NEW

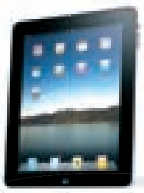
THE MAGAZINE THAT FEEDS MINDS

HOW IT WORKS

SCIENCE | ENVIRONMENT | TECHNOLOGY | TRANSPORT | HISTORY | SPACE

INSIDE

INTERVIEW
JOHNNY BALL
THE FATHER OF INFOTAINMENT



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ip IMAGINE PUBLISHING

WELCOME

The magazine that feeds minds! ISSUE FIVE

Get in touch

Have YOU got a question you want answered by the How It Works team? Get in touch by…
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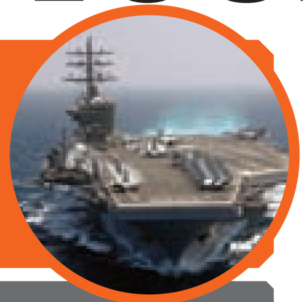
"FEED YOUR MIND!"

Editor's pick



Ever wondered how you land a huge, powerful flying machine onto a big chunk of metal floating in the sea? Me too, so find out just how pilots get jet fighters to land on and take off from aircraft carriers on page 22.

What you're saying about How It Works

It is really refreshing to see a broad range of intellectual content versus all the selfish, celebrity trash in most publications today. – **Jason Flowers, email**

I just wanted to say how much I enjoyed your second issue. I had popped into my local supermarket, and while in the queue I looked over the women in front's shoulder to see her flicking through your mag. Having taken only a small amount of cash out, I decided to ditch my Christmas edition of the *Radio Times* and bought yours instead. – **Claire, email**

It's great to have a "magazine that feeds your mind" when you just want to relax and have a bit of light reading. I would say How It Works is for all ages and it's good that you don't get bogged down with every bit of detail possible on each subject. It is in good bite-size chunks, making it a gentle learning process. – **David Bonnett, website comment**

Have yet to read it, but I am liking what I see, especially the guides more than the questions, and it has loads of different sections, that cover everything, which is great. – **cjayp33, website comment**

Welcome to How It Works, the magazine that answers your questions about how all the amazing things in the world work. If you're one of the growing band of regulars you'll already know how many fascinating facts and articles we can cram into one issue. If you're a first timer tempted in by our fantastic Formula One cover then we hope to surprise you with the exhaustive range of topics that we explain each month.

Yes, this issue pays homage to the start of a new Formula One season by explaining the technology behind some of the fastest sportsmen on the planet. While I can't admit to being an F1 fan myself, the engineering excellence that goes into the sport is truly breathtaking and worthy of receiving the How It Works treatment from page 14 onwards.

Other highlights this issue include an interview with the pioneer of popular science shows Johnny Ball, who shares his views on a number of topics on page 12, and a look at how your body has been fighting off colds and flu all winter. Finally, a big thank you to all the subscribers, regulars and first time readers that are helping to make How It Works such a great success.

Dave Harfield
Editor in Chief

Meet the experts

How It Works is created by a team of experts that's more like family than work colleagues, and it's a family that's growing all the time…

Helen Laidlaw
Landing on an aircraft carrier

Deputy editor Helen got all *Top Gun* this month as she researched the aircraft carrier article. She even took up volleyball and motorcycle riding and got us to call her Goose to add a little bit of authenticity…

Rob Jones
The rainforest

Rob spent a lot of time researching the rainforests and talking to various experts to bring us the excellent article on page 44. He's now an expert on the poisonous tree frog and likes to dress up as Tarzan…

Phil Raby
Formula One

The Editor in chief of Total 911 magazine jumped at the chance to write our cover feature this issue. If you have ever wondered just what goes on at the heart of the sport read his article on page 14, it's one hell of a ride!

Tom Harris
The immune system

Tom was one of the original writers at howstuffworks.com where he headed up an award-winning content team. These days he's a pen-for-hire and contributed an excellent piece on how your body fights disease.

Lynsey Kay Porter
Human respiration

After completing an anthropology degree and travelling across the world, Lynsey is now based back in the UK where she gets fed up with the weather and writes numerous science articles for How It Works.

With thanks to

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

sciencemuseum REUTERS DK Spotify NASA

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

HOW IT WORKS

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The magazine that feeds minds!

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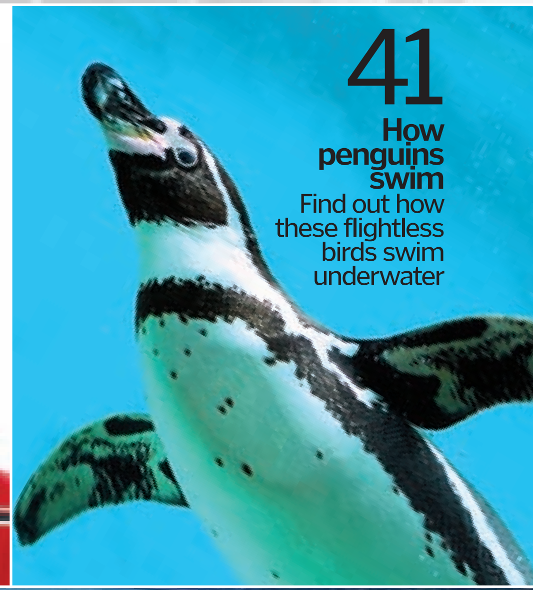

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Discover the most amazing plants, animals and insects on Earth

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The science and tech behind the latest sound systems

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The human immune system explained

E NOW!

BRAIN DUMP
Because enquiring minds want to know...

Alison Boyle
Astronomy Curator
Alison Boyle answers all the space enquiries this issue

Rik Sargent
Science Museum Explainer
Rik takes on all the science questions this month

THE HOW IT WORKS KNOWLEDGE
For connoisseurs of kit and savants of stuff

iPad has landed

Apple to corner all markets with its hybrid digital wonder

An on-screen Qwerty keyboard will make iPad's laptop functions interesting, but the system does come with a dock for full-sized keyboard, so all areas are covered

The Statistics

Apple iPad

Height: 9.56 inches (242.8mm)
Width: 7.47 inches (189.7mm)
Depth: 0.5 inch (13.4mm)
Weight: 1.5 pounds (0.68kg) Wi-Fi model; 1.6 pounds (0.73kg) Wi-Fi + 3G model
Display: 9.7-inch (diagonal) LED-backlit Multi-Touch with IPS technology and fingerprint-resistant coating
Processor: 1GHz Apple A4 custom-designed, high-performance, low-power system-on-a-chip
Memory: 16GB, 32GB, or 64GB flash drive
Battery: Built-in 25-watt-hour rechargeable lithium-polymer battery (ten hours of surfing the web on Wi-Fi, watching video, or listening to music). Charge with power adaptor or USB to computer system
Pricing: $499-$829 (worldwide pricing TBC)

On 27 January, when Steve Jobs took to the stage to unveil Apple's latest slice of lifestyle gadgetry, the digital world held its breath in anticipation of something extraordinary. So now that the commotion has died down, what does iPad offer today's trendy technophile?

Depending how you view it, iPad is essentially either a giant iPhone or a mini laptop – the midway point between 'pocket-sized' and 'just annoying to carry'. At 1.5 pounds, it might not be the lightweight piece of kit its slim form suggests, but iPad remains portable, practical and positively elegant. It's sold as the best way to surf the net, an experience to slot into your life at home or on the move, whether it's watching movies, viewing photos, or simply enabling fast access to networking sites.

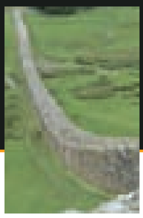
One of iPad's biggest boons is the latest in Apple's chain of iStores: the iBookstore supplied by the likes of publishing giants Harper Collins, Macmillan and Penguin Books. The iBooks app will undoubtedly provide a worthy challenge to Sony and Amazon's now-established eBook readers as iBooks makes for an intuitive reading experience upon a single sheet of Multi Touch, fingerprint-resistant glass as you turn the pages by tapping your finger or flicking the page in one fluid motion.

Dissenters have questioned whether consumers have any need for a digital device that doesn't really do anything other similar wares don't already do. While we agree iPad offers little over and above the likes of today's top-of-the-range smartphones and laptops, the luxury build and convenient dimensions of this small marvel make it hard to resist.

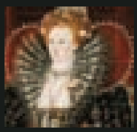
This day in history

25 February: How It Works issue five goes on sale, but what else happened on this day in history?

138 Emperor Hadrian – of Hadrian's Wall fame (see page 76) – adopts Antoninus Pius as his son and therefore his successor.

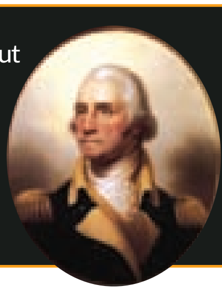


1570 Pope Pius V excommunicates Queen Elizabeth I.

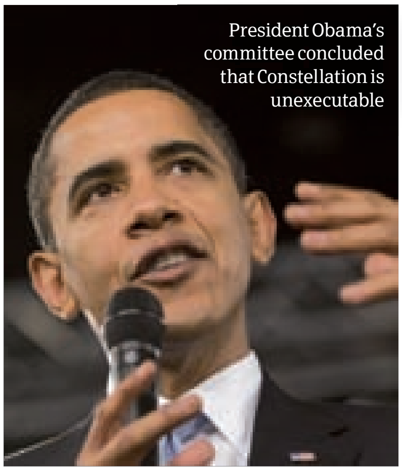


1723 This date in history marks the death of legendary English architect Sir Christopher Wren who designed the new St Paul's Cathedral after it was destroyed in the Great Fire of London (see page 75).

1793 George Washington holds his first Cabinet meeting as president.



1841 On this day in 1841 French impressionist artist Pierre-Auguste Renoir was born.


President Obama's committee concluded that Constellation is unexecutable

Obama shelves Constellation spaceflight programme

NASA's dreams of putting man back on the moon by 2020 are ended

For months the fate of NASA's $81 billion human spaceflight initiative Constellation has been in the hands of Barack Obama.

The programme had intended to return to the moon with a human cargo in a venture similar to the Apollo programme, but in his 2011 budget plan on 1 February the American president announced he wouldn't support the programme, describing it as over-budget and behind schedule. Obama has instead instructed NASA to concentrate on approaches that capitalise on the ISS and prioritise the research and development of such projects as in-orbit fuel depots.

On 7 February, as the Space Shuttle Endeavour embarked on its last ever night-launch, we were reminded that NASA will soon be reliant on Russian spacecraft Soyuz once the Shuttle is retired at the end of the year.

The news that Constellation has been cut from Obama's budget has been criticised by the likes of Republican senator Richard Selby who says the decision "begins the death march for the future of US human space flight". It would be a shame if the US were to fall behind in the realm of space exploration and technology, but it seems the only chance the agency has of returning to the moon is if commercial space operations can provide a viable alternative.

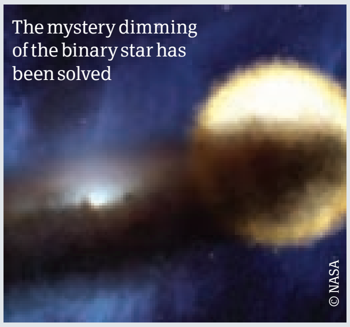
Spitzer solves star mystery

The nature of the star that inexplicably dims every 30 years has finally been explained by NASA's incredible new space telescope

Every 27 years an eclipsing binary star known as Epsilon Aurigae fades slowly before the eyes of astronomers over a period of two years before brightening up again.

For centuries the nature of this event has been puzzling stargazers. Epsilon Aurigae was thought to be a very large luminous star known as a supergiant that was being eclipsed by some unidentified mass far bigger than itself – probably a bunch of dust particles – fading to one half of its brightness during each eclipse.

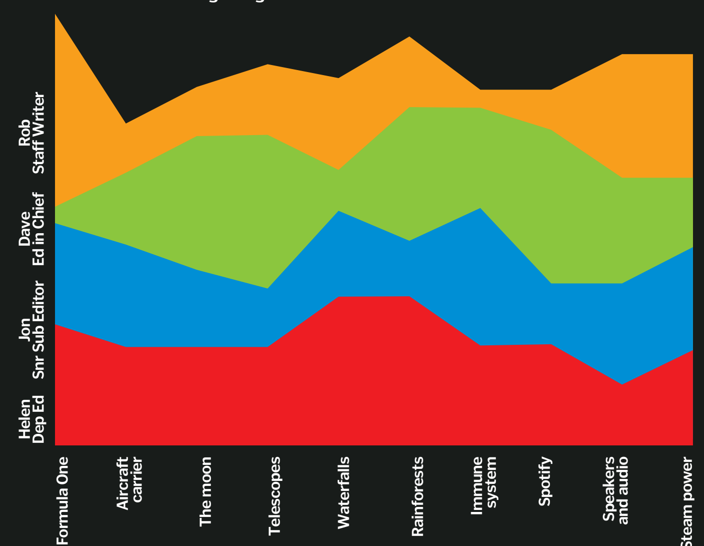
Now, using infrared data gathered by NASA's Spitzer Space Telescope (which you can learn more about next issue) the secret behind this very strange star and its shadowy behaviour has been revealed. The dark eclipsing 'companion' object is indeed a large dusty disc swirling round the main star (as you can see from this image). However, the numbers people at NASA have used the collected data to calculate the size of the dust disc, the results of which rule out the notion that Epsilon Aurigae is a supergiant. Instead it has been identified as a bright dying star with a lot less mass.


The mystery dimming of the binary star has been solved

© NASA

HOW IT WORKS EXCITE-O-METER!

Every issue we offer this visual guide to what's been getting us excited in this issue of **How It Works**



Jon reached unprecedented levels of excitement this issue as he hit the roof (in a good way) when he heard we would be featuring six pages of Formula One motor madness. In fact F1 floats everyone's boat apparently. Hippy Helen was really impressed with Rob's rainforests extravaganza, which was another hot topic this month, she just loves the animals. On the whole, the team were in high spirits this month with no topic falling below a two on the thrill scale.

HOW IT WORKS TV

The How It Works website is regularly updated with the most amazing videos the net has to offer

Parrot AR Drone

Check out this remarkable toy from techno genius Parrot. A fun quadricopter that handles like a dream, the AR Drone is definitely one to add to your wish list.

Kermit's iceberg

Okay, so the informative part of this video is the piece of iceberg calving into the sea at the start, but you should keep watching as the cameraman's Kermit the Frog voice is very funny.

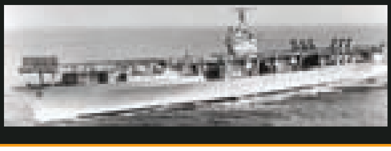
Fairey Rotodyne

Remember the amazing V-22 Osprey we featured in issue three? Well, check out this promotional video of a similar vehicle more than 40 years earlier.

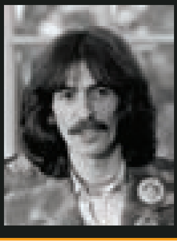
Ares 1 take-off and re-entry

Would-be successor to the Shuttle, this video reveals Ares 1's impressive launch system and re-entry procedure.

1933 America launches its first purpose-built Navy aircraft carrier: the USS Ranger (CV4). Find out how aircraft carriers work on page 22.



1943 Beatle George Harrison is born in 1943 in Liverpool to parents Harold and Louise Harrison.

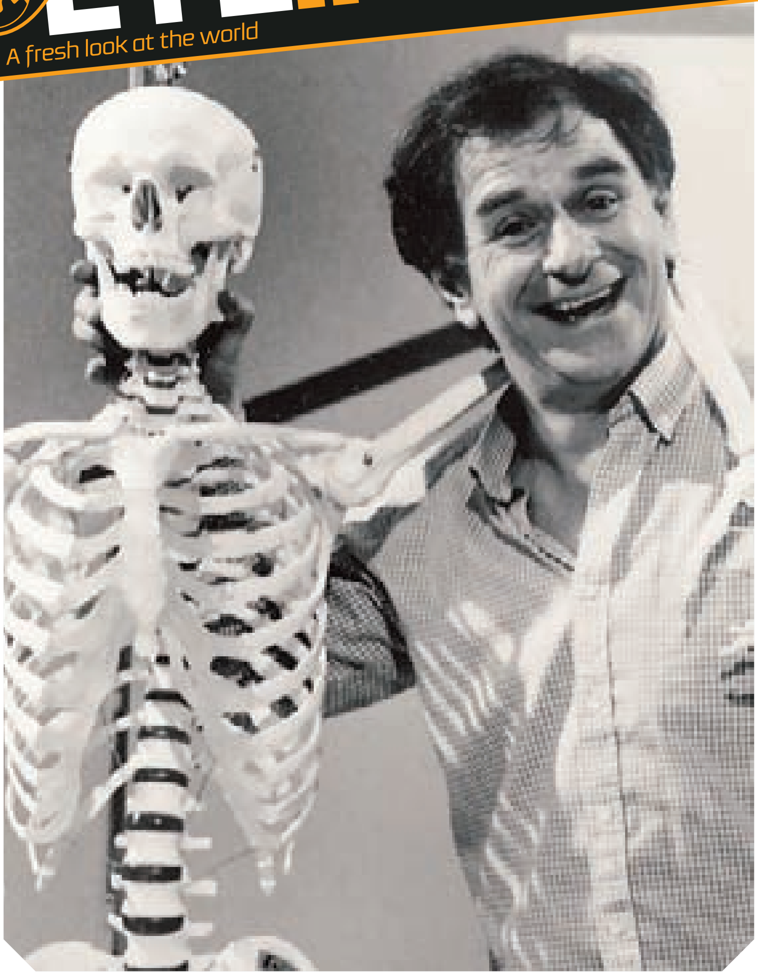


1945 The Turks declare war on Germany during the Second World War.

1964 Cassius Clay KOs Sonny Liston to become the heavyweight champion of the world. He certainly stung like a bee that night.

GLOBAL EYE INTERVIEW

A fresh look at the world



Johnny Ball

Shows like *Think Of A Number* and *Think Again* introduced a whole generation to science-based entertainment shows. Recently the father of infotainment TV has caused some controversy with his views on global warming. Johnny kindly spent some time talking about all of this with How It Works

"Our assumptions of the damage we are causing are grossly overstated"

HIW: Your website describes you as a populariser of science and mathematics and we like to think of you as the pioneer of popular science shows. Why do you think your shows like *Think Of A Number*, *Think Again* and *Johnny Ball Reveals All* are still so fondly regarded today by the audience of the time?

Johnny Ball: I was lucky in that I had ideal training. I was a Butlin's Redcoat 1960/61/62 where I started doing stand-up. I did *Play School* simply to learn television. Strange thing was, I loved it and stayed for 16 years. My hobby all along had been recreational maths and when asked what I would do for my own show, I said maths. So, all my comedy and writing experience was suddenly dovetailed with my love of all things scientific and to do with engineering. As with stand-up comedy you need to reveal the story bit by bit – that goes for science and all information – you also need the hint of a joke or something surprising or amazing at every turn – and control how you reveal it, carefully.

HIW: You have been quoted as saying that one of your passions and the inspiration behind your TV shows is "recreational maths". Can you tell us what recreational maths is and why you find it so exciting?

JB: Recreational maths is all to do with games and puzzles. But it also includes any kind of whacky design ideas, cartoons and amazing images and unusual phenomena. Whether it is the geometry of buildings or the maths statistics of atoms or galaxies, it all becomes interesting if viewed with a mathematical eye.

HIW: You've recently been quoted as saying that "spiders' flatulence is more damaging to the environment than fossil fuels". Was that taken out of context or is this really the case?

JB: The quotes were incorrect, and some of them came from people with supposedly scientific credentials. In 1939 Bristowe counted the spiders in an English acre. There were so many, he realised that UK spiders must eat more than the weight of the human population of the UK each year, by a pretty good margin. As spiders proliferate worldwide, one can assume that they eat more than the weight of 6.7 billion humans every year. The chemicals are released back into the atmosphere, and it can be likened to cremating 6.7 billion people with no controls preventing the so-called global warming gases getting back into the atmosphere.

From Emsley, we find that land-based rotting plant life, with the aid of insects, produces nothing less than 350 billion tons of CO_2 annually. The oceans produce most, certainly more as of all plant life on earth, 80 per cent is in the oceans. At most, the human race produces 23 billion tons. Our assumptions of the damage we are causing are grossly overstated. That is not to say that we should not care what we do in the way of pollution. But too many people with vested interests are manipulating the science for all kinds of spurious reasons. Over the last 12 months, many of these exaggerations have become increasingly apparent, but we still have a long way to go to get back to rationality.

HIW: Why do you think that your personal standpoint on the subject of global warming has gone on to cause so much controversy?

JB: It hasn't. The controversy has always been there and always will be. The most unscientific thing to ever do, is to say "the science is settled!" But that is what the lobby groups and IPCC advocates have been saying, so forcefully and without conscience. It has been said that I spotted some error in statistics on one particular aspect of suggested climate change and then question the lot. Wrong. There is hardly one aspect of the debate that is being stated correctly – an excellent girl heading for a career in neuroscience recently told me why she dropped out of her environmental courses – her words were, "It is all propaganda with no scientific substance!" A senior Forces weatherman wrote to me recently to point out manipulation of weather figures that clearly indicate lower temperatures over the past ten years – his subject has not been considered or discussed in the press yet. It is temperature measurement a few inches below ground. Here the changes take more time, but the trends are clearer and they are currently down, year on year. This is being ignored by the IPCC advocates.

HIW: Your latest book, *Mathemagicians*, was published last year. Tell us a bit about it and what you hope it will achieve?

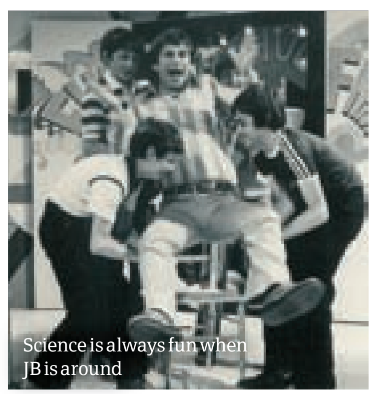
JB: This one explains a lot about how we use maths to measure things. I could not find a similar book for children, that had been written in the past 50 years in the English language.

HIW: What's your favourite gadget that you currently own?

JB: My electronic Roland TD 20 Drumkit.

HIW: What's next on your gadget/technology shopping list?

JB: Surround Sound, which is daft really, as now I have 70-year-old ears to listen with!



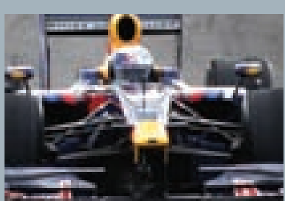
Science is always fun when JB is around

CAREER

1938	Born 23 May 1938. Spent his primary years in Bristol before moving to Bolton, Lancashire where he attended Bolton School.
1960	Became a Butlin's Redcoat and worked at this through 1960-1963. Started doing stand-up performance and writing routines.
1964	Started working professionally as a stand-up comedian, becomes a host on the BBC's *Play School*.
1977	His first show, *Think Of A Number*, debuts on BBC and establishes his reputation for entertaining science shows.
1981	Johnny's second run of BBC shows begins. *Think Again* ran for five series and finished on 15 October 1985. He worked regularly on the BBC until 1988.
1994	Was elected by students as Lord Rector of Glasgow University and held the post until 1996.
1995 > PRESENT	Launches a musical *Tales Of Maths And Legends* and continues to speak and address across the UK.

This month in **Transport**

On 14 March the 2010 Formula One season will kick off with the first grand prix taking place in Bahrain. While the thrill of high-speed driving might not be for everyone, we doubt there's a **How It Works** reader that can fail to be impressed by the feats of technology and engineering that lie behind each race. So even if you're not an F1 fan, take a look through our main feature for an impressive look behind the scenes of one of the fastest sports on Earth.



TRANSPORT

The science of speed

Discover the technology behind the pinnacle of motor racing and one of the fastest and most exciting sports on Earth

Car racing can trace its roots as far back as the end of the 19th Century, when daring French drivers flung their primitive automobiles along dusty lanes from one town to the next. By the start of the next century, racing had become organised into grands prix – 'large prizes' – and the first ones took place on closed roads at Le Mans – it was soon realised that racing on public roads was too dangerous. The first purpose-built racetrack was built at Brooklands, England in 1907.

Before the Second World War, grands prix were run in different countries but there was nothing to tie the races together. After the war, however, the Fédération Internationale de l'Automobile (FIA) linked up a number of national grands prix to create the Formula One World Championship. This enabled drivers from all around the world to compete against each other. The first race was held at Silverstone in 1950, and that year's championship was won by Italian Giuseppe Farina in an Alfa Romeo.

As time went on, the sport became more and more expensive, and in recent years, teams pushed technology to the limits to produce cars that were competitive and safe to drive.

After a recent drop in viewing figures and waning interest as races became a battle of which team could spend the most money, we can look forward to an interesting season ahead. Not least because the reigning champion, Jenson Button, will be in the same team as the previous winner, Lewis Hamilton. 2010 will be a Formula One season worth following.

© BMW Motorsport

Steering wheel

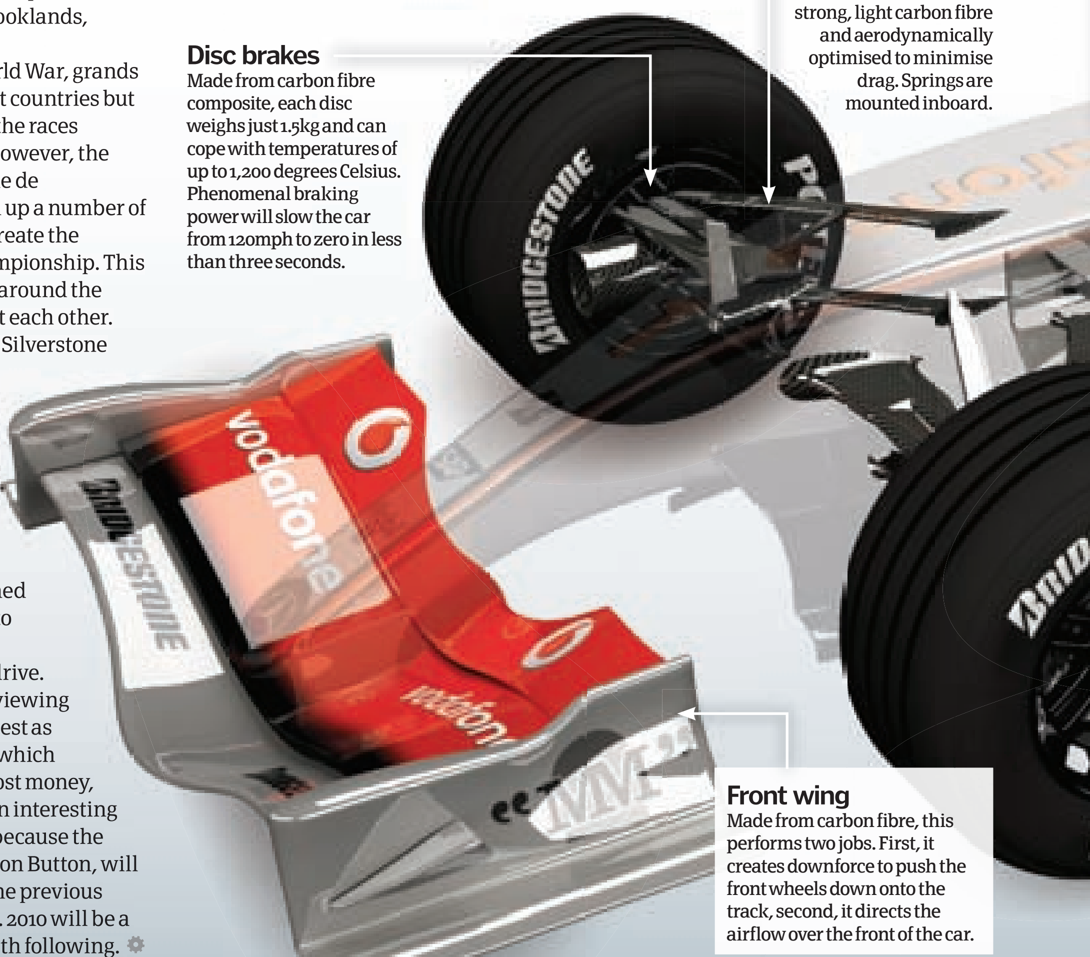
Has to be fitted once the driver is in place and only turns through 270 degrees. Small but very high-tech, it contains almost every control the driver needs; including gear changing, fuel mixture, brake bias and much more.

Suspension

Very firm but fully adjustable to suit the circuit. The suspension arms are made from strong, light carbon fibre and aerodynamically optimised to minimise drag. Springs are mounted inboard.

Disc brakes

Made from carbon fibre composite, each disc weighs just 1.5kg and can cope with temperatures of up to 1,200 degrees Celsius. Phenomenal braking power will slow the car from 120mph to zero in less than three seconds.



Front wing

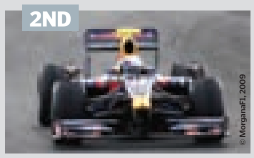
Made from carbon fibre, this performs two jobs. First, it creates downforce to push the front wheels down onto the track, second, it directs the airflow over the front of the car.

1ST


© José M^a Izquierdo Galiot, 09

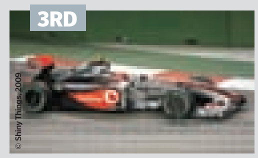
1. Brawn GP F1 Team
Drivers: Jenson Button, Rubens Barrichello
Engine: Mercedes
Race wins: 8
Podiums: 15

2ND


© Morgana F1, 2009

2. Red Bull Racing
Drivers: Mark Webber, Sebastian Vettel
Engine: Renault
Race wins: 6
Podiums: 16

3RD


© Shiny Things, 2009

3. Vodafone McLaren Mercedes
Drivers: Lewis Hamilton, Heikki Kovalainen
Engine: Mercedes
Race wins: 2
Podiums: 5

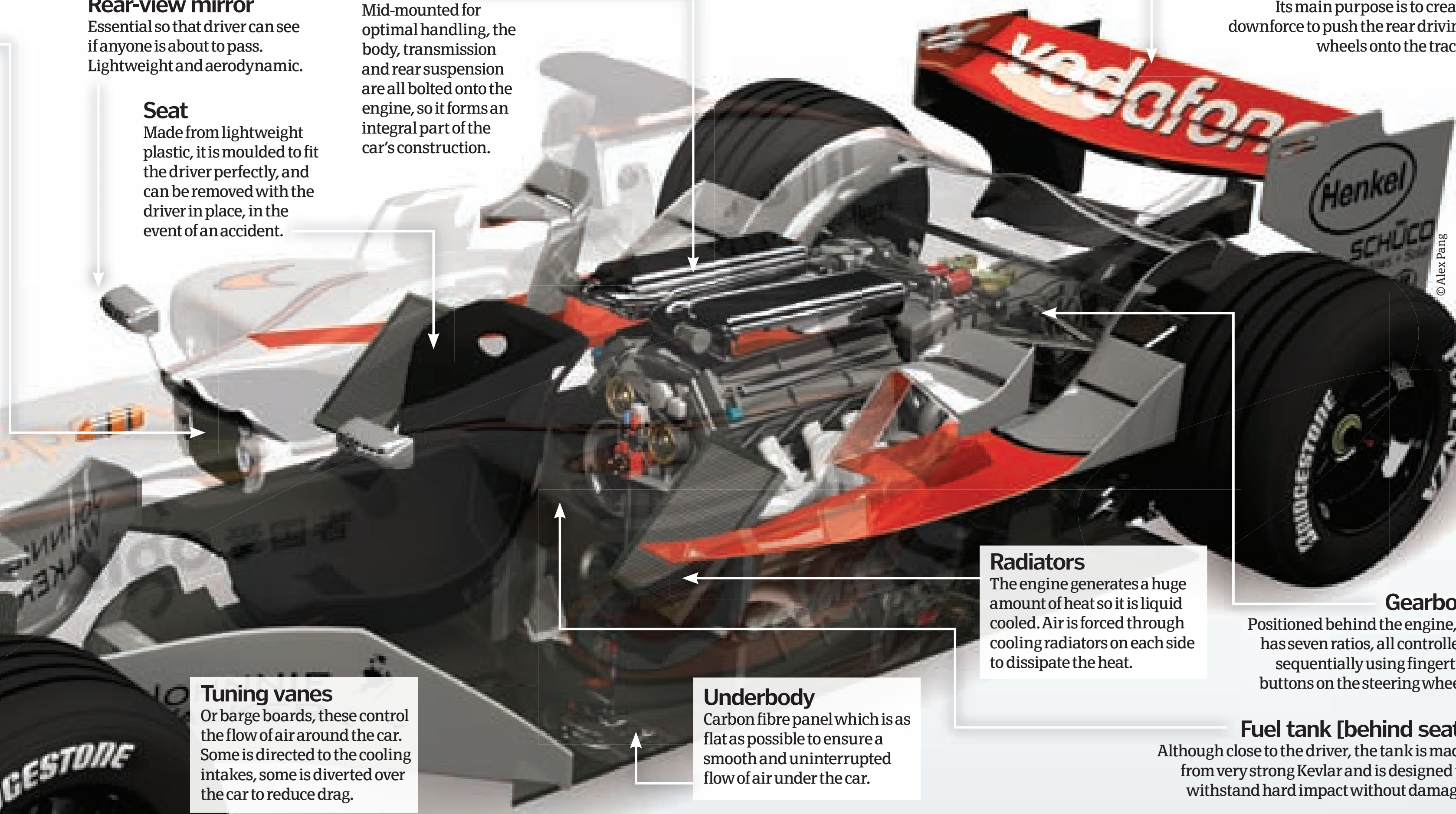
DID YOU KNOW? *The very first Constructors' Championship was awarded to Vanwall back in 1958*

Inside the F1 engine

Mounted low down behind the driver (to ensure even weight distribution for optimal handling), the engine has eight cylinders in a 'V' configuration and a capacity of 2.4-litres. This is similar to the engine in a large family car yet a Formula One engine produces over 700bhp – about three times the power of that family saloon, while each cylinder only has one fuel injector and one spark plug.

The high power is possible because the F1 engine revs much higher – up to 18,000 revs per minute compared to a road car's 8,000. All engines have valves that open and close to allow fuel and air in and exhaust gases out; normally, these are held closed by metal coil springs, but at such high revs pneumatic springs are required. A road car's engine has to run reliably for well over 100,000 miles, but an F1 unit can be rebuilt after a weekend's racing. Much of the engine is made of lightweight aluminium alloys and the tolerances are so tight that, when the metals are cold, the engine is seized solid – it has to be preheated electrically before being started.

Try fitting this into your souped-up Corsa...



© Alex Pang

Rear-view mirror
Essential so that driver can see if anyone is about to pass. Lightweight and aerodynamic.

Seat
Made from lightweight plastic, it is moulded to fit the driver perfectly, and can be removed with the driver in place, in the event of an accident.

Engine
Mid-mounted for optimal handling, the body, transmission and rear suspension are all bolted onto the engine, so it forms an integral part of the car's construction.

Rear wing
Its main purpose is to create downforce to push the rear driving wheels onto the track.

Radiators
The engine generates a huge amount of heat so it is liquid cooled. Air is forced through cooling radiators on each side to dissipate the heat.

Gearbox
Positioned behind the engine, it has seven ratios, all controlled sequentially using fingertip buttons on the steering wheel.

Fuel tank [behind seat]
Although close to the driver, the tank is made from very strong Kevlar and is designed to withstand hard impact without damage.

Tuning vanes
Or barge boards, these control the flow of air around the car. Some is directed to the cooling intakes, some is diverted over the car to reduce drag.

Underbody
Carbon fibre panel which is as flat as possible to ensure a smooth and uninterrupted flow of air under the car.

Wheels
Usually made from super-light forged magnesium to keep weight to a minimum. Single central locking nut allows for very fast wheel changes during pitstops.

Aerodynamics explained

A modern Formula One car looks strange – that's because the body shape is designed purely with aerodynamics in mind. The car has to cut through the air at high speed with the minimum of effort to ensure optimal performance and to save fuel.

However, aerodynamics also play another role. They create downforce to force the car onto the track at high speed, so that the tyres maintain traction and the car is able to go round corners effectively. To do this, the car is fitted with wings front and rear which work in exactly the same way as those on an aeroplane – only the other way round. Inside of creating lift, they create downforce. Aerodynamics are now so sophisticated that teams alter the car's wings to suit a particular track.


© Mercedes Petronas GP
He's never going to fit in that...

8. Straight
Long, straight section of track where Formula One cars reach speeds of up to 220mph.

7. Hairpin
Sharp, 180-degree bend that forces the cars to slow right down – to as little as 30mph in some cases.

10. Pits
Each team has its own garage where the cars come in for refuelling and tyre changes, usually in view of spectators.

9. Kink
A small bend in an otherwise straight section of track, that can be taken at high speed.

11. Pit lane
Leads to and from the pit garages. Split into two lanes; fast lane for cars, and inner lane where the pit crew work.

6. Run-off zone
Especially on the first corner, there is a generous escape area with a asphalt surface, where cars can safely career off the track, usually without damage.

© BMW Motorsport

5. Chicane
Two consecutive sharp bends designed to slow a car down. Often introduced into straights that have been deemed too fast for safety.

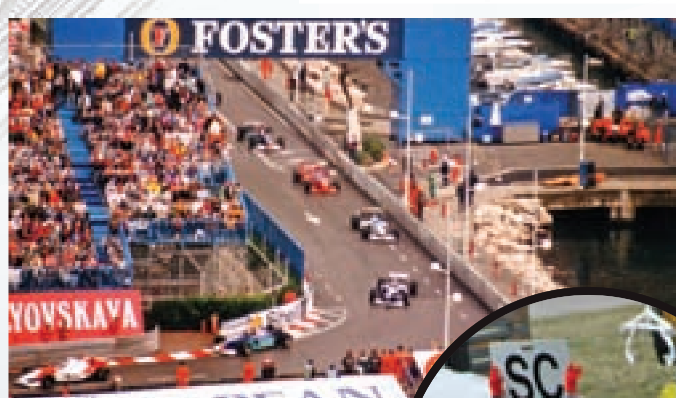
12. Finish line
Cars race for approximately 190 miles, lap after lap, then the first to cross the finish line is the winner.

© BMW Motorsport

1. Starting grid
Positioned at the beginning of a straight and where spectators can see it clearly. Qualifying sessions determine where each driver is placed on the grid.

4. Grandstand
Tiered seats overlooking the most interesting sections of track. Depending on the circuit, these can be covered, open or a mixture of both.

2. Track
Track surface varies from circuit to circuit and is usually made of asphalt, although one or two are concrete. Freshly laid asphalt can be slippery, while older surfaces may be bumpy.



3. First corner
At the end of the starting straight, the cars are still bunched up when they reach here, so there's intense competition to get the best line around the corner. Leads to intense excitement for spectators.

Anatomy of a Formula One circuit

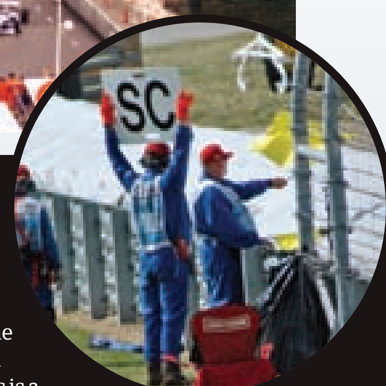
Most Formula One races take place on purpose-built tracks. These are designed to test the drivers' skills, with a mix of fast straights, chicanes and bends. They also take into account viewing areas for spectators, pit lanes, run-off areas, and access for emergency services.

Over the years, some classic circuits have been redesigned to actually slow the cars down; as power and speeds increased some tracks allowed the cars to go too fast along the straights, which led to serious accidents on the subsequent bends. Chicanes have been introduced which not only slow down the cars, they also make for more exciting racing.

Some grands prix – most famously Monaco – take place on public roads. For safety reasons, they are closed to the public and much work is done to prepare the roads for the race. It takes six weeks to create the Monaco Grand Prix circuit each year, and another three weeks to return the roads to normal.

Whether on road or track, each grand prix circuit has its own unique characteristics, which helps make Formula One exciting. Some tracks are tight and twisty, while others are wide and straightforward. There are flat ones, and ones that go up and down hill. The surroundings make a difference too – varying from forests and countryside, to deserts and cities. And, of course, the weather conditions vary from country to country.

Safety circuit



Motor racing used to be very dangerous. Today, though, serious accidents are rare. This is partly thanks to improvements in car and driver safety, but the circuit also plays a huge part in ensuring that tragedy is avoided.

Corners have run-off zones, so that an out-of-control car can swerve off without hitting a hard wall or a crowd of spectators. These zones used to be gravel, to slow the car down, but in recent years asphalt has been favoured as it allows the driver to regain control, and eliminates loose stones flying around.

The race director also has control over the speeds the cars drive at. Marshalls use flags (see right) to warn drivers of danger and tell them to slow down or stop.

To force all the cars to slow down, the safety car will come out. This is a high-performance saloon and no race cars are allowed to overtake either it or each other. However, the cars are allowed to maintain enough speed to ensure that their brakes and tyres do not cool down so much that their effectiveness – and therefore safety – is compromised.

Each circuit also has fully equipped fire trucks, salvage cars and medical cars. All are manned by highly trained professionals, and helicopters and ambulances are on standby.

5 TOP TRACKS

1. Silverstone
Location: England
Turns: 17
Lap record: 1:18.739 (Michael Schumacher, 2004)
Fact: The home of British Formula One and site of the first World Championship race in 1950.

2. Circuit de Monaco
Location: Monaco
Turns: 18
Lap record: 1:14.439 (Michael Schumacher, 2004)
Fact: Run on the streets of Monte Carlo, this is one of the narrowest, twistiest and most exciting tracks.

3. Hockenheimring
Location: Germany
Turns: 16
Lap record: 1:13.780 (Kimi Raikkonen, 2004)
Fact: Originally boasting two long straights, chicanes were added to slow drivers down.

4. Spa-Francorchamps
Location: Belgium
Turns: 21
Lap record: 1:47.263 (Sebastian Vettel, 2009)
Fact: Opened in 1924, with its hills, corners and fast straights, it remains an exciting circuit.

5. Yas Marina
Location: Abu Dhabi
Turns: 21
Lap record: 1:40.279 (Sebastian Vettel, 2009)
Fact: This brand new £800 million circuit is situated on a man-made island.

DID YOU KNOW? *The fire extinguisher pit member became standard after Jos Verstappen's pit fire in '94*

© BMW Motorsport

What happens in the pits

Pit stops can be as exciting as the racing itself, as the highly trained, helmeted and overalled crew descend on the car and rapidly change the wheels and, until last year, refuelled the car, completing the task in mere seconds.

Now refuelling during a race has been banned, so pit stops are really only required for tyre changes – tyres wear out or, if conditions change, the team manager may decide it's worth changing to another type of tyre. Occasionally, though, a pit stop may be needed if the car's not running correctly.

The pit crew is in radio contact with the driver, so they know when the car is going in and can ensure that each team member is in place, ready for action. A 'lollipop man' guides the driver into the correct position using a distinctive handheld sign. Once the car is stopped, the sign is held in front of the driver, telling him to keep the brakes on. He then raises up the sign when it is safe to drive away.

When in the pit lane, the car is limited to a top speed of 62mph and drivers are penalised for any violations. Therefore, it is down to the pit crew to make the stop as short as possible; a well-organised crew can lift up the car, remove the old wheels and tyres and fit new ones in as little as five seconds.

© Bridgestone

Burning rubber

A Formula One tyre is made of rubber with a woven nylon and polyester core that helps it hold its shape during hard cornering.

The rubber is much softer than that in a road car's tyre, to ensure that it grips well, the compound is made softer by adding oil to it. The downside of a soft tyre is that it wears very quickly. In dry conditions the team is likely to select 'slick' tyres that don't have any tread; if it's raining they use a tyre with a tread that will expel the water from between it and the ground.

Tyres grip best when they are hot. They heat up as the car races around the track, but to give them a headstart, the tyres were preheated using electric 'blankets'; these have now been banned. To minimise the change in pressure , the tyre is inflated with a nitrogen-air mixture rather than plain air.

Black flag
Car must return to the pits immediately, often due to disqualification

Black/orange
The car has a mechanical problem, must return to the pits

White/black
A warning for unsportsmanlike behaviour

Blue flag
A faster car is trying to overtake – lapped cars must let faster cars past

Chequered flag
The race has ended – waved as each car crosses the line

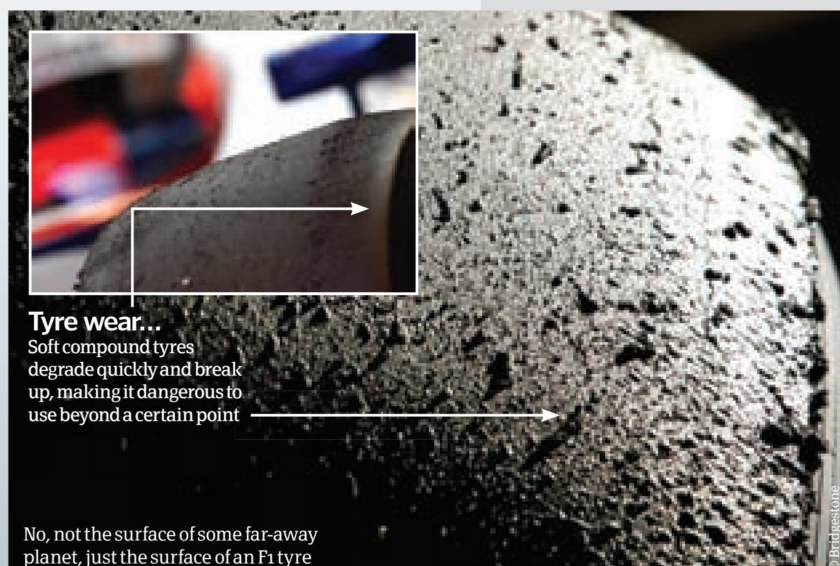
Green flag
All clear – a hazard or dangerous situation has been cleared

Red flag
The race has been stopped, due to accident or poor conditions

Red/yellow stripe
Slippery track, usually due to oil or water being spilled

White flag
Slow-moving vehicle on the track – a recovery truck or safety car

Yellow flag
Danger ahead – no overtaking until told otherwise



No, not the surface of some far-away planet, just the surface of an F1 tyre
© Bridgestone

"Many are keen mountain bikers or road cyclists, with running and swimming also popular"

Red Bull Racing had a very strong end to the 2009 F1 season

© RedBull Racing GP

Fit to drive

Racing a Formula One car is a severe test on your body

Formula One drivers put their bodies through intense stresses during a race. They have to cope with cornering forces of up to 4g, constant vibration, noise and intense heat – they can lose up to 3kg through sweating. It's said that competing in a Formula One race is akin to running a marathon. No wonder the drivers have to be in peak physical condition.

