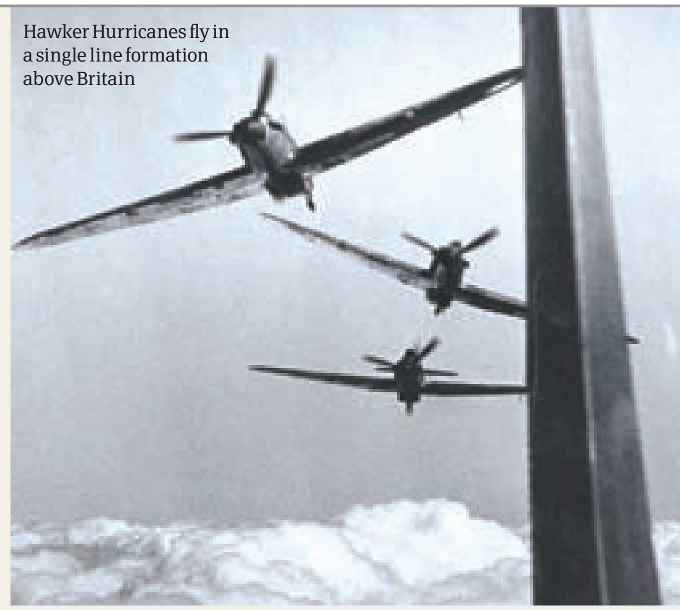
Thanks to the skilful implementation of the emerging technology of radar, allied forces were better equipped to counter German attacks

The importance of radar in the Battle of Britain was massive, something that its then leader Hugh Dowding knew all too well. Britain was facing larger numbers of enemy aircraft, pilots with more flight experience and frequent bombing runs in the dead of night – the favoured time for German attacks. Radar then was key, allowing enemy airborne movement to be tracked from across the Channel and, crucially, allowing Britain's smaller air force to be managed more acutely.

The main advantage that radar gave was the ability to launch intercepting attack aircraft at the right time. Not too early – forcing planes to reland for refuelling, leaving them vulnerable to attack and costing cash-strapped Britain in fuel bills – and equally not too late – giving the German planes a crucial height advantage in the proceeding dogfight and allowing them to reach inland areas of Britain. Dowding, operating his stringent Fabian Strategy, used this to great effect, having information on approaching aircraft sent from coastal stations to Bentley Priory (Fighter Command headquarters) with great haste so that finessed tactical plans could be quickly drawn up and relayed to air force bases.

The system did have drawbacks however. While radar was excellent and highly accurate in detecting aircraft movement, it was quite poor in expressing the numbers of aircraft and their formations, two factors crucial in decision-making if an effective resistance was to be mounted. Because of this, Dowding's system also incorporated RDF-based detection – which allowed formations to be determined as they formed over France – and the pre-existing Observer Corps, groups of mainly volunteer civilians dotted throughout Britain, visually relaying information on approaching aircraft numbers and formations to Fighter Command. Indeed, many historians argue that without the Observer Corps, no matter how refined Britain's radar-based systems became, the Battle of Britain would've been lost – an opinion vocalised by Dowding when he said that "they constituted the whole means of tracking enemy raids once they had crossed the coastline. Their works throughout [the war] was quite invaluable."

Importantly, despite the benefits radar was providing Britain's air force, Göring and his commanders underestimated its ability and importance in what was going to be the deciding factor in the Battle of Britain. While initially the Luftwaffe were ordered to attack RAF radar stations (an activity they completed with little success, knocking out only one radar station on the Isle of Wight for under 24 hours), their attention was soon turned to the towns and cities of Britain, as their grip on the conflict slackened. It is generally agreed by historians that if Göring had persisted with his targeting of Britain's radar stations, Germany would have had considerably more success than they historically achieved.


Hawker Hurricanes fly in a single line formation above Britain


Members of the RAF Observer Corps count and identify incoming raids

303 Squadron

The Battle of Britain saw over a thousand enemy aircraft shot down by British RAF squadrons, and none more so than the famous Polish 303s. No. 303 Polish Fighter Squadron was one of 16 Polish squadrons in the Royal Air Force during the Second World War and won acclaim for their marksmanship and aerial ability during the conflict. Scoring higher than any other squadron, 303 competed with other RAF squadrons in a competition as to who could shoot down the most enemy aircraft. By the end of the Battle of Britain they had won unequivocally, recording an immense 808 hits. In fact, the top three places in this competition's leaderboard were taken by three of the 12 Polish squadrons, outgunning the best British squadron by far, who only racked up 150 hits.

A 303 captured Messerschmitt sporting anti-Hitler graffiti


RAF and WAAF staff plot bombing raids at RAF Uxbridge

5 TOP FACTS BATTLE OF BRITAIN

Baron

1 Reich Minister of Aviation Hermann Göring was the last commander of the legendary World War I fighter ace Manfred von Richthofen, aka 'The Red Baron'.

Speech

2 The naming of the Battle of Britain originated from a speech by Winston Churchill, when he said: "The Battle of France is over. I expect the Battle of Britain is about to begin."

Axis

3 Joining the Luftwaffe in the attack on Britain during the battle was a small section of the Italian Air Corps, which saw much action in late 1940 but with limited success.

Eagle

4 The first main attack on Britain by Germany was code-named 'Eagle Attack', and it was designed to knock out numerous allied radar stations.

Celebration

5 The Battle of Britain is commemorated each year in the United Kingdom on 15 September, where it is referred to as Battle of Britain Day.

DID YOU KNOW? No. 303 Polish Fighter Squadron recorded 808 hits during the Battle of Britain

Hugh didn't think much of Fighter Command's new headquarters

Members of staff at the RAF museum, London, participating in a Battle of Britain re-enactment

The Battle of Britain memorial is located in Capel-le-Ferne, Kent

Interview

How It Works speaks to RAF historian David Keen about the Battle of Britain

How It Works: Was the Battle of Britain a turning point in World War II?

David Keen: The Battle of Britain was not a turning point in the war but was highly influential in the direction that it progressed. This was because in winning the Battle of Britain, Hugh Dowding, the then Air Chief Marshal of the RAF, prevented Fighter Command from being destroyed by the Germans and the Luftwaffe gaining complete air dominance. If this had been the case then Hitler could have rolled out his planned sea and land invasion of Britain (Operation Sea Lion) with very little resistance and the American forces would have had no base to launch their own attacks from.

HIW: In what state was Britain's air force in the run-up to the battle, how were the odds stacked?

DK: The German Luftwaffe found themselves in a strong position going into the Battle of Britain, with a solid infrastructure in place from World War I, vastly experienced pilots who had seen much combat experience during the Spanish Civil War and a total numerical superiority. The British, in contrast, had been very slow to start in its preparations for war (famously Lord Halifax had promoted and favoured a policy of appeasement with Germany until their invasion of Poland) and modernisation of their outdated air force. For example, Fighter Command was only set up in 1936 and without Dowding's good management and re-organisation would have struggled to combat the German threat. The RAF was also numerically inferior going into the battle and had less experienced pilots.

HIW: How important was Dowding and his integration of radar in the allied victory?

DK: The integrated use of radar was very important as it gave Fighter Command a far greater view over the Channel than it had ever had before, allowing approaching aircraft to be detected and identified far sooner and that information relayed back to Bentley Priory, Fighter Command's headquarters. By splitting the RAF into four main sectors – 10 for the south east, 11 for London, 12 for the Midlands and 13 for the north and Scotland, the radar garnered information could then be filtered quickly and effectively to the area of the country were action was necessary.

HIW: Aircraft had taken a massive step forward since they were last used in the First World War, what technology did the RAF and Luftwaffe have at their disposal?

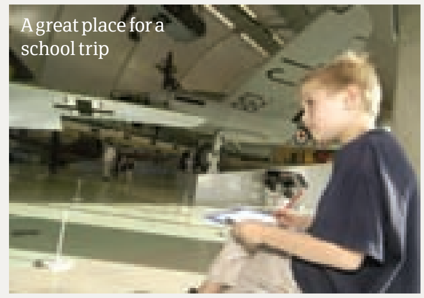
DK: The RAF used two main fighters during the battle, the Hawker Hurricane and the Spitfire. Despite the Spitfire's lasting fame as the poster vehicle of the war, it was actually the Hurricane that was in greater use by the RAF and they shot down more enemy aircraft than the Spitfire throughout. The Hurricane was a solid fighter and was seen as the workhorse of the allied forces, providing good all-round performance and a solid gun platform. The Spitfire, for which there were fewer numbers, was technically the superior vehicle and in the hands of a fighter ace was a more formidable opponent though. In contrast, the Luftwaffe used mainly the Messerschmitt 109, which was classed as a heavy fighter and was famed for its stability and durability. Despite the aircrafts' differences, they were largely the same though and a skilled pilot in one would normally always get the better of another with an amateur at the helm.

HIW: Finally, in retrospect, what should Germany have done to win the Battle of Britain?

DK: Indecision and the spreading of forces was the real downfall for Germany at the time, something that stemmed right from the very top of the chain of command. Before their invasion of Poland, Hitler had promised Britain that if they left Germany alone during its military campaigns then he would leave it alone in payback, something that was favoured by many in Britain at the time. So when Germany suddenly found itself at war with Britain, no firm invasion plan had been secured and after Göring and his commanders failed to deliver the quick victory they predicted, many conflicting tactics entered the fray. With no land and sea invasion in place, the Luftwaffe were constantly ordered to change their bombing priorities, sometimes to go after Britain's radar stations, sometimes their cities (such as Coventry). Further, as Germany's progress on the Eastern front stagnated against the Russians, more and more aircraft were diverted to bolster their forces. In order to win the Battle of Britain Germany should have first concentrated on Britain's radar stations, then once they were destroyed shifted their total focus onto the airfields.

RAF museum

The RAF museum in London is currently celebrating the Battle of Britain's 70th anniversary with a host of events and its newly refurbished Battle of Britain exhibition hall. For more information about the Battle of Britain and what's on at the museum visit: www.rafmuseum.org.uk.



A great place for a school trip

BRAIN DUMP

Because enquiring minds want to know...

? Send us your questions!

The How it Works experts are ready and waiting to answer your questions so fire them off to...
howitworks@imagine-publishing.co.uk

HOW IT WORKS EXPERTS

How It Works is proud to welcome the curators and explainers from the National Science Museum to the Braindump panel

Dan Plane
Science Museum Explainer

Dan has a background in education, working with primary aged children with special needs before coming to the museum. He performs shows at the museum about subjects as varied as structures, bubbles and blood and recently got to drive the replica of Stephenson's Rocket.

Dominique Sleet
Science Museum Explainer

Dominique, a first-time **How It Works** panel member, studied Natural Sciences at university before becoming an Explainer at the Science Museum. In her spare time she likes painting and drawing to relax.

Why do humans prefer some smells over others?

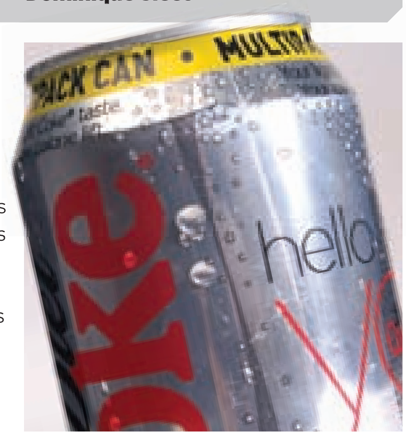
Dina Al-Qassar

■ There are currently two theories for why humans prefer some smells over others. One theory states that we have innate (born with) preferences to certain smells. However, another increasingly supported theory suggests that smell preferences are learned. Early in human development we begin associating certain smells with emotional experiences, ie smells detected during enjoyable experiences are perceived as pleasant. Taking this second viewpoint, it's easy to explain how we determine whether smells are dangerous or not: we learn. This has been exploited to ensure easier detection of gas leaks. Gas naturally has no discernible smell. However, a strong smell is added so that when we detect the smell we associate it with danger and can raise the alarm.
Dominique Sleet

What makes diet cola diet?

Douglas Heaton

■ Diet cola is actually not a modified form of the original cola recipe but is produced from an entirely different recipe. Original cola contains the sugar sucrose or high-fructose corn syrup depending on the country of origin, which both have a high calorific value. Diet cola, on the other hand, contains a blend of sweeteners – including aspartame and sucralose – which is 200 and 600 times sweeter than regular sugar respectively. This means much smaller quantities of sweeteners can be used to achieve the same level of sugariness without adding lots of calories – a regular can of cola contains around 142 calories compared to just 1.3 calories found in a can of diet cola.
Dominique Sleet



Does a metal spoon stop sparkling wine from going flat?

Mark Blackmore

■ This is a widespread myth and has some variations, sometimes the spoon must be silver other times the material doesn't matter. It's unlikely that the spoon makes any difference. There is some suggestion that the metal will absorb more heat energy and keep the air in the bottle colder, which may aid the preservation of the sparkle in your wine.

The temperature is certainly important though. Colder liquids can hold more gas, in the case of sparkling wines, carbon dioxide (CO_2). This is because the higher the temperature the more energy the atoms or molecules in the liquid and gas have, making it more likely that the gas molecules can escape the liquid. So the lower the temperature the lower the energy and less CO_2 can escape. So putting the wine in the fridge is the most beneficial thing. The best thing to do, though, is finish the bottle!

Dan Plane

How can I keep my PC safe when using Spotify?

Luke De Costa

■ The most reliable way is to have up-to-date anti-virus software on your computer. You could try to operate by trust alone, but many viruses are – as you know – hidden and the person who sent it to you may not know the virus is there, or even that they are sending anything.

Anti-virus software can work in two separate ways. One is to look for suspicious behaviour, such as a file that copies itself. The other is to check any files being received, created or saved against what is known as a virus dictionary. This is a list of all known viruses and needs to be kept up-to-date with the latest definitions of viruses.

Spotify itself, which shares music between users, doesn't let the users upload anything manually, so no one can add a virus into the mix. It also controls and encrypts what is being transferred, presumably running them through its own virus protection too.

Dan Plane

How do ear thermometers work?

Kevin Kennedy

■ These are also called tympanic thermometers. This is because they take measurements from the tympanic membrane, the 'drum skin' of your eardrum.

Unlike traditional mercury thermometers, which use the expansion of mercury at higher temperatures to measure those in the body, tympanic thermometers measure infrared radiation. Infrared radiation, or IR, is a form of electromagnetic radiation, like light or radio waves, that is given off by anything that has a temperature.

The probe part of the thermometer is inserted into the ear where its IR sensor is within range of the membrane and can get a reading. For hygiene, the probe has a disposable plastic cover, which the IR can pass through and for ease an extension can be used to place it in the ear of unconscious surgery patients. The reading is much quicker and convenient, two seconds compared to two minutes for an accurate rectal thermometer reading.

Dan Plane

sciencemuseum

What's on at the Science Museum?

Who am I?

■ Opening 26 June ■ Free

To mark the end of its Centenary year, the Science Museum will open an upgraded 'Who am I?' gallery on 26 June. Currently one of the most popular galleries in the Science Museum, Who am I? presents the latest in brain science and genetics through a mixture of interactive exhibits and object-rich displays. What makes you, you? How do your genes impact on your brain, your actions, your thoughts and your appearance? Visitors to the redeveloped gallery will get the chance to explore answers to these questions and more by encountering object displays, artworks and by sharing their opinions on issues in science.

LAST CHANCE TO SEE

1001 Inventions: Discover the Muslim Heritage in Our World

■ Open until 30 June ■ Free

Tracing the forgotten story of 1,000 years of science from the Muslim world, from the 7th Century onwards. Featuring interactive exhibits, displays and dramatisation, the exhibition explores the shared scientific heritage of diverse cultures and looks at how many modern inventions can trace their roots back to Muslim civilisation.

COMING SOON

Legends Of Flight at the IMAX 3D Cinema

■ Coming up this summer

■ Charges apply

Legends Of Flight is a captivating new film showcasing some of history's most amazing aircraft. Soar over the highest peaks, feel the gut-wrenching force of take-off and loop and roll above the ocean. From one of the first passenger airliners to make long-range flying practical to the Boeing 787 Dreamliner which seeks to take its place among aviation greats, *Legends Of Flight* brings together the past and future of air travel.

sciencemuseum

What's on at the Science Museum?

COMING SOON

Antenna

■ Opening in June ■ Free
'Antenna' hosts a series of events allowing visitors to get up close with new developments in science and breakthrough technologies. A new concept for Antenna will be unveiled in June 2010 providing an innovative new way for the public to engage with contemporary science.

Science Museum Lates

■ 30 June: 6.45pm to 10pm ■ Free
To celebrate the opening of the new Who Am I? biomedical gallery, the next Lates held on Wednesday 30 June will explore the question of identity. Visitors can take part in a variety of activities centred on the themes of genetics, DNA and psychology. At 7.30pm, you are also invited to participate in a live recording of BBC World Service's The Forum, presented by Bridget Kendall.

Forget Me Knot

■ 1 July, 7pm to 8:45pm
Does your memory let you down? Could drugs, technology or memory tricks really enhance your ability to recall? Open up your mind and test out your memory skills on a night you'll be sure to remember.

For further information visit the What's On section at www.sciencemuseum.org.uk/centenary.

Visit the Museum

Exhibition Road, South Kensington, London SW7 2DD. Open 10am – 6pm every day. Entry is free, but charges apply for the IMAX 3D Cinema, simulators and some of the special exhibitions.

Will we change the mass of the planet by extracting all the oil?

Peter Webber

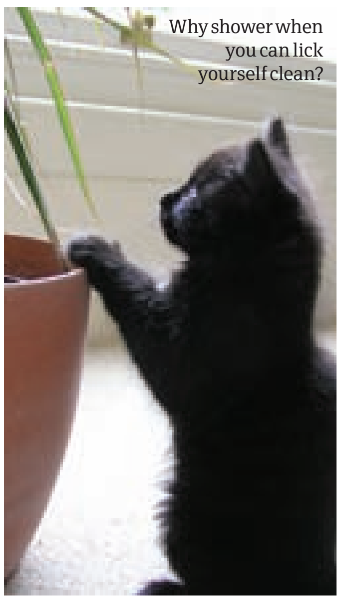
■ We are indeed redistributing mass around the planet, but the total stays the same. Earth's mass does slightly change over time, due to loss of atmosphere and a gain from meteorites, but it's negligible. If the mass were to considerably increase, our orbital radius around the Sun would decrease, the planet's motion would be faster and a year would be shorter.

However, although Earth's mass isn't changing, redistribution could change the length of a day. Angular momentum is a product of the rate at which an object spins, and the distance of its mass from its axis, and the Conservation of Angular Momentum says it must stay the same at all times. It means that if mass is moved further from the centre of Earth, the rate of rotation must slow down, increasing the length of a day.