Each driver has his favourite cardio-vascular training; many are keen mountain bikers or road cyclists, with running and swimming also popular. Gym work is tailored, using special training equipment, to build up arm, neck and back muscles in the best form to be able to withstand the extreme cornering forces.

Diet is important and each driver is assigned a dietician to ensure that he maintains an optimal weight and eats a good balance of nutritious food. Immediately prior to a race, drivers switch to a high carbohydrate diet, such as pasta, to ensure they have enough energy and stamina. A high intake of water is also essential to avoid dehydration.

The seats are moulded to the driver's individual shape

© RedBull Racing GP

© RedBull Racing GP

1. Grab handles
Fabric straps on each shoulder are strong enough to allow the driver and his seat to be lifted up by them.

2. Race suit
Made from a fire-retardant and heat-resistant fabric called Nomex. Tested to a temperature of 840 degrees Celsius and, for 11 seconds, the temperature inside must not exceed 41 degrees Celsius. It is also lightweight and breathable.

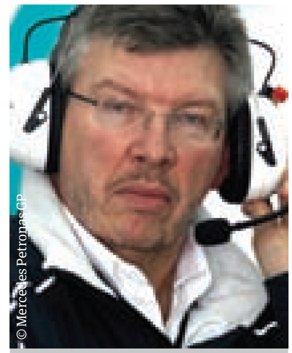
3. Elasticated cuffs
On wrists and ankles to avoid fire and fluids from entering the suit. Also stops loose fabric from flapping around.

4. Gloves
Made from Nomex with soft suede palms that allow the driver to grip the steering wheel while retaining the necessary feel.

5. Underwear
The driver has a fire-retardant under-suit, socks and balaclava.

6. Helmet
Made especially for the driver and finished in the team and/or sponsor colours.

7. Boots
Tailored to the driver's feet, they are made from soft leather with thin rubber soles so that the driver can accurately control the brake and accelerator pedals.



© Mercedes Petronas GP

Radio contact

The modern F1 driver is far from alone as he races around a circuit

The driver's helmet contains two tiny microphones and in-ear headphones. One microphone is outside the helmet and picks up the noise of the engine; noise-cancelling technology then eliminates 80 per cent of that sound, so that the driver and his team can hear each other. Each team is allocated its own frequency at the circuit.

Although all the pit crew have radio systems, communication with the driver is strictly controlled. The driver will convey information about the car's performance and handling to the engineers, so that changes can be made during pit stops.

The team manager will tell the driver when to come into the pits. Some teams supply their radio communications to broadcasters, so that spectators can hear what's being said.

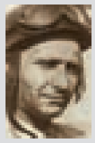
Historical dates in F1

Many changes have occurred since the sport began, here are the major ones…

- **1950** The first Formula One grand prix takes place at Silverstone
- **1958** Stirling Moss is the first driver to win with a mid-engined car
- **1968** Cars appear with sponsors' livery
- **1968** Wings are used to create downforce for the first time
- **1977** Tyrrell competes with a six-wheeled car
- **1977** The first turbocharged cars emerge, from Renault
- **1978** Lotus introduces ground-effect aerodynamics
- **1981** Ground-effect side-skirts banned
- **1989** Turbocharged engines are banned

5 TOP DRIVERS

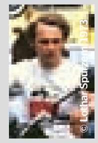
1. Michael Schumacher
Nationality: German
Races: 250
Wins: 91
Pole positions: 68
Championship wins: 7



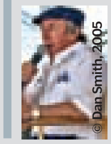
2. Juan Manuel Fangio
Nationality: Argentine
Races: 52
Wins: 24
Pole positions: 29
Championship wins: 5

© Gabriele, 1989

3. Ayrton Senna
Nationality: Brazilian
Races: 162
Wins: 41
Pole positions: 65
Championship wins: 3



4. Niki Lauda
Nationality: Austrian
Races: 177
Wins: 25
Pole positions: 24
Championship wins: 3



© Dan Smith, 2005

5. Jackie Stewart
Nationality: British
Races: 100
Wins: 27
Pole positions: 17
Championship wins: 3

DID YOU KNOW? Juan Manuel Fangio was 46 when he won his fifth world championship

© BMW Motorsport

6. Design
The helmet is painted to suit the driver's personal taste or, increasingly, to promote the all-important sponsors.

4. Ventilation
F1 drivers get very hot, so the helmet has a number of vents with filters to stop debris entering them.

2. Visor
Made from light, tough polycarbonate. Usually tinted and treated with anti-fogging coating on the inside. Covered with a number of clear sheets, which the driver can tear off during the race.

3. Outer shell
Made from resin and carbon fibre, this is very lightweight and covers a strong inner layer designed to absorb impacts. The entire helmet weighs just 1.25kg.

5. Shape
The driver's head is exposed in a Formula One car, so the shape of the helmet is integral to the car's overall aerodynamic performance.

7. Communications
The helmet incorporates headphones and microphone so the driver can be in touch with his pit crew.

1. HANS anchor points
One each side of the helmet, the HANS tether strap is attached to the helmet using mounting points.

In-car safety

Using the latest technology to make the driver the safest he can possibly be

An F1 driver is securely cocooned inside his car's cockpit. The survival cell, as it's known, is an integral part of the car's structure but, in many ways, it's isolated from it – water, fuel and oil lines are not allowed to pass through it. The cell is made from strong but light carbon fibre and reinforced with 6mm of the material used for bulletproof vests.

Regulations insist that the driver must be able to get himself out of the cockpit in just five seconds – and in that time he has to remove both his six-point harness and the steering wheel. The latter must be able to be refitted in another five seconds, in case the car has to be moved. A rollbar behind the seat protects the driver in the event of the car turning over.

The driver's head and neck is protected by a HANS (head and neck support) device. This is a U-shaped yoke that fits over the driver's shoulder and is attached to the helmet. In the event of an accident, it stops the head from whipping forward and causing life-threatening injuries.

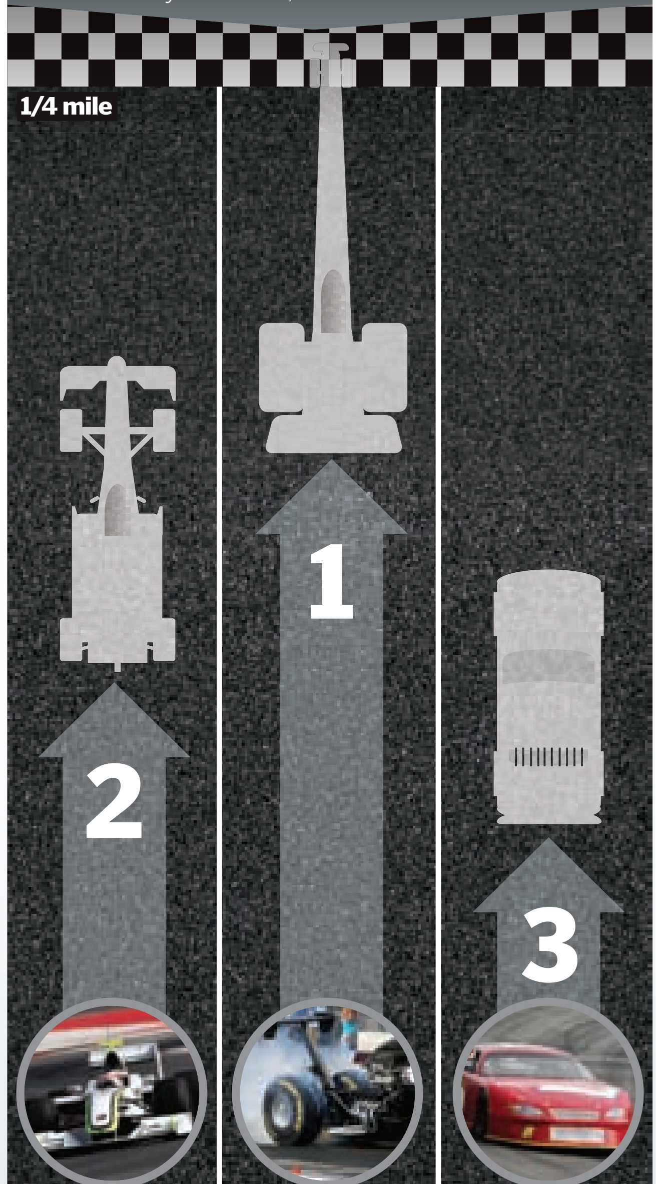
The car's equipped with an automatic fire extinguishing system which smothers the engine and car in foam in the event of fire. A master switch allows the driver – or a marshal – to turn off the car's electrical systems.

1994	1998	2005	2009	2010
Deaths of Roland Ratzenberger and Ayrton Senna lead to overhaul of safety regulations	Grooved tyres introduced to reduce speeds	V10 engines banned in favour of smaller V8 units	Most aerodynamic aids banned, except for front and rear wings	Cost-cutting measures introduced, including reducing team staff numbers

Head-to-Head

Fastest cars on Earth in 1/4 mile drag race

They are all fast, but which would win?



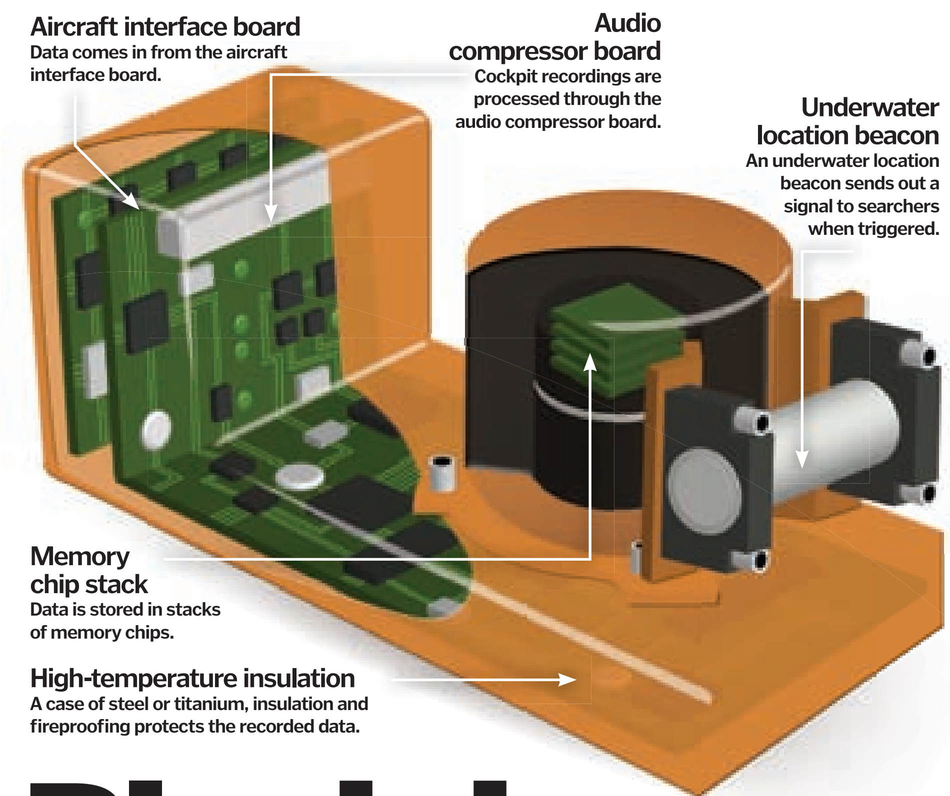
F1 car
Top speed: 250mph
Acceleration: 0-186mph in 8.6 seconds
Power: 750bhp

Dragster
Top speed: 330mph
Acceleration: 0-330mph in 5 seconds
Power: 8,000bhp

NASCAR
Top speed: 230mph
Acceleration: 0-60mph in 3.0 seconds
Power: 850bhp

Over a quarter mile drag, the sheer power generated by the dragster's engines and its streamlined and straight-drive focus allows it to take the trophy. However, both the Formula One car and NASCAR don't take much longer to cross the line. If it were a fastest lap test, however, the dragster would be obliterated by both other vehicles as they are constructed to maintain high speeds through bends and chicanes.

"The Cockpit Voice Recorder picks up sound from inside the cockpit, including the pilot and copilot's headset"



Black box

How important aircraft data is designed to survive the worst disasters

Black box recorders are used to retrieve data about an aeroplane and its operating environment in the event of a crash. There are two types of black box: the CVR or Cockpit Voice Recorder, and the FDR or Flight Data Recorder. Both record different types of information, and when combined this information can be used to build up a picture of what happened during a crash.

The Cockpit Voice Recorder picks up sound from inside the cockpit, including the pilot and copilot's headset microphones and those of any other cockpit staff. There's also a microphone placed centrally in the cockpit to record any other ambient sound, such as conversations with other crew members, radio, and even the noise of switches and dials. They used to be magnetic tape recorders but are now more reliable solid state devices akin to flash drives. These record around two hours of information at a time, recording over and replacing older audio. The CVR allows listeners to find out what the cockpit staff were doing in the event of the crash; what they observed and reacted to among the circumstances that caused it, if they sent out a Mayday message or signal or recorded any grid co-ordinates.

The Flight Data Recorder, on the other hand, records important information about what the plane was doing at the time. There are several areas of the plane it takes data from, including the wings, engines, landing gear and rudders. This information is aggregated in the Flight Data Acquisition Unit at the front of the plane and fed into the FDR at the back. Typically it includes factors like speed, altitude, engine performance and the positions of the wings, rudder and landing gear.

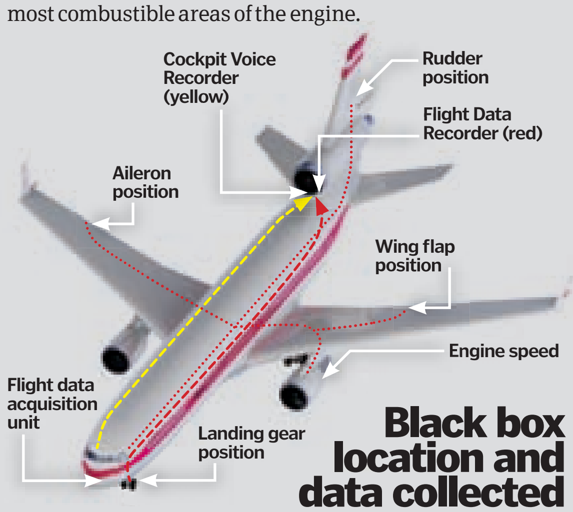
Brazilian Air Force personnel recover the flight data recorder of PR-GTD, the Boeing 737-8EH used for Gol Transportes Aéreos Flight 1907, in the Amazon Rainforest. PR-GTD crashed after a mid-air collision.

The black box can be more eyecatching than the name suggests…

Where is it kept?

Where is the recorder most likely to survive?

Sensors that feed data to black box recorders are located in key areas of the plane, such as the engines, wings, rudder and landing gear. Microphones and data recording and processing units are stored around the cockpit to record voices, ambient noise and data from the cockpit instruments. The actual black boxes themselves though – the units in which the recorded data is stored – are located at the back of the plane beneath the tail. This location lessens the chance of the black box being destroyed, as it's not in an area which would take the impact of a head-on or belly-down crash, and it's as far away as possible from the most combustible areas of the engine.



Black box location and data collected

5 TOP FACTS BLACK BOXES

1 The Wright Brothers
The Wright Brothers pioneered a device which recorded propeller speed.

2 The black box name
The black box name may be linked to a device designed in 1939 by Francois Hussenot which recorded photographic data using lines of light reflected inside a black case.

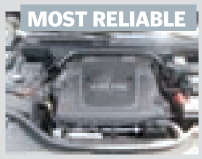
3 High temperatures
The housing around a black box is specified to withstand temperatures of 1,000° Celsius.

4 Satellite beacon
A black box recorder's locator beacon uses a satellite network connection to send radio signals.

5 Onboard cameras?
The US is now looking into placing image recorders in commercial flight cockpits.

FASTEST

1. Petrol
Generally faster than diesel or electric, the petrol engine provides plenty of power thanks to its spark ignition system, literally exploding fuel under high pressure.



MOST RELIABLE

2. Diesel
While not as quick as similar petrol variants, due to robust components and gentler burning of fuel instead of exploding it, diesel engines are reliable and durable.

GREENEST

3. Hydrogen
Hydrogen engines use fuel cells – which separate the hydrogen electrons – to drive an electric motor. Power and speed are good while emissions can be non-existent.

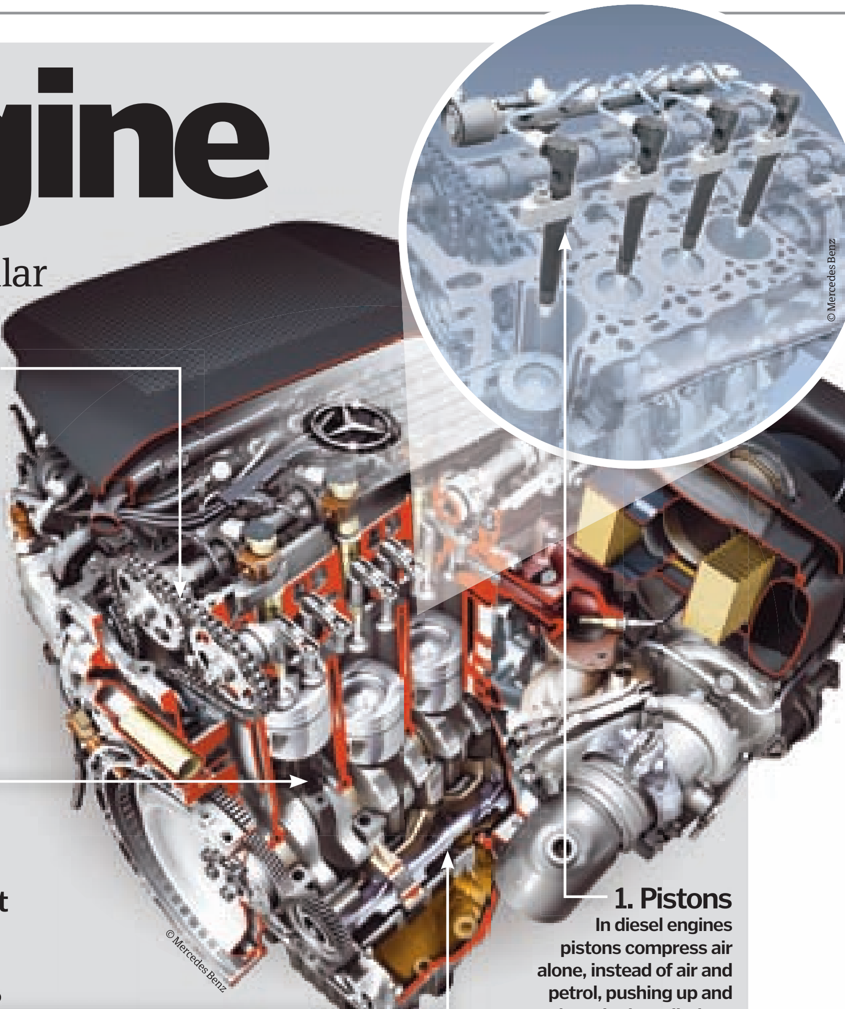
DID YOU KNOW? *Diesel engines are compression-ignition systems, burning fuel by admixing fuel to highly pressurised air*

Diesel engine

Offering greater fuel economy and longevity, diesel engines are becoming increasingly popular compared to their petrol counterparts

Contrary to the workings of a petrol engine – where a petrol/air mix is compressed by a piston within a cylinder to roughly 1/9th of its original volume, before being ignited by a spark plug – a diesel engine operates by the compression of air alone, spraying diesel into the cylinder once pressurised. This is because diesel burns instead of explodes, relying on the rapid expansion of gases to push the piston back down the cylinder, instead of the kinetic force generated by an explosion.

For example, in a petrol engine as the piston in one of the car's cylinders moves down on its first stroke (the initial stage of the ignition cycle) it draws in a pre-mixed amalgamation of petrol and air. Once this is achieved it then moves back up the cylinder (compression stroke), compressing the mix before igniting it with a spark plug, sending the piston flying back down the cylinder and providing power to the crankshaft (power stroke). Finally, the piston moves back up the cylinder, expelling its used contents (exhaust stroke). In a diesel engine, however, on the first stoke only a large quantity of air is drawn into the cylinder and it is solely this that is compressed when the piston moves back up. At this point, diesel is then sprayed into the cylinder in small droplets that are ignited due to the extreme heat and pressure created by the compressed air. Diesel is then continually released into the cylinder down through the power stroke.



2. Spur belt
The diesel engine's overhead camshaft and fuel-injection pump are powered here.

3. Cylinders
Once air is compressed in the cylinders by the pistons, diesel is sprayed into them and burns under pressure.

4. Crankshaft
The crankshaft converts the reciprocating linear piston's motion into rotation.

1. Pistons
In diesel engines pistons compress air alone, instead of air and petrol, pushing up and down in the cylinders.

Flight helmet

How a pilot's headgear protects against the effects of high-G environments

As exhilarating as it may sound, being a fighter pilot in the jet age involves enduring some pretty adverse conditions. Without specialised equipment a fighter pilot would almost certainly pass out. When taking to the skies at supersonic speeds, a pilot needs a modern flight helmet to help overcome such harsh conditions. Therefore, today's helmets serve numerous purposes and feature advanced technology that provides air personnel with comfortable cranial cushioning and protection against ear-damaging noise while also reducing the pressure of the extreme acceleration that causes headaches and sinus problems.

Visor
Today's visors are made from contoured polycarbonate, which is known for its impact resistance and sophisticated optical properties. A well-designed visor will be cut back at the temples, offering the wearer maximum peripheral vision.

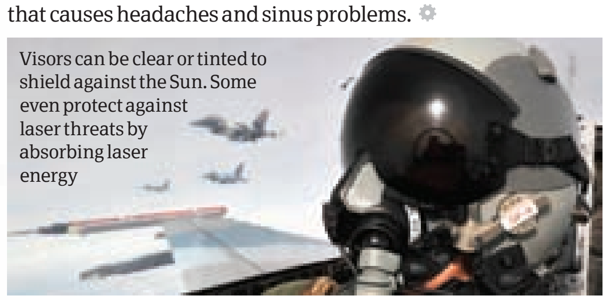
Outer casing
A rigid composite outer casing designed to be as low profile as possible will keep the weight of the helmet much lower than fibreglass materials.

Core
Within the hard outer casing, a soft foam core offers comfort and support for the head.

Communications
Helmets feature essential equipment enabling communication with other pilots or ground control. The mask-mounted microphone allows the user to keep up with ongoing mission scenarios.

Strap
Chin and nape straps hold the helmet securely, supporting the neck.

Oxygen mask
An oxygen mask attached to the front of the helmet supplies the pilot with a continuous flow of breathable air through a regulator.



Visors can be clear or tinted to shield against the Sun. Some even protect against laser threats by absorbing laser energy

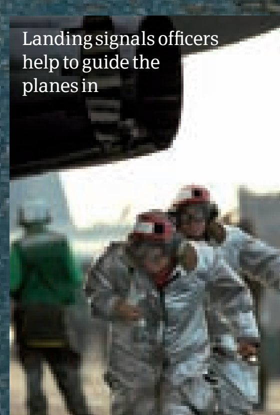
"The flight deck is a true danger zone with high-speed jets constantly coming and going"

Landing on an aircraft carrier

How do fighter jets take off and land on such short runways?

Aircraft carriers are big floating runways that act as roving military bases for hundreds of aircraft coming in to land every day. Steering a high-speed jet on to a tiny target calls for precision guidance equipment and, among other things, today's naval aviators rely on the Improved Fresnel Lens Optical Landing System (IFLOLS). IFLOLS involves positioning a series of lights and fresnel lenses, which are thin and visible over long distances, on the flight deck with a line of green lights protruding from either side. Shining a fibre-optic 'source' light into the lenses creates the optical illusion of a ball whose up-and-down motion, when compared to the position of the green lights, reveals to the pilot his position in relation to his desired flight path. If the ball appears to be above the green lights he is too high and vice versa.

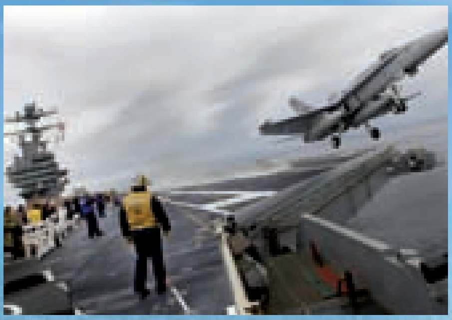
Landing on a carrier is one of the most dangerous manoeuvres – a pilot must perform



Landing signals officers help to guide the planes in

The Landing Signals Officers

The crew on board an aircraft carrier have one of the world's most notoriously dangerous jobs, and with high-speed jets constantly coming and going, the flight deck is a true danger zone. One very important group lurking about on the flight deck are the Landing Signals Officers (LSOs). An LSO has as much experience as a jet pilot and so can provide essential information in addition to that supplied by the IFLOLS. The LSO guides the plane in to land through a combination of radio comms and light signals. The light signals can be used to either correct a pilot's mistakes or indicate that they should give up and come round for another attempt.

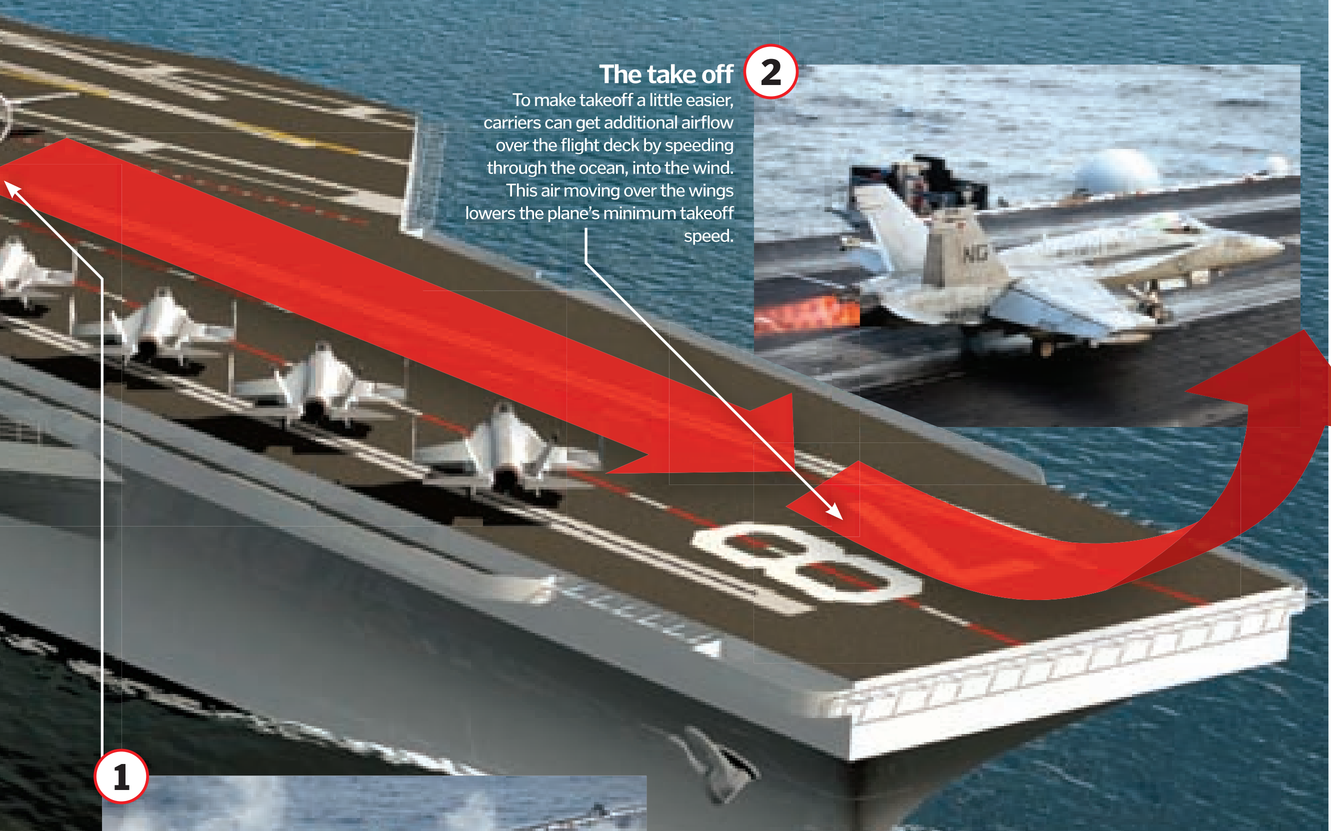


Taking off is hard to do

Because the flight deck is so short, aircrafts need mechanical assistance to generate the acceleration to force enough air over the wings to produce lift. This is achieved by catapulting the plane off the end of the runway using pressurised steam. High-pressure steam is released into two cylinders below the flight deck. Once the aircraft is attached to the catapult, a catapult officer releases steam into the cylinders. Pistons inside the cylinders are attached to the plane's nose gear (front wheels), and once the cylinders reach the optimum pressure for the conditions on deck, the pilot fires up the engines. Once the aircraft is cleared for take off, the catapult officer releases the pistons.

Stopping on a sixpence

While traditional runways are thousands of metres long, the average carrier runway is just a few hundred metres, and without specialised equipment this is not enough space for a high-speed aircraft to stop. The aircraft must decelerate quickly as soon as it touches down, so a plane is lassoed by strong wires. Attached to the back of the plane is a tail hook, which latches on to one of four high-tensile steel cables called arresting wires. These wires are laid across the deck at 50m intervals, giving the plane four chances to snag a wire. At both ends of each wire is a system of hydraulics that absorbs the plane's energy as soon as it is stopped by the wire.



The take off 2

To make takeoff a little easier, carriers can get additional airflow over the flight deck by speeding through the ocean, into the wind. This air moving over the wings lowers the plane's minimum takeoff speed.

1 Clearance needed

Aircraft take off from the front, into the wind. On some ships a steam-powered catapult is used to propel the aircraft forward and assist the power of the engines during take off.

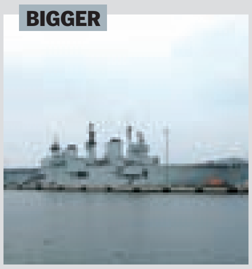
Head to Head AIRCRAFT CARRIERS

BIG

1. HMS Audacity (D10)

Class: N/A (escort carrier)
Launch date: 29 March 1939
Status: Sunk 21 December 1941
Displacement: 11,000 tons
Length: 142.42m
Beam (width): 17.15m
Speed: 15 knots
Complement: Unknown
Aircraft carried: 6-8

BIGGER



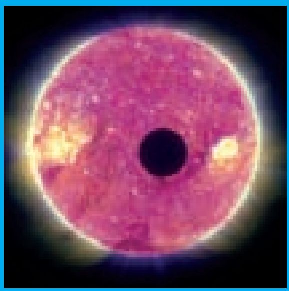
2. HMS Illustrious (R06)

Class: Invincible (light aircraft carrier)
Launch date: 14 December 1978
Status: Active
Displacement: 22,000 tons
Length: 209m
Beam (width): 36m
Speed: 30 knots
Complement: 685 crew
Aircraft carried: 22

BIGGEST

3. USS Constellation (CV-64)

Class: Kitty Hawk (supercarrier)
Launch date: 8 October 1960
Status: Inactive
Displacement: 61,981 tons
Length: 332m
Beam (width): 86m
Speed: 34 knots
Complement: 3,150 crew
Aircraft carried: 72



This month in Space

Another space section filled with spectacular celestial-based sights, stories and statistics. If you've looked up at the night sky and wondered about Earth's next nearest neighbour you'll love this spread as it reveals all manner of facts about our moon. Other exciting titbits on offer include the Apollo Lander, solar eclipses and discovering how telescopes work.

27 The Apollo Lander

29 Solar eclipse

32 Telescopes

The moon

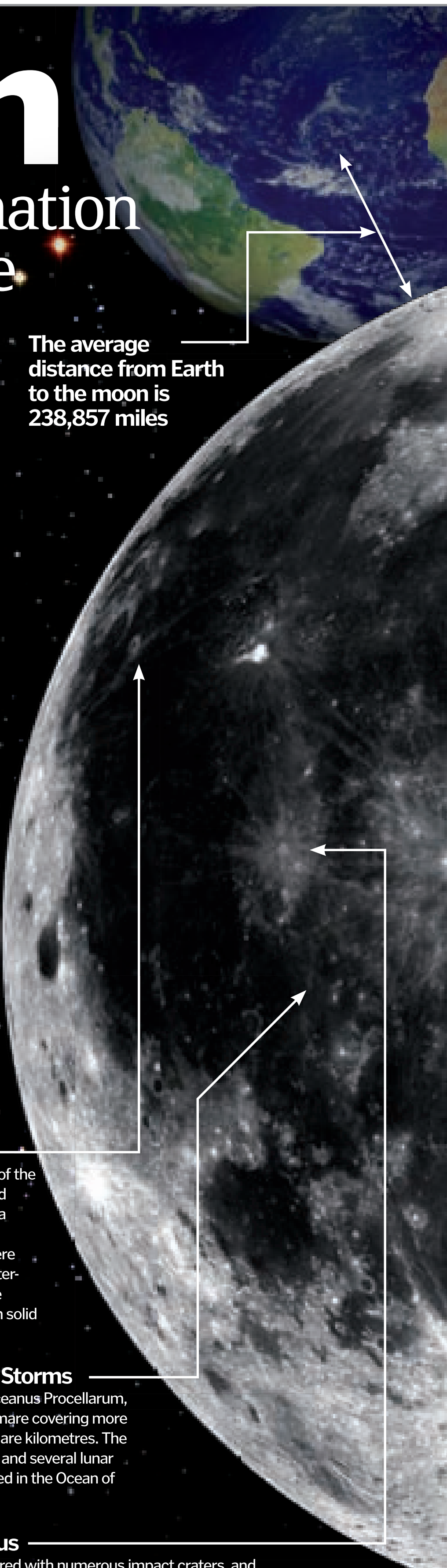
Understanding man's fascination with Earth's natural satellite

Not only is the moon our only satellite, it's one of the biggest in the solar system and the only other celestial body upon which man has stood. It's much smaller than the Earth, with a diameter about 25 per cent that of Earth's diameter. The Earth's mass is also about 80 times that of the moon. The moon has a much lower gravitational force than the Earth – its gravity is about one-sixth that of our home planet's.

The moon is often referred to as dead, mainly because there is no life and its surface hasn't changed much over the billions of years. Temperatures at is poles can be as high as 127 degrees Celsius during the day and as low as -173 degrees Celsius at night. The moon is also covered in deep craters that can stay as cold as -240 degrees Celsius.

Its apparent glow is just light reflected from the Sun. There's no atmosphere and no air, although there is a collection of gases above the surface known as an exosphere. The moon does have days that last about 29.5 hours, although the sky is always dark with visible stars. It rotates on its axis in about the same time it takes for it to orbit the Earth, a phenomenon known as synchronous rotation. This means that the same side – called the near side – is typically facing the Earth. The far side is often called the dark side, but it's illuminated by the Sun once per lunar day just like the near side.

As the moon orbits around the Earth, it goes through four phases – the new moon, first quarter moon, full moon, and last quarter moon. During the new moon, the moon is between the Sun and the Earth, so the sunlit side is turned away. Every seven days, more of the moon becomes visible. This process is known as waxing. Halfway through the lunar month there is a full moon. Then as the moon's orbit takes it further away from Earth, it wanes and less of it is visible.



The average distance from Earth to the moon is 238,857 miles

1. Maria
The darker areas of the moon are cratered plains called maria (Latin for 'seas'). Originally they were thought to be water-filled, but they are actually filled with solid lava.

4. Ocean of Storms
Also known as Oceanus Procellarum, this is a massive mare covering more than 4 million square kilometres. The Apollo 12 mission and several lunar probes have landed in the Ocean of Storms.

5. Copernicus
The moon is covered with numerous impact craters, and Copernicus is one of the most prominent. It's about 800 million years old and light in colour because it doesn't contain lava.

The surface of the moon

Astronauts who have visited the moon describe the surface as being covered with a fine, powdery dust that was very slippery. Movements had to be planned several steps ahead. Although the gravity is one-sixth that of Earth's, simulations helped them to cope with the differences.

This photo of Buzz Aldrin was taken by Neil Armstrong during the Apollo 11 mission

5 TOP FACTS THE MOON

Nobody owns it
1 There are US flags and Soviet pennants on the moon but they are purely symbolic. The Outer Space Treaty gives the moon the same status as international waters.

Man in the moon
2 The stark contrasts between the maria and terrae have been interpreted as various patterns including a human face, head or body and even a small dog.

No weapons allowed
3 Under the Outer Space Treaty, the moon can only be used for peaceful purposes. In fact no nuclear weapons or WMDs are allowed to be in orbit or installed on any celestial body.

Were we really there?
4 Some believe that the moon landings were faked by the US government, possibly to gain prestige, although these theories have been repeatedly disproved.

A second moon
5 3753 Cruithne is an asteroid in orbit around the Sun. It has been called "Earth's second moon", although it is only a quasi-satellite with 364 day orbit of the Sun.

DID YOU KNOW? *Our ocean tides are caused by the pull of the moon's gravitational force*

A guided tour

The moon is covered with interesting features, including plains, highlands, and craters

3. Sea of Tranquillity
Known in Latin as Mare Tranquillitatis, this mare was the landing site for the Apollo 11 mission. It looks very blue in photographs due to its high metallic content.

2. Terrae
The lighter regions of the moon are called highlands or terrae (Latin for 'lands'). There are several mountain ranges and ancient volcanoes present.

Could we ever live there?

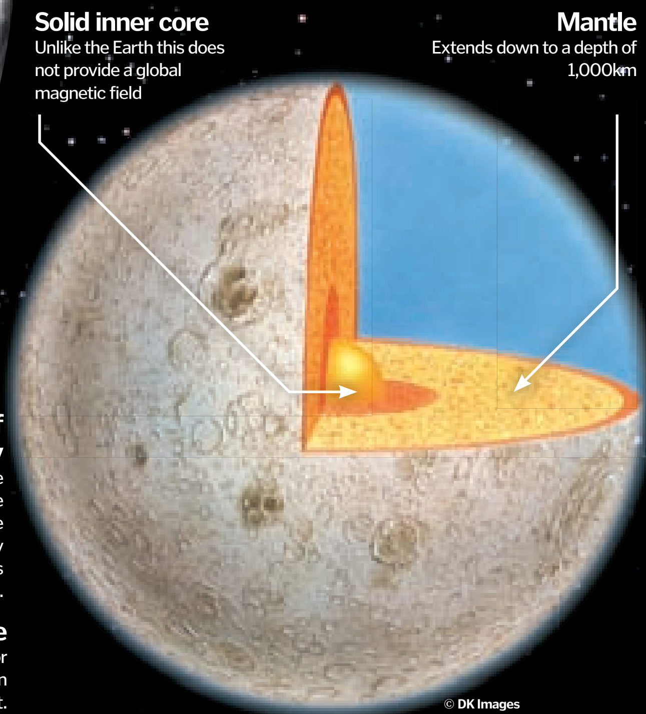
A moon colony has its pros and cons

Many people believe that we may someday colonise the moon. Space tourism could be a huge source of income and a permanent colony would make it easier to construct and launch spacecraft to explore other planets. It doesn't take long to reach the moon – just three days – and there isn't much delay in communications between the moon and the Earth. Many experiments that could result in new findings could be conducted there. It's an excellent site for an observatory because of its slow rotation and inactivity compared to the Earth. There also appears to be water at the poles.

However, there are some negatives to the idea of moon colonisation. The low gravity would require compensation because of its detrimental effect on the human body. The lack of atmosphere and extreme temperatures, as well as the relatively long lunar night (15 hours), would also require advanced technologies to allow for any kind of habitation.

A possible future lunar mission would include establishing a Lunar Observatory with a telescope

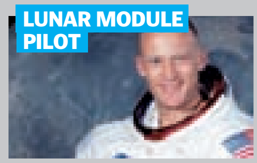
Beneath the surface of the moon



Head to Head
The Apollo 11 crew

1. Neil Armstrong
The first man on the moon and commander of the Apollo mission. This was his second, and last, space flight.

2. Michael Collins
Collins looked after the command modules while Aldrin and Armstrong landed the Eagle on the moon.



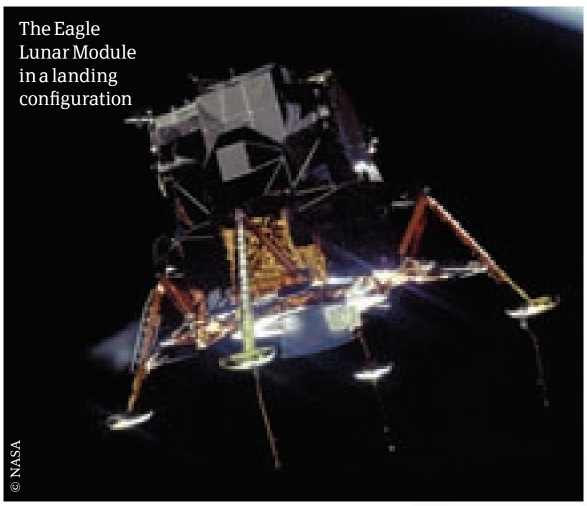
3. Buzz Aldrin
The pilot of the Eagle was the second man to ever set to set foot on the moon, following mission commander Neil Armstrong.

DID YOU KNOW? *The Apollo 13 LM helped save the lives of its crew after a systems malfunction*

Inside the Apollo Lander

The Apollo Lander was the landing module of the Apollo spacecraft

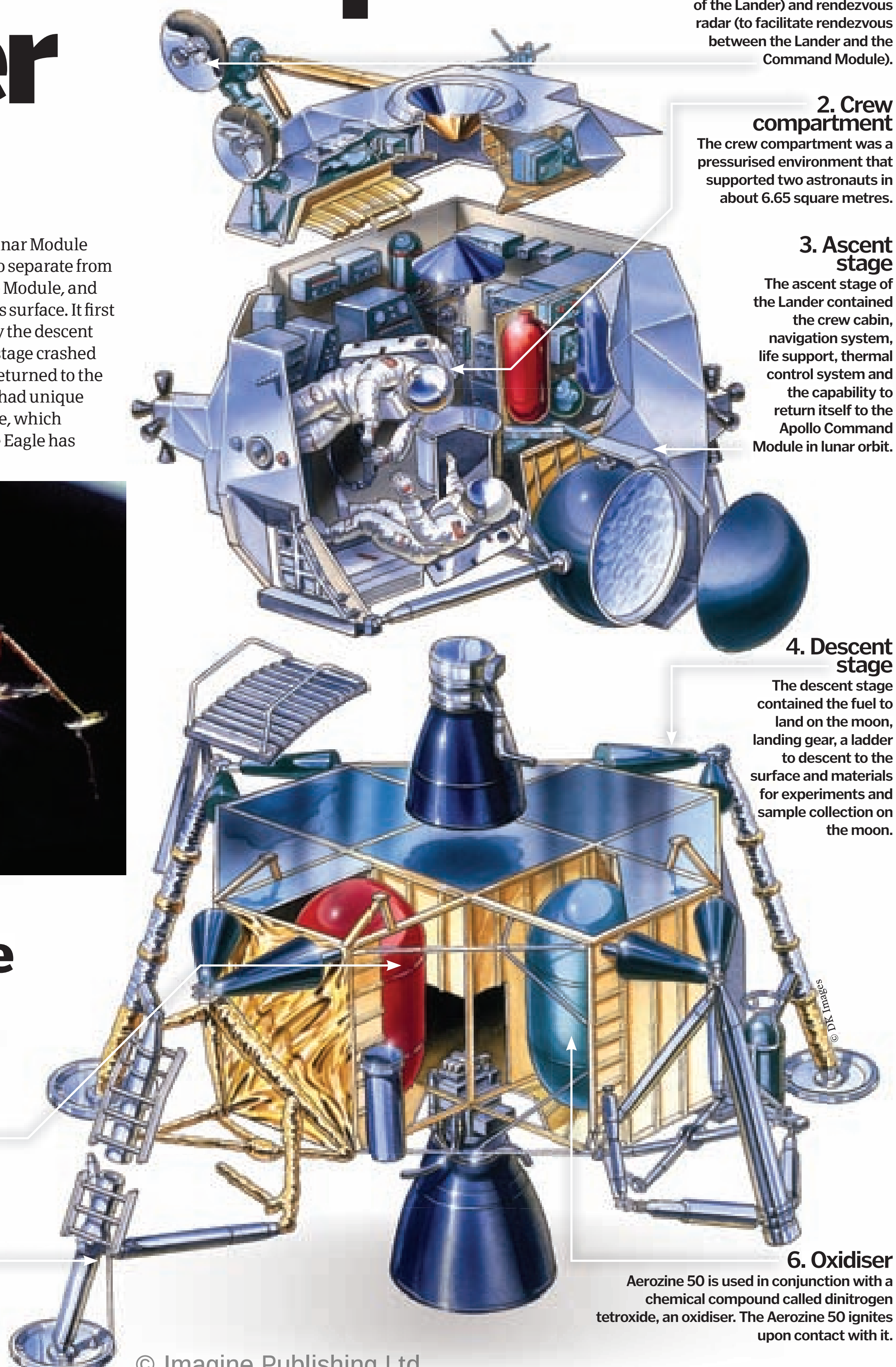
The Lander, also known as the Lunar Module (LM), was a two-stage craft built to separate from the Apollo Command and Service Module, and then travel to and from the moon's surface. It first landed on the moon on 20 July 1969. Generally the descent stage was left on the moon, while the ascent stage crashed into the moon's surface once the astronauts returned to the Command Module. Each of the 15 Apollo LMs had unique names. The Apollo 11 LM was named the Eagle, which explains why Neil Armstrong stated that "the Eagle has landed" when it touched down.