Earthquakes shift mass closer to the centre, hence speed up rotation and shorten the day. However, NASA states that the Chilean earthquake in 2010 shortened the day by an actual 1.26 microseconds, that's 0.00000126 seconds.

Dan Plane

Earht © iStock Photo / Straw © Martin Belam



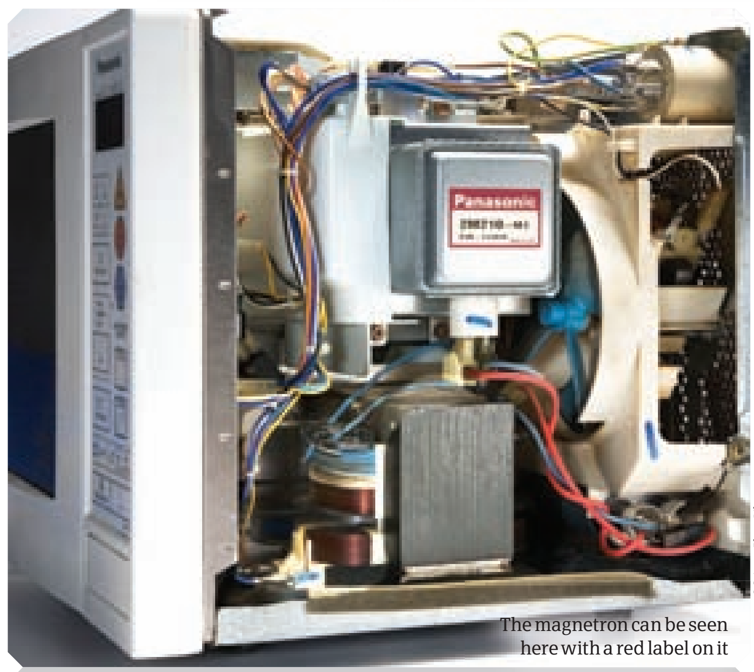
Why shower when you can lick yourself clean?

What are fur balls?

Ashley Stephenson

■ Cats take a lot of care over their coats and regularly groom themselves by licking off any loose hairs. Cats' tongues are quite rough and they pull a lot of hair out, most of which they'll swallow. In small amounts, this just passes straight through the cat's digestive system. But if, for example, your cat has a particularly thick coat the hair may build up too quickly and form trichobezoar, or fur balls. The quickest way to get these out of the stomach is to vomit them up. As to why your cat chooses the carpet, you'd best ask them.

Dan Plane



© Science Photo Library

The magnetron can be seen here with a red label on it

Why does metal react so violently in a microwave oven?

Tom Boon

■ Microwaves are a kind of electromagnetic wave and as such can create electric currents in metals. Many of the microwaves are actually reflected by the metal and can reflect back onto the magnetron – the part of the oven that produces the microwaves, which can overheat and become damaged. When microwaves hit metal surfaces, free electrons (negatively charged particles) in the metal start to move around and the movement of this charge is how an electric current arises. Some of these electrons will move too much and will actually jump from the metal to the air which becomes temporarily ionised (charged). This can result in a phenomenon called 'arcing' where an electric spark similar to a flash of lightning is produced. Thin metal such as rims of mugs, produce more resistance to an electric current than thick metal, and so can become very hot. If sufficiently thin the metal can become so hot that it actually burns or melts!

Dominique Sleet

The Ghostbusters take the Statue of Liberty for a swim

Why has flooding become such a problem?

Donald Rempstone

■ Unfortunately, flooding is simply a part of nature. One in six properties are at risk of flooding in England and Wales. Changes in our climate, such as more severe storms and wetter winters, will increase the risk of flooding in the future. There are a variety of ways to tackle flooding and these are just a few of them…

Changes in land use, such as building houses or putting down concrete, can increase the risk of flooding. Because of this, we advise against developments that will have an adverse affect on flooding.

When building flood defences we look for ways to work with nature rather than against it. Creating mudflats and salt marshes to store flood water can prevent flooding elsewhere, and can also provide environmental benefits such as new habitats.

Individuals and communities also have a role to play in protecting themselves and their properties from flood risk.

The Environment Agency

How do ants breathe?

Daniel McDermott

■ Ants, like all insects, don't have lungs, breathing through tiny holes in their sides – spiracles – one pair per segment. These lead into a network of tiny tubes – tracheae – permeating their entire body, getting narrower and narrower, supplying air (and hence oxygen), right to the tissues that use it, rather than using blood to transport it like us. Though they can open and close their spiracles, they have little ability to pump air in and out, which happens just through general movement. It's this inability that stops insects getting as big as us, with our ultra-efficient lungs and blood.

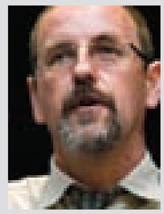
Dr Roger Key, Consultant to Royal Entomological Society

HOW IT WORKS EXPERTS

How it Works is proud to welcome the experts from International Year of Biodiversity in the UK (IYB-UK) to the Braindump panel

IYB-UK is made up of over 400 major organisations, charities, universities, businesses, schools, museums and arts practitioners. Dr Robert Bloomfield, the director of International Year of Biodiversity in the UK, will be marshalling a range of experts from across the partnership to answer your questions.

Dr Robert Bloomfield
Director IYB-UK/Head of Innovation and Special Projects, Natural Museum History



Bob is Head of Innovation and Special Projects at the Natural History Museum where he has delivered Darwin200 and is now directing IYB-UK during 2010. With a PhD in Genetics, Bob has pursued a career in science and public engagement, leading major science communication projects. In 2002 Bob was awarded a NESTA Dream Time Fellowship which he ultimately used to retrace the first voyage of Captain James Cook.

International Year of Biodiversity – What's On June and July 2010

Plantastic!

■ Daily until 5 September 2010
■ Free ■ World Museum Liverpool, William Brown St, Liverpool, Merseyside, L3 8EN (open from 10am to 5pm every day)

Discover the secret world of plants in Plantastic!, an interactive exhibition for all the family. There will be around 40 exciting interactive displays that show the dynamic life of plants and explore the themes of feeding, providing, reproducing, moving and surviving.

Gannet and Puffin cruises

■ Daily until 10 July 2010 (cruises take place morning and afternoon) ■ Tickets cost £15 for adults, £7.50 for children, and £37.50 for family tickets (two adults and two children ■ Bridlington, North Yorkshire
From May onwards, the cliffs of Bempton and Flamborough become crowded with over 200,000 seabirds setting up home for the summer. On the three-hour round trip from Bridlington Harbour, you'll visit the spectacular chalk cliffs at Flamborough Head. Expert commentators from the RSPB's East Yorkshire Local Group are on board each cruise to help you identify the birds.

The Deep

■ Daily (10am to 6pm) until 30 October 2010 ■ Adult £8, child and concession £4.50, family £22. pupil in school group £3.50. ■ The Natural History Museum, Cromwell Road, London SW7 5BD
Your imagination stops at 100 metres, but the Natural History Museum's new exhibition will take you all the way down to 11,000 metres. The Deep will plunge visitors into the abyss, revealing a deep sea environment that – amazingly – is less explored than the surface of the moon. Discover the history of deep sea exploration, cutting-edge technologies used today and how museum scientists are helping to preserve this extremely important ecosystem.

Biodiversity – what's it all about?

■ Daily (12am to 1pm) until 30 September 2010 ■ Free, but please register with the guide 15 minutes before the tour, first-come, first-served basis ■ Guides' Desk, Victoria Plaza, Royal Botanic Gardens, Victoria Gate, Kew Road,Kew, Richmond, Surrey, TW9 3RB
Join one of the Royal Botanic Garden Kew's expert volunteer guides for a biodiversity-themed tour of the beautiful gardens and learn what you can do to help prevent the loss of habitats and plants which all help to encourage biodiversity.

What are starfish?

Nathan Cooper

■ Starfish are echinoderms, along with sea urchins and sea cucumbers. This name comes from Greek, meaning 'spiky skin'. Their spiky skin is made up of many tiny skeletal plates and spines made of calcium carbonate minerals such as calcite and aragonite. However, because it is an invertebrate it also does not simply have one large protective coat.

Inside, starfish are made of much the same material as you and I, having cells, tissues and organs. However, their arrangement is extremely different and contains a large number of specialisations. The most important difference is that they have a 'hydrostatic' skeleton. This means that the body movement and rigidity is controlled using water pressure and not bones.

The body consists of (usually) five arms radiating from a central disc. The mouth is found in the centre of the underside of the body, with grooves running along the middle of each arm containing tube feet. The feet often have suckers on the ends to allow the starfish to grip the ground.

Starfish are typically predatory and interestingly, when feeding they push their stomach outside their body and digest their prey where they are found, then draw their stomach back inside.

Dan Bayley, MarLIN at the Marine Biological Association

Do Komodo dragons have a venomous bite?

Neil Cobb

■ Recent studies have shown that Komodo dragons, indeed all monitor lizards, have saliva that is venomous to some degree. However, this 'venom' is not like that of say a cobra that can kill prey in as little as a few hours, so dragons have a few tricks up their sleeves. It appears that the venomous saliva combines with infectious bacteria, blood loss, as well as physical injury, to kill prey. Few animals are likely to survive a dragon attack and that includes humans, and death can often be slow and pretty painful. So the secret is, do NOT get bitten!

Dr Ian Stephen, Assistant Curator of Herpetology, ZSL London Zoo

© Mats Stafseng Einarsen

Why do leaves turn red in autumn?

Caroline Appleby

■ The autumnal colours of our deciduous trees in the northern hemisphere are a signal that winter is fast approaching. The green colour of leaves is due to the presence of a pigment called chlorophyll which is used for photosynthesis. Chlorophyll is a dominant green pigment that masks the rest of the colour pigments found in leaves. These include the carotenoids which give us the orange and yellows, the same pigment that colours daffodil flowers and bananas, and anthocyanins which begin to develop towards the end of summer, giving us the reds and purples, which we see in strawberries and cranberries.

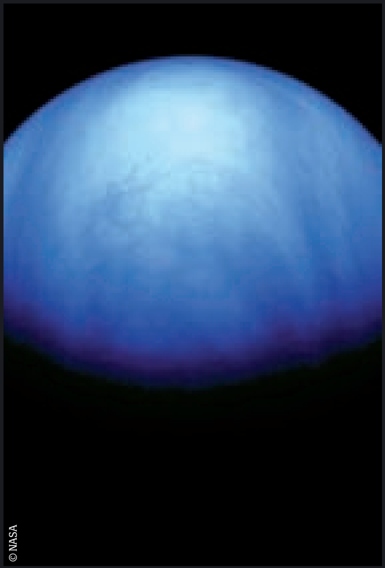
Towards the end of summer and into autumn, the many veins of a leaf that are used to transport liquid to and from the leaves begin to shut down and chlorophyll production decreases. This allows the carotenoids and anthocyanins that are normally masked by the chlorophyll to show through and give us the colours that we know as autumn colour.

So why colour up? We believe for two reasons, the first being that the red anthocyanins protect the leaves from harmful rays of the Sun during cold weather and at the same time act as a warning signal for insect pests to avoid, while the tree sheds its leaves.

Tony Kirkham, Head of Arboretum, Royal Botanic Gardens Kew

FROM THE FORUM

*Every month we'll feature a reader's question from our fantastic forum at **www.howitworksdaily.com/forum***



© NASA

Why is Venus referred to as Earth's twin?

Beatrice Cook

Some of the reasons for this are that Venus is almost exactly the same size as Earth, just 400 miles shorter in diameter and 20 per cent smaller in mass. During the early evolution of the solar system both Venus and Earth would have been almost mirror images of each other. This, however, was not to last and differences in our atmospheres' compositions play a part in the vast differences we see today. With surface temperatures approaching 500° Celsius and an atmosphere of around 96 per cent carbon dioxide, Venus exhibits the kind of runaway greenhouse effect people are worried might befall Earth if we carry on pumping carbon dioxide into the atmosphere.

Along with more than three per cent nitrogen and the rest largely composed of sulphuric, hydrochloric and hydrofluoric acids, when it rains on Venus it's actually almost pure acid carried by weather patterns not that dissimilar to those we find on Earth. Fortunately our rain isn't usually quite so harmful!

Fossils are a glimpse into the past

© Masur

How are fossils formed?

James Harfield

Fossils are the preserved remains or traces of ancient organisms which have become entombed in sedimentary rock. Fossils have also been found in volcanic ash, tar, ice and amber. Those trapped in rock are preserved by the natural process of burial in sediments such as mud, silt or sand typically from a marine, lake or swamp habitat.

To increase the chances of fossilisation the organism needs to be buried by sediment quickly after its death to stop it being scavenged and to impede decomposition. Following burial the remains go through physical and chemical changes over thousands or even millions of years to become fossilised as the sediments are more deeply buried and are transformed into sedimentary rock. Hard tissues of organisms such as shell, bone and teeth are normally the only parts fossilised as they contain biominerals secreted by the living animals which makes them more resistant. Only rarely are soft tissues such as muscles preserved.

Fossilisation can occur when cavities within organisms, such as porous cell walls, become filled with minerals precipitated from groundwater. This preserves the overall shape and structure of the organism which could otherwise be crushed by the overlying sediment.

Fossilisation can also occur when the remains are dissolved by acidic groundwater and the residual void is a mould of the external surface left as an impression in the surrounding rock. If the void is later filled with minerals then this creates a fossil cast of the original organism. Similarly a 3D internal mould can form when sediments or minerals fill internal spaces of the organism before original tissues are dissolved.

In addition some fossils can form through mineral replacement of the original tissue or through recrystallisation where mineral composition remains the same but in a different crystal form.

Lindsay Percival, Curator Cephalopods, Dept of Palaeontology, the Natural History Museum

International Year of Biodiversity – What's On June and July 2010

Wildlife photography safari in London

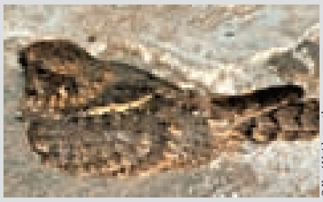
■ 18 June 2010 1pm to 5pm ■ Adults only admission cost: £50/£55 supporter/non-supporter, pre-booking required, People's Trust for Endangered Species 020 7498 4533 ■ London

Discover some of London's wildlife gems and brush-up on your photography skills during this walking safari. Practical photography tuition will be suitable for beginners. Led by Iain Green, wildlife photographer and author of *Wild London*.

Father's Day Nightjar Ride

■ 20 June 2010 9:30pm to 10:30pm ■ Free, pre-booking required (open to families) www.eastdevonaonb.org.uk ■ Trinity Hill Forestry Commission, near Axminster, Devon

Enjoy an Area of Outstanding Natural Beauty in East Devon with a family-friendly introduction to off-road night rides and hear the amazing sound of the nightjars. A great experience for dads and kids alike. Cycle helmet and lights essential, suitable for off-road bikes only. Accompanied children over nine years old. Booking essential on 01404 46663.



© Kavi Vaidyanathan

Firth of Forth seabird cruises

■ Wednesdays and Sundays until 14 July 2010 ■ Advance booking on 0131 311 6530 is essential. Tickets cost £13 for adults and £6.50 for children. Family tickets are also available ■ Departing from Hawes Pier, South Queensferry, Edinburgh.

2010 has been declared the International Year of Biodiversity (IYB) by the United Nations

Visit the website

www.biodiversityislife.net This is the website of IYB-UK, which is the UK partnership supporting IYB. It's a great source of news and events concerning biodiversity and the environment.

THE HOW IT WORKS KNOWLEDGE

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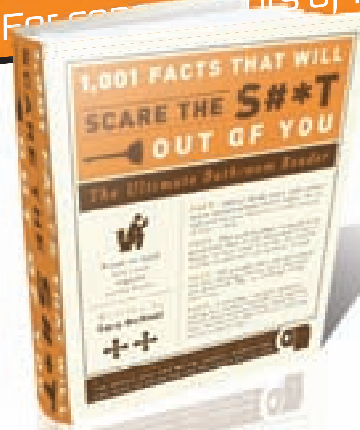
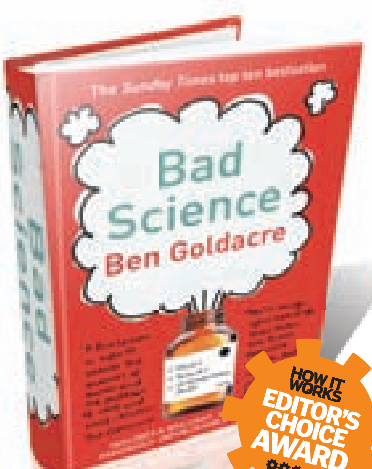


1,001 Facts That Will Scare The S#*T Out Of You

Price: £7.49 / $12.95
ISBN: 978-1-60550-624-1

Did you know office desks have 400 times more bacteria than toilet seats? That's more likely to gross us out than scare the s#*t out of us, but there are more than just a few choice gems in this fact-packed tome of wisdom.

Verdict: ★★★★



HOW IT WORKS EDITOR'S CHOICE AWARD

Bad Science

Price: £4.59 / $6.59
ISBN: 978-0-00728-487-0

Written by the notable Dr Ben Goldacre, *Bad Science* presents a funny, invigorating and informative journey into the world of the bad science we are bombarded with every day by the media and advertising agencies. Debunking quacks, hacks and supposed miracle cures, Goldacre pulls no punches in showing how science can be used to prove everything and nothing.

Verdict: ★★★★★

HOW IT WORKS EDITOR'S CHOICE AWARD

If Carlsberg did radios…

Pure Evoke Flow DAB internet radio

Price: £149.99 / N/A
Get it from: www.direct.tesco.com

DESPITE THE HUGE push towards digital in the last decade, DAB radios haven't had nearly as enthusiastic a reception from a market that couldn't wait to ditch CRTs in favour of LCD televisions. So maybe Pure's Evoke Flow DAB internet radio could help instigate a trend? Because it's certainly stylish enough to sit alongside the latest, wall-mounted flat-screen telly.

Its simple geometric lines and gloss finish are eye-catching enough but if we didn't know any better we would say that its looks understate the technology within, until you tap the touch-sensitive power button and the green OLED display lights up, that is. The contrasting pixellated neon glow on soft black has a retro attraction to it and the sheer accessibility of the Evoke Flow's many features enhance that appeal.

It combines standard FM and DAB digital radio with internet broadcasts (including podcasts and listen again programmes) and Pure's "Lounge", a Pure radio owner's webpage where you can register your product and customise content according to your taste before broadcasting it over Wi-Fi to your radio. You can even stream your entire music collection wirelessly from your PC to the Evoke Flow, which is somewhat redundant a feature in an era of iPods and portable music devices, but the option is a welcome bonus.