The Eagle Lunar Module in a landing configuration

© NASA

Now boarding for the surface of the moon

The Apollo Lander was a feat of technological engineering



© DK Images

1. Antennas
The Lander had three different types of antenna: VHF (for communication), S-band steerable (to facilitate control of the Lander) and rendezvous radar (to facilitate rendezvous between the Lander and the Command Module).

2. Crew compartment
The crew compartment was a pressurised environment that supported two astronauts in about 6.65 square metres.

3. Ascent stage
The ascent stage of the Lander contained the crew cabin, navigation system, life support, thermal control system and the capability to return itself to the Apollo Command Module in lunar orbit.

4. Descent stage
The descent stage contained the fuel to land on the moon, landing gear, a ladder to descent to the surface and materials for experiments and sample collection on the moon.

5. Fuel
The Lander was powered by a rocket fuel called Aerozine 50. It is still used in spacecraft and rockets because it is a highly stable fuel with a low freezing point.

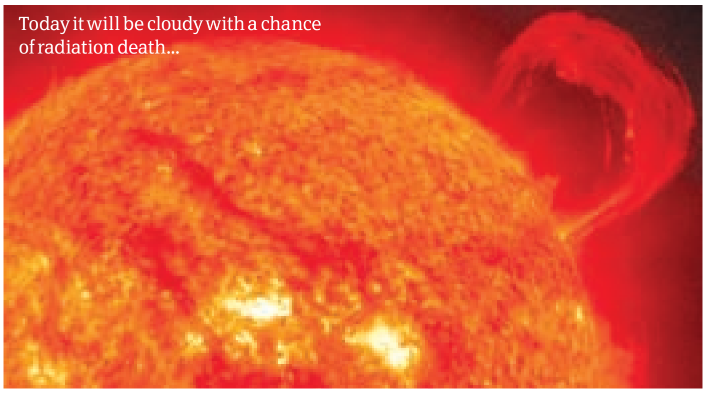
6. Oxidiser
Aerozine 50 is used in conjunction with a chemical compound called dinitrogen tetroxide, an oxidiser. The Aerozine 50 ignites upon contact with it.

7. Landing gear
Initial designs had three legs, which could have resulted in a toppling Lander if one was damaged. Five legs were preferred, but they made the Lander too heavy. Four was an acceptable compromise.

> "Working together they actually hold the material in place like a pair of inter-planetary bookends"

What's the weather like in outer space?

The weather on Earth can be terrible, but in space it can be positively cataclysmic…


Today it will be cloudy with a chance of radiation death…

Had NASA decided to launch an extra mission between Apollo 16 and 17, its astronauts would've been killed by an acute overdose of radiation caused by a solar radiation storm courtesy of a solar flare.

In extreme circumstances, you wouldn't even have to be in space to suffer the consequences of increased energetic particle activity caused by a nasty solar flare – passengers on commercial airlines would receive a unhealthy dose of radiation too. During this extreme solar weather, satellites can be rendered useless and high frequency communications would stop working near the polar caps.

Geomagnetic storms are potentially more deadly, however. Disturbances in the Earth's magnetic field caused by the Sun's solar wind have been enough to wreak havoc with power systems across the world. In 1989 an electromagnetic storm wiped most of Quebec off the power grid for nine hours. In fact, the effects were so strong auroras (the visible effects of particles interacting with the Earth's magnetic field) could be seen as far south as Texas.

There's also the thought of micrometeor showers. Space rain is actually made of tiny particles of rock and metal travelling at tens of miles per second. Micrometeoroids are remnants of the creation of the solar system and millions of them bombard the Earth from space every day.

Space weather

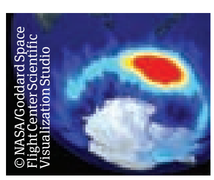
The most common forms of space weather include solar wind, raining micrometeoroids and geomagnetic storms

Micrometeoroids

These are only called micrometeorites once they've fallen to Earth. They can potentially destroy satellites and other space-based technology, though rarely make their way to Earth.

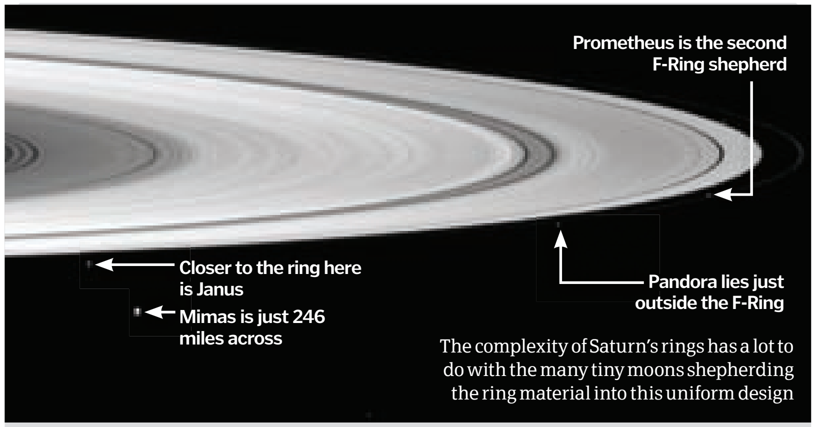
Solar radiation storms

Caused by solar flares rushing at the Earth, solar radiation storms could potentially kill an astronaut stone dead and even severely harm unfortunate airline passengers.



Geomagnetic storms

Ever-changing solar winds create geomagnetic storms, which could completely overload power systems and cause devastating country-wide blackouts.



The complexity of Saturn's rings has a lot to do with the many tiny moons shepherding the ring material into this uniform design

Saturn's elusive Shepherd moons…

Saturn's rings might have disappeared a long time ago without these celestial bodies…

Without them Saturn would be just another gas giant, but the Saturnian system's rings have been a thing of wonder since Galileo first spotted a pair of fuzzy 'ears' around our solar system's second largest planet some 400 years ago. Since we've only recently started to explore the outer planets, there is still some debate as to the actual origin of Saturn's rings. While some think they originate from a moon that could have succumbed the Roche limit (when a body reaches an orbit close enough to its parent body to be literally ripped apart by gravitational forces) or obliterated by a comet, others think the ring system is almost as old as Saturn itself and is in fact material left over from the planet's own creation.

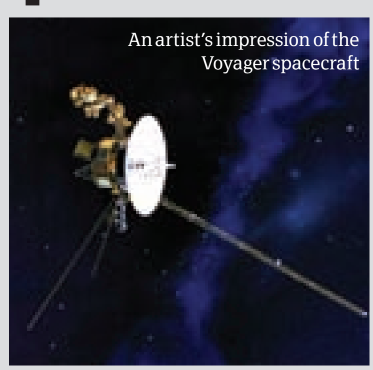
One thing scientists are quite sure about is the vital role a selection of Saturn's 62 moons play in the ring system's outstanding beauty. These Shepherd moons actually shape and maintain the crisp edges separating the famous rings on their orbits between the various 'gaps' – without them the Saturnian system's crowning jewel might not even exist at all.

While a single Shepherd moon's gravity is capable of pushing and pulling the small particles of a particular ring into a uniformed knife edge, the outer F-Ring is an example of a ring maintained by a pair of Shepherds – Prometheus and Pandora – one either side of the ring. Working together they hold the material in place like a pair of inter-planetary bookends.

There's still a lot to learn about Saturn's Shepherd moons, not least because more are being discovered. The most recent Shepherd spotted keeping tabs on the outer B-Ring was found just last year as part of the Cassini mission, but with a diameter of little more than 300 metres it's barely perceptible, even to man's most advanced orbiting probes.

Up close and personal

Before we ventured into 'deep' space with the Voyager missions launched in the late Seventies it was thought that Saturn only had a small selection of rings . It wasn't until Voyager 1 and 2 sent back nearly 2,000 pictures of the Saturnian system that the rings were revealed and tens of thousands of lesser rings were seen. These missions and the more recent Cassini mission confirmed that these intricate structures were the handiwork of a partnership between Saturn's larger moons and smaller Shepherd moons.


An artist's impression of the Voyager spacecraft

All Images courtesy of NASA

5 TOP FACTS SOLAR ECLIPSES

Larger than it appears
1 In a total eclipse the Sun and the moon appear to be the same size, due to their respective diameters and distances. The size difference is actually monumental.

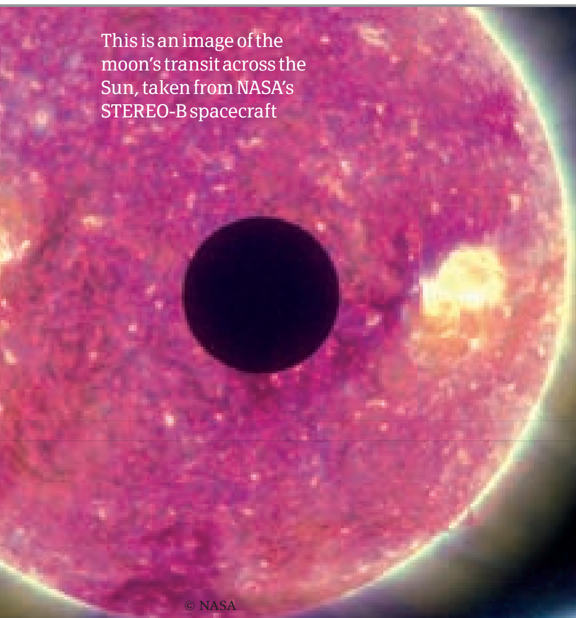
Don't stare directly
2 Our retinas cannot sense any pain, so permanent vision loss caused by staring at an eclipse may not become evident until hours later, so be sensible when viewing.

'Tis the season
3 Eclipse season happens twice a year (approximately every 173 days), when the moon crosses the orbital plane of the Earth. Each season lasts between 24 and 37 days.

A brief observation
4 Total eclipses generally take a couple of hours from start to finish, with the period of totality lasting for a few minutes and plunging an area into complete darkness.

An indirect view
5 The best and safest way to view any kind of eclipse is through a special solar filter (such as eclipse sunglasses) or possibly a pinhole camera.

DID YOU KNOW? *Ancient cultures were often frightened by solar eclipses and attributed them to supernatural beings*



This is an image of the moon's transit across the Sun, taken from NASA's STEREO-B spacecraft

© NASA

Solar eclipse

Solar eclipses occur when the moon passes between the Earth and the Sun

The view of the shadow cast by the moon during a solar eclipse in 1999, taken by the Mir space station

© NASA

The next total solar eclipse will occur on 11 July 2010

During a solar eclipse, the moon casts shadows on the Earth known as umbra or penumbra. The umbra is the darkest part of the shadow, while the penumbra is the area where part of the moon is blocking the Sun. Partial eclipses happen when the Sun and moon are not in perfect alignment – only the penumbra of the moon's shadow passes over the surface of the Earth. In a total eclipse, the umbra touches the Earth's surface.

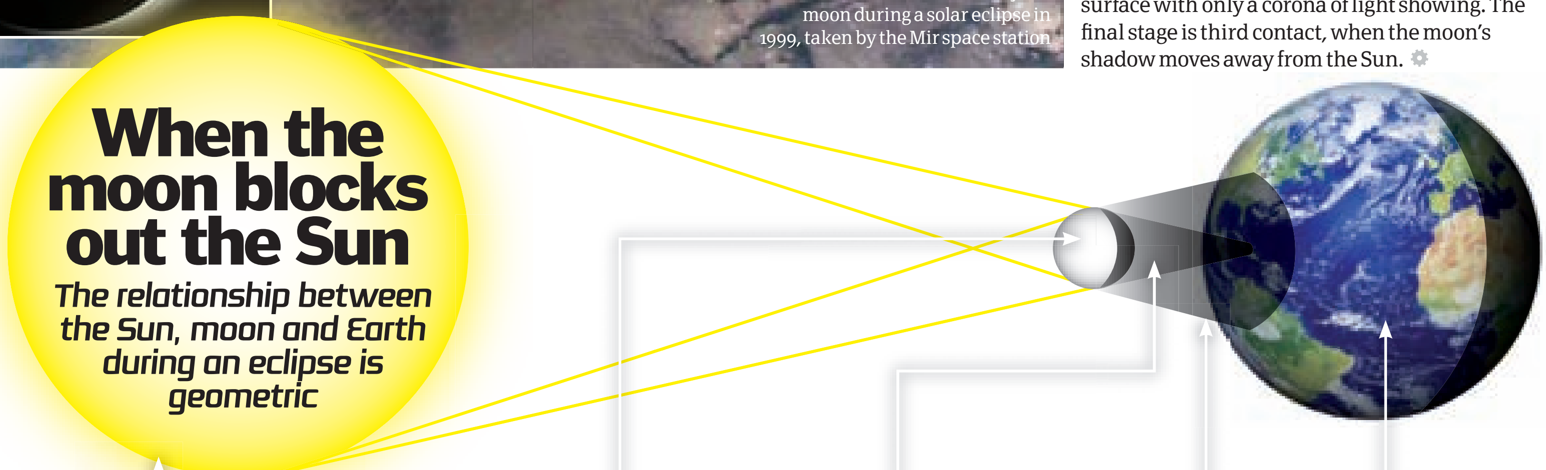
There are also annular eclipses, in which both the Sun and the moon are in alignment but the moon appears to be slightly smaller than the Sun. The Sun appears as a bright ring, or annulus, around the moon's profile. The umbra is still in line with a region on the Earth's surface, but the distance is too great to actually touch the surface of the Earth.

Depending on your location, an eclipse may appear to be any of the three possible types. For example, if your region lies in the path of totality, you will experience a total eclipse, while people in other regions may only see a partial eclipse. Solar eclipses occur between two and five times per year, with most of these being partial or annual eclipses.

Total eclipses have four phases. First contact occurs when you first notice the shadow of the moon on the Sun's surface. During second contact, you will observe a phenomenon called Baily's beads, when sunlight shines jaggedly through the rugged peaks and valleys of the moon's surface. When one bead of light is left, it appears as a single dot in the ring, known as the diamond ring effect. Next, the moon completely covers the Sun's surface with only a corona of light showing. The final stage is third contact, when the moon's shadow moves away from the Sun.

When the moon blocks out the Sun

The relationship between the Sun, moon and Earth during an eclipse is geometric



1. Sun
The Sun and the moon often appear to be the same size, because the ratio between their diameters is about the same as the ratio between their respective distances from Earth.

2. Moon
The magnitude of an eclipse is the ratio between the angular diameters of the moon and Sun. During a total eclipse this ratio is one or greater.

3. Umbra
The umbra is the central area of the shadow of the moon. If this area passes over you, you'll see a total eclipse. The sky will be completely dark.

4. Penumbra
The penumbra is the outer part of the moon's shadow. You will see a partial eclipse if this part passes over you and the sky will only be partially dark.

5. Earth
In an annular solar eclipse, the umbra never touches the Earth because the moon is too far away in its orbit. The Sun appears as a bright ring around the moon's profile.

"It's designed to observe planets crossing across the face of their stars"

The Kepler mission

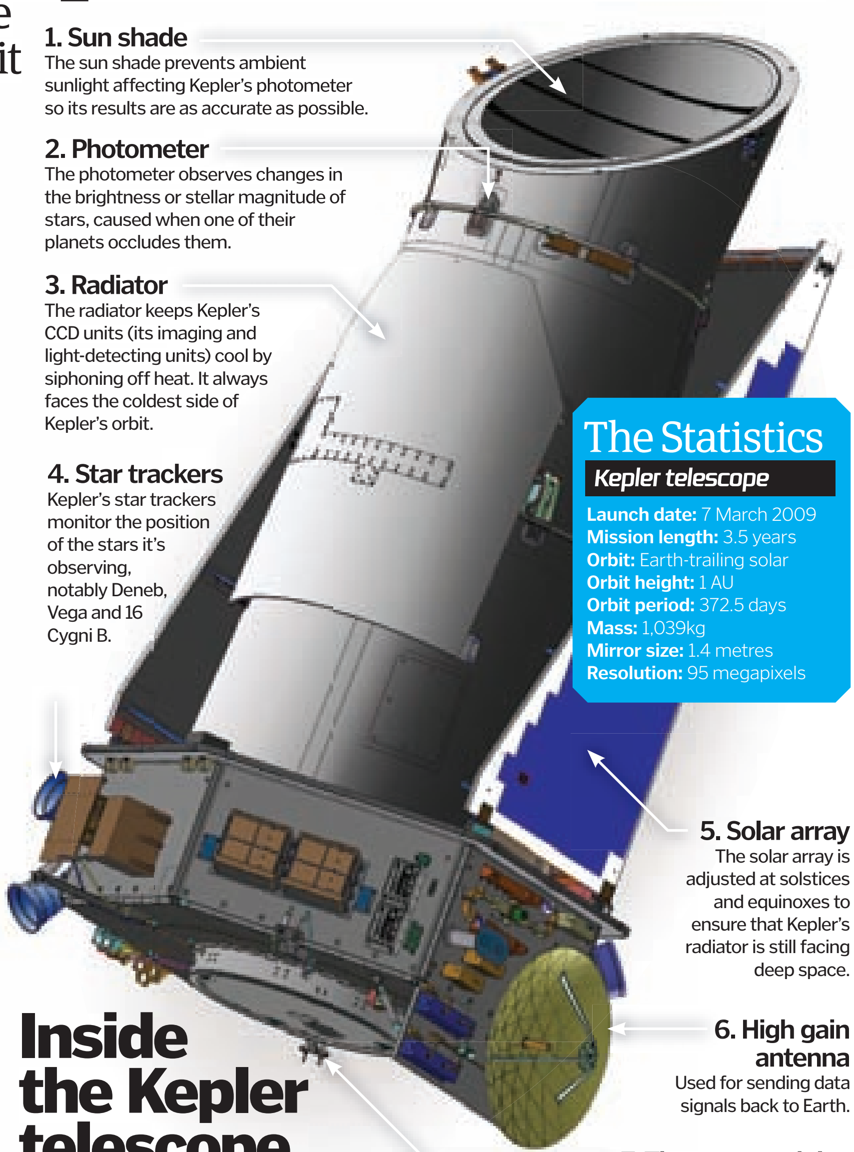
The telescope on the lookout for planets fit for human life

Ever heard of the Goldilocks Zone? Well, if you'd read issue two of How It Works you'd know that it's a name given to an area around a star where it's warm enough for water to be liquid, also known as the circumstellar habitable zone. In other words it's similar to Earth's orbit around the Sun, and therefore may offer just the right conditions for supporting life. Some scientists also believe that such planets need to exist within galactic habitable zones, places where there are the necessary heavy elements to form rocky planets. Planets within Goldilocks Zones could be capable of supporting extraterrestrial life or, with the right atmosphere and gravitation, human colonies from Earth.

This is what the Kepler mission is looking for – planets with the potential to support life, either alien or human. Its aim is to look at the planetary systems around a range of stars and gather data on a wide variety of factors, such as the behaviour of gas giant planets, but one of its most particular objectives is to identify Earth-sized or larger planets in or near a star's Goldilocks Zone.

Kepler itself is a space telescope akin to Hubble. It follows the Earth at a distance of one AU (Astronomical Unit or 92,955,887 miles, the average distance from the Earth to the Sun) in an orbit around the Sun, taking slightly longer than an Earth year to complete a circuit. Launched in March 2009, it's designed to observe planets crossing across the face of their stars. The size of a planet affects the amount it dims the light from its parent star when occluded by it; Kepler is looking for relatively tiny fluctuations in the star's light – around 0.01 per cent of its stellar magnitude.

The Kepler space telescope looks at one particular area of the sky which is not affected by light from the Sun from the angle at which Kepler observes it. This is because it uses a photometer to measure the light of stars, and sunlight would drastically affect the results. The star field it primarily observes is made up of the constellations Cygnus, Lyra and Draco.



1. Sun shade
The sun shade prevents ambient sunlight affecting Kepler's photometer so its results are as accurate as possible.

2. Photometer
The photometer observes changes in the brightness or stellar magnitude of stars, caused when one of their planets occludes them.

3. Radiator
The radiator keeps Kepler's CCD units (its imaging and light-detecting units) cool by siphoning off heat. It always faces the coldest side of Kepler's orbit.

4. Star trackers
Kepler's star trackers monitor the position of the stars it's observing, notably Deneb, Vega and 16 Cygni B.

5. Solar array
The solar array is adjusted at solstices and equinoxes to ensure that Kepler's radiator is still facing deep space.

6. High gain antenna
Used for sending data signals back to Earth.

7. Thruster modules
Thruster modules provide propulsion that allows Kepler to right its orbit when necessary.

Inside the Kepler telescope

Find out what makes up the Kepler space telescope

The Statistics

Kepler telescope

Launch date: 7 March 2009
Mission length: 3.5 years
Orbit: Earth-trailing solar
Orbit height: 1 AU
Orbit period: 372.5 days
Mass: 1,039kg
Mirror size: 1.4 metres
Resolution: 95 megapixels

Where is Kepler looking?

Kepler looks out into a star field on a spiral arm of the Milky Way galaxy, an area like our own in which the chance of finding rocky planets with liquid water is higher thanks to the distribution of heavy metals throughout the galactic arms. The constellations Kepler looks at are primarily Lyra, Cygnus and Draco, seen in Earth's northern sky.

Images courtesy of NASA

First five

Here's five of the planets Kepler has found. RE stands for Earth Radius, and denotes their size…

Kepler 4b
Temperature: 1,650 Kelvin
Size: 3.99 R_E
Details: This Neptune-like planet orbiting the G5V-class star Kepler 4 is the smallest discovered so far at only three times the size of Earth.

Kepler 5b
Temperature: 1,868 Kelvin
Size: 16.00 R_E
Details: Larger than Jupiter and orbiting the star Kepler 5 in the Cygnus constellation, this planet orbits its parent star in just 3.5 days.

Kepler 6b
Temperature: 1,500 Kelvin
Size: 14.79 R_E
Details: Also in Cygnus but orbiting the star Kepler 6 is Kepler 6b, a similar size to Kepler 5b and orbits in just three days.

Kepler 7b
Temperature: 1,540 Kelvin
Size: 16.52 R_E
Details: 50 per cent larger than Jupiter but with only half its mass, this intriguing planet orbits Kepler-7 in the constellation Lyra.

Kepler 8b
Temperature: 1,764 Kelvin
Size: 15.86 R_E
Details: The hottest exoplanet of the five, it orbits the star Kepler 8 in the constellation of Lyra.

Sizes compared to Jupiter
Jupiter

DID YOU KNOW? Epsilon Eridani is approximately 10.5 light years away from Earth

Epsilon Eridani

Earth's nearest planetary system explained

This artists impression of the system shows both asteroid belts and one of the possible planets lying just outside the second belt

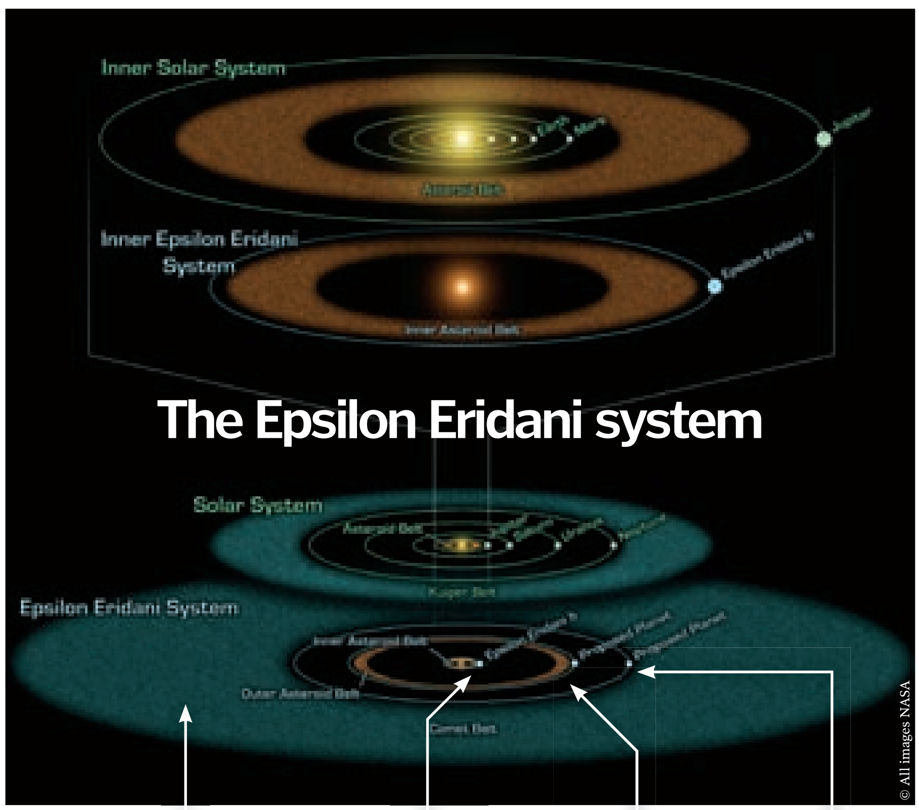
At only 10.5 light years away, Epsilon Eridani is the nearest star with an orbiting planet, find out more...

Epsilon Eridani is a surprisingly important star as far as your average fiery ball of plasma goes. For starters, it's the third nearest star that can be observed from Earth with the naked eye, lying just ten light years away in the Constellation Eridanus (otherwise known as the River). In astronomical terms we're pretty much as good as roommates.

It's also of quite similar composition to our very own Sun, which wouldn't be all that exciting were it not for its close proximity and tender age making it of great interest to those scientists who are interested in the birth and development of our own Sun. At just 800 million years of age Epsilon is still a very young star and a whole 3.7 billion years our Sun's junior. Given the absence of a working time machine, it's probably one of our best bets for studying its birth and development. It's also the unsuspecting next-door neighbour to *Star Trek*'s very own Mr Spock. His famous home world Vulcan orbits 40 Eridani A – which is just six light years farther away than Epsilon from home.

The question as to whether there's life – and if it's as we know it – isn't quite as daft as it might seem though. You see, while all these facts make this young, energetic star of familiar breed and bearing of great interest to the scientific community, its biggest claim to fame makes the rest pale in comparison; it harbours planets, extrasolar planetary bodies – perhaps as many as three. Extrasolar planets are very hard to detect and almost impossible to see, but by measuring the source star's radial velocity, one of a growing number of extrasolar detection methods, scientists can indirectly detect the presence of these planets and – hopefully in time – a dusty ball of rock, not entirely unlike our own.

The Epsilon Eridani system



Does size really matter?

While Epsilon Eridani is actually smaller than our own, the system itself is quite noticably wider – this blown up view only shows the inner part of the very much larger system.

Jupiter-class planet

Epsilon Eridani B, which actually orbits the star at around three and a half times the Earth's distance from the Sun, is thought to be a gas giant not entirely different from Jupiter.

The bigger picture

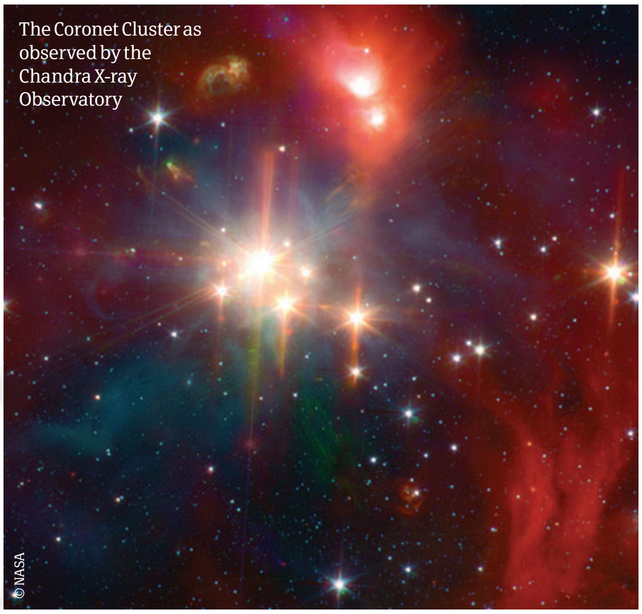
There are clues to this system's size. A second uniform asteroid belt between the inner one indicates the presence of a further planet and the icy comet belt further out suggests another.

Historical centrepiece

Epsilon Eridani itself is younger than our Sun, so any planets orbiting it will be in an early state of development. Its age also means it's a virile sun – giving off plenty of radiation.

Spotting extrasolar planets

Finding planets around other stars is very difficult. Scientists use sophisticated ways to calculate their presence. So far the most common of these methods is to measure the source star's radial velocity, and this is how Epsilon Eridani was found to be a system. Radial velocity measures the Doppler-style shift of the star as the planet(s) around it pull it off its centre of gravity making it 'wobble'. Scientists then measure the speed at which the star wobbles to infer details about the planet itself.



The Coronet Cluster as observed by the Chandra X-ray Observatory

© NASA

Telescopes are a wide-ranging form of technology used by scientists, astronomers and civilians alike, to observe remote objects by the collection of electromagnetic radiation

How do telescopes see stars?

From their origins as simple hand-held instruments formed from a crude coupling of convex objective lens and concave eyepiece used to observe distant objects, to their utilisation in collecting and monitoring electromagnetic radiation emanating from distant space phenomena, telescopes are one of the human race's most groundbreaking inventions. Indeed, now there are telescopes which can monitor, record and image almost all wavelengths of the electromagnetic spectrum, including those with no visible light and their usage is widening our understanding of the world around us and the far-flung reaches of space. Here, we take a look at some of the forms of telescope in use today, exploring how they work and what they are discovering.

Head to Head OPTICAL TELESCOPES

SINGLE MIRROR

1. GTC
Found in an observatory in the Canary Islands, the Gran Telescopio Canarias is the world's biggest single-aperture optical telescope.

TWO MIRRORS

2. LBT
The Large Binocular Telescope in the mountains of southeast Arizona is the world's largest optical telescope on a single mount.

MIRROR ARRAY

3. SALT
The Southern African Large Telescope is a large optical telescope capable of recording stars a billion times too faint to see with the naked eye.

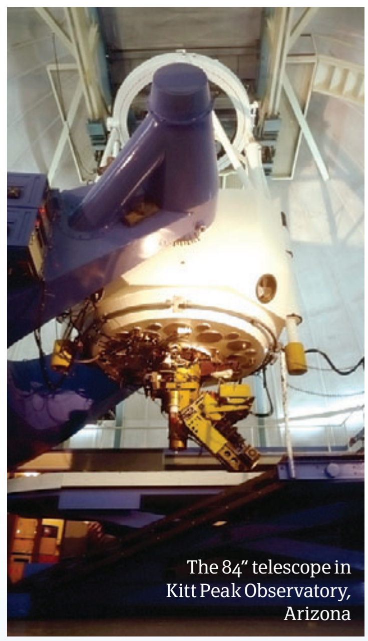
DID YOU KNOW? *The original patents for the optical telescope were filed in 1608 and it was first unveiled in the Netherlands*

Messier 82 is about 12 million light-years away but the Hubble telescope still captured this amazing image

© NASA

NGC 281 is visible in amateur telescopes from dark sky locations

© NASA



The 84" telescope in Kitt Peak Observatory, Arizona

The optical telescope

Since its creation in 1608, the optical telescope has made the close viewing of far away things a piece of cake. But how do they work?

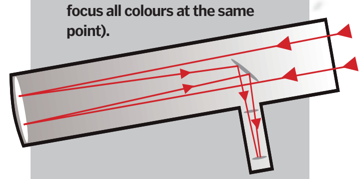
The standard optical telescope works by reflecting or refracting large quantities of light from the visible part of the electromagnetic spectrum to a focus point observable through an eyepiece. In essence, the large objective lens or primary mirror of the telescope collects large quantities of light from whatever it is targeted at, then by focusing that light on a small eyepiece lens, the image formed is magnified across the user's retina, making it appear closer and considerably larger than it actually is. Therefore, the power of any given telescope is directly relative to the diameter or aperture of the objective lens or primary mirror, with the larger the lens/mirror, the further and larger the image produced.

8. Azimuth adjustment knob
A crucial mechanism used to adjust the telescope to the direction of the celestial target

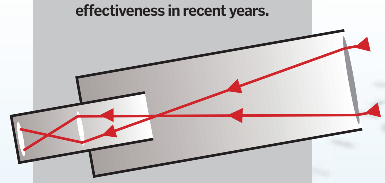
TYPES OF... OPTICAL TELESCOPES

Learn all about the types of optical telescope used by amateur and professional astronomers alike

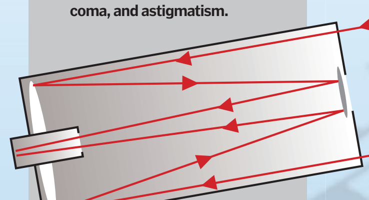
1 Reflecting
One of the most common types of optical telescope, a reflector utilises one curved mirror and one flat mirror to directly reflect light throughout its main body and form an image. The reflecting telescope was created in the 17th Century as an alternative to the refracting telescope, which at the time suffered from severe chromatic aberration (a failure to focus all colours at the same point).



2 Refracting
The first type of telescope to be invented in 1608 was a refractor. Utilising a partnership of a convex objective lens and a concave eyepiece lens to form its image, refractors are still used today. However, there are numerous technical considerations including lens sagging, chromatic aberration and spherical aberration that have demeaned their effectiveness in recent years.



3 Catadioptric
The most advanced and stable of all optical telescopes are catadioptrics, which employ a mixture of mirrors and lenses to form an image, as well as a number of correctors to maintain accuracy. The first catadioptric telescope was made by the optician Bernhard Schmidt who, with his patented Schmidt telescope, corrected the optical errors of spherical aberration, coma, and astigmatism.



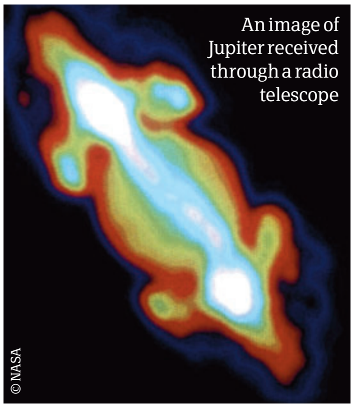
> "The largest filled-aperture telescope is the Arecibo radio telescope in Puerto Rico, which boasts a 305-metre dish"

Radio telescopes

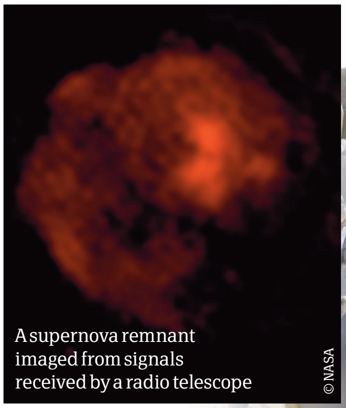
Characterised usually by their large dishes, radio telescopes allow us to receive signals from the depths of space


The Mount Pleasant radio telescope in Australia

© Noodlesnacks


An image of Jupiter received through a radio telescope

© NASA

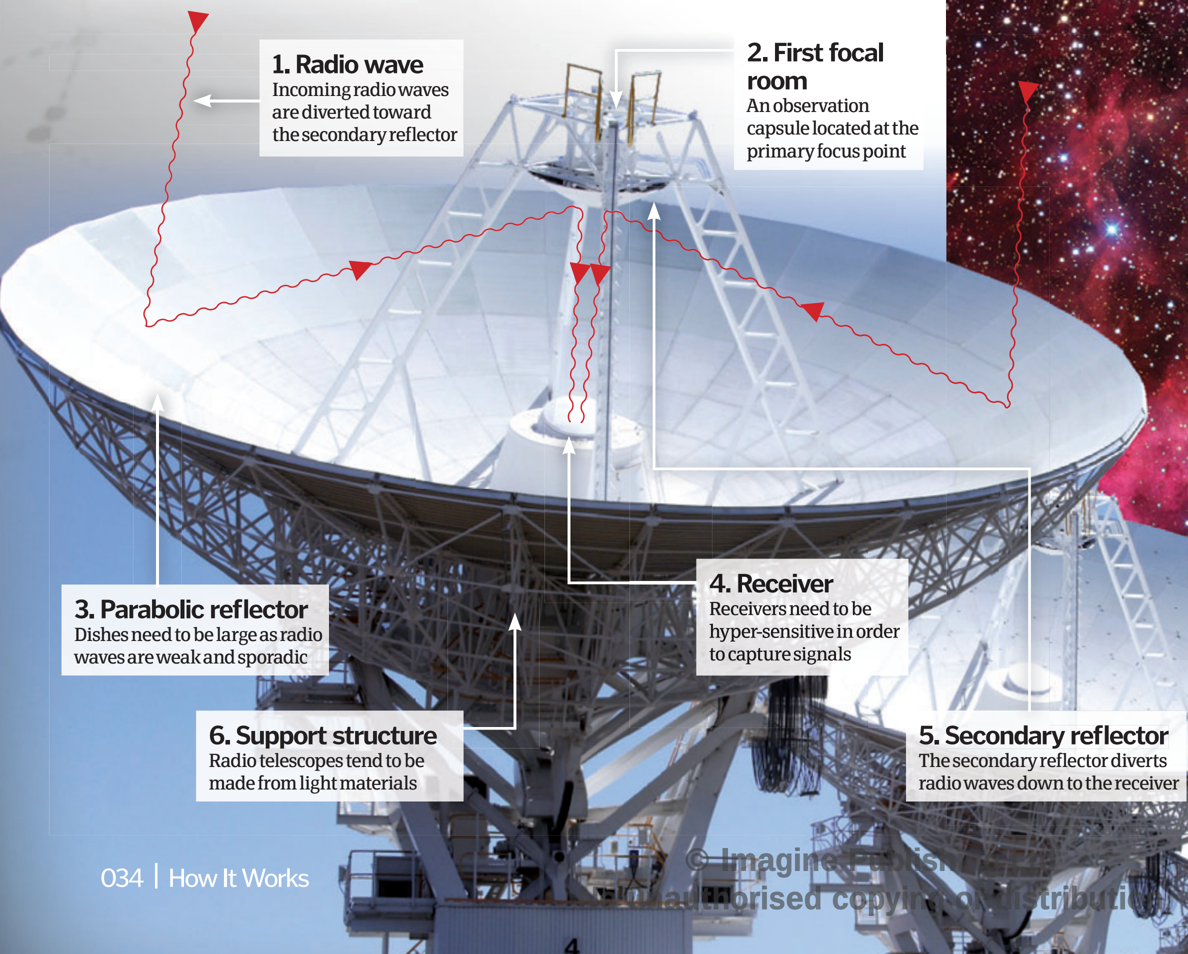

A supernova remnant imaged from signals received by a radio telescope

© NASA

The radio telescope works by receiving and then amplifying radio signals produced from the naturally occurring emissions of distant stars, galaxies and quasars. The two basic components of a radio telescope are a large radio antenna and a sensitive radiometer, which between them reflect, direct and amplify incoming radio signals typically between wavelengths of ten metres and one millimetre to produce comprehensible information at an optical wavelength. Due to the weak power of these cosmic radio signals, as well as the range in wavelength that they operate in, radio telescopes need to be large in construction, as the efficiency of the antenna is crucial and can easily be distorted by terrestrial radio interference.

The most common radio telescope seen is the radio reflector; this consists of a parabolic antenna – the large visible dish – and operates in a similar manner to a television satellite dish, focusing incoming radiation onto a receiver for decoding. In this type of radio telescope, often the radio receiver/solid-state amplifiers are cryogenically cooled to reduce noise and interference, as well as having the parabolic surface of the telescope equatorially mounted, with one axis parallel to the rotation axis of Earth. This equatorial mounting allows the telescope to follow a fixed position in the sky as the Earth rotates, therefore allowing elongated periods of static, pinpoint observation.

The largest filled-aperture telescope is the Arecibo radio telescope located in Puerto Rico, which boasts a 305-metre dish. Contrary to other radio telescopes with movable dishes however, the Arecibo's dish is fixed, instead relying on a movable antenna beam to alter its focus.



5 TOP FACTS TELESCOPES

Famous Hubble
1 One of the most famous telescopes is the Hubble Space Telescope. Orbiting 600km above the Earth, it can look deep into space as it's above the atmosphere.

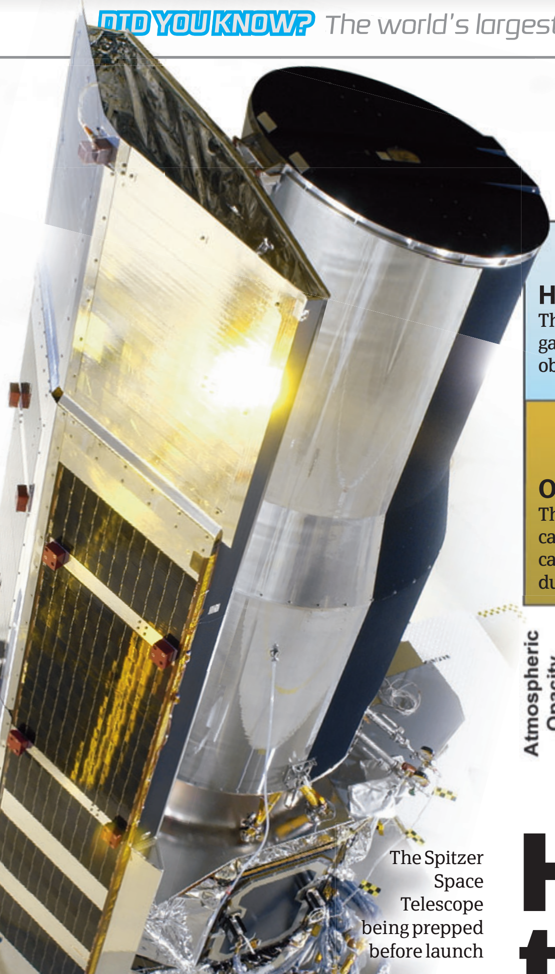
Types of light
2 Using different types of light can reveal new discoveries about the universe. When scientists first used x-rays to study the sky they discovered black holes.

Long story
3 Before reflecting telescopes were developed in the 17th Century as an alternative, some refracting telescopes were as much as 600 feet long.

First radio telescope
4 The first radio antenna used to identify an astronomical radio source was one built by Karl Guthe Jansky, an engineer with Bell Telephone Laboratories, in 1931.

Do it yourself
5 Buying and using even a low power telescope will reveal some amazing sights including the same observations made by Galileo all those centuries ago.

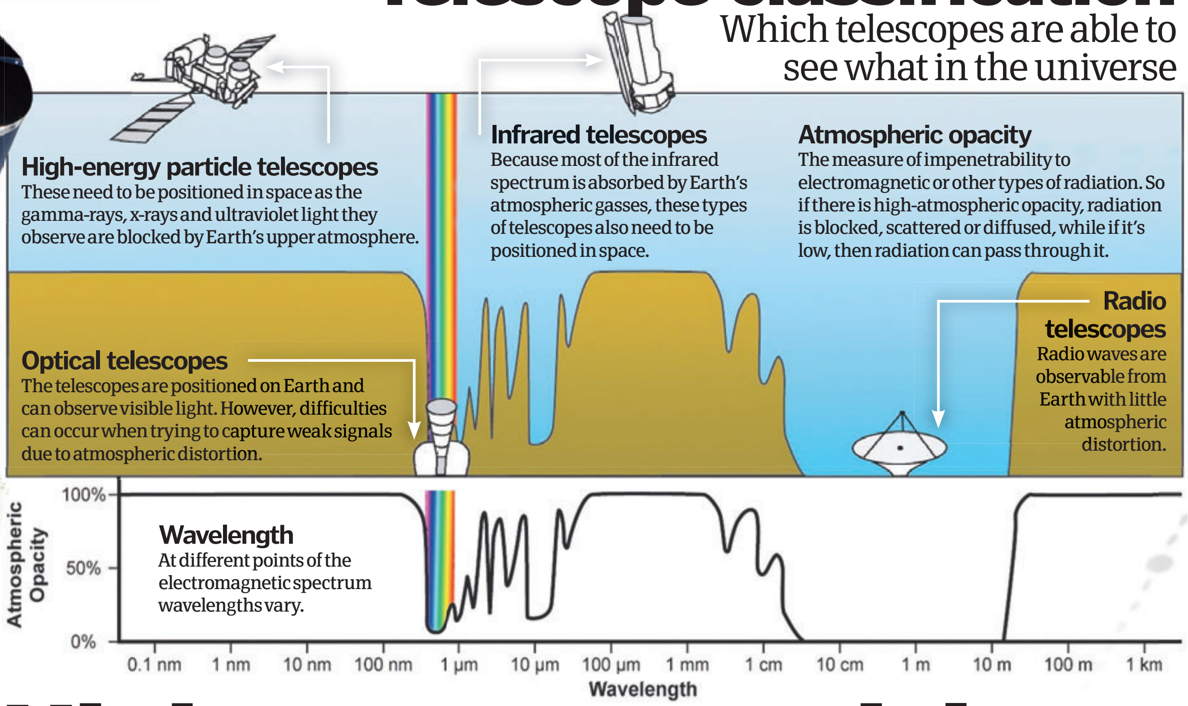
DID YOU KNOW? The world's largest filled-aperture radio telescope based in Arecibo, Puerto Rico has a 305-metre dish



The Spitzer Space Telescope being prepped before launch

Telescope classification

Which telescopes are able to see what in the universe



High-energy particle telescopes

Advanced technology is pushing back the boundaries of high-energy astronomy

The Rosette Nebula

© NASA

The limits of radio and optical telescopes have led scientists in exciting new directions in order to capture and decode natural signals from distant galaxies.

One of the most notable is the x-ray telescope, which differs in its construction thanks to the inability of mirrors to reflect x-ray radiation, a fundamental necessity in all reflection-based optical and radio telescopes. In order to capture x-ray radiation, instead of being directly reflected into a hyper-sensitive receiver for amplification and decoding, it is acutely reflected a number of times, changing the course of the ray incrementally each time. To do this the x-ray telescope must be built from several nested cylinders with a parabolic or hyperbolic profile, guiding incoming rays into the receiver.

The Chandra X-ray Observatory

© NASA

Crucially, however, all x-ray telescopes must be operated outside of the Earth's atmosphere as it is opaque to x-rays, meaning they must be mounted to high-altitude rockets or artificial satellites. Good examples of orbiting x-ray telescopes can be seen on the Chandra X-ray Observatory and the Spitzer Space Telescope.