Tuning into a radio station really is effortless: you select your location and time zone, then the Evoke Flow spends 30 seconds or so auto-tuning available stations in your area. We chose Radio 6 and were pleasantly surprised by the punchy quality of Tom Robinson's voice we got from the three-inch drive unit. Connectivity includes an iPod input plus headphone and stereo speaker outputs, plus a patented "Snoozehandle", which shuts off the alarm clock when touched (a capacitance change-sensor, in case you were wondering).

Truly, this is a multi-media lifestyle device that most certainly has as much a place in the house as any of the latest digital technology.

Verdict: ★★★★★

Sanyo Xacti CS1

Not Xacti what we had in mind

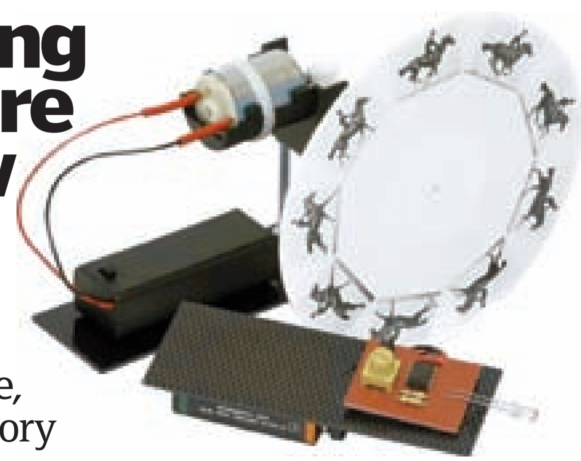
Price: £249 / $299
Get it from: www.jessops.com

AN UNFORESEEN CONSEQUENCE of the exponential rise in the popularity of the iPhone is that one of our most reviled mobile trends, flip phones, are beginning to die off. The same thing can't be said of the flip design on portable video cameras, though at least on Sanyo's Xacti CS1 the 2.7-inch swivel viewfinder has a more practical application than to show anyone watching you how 2001 you are.

Due to its ease of use this pocket video camera is YouTube endorsed, allowing a generation of self-conscious and media-savvy teenagers to simply shoot eight megapixel stills or video, then upload via AV or mini-HDMI to the internet. It's the crispness and stability of the image that makes this device remarkable. It easily puts this pocket video camera in competition with more "serious" portable cameras. Our two criticisms are the tiny amount of internal memory (utterly pointless at 50MB) and the build, which leaves you holding a rather flimsy bottom half when the viewfinder is extended.

Verdict:

Moving Picture Show



Build a tachyscope, create history

Price: £9.99 / N/A
Get it from: www.mutr.co.uk

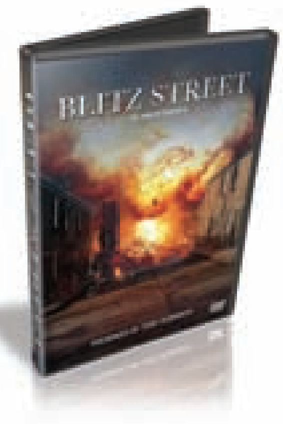
IT STARTED OUT as a bet about the way horses galloped, which Eadweard Muybridge was asked to settle in 1872. Twenty years later, he invented an early projector called the zoopraxiscope that a German photographer called Ottomar Anschütz used to create the tachyscope, a forerunner of Edison's camera and the Lumiere brothers' early cinema. This offering from Middlesex University's broad back catalogue of scientific toys isn't exactly a replica of the original tachyscope, but the concept is the same: a series of sequential images rotated on a spindle, isolated by a focused light source to create the illusion of movement.

This do-it-yourself kit is driven by a small, battery-powered motor and lit by a single flashing LED (the stroboscope). It's fairly easy to construct and overall took us approximately ten minutes to put together, but the results are still quite charming despite the century of cinematic evolution that's passed since it was invented.

Verdict:

DVD reviews

Blitz Street

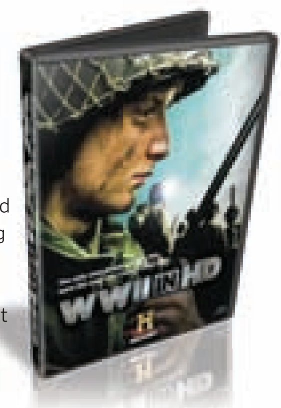


- **Price: £15.99 / $22.99**
- **Get it from: www.bbcshop.com**

Commemorating the 70th anniversary of the Blitz, *Blitz Street* is a four-part series presented by Tony Robinson that reveals what it was like to live through the devastation and psychological torment of wartime Britain. To do this the programme built a row of wartime-era terraced houses and then subjected them to the types of bomb explosions real peoples' houses suffered by the hands of the Luftwaffe. The show also details scientific investigations into the effects of each bomb and testimony from surviving Luftwaffe pilots.

Verdict:

WWII In HD

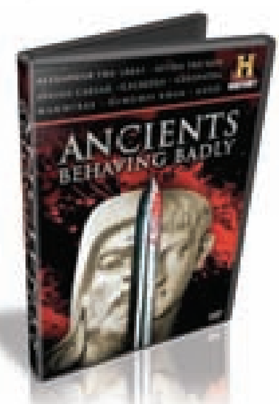


- **Price: £24.99 / $ 39.95**
- **Get it from: www.shop.history.com**

Carefully selected from over 3,000 hours of colour footage and painstakingly transferred to HD, *WWII In HD* is a visually impressive documentary from the History Channel that presents the soldiers, battles and technology of World War II like never before. Covering all parts of this global conflict, from the war in the Pacific to the heart of the engagement in western Europe, this is an epic production and brings this most important of conflicts into the 21st Century.

Verdict:

Ancients Behaving Badly

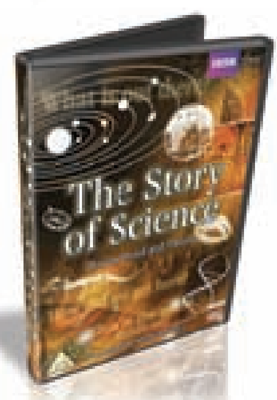


- **Price: £17.00 / $24.99**
- **Get it from: www.shop.history.com**

Ancients Behaving Badly is an informative and entertaining look at some of history's most notorious rulers. From Alexander the Great, through Attila the Hun to Genghis Khan, this series pulls no punches in hammering home the actions, brutality and mindset that these scandalous figures have become famed for. A mixture of re-enactment, scientific investigation, historical analysis and computer animation, this series aims to present an accurate portrait of these characters and, on the whole, does so well.

Verdict:

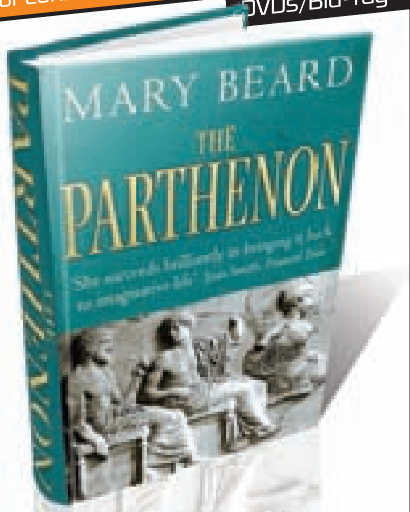
The Story Of Science



- **Price: £9.00 / $13.00**
- **Get it from: www.bbcshop.com**

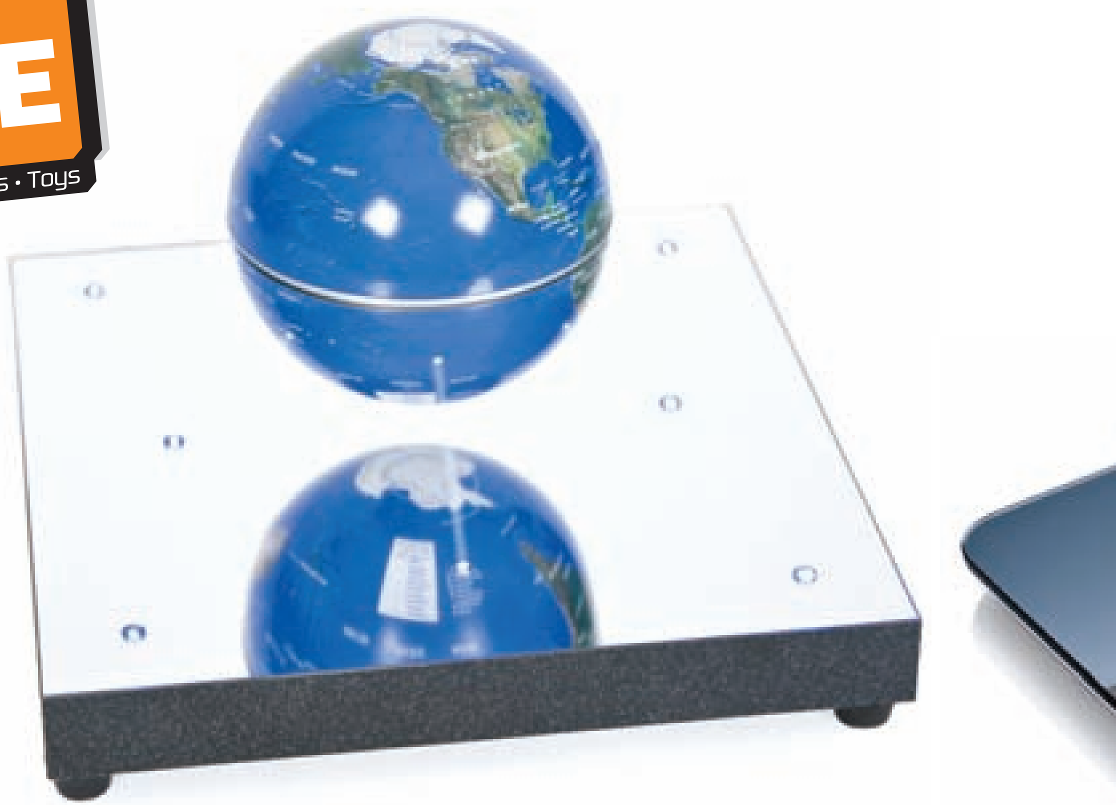
Presented by the respected and articulate Michael J Moseley, the DVD version of the *The Story Of Science* tells the story of the forces that came together to create scientific knowledge. Detailing the men, machines, voyages, discoveries, scandals, experiments and numerous failures that have combined to shape the world and modern science, this is a serious and detailed exploration of 3,000 years of human inquiry.

Verdict:



The Parthenon

Price: £8.99 / $14.95
ISBN: 9778-1-84668-349-7
Classicist Mary Beard asks the question 'what is the Parthenon?' Sure, it's a remarkably well-preserved temple dedicated to the goddess Athena found on a hill above Athens. But why did it make Lord Byron cry and why did it cause Freud such consternation? A surprisingly light and interesting read for such an academic topic.
Verdict:

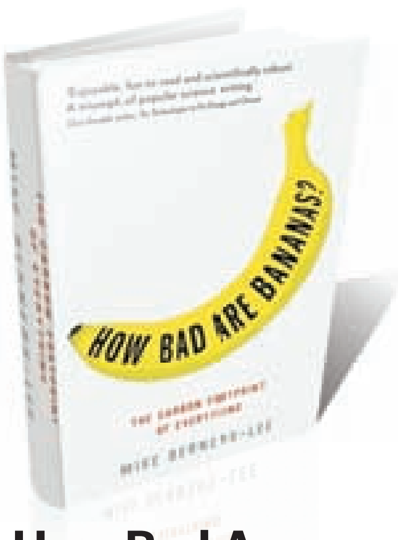


Levitron World Stage Anti Gravity Platform

Coming soon: teleportation panels!

Price: £76.95 / $89.99
Get it from: www.amazon.co.uk
"AN ANTI-GRAVITY platform? Surely the stuff of science fiction?" you say. But no, this is science fact and a fairly basic one that's been known for several hundred years. The Levitron World Stage works using the basic principle of magnets; the bottom panel contains one magnet and the globe contains the other, the idea being that you find the sweet spot an inch or so above the panel where attraction and repulsion are in equilibrium, and let the globe hover there.

In practise it's a bit fiddly, but once you've located the perfect position then half the fun is finding it again. With an LED-lit, reflective platform, the World Stage's performance is mostly smoke and mirrors distracting you from the fact that it's just some carefully placed magnets. But these inert metallic lumps that spring to life in proximity to each other have always spellbound us, and anyone with the same fascination will never tire of this toy.
Verdict:



How Bad Are Bananas?

Price: £8.99 / $15.08
ISBN: 978-1846688911
It's about health, of course. The health of the planet Earth and human impact on it: this small volume categorises and details the carbon footprint human decisions have from the mundane, like a single web search (0.2 grams) to the Australian bushfire of 2009 (at 165 million tons). A perfect read for the bathroom.
Verdict:

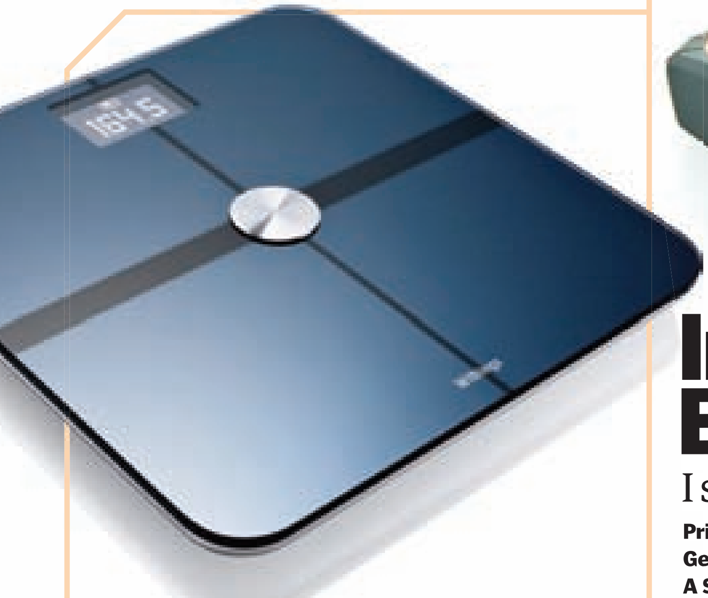
Cideko Air Keyboard

Move over air guitar

Price: £69.99 / $89.99
Get it from: www.firebox.com
BIZARRELY, AS WE type this article from the other side of the room on a handheld device that ergonomically, feels like it should be interacting with the latest Xbox 360 game, we don't miss our conventional keyboard whatsoever.

Rather than emulate standard keyboard design into a portable device, the Cideko Air Keyboard combines all the features you'd expect onto a wireless handheld that works more like a game pad. On its face is a full Qwerty set-up, including number keys and a start menu button, plus a comprehensive set of multi-media buttons: audio and visual, rewind, play, stop, internet button and ingeniously, arrow keys that control the cursor within a field and the mouse, with the left and right mouse button mounted on the shoulders.

The air keyboard comes supplied with two AA batteries, you'll need to plug a receiver dongle into a spare USB port, it's Mac, PC and PS3 compatible and it has an effective range of up to 100 feet… theoretically. Our Air Keyboard was a bit of a temperamental beast unfortunately, intermittently failing to respond to our key strokes at any distance beyond our desk chair. A shame it falls down on its most essential function, because otherwise it would have been a perfect media centre system peripheral.
Verdict:



Wi-Fi Scales

Your weight, digitised

Price: £119.99 / $172.99
Get it from: www.withings.com

NOW SUMMER IS finally here, losing all that weight you were supposed to lose in the new year suddenly becomes a priority. Luckily, the Wi-Fi Scales from Withings automatically monitors your weight, fat mass and BMI before then allowing you to view them from your computer or iPhone.

Up to eight individuals can have their data recorded per set of scales, ideal for family fat loss, and the stored information is presented in a series of simple and easy-to-follow graphs, allowing weight loss to be monitored over extended periods.

Verdict: ✪✪✪✪

Immortal Eye Gear

HOW IT WORKS EDITOR'S CHOICE AWARD ✪✪✪✪✪

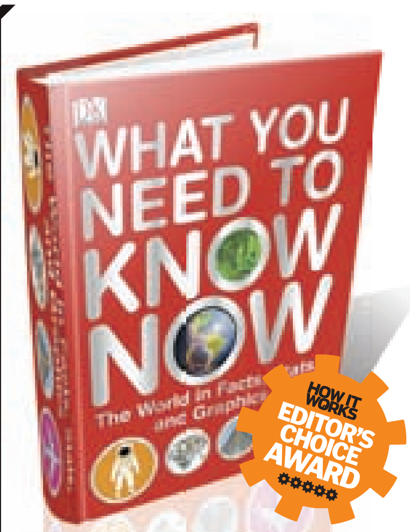
I spy eyewear

Price: £249.99 / $359.99
Get it from: www.immortal.co.uk

A STYLISH PAIR of video eyewear, the Immortal Eye Gear allows adrenaline junkies world wide to record their latest death-defying exploits and then download and replay them at a later date. Within the stylish exterior is a three-megapixel video camera with 736x480 resolution, 4GB of data storage and a 500mAh battery, allowing two and a half hours of continuous running time. In addition to the built-in tech, the Immortal also comes with three sets of interchangeable lenses covering all different light conditions: polarised flame orange, polarised dark grey and clear.

On test the Eye Gear was simple to operate, with only two buttons necessary for 100 per cent functionality, allowing for easy on-the-go adjustments. The hands-free, wire-free nature of the glasses was also impressive and, unlike many glasses in the video eyewear category, they were comfortable to wear for prolonged periods. Downloading the recorded video was simple too and the respectable resolution of captured content really helped to bring the footage to life. The only downside to the Immortal Eye Wear is that it is not waterproof.

Verdict: ✪✪✪✪



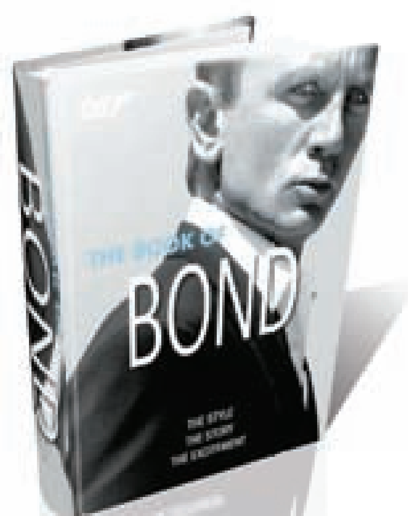
HOW IT WORKS EDITOR'S CHOICE AWARD ✪✪✪✪✪

What You Need To Know Now

Price: £16.99 / $24.49
ISBN: 978-1405353717

If infographics are your thing then you'll love this new title from DK. Stuffed with facts, stats and graphics detailing cool and fascinating facts about planet Earth, questions such as 'What are the chances of being killed by a coconut?' are answered vividly and, most importantly, visually. We love it.