Other high-energy particle telescopes include gamma-ray telescopes, which study the cosmos through the gamma-rays emitted by stellar processes, and neutrino telescopes, a form of astronomy still very much in its infancy. A neutrino telescope works by detecting the electromagnetic radiation formed as incoming neutrinos create an electron or muon (unstable sub-atomic particle) when coming into contact with water.

Because of this, neutrino telescopes tend to consist of submerged phototubes (a gas-filled tube especially sensitive to ultraviolet and electromagnetic light) in large underground chambers to reduce interference from cosmic rays. The phototubes act as a recording mechanism, storing any Cherenkov light (a type of electromagnetic radiation) emitted from the interaction of the neutrino with the electrons or nuclei of water. Then, using a mixture of timing and charge information from each of the phototubes, the interaction vertex, ring detection and type of neutrino can be detected.

Cherenkov radiation glowing in the core of the Advanced Test Reactor

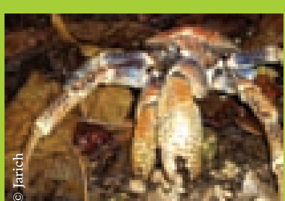
© NASA

How a waterfall is formed

This month in **Environment**

This issue we explore the tropical rainforests of South America, looking at the unusual species and ecology of this incredible ecosystem. You can also learn about the crab that can climb trees, the ozone-friendly process of carbon capture, the lives of penguins and lots more…

39 Anatomy of a plant



40 The coconut crab

43 Iceberg formation

ENVIRONMENT

Waterfall

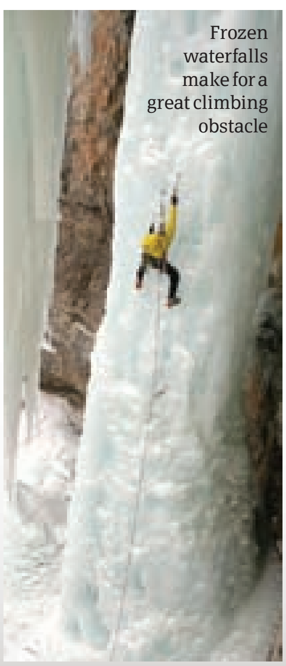
How are these dramatic geological river features formed?

Niagara: the most famous waterfall in the world

The often-breathtaking natural product of vertical erosion, a waterfall occurs in a river's steep upper course high above sea level. A waterfall forms over many thousands of years as river water flows over a band of hard rock lying next to a band of soft rock downstream. The erosive effects of hydraulic action (water pushing air into tiny cracks in the riverbed) and abrasion (rocks scraping over each other) cause the soft rock to erode quicker than the hard. So while the hard rock remains solid for longer, the soft rock below is worn away, lowering the riverbed from that point and forming a step drop.

At the foot of the step, a deep plunge pool forms where water and rocks collect and swirl about, abrading more of the riverbed and less-resistant rock in the process. The harder, overhanging 'cap' rock is gradually undercut and eventually collapses due to its own weight, breaking off into the plunge pool.

Further collapse of the hard rock sees the waterfall itself recede back upstream, creating steep-sided gorges either side of the waterfall.



Frozen waterfalls make for a great climbing obstacle

A waterfall formed by volcano

Located on the border between Argentina and Brazil and surrounded by subtropical rainforest, Iguazu Falls is one of the most impressive waterfall systems on the planet. Part of a World Natural Heritage Site, Iguazu is distinctive because it was formed as a result of a massive volcanic eruption, which left a massive crack in the earth. Though there are many taller and more powerful falls, at 1.67 miles Iguazu is one of the widest, making it an undeniably awesome spectacle. The whole area consists of 275 individual waterfalls spread out across the Iguazu River. A mammoth semicircular waterfall lies at the heart of a series of cascading falls, and the main plunge waterfall, known as Garganta del Diablo, or the Devil's Throat, is 82 metres tall.

Iguazu Falls is a major draw for tourists in South America

Head to Head WATERFALLS

TALL

1. Niagara Falls
Facts: Situated on the US/Canada border, Niagara Falls is undoubtedly the most famous waterfall in the world, yet it stands at a mere 51 metres tall.

TALLER

2. Victoria Falls
Facts: Named after Queen Victoria who reigned during its discovery, this impressive fall on the Zambia/Zimbabwe border has a total height of 107 metres.

TALLEST

3. Angel Falls
Facts: Found in Venezuela, Angel Falls' total height is a whopping 979 metres, making it the tallest waterfall on Earth, and the world's longest drop.

DID YOU KNOW? *Waterfalls can freeze mid-flow due to freezing temperatures slowing the water molecules down*

formation

That's some water feature for a garden that size

Waterfall creation

What processes happen to make a waterfall

1. Undercutting/overhanging
A layer of resistant hard rock is undercut by the erosion of the softer rock beneath. This forms a step over which the water flows.

2. Plunging
The force of the falling water hitting the soft rock below creates a plunge pool, which is deepened by the abrasion of fallen angular rocks.

3. Collapsing
Further erosion, worsened by splashback from the falling water in the plunge pool, causes the overhanging hard rock to eventually collapse under its own weight.

4. Receding
As this cycle of erosion and collapsing continues, the waterfall steepens and recedes back upstream, creating a steep-sided gorge and an increasingly tall waterfall.

TYPES OF… WATERFALLS

There are ten different ways to classify waterfalls

1 Block
Occurring over a wide stream where the waterfall is wider than it is tall. It spills over like a wide sheet of water.

2 Cascade
Flows either over a series of small steps in the rock in quick succession, or over a rugged sloping surface.

3 Curtain
Found on a wide section of stream where the fall is taller than it is wide. These falls tend to narrow during periods of low discharge.

4 Fan
Occurring when the width of the water spilling over increases as it descends, making the base appear much wider than the top.

5 Horsetail
Found on vertical waterfalls, the falling water is in constant or semi-constant contact with the bedrock.

6 Plunge
Water spills over vertically, usually losing contact with the bedrock altogether. Often known as a cataract waterfall.

7 Punchbowl
The flow of water is squeezed through a narrow opening and is then blasted out and down into a pool.

8 Segmented
If the stream is broken into multiple channels this will cause several falls to occur side by side.

9 Slide
Slide waterfalls flow down over a smooth, sloping bedrock surface while maintaining contact with the bedrock.

10 Tiered
Tiered waterfalls form when several distinct drops occur one after the other, in close succession.

Learn more

For more information about different waterfalls around the world, head on over to **www.world-waterfalls.com/** where you can read about waterfalls from every corner of the Earth, and choose your favourite!

Shape The unique shape of a snowflake is dependent on temperature and moisture.

Main facet Water vapour freezes on to a molecule of ice, creating a flat surface called a facet.

Main branches Each snowflake develops six branches from the central hexagonal facet.

Symmetry Each branch extends outwards at exactly the same rate as all the others.

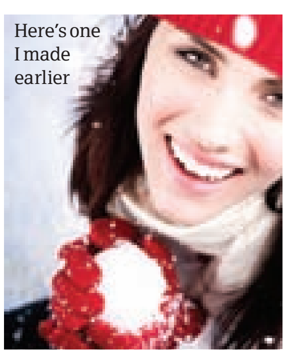
Snowflakes

How are these beautiful crystals of ice formed?

The formation of a snowflake begins when a microscopic cloud droplet freezes as a tiny ice particle. Water vapour that condenses on its surface causes the ice to develop flat, polished surfaces, known as facets, which continue to grow into a hexagonal prism shape. At each corner of the hexagon shape, new branches extend outwards each at the same rate. All snowflakes have six sides and can be either prism-shaped, plate-shaped or star-shaped.

As the snowflake moves around within the cloud, it encounters a variety of temperatures that change the growth behaviour of each flake, causing the six branches of the crystal to grow in exactly the same way, creating six-way symmetry and a unique flake every time.

The first person to photograph a snowflake was American Wilson Bentley. Bentley took his first snowflake snap in 1885, using a bellows camera and a compound microscope, and went on to assemble a large collection of beautiful snow crystal images.



Here's one I made earlier

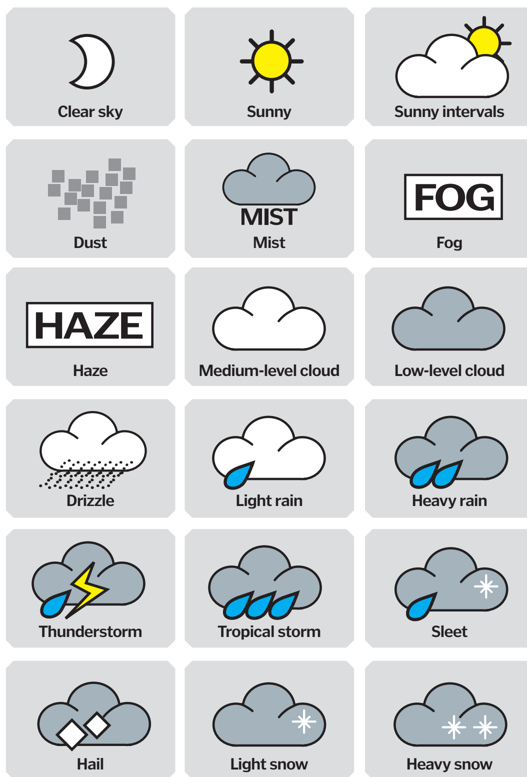
Weather symbols

How to read and understand the symbols on a weather map

Weather forecast centres around the world are constantly analysing atmospheric conditions on Earth. The public are then supplied with this information in the form of pictographic maps detailing precipitation, cloud, wind speed/direction, temperature, and frontal systems.

Types of weather

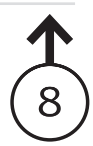
The other symbols found on a weather map include the various types of weather. The following classification symbols are based on those the MET Office uses. There are additional symbols for day and night variations…



Temperature

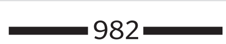
Temperature is shown as a figure (measured in degrees Fahrenheit or degrees Celsius) depicted either by a number in a circle/square, or as an isotherm, which is a line linking points of equal temperature.

Wind



Wind also features a figure that shows wind speed in miles per hour. This number is accompanied by an arrow to indicate which direction the wind is travelling.

Pressure



Atmospheric pressure is shown in the form of isobars, which are lines of equal mean sea-level pressure. When there is a difference in air pressure, air is accelerated from high to low pressure, causing windy conditions.

Fronts

A weather front is the line on a map dividing two air masses of different densities. Here conditions will be unsettled. The symbols for fronts are arranged on lines consisting of semicircles, triangles or a mixture of the two.

Cold front

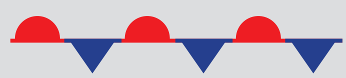
Associated with brief episodes of severe weather, and identified by a blue line with triangles that point in the direction of movement, a cold front marks the leading edge of an advancing mass of cold air. Because cold air is denser, it pushes the warmer air up where it condenses into clouds and precipitation. Dense cold air also travels faster than warm.

Warm front

Slower-moving warm fronts are marked on weather maps as a red line with semicircles that point in the direction of movement. These represent the leading edge of an advancing mass of warm, moist air, bringing with it cloud, precipitation and warm temperatures.

Occluded front

This purple line of alternating triangles and semicircles denotes an occluded front, or occlusion, which forms when the faster-moving cold front catches up with the warm front, forcing the less-dense warm air up above the surface.



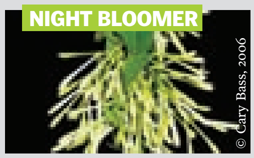
Stationary front

These stationary, or slow-moving fronts represent the boundary between two air masses neither of which has the ability to replace the other. Stationary fronts are depicted by an alternating line of red semicircles and blue triangles pointing in opposite directions. Clouds and prolonged precipitation are associated with these fronts.

CARNIVOROUS

1. Pitcher plant
Remember the rat eating plant from issue two? After trapping its prey, this species then digests them with powerful enzymes.

NIGHT BLOOMER


© Cary Bass, 2006

2. Lady of the Night
Lady of the Night is a plant with flowers that are closed during the day but open up at night, releasing its scent.

SENSITIVE


© Frank Vincentz, 08

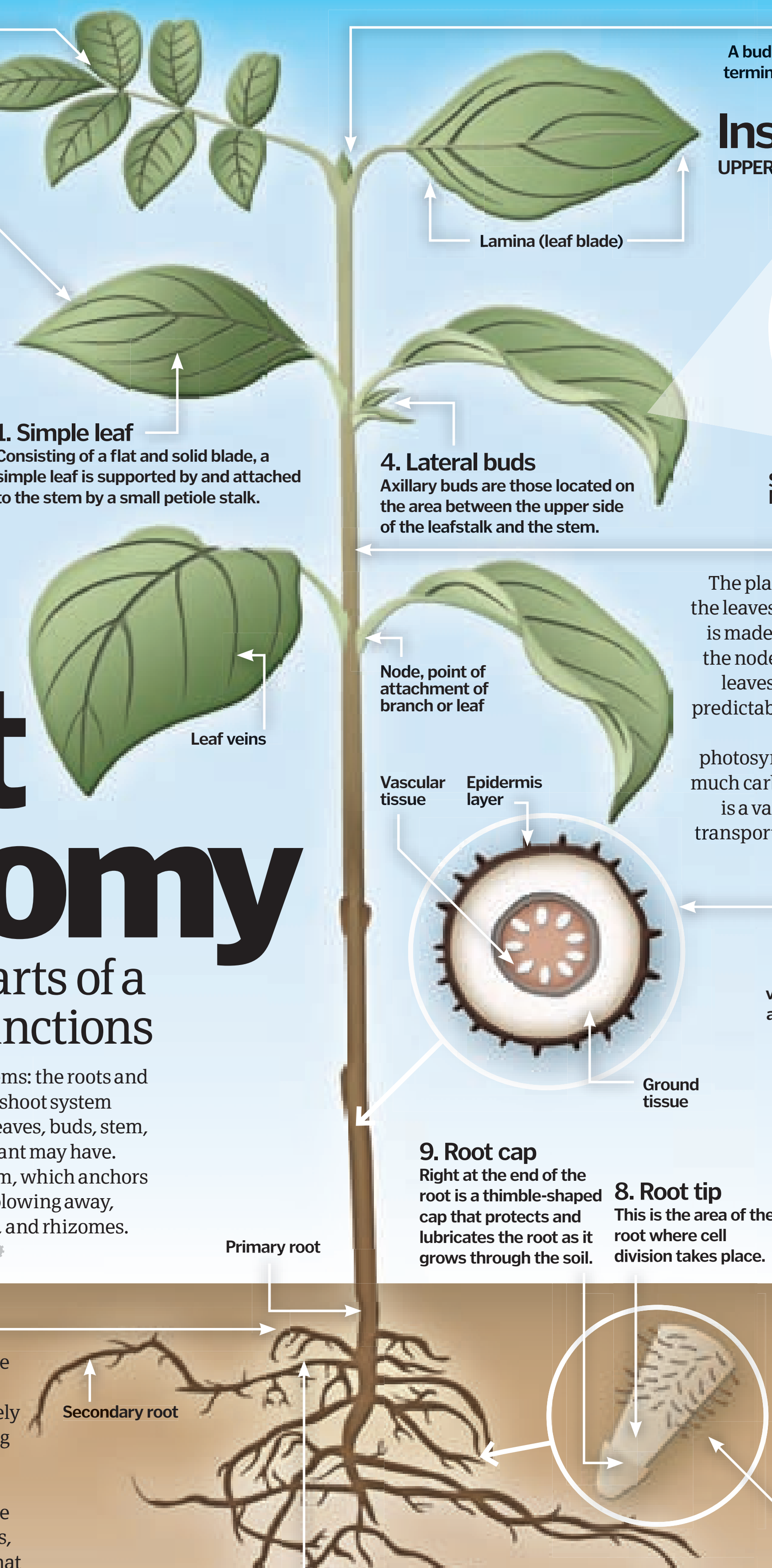
3. Makahiya
The Makahiya's leaves react to touch, light or heat due to a drop of pressure in its cells. The leaflets will furl up and the stalk will droop.

DID YOU KNOW? *The largest species of plant and the tallest living organism in the world is the California Redwood tree*

Plant anatomy

Explaining the parts of a plant and their functions

Plants feature two main systems: the roots and the shoots. Above ground the shoot system comprises the food-making leaves, buds, stem, and any flowers or fruit the plant may have. Below ground the food-storing root system, which anchors the plant in the soil and prevents it from blowing away, features nutrient-absorbing roots, tubers, and rhizomes. Let's start from the top and work down.



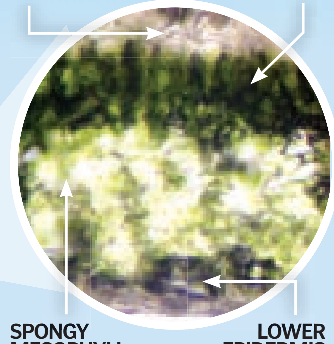
2. Compound leaf
Compound leaves are divided into smaller leaflets. There is a single bud at the base of the petiole stalk.

Leaves
These green fleshy parts are vital to the plant's ability to create its own food. The process of photosynthesis enables a plant to produce carbohydrates from the Sun's energy. The leaves therefore expose as much surface area as possible in order to absorb the most sunlight, they will even turn towards the Sun for maximum absorption.

1. Simple leaf
Consisting of a flat and solid blade, a simple leaf is supported by and attached to the stem by a small petiole stalk.

3. Terminal buds
A bud found at the tip of the stem is called a terminal bud and will allow the stem to grow in length.

Inside a leaf



4. Lateral buds
Axillary buds are those located on the area between the upper side of the leafstalk and the stem.

Stem
The plant's strong stem offers support for the leaves and other above-ground parts. It is made up of nodes and internodes, with the nodes representing the site where the leaves are attached and the internodes, predictably, indicating the area of the stem between nodes. Green stems are photosynthetic, they just don't produce as much carbohydrate as the leaves. The stem is a vascular system, which means they transport water and minerals to the leaves and the roots.

6. Stem cross section
Stems consist of a thin transparent epidermis layer that produces a juicy substance that can attract insects, a vascular tissue layer made up of xylem and phloem (the transport tissues that move water and sugars through the plant), and providing the bulk of the stem's mass is the ground tissue, in which starch can be stored.

9. Root cap
Right at the end of the root is a thimble-shaped cap that protects and lubricates the root as it grows through the soil.

8. Root tip
This is the area of the root where cell division takes place.

Roots
The roots permeate the soil, anchoring the plant. The part of the plant embryo that sprouts into a root (the radicle) immediately gets to work securing the plant by growing downwards and branching off to grow secondary roots.

Many plants develop structures that are not roots but specialised stems. Rhizomes, for example, are horizontal plant stems that grow underground and can develop new roots and shoots. Below the surface you may also find tubers, which are thickened swollen plant stems (such as potatoes).

7. Root hairs
The hairs on a root have a huge surface area, enabling it to more efficiently soak up water and minerals – especially nitrogen and sulphur – by way of either osmosis, diffusion or active transport.

5. Adventitious buds
These unruly buds will develop anywhere but where they're meant to, such as on the root.

Coconut crabs

A roguish crustacean that climbs trees and steals the burrows of land crabs, yet still faces extinction

Measuring three feet from claw to claw the coconut crab is one mighty crustacean

An enormous specimen, weighing up to 5kg, with a body length of up to 40cm and a leg span of 91cm, the Birgus latro is the world’s largest terrestrial arthropod. Despite an array of misleading names, it is not a crab. However, we’ll refer to it as the coconut crab – so-named due to its ability to climb palm trees and break into coconuts with its pincers (or chelae).

The coconut crab, which can live for up to 30 years, mainly inhabits the forested coastal areas of the islands of the South Pacific and Indian Oceans. A mostly nocturnal crustacean, it hides during the day in underground burrows.

Although coconut crabs mate on dry land, as soon as the eggs are ready to hatch the female releases them into the ocean. Once hatched, the young will visit the ocean floor in search of a shell before coming back to dry land. Once ashore, the coconut crab permanently adapts to life on the land – so much so that it would drown in water because it has developed branchiostegal lungs and special gills more suited to taking oxygen from the air than from water.

The fact that the coconut crab spawns at sea is the main reason for its widespread distribution as currents carry the larvae far afield. Still, the coconut crab remains an endangered species because it is considered a delicacy and is collected as food.

Reducing CO_2 emissions is a top priority

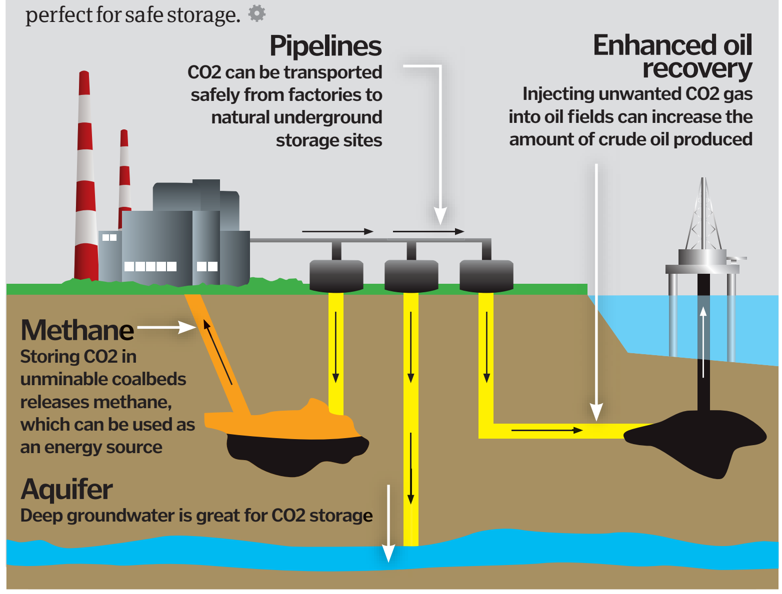
Carbon capture and separation

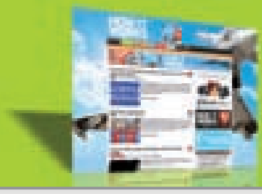
How we can grab CO_2 out of the air and store it deep underground

Carbon dioxide (CO_2) is one of the greenhouse gases that traps some of the Sun’s heat so that life on Earth can continue. A build-up of greenhouse gas, however, could lead to a gradual increase of the Earth’s temperature. Most man-made CO_2 emissions come from factories and energy plants that burn fossil fuels, so scientists have been capturing emissions at the source and transporting them in pipes to underground storage areas. This is achieved by a process called carbon capture and storage (CCS).

The CO_2 must first be trapped and separated from other gasses. There are three ways to do this. First, post-combustion involves capturing the CO_2 after the fuel has been burned. Such a process can be added to any existing plant by adding a filter in the chimney. Pre-combustion traps the gas before the fossil fuel has been burned and mixed with other flue gases. Oxy-combustion sees the fuel burned in oxygen rather than air, which produces a CO_2 and water vapour exhaust, which is easy to separate and transport.

The CO_2 is then transported to natural storage areas underground or under water. Pipelines can transport CO_2 in any state, but as a gas pushed by compressors is best. Depleted oil and gas fields deep below the Earth’s surface are ideal for storing CO_2. Other geological stores, known as saline aquifers, which are porous underground rocks full of useless salty water, are also perfect for safe storage.





HOW IT WORKS TV

See an amazing video of penguins trying to escape a leopard seal

www.howitworksdaily.com

DID YOU KNOW? Penguins only live in the southern hemisphere

How do penguins swim?

Revealing the secret of the penguin's underwater prowess

The flippers are key to the penguin's swimming abilities

Don't hold the awful jokes against the bird, blame McVitie's

Though ungainly on land, the flightless penguin has physical characteristics perfect for swimming through water – fortunate, as some species are known to be at sea for up to 75 per cent of their lives. Spending so much time in the water puts penguins at risk from predators, so swimming skills are essential. While their long, streamlined bodies and short legs give them a clumsy gait when waddling on land, penguins' wings have a unique characteristic that gives them surprising agility in water.

While penguins' wings are not suitable for aerial flight – mainly because, unlike the delicate lightweight bones of other birds, penguin bones are solid – they are perfect for soaring through water, with the Gentoo penguin reaching speeds up to 22mph. Referred to as flippers, the penguin's stiff wings act as the perfect natural paddle. What's most interesting, however, is the recent discovery that as well as being able to flap their flippers up and down like wings, penguins can also twist them in a corkscrewing motion.

The joint attaching the flipper to the body is similar to that of a human shoulder, enabling the bird to better control its movements and speed. A swimming penguin can rotate one flipper in one direction and the other in another, enabling it to turn instantly or stop suddenly. Twisting causes a greater surface area of the wing to move over the water, which generates a greater thrusting force so the penguin can increase its speed without the need for more flapping.

Another technique the penguin uses for moving through water is porpoising. Whenever it needs to breathe, the penguin will periodically swim fast under the water and then use its flippers to leap from the water in an arc. The momentum of porpoising helps penguins when they need to flee quickly from predators.

The humble penguin is one of the planet's best-equipped swimmers and the 'twisting flipper' motion is currently being applied by scientists who are looking to develop robot technology that helps to improve the efficiency and performance of underwater vehicles.

Penguins in motion

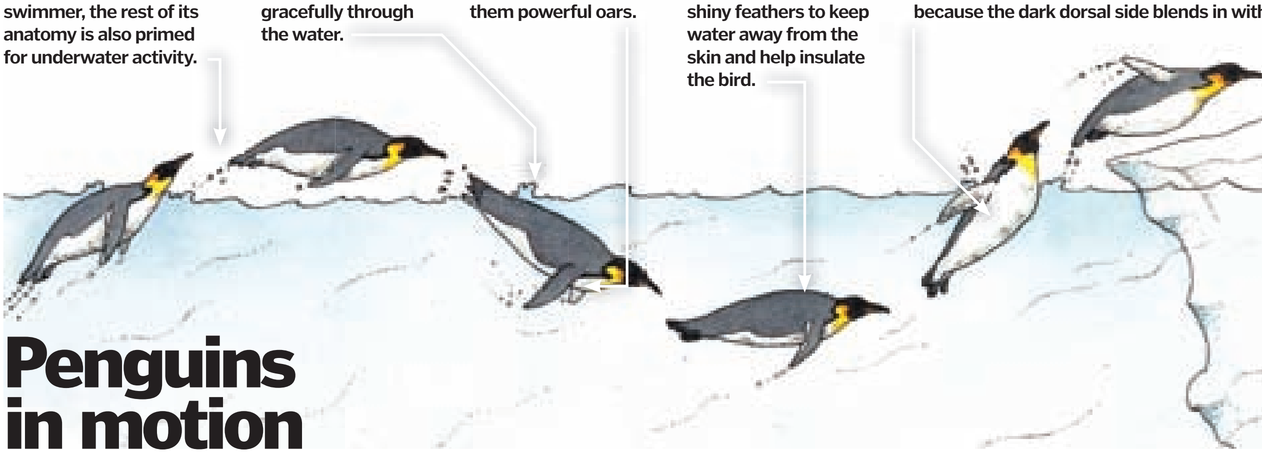
1. P-p-p-propel like a penguin
And it's not just the flippers that make the penguin such an able swimmer, the rest of its anatomy is also primed for underwater activity.

2. Body
A long fusiform, or torpedo-shaped, body helps the penguin glide gracefully through the water.

3. Flippers
The stiff yet flexible flippers are shorter than the wings of other birds, making them powerful oars.

4. Feathers
For every square inch of flesh a penguin can have up to 70 overlapping short, shiny feathers to keep water away from the skin and help insulate the bird.

5. Colouring
A penguin's striking colouration is essential for helping to keep it safe from predators in the water. If a killer whale looks up, it will not see the penguin because the light ventral underside blends in with the light from above. A predator looking down on a penguin, meanwhile, shouldn't spot the creature because the dark dorsal side blends in with the murky depths below.



© DK Images

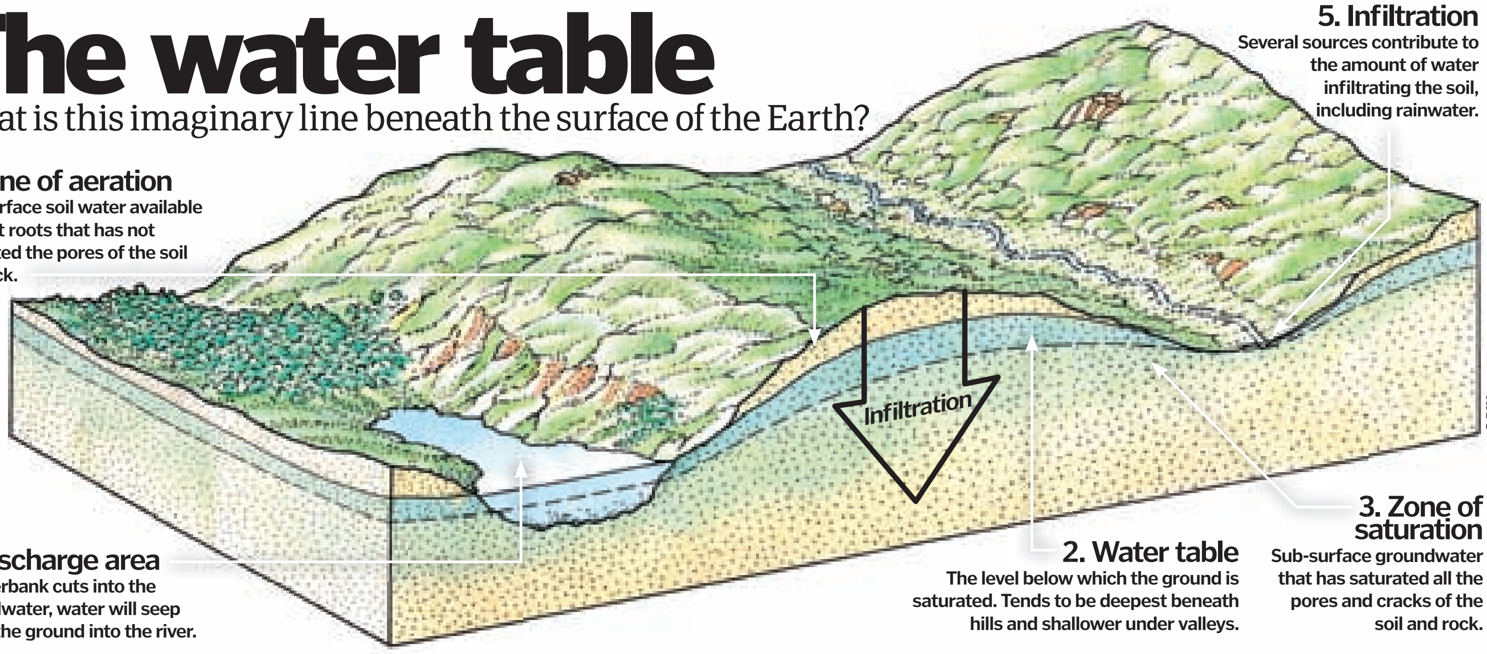
Learn more

German automation company Festo has developed a hydrodynamic Aqua Penguin robot that uses principles from Mother Nature to create automatons that improve performance with minimum energy consumption. To find out more visit **http://www.youtube.com/watch?v=L5JHMpLlq04**.

"The amount of groundwater is determined by such factors as rainwater, runoff from rivers and melted snow"

The water table

What is this imaginary line beneath the surface of the Earth?



1. Zone of aeration
Sub-surface soil water available to plant roots that has not saturated the pores of the soil and rock.

2. Water table
The level below which the ground is saturated. Tends to be deepest beneath hills and shallower under valleys.

3. Zone of saturation
Sub-surface groundwater that has saturated all the pores and cracks of the soil and rock.

4. Discharge area
If a riverbank cuts into the groundwater, water will seep out of the ground into the river.

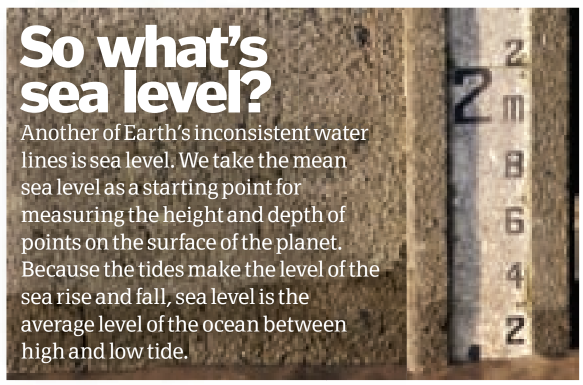
5. Infiltration
Several sources contribute to the amount of water infiltrating the soil, including rainwater.

Groundwater is a store of water beneath the earth. The upper surface of an area of groundwater is known as the water table, below which point the rock and soil is waterlogged. This is the zone of saturation (or phreatic zone). Meanwhile, the area of soil and rock above the water table does still contain sub-surface water, but it is not saturated – instead it contains pockets of air. This is the unsaturated zone, or zone of aeration.

The amount of groundwater is determined by such factors as rainwater, runoff from rivers and melted snow, which trickle through the soil water. A lack of precipitation, or excessive water extraction by humans, may cause riverbeds and groundwater to dry up.

Despite the fact that the word 'table' suggests it's a flat line, the water table is rarely level, and depending on the porosity of the neighbouring rock, human activity, and weather changes, the water table can greatly range in depth.

Permeable rock that can hold and conduct large amounts of water is an underground geological formation known as an aquifer, which is useful for providing fresh water for the human population to drink and use for irrigation. We can access this groundwater by digging down to the water table with wells.



So what's sea level?

Another of Earth's inconsistent water lines is sea level. We take the mean sea level as a starting point for measuring the height and depth of points on the surface of the planet. Because the tides make the level of the sea rise and fall, sea level is the average level of the ocean between high and low tide.

How compost works

One of the most natural ways to recycle, composting is used by companies and households alike

Composting is a powerful biological process in which the breaking down of organic waste such as leaves, grass, food, manure and paper into a useful humus-like substances is undertaken through micro-organisms. These organisms, which include ants and worms, decompose the organic waste over time, metabolising and biodegrading the matter in any atmosphere containing oxygen, water and carbon dioxide. The speed in which the organic matter biodegrades depends on the environment – with many home composters storing the organic waste in purpose-designed composting bins, where temperature and moisture can be carefully controlled – and some substances may only be compostable under very specific conditions.

Composting organisms require various mixtures of carbon, nitrogen, oxygen and water to operate successfully, with the ideal ratio containing a 30-to-one carbon/nitrogen mix. However, composting will occur in any environment where these four elements are present, with just the speed and quality of the compost varying. A typical composting process will see the oxidisation of carbon through nitrogen-fuelled organisms, often maintained in a moisture-rich atmosphere. Because of this, compost is best when a wide variety of carbon and nitrogen-rich substances are intermingled, with straw, stalks and leaves being high in carbon, and plant material, animals (including humans) and kitchen waste high in nitrogen.

The importance of compost is proven in its ability to return nutrients and beneficial bacteria to other plants and soil, which aid future growth and prosperity of all organisms in the immediate vicinity. For example, one of the largest visual sources of the composting process can be seen in the floor of any forest, with any dead leaves, fruit, insects and animals fuelling and feeding the next generation of growth through the mulching and biodegrading which they naturally undertake.


Household composting is relatively common and is a good way to use waste constructively

Head to Head TYPES OF ICEBERG

FLAT

1. Tabular
Steep sides with a flat top – like a huge tablet. These are very solid and often break away from ice sheets or ice shelves.

POINTED

2. Pinnacle
An iceberg with one or more spires like the one captured here off the north-eastern coast of Baffin Island, an archipelago of Canada.

CURVED

3. Drydock
An iceberg which is eroded to form a little U-shaped harbour-like enclosure – like a drydock. As seen in the picture to the left.

DID YOU KNOW? B-15, one of the world's largest recorded icebergs, was larger than the island of Jamaica

Icebergs explained

Where do these floating ice masses come from?

An iceberg only becomes an iceberg once it has broken away from the front of a glacier. When glacial ice arrives at the coast, it carries on moving out over the water and becomes an ice shelf. The movement of the tides, together with the sheer weight of the ice shelf, causes fissures that weaken the ice, causing bits to break off and float away. This 'breaking off' is called calving and the 'bits' are known as icebergs.

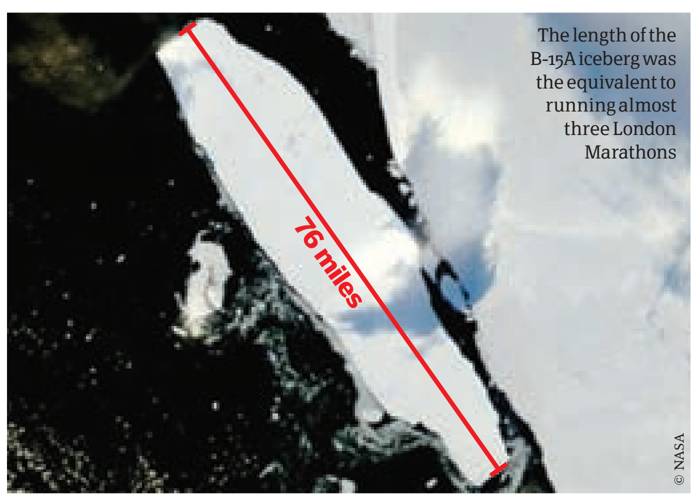
You only see a fraction of the iceberg above sea level, but it doesn't sink thanks to buoyancy. The upward force of buoyancy acting upon an object floating in a liquid is equal to the weight of the volume of liquid that is displaced by the object. The reason the ice isn't immersed is that – unlike other solids – ice is less dense than the liquid form it once had. When water is frozen it crystalises, meaning there's air between the molecules, reducing its density and enabling it to float.

Icebergs float because ice is lighter than water

Very large iceberg

Take a crash course in iceberg lingo

Icebergs range from the car-sized 'growler' to the house-sized 'bergy bit' (both genuine classifications), through to the less well-named small, medium, large, and very large. To get an idea of how large an iceberg can be, in 2000 a chunk of ice known as the Iceberg B-15 was calved off the Ross Ice Shelf in Antarctica. B-15 was half a mile thick and covered an area of 4,500 square miles. It's been suggested that it could've supplied America with water for five years.



The length of the B-15A iceberg was the equivalent to running almost three London Marathons

© NASA

"Rainforests are complex and intricate systems, consisting of multiple layers that shroud the plethora of activity"


Lying around is just so tiring

Explaining rainforests

Receiving up to 2,000 millimetres of rainfall annually, as well as home to over 50 per cent of all Earth's species, the rainforests of our planet are a unique and life-abundant environment which still remain largely unobserved

Rainforests are found mainly in tropical regions near the equator where the climate is consistently hot and wet, allowing the rapid and prolific expansion of all forms of life, be it flora or fauna. From the heartlands of South America, through the jungles of Africa and India, to the north coast of Australia, the rainforests are a phenomenal breeding ground for evolutionary processes and major players in maintaining the world's natural cycles, responsible for over 28 per cent of its oxygen turn over.

However, despite their massive selection of indigenous life forms and overall importance to the Earth's oxygen production, the rainforests cover less than six per cent of its surface, a number that thanks to perpetual deforestation is reducing daily, causing many species to be driven to extinction and the climate of many parts of the globe to change radically. This is because despite initial appearances, rainforests are highly complex and intricate systems, consisting of multiple layers that shroud the plethora of activity that is undertaken in each. Indeed, it has only been thanks to recent advances in science and technology that scientists and biologists have been able to study the rainforests in their full glory, recording footage, imagery and results that have highlighted, if anything, how much we still don't understand about them.

Luckily, many discoveries have already been made in the rainforests of the Earth, each providing a snapshot into this alien world. Here we take a closer look at how the rainforests tick, with specific emphasis on their makeup, diverse species of plants and animals, natural processes and the threat to them from deforestation.


Many species of parrot dwell in rainforests

ON THE MAP

Where do the rainforests grow?

There are two types of rainforest, tropical and sub-tropical. Where they are situated on Earth can be seen on the adjacent map.

- Sub-tropical
- Tropical

Percentage power
1 Scientists believe up to 75 per cent of the Earth's species are indigenous to the rainforests. Despite this stunning figure, it is also postulated that millions have yet to be discovered.

Parrots-et-em-all
2 The rainforests are home also to a large number of plants from which modern medicines are derived. These include, among others, remedies for fever and burns.

Small waistline
3 Despite the wide diversity of plant and animal life, tropical rainforests only appear in a relatively narrow band around the Earth's equator. This band is called the monsoon trough.

Anybody out there?
4 Despite man's encroachment on the rainforests there are still thought to be over 40 uncontacted indigenous tribes living in them, notably in Brazil and New Guinea.

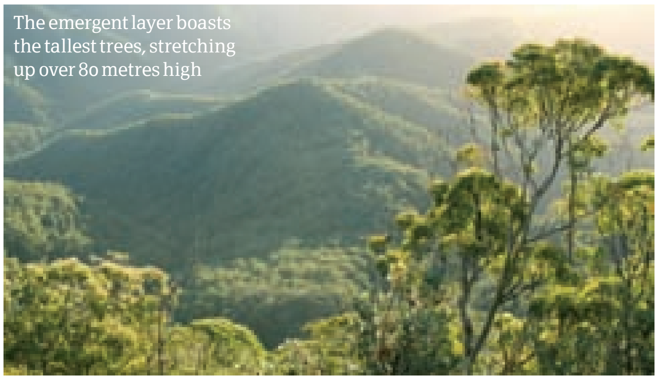
Total wipeout
5 With deforestation rampant, many of the Earth's rainforests are being cut down. Over 90 per cent of West Africa's rainforest has been destroyed so far.

DID YOU KNOW? *There are two different types of rainforest, tropical and sub-tropical*

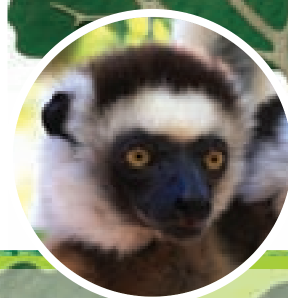
The layers of rainforests

Uncovering life below the surface

EMERGENT LAYER Height: 70-80m


The emergent layer boasts the tallest trees, stretching up over 80 metres high

The highest level of any rainforest is the emergent layer, consisting of large (70-80 metre tall), spaced-out trees that reach far above the general canopy. These giants of the forest are characterised by their umbrella-type tops, perfect for catching light, as well as their super-thick trunks, ideal for keeping them upright when strong winds hit their exposed upper extremities. The emergent layer is home to many species of bird, insect and mammal, including eagles, monkeys and butterflies. However, due to its height and direct exposure to the Sun and high winds, the emergent layer houses only a fraction of the life to be found in a rainforest.



CANOPY LAYER Height: 35-40m

Estimated to house over 50 per cent of all plant species on Earth, the canopy layer is one of the densest layers of biodiversity to be found in a rainforest. The canopy layer is similar in fauna to the emergent layer, but far more diverse due to shade, moisture and moderate temperatures. It mainly consists of a thick-layered system of vines and branches where animals shelter from the Sun's rays. Examples of animals that live in the canopy layer include sloths, parrots and toucans.

UNDERSTORY LAYER Height: 0.5-35m

Directly beneath the canopy layer and on top of the forest floor lies the understory layer, a dark, dense, humid maze of shrubs, vines and broadleaf trees. Home to animals such as the snakes, jaguars and lizards the understory layer is one of the most hostile of all, where the battle for survival is fierce. Very little light manages to break down to this level thanks to the overarching canopy, causing many plants and trees to grow large leaves to maximise whatever light they can get. Insect life is prolific at this level, with leaf-cutter ants, spiders, mosquitos and moths a common sight.

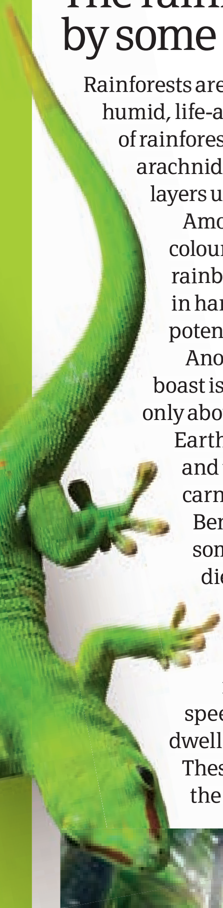
FOREST FLOOR Height: 0-0.5m

The lowest layer in any rainforest is the forest floor, a ground layer where the soil quality is exceptionally poor due to the almost total lack of sunlight. This level is prolific, however, in mosses, fungi and microorganisms (such as termites and earthworms).

"The three-toed sloth is an almost totally tree-dwelling species"

The animals of the rainforests

The rainforests of the globe are inhabited by some of its most amazing creatures



Rainforests are tremendously rich in animal life thanks to their humid, life-abundant climates. A usual population for an area of rainforest can contain insects, reptiles, amphibians, birds, arachnids and mammals, with a diversity across all its layers unmatched anywhere else on the planet.

Among the most exotic include toucans, brightly coloured birds characterised by their enormous rainbow bills, ideal for reaching for fruit and other food in hard-to-reach places, as well as to intimidate potential predators.

Another species of animal the eastern rainforests boast is the endangered Bengal tiger, of which there are only about 2,000 left in the wild. The second largest tiger on Earth, Bengal tigers can grow up to over three metres and their average weight is 221 kilograms. As obligate carnivores, the amount of meat required to feed a Bengal is staggering (20kg in a single sitting), something that they achieve through a consistent diet of boars, deer, monkeys, birds and, in extreme circumstances, elephants, bears, leopards, wolves and even humans.

Three-toed sloths can also be found in the rainforest. Famously slow moving (they have a top speed of just 0.24km/h), it is an almost totally tree-dwelling species, with its entire body built to hang. These sloths tend to inhabit the understory layer of the forest.

Never one to rush through a meal...

A Bengal tiger stalks through the rainforest

Numerous frogs live in rainforests; many are poisonous

The swampy and sun-deprived understory

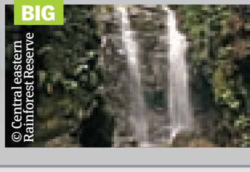
The plants of the rainforests

Known as the 'world's largest pharmacy', many of the natural medicines we use originate here

The amounts of chemicals that can be found in the plants of the rainforests are quite staggering. Take the cocoa tree for example, which produces more than 150 chemicals in its leaves, fruit, seeds and bark. The chemicals of this highly medical plant have been used to treat anxiety, fever and kidney stones, as well as holding polyphenols that reduce the chance of cardiovascular disease and even cancer.