Verdict: ✪✪✪✪✪



The Book Of Bond

Price: £9.99 / $17.99
ISBN: 978-1405355346

The *Book Of Bond* is a fat, hardback compendium detailing everything about James Bond, from the styles and skills he possesses, to the plots, enemies and gadgets he has interacted with over the years. Of high production value, this is a glossy and picture-led title that any Bond fan will get a lot from.

Verdict: ✪✪✪✪

Dyson Air Multiplier

Cool air; no blades

Price: £199.99 / $285.99
Get it from: www.dyson.co.uk

THE DYSON AIR Multiplier – a 100 per cent bladeless fan from the famous inventor Sir James Dyson – is an expensive but highly effective desktop cooling device. Generating a massive airflow from an in-built impeller, which is then accelerated over a 16-degree airfoil into the surrounding environment, the Air Multiplier provides a smooth, constant and unbuffered supply of air when operated. Partner this with the Multiplier's touch-tilt technology (allowing it to be angled with the press of a finger), variable airflow (something not possible with traditional set-speed fans) and its sleek, minimalist styling, and the only thing standing against its immediate purchase is the £200 price tag.

Verdict: ✪✪✪✪

GROUP TEST Portable DAB radios

Take your favourite radio stations with you wherever you go

Pure Move

Price: £79.99 / $114.99
Get it from: www.pure.com
Kicking off the group test, the Move is a palm-sized compact digital and FM radio (20 preset stations) with 40 hours battery life, iPod/MP3 connection port and built-in speaker. Similar to the 1500 but packing more features, there is only its slightly dubious styling and lack of included headphones to mark it down. It's cheaper than the 1500 to boot too.
Verdict: ★★★★

Pure PocketDAB 1500

Price: £89.99 / $128.99
Get it from: www.pure.com
The second entry from Pure is the PocketDAB 1500, a digital and FM portable radio with a lot going for it. The 1500 comes with 20 preset stations – including Radio 1, Classic FM and Radio 4 – textSCAN™, a rechargeable 24-hour battery and a respectable pair of Sennheiser headphones. This is a good portable radio at a decent price.
Verdict: ★★★

Roberts Solar DAB

Price: £79.99 / $114.99
Get it from: www.robertsradio.co.uk
The Solar DAB is a larger and more conventionally styled unit with an in-built solar panel for power-free listening. This is a welcome feature and makes listening to the radio outdoors very convenient. In terms of features the Solar packs all DAB/FM RDS wavebands, iPod/MP3 port, headphone socket, one-touch favourite station button and rotary tuning and volume controls. It is not as portable as the other units however.
Verdict: ★★★★

Roberts Sports DAB II

Price: £81.73 / $116.99
Get it from: www.robertsradio.co.uk
The Sports DAB II from Roberts is an excellent all-round package. The radio is sleek, well designed and comes equipped with DAB/FM wavebands, 20 preset stations, built-in loudspeaker, built-in rechargeable battery, telescopic antenna, large backlit LCD display and included headphones. Its sound quality, features and styling earn it top marks.
Verdict: ★★★★★

HOW TO MAKE
A mint tin flashlight...

Mint tin flashlig

Unlike the owl, humans struggle to find things in the dark, often resulting in large amounts of colourful language and exclamations of sentiments such as, 'where is the damn torch!' Luckily, help is now at hand, as with a few simple materials, a compact and portable light source can be a grab of your key chain away. Useful for finding objects and, in the event of World War III, sending messages in Morse code, just make sure you don't lose your keys! Here, then, is a simple guide to building your very own mint tin flashlight.

Construction materials:

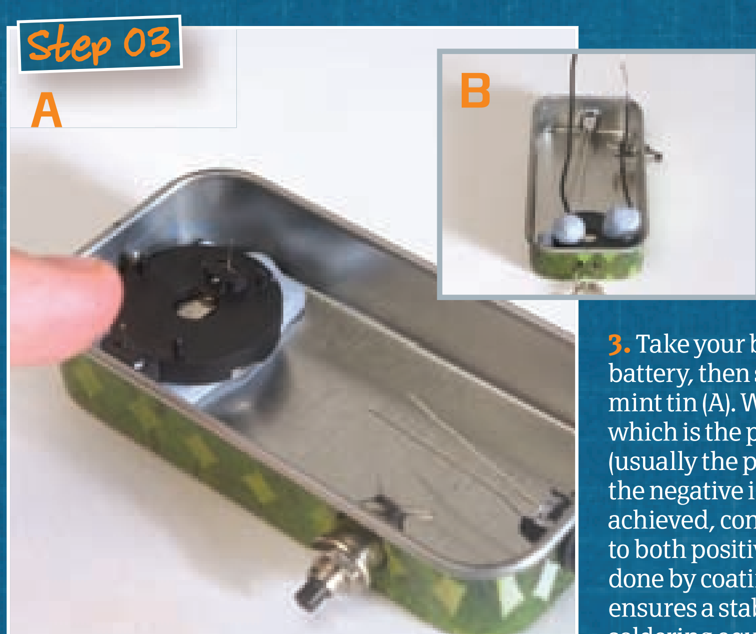
- 1 x Mint tin (although any suitable sweet tin can be used)
- 1 x 1 LED (5mm)
- 1x Battery clip
- 1 x 3V coin cell battery
- 1 x Push button switch
- 1 x Resistor (optional)
- 1 x Thin, insulated copper wire (20 centimetres will suffice)
- 1 x Blu tack pack
- 1 x LED holder
- 1 x Sharp cutting implement (to strip wire)
- 1 x Electric drill

All construction materials can be acquired at Maplins.

Turn a used mint tin into a portable light source

1. Take your mint tin and remove its lid before setting to one side. Next drill a hole in the front of the tin's base section roughly 6mm in diameter; this is the hole the flashlight's LED will fit into (A). Once this is achieved, drill a second hole into the front right side of the tin's base like this (B). This is the hole the flashlight's switch will pop out of. Take your time with this, as both the switch and the LED ideally need to fit snugly, with no room for manoeuvre (C).

2. Next, line the inside of the tin with tape or Blu-tack. This is important, as you don't want any of the internal wires to make contact with the tin's body, as then the circuit will short out and not work (A). Obviously, any tape/tack that runs over the holes you just drilled needs to be pierced itself to allow the LED and switch to fit correctly.

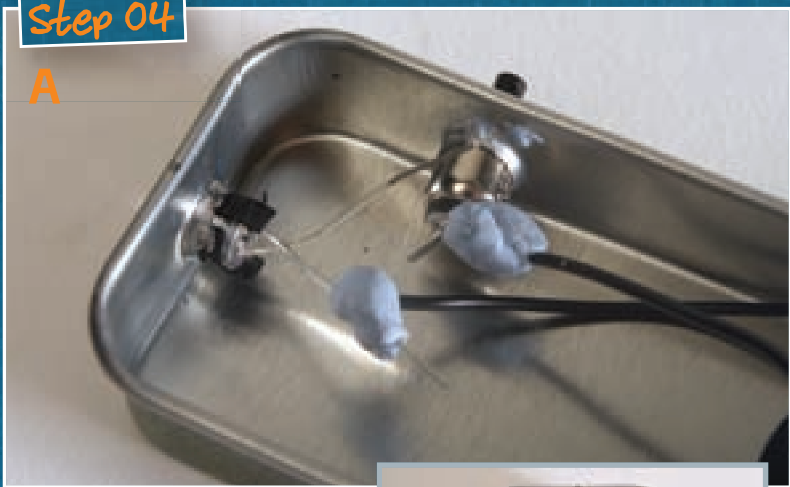


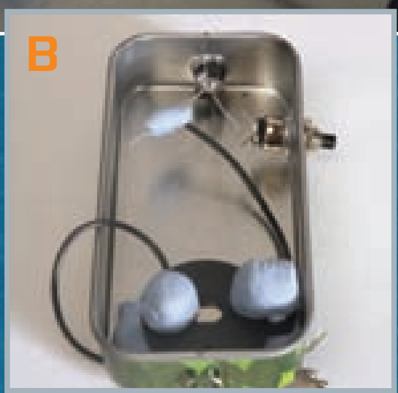
3. Take your battery holder and insert your coin cell battery, then stick both to the rear centre of the mint tin (A). While doing this ensure that you note which is the positive and negative connector (usually the positive lead is the one in the back and the negative is the one on the bottom). Once this is achieved, connect two pieces of copper wire (5cm) to both positive and negative leads (B). This can be done by coating the wire in blobs of Blu-tack, which ensures a stable connection without the need for soldering equipment.

ht

GET INVOLVED! Have you created a torch that puts ours to shame? Send your pictures to howitworks@imagine-publishing.co.uk and we'll show it to the world!

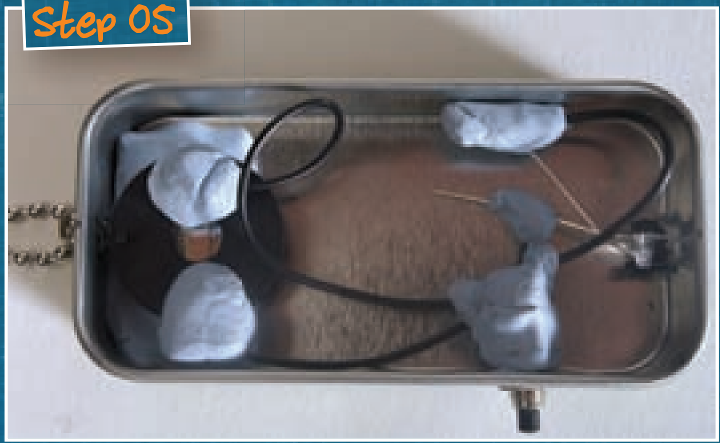
Step 04





4. Now take the wire emanating from the positive lead on the battery holder and connect it in the same way to the positive lead on the LED (that is the longer prong of the two) (A). Then take the wire emanating from the negative lead of the battery holder and connect it to one of the switch's two pronged leads (it doesn't matter which as the switch doesn't have polarity) (B).

Step 05



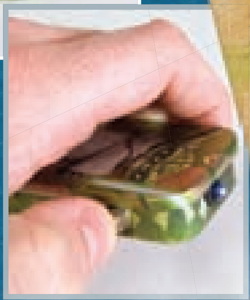
5. Finally, take another piece of copper wire and connect the negative lead on the LED (the shorter prong of the two) to the remaining prong on the switch. This should complete your internal circuit and look like this (A). At this point if you want to add a resistor (which should not be necessary because the forward voltage of the LED is already greater than the voltage on the coin cell battery) you can do by connecting it alongside the aforementioned connection in this step.

Congratulations! You'll never get lost in the dark again!

Step 06

6. Penultimately, ensure that all your connections are complete and that your switch can withstand being pushed inwards without moving. If it does so, secure it in place with Blu-tack. Then take your lid and snap it back on to the top of the base. You should now be looking at this. (A)

Step 07



7. Finally, press the button on the side of the tin and marvel at the luminosity that appears before your eyes. Congratulations! You have now made your very own portable mint tin flashlight.

Completed!

HOW IT WORKS INBOX

Feed your mind. Speak your mind

Letter Of The Month

How It Works: the old generation

■ Hi there, I saw your magazine in WHSmiths the other day and couldn't believe it. I have the complete original collection of the Marshall Cavendish *How It Works* magazines from back in the Seventies, all seven volumes in their binders. They're mint condition and I wondered whether there is any value attached?

Pete Gammon

HIW: We too have the vast majority of those fine magazines stowed away in our library – although they're a bit dusty and have that musty aroma ancient artefacts acquire after many years in a cupboard.

With regard to attaching a value to your collection, we paid somewhere in the region of £25-£50 for our incomplete set. If you can bear to part with yours it might be worth an auction as this kind of collection often comes up. When searching for 'How It Works' on eBay, don't be surprised if you see a few of the current generation up for grabs – some of our out-of-stock issues are listed as rare and sell for a pretty penny.

Get in touch!

If you've enjoyed this issue of How It Works, or have any comments or ideas you'd like to see in a future edition, why not get involved and let us know what you think. There are several easy ways to get in touch...

ISS is a fair way away… but not that far

■ Someone probably pointed this out already, but on page six of issue 6 How It Works states that the ISS is "thousands of miles above the Earth." Oops! The correct answer is printed on page 21 regarding ISS orbits in the thermosphere "between 320 and 380km" about 260 miles plus or minus.

Other than that, How It Works is one of the best things to hit the 'colonies' since the British Invasion and *Doctor Who*! I love your Photoshop mags too.

Dan Rodriguez, via email

We love Cox

■ I'm so happy that your magazine is featuring an interview with Professor Brian Cox. I've been glued to his *Wonders Of The Solar System* series and as a result he has sparked my passion for all things scientific once again, which led me to finding this magazine. Thank you.

Nikki Willis, via HIW Daily

HIW: We hope you enjoyed the interview, Nikki. We were thrilled when we found out he'd agreed to be in the magazine. And we have plenty more awesome interviewees up our sleeves for forthcoming issues.


© BBC

Love at first sight

■ My first sighting of your most interesting mag was in my dentist's waiting room and I hoped he would take his time in order that I may digest as much as possible. Even when one is over 80 such reading is certainly 'my thing'. I am considering taking up your offer of three issues for £1. Great stuff.

Ron Morgan, via HIW Daily

Has this reader stumbled upon the truth behind why we hiccup?

■ Hello. While gestating our three daughters years ago – daughters who regularly hiccupped in the uterus – I hypothesised that the function of hiccups is to exercise the diaphragm of an infant without allowing it inhale. Inhaling amniotic fluid is dangerous; having an underdeveloped diaphragm is also dangerous. I can't think of a test that would be possible that would not transgress the boundaries of scientific ethics, but tend to favour the proposition 'faute de mieux'.

James Benton, vie email

Pixel versus print – the dilemma

■ I would like to make two points. First, the graphics in How It Works magazine are very informative and easily understood: congratulations on this. However, I've noticed that most of the anatomical drawings are based on the male human body. I for one would like to

Can't get enough of How It Works?

Signing up to the forum couldn't be easier, just take a few minutes to register and then start sharing your questions and comments. The How It Works staff will be on hand to answer your questions and initiate debate.

www.howitworksdaily.com/forum

Forum

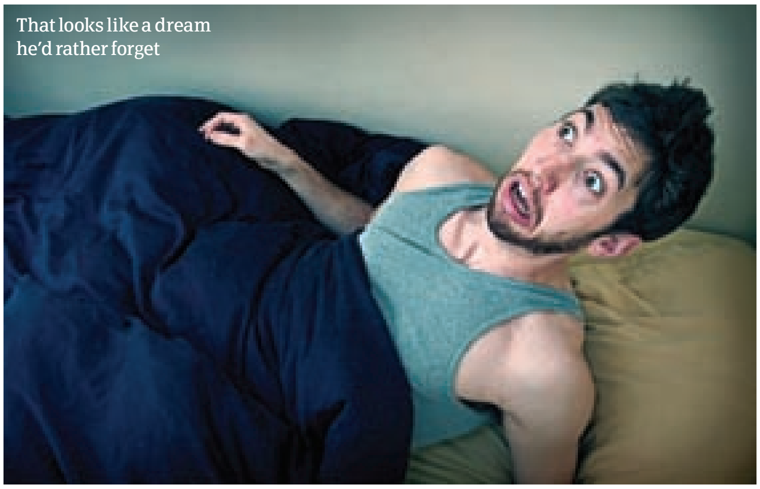
Those who like to spark debate and enjoy healthy discussions among like-minded individuals can visit www.howitworksdaily.com/forum and put their questions to the How It Works experts.

Email

If you'd like to contact us directly and perhaps even see your letter featured right here then get online and tell us what you think. Just email: howitworks@imagine-publishing.co.uk

Snail mail

Yes, we even welcome the good old postal method of communication, and you can send your letters to How It Works Magazine, Richmond House, 33 Richmond Hill, Bournemouth, Dorset BH2 6EZ.



That looks like a dream he'd rather forget

see a few more female examples? Secondly, I have a 12-month subscription but would also like to view the app on my iPhone. Does this mean that I will need to pay twice?

Jennifer Ford, via email

HIW: With regard to the How It Works pixel mags, you can download the first issue free of charge. However, while the app provides a remarkable new way for you to enjoy the magazine, it's not currently possible to combine print and digital subscriptions. For now it's one or the other – or both of course!

Weeping for missed opportunities

■ [The Fairey Rotodyne a predecessor to the V-22 Osprey] is yet another item in the long and tragic list that has seen so much of the UK's technology base disappear. Aircraft, space, automotive, motorcycles – all world winners once upon a time, but mostly trashed by a combination of witless politicians and bad management.

The legacy is still with us today: witness the late and over-budget F-35, a project little better than the Hawker P1154, which was cancelled nearly half a century ago. For an example of what the UK could do in years gone by, travel to the Isle of Wight to see the sad remains of the rocket testing area by the Needles. There's a museum that reveals how high-thrust orbital engines once thundered across the English Channel, and how the UK decided to ditch its space effort after – after! – orbiting its first satellite, Prospero. It's still up there 39 years after launch. Argh, it makes you weep.

David, via HIW Daily

You promised us chocolate power

■ Dear editorial team. Your magazine is brilliant. In issue 7 the Global Eye article about the chocolate-powered racer said that you would be taking an in-depth look at it in the next issue. I was really looking forward to it, but when I got issue 8 it wasn't there. So please please please put it in one of the next two issues.

Joshua Mitchell, via email

HIW: As long as those pesky circumstances don't get in the way, you can be sure that we do try our best to include everything mentioned on the next month page each issue. We hope to bring you more on the choco-car soon.

Cool tip for remembering your dreams

■ After reading the Braindump article 'Why do we sometimes remember our dreams, but sometimes not?' I thought I'd offer this tip. Since an average sleep cycle takes around 90 minutes and REM sleep occurs at the end of this cycle, if you want to have a better dream recall, wake up at intervals of 90 minutes. For example, set your alarm for three, four and a half and six hours after you go to bed.

Paul, via HIW Daily

Crane crazy no more

■ Last issue you published the letter that I sent you about not being able to do the origami crane because I found it too difficult. I'm writing back to say a big thank you for giving me the link to the video. I found it really easy to follow and had it done in no time. Here is a picture of the origami crane I made. I felt really great when I finished it and I found it so much fun that I am planning on doing even more origami models. Thank you once again. I love your magazine. Keep up your amazing work.

Nathanael Nunes (age 12), via email

HIW: We're loving your origami skills, Nathanael. Certain members of the HIW team have never been able to master of the fine art of paper folding – just don't have the patience – so well done.

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