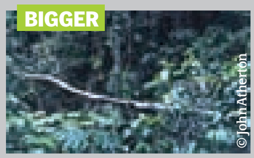
Another much-used medicinal plant from the Amazonian rainforest is the Achiote. Parts of this small shrub/tree can be used to make medical remedies for conditions such as leprosy, tonsillitis, pleurisy and apnoea. In addition, the sap from the Achiote's fruit is used frequently to treat type 2 diabetes. Historically, records have shown that the native peoples of South America used the

BIG



1. Gondwana
Not the largest by any means, but at 3,665km² there is still something to protect of Australia's long strip of tropical rainforests.

BIGGER



2. Africa
At 3.6 million km² the rainforests of Africa are big, but they could have been much larger if it wasn't for mass-logging and deforestation.

BIGGEST

3. Amazon
At 7 million km² the Amazonian rainforest is the biggest of them all and spans numerous countries including Brazil and Venezuela.

DID YOU KNOW? *The roar of a Bengal tiger can be heard for up to three kilometres*

Deforestation and climate change

Deforestation of the rainforests is escalating at an alarming rate

The effects on the Earth that deforestation brings are severe, with regional and global climate changing wildly, flooding more frequent, and the extinction of thousands of species of animals and plants. The causes of this destruction are many, with logging and cattle ranching the most serious.

Logging is the systematic processing of hectares of trees to be used in local and international markets, and it is estimated by conservationists that over 75 per cent of the world's forests have been destroyed or degraded by logging.

Cattle ranching also massively eats away at the borders of rainforests, and is increasing flood-prone areas greatly. This is because when ranchers cut down trees to create areas for their animals to pasture, they remove the sponge effect the rainforest provides, so instead of absorbing the large amount of rain the forest receives and distributing slowly, the newly stripped area just floods and channels quickly off into nearby rivers which then also flood.

The reduction in trees also has an impact on the local and global climate, as each time a part of rainforest is lost the net oxygen output from the area, due to photosynthesis, is reduced. Biosequestration (the capture and storage of greenhouse gases) is also reduced, as is the excess quantities of carbon produced under the rainforest, an important source of fuel for the future wellbeing of Earth.

"The causes of this wholesale destruction are numerous, with logging and cattle ranching the most serious"

properties of the Achiote to lower blood pressure and as an insect repellent.

However, not all plants of the rainforest are medicinal, with many of the most aggressive and carnivorous species thriving in the humid, moisture-abundant conditions. Among the most famous of these are the carnivorous Venus flytrap and Pitcher plant, both of which devour numerous insects, reptiles and small mammals.

The Pitcher plant, which can be found mainly on the island of Borneo, traps its prey by luring insects and small animals into its conical body through its attractive appearance and corpse-like smell. Once inside the victim slips into a pool of lethal liquid at its bottom due to slick inner walls, before drowning and being slowly digested. Pitchers have evolved this unnatural taste for blood due to the harsh conditions in which they grow, only found on the forest floor layer of a rainforest.

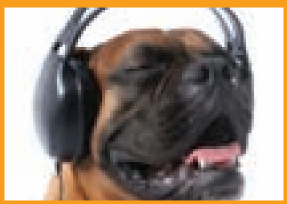
The Venus flytrap, on the other hand, devours prey in a far more elegant manner. Luring prey into its waiting jaw through the sweet sticky nectar within, the flytrap then snaps shut on its prey when minuscule hairs are brushed against. The closing of its two leaves over the insect takes only a fraction of a second, and while certain bugs may escape, the majority get encased and slowly digested.

It can eat rats don't you know!

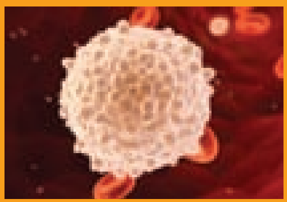
This month in **Science**

You lot seem fascinated by the wonders of human anatomy so this issue we're looking at how oxygen is transported around the body. And the rest of the science section is not to be sniffed at as we find out how we smell, why we age and how our body's natural defences keep us healthy.

50 Obesity



55 Dogs' hearing



58 The immune system

SCIENCE

Human respiration

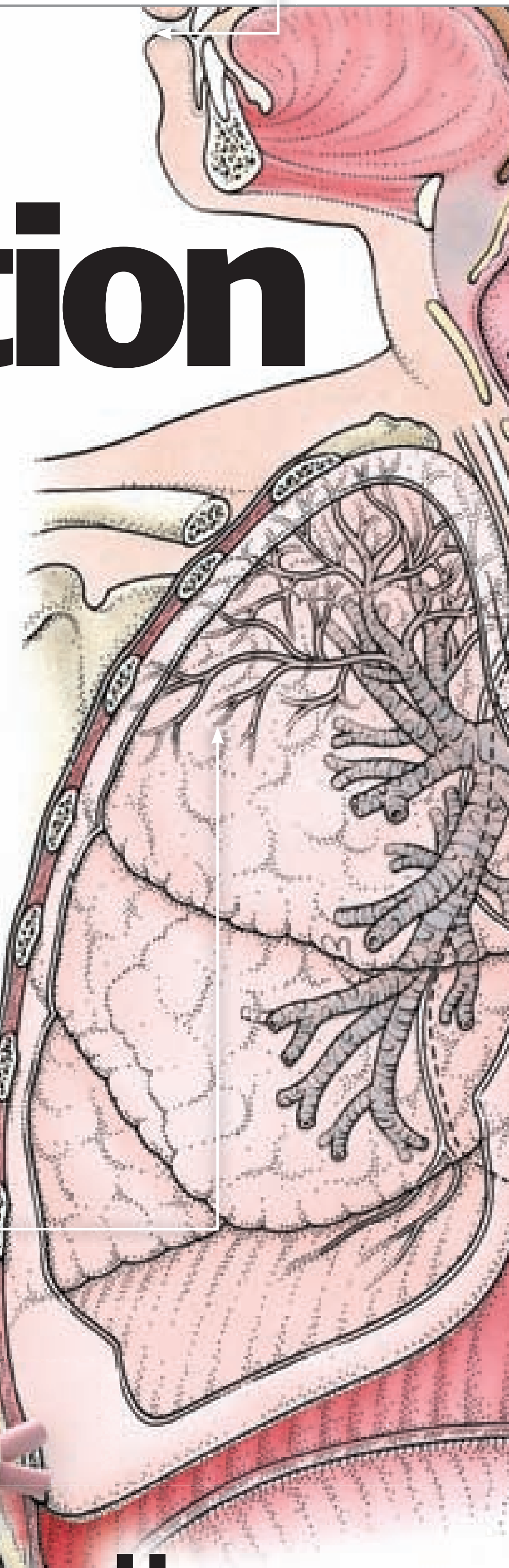
Respiration is crucial to an organism's survival. The process of respiration is the transportation of oxygen from the air that surrounds us into the tissue cells of our body so that energy can be broken down

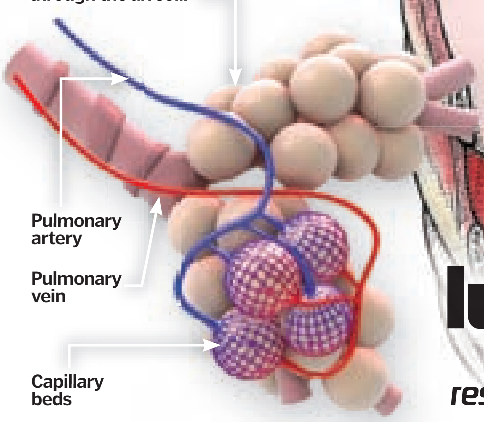
The primary organs used for respiration in humans are the lungs. Humans have two lungs, with the left lung being divided into two lobes and the right into three. The lungs have between 300–500 million alveoli, which is where gas exchange occurs.

Respiration of oxygen breaks into four main stages: ventilation, pulmonary gas exchange, gas transportation and peripheral gas exchange. Each stage is crucial in getting oxygen to the body's tissue, and removing carbon dioxide. Ventilation and gas transportation need energy to occur, as the diaphragm and the heart are used to facilitate these actions whereas gas exchanging is passive. As air is drawn into the lungs at a rate of between 10-20 breaths per minute while resting, through either your mouth or nose by diaphragm contraction, and travels through the pharynx, then the larynx, down the trachea, and into one of the two main bronchial tubes. Mucus and cilia keep the lungs clean by catching dirt particles and sweeping them up the trachea.

When air reaches the lungs, oxygen is diffused into the bloodstream through the alveoli and carbon dioxide is diffused from the blood into the lungs to be exhaled. Diffusion of gases occurs because of differing pressures in the lungs and blood. This is also the same when oxygen diffuses into tissue around the body. When blood has been oxygenated by the lungs, it is transferred around the body to where it is most needed in the bloodstream. If the body is exercising, breathing rate increases and consequently so does heart rate to ensure that oxygen reaches tissues that need it. Oxygen is then used to break down glucose to provide energy for the body. This happens in the mitochondria of cells. Carbon dioxide is one of the waste products of this, which is why we get a build up of this gas in our body that needs to be transported back into the lungs to be exhaled.

The body can also respire anaerobically, but this produces far less energy and instead of producing co2 as a byproduct, lactic acid is produced. The body then takes a time to break this down after exertion has finished as the body has a so-called oxygen debt.





How our lungs work

Lungs are the major respiratory organ in humans

1 Lung capacity varies hugely
Dependant on sex and body size, alongside external factors such as altitude, lung capacity ranges between 4,000 and 6,000cm³.

2 The right lung is bigger
The left lung is slightly smaller than the right because the left lung has to make room for the heart to fit in.

3 We have excess lung capacity
On average, we only use about one-eighth of the capacity of our lungs for each breath so we have a large reserve volume.

4 Alveoli have massive surface area
One person's entire alveoli laid out would have the surface area of about $70cm^2$ – roughly half a tennis court!

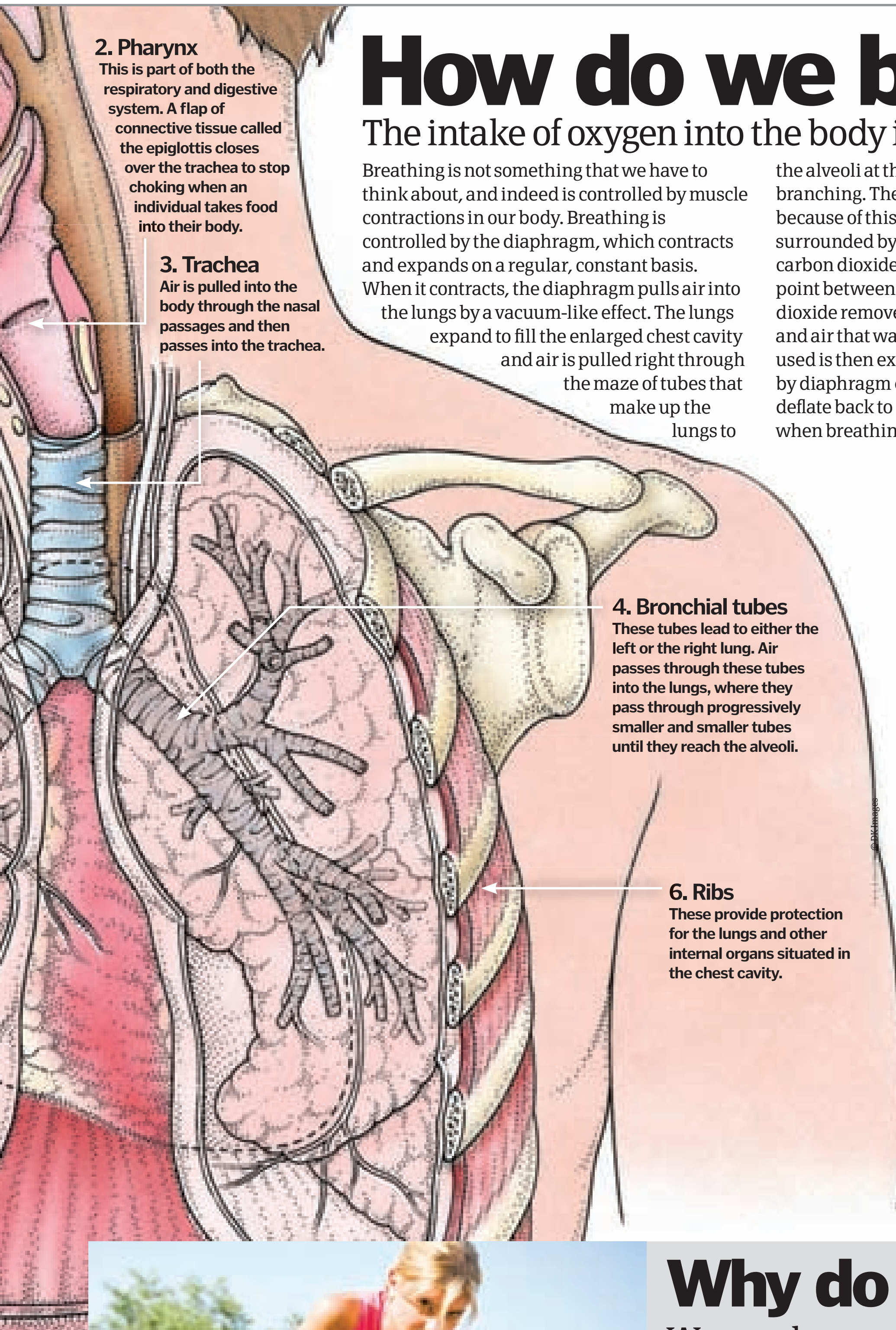
5 We breathe 11,000 litres of air per day
On average, one individual will breathe in 11,000 litres of air a day. If we exercise heavily during that day, this will increase further.

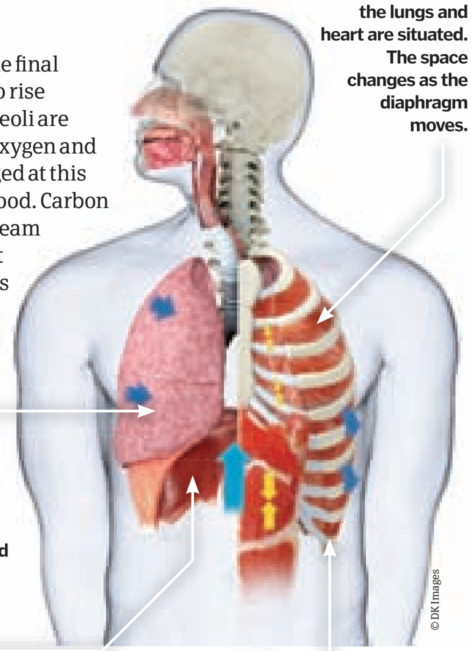
DID YOU KNOW? *Trained free-divers can hold their breath underwater for up to nine minutes*

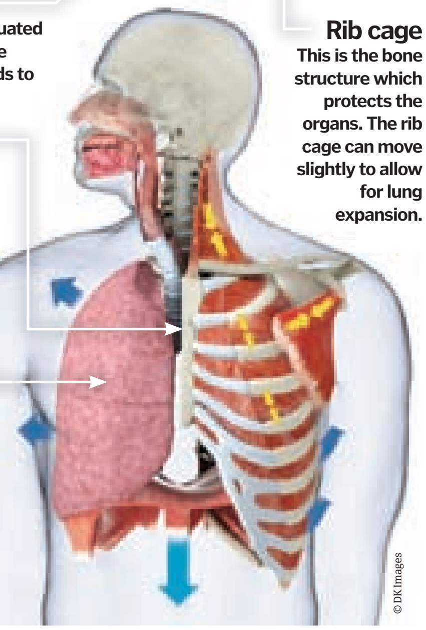
How do we breathe?

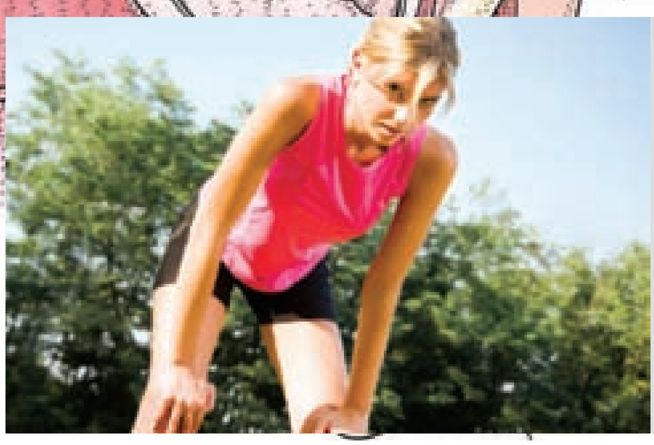
The intake of oxygen into the body is complex

Breathing is not something that we have to think about, and indeed is controlled by muscle contractions in our body. Breathing is controlled by the diaphragm, which contracts and expands on a regular, constant basis. When it contracts, the diaphragm pulls air into the lungs by a vacuum-like effect. The lungs expand to fill the enlarged chest cavity and air is pulled right through the maze of tubes that make up the lungs to the alveoli at the ends, which are the final branching. The chest will be seen to rise because of this lung expansion. Alveoli are surrounded by blood vessels, and oxygen and carbon dioxide are then interchanged at this point between the lungs and the blood. Carbon dioxide removed from the blood stream and air that was breathed in but not used is then expelled from the lungs by diaphragm expansion. Lungs deflate back to a reduced size when breathing out.









Why do we need oxygen?

We need oxygen to live as it is crucial for the release of energy within the body

Although we can release energy through anaerobic respiration temporarily, this method is inefficient and creates an oxygen debt that the body must repay after excess exercise or exertion has ceased. If oxygen supply is cut off for more than a few minutes, an individual will die.

Oxygen is pumped around the body to be used in cells that need to break down glucose so that energy is provided for the tissue. The equation that illustrates this is:

$$C_6H_{12}O_6 + 6O_2 = 6CO_2 + 6H_2O + \text{energy}$$

The effects of ageing

What happens to our bodies as we get older?

Many scientists are still baffled by why we age, only knowing that it makes us frail and weak, and eventually causes us to die. Visual effects of ageing are clear to see, skin wrinkles and hair greys, but there are massive changes that occur inside the body as well. Organs start to lose effectiveness, bones start to calcify and brain function decreases.

Although there have been many proposed theories for ageing, there is actually no agreed scientific reason for the process, just two commonly accepted theories. The mutation accumulation theory suggests that traits linked to ageing, which will only affect us after reproductive age, can be passed on to our offspring when we reproduce as they are neither selected for or against survival as they are neutral at that point. These kinds of mutation then build up in the population.

The other major theory is the antagonistic pleiotropy theory that states that genes which aid reproduction or growth in childhood have a cost later in life, meaning they are actively selected for when we reproduce even though they have a negative cost for the individual later on. These theories are similar, but one assumes mutations are collected without intention, and the other suggests they are selected for a reason.

Understanding ageing is very important as once we understand exactly how we age, we can then better treat problems that are brought about by ageing and then hopefully extend life expectancies across the globe.


Older doesn't necessarily mean wiser, especially after three sherries

DID YOU KNOW? The world's elderly population, individuals of 60 or over, is forecast to reach 2 billion by 2050.


"Hold the fries please, I'm on a diet"

Why do we get fat?

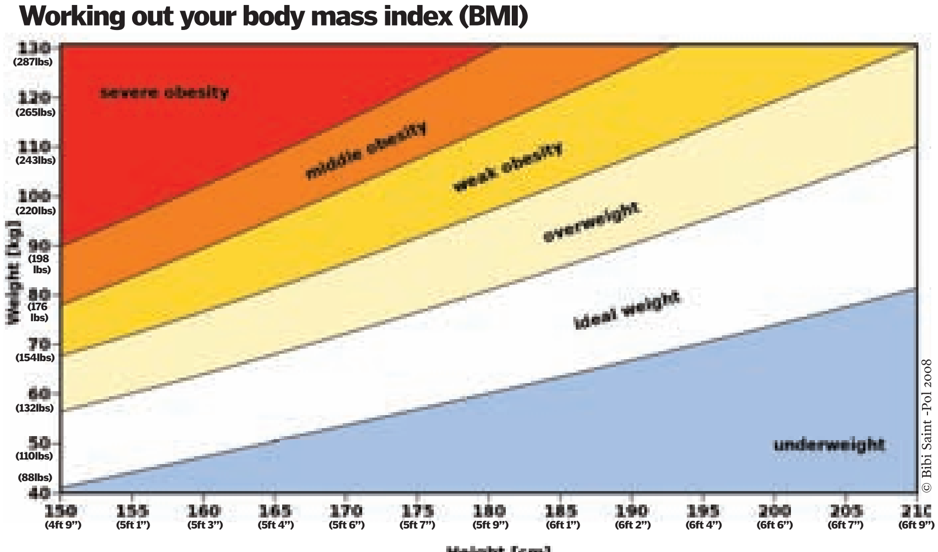
As the obesity epidemic grows, it is important to understand just what causes us to gain weight

Daily calorie intake for an average adult is set between 2,000 and 2,500kcals and recommended fat intake is between 70 and 90 grams. The body needs this level of calories in order to function at maximum efficiency. However, if we consume more than is needed to run our body, it stores these extra calories as fat. These fat stores can serve as a reserve if we don't eat enough, but if someone consistently over-eats, they'll become overweight as the body continues to store the excess calories.

Obesity is becoming more prevalent across the world, within developed and developing countries. Highly calorific food and snacks, with generally poor nutritional value, have become more widely and cheaply available and the amount of saturated fat being consumed by an average adult is much higher than 20 years ago. Changes in behavioural patterns of societies have also contributed to the problem as average levels of physical activity have reduced. Eating patterns have also changed due to lifestyle changes. Busy lives and more focus being placed on careers has led to the advent of the 'ready meal' and an increase in the number of takeaways eaten – which are often very high in saturated fat and calories. Genes can also have an impact on weight gain, but most cases of obesity that we see are actually due to average calorie intake increasing, with actual need reducing.

Over the last 20 years, child obesity levels have also been increasing dramatically, again primarily due to physical exertion decreasing and calorific intake increasing. This is of particular concern because of the many health problems associated with obesity such as type 2 diabetes, cardiovascular disease, strokes and certain forms of cancer among others.

Working out your body mass index (BMI)

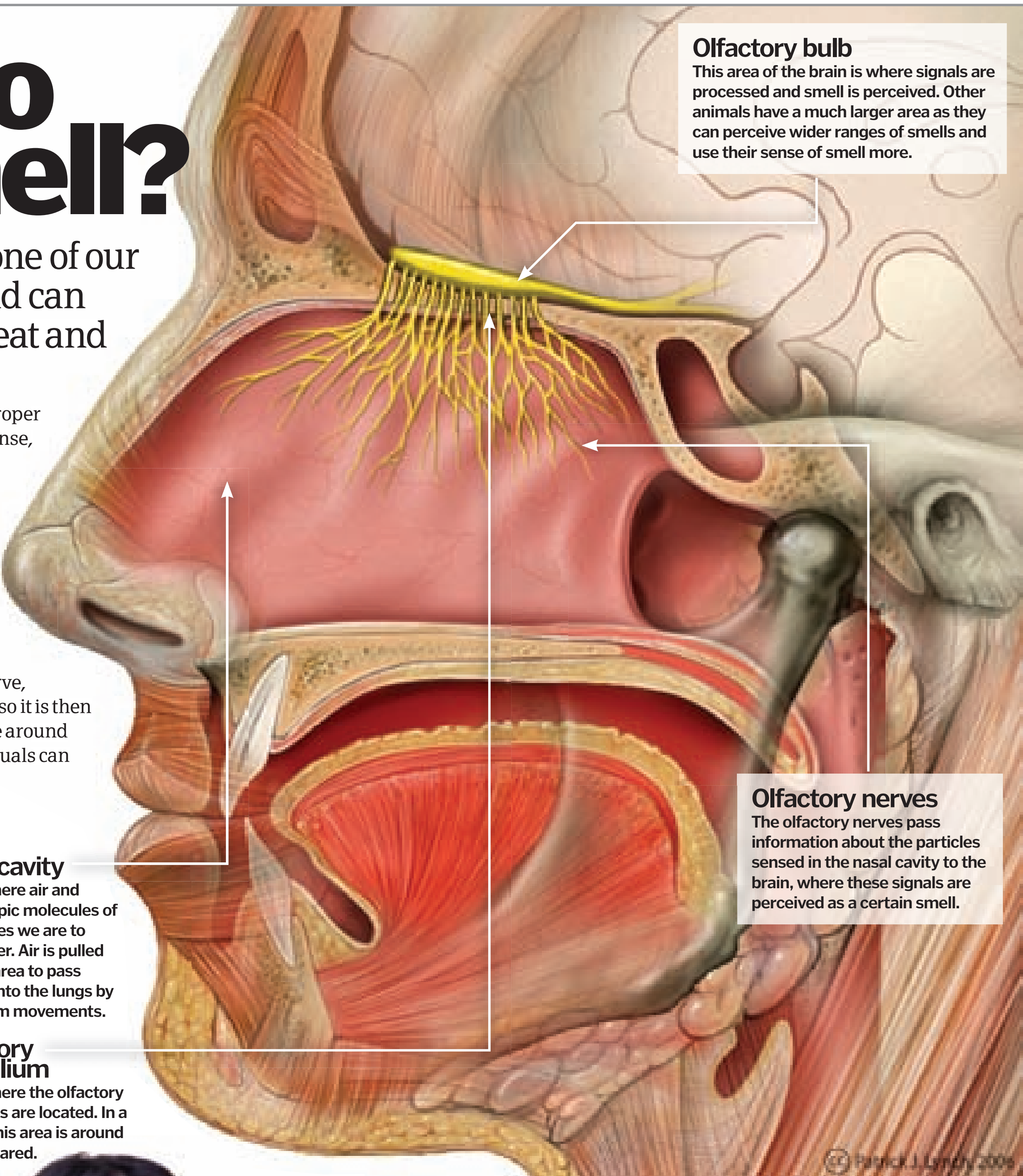


“We actually breathe in microscopic bits of the substance that we smell”

How do we smell?

The ability to smell is one of our most crucial senses and can influence the food we eat and the people we date…

Smell, or olfaction to use the proper terminology, is a very direct sense, in that we actually breathe in microscopic bits of the substance that we smell. These hit the olfactory epithelium, a mucus membrane in the nasal cavity, which contains millions of olfactory receptor neuron cells. Each of these sensory cells is covered in small hair-like structures, called cilia, which react to the odour and send signals to the olfactory nerve, which relays this information to the brain so it is then perceived as smell. Humans can recognise around 10,000 different odours and no two individuals can sense anything exactly the same.



Olfactory bulb
This area of the brain is where signals are processed and smell is perceived. Other animals have a much larger area as they can perceive wider ranges of smells and use their sense of smell more.

Nasal cavity
This is where air and microscopic molecules of substances we are to smell enter. Air is pulled into this area to pass through into the lungs by diaphragm movements.

Olfactory epithelium
This is where the olfactory nerve cells are located. In a human, this area is around 10cm squared.

Olfactory nerves
The olfactory nerves pass information about the particles sensed in the nasal cavity to the brain, where these signals are perceived as a certain smell.

© Patrick J. Lynch 2006

5 TOP FACTS SMELL

1 Women smell better!
Consistently, women out-perform men in smelling ability tests, and research has shown that women can recognise the smell of their baby only days after birth.

2 Smell affects taste
The human nose is actually the main organ involved in perceiving taste. Taste buds can only distinguish sweet, sour, bitter and salt, everything else perceived comes from smell!

3 Blind people can’t smell better
It’s a common myth that blind people can smell better than sighted. However, this has never been proven and most studies refute the fact.

4 Smelling ability doesn’t improve after childhood
At about eight, sense of smell reaches its full potential. Smelling ability reduces as you age.

5 Sense of smell improves throughout the day
When you first wake up, your sense of smell is far less acute than in the evening.

We can detect 10,000 different odours!

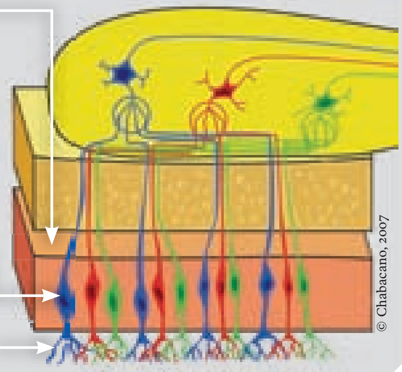
Cells that smell

The patch of sensory cells located in the nasal cavity are made up of several different parts

Mucosa
Mucosa lines the epithelium inside the nasal cavity, and catches the particles to be sensed by the receptor neuron cells.

Olfactory receptor neuron cells
These are odour-sensitive cells that are stimulated by the cilia. They then send messages through to the brain.

Olfactory cilia
These sense the particles in air. There are 8-20 of these on each olfactory nerve cell which line the epithelium.



© Chabacano, 2007

DID YOU KNOW? *Glass is an amorphous solid and there is no evidence to support the myth that it flows over time*

Now that's what you call a hotline! Sorry

Why does plastic melt?

Chemical structure returns to its default state

Plastic is the generic name we give to a wide variety of substances made out of organic oily compounds. For this question, let's imagine plastic as the hard, moulded substance that makes up Tupperware and other kitchen goods as well as toys and household items. These plastics are known as 'amorphous' which refers to how easy it is to mould them into shape over and over again (think of recycling a bottle). They're made up of polymers of the chemicals found naturally in oil; how these polymers are chemically made affects what the plastic can be moulded into and whether it can be something sturdy or flimsy. With a melting point of around 300° Celsius, these kinds of plastics return to their amorphous nature when heated too harshly. Once they cool, they'll stay in the shape they melted into – until heat breaks their chemical bonds again.

How is glass made?

From windows to pint glasses

Glass can be both man-made and made by nature. The basic ingredients are sand and minerals – primarily sodium carbonate and calcium carbonate, and to make glass these elements need to be heated to around 2,000° Celsius. The most common way glass is made by nature is when lightning hits either a sandy area, or rocks. This intense bolt of heat quickly melts the sand and it fuses together. If glass is man-made, generally a furnace will be used to heat the raw materials to this temperature.

The process by which glass is made is straightforward; as the temperature increases, the raw materials lose their forms and fuse together into a liquid. In man-made glass production, this liquid is refined at this stage, using agents such as sodium chloride or sodium sulfate, to ensure removal of air bubbles but in naturally occurring glass, bubbles are often present and the clarity of glass is reduced. This liquid can then be set into a any shape you wish, and as it cools it will retain this shape and become solid.

The reason glass is transparent is because the temperatures needed to form it are so high that its original raw materials, which are opaque, lose their crystalline forms when the substance becomes a liquid. When it sets into a solid, glass retains the random molecular organisation we see in liquids and therefore remains transparent. This cooling period must be quick, otherwise crystallisation may well reoccur and transparency lost.

Additions to glass, such as sodium carbonate used to refine melted glass, can affect the perceived colour – in this case, thick layers of glass will have a green tint.

This is an example of a furnace which heats raw materials to the temperature needed for them to melt to form glass

Elasticity explained

We promise not to stretch the truth…

Elasticity is the ability of a material to deform under pressure only to then return to its original shape. Typical elastic materials include glass, steel and rubber, all of which hold a certain degree of elasticity or 'stiffness' that varies from material to material. This temporary change in shape that a material undertakes is called 'elastic' deformation, and involves the stretching of its bonds by an external 'stress' (an applied force), with the relative amount of deformation (stretch, bend etc) referred to as the 'strain' of the material. This linear relationship between stress and strain defines elasticity and is visualised with the equation: Elasticity = Stress / Strain.

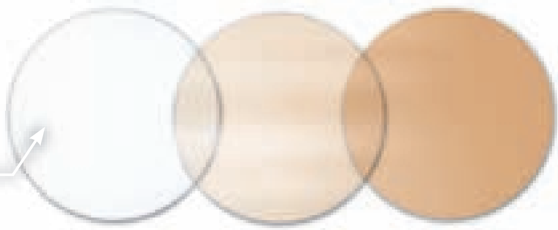
Interestingly, the stress and strain of any elastic material is directly proportional – a discovery made by Robert Hooke in 1678 – and providing the material isn't subjected to a stress above its proportional limit, then its physical properties will not change and will revert to its regular shape. However, if a material is taken over its proportional limit then it is subject to 'plastic' deformation, a process where its atomic bonds are broken by dislocation and it is irreversibly deformed. In an elastic band, this is where it snaps.

A linear relationship between stress and strain defines elasticity

"This compound is highly effective in killing bacteria"

Why photochromic lenses change colour

How light-sensitive glasses tell the difference between sun and artificial light



Clear to amber
Lenses can be clear to amber or clear to dark blue

We all know someone who has a pair of those cool glasses which darken in sunlight and revert to transparency indoors. It's usually our grandad, to be honest. This is because grandad can afford clever little lenses that differentiate between the 18th hole and the halogens in the Golf Club bar.

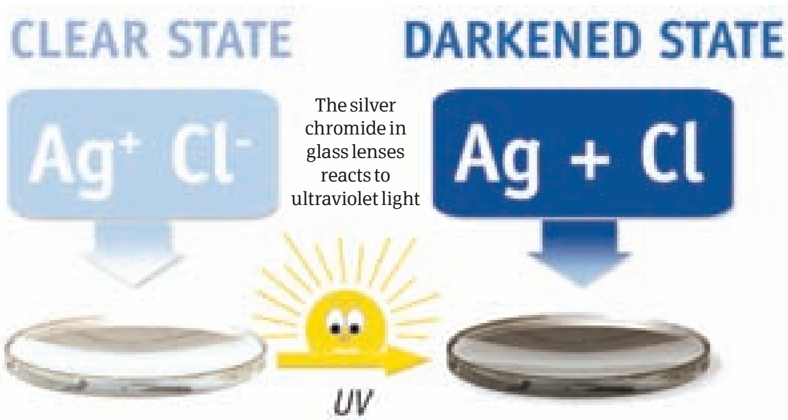
The reason that photochromic lenses can do this is that they react to ultraviolet light. Light that's coloured in the ultraviolet spectrum is present in sunlight but not in most artificial lights (with the notable exception of sunbeds and sunlight lamps). Photochromic lenses utilise chemicals which react to ultraviolet light, that are embedded into the molecular structure of the glass or plastic that the lenses are made of. These are typically a compound based on silver, notably silver halides in glass and oxazines (made of oxygen and nitrogen) in plastic lenses. Silver halides are commonly used when making and developing photographic film because of their light-sensitive properties.

Plastic lenses are preferable, because in glass lenses the degree of darkening that's possible in the lens depends on how thick it is. This is because the light-sensitive elements are embedded within the structure of the glass, and this produces variable results depending on how thick the lenses are. By contrast, plastic lenses are coated in a layer of photo-sensitive chemicals, which is distributed evenly across the surface of the lens and so produces more predictable and even results. The pigments darken quickly under UV light, and carry on doing so for around 15 minutes.

1. The lenses remain transparent while indoors

2. The lenses darken as ultraviolet light is detected

3. Voilá... a pair of sunglasses



The silver chromide in glass lenses reacts to ultraviolet light

There's no place here for toilet humour...

How does bleach work?

Clever chemistry with salt

Bleach is mainly used for two key purposes: to kill bacteria and to whiten or purify liquids and other substances. There are two main types of bleach: chlorine, which is typically used to clean and kill bacteria around your home, and peroxide, which is used for whitening – it's a key ingredient in hair dye.

Bleach is essentially salted water which has been treated with a process called electrolysis. This causes the molecules of sodium (salt) to throw off ions of chemical compounds. In the case of ordinary household bleach used for cleaning, that compound is typically sodium hypochlorite. This compound is highly effective in killing bacteria, so in much more diluted doses it's also used to treat drinking water.

Bleach whitens or removes stains because when it reacts with water it produces hydrochloric acid and oxygen, which react with and destroy compounds called chromophores, the molecules which create colour.

DID YOU KNOW?

Peroxide bleach is used in hair dye to strip the hair of its original colour, turning it white and opening the hair follicles. Colour is then applied onto the whitened hair. It retains that colour permanently, though it will fade.

5 TOP FACTS DOG'S HEARING

Dogs hear at high frequencies
1 The average human hearing range is between 20Hz and 20,000Hz whereas a dog's range is much higher from 40Hz to 60,000Hz.

Erect ears hear better
2 Dogs who have erect, pointy ears are noted to be able to hear slightly better than dogs with large, hairy 'floppy' ears.

Hearing is a dog's secondary sense
3 Smell is thought to be the most important sense to a dog, but hearing comes in second over sight, taste and touch.

Dogs have impressive selective hearing
4 Dogs can hear far more than a human, but have an ability to separate out sounds and focus on ones they want while ignoring others.

Dolphins have better hearing than dogs!
5 Dolphins are actually thought to have the best hearing in the animal kingdom, with sound reception likely to take place in the lower jaw.

DID YOU KNOW? *Dogs have the ability to screen sound, which allows them to focus on one particular sound*

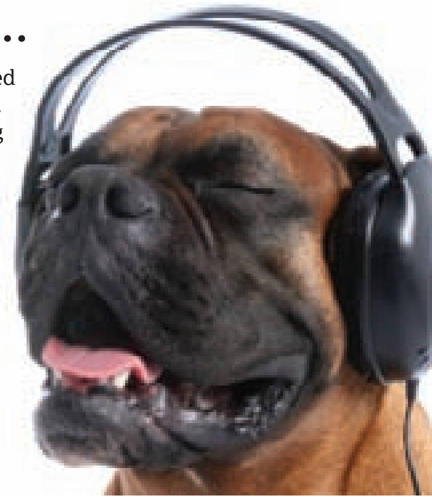
Why can dogs hear better than humans?

Identifying why Fido can hear better than you…

A full check-up made this dog paws for thought…

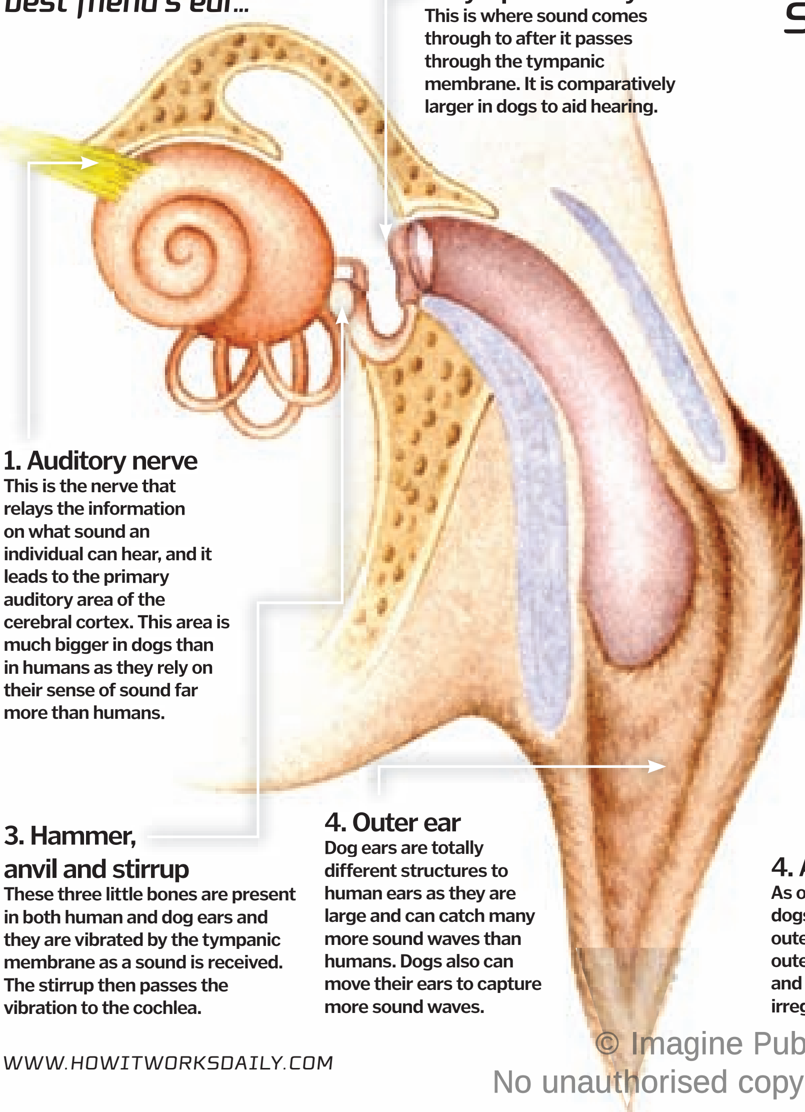
The biology of a dog's ear compared to a human's ear is quite different. Dogs also have a far wider hearing range than humans, allowing them to detect sounds far above a human's auditory limit.

One of the major differences in biology is the size and shape of the outer ear. This is the part of the sensory organ responsible for catching sound. Dogs have far bigger outer ears, which are also mobile, and dogs use 18 muscles located in and around the outer ear to rotate, raise or lower the ear to aid hearing. They can identify a sound and its location much quicker than humans, and can hear sounds four times as far away as humans.



Inside a dog's ear

The anatomy of man's best friend's ear…



© DK Images

1. Auditory nerve
This is the nerve that relays the information on what sound an individual can hear, and it leads to the primary auditory area of the cerebral cortex. This area is much bigger in dogs than in humans as they rely on their sense of sound far more than humans.

2. Tympanic cavity
This is where sound comes through to after it passes through the tympanic membrane. It is comparatively larger in dogs to aid hearing.

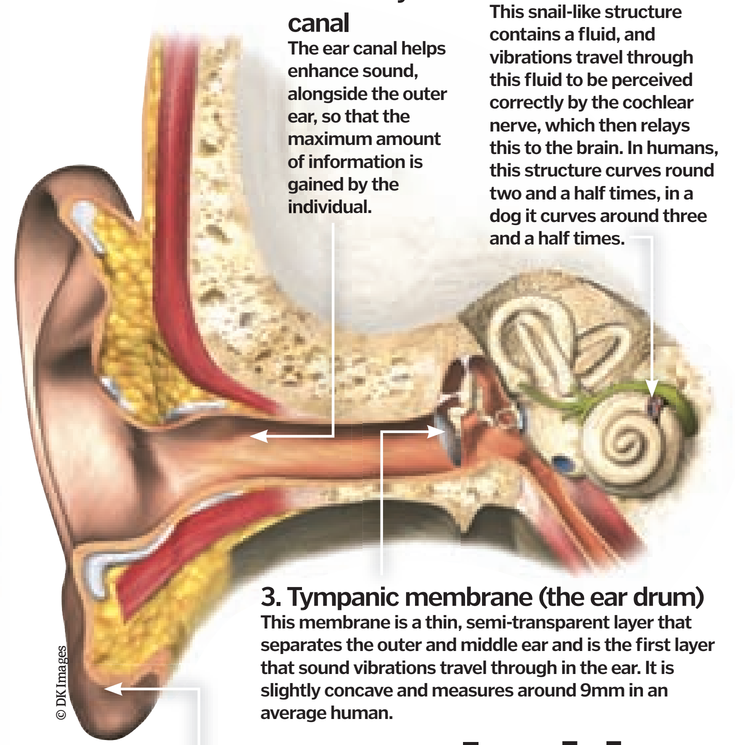
3. Hammer, anvil and stirrup
These three little bones are present in both human and dog ears and they are vibrated by the tympanic membrane as a sound is received. The stirrup then passes the vibration to the cochlea.

4. Outer ear
Dog ears are totally different structures to human ears as they are large and can catch many more sound waves than humans. Dogs also can move their ears to capture more sound waves.

"One of the major differences in biology is the size and shape of the outer ear"

Inside a human ear

How do we hear and decipher sounds?



© DK Images

1. Auditory canal
The ear canal helps enhance sound, alongside the outer ear, so that the maximum amount of information is gained by the individual.

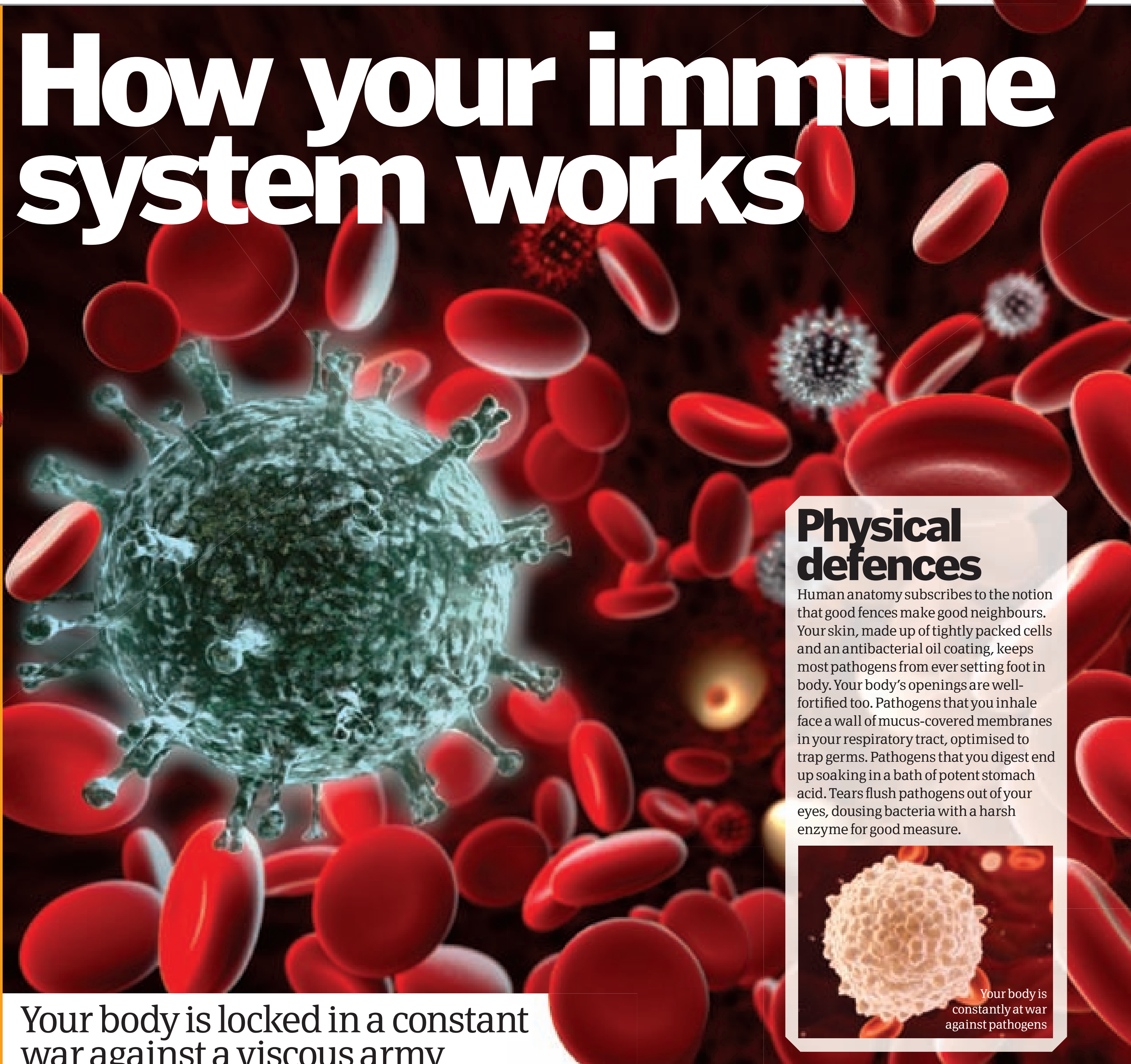
2. Cochlea
This snail-like structure contains a fluid, and vibrations travel through this fluid to be perceived correctly by the cochlear nerve, which then relays this to the brain. In humans, this structure curves round two and a half times, in a dog it curves around three and a half times.

3. Tympanic membrane (the ear drum)
This membrane is a thin, semi-transparent layer that separates the outer and middle ear and is the first layer that sound vibrations travel through in the ear. It is slightly concave and measures around 9mm in an average human.

4. Auricle (outer ear)
As opposed to the large outer ear seen on dogs, humans have a comparatively small outer ear made up of cartilage. Human outer ears are also immobile with hollows and ridges we see forming a type of irregular funnel, leading into the ear canal.

“Dangerous bacteria release toxins in the body that cause diseases”

How your immune system works



Physical defences

Human anatomy subscribes to the notion that good fences make good neighbours. Your skin, made up of tightly packed cells and an antibacterial oil coating, keeps most pathogens from ever setting foot in body. Your body’s openings are well-fortified too. Pathogens that you inhale face a wall of mucus-covered membranes in your respiratory tract, optimised to trap germs. Pathogens that you digest end up soaking in a bath of potent stomach acid. Tears flush pathogens out of your eyes, dousing bacteria with a harsh enzyme for good measure.

Your body is constantly at war against pathogens

Your body is locked in a constant war against a viscous army

It’s true: while you’re sitting around watching TV, trillions of foreign invaders are launching a full scale assault on the trillions of cells that constitute ‘you’. Collectively known as pathogens, these attackers include bacteria, single-celled creatures that live to eat and reproduce; protists, larger single-cell organisms; viruses, packets of genetic information that take over host cells and replicate inside them; and fungi, a type of plant life.

Bacteria and viruses are by far the very worst offenders. Dangerous bacteria release toxins in the body that cause diseases such as E. coli, anthrax, and the black plague. The cell damage from viruses causes measles, the flu and the common cold, among numerous other diseases.

Just about everything in our environment is teeming with these microscopic intruders... including you. The bacteria in your stomach alone outnumber all the cells in your body, ten-to-one. Yet, your scrappy microscopic soldiers usually win the day against pathogens, through a combination of sturdy barriers, brute force, and superior battlefield intelligence, collectively dubbed the immune system.

5 TOP FACTS IMMUNE SYSTEM

The cure can sometimes hurt
1 Sneezing, coughing, a sore throat, and fever are all means of expelling pathogens, so as annoying as they are, each one is necessary.

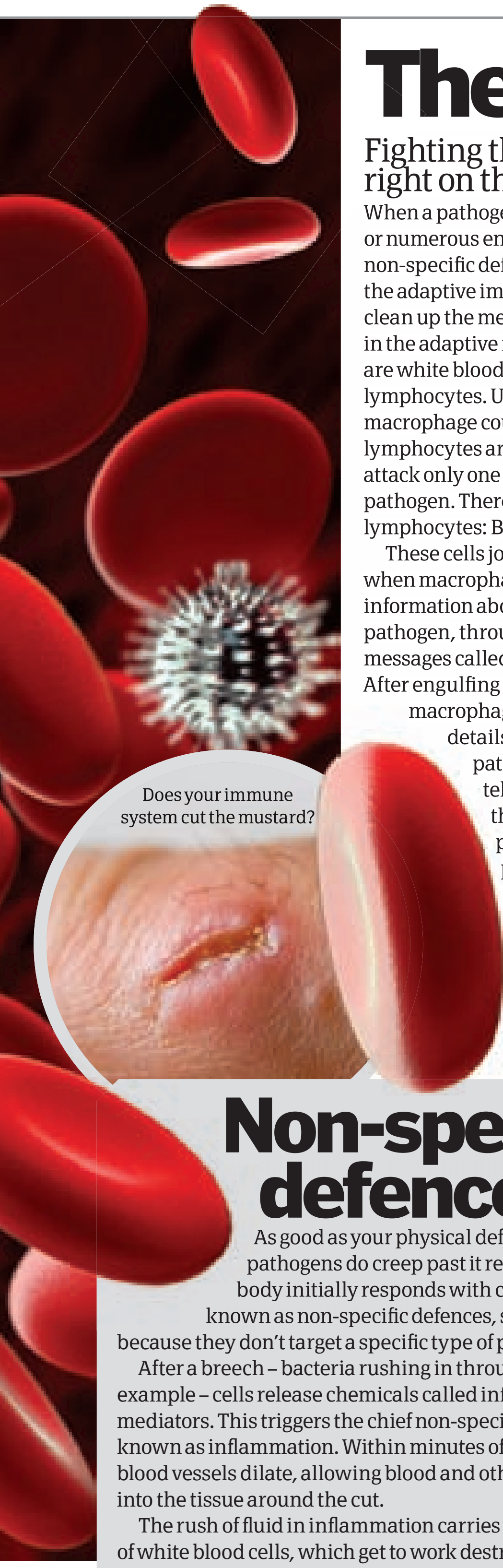
Immunity soldiers are everywhere
2 A single drop of blood contains around 375,000 white blood cells, and blood constitutes for seven per cent of your total body weight.

You can 'borrow' immunity
3 Antibodies in breast milk give babies temporary immunity from diseases their mother is immune to, preventing infancy infection.

It deals with internal troubles, too
4 In addition to fighting pathogens, T-cells fight the body's own cancerous cells and some cancer therapies boost the number of T-cells.

It has trouble with change
5 Unfortunately you cannot develop immunity to the flu and common cold because the viruses are always mutating.

DID YOU KNOW? Dr Karl Landsteiner first identified the major human blood groups – A, B, AB and O – in 1901



The adaptive immune system

Fighting the good fight, and white blood cells are right on the front line...

When a pathogen is tough, wily, or numerous enough to survive non-specific defences, it's up to the adaptive immune system to clean up the mess. The key forces in the adaptive immune system are white blood cells called lymphocytes. Unlike their macrophage cousins, lymphocytes are engineered to attack only one specific type of pathogen. There are two types of lymphocytes: B-cells and T-cells.

These cells join the action when macrophages pass along information about the invading pathogen, through chemical messages called interleukins. After engulfing a pathogen, a macrophage communicates details about the pathogen's antigens – telltale molecules that characterise a particular pathogen. Based on this information, the immune system identifies specific B-cells and T-cells equipped to recognise and battle the pathogen. Once they are successfully identified, these cells rapidly reproduce, assembling an army of cells that are ready and equipped to take down the attacker.

The B-cells flood your body with antibodies, molecules that either disarm a specific pathogen or bind to it, marking it as a target for other white blood cells. When T-cells find their target, they lock on and release toxic chemicals that will destroy it. T-cells are especially adept at destroying your body's cells that are infected with a virus.

This entire process takes several days to get going and may take even longer to conclude. All the while, the raging battle can make you feel terrible. Fortunately, the immune system is engineered to learn from the past. While your body is producing new B-cells and T-cells to fight the pathogens, it also produces memory cells – copies of the B-cells and T-cells, which stay in the system after the pathogen is defeated. The next time that pathogen shows up in your body, these memory cells help launch a counter-attack much more quickly. Your body can wipe out the invaders before any infection takes hold. In other words, you develop immunity.

Vaccines accomplish the same thing by giving you just enough pathogen exposure for you to develop memory cells, but not enough to make you sick.

Does your immune system cut the mustard?

Non-specific defences

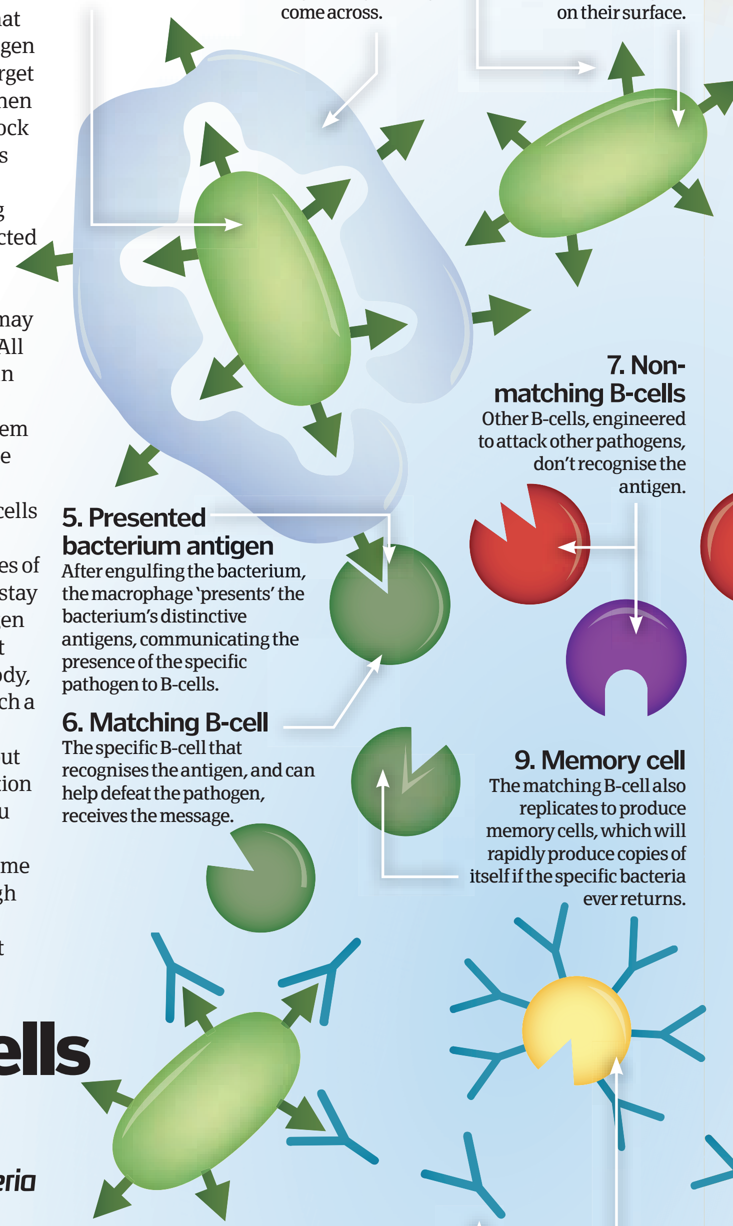
As good as your physical defence system is, pathogens do creep past it regularly. Your body initially responds with counterattacks known as non-specific defences, so named because they don't target a specific type of pathogen.

After a breech – bacteria rushing in through a cut, for example – cells release chemicals called inflammatory mediators. This triggers the chief non-specific defence, known as inflammation. Within minutes of a breach, your blood vessels dilate, allowing blood and other fluid to flow into the tissue around the cut.

The rush of fluid in inflammation carries various types of white blood cells, which get to work destroying intruders. The biggest and toughest of the bunch are macrophages, white blood cells with an insatiable appetite for foreign particles. When a macrophage detects a bacterium's telltale chemical trail, it grabs the intruder, engulfs it, takes it apart with chemical enzymes, and spits out the indigestible parts. A single macrophage can swallow up about 100 bacteria before its own digestive chemicals destroy it from within.

How B-cells attack

B-cells target and destroy specific bacteria and other invaders



1. Bacterium
Any bacteria that enter your body have characteristic antigens on their surface.

2. Bacterium antigen
These distinctive molecules allow your immune system to recognise that the bacterium is something other than a body cell.

3. Macrophage
These white blood cells engulf and digest any pathogens they come across.

4. Engulfed bacterium
During the initial inflammation reaction, a macrophage engulfs the bacterium.

5. Presented bacterium antigen
After engulfing the bacterium, the macrophage 'presents' the bacterium's distinctive antigens, communicating the presence of the specific pathogen to B-cells.

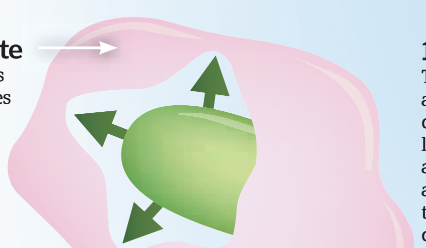
6. Matching B-cell
The specific B-cell that recognises the antigen, and can help defeat the pathogen, receives the message.

7. Non-matching B-cells
Other B-cells, engineered to attack other pathogens, don't recognise the antigen.

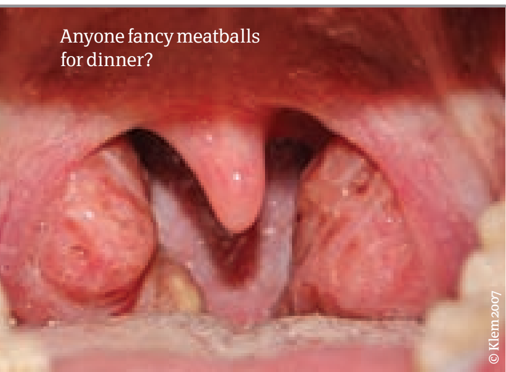
8. Plasma cell
The matching B-cell replicates itself, creating many plasma cells to fight all the bacteria of this type in the body.

9. Memory cell
The matching B-cell also replicates to produce memory cells, which will rapidly produce copies of itself if the specific bacteria ever returns.

10. Antibodies
The plasma cells release antibodies, which disable the bacteria by latching on to their antigens. The antibodies also mark the bacteria for destruction.

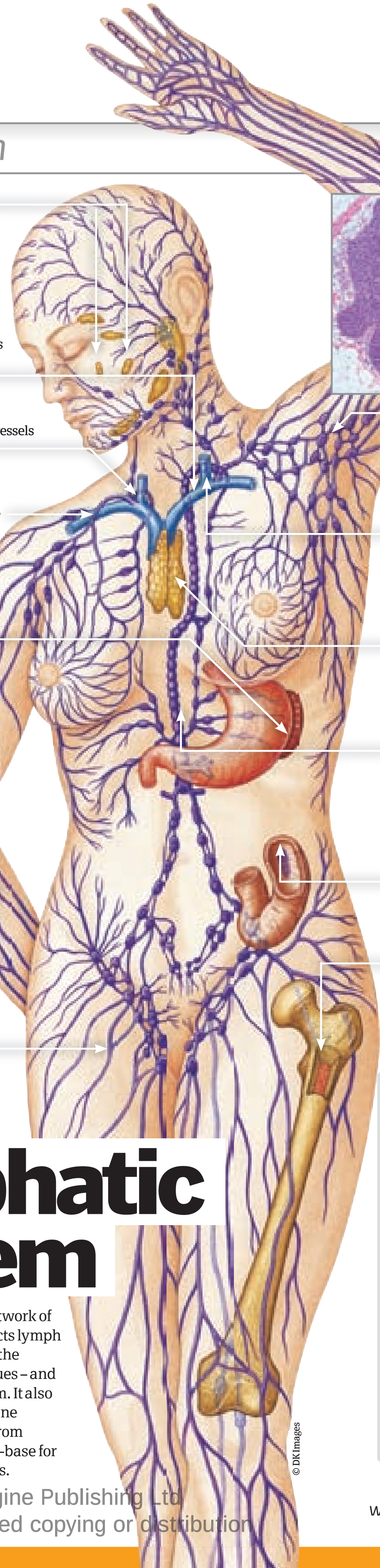


11. Phagocyte
White blood cells called phagocytes recognise the antibody marker, engulf the bacteria, and digest them.


Anyone fancy meatballs for dinner?

The lymphatic system

The lymphatic system is a network of organs and vessels that collects lymph – fluid that has drained from the bloodstream into bodily tissues – and returns it to your bloodstream. It also plays a key role in your immune system, filtering pathogens from lymph and providing a home-base for disease-fighting lymphocytes.



1. Tonsils
Lymphoid tissue loaded with lymphocytes, which attack bacteria that get into the body through your nose or mouth.

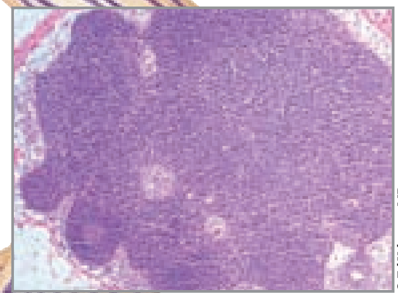
2. Left subclavian vein
One of two large veins that serve as the re-entry point for lymph returning to the bloodstream.

3. Right lymphatic duct
Passageway leading from lymph vessels to the right subclavian vein.

4. Right subclavian vein
The second of the two subclavian veins, this one taking the opposite path to its twin.

5. Spleen
An organ that houses white blood cells that attack pathogens in the bloodstream.

6. Lymph node cluster
Located along lymph vessels throughout the body, lymph nodes filter lymph as it makes its way back into the bloodstream.



7. Left lymphatic duct
Passageway leading from lymph vessels to the left subclavian vein.

8. Thymus gland
Organ that provides area for lymphocytes produced by bone marrow to mature into specialised T-cells.

9. Thoracic duct
The largest lymph vessel in the body.

10. Lymph vessels
Lymph collects in tiny capillaries, which expand into larger vessels. Skeletal muscles move lymph through these vessels, back into the bloodstream.

11. Peyer's patch
Nodules of lymphoid tissue supporting white blood cells that battle pathogens in the intestinal tract.

12. Bone marrow
The site of all white blood cell production.

Disorders of the immune system

Who watches the watchmen?

The immune system is a powerful set of defences, so when it malfunctions, it can do as much harm as a disease. Allergies are the result of an overzealous immune system. In response to something relatively benign, like pollen, the immune system triggers excessive measures to expel the pathogen. On the extreme end, allergies may cause anaphylactic shock, a potentially deadly drop in blood pressure, sometimes accompanied by breathing difficulty and loss of consciousness. In autoimmune disorders such as rheumatoid arthritis, the immune system fails to recognise the body's own cells and attacks them.


In an allergic reaction, the body may resort to sneezing to expel a fairly harmless pathogen


In rheumatoid arthritis, the immune system attacks joint linings

Lymph nodes explained

Lymph nodes filter out pathogens moving through your lymph vessels

Your immune system depends on these .04-1-inch swellings to fight all manner of pathogens. As lymph makes its way through a network of fibres in the node, white blood cells filter it, destroying any pathogens they find.

MOST DEADLY

1. Influenza
The flu kills hundreds of thousands of people in a good year. And every once in a while, a virulent form can take out tens of millions.

MOST CONTAGIOUS

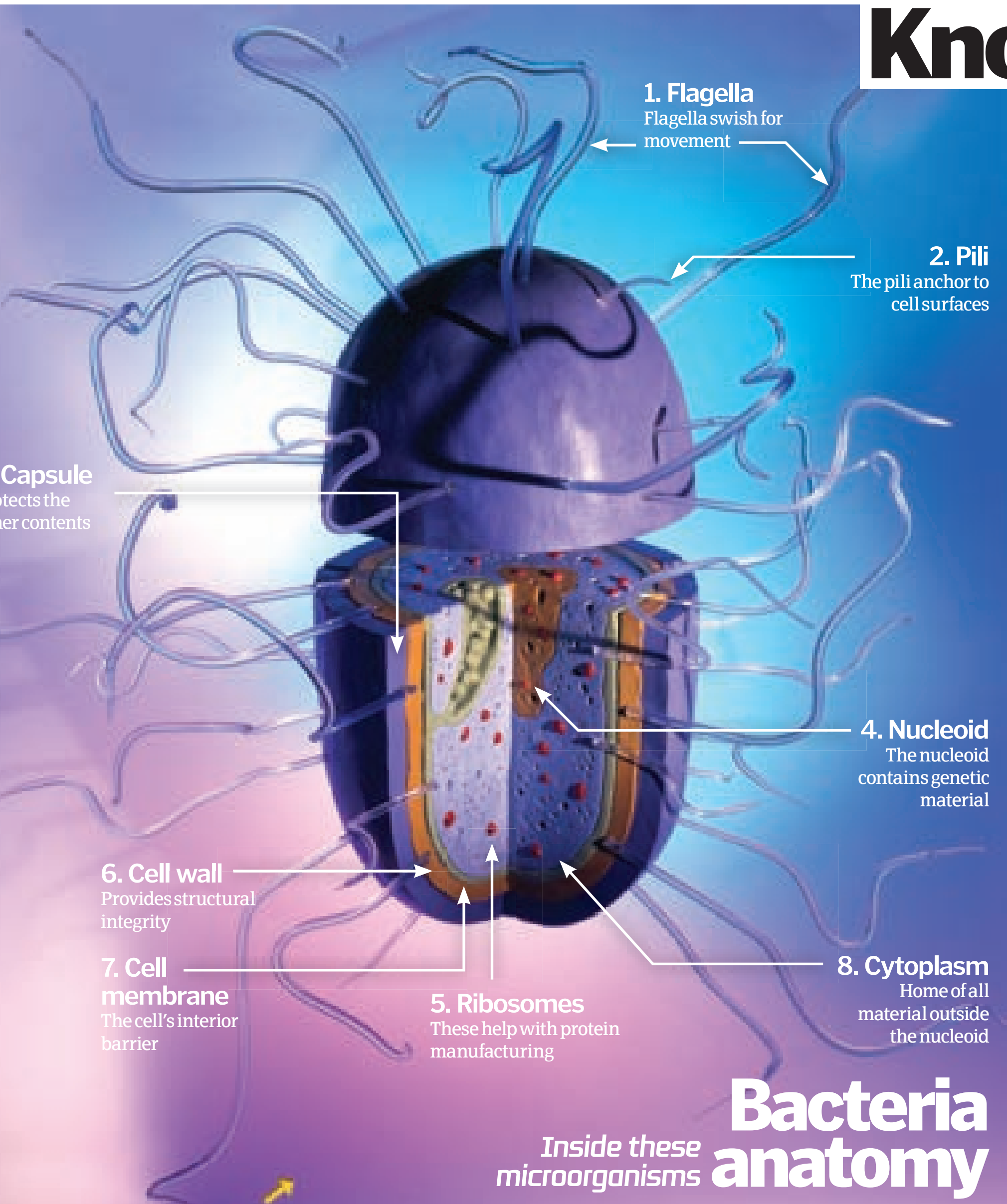
2. Measles
One person infected with measles will spread the virus to just about every unvaccinated person they encounter. Luckily, the vaccine is very effective.

MOST COMMON

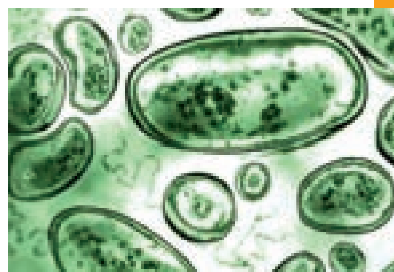
3. Tuberculosis
Ancient Egyptian mummies show signs of tuberculosis, and the disease is still thriving today. Around 2 billion people are infected.

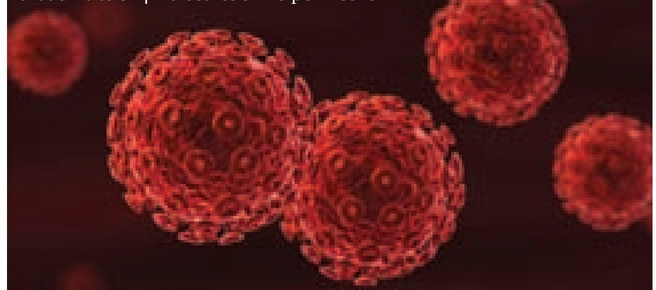
DID YOU KNOW? *In 2008, approximately 33 million people worldwide were living with HIV or AIDS*

Know your enemy: Bacteria



Bacteria are the smallest and, by far, the most populous form of life on Earth. Right now, there are trillions of the single-celled creatures crawling on and in you. In fact, they constitute about four pounds of your total body weight. To the left is a look at bacteria anatomy…

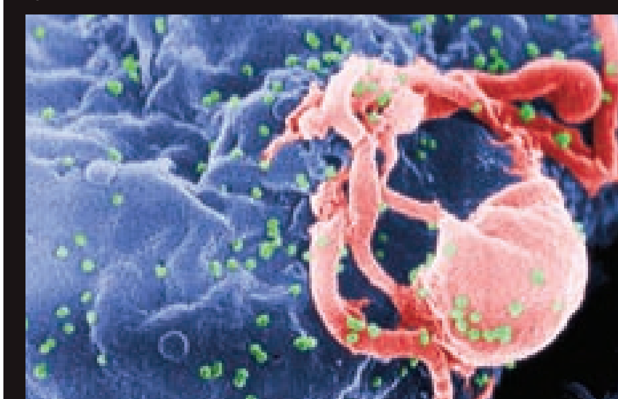




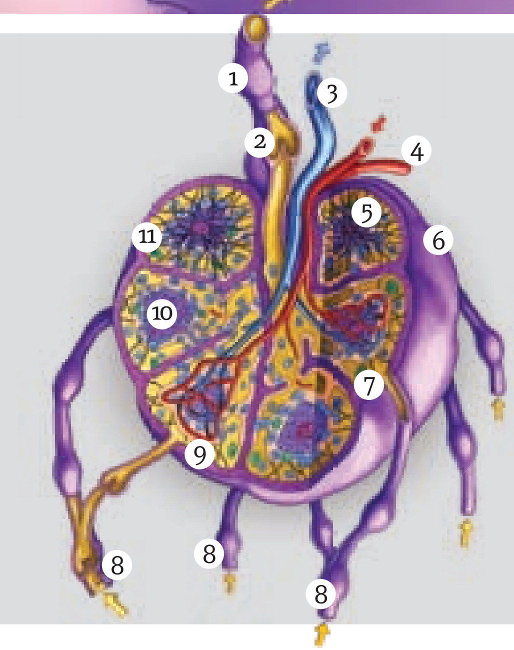
Free HIV particles, with protruding antigens that bind to CD4 molecules on helper T-cells

What is HIV…
…and how does it affect the immune system?

The human immunodeficiency virus (HIV) is a retrovirus (a virus carrying ribonucleic acid, or RNA as it's known), transmitted through bodily fluids. Like other deadly viruses, HIV invades cells and multiplies rapidly inside. Specifically, HIV infects cells with CD4 molecules on their surface, which includes infection-fighting helper T-cells. HIV destroys the host cell, and the virus copies go on to infect other cells. As the virus destroys helper T-cells, it steadily weakens the immune system. If enough T-cells are lost, the body becomes highly susceptible to a range of infections, a condition known as acquired immune deficiency syndrome (AIDS).



Scanning electron micrograph of HIV-1 budding (in green) from cultured lymphocyte. This image has been coloured to highlight the most important features. Multiple round bumps on the cell surface represent sites of assembly and budding of virions.



Major points of the lymph node

1. Outgoing lymph vessel
The vessel that carries filtered lymph out of the lymph node

2. Valve
A structure that prevents lymph from flowing back into the lymph node

3. Vein
Passageway for blood leaving the lymph node

4. Artery
Supply of incoming blood for the lymph node

5. Reticular fibres
Divides the lymph node into individual cells

6. Capsule
The protective fibres surrounding the lymph node

7. Sinus
A channel that slows the flow of lymph, giving macrophages the opportunity to destroy pathogens

8. Incoming lymph vessel
A vessel that carries lymph into the lymph node

9. Lymphocyte
The T-cells, B-cells and natural killer cells that fight infection

10. Germinal centre
Site of lymphocyte multiplication and maturation

11. Macrophage
Large white blood cells that engulf and destroy pathogens

What is Spotify?

How Spotify works

A quick guide to the ins and outs of Spotify

1. Log in and share
As user one logs on, the contents of their Spotify cache are indexed and sent to the Spotify streaming hub when they connect to the service. Music files are stored to their cache as they play them.

2. Search for music
User two performs a search for a song or artist. This request is then processed by the hub against the index that it compiles from all users.

3. Process the request
The Spotify hub responds to a search by firstly requesting the first piece of the song file from the Spotify servers. Meanwhile, it searches the peer-to-peer network for the remainder. It then switches back and forth between Spotify servers and peers as needed.

4. Share & share alike
The hub then streams the requested song from either the servers or via peer to peer from other users, back to user two's computer where he can listen to it.

5. Listen & share
As user three launches the Spotify app, their computer also starts listening for incoming connections from other Spotify users, as well as intuitively connecting to other users to exchange songs as appropriate.

6. Pay the premium
As a paying premium subscriber, user four can do all this at faster connection speeds and without the adverts between songs.

JARGON EXPLAINED

Hub
A hub is a common connection point for devices in a network. It can receive information from a connected computer and forward it to another on the network.

Peer-to-peer
A method of sharing files and information directly between two computers without the need to access a central server.

Streaming
Playing audio or video immediately as it is downloaded from the internet, rather than storing it in a file on the receiving computer first.

This month in Technology

The diversity of subjects covered in our technology section mirrors the breadth of tasks that technology is used for in today's world. For instance, this month we cover mundane, everyday, but nonetheless interesting stuff like microwave ovens, fax machines and fire extinguishers to more extreme machines such as flamethrowers and bulletproof vests. Cool. Audiophiles and music lovers get special attention too with an explanation of Spotify and speakers.

64 Fax machines

66 Flamethrowers

68 Speakers

TECHNOLOGY

NEWEST

1. Spotify
The pairing of a minimal UI and instant musical gratification, thanks to audio being streamed instead of downloaded, makes Spotify a real contender for the crown.

BIGGEST

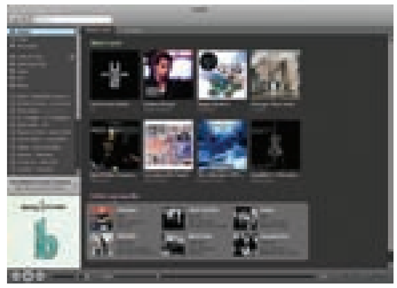
2. iTunes
With no monthly subscription, the best UI on the net, fantastic pairing with iPhones and iPods, as well as the ability to buy single tracks, iTunes is rightly the market leader.

MOST CUSTOMISABLE

3. Last.fm
Last.fm is a popular internet radio and music service which uses a music recommender system call 'Audioscrobbler' to custom build a profile for each of its users.

DID YOU KNOW? Spotify has been active in various European countries since October 2008

What is Spotify?



Seen by many to be the next stage in the evolution of music distribution and reproduction, Spotify is bringing music to the world of cloud computing

Spotify is a new application that is available for PC and Mac – along with some modern smartphones – which allows you to stream music from a vast catalogue distributed through the Spotify central hub and sourced from every other Spotify user.

To use Spotify you would first need to download the Spotify software from **www.spotify.com**, currently you can only do this if you have an invite from an existing Spotify user. Once installed, Spotify looks a lot like other media players such as iTunes, but there is a big difference. With Spotify, you don't have to download the music in order to listen to it (although this is also possible). Instead you can simply stream it over your internet connection.

How does this work? Well, Spotify delivers music to your PC using a combination of peer-to-peer sharing and streaming from its servers (see the jargon boxout on the previous page for an explanation of these terms). When a Spotify user opens the application it makes an index of the contents of their Spotify cache and sends this to the Spotify streaming hub. The cache contains all the music files or pieces of music files that Spotify sends when a user is listening to tracks. The streaming hub can then use this index to share these music files and pieces of files with other Spotify users. So while you are receiving the music stream, your computer is also sending music to other users on the network and it's this combination of peer-to-peer sharing and streaming from a server that gives Spotify its famously fast response time.

In other respects, Spotify works like many other media players and online music stores, allowing users to browse its 6 million tracks via name, genre, artist etc, as well as allowing custom playlists to be created and random radio lists to be constructed. Individual tracks, albums, playlists, as well as money to extend subscriptions or buy downloads, can also be shared easily from user to user and there are community forums in order for users to stay in touch with each other.

Spotify makes money from both interspersing music tracks with advertisements (the frequency of these ads can vary depending on time-frames and last between 10-30 seconds), or by getting its users to sign up as a premium user, which costs £9.99 per month. If users take up a premium subscription then there are no advertisements between tracks, allowing for continuous playback.

Cofounders of Spotify Daniel Ek and Martin Lorentzon

ON THE MAP

Where is Spotify available?

Currently it can be used in:
- United Kingdom
- France
- Sweden
- Spain
- Norway
- Finland

It will also be available in:
- Italy
- Portugal
- Germany
- Denmark
- Netherlands
- Estonia
- Poland
- Belgium
- Austria
- Switzerland
- Romania
- Greece

"It can be programmed to recognise certain people"

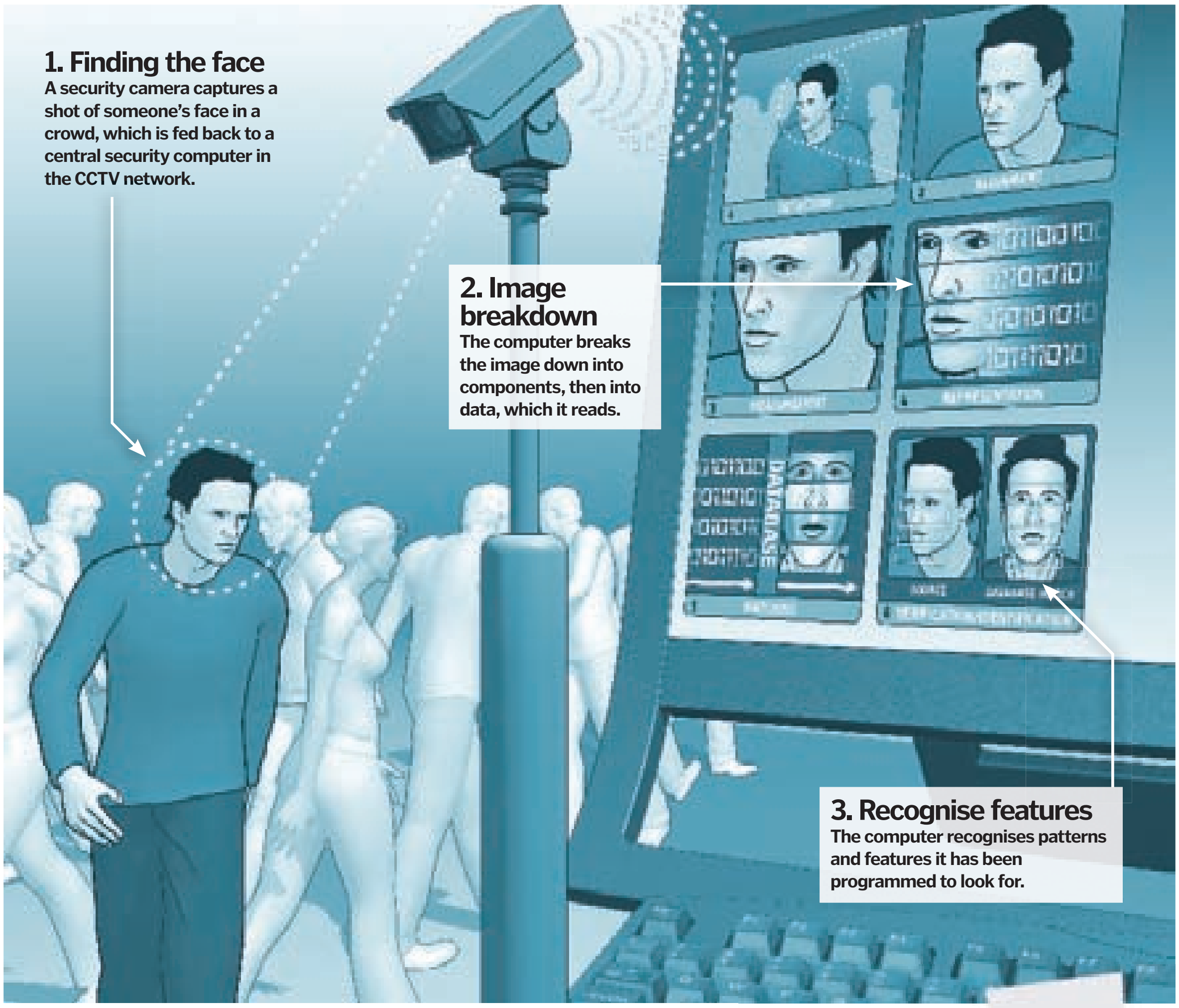
Facial recognition explained

Find out how a computer can pick you out from the crowd

Facial recognition is something that comes easily to humans – we learn it within weeks of birth – but it was a much harder feat to achieve with a computer. We recognise faces because we are, essentially, 'programmed' to do so by our evolutionary psychology, but a computer – which is based on a structure of logical, mathematical principles – doesn't have the emotional input that allows us to recognise even a colon and an end-bracket as a smiley face.

To get a computer to recognise a face you have to program it to look for certain things. For a start it has to be able to distinguish between a human face and everything else. This is done by programming a piece of software to look for what are known as 'nodal points'. These statistics govern things like the common width of noses or the standard range of depth for eyes.

Once the software can recognise the basic concept of a face, it can be programmed to recognise certain people. Your camera may have a Face Recognition feature, which you have to initially set up, taking several pictures of people and tagging them by name. The software learns the measurements of the nodal points around their faces thus recognising them automatically.



The fax machine

How images can be sent using sound

The humble fax machine, despite its analogue origins, actually shares a great deal of history and technology with computers and the internet. The image is scanned at user chosen resolutions and is treated as multiple lines. Each line is a series of dots in the horizontal plane and the pattern of dots is encoded into known binary patterns (ones and zeros) from a lookup table. A lookup table is an unordered collection of values with each value indexed by a "key," a value of any type that's used to look up another value stored in the table.

The binary codes are then modulated by a modem which further changes the pattern of ones and zeros. Depending on the new pattern of ones and zeros many different tones will be sent to the fax machine at the other end where the information is decoded and reprinted on another sheet of paper.

5 TOP FACTS
FIRE EXTINGUISHERS

Remove basic elements
1 All fire extinguishers work by removing any one of the three basic elements necessary for fire to burn – these being oxygen, heat and fuel.

Type matters
2 There are eight different types of fire extinguisher available, including: water and foam, dry and wet chemical, clean agent and powder variants.

Class of fire
3 The five classes of fire are class a, ordinary combustibles; class b, flammable liquids; class c, electrical; class d, combustible metals and finally class k, oil fires.

Fire in the hole
4 The fire grenade was an early experiment involving a small glass bottle filled with extinguishing agent thrown into fires in an attempt to put them out.

Colour co-ordinated
5 The colour of a fire extinguisher varies from country to country. UK fire extinguishers are red with coloured bands to denote their type.

DID YOU KNOW? The very first fire extinguisher was patented in England in 1723

Inside fire extinguishers

Since their creation in the 18th Century, fire extinguishers have played their part in saving countless lives


Another family barbecue suffers due to over-enthusiastic use of firelighters

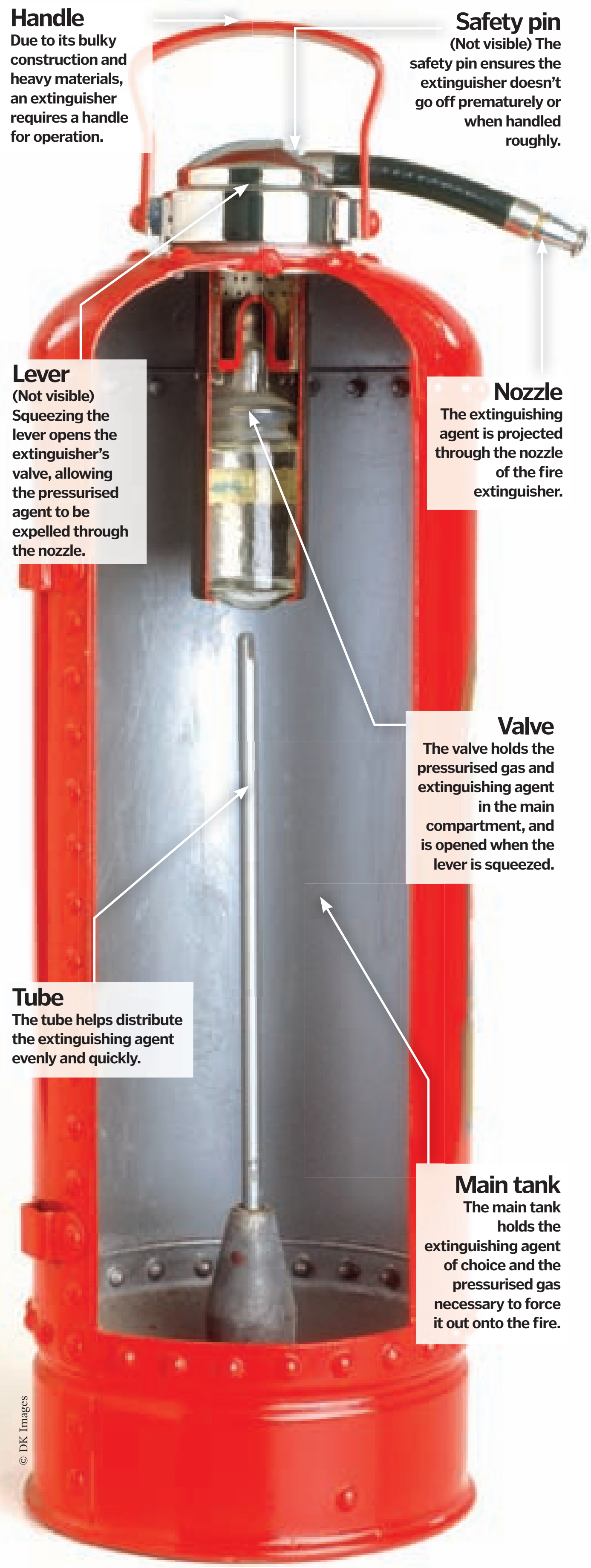
There are two main types of fire extinguisher; those with internal stored pressure, and those where pressure is delivered through a cartridge system. The most common by far of these two is the former, with cartridge-based systems reserved mainly for industrial use. Both variants of extinguisher work in the same way though, removing one of the three things fire needs to burn: oxygen, heat or fuel. This is achieved by holding their contents under pressure – either from pressure within the main tank or from the external cartridges – causing a rapid expulsion of extinguishing agent when operated. Basically, when the lever is squeezed on the top of the canister, a valve is forced open allowing the release of the pressurised gas and contained agent through the fire extinguisher's nozzle.

Despite the delivery method and vehicle split between only two main variants, there are many differing extinguishing agents used in modern-day fire extinguishers. Water and water-additive fire extinguishers work by propelling water by pressurised gas onto a fire to cool it and soak its fuel, preventing it burning further. Foam and powder extinguishers – which propel powder and foam under low pressure – do not put out fires in this manner, achieving a neutral environment by smothering a fire with its agent, cutting off its oxygen supply instead of dowsing its fuel. CO_2-based systems work in a similar manner too, expelling the gas – which is extremely cold – onto the blaze, cooling it and displacing any oxygen in the atmosphere.

The modern pressurised fire extinguisher we are familiar with today was created in 1818 and consisted of a three-gallon copper vessel of a potassium carbonate solution contained within compressed air.

A typical, internally pressurised fire extinguisher, found in most private homes

A rare cartridge-based fire extinguisher, used mainly in industrial environments



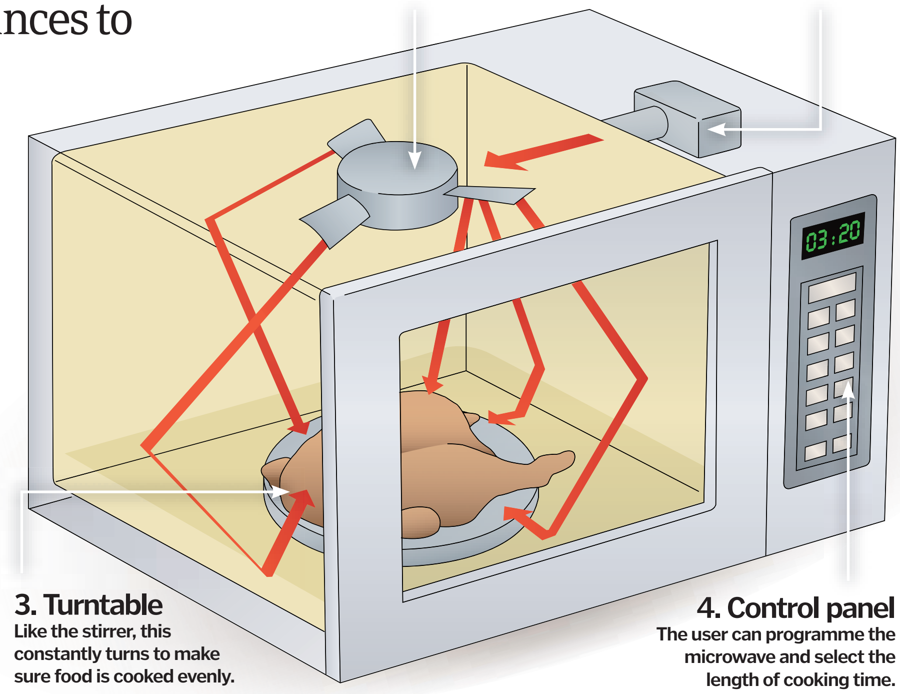
“Liquid substances absorb these waves”

Microwave ovens

What enables these kitchen appliances to cook food at high speed?

The microwave may be ubiquitous now but just a few decades ago it was one of the most exciting innovations to hit your kitchen counter. Microwaves cook food much faster than conventional ovens, meaning that we spend less time in the kitchen. How do they do this? Surprisingly, it’s with radio waves – a particular kind known, not surprisingly, as microwaves. Liquid substances like water or the sugars and fats in your food absorb these waves. When they do so, the energy in the waves is converted into heat. This is because the waves have a relatively short wavelength, meaning that they can pass into porous substances like food but not into thicker, more solid substances like ceramic plates (it’s the heat from your food that causes these to be hot when you get them out of the microwave). Metal, however, reflects microwaves, bouncing them around inside the oven and intensifying them – which is why it’s not a good idea to put metal in your microwave!

DID YOU KNOW? Microwaves differ from conventional ovens because they excite atoms of food at a molecular level, causing them to create heat.



Portable flamethrowers

A weapon that packs a lot of heat…

Fire has been employed by humans for war since it was first controlled and created by prehistoric man. However, as a weapon its most portable and horrific usage came at the start of the 20th Century. The handheld flamethrower, as used in both World Wars, as well as the Vietnam, Gulf and Iraq conflicts, works by propelling a lit stream of flammable liquid from a pressurised container.

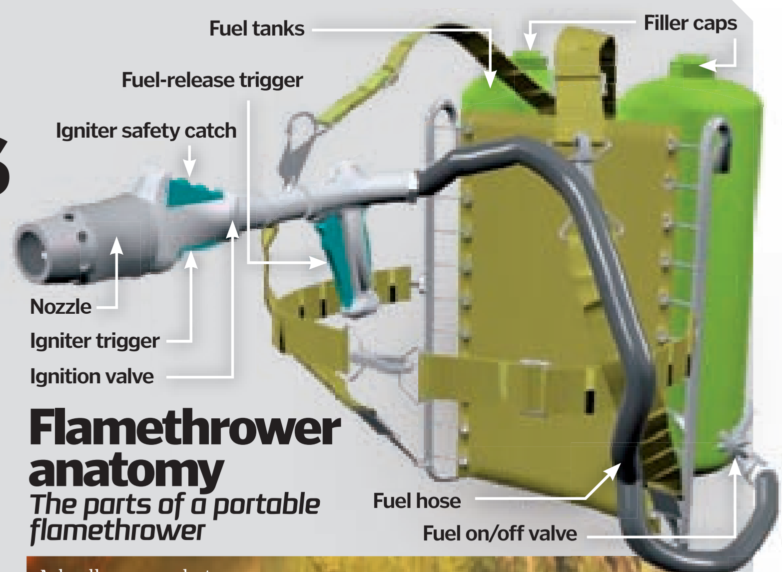
Typically, the flamethrower consists of three cylindrical containers, two of which contain inflammable liquid – usually petrol with added fuel thickener – and one that holds compressed, inert propellant gas. The gas, which is typically nitrogen, propels the inflammable liquid down a flexible pipe to the second part of the flamethrower system, the gun element. The gun element, which is the heavy, dual handle part of the system held by the user, consists of the body, fuel release trigger, valve plug, ignition valve and trigger, battery unit and spark plug.

Once the inflammable liquid is pushed into the gun element from the backpack containers, it fills up a long rod container, which is then held in place by the system’s valve plug. This valve prevents the liquid from flowing out of the nozzle when the trigger is released. When the operator pulls the trigger this rod is pulled backwards within the body, opening the valve, and allowing the pressurised liquid to burst forward towards the nozzle. In order to actually ignite the liquid, however, it must pass over the battery-powered spark plugs. To do this, the operator flicks the ignition valve release switch before pulling the ignition trigger, activating the spark plugs and lighting the fuel stream.

Typically, a portable flamethrower can shoot a full stream of ignited fuel over 70 metres, and is often used to smoke out enemies as well as to clear areas of intense natural growth.

Flamethrower anatomy

The parts of a portable flamethrower




A deadly weapon but also a handy item for camping trips…

Bulletproof vests explained

How does armoured apparel stop a bullet?

There are two different types of bullet-resistant vests – soft and hard – with many varieties using a combination arrangement to absorb the impact from firearm-fired projectiles and shrapnel from explosive devices. So-called 'soft' bulletproof vests are made from multiple layers of woven, interlaced laminated fibres, which prevent bullet penetration by spreading its impact force throughout its layers and dispersing the energy that would otherwise have punctured the target. Of course, the material used to create the finely woven fibres needs to be exceptionally strong also, and in the majority of modern day vests Kevlar is the material of choice as it offers five times the strength of steel. Further, Kevlar is lightweight, allowing the wearer to retain maximum mobility. Soft bulletproof vests provide protection from the majority of pistol rounds, shotgun shrapnel and knife attacks.

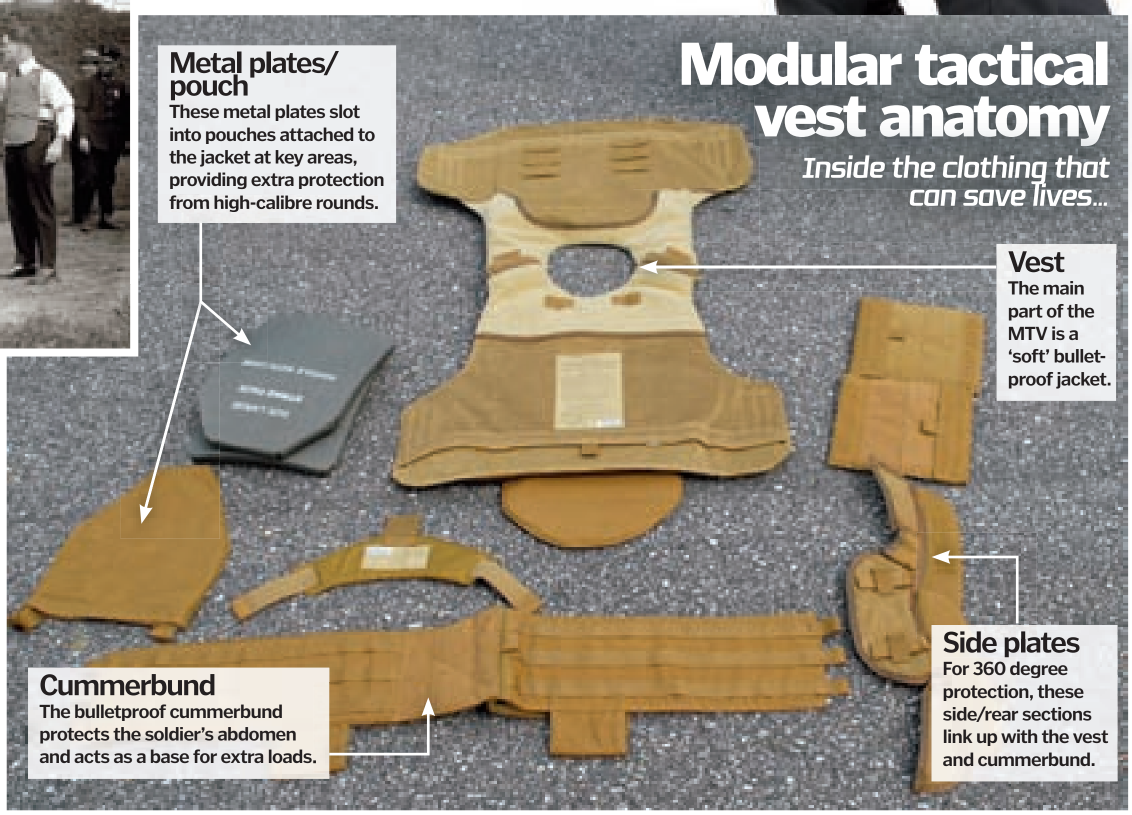
There are natural limits to a soft vest however, with super-hard rounds fired at high velocity capable of tearing its material and breaching its critical kinetic energy threshold. For these, 'hard' bulletproof vests are required, which use the same technology as the soft suits, yet have integrated ceramic (usually alumina) and hard-metal plates to halt and deflect larger, quicker rounds. These plates are designed to slow or deform any bullet that comes into contact with them, often mushrooming the bullet's shape and dispersing its energy. In addition, while soft vests have a certain knife tolerance, these plates provide added protection against bladed weapons. Hard vests are usually integrated into military outfits.

Current advances into personal bullet-resistant body armour have seen the rise of fully ceramic vests, which use two and three-dimensional arrays of ceramic elements that can be rigid, semi-flexible or flexible, as well as providing a high-calibre multi-hit threshold. Further, at the cutting edge of this rapidly advancing field, vests are now being created out of nanomaterials, utilising the fine weaves of carbon and tungsten nanotubes to provide protection from projectiles of velocities up to 1.5km/s, as well as withstanding impact pressure up to 250 tons per square centimetre. Unfortunately, however, despite the phenomenal stopping power that these vests can achieve, the materials needed to create them are currently prohibitively expensive for a mass-market release.

A SWAT Marine posing in full body armour

"Now hold still, this won't hurt a bit…"

Bulletproof vests are now often given to dogs that are operating in war zones



> "No longer was music trapped in the present. Now it could be recorded, stored and replayed in the future"

Audio reproduction

Since the creation of the phonograph in the late 19th Century, sound reproduction systems have evolved massively, culminating in the hi-tech audio and loudspeaker systems we use today


© Monitor Audio

The recording and reproduction of audio undertook sweeping changes throughout the late 19th and 20th Centuries, offering numerous new storage mediums, playback systems and methodologies that allowed humans to control the sound wave like never before. At first relying on mechanical inscription and recreation techniques, before advancing onto electrical methods, the analogue and digital recording of speech, music and environmental noise has brought sounds never before heard to the masses, as well as creating two of the most dominant entertainment business on the planet, music and film.

Indeed, when the phonograph (the earliest form of audio recording and reproduction system, partnered with a horn loudspeaker) was first invented in the latter half of the 20th Century, it advertised a system that could 'transport you to the realms of music' and that it could 'bring the theatre or opera to your home' after a hard day's work. It was a revelation. The sound wave had been captured and harnessed by man. No longer was music and speech trapped in the present. Now it could be recorded, stored and replayed in the future. Higher forms of musical entertainment were no longer the reserve of only the rich and powerful, with the best opera and ballet scores transported to the homes of many.

Since then techniques and machines used to record and reproduce audio have progressed rapidly, and with them have the loudspeakers necessary to output their signals. Most early phonographs or gramophones used horn loudspeakers, which acted like modern-day amplifiers, and worked by increasing the coupling efficiency (akin to increasing the surface area of an object) between the system's driver, which was often a small metal diaphragm, and the surrounding air. This mechanical amplification effectively increased the volume of the outputted vibrations emanating from the diaphragm, and made the sound audible to listeners over a wider area.

Now, of course, amplification is normally achieved through electrically driven amplifiers, and the complex loudspeaker systems in use today rely on more than just spreading the surface area of sound waves. Here we take a closer look at how modern loudspeakers work.

History of audio systems

Audio systems have evolved massively since their creation in the late 19th Century

Cylinder phonograph

Date made: 1877

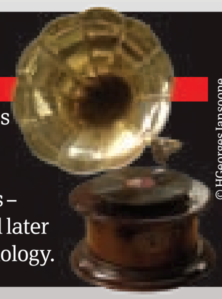
By rotating cylindrical records on which audio was engraved, these engravings would, via the medium of a stylus, vibrate a diaphragm at the base of a metal horn, which would in turn amplify the sound.


© Holger Ellgaard

Gramophone

Date made: 1892

Gramophones read the grooves in the circular disks by their needle – like the cylindrical phonograph did with its stylus – amplifying sound by horn and later electronic amplification technology.


© HGeorges Jansoone

5 TOP FACTS SPEAKERS AND AUDIO

Feel the base

1 At 190 decibels the human eardrum has a 50 per cent chance of rupturing, and this can result in loss of hearing and take weeks before the eardrum heals completely.

Maximum power

2 The world's loudest speaker is the Wyle Labs' WAS 3000, which can produce a sound level of 165 decibels, five times louder than a space shuttle taking off.

Do you retro?

3 The last mass-market cylindrical phonograph record was produced as late as 1929, while today they are still made by specialist audio companies for collectors.

Crossed channels

4 During WWII the residents of Dover reported that they could hear the sound waves emanating from warfare across the channel in France, a distance of 21 miles away.

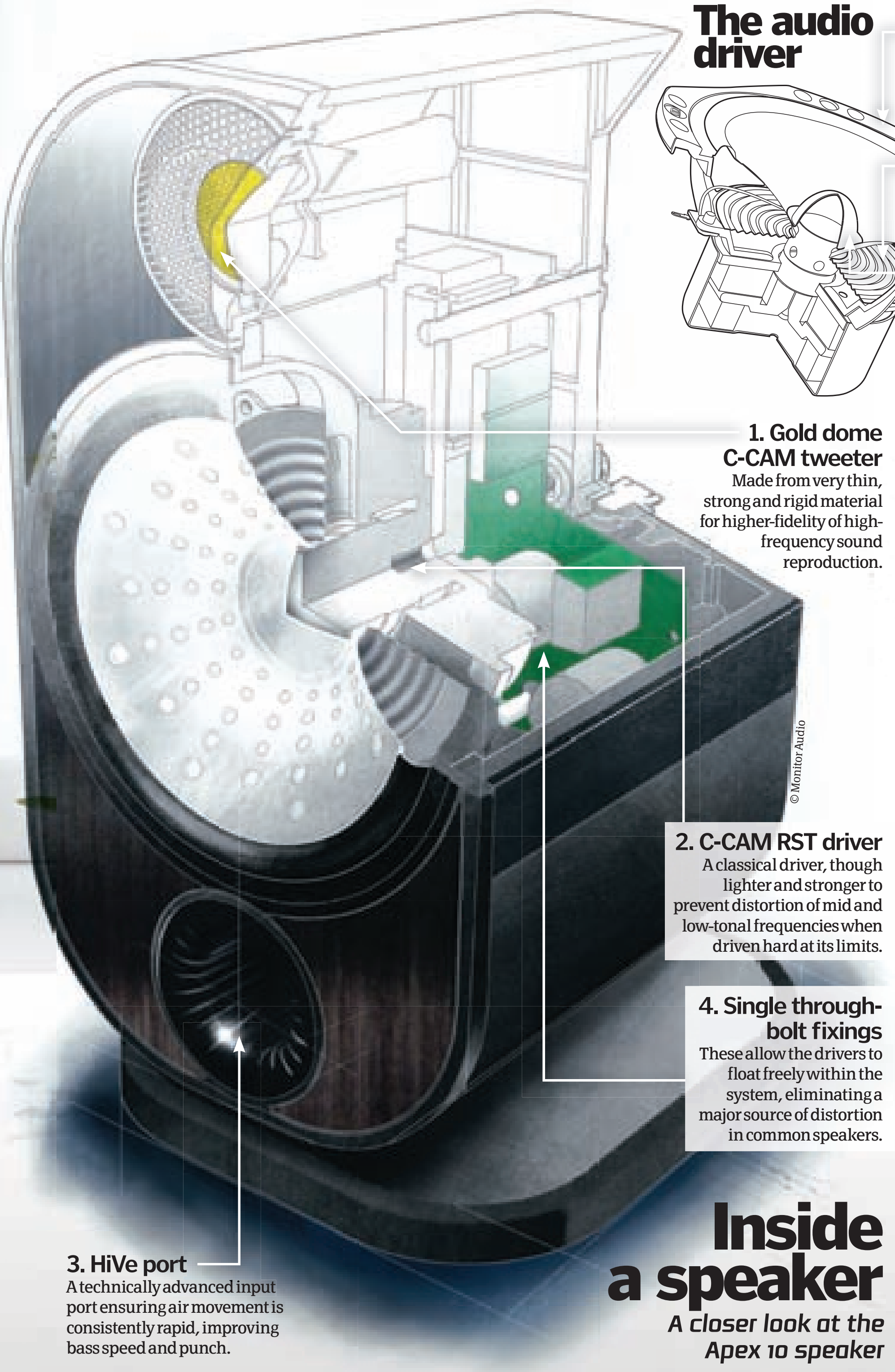
Can't keep it down

5 Despite the dominance of the CD, over 1.8 million vinyl records were sold in the United States in 2008, an increase of over 800,000 from 2007.

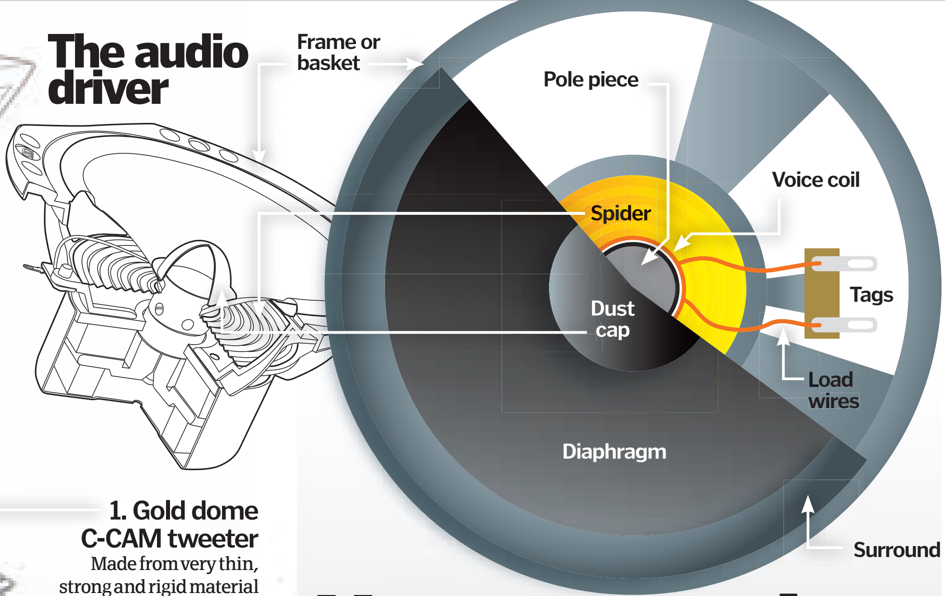
DID YOU KNOW? *German scientist Johann Philipp Reis created the original loudspeaker in 1861*

Inside a speaker

A closer look at the Apex 10 speaker



The audio driver



How a speaker works

Even the clearest of recordings are useless without a good loudspeaker

The modern loudspeaker, as demonstrated by the Monitor Audio Apex series, produces sound by converting electrical signals from an audio amplifier into mechanical motion, from which sound waves emanate. Loudspeakers can consist of an individual transducer (audio driver) or a series of drivers encased within large chassis, each dealing with a certain frequency band to improve the overall gamut and fidelity of reproduced sounds.

For example, larger subwoofer speakers deal with low frequencies, while smaller speakers called tweeters deal with high frequencies. These various drivers are controlled by a filter network, which organises the different frequency signals coming from the amplifier and directs them to the driver most suitable to deal with it.

The construction of a single loudspeaker driver is a complex process, the central element of which is a concave plastic or paper conical disc. This is the part that moves backwards and forwards in the generation of sound, fixed in the centre of a concave metal frame. Attached to the cone is a hollow cylinder of aluminium and a pair of wire coils suspended by a flexible fabric disc. These coils are attached to the amplifier and positioned inside a narrow cylindrical groove in the centre of a magnet. By doing this, every time a signal travels through the wires, the coil emits a magnetic field that pushes or pulls the cone backwards or forwards, forming sound waves.

Tape player

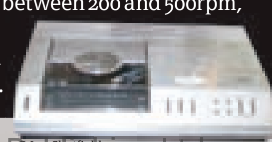
Date made: 1950

The invention of magnetic tape lead to the creation of reel-to-reel tape players. Magnetic tape allowed large recordings to be stored for lengthy periods of time and done so in multiple takes.

CD player

Date made: 1982

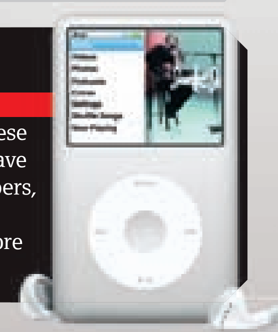
With the introduction of compact discs, CD players took over as the dominant audio system. CD players work by rotating a disc between 200 and 500rpm, reading the encoded information contained on it with a laser beam.



MP3 player

Date made: 1997

The current player of choice, these work by converting an audio wave into a sequence of binary numbers, which can then be stored in a digital format such as MP3, before utilising audio codecs.



DID YOU KNOW?

Speaker placement can alter sound quality

Due to the fact that sound bounces off of the objects in your room, where you position your speakers will directly effect the quality of the sound that you hear. For instance, placing speakers too close to the wall will increase the bass sound, making it too loud or boomy. In general try to keep the speaker three inches from the wall, the speakers' distance from the side wall should be 1.6 times the distance from the front wall. Angle the speakers inwards towards the general listening spot.

Inside a freestanding speaker

The Monitor Audio PL300 demonstrates what lies inside the cabinet

1. Bitumastic damping
This adhesive is applied to all internal cabinet walls to reduce resonance damping as well as aiding structural rigidity.

5. Tapered Line Enclosure (TLE)
Formed from a ARC thermo-set polymer, the Tapered Line Enclosure houses all of the mid-range drivers in the PL300, preventing the propagation of standing waves and modal resonances.

2. Polymer casing
Almost all elements of the PL300 loudspeaker's case, including front baffles, plinths and mid-range driver housings, are cast from a thermo-set polymer characterised by its high mineral content.

3. Steel 'pin hole' brace
A set of four steel braces, tightened to a specific torque, run through the polymer casing to further reduce unwanted resonance.

4. HiVe II high velocity reflex ports
Twin HiVe II ports allow maximum airflow in and out of the cabinet quicker than a conventional port as well as reducing turbulence, providing super-powerful base and a superior transient response.

6. Composite plinth
Raising the casing from the floor, the composite plinth helps prevent vibration distortion as well as reducing resonance.

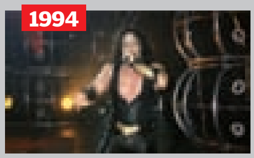
© Monitor Audio

© Monitor Audio

The PL300 from Monitor Audio represents the current pinnacle of multi-driver, loudspeaker technology

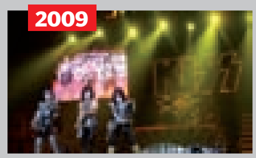
1976

1. The Who
Where: London, England
When: 31 May 1976
How loud: 126dB



1994

2. Manowar
Where: Hanover, Germany
When: 8 March 1984
How loud: 129.5dB



2009

3. Kiss
Where: Ottawa, Canada,
When: 15 July 2009
How loud: 136dB

DID YOU KNOW? *The speed of sound varies depending on temperature and altitude*

Multi-driver loudspeaker enclosures

Floor-standing loudspeakers are now being produced which combine multiple audio drivers with audio-friendly, structurally complex cases

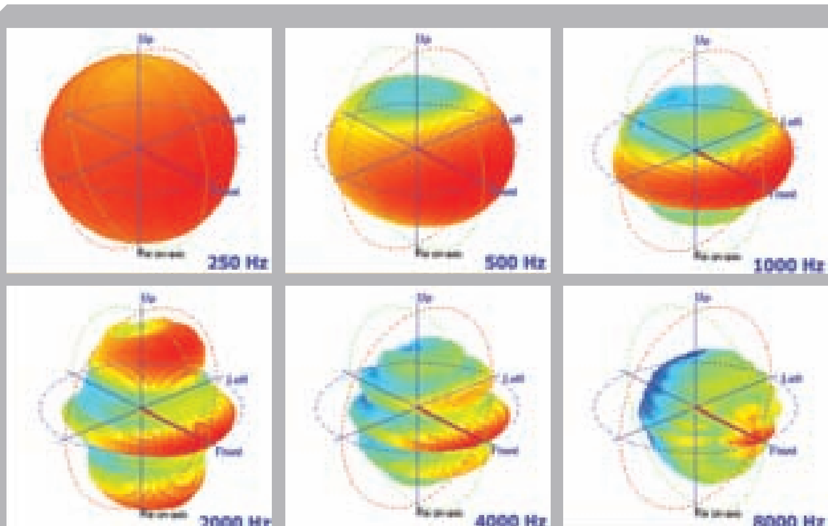
An example of an older, metal-framed, audio driver chassis

The enclosure of any loudspeaker plays a highly significant role in the reproduction of sound, as well as providing a unit in which the speaker's drivers, electronic circuitry, crossover control and amplifier are all mounted.

Current state-of-the-art enclosures are built from composite materials and include numerous struts, baffles air ports and acoustic insulation materials and adhesives. These work together to reduce echo and reverberation caused by rearward sound waves generated by the speaker's drivers reflecting off the back and sides of the case. This is important for audio fidelity and accuracy of reproduction, as rogue or errant sound waves can interfere with forward-generated waves, distorting them and adding effects not part of the original recording. The enclosure, thanks to its complex construction, is also the key factor in reducing vibrations caused by the back and forth movement of the driver diaphragm, shake of the driver chassis and rumble of any subwoofer.

Historically, in early forms of loudspeaker, drivers were often left exposed completely or partially due to heat-related issues with their electronics, as well as because of the fixed, unsuspended nature of the driver chassis and the difficulty in securing a consistent airflow. Further, the materials used in these early loudspeakers (usually heavy metals) were prone to vibration issues and did little to prevent standing waves, while their chunky and bulky designs caused diffraction of sound waves from their sharp edges.

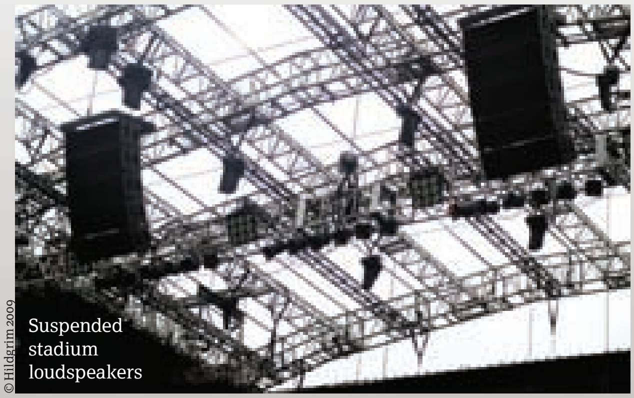
Today, these flaws are minimised by audio-friendly, lightweight polymer casing materials, which are manufactured with smooth edges to reduce refraction and coated with resonance and vibration damping adhesives. Single component plinths, baffles and struts, as well as lightweight driver chassis also aid the accuracy of sound reproduction and, thanks to the inclusion of transmission lines (an internal structure within the loudspeaker enclosure designed to guide up to 90 per cent of a driver's rear wave output away from distortion-prone areas) in modern cabinets, has allowed sleeker and more compact driver arrays.



Polar frequency patterns

Frequency has dynamic effects on loudspeakers

Composite images of six loudspeaker polar patterns taken at six frequencies over a five octave range. The speaker is a Bosch 36 watt column with four four-inch drivers arranged in a columnar enclosure 841mm high. The Polar prediction software used is CLF viewer and loudspeaker information was gathered by the manufacturer.

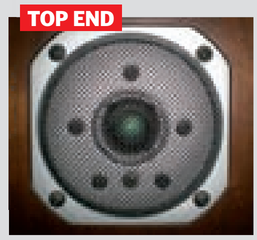


Suspended stadium loudspeakers

© Hildgrim 2009

Where does he put the luggage?

Head to Head SPEAKER DRIVERS



TOP END

1. Tweeters

Tweeters are much smaller units, designed to produce the highest frequencies typically from around 2,000Hz to 20,000Hz. Some tweeters can manage response up to 45kHz. Nearly all tweeters are electrodynamic drivers, using a voice coil suspended within a fixed magnetic field. The name is derived from the high-pitched sounds made by birds.

MIDDLE

2. Midrange

As the name suggests, midrange drivers produce a range of frequencies in the middle of the sound spectrum, with a frequency range from approximately 300-5,000Hz. Midrange drivers handle the most significant part of the audible sound spectrum. For this reason the midrange speaker must be good quality or discrepancies will be heard.

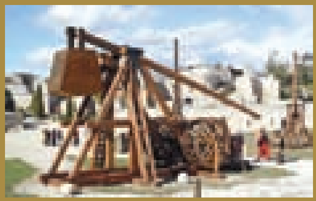
BASS IN YER FACE

3. Woofer

Designed to produce low frequency sounds, typically from around 40Hz up to about a kilohertz or higher. The most common design for a woofer is the electrodynamic driver, which typically uses a stiff paper cone, driven by a voice coil which is surrounded by a magnetic field. The voice coil is attached by adhesives to the back of the speaker cone. Woofers are generally used to cover the lowest octaves of the system's frequency range although subwoofers are also sometimes employed.

This month in **History**

We have a veritable banquet of tasty historical treats for you this month. To kick things off we take a look at the great steam inventions that shaped the industrial revolution of the 19th Century. We also find out what happened when a huge fire took hold of England's capital city in 1666, as well as discovering the mechanisms of one of the most destructive inventions of the Middle Ages, the trebuchet.



HISTORY

The steam en

For centuries the steam engine has been powering the British industry and even today steam plays a big part in the generation of electricity. We take a look at the men behind these major inventions

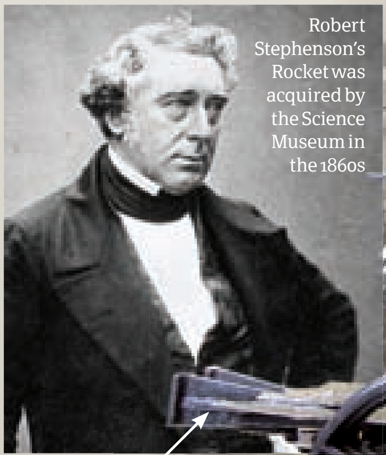
Until the start of the 18th Century, machines were powered by muscle, water or wind, but steam power provided the potential for growth and flexibility on a mass scale. Steam engines facilitated the birth of large factories as production moved from rural riverbanks to industrial towns creating the formation of the cities we know today.

Steam power had been around for generations but it wasn't until 1698 that its application into industry was made. Military engineer Thomas Savery created a patent for raising of water by "the impellent force of fire" the first noted design of a steam pump. In 1712 Thomas Newcomen continued Savery's work and constructed the first successful steam engine, the atmospheric engine. Its purpose was to rid coalmines of floodwater, allowing miners to reach new depths. It was considered so efficient for its time the design wasn't altered for six decades and the template was copied up and down the country.

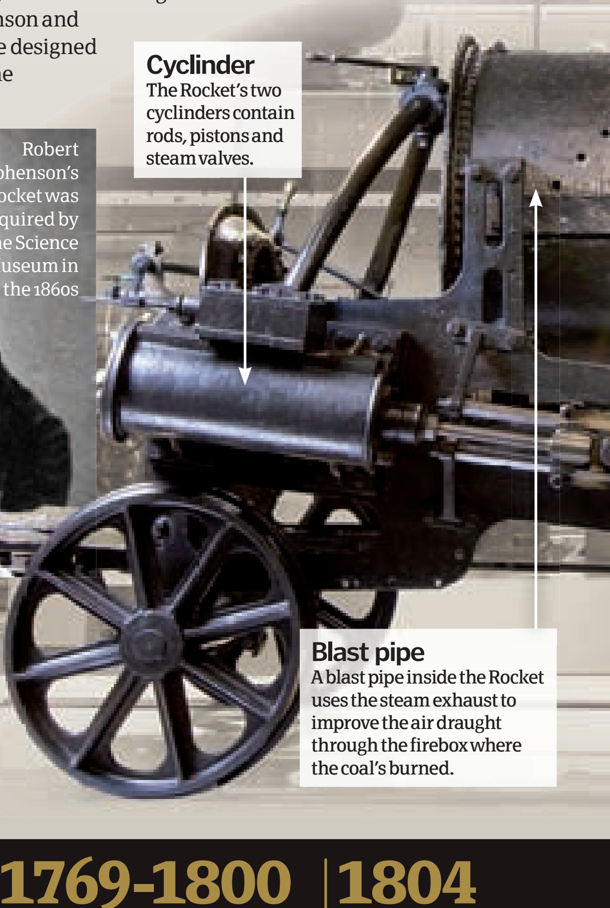
British engineer James Watt came to largely represent the face of the steam movement, because his many patents prevented other engineers from furthering the progression of steam-powered machinery until they expired in 1800, at which point a hungry new league of engineers took up the baton. Richard Trevithick pioneered 'strong steam' (steam at high pressure), meaning vapour could be 'compounded' and used repeatedly in a series of cylinders. Such a method was used in ships, railways and agriculture, inspiring new vehicles and machines, from self-propelled steam boats and carriages to traction engines for the land and engine houses for grinding and processing grain.

By 1820 steam locomotives were commonplace and in 1830 'The Liverpool and Manchester Railway' opened as the world's first passenger service, engineered by George Stephenson and utilising locomotives that were designed by his son Robert, including the magnificent Rocket.

Towards the end of the 19th Century inventors found new ways to maximise steam efficiency and in 1884 Charles Parson's steam turbines opened a whole new world of possibilities. Today steam-powered engines are no longer in widespread commercial use, but some of their applications can still be seen from the production of electricity to underwater jet engines.



Robert Stephenson's Rocket was acquired by the Science Museum in the 1860s



Cyclinder
The Rocket's two cyclinders contain rods, pistons and steam valves.

Couple
Any coaches attached to the Rocket were fastened by a couple at the back of the steam engine.

Blast pipe
A blast pipe inside the Rocket uses the steam exhaust to improve the air draught through the firebox where the coal's burned.

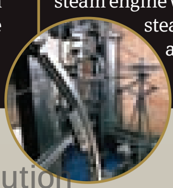
A history of steam…

1698
Thomas Savery patents his machine for the raising of water by the "impellent force of fire", the first design of a steam pump.

1712
Thomas Newcomen builds the first practical steam engine. It is erected near Dudley Castle in Staffordshire.

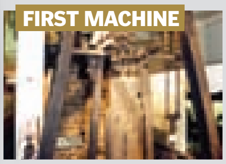
1733
Savery's patent expires meaning more Newcomen engines could be built without infringement.

1769-1800
James Watt dominates steam-engine design and improvement. The Watt steam engine was the first to use steam at a pressure above atmospheric to drive the piston.



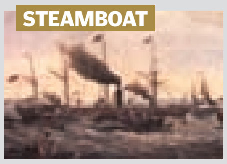
1804
Arthur Woolf builds a compound engine that matches the work of Watt's machines using half the fuel.

FIRST MACHINE



1. Newcomen's steam pump (atmospheric engine)
Designed for the coalmining industry, it pumped water out of the mines, allowing workers to penetrate deeper.

STEAMBOAT



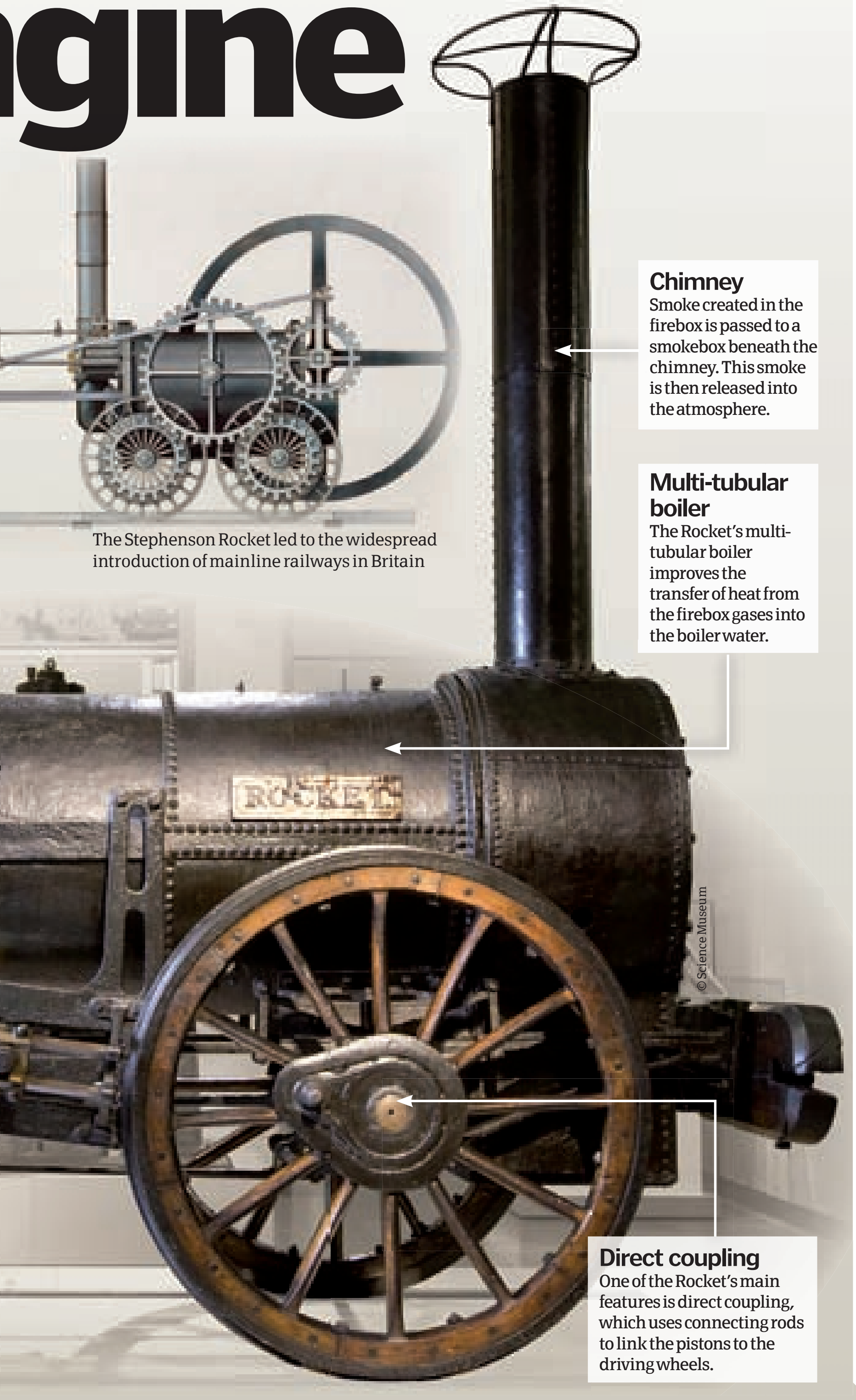
2. Great Western
By the 1830s ocean-faring steamships appeared like Isambard Kingdom Brunel's paddle steamer the Great Western, which employed high-pressure steam.

FIRST BUS SERVICE

3. The Enterprise
In 1833 the Walter Hancock Enterprise carriage became the first self-propelled vehicle to operate a scheduled bus service for fare-paying customers.

DID YOU KNOW? *The rest of Europe was desperate to snaffle Britain's steamy ideas and espionage became rife*

gine



The Stephenson Rocket led to the widespread introduction of mainline railways in Britain

Chimney
Smoke created in the firebox is passed to a smokebox beneath the chimney. This smoke is then released into the atmosphere.

Multi-tubular boiler
The Rocket's multi-tubular boiler improves the transfer of heat from the firebox gases into the boiler water.

Direct coupling
One of the Rocket's main features is direct coupling, which uses connecting rods to link the pistons to the driving wheels.

The Science Museum Ben Russell

We spoke to Ben Russell, the curator of mechanical engineering at the Science Museum, to find out more about the early steam industry

How It Works: Why was steam so significant to British industry?
Ben Russell: Using a waterwheel to drive stuff only gets you so far. If Britain was to become this huge industrial nation, it needed a way of getting power to wherever people needed it – and steam was the way of providing that.

HIW: Why is Stephenson's Rocket such an icon of the steam age?
BR: The Rocket was built for the Rainhill Trials in 1829, intended to choose the locomotive design for the Liverpool Manchester Railway. It was competing against a number of other engines, but it won because it packaged together a whole series of innovations in engine design, and in doing so laid the basis for locomotive design up until the 20th Century.

HIW: What is the importance of Newcomen's steam pump?
BR: If we didn't have enough coal the Industrial Revolution would have faltered early on [we might never have become the industrial capital of the world]. This development depended on making a mine deep enough to get to deep coal reserves without the mine filling with floodwater. For the first time the engine was capable of providing a huge amount of power to keep the mines free of floodwater so they could get to that coal and produce sufficient coal to keep the industry ticking over.

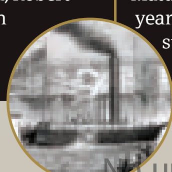
HIW: How significant was James Watt's contribution to the history of steam power?
BR: Watt died in 1819 and even then he and his son had spent a lot of time building this 'Watt myth' that he's the bloke who created modern Britain. There was a lot of myth-making and many engineers were written out of the story of the development of the steam engine. When Watt died, the workshop at his house in Heathfield, Birmingham, was left untouched until the 1860s and preserved as it was when he left it.

In 1924 the house was demolished and it was [offered to] the Science Museum. We have an entire room with 6,500 objects in it. You're standing on the original floorboards, looking through the original window, opening the original drawers… It's like a proto-shed because, as nowadays, people have stuff in sheds that sits gathering dust, which is exactly what Watt did except the projects he was working on an outstanding physical record of his work. He could've had an equally successful career as a potter, chemist or surveyor as steam engineer. So Watt was a very multitalented bloke.

The Newcomen engine could replace 120 horses turning chain pumps, or the equivalent of about 2,000 men with buckets doing the same work

1806
Richard Trevithick becomes the first British engineer to use high-pressure 'strong' steam. The machine revolutionised transport.

1807
The first proficient commercial steam boat was launched; Robert Fulton's North River Steamboat.



1812
First commercial locomotive constructed by Matthew Murray. Eight years later there were 20 steam locomotives in service.

1827
Goldsworthy Gurney built a steam carriage to be used as a vehicle on the roads, motoring along at 15mph.

1884
The steam turbine replaced steam power in its previous form with Charles Parson's axial-flow turbine.

1918
The end of the longest working atmospheric engine. Built by Francis Thompson in 1791 it stood at Pentrich Colliery.

DID YOU KNOW?

Casualty confusion

Although damage of the fire was extensive, the actual recorded death toll was only six. However, this figure has been challenged in recent times as the deaths of the poor and middle classes were not recorded and many victims may have been incinerated beyond recognition.

DID YOU KNOW? *The smoke from the fire could be seen as far away as Oxford*

How did the Great Fire of London start?

Understanding how the fire took hold of the city

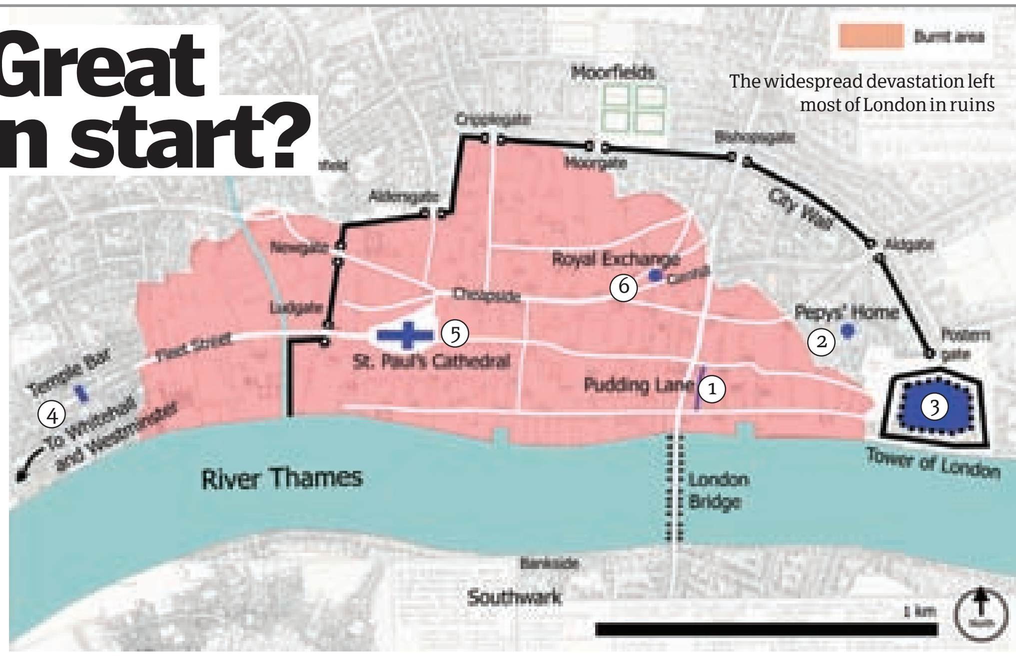
In 1666 London was the largest city in England. Home to 500,000, its congested design comprised an urban sprawl of over-crowded wooden homes inside a defensive city wall.

The Great Fire started on 2 September 1666 in the bakery of Thomas Farriner on Pudding Lane **(1)**, Eastcheap. It's thought his maid forgot to ensure the ovens were put out, and just after midnight the fire took hold. The summer had dried the housing timber and a strong easterly wind fanned the blaze, ensuring it swept rapidly through the heart of the city on a three-day rampage.

The fire-fighting method of the time involved destroying the buildings in the path of the fire to isolate and control it. However, the Lord Mayor of London, Sir Thomas Bloodworth, delayed in giving the order to commence demolition.

Upon being woken by his servant in the early hours, MP Samuel Pepys who lived nearby **(2)** decided to climb the Tower of London **(3)** to survey the destruction. When he discovered the fire had begun to spread west, he took a boat along the Thames to Whitehall **(4)** to inform King Charles II, who immediately ordered Bloodworth to start demolishing buildings and control the spread.

The Tower of London garrison used gunpowder to create breaks and halt the progression east, sparing the Tower and Charles II's court itself, but medieval London was already consumed. The fire was quenched when the strong winds dropped, but monuments including St Paul's Cathedral **(5)** and London's centre of commerce the Royal Exchange **(6)** had already succumbed. 87 churches were razed and 13,200 houses destroyed, rendering 90 per cent of the population homeless. The city was rebuilt on roughly the same street plan and Londoners were encouraged to relocate by the sovereign who feared a rebellion by dispossessed refugees.



The widespread devastation left most of London in ruins

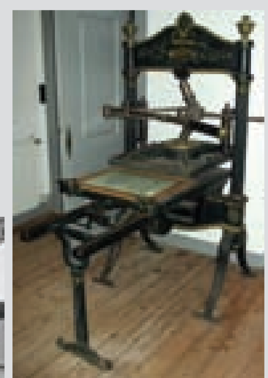
The first printing press

Not only did the printing press speed up book production, it ushered in the democratic dissemination of knowledge, find out how it worked…

Before 1440 only a few thousand handwritten texts existed across Europe. Inspired by the growing demand for lower cost books, Johannes Gutenberg, a German goldsmith, created the printing press – a faster form of semi-mechanical production that revolutionised the world.

Based on the same principles of the screw-type presses used to squash grapes in the Rhine Valley, Gutenberg fathomed a machine that applied pressure to an inked surface on text that rested upon a medium such as paper, thereby transferring an image or text. The machine first featured moveable wooden letters carved by hand, but the plucky inventor later developed an alloy from lead, tin and antimony that could be moulded precisely and quickly into long-lasting printing blocks. Handwritten tomes used water-based ink, but Gutenberg devised the creation of oil-based inks which stuck better to the metal types. These inky-surfaced type blocks were arranged into words and sentences and held by a wooden form, pressure was applied and the letters were pressed onto the surface of paper.

It is thought that the German produced hundreds of texts during his life, but his magnum opus is regarded as the Gutenberg Bible, the very first book to be published as a volume.



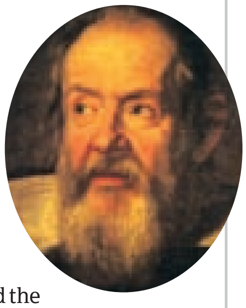
Johannes Gutenberg's printing press replaced the primitive process known as block printing

"With his contraption, Galileo achieved groundbreaking astronomical discoveries"

The invention of the telescope changed many ways of thinking

Galileo's Telescope

How the ancient astronomer explored the skies



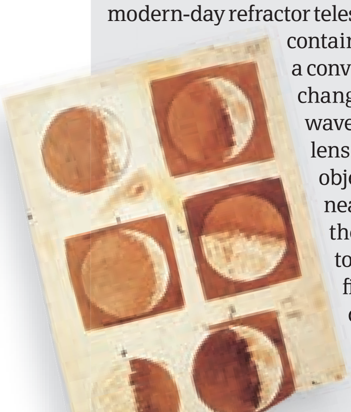
A name now associated with the most advanced modern space discoveries, Galileo Galilei was an Italian astronomer and philosopher born in Pisa in 1564. By far his most celebrated invention was his telescope. Modelled on others of the time, by November 1609 Galileo had invented the world's first telescope with x20 magnification.

With his contraption Galileo achieved groundbreaking astronomical discoveries with the potential to change the way 17th Century man perceived the cosmos. 400 years ago he was the first to realise that the moon was not completely spherical but in fact had cavities and imperfections. He also discovered the first four moons of Jupiter, which became known as the Galilean moons.

In 1610, upon observing the lighting variations across the surface of Venus, or the 'phases of Venus', Galileo came to the assumption that Venus moved around the Sun – a theory that wrenched the Earth from the centre of the universe.

How the telescope worked

Galileo's telescope employed the same mechanics as modern-day refractor telescopes. It consisted of a tube containing a simple arrangement of a convex objective lens (which changes the path of incoming light waves) and a concave eyepiece lens. Light passing through the objective lens is bent to a focus near the eyepiece, magnifying the image. The main downside to the telescope was its narrow field of view, which diminished with magnification, so only a portion of the moon can be viewed at one time.

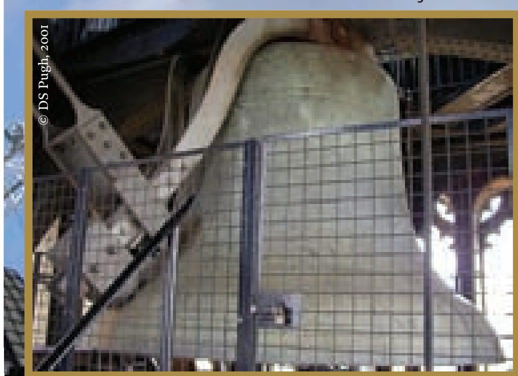


Big Ben

The untold saga of Britain's most famous bell

Though synonymous with the clock tower, 'Big Ben' is the nickname of the 13-ton bell at the heart of the building. Big Ben was cast by Warners of Norton near Stockton-on-Tees in August 1856 and taken to London by rail and sea, and crossed Westminster Bridge on a carriage pulled by 16 white horses.

Before being winched up the tower, it was tested daily until in October 1857 a huge crack appeared. Warners blamed the clockmaker for upping the hammer's weight from 355kg to 660kg and demanded a fortune to start over. So it was decided the new bell would be cast by George Mears at the Whitechapel Bell Foundry. Mears' bell was 2.5 tons lighter but had to ascend the tower on its side – a task that took 30 hours. Then, in September 1859 the new bell also cracked and didn't ring for four years until Sir George Airy, the Astronomer Royal, suggested turning the bell and cutting a square into the metal to halt the crack, plus using a lighter hammer. And this is the bell we hear today.



© DS Pugh, 2001

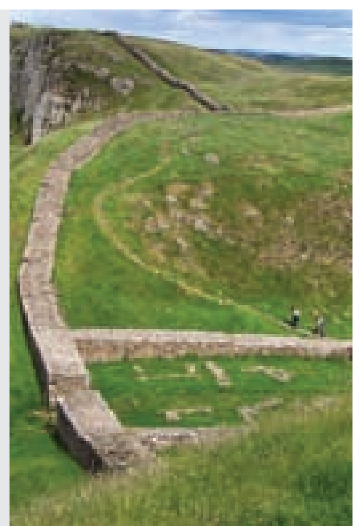
Big Ben was the largest bell ever cast at the time, and since Sir George Airy solved the cracking conundrum it's continued to strike more or less without a hitch

Hadrian's Wall

Was this ancient man-made border really built to exclude the Scots?

An enduring sight on the rural landscape of northern England, Hadrian's Wall stands as a symbol of Roman engineering. Commissioned by Emperor Hadrian in 122AD, for around six years three legions of the Roman army worked on its construction. At 73 miles the fortification is northern Europe's largest ancient monument, extending across the north of England from Bowness-on-Solway in the west to Wallsend near Newcastle-upon-Tyne in the east.

45 miles of the eastern portion was constructed from local stone with an inner core of rubble. The area to the west, meanwhile, consisted of a turf barrier made with a cobbled base. Hadrian's Wall was mistakenly thought to have been built to keep the Scots out, but historians believe it was likely built as a form of border control to monitor population flow between England and Scotland.

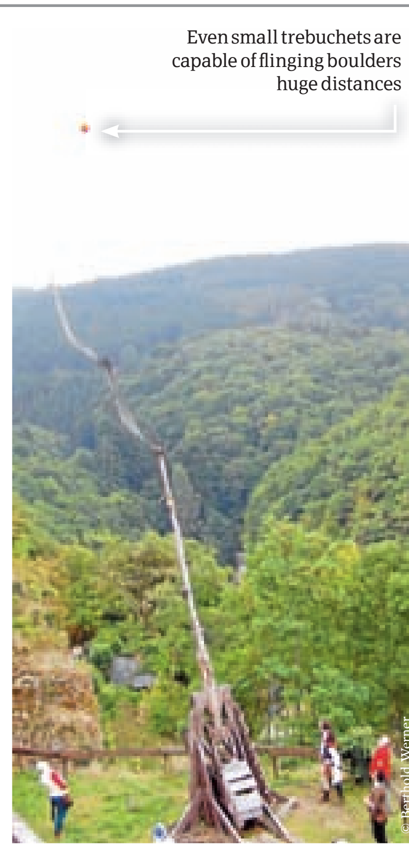


At intervals of one Roman mile were small defensive fortlets called milecastles for sheltering the troops patrolling that section of the wall

DID YOU KNOW? While used mainly in the Medieval period, counterweight trebuchets were still in operation till the late-1600s

A historical re-enactment of the loading and operation of a counterweight trebuchet

© C.Recoura



Even small trebuchets are capable of flinging boulders huge distances

© Berthold Werner

Trebuchets

At the height of its power the trebuchet was an unstoppable force, crushing fortifications, buildings and men alike

The setting: King Richard's crusades in the latter half of the 12th Century. A counterweight trebuchet's arm and sling swing up to a vertical position, releasing its housed projectile at a ferocious speed and power. The result? Twelve men crushed by a single, giant stone.

Built originally in the middle ages to bombard and besiege enemy fortifications and troops, the counterweight trebuchet was used as recently as 1600, the equivalent of today's long-range artillery cannons. Capable of launching objects of tremendous weight – including stone boulders, burning animals and even diseased human corpses used as an early form of biological warfare – over large distances, the counterweight trebuchet still to this day is a phenomenal feat of engineering.

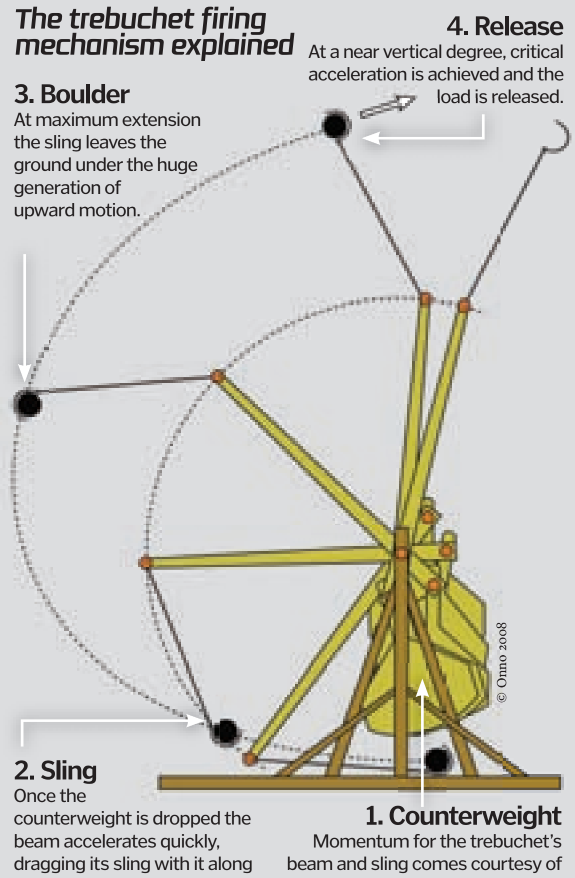
Differing from the far earlier traction trebuchets, which relied on torsion and manpower, the counterweight trebuchet earned its reputation through the simplicity of its central design concept, relying on gravity alone to propel its ammunition further and more consistently than its predecessors. By increasing projectile propulsion by relying on the mechanical advantage principle of leverage, rather than that of torsion and manpower, for centuries the counterweight trebuchet laid waste to city walls and fortifications worldwide.

A counterweight trebuchet consists of five basic parts; the frame, guide chute, beam, sling and counterweight, which in order to propel an object must all work in harmony. Supported by the frame – which provides the all-important raised position needed for this gravity-reliant system – the counterweight is dropped which in turn rotates the beam and attached sling. The sling, which is guided along the chute until critical acceleration is achieved (therefore keeping the projectile in the sling), then reaches a near vertical degree before releasing its contents.

While historians still argue to this day about the precise details of early counterweight trebuchets – such as their numbers, design and origin – one thing is definitely clear; it was most certainly a weapon of epic proportions giving whoever wielded it a considerable advantage in any siege.

How it fires...

The trebuchet firing mechanism explained



5 TOP FACTS STONEHENGE

Tallest stone
1 The largest stone of the monument is one of the five Trilithons in the Sarsen Circle. It measures 7.3 metres high and weighs a quite ridiculous 45 tons.

Conspiracy theories
2 Theories for what the site was built for include a place for worship/healing, a burial site, an archaeoastronomical observatory, or even an alien spacecraft landing area.

Morning glory
3 From the centre of the circle facing northeast is an entrance through which someone standing in the centre can see the Sun rise on midsummer morning.

The Aubrey holes
4 Circling the inner edge of the henge are 56 pits called the Aubrey holes. Although their purpose is a mystery, it has been suggested that they may have held timber posts.

A henge with Heritage
5 Stonehenge is owned by the Crown and managed by English Heritage. The surrounding area is National Trust land, and it became a World Heritage Site in 1986.

DID YOU KNOW? Close visitor contact of the stones has been prohibited since 1978

A henge is an area containing a circle of either stone or wooden posts, dating from the Neolithic (New Stone Age) and Bronze Ages

How was Stonehenge built?

This cumbersome monument was constructed by prehistoric men and their bare hands before the invention of the wheel. But how?

An enigma of prehistoric civil engineering and a dramatic silhouette on the landscape of Salisbury Plain, the megalithic monuments at Stonehenge are a constant reminder of the incredible resourcefulness of ancient civilisations.

Construction of Stonehenge was divided into three main stages. The first, between around 3000 and 2500 BC, involved the creation of an ordinary henge monument (a circular enclosure bounded by banks and a ditch) that was initially used for ceremonies and burials.

The second stage saw the arrival of Welsh bluestones from the Preseli mountains. In around 2150 BC, men began transporting these four-ton stones to Wiltshire using a combination of rollers and sledges on land, and rafts across the sea and rivers. At the end of the 240-mile journey the stones were arranged as a double circle in the centre of the Stonehenge site. These bluestones provided a sacred focus, which Stonehenge experts professors Timothy Darvill and Geoff Wainwright suggest was due to the stones' perceived magic healing powers. Once the stones were set up, the site attracted more interest with visitors and pilgrims from all over northern Europe.

In around 2000 BC, the third phase of construction began when Sarsen stones were transported from a site 25 miles from the monument. These immense stones – the heaviest of which weighed 50 tons – were positioned upright in an outer circle with horizontal lintels running between each vertical.

The history of Stonehenge…

3100 BC
Henge established
The original henge comprised a ditch, an earthen bank and the mysterious Aubrey Holes – a circle of 56 small pits.

2150 BC
Welsh bluestones arrive
82 stones are transported from the Preseli mountains and arranged as a double circle within the henge.

2000 BC
Sarsen stones arrive
Each Sarsen is brought to the site from north of Salisbury Plain by 600 men – 500 to pull the sledges with leather ropes and 100 to lay the rollers.

1500 BC
Bluestones moved
The bluestones are rearranged in the semicircle shape we see today. Some of the original stones were broken up or removed.

Timothy Darvill

Professor of Archaeology in the School of Conservation Sciences at Bournemouth University

How It Works speaks to Timothy Darvill about the history and significance of this magnificent monument

HIW: For what reasons might the makers of Stonehenge have decided to move the bluestones all the way from Wales?

Timothy Darvill: [Professor Geoff Wainwright and I] believe the bluestones, which come from a variety of outcrops on and around the Preseli Hill of North Pembrokeshire, were perceived to have magic powers because of the healing properties associated with holy wells and springs at their source. It is likely that the Preseli Hill lay at the extreme western end of the territory of those who built Stonehenge and so the hills may also have been regarded as a sacred mountain or the home of the gods – a sort of neolithic Mount Olympus.

HIW: Have you ever considered how long the site might realistically be preserved against the effects of the elements, acid rain and so on? We've seen photos of birds nesting in holes caused by such erosion…

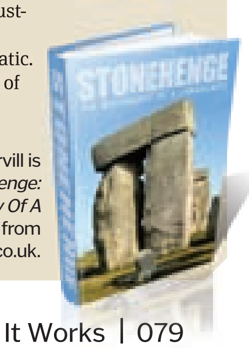
TD: Thanks to the efforts of English Heritage, the site is well looked after and in no great danger. There is very little erosion going on and the only concern is some natural or human catastrophe, the stones are already 5,000 years old and still looking good (although there was some cosmetic surgery in the Fifties and early-Sixties when some were straightened and others re-erected).

HIW: How do archaeologists go about chronicling the timing of the different phases of Stonehenge's construction?

TD: Two ways. First is what is known as stratigraphic: the order or sequence of events and structures revealed through excavations and surveys. Second is chronological: adding dates to events within the stratigraphic sequence through the use of radiocarbon dating. Our excavation in 2008 was the first for more than 40 years and we are still working on the samples we took.

HIW: Why has Stonehenge become the go-to henge for people around the world?

TD: Stonehenge is a must-see site because it is so unusual and so enigmatic. People love the debate of interpretation.



Professor Timothy Darvill is the author of *Stonehenge: The Biography Of A Landscape* available from www.thehistorypress.co.uk.

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

Proudly associated with sciencemuseum
www.sciencemuseum.org.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

Alison Boyle
Curator of Astronomy and Modern Physics

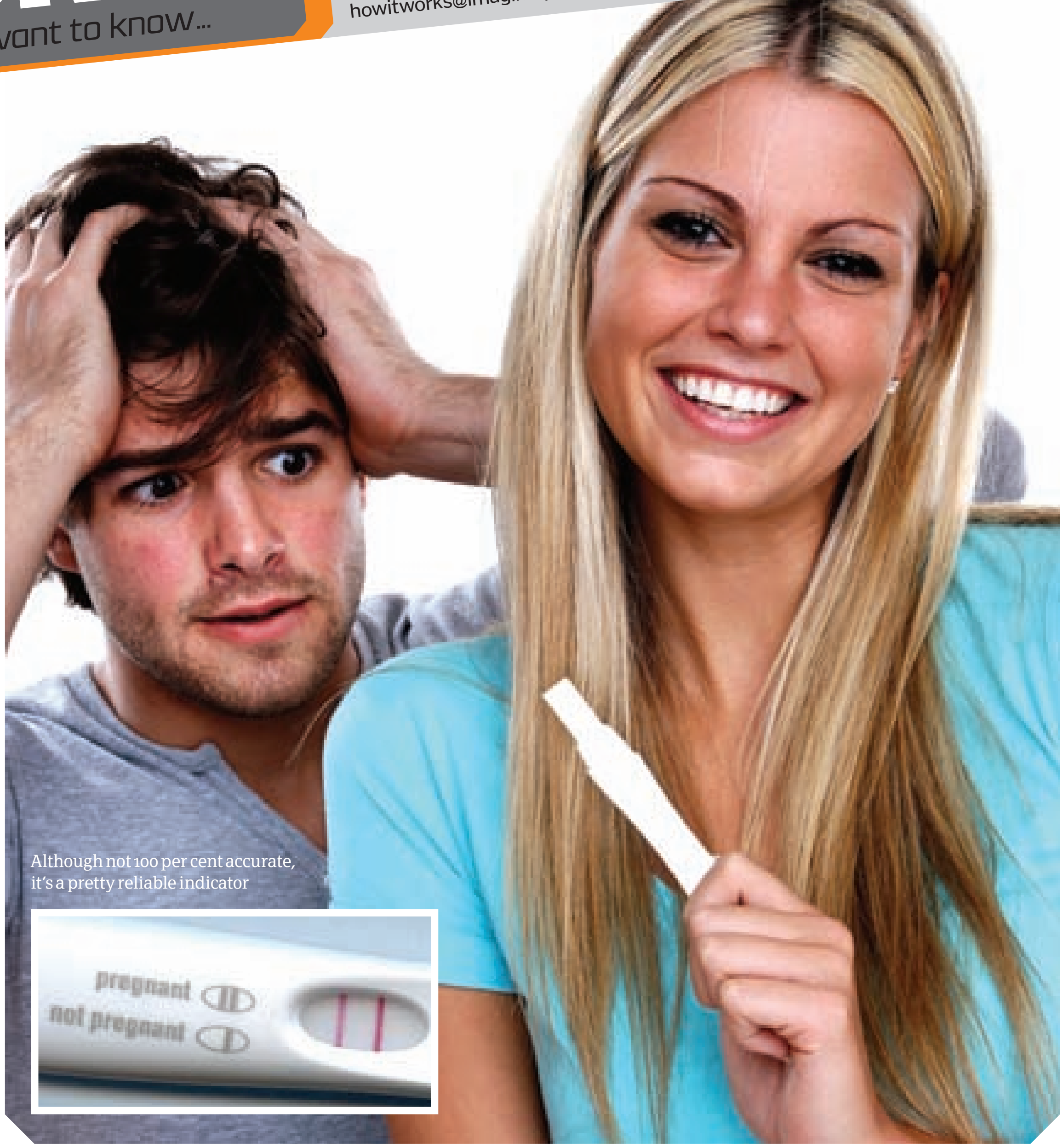
Alison is responsible for a range of collections spanning most of the space-time continuum. Since joining the Science Museum back in 2001 as part of the Antenna Science News team, Alison has worked on several astronomy and space exhibitions and is currently researching particle accelerators.

Doug Millard
Space Curator

Doug Millard is Senior Curator of ICT and Space technology. He has worked at the Science Museum for many years and contributed to a large number of exhibitions and publications on the exploration of space. Doug is currently working on a proposal to bring the treasures of the Russian space programme to the Museum.

Rik Sargent
Science Museum Explainer

Rik is an Explainer in the Science Museum's interactive Launchpad gallery. When Rik isn't blowing up stuff or putting people in bubbles he trains the Explainer team in the principles of science.



Although not 100 per cent accurate, it's a pretty reliable indicator

How does the home pregnancy test work?

Mohammed Al Hajji, email

■ Home pregnancy tests work by detecting a hormone called human chorionic gonadotropin (hCG) in the urine. hGC is only produced by pregnant women therefore any amount of hCG detected in the woman's urine will indeed mean they are expecting a baby. hCG is produced by cells in the uterus and is responsible for signalling the ovaries to produce oestrogen and progesterone to help the foetus grow. hGC can be found in the urine or blood and the levels of hGC increase as pregnancy progresses. Very sensitive home pregnancy tests can detect hCG as early as 9-10 days after ovulation.

The detection of hCG is carried out by human-made proteins called monoclonal antibodies. They basically bond with the hCG upon detection which creates a distinct colour change in the test. The colour produced will vary in intensity based on how much hCG is in the urine.

When you take a home pregnancy test, you need to soak a part of the test in your urine. Most home pregnancy tests have two lines, one is the control line and should stay the same regardless of whether you are pregnant or not. This line or symbol shows whether the test is working properly. If the control indicator does not appear, the test is not working properly and you should not rely on any results from a HPT that may be faulty.

The other line contains the monoclonal antibodies which will indicate pregnancy if there is a colour change.

Rik Sargent

Why do skunks smell?

Susie, email

Skunks are renowned for their ability to smell really bad. Not something you want to have associated with your species, but for skunks it's a massive advantage. Skunks do this by spraying a chemical called thiols which is made of sulphurous compounds and they have a very strong odour. Not only that but these thiols are very good at sticking to materials and mixing with chemicals to make the smell stick. If a skunk has sprayed this on any of your upholstery the smell can often last for weeks.

In fact scientists have successfully isolated the compounds that make the smell stick and applied it to perfumes and fragrances in order to give a longer lasting smell. A skunk will only spray if it is agitated or stressed and releases the spray from scent glands in the anus. In addition to smelling awful, the spray can cause vomiting and have effects similar to tear gas, which is a great defence mechanism. As an interesting side note, skunk spray is also phosphorescent, so it will glow in the dark.

Rik Sargent

How does de-icer work?

Carly Johnson

De-icers work by lowering the freezing point of water causing it to turn back from ice into liquid water. Usually this is due to addition of a chemical compound such as sodium chloride (often called rock salt) or calcium chloride. Most de-icers aren't designed to melt every piece of ice they come into contact with – they break the bond between the ice and the surface allowing for easier manual removal of the ice.

Rik Sargent

Is it possible to knock Earth out of its orbit?

Dan C

Yes, it's possible, but the impact required would be so large that the Earth would likely be destroyed in the process. Many astronomers think that around 4.5 billion years ago, when the solar system was forming, the Earth got a 'big whack', which resulted in our moon being formed. According to this theory, a Mars-sized object struck the early Earth. At this stage in the solar system's evolution both bodies would have been made mainly of molten material that had not yet solidified. Their iron-rich cores merged, while parts of their outer layers were vaporised and thrown into orbit around the Earth. This material eventually coalesced to form our rocky moon. The Earth gained angular momentum, and its orbit may have changed, although only slightly. This impact is likely to have been 100 million times bigger than the impact that wiped out the dinosaurs. If a body that size hit today's mostly solid Earth, we would be blasted to smithereens.

Alison Boyle

sciencemuseum

What's on at the Science Museum?

1001 Inventions

21 Jan - 25 Apr (Please note: the exhibition will be closed between 25 Feb-12 Mar) ■ 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.

Cosmos & Culture: how astronomy has shaped our world

Until 2010 ■ FREE

Cosmos & Culture traces 400 years of telescope technologies, explores our changing perceptions of our place in the cosmos, and examines the role astronomy has played in our everyday lives.

Centenary Talks – James Lovelock

9 Mar, 19:30-21:00 ■ £7 – to book your place call 0870 870 4771

The Science Museum continues to celebrate its centenary year with a series of Centenary Talks giving people the chance to meet and hear from some fascinating experts. On 9 March James Lovelock, the famous originator of the Gaia hypothesis, talks about his life and work in science. Find out how his early work on the Earth's atmosphere helped change our views of human impact on the environment.

The Smell of the Crowd

26 Feb, 19:00-20:45 ■ Charges apply (over 18s only)

The Dana Centre is the Science Museum's café bar and venue for exploring issues in contemporary science through dialogue, interaction, performance and art. The Grand Union Orchestra is here to play and illustrate the art of circular breathing. Get insight into this amazing technique featuring live music and new software offering real-time visualisations of the musicians' exhalations.

For further information visit the What's On section at www.sciencemuseum.org.uk/centenary.

BRAIN DUMP

Because enquiring minds want to know...

> "When lightning occurs, the strike point can reach temperatures of up to 30,000°C"

Fulgurite is formed from sand or other sediment fused by lightning

That umbrella's not going to help you if the lightning strikes mate…

Can glass be made from lightning hitting sand?

Gwyneth Barton

This is indeed possible as glass and sand are both made from the same chemical, silicon dioxide. Silicon dioxide has an extremely high melting point, so first the sand has to be heated past this for it to become a liquid. In sand the silicon and oxygen atoms are arranged in a very orderly way. When the sand is heated to very high temperatures, this arrangement breaks down and the position of the atoms becomes disorderly and random. If the sand is cooled quick enough then the atoms of oxygen and silicone don't have enough time to revert back to their nice orderly arrangement so they form the substance we know as glass.

When lightning occurs, the strike point can reach temperatures of up to 30,000°C, which is much hotter than the surface of the Sun. Providing the sand is of the right kind then it is possible that glass will form. Fulgurite is the term given to what is left over, which is a hollow glass tube and can sometimes penetrate up to 15 metres below the surface of the sand.

The type of sand the lightning strikes is a major factor as to whether it will turn into glass or not. Meteorite impacts have also been known to release a large enough amount of energy to convert sand into glass.

Due to the unpredictable nature of lightning strikes and given that they can be highly dangerous, it might be a risky business opportunity in more than just the financial sense. On average there can be more than 100 lightning strikes happening every second across the globe, but the chances of these being over the right type of sand at exactly the right moment are very low, so don't get your hopes up!

Rik Sargent

FROM THE FORUM

*Every month we'll feature a reader's question and a reader's answer from our forum at **www.howitworksdaily.com/forum***

Deadly this way up, little danger when on its back

Why do sharks go into a tonic state when flipped over?

Carol, forum user

Many animals are capable of entering a trance-like state called tonic immobility whereby they appear dead to their surroundings. In the case of sharks it has been observed on many different species such as the lemon shark, reef shark and tiger sharks upon simply placing them upside down.

During tonic immobility the dorsal fin becomes straightened and the breathing and muscle contractions become more relaxed. It is such a reliable behaviour in certain sharks that it is used as a type of anaesthesia before minor surgery.

Some killer whales have learned to take advantage of this by using their tails to create currents in the water that can turn a shark over in order to eat it. The reason this happens to sharks is unclear, but it can be argued that tonic immobility has a role to play in survival allowing the shark to blend into the surroundings by being completely motionless, but in this case it's obviously a disadvantage for the shark.

It has also been speculated that it may be something to do with the mating ritual of certain shark species as in some cases it can be induced by massage.

Rik Sargent

How do you tell if a mushroom is poisonous or not?

Zaki Hassan

■ There are many different types of mushroom so without getting a good grasp of individual kinds of mushroom it would be difficult to say whether it is poisonous or not. A general rule would be to never consume a mushroom unless you have a positive identification of that mushroom.

Some deadly varieties of mushroom include the death cap, destroying angel, Galerina species, small Lepiota species and the deadly webcap and to be able to detect these you would need to have observed them all at different stages in their development. Also having knowledge of where the mushroom has come from can help as some mushrooms that are safe in Europe have deadly lookalikes in North America.

It is wise to avoid old wives' tales such as 'a mushroom is poisonous if it tarnishes silverware or turns blue when bruised' as these are both completely false statements. The truth of the matter is that there are no external easy-to-identify characteristics that all poisonous mushrooms have in common.

To be absolutely safe, unless you are an expert mushroom identifier then we would advise buying your mushrooms from a reliable source such as supermarkets or restaurants.

HIW

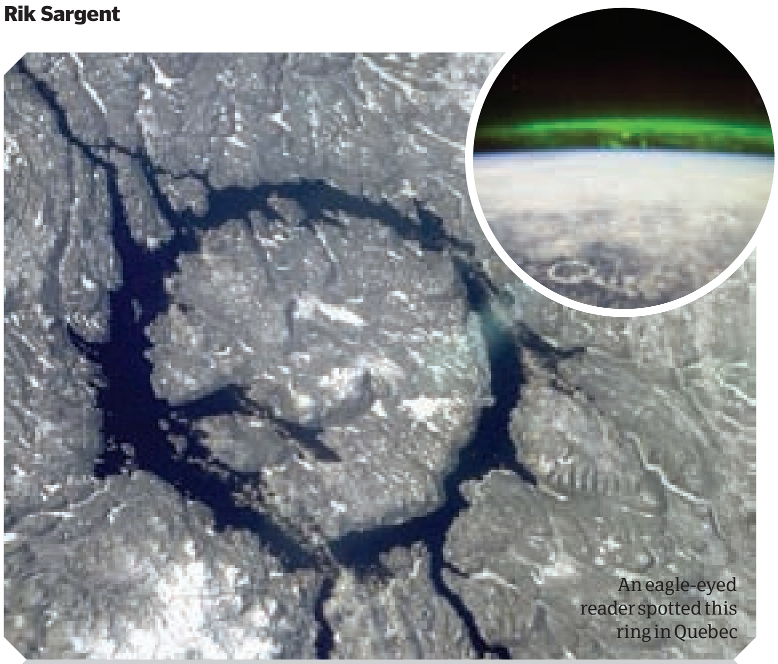
How do the holes get in Swiss cheese?

James Butler

■ To make cheese you need the help of bacteria. Different types of bacteria in different combinations give rise to the distinct variety of flavours in many cheeses. There are various different types of bacteria used for making Swiss cheese, the one responsible for the holes is called Propionibacterium shermanii. Once this bacteria is heated slightly it reacts forming bubbles of carbon dioxide, which become the final holes in the product.

The technical term for these holes is 'eyes'. The size of these 'eyes' can be controlled by the cheesemakers by altering the acidity, temperature and curing time of the mixture. Generally, in most foods which require fermentation, bubbles of carbon dioxide will be formed but most of the time they escape. The procedure which goes into making Swiss cheese means those bubbles remain trapped inside which means there will be 'eyes' in the final product.

Rik Sargent



An eagle-eyed reader spotted this ring in Quebec

There's a large ring on the photo of the northern lights on page 25 of issue two. What could it be?

Lee Massey

■ It's the Manicouagan crater in Quebec, Canada. It is around 70km across and is thought to have been caused by an asteroid impact over 200 million years ago during the Triassic geological period. It has been photographed from space several times – the original picture from issue two was taken by astronaut Donald Pettit aboard the International Space Station in 2003. The crater is occupied by a lake and a central island, so viewed from above it has a distinctive ring shape which has led to it being called the 'Eye of Quebec'.

Alison Boyle

sciencemuseum

What's on at the Science Museum?

Fast Forward: 20 ways F1™ is changing our world

■ Until spring 2010 ■ FREE

British teams, engineers and mechanics have shown themselves to be at the forefront of Formula 1™, a world where human skill, passion for innovation and cutting-edge technology are pushed to the extreme. This new exhibition shows how Formula 1™ technology can be applied to different fields of research and innovation to offer new solutions to our everyday lives. Find out how sophisticated composite materials, telemetry systems and rigorous pit-stop strategies devised by British teams are currently applied to improve safety and efficiency in our hospitals, homes and work places.

Science Museum IMAX 3D Cinema

■ Now showing ■ Prices: £8.00 adults and £6.25 children/concessions

– Fly Me To The Moon 3D (U)

Get ready to launch into this animated space spectacular and join three houseflies that sneak on board the Apollo 11 spaceship mission to embark on a cosmic adventure. Featuring the voice of Buzz Aldrin, viewers can relive the momentous occasion when the world was united for man's first steps on the moon.

– Space Station 3D (U)

Feel the force of a rocket launch, accompany astronauts on a space walk and experience life in zero gravity as you blast off into space. With stunning views of Earth and incredible footage of life on-board the International Space Station it's the closest you will probably come to actually being there!

– Also showing: Dinosaurs Alive! 3D (PG), Sea Monsters 3D (PG), Deep Sea (PG)

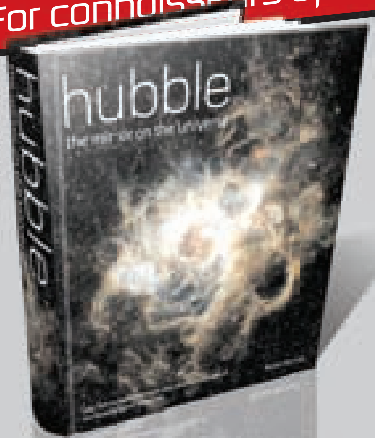
Visit the Museum

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.

THE HOW IT WORKS KNOWLEDGE

For connoisseurs of kit and savants of stuff

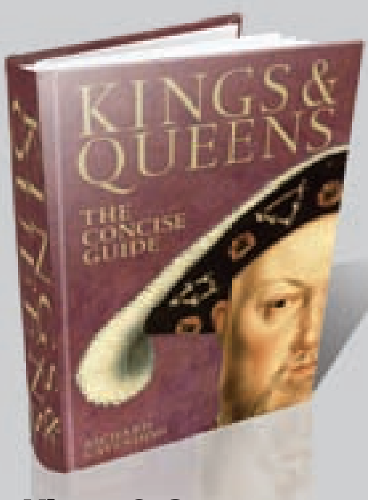
DVDs/Blu-ray • Books • Gadgets • Videoga



Hubble: The Mirror On The Universe

Price: £12.99 / $22.99
ISBN: 978-0715329238
An informative and well-presented book detailing some of the most awe-inspiring images captured by the Hubble Space Telescope, this book provides various chapters on most known space phenomena. From shooting stars to colliding galaxies, this is a great reference book.

Verdict: ✪✪✪✪



Kings & Queens

Price: £6.46 / $11.69
ISBN: 978-0715323762
A super little book detailing the complete history of Britain's kings and queens that provides great insight into the key turning points, battles, characters and stories that characterised their individual reigns. The title is plush too, stuffed with high-quality images and tables, as well as coming in a postcard-sized hardback format.

Verdict: ✪✪✪✪

HOW IT WORKS EDITOR'S CHOICE AWARD

View and record microscopic detail like never before

LCD Digital Microscope

Price: £275.00 / $335.95
Get it from:
www.celestron.uk.com

REPLACING THE TRADITIONAL eyepiece of a microscope with a new LCD screen for vivid, bright images, the LCD Digital Microscope from Celestron allows you to look at, display and share objects and organisms close-up easier than ever before.

The screen itself is a high-resolution, 3.5" 88mm display encased within a chunky silver frame, adorned onto which are its controls. It also houses a 2MP digital camera with 4x digital zoom that allows for snapshots to be taken at any time, as well as short videos, which then can be uploaded onto SD card for transition to a PC or Mac before being archived, distributed or edited.

On test the LCD Digital Microscope impressed mightily and proved an office favourite. The microscope's three objective lenses provide 40x, 100x and 400x optical magnification levels, which when combined with the aforementioned 4x digital zoom, allows you to view objects at up to 1,600 times their original size. You get a bundle of extras too to help get you on your way, including 128MB of internal memory, carry case, five prepared specimen slides and a USB cable for those without SD card readers built into their PC or Mac.

At first we thought that the LCD screen would detract from the actual scope, dismissing it as slightly gimmicky, but after testing it was obvious that this is a serious piece of scientific kit, that instead of hindering the observation, actually provides the average user greater functionality and usability outside of a lab environment. If you have any interest in observing the world we live in from a different perspective, you should definitely take something away from time spent with this. Top-draw edutainment!

Verdict: ✪✪✪✪✪

Teufel Motiv 5

An excellent and stylish 5.1 speaker system

Price: £381.00 / $599.99
Get it from: www.amazon.co.uk

TEUFEL IS KNOWN for its quality audio systems, and the Motiv 5 continues that trend delivering great sound quality from an elegant set of speakers. Designed to be used as part of a home cinema system, the Motiv 5 includes a six-channel subwoofer, five minimal satellite speakers and a central connection hub and decoder.

Design-wise, the Motiv 5 is gorgeous, with its satellite speakers (100mm mid-tone, 25mm tweeter) curved in soft triangles of shiny, black gloss, one-piece plastic shells, as well as its bulky, matte-finished subwoofer delicately poised on sturdy yet stylish conical legs. The simple amp-styled LEDs and buttons adorned on a chrome plate above the subwoofer's main 250mm driver also add a pedigree of appearance rare in other systems in its price bracket.

In terms of sound quality, the Motiv 5 impressed greatly, delivering rich and dynamic sound across all frequencies. Bass was distortion and compression free, delivering powerful audio reproduction of explosions and the like, while the satellites handled mid- and high-range frequencies almost perfectly, with depth and subtlety when replicating quieter moments or environmental or ambient sounds.

Verdict: ★★★★

ION U RECORD

Convert tape and vinyl to MP3

Price: £49.99 / $49.99
Get it from: www.ionaudio.com

A NIFTY LITTLE input box for your PC or Mac, the U RECORD allows you to record any audio source emanating from a tape player, radio, turntable, microphone or instrument, before digitising it into MP3 format. The box itself connects to the computer via USB and handles compatibility and pre-amps itself, allowing you to literally turn it on and watch the unit convert away. Once converted, you can then order, label and send the tracks to any music player of choice with the bundled software.

The box itself is a well-built and simple device, with minimal inputs, a phono/line switch and top-mounted recording level knob. The packaged software, which includes the freeware Audacity audio editing software, is simple and, in terms of Audacity, provides powerful ways to label, sort, edit and adjust tracks to your liking. The small size of the U RECORD also makes travelling with it easy.

The one reservation that we have with the U RECORD unit is its genuine usefulness in reality to the average consumer. However, providing you still have that turntable or tape deck on hand, then the U RECORD will offer great value for money, for those who don't, less so.

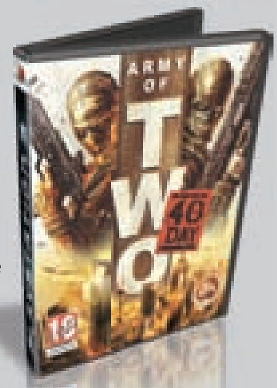
Verdict: ★★★

Bayonetta

- **Format: Xbox 360**
- **Price: £34.99 / $56.99**

Like *Devil May Cry* on steroids, *Bayonetta* delivers almost perfect third-person action in a stylish, satirical world where the player controls an all-powerful, leather-clad witch in search for clues to unlock her forgotten past. Gameplay centres around a slick combo system that incorporates simple punch, kick and shoot commands, as well as a host of special moves and show-off skills. Action is quick, free flowing and rewarding at all three of the game's difficulty levels, which gently introduce even the most casual player into the crazy game world before smoothly ramping up the hardness.

Verdict: ★★★★

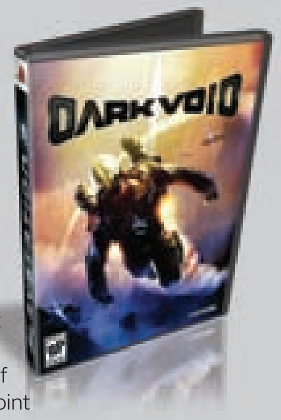


Army Of Two: The 40th Day

- **Format: PS3**
- **Price: £39.70 / $56.99**

Continuing the gaming industry's current co-op everything trend, *Army Of Two: The 40th Day* delivers a charmless third-person shooter with more gimmicks than sense. Indeed, when the closest point of reference for *Army Of Two: The 40th Day*, other than its own forebear, is a game starring 50 Cent – and it fails to measure up even to that – you know you are onto a bad thing. The major problems come from its lazy and gimmick-ridden obsession with a co-operative theme, that rather from enhancing the gaming experience only serves to dumb it down.

Verdict: ★★

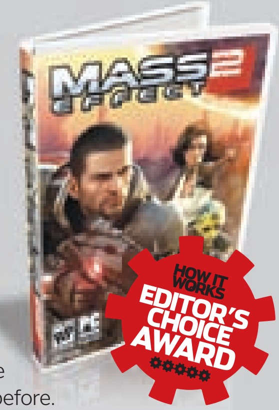


Dark Void

- **Format: PS3**
- **Price: £29.70 / $55.99**

Usually, when we toss a title into the also-ran pile, it is due to its solid idea but sloppy execution. Very rarely is this trend reversed. *Dark Void* just happens to be one of those rare titles. It's a crap idea, well executed. Gameplay-wise this is a third-person, cover-system heavy title, where the big seller is that you can fly. Of course, the freedom you would think that brings does not materialise, with the majority of vertical flight very firmly on-rails. With this selling point firmly grounded, the title's competent controls and pleasant visuals leave it overshadowed by its other, more prolific contemporaries.

Verdict: ★★★

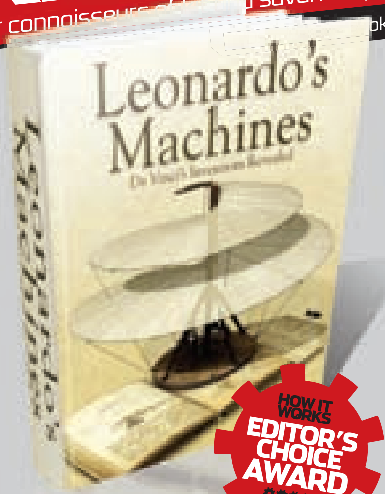


Mass Effect 2

- **Format: PC**
- **Price: £26.99 / $56.99**

There isn't much to say about *Mass Effect 2* other than it is better than the original in every aspect – and we all know how good that was. Indeed, *Mass Effect 2* builds on what little failings there were in *Mass Effect* – notably the average combat, which has now had a complete overhaul and relies on physics rather than unseen dice rolls – to deliver a piece of sci-fi entertainment that penetrates the line between gaming and cinema like no title has done before. Without doubt, this is the finest blend of shooting and role-playing we've seen this generation and already is a serious contender for game of the year.

Verdict: ★★★★★

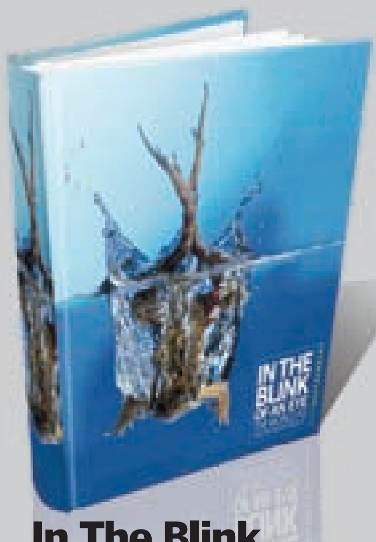


Leonardo's Machines: Da Vinci's Inventions Revealed

Price: £11.29 / $16.49
ISBN: 978-0715324448

Leonardo's Machines brings some of the most spectacular inventions of Leonardo da Vinci crashing into the 21st Century. Stuffed with cutaways and models of inventions, this title shows you everything you need to know about the great man's work.

Verdict: ✪✪✪✪✪



In The Blink Of An Eye

Price: £14.99 / $24.99
ISBN: 978-0715326503

In The Blink Of An Eye delivers a series of 100 close-up images detailing some of the smallest events and forces in operation in our natural world. From reflections in raindrops and rainbows in soap films, to pinches of turmeric powder exploding like volcanoes and the strange forms milk undertakes when disturbed, the images are visually arresting and provide snapshots into a world we cannot naturally perceive.

Verdict: ✪✪✪

Celestron SkyScout

Literally, a pocket planetarium for your, well, pocket…

Price: £299.00 / $399.99
Get it from: www.celestron.uk.com

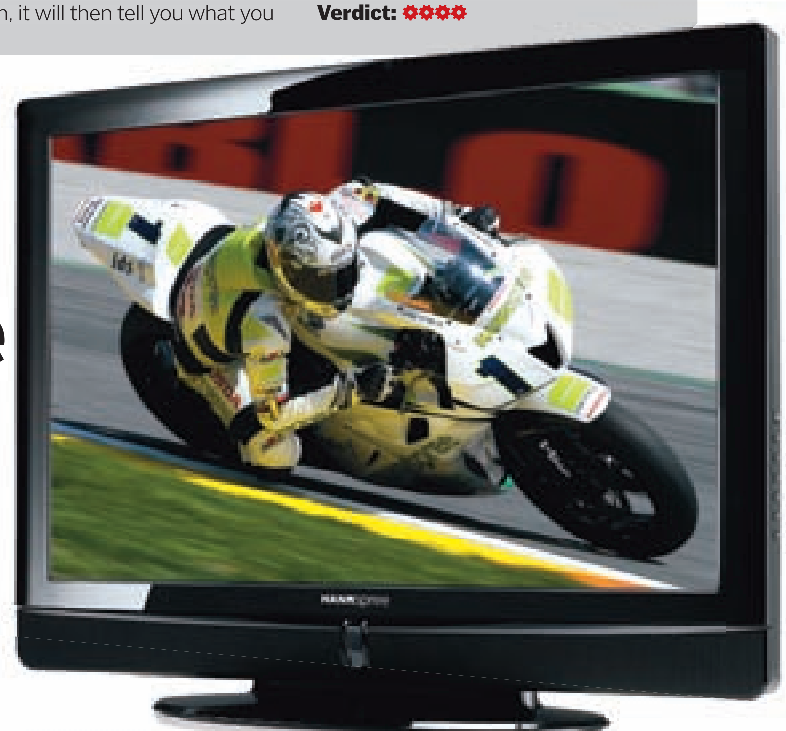
A FANTASTIC LITTLE tool for any astronomer, the SkyScout allows you to simply and easily locate and identify over 50,000 stars, planets and constellations from an in-built celestial database. Once located and identified the SkyScout then provides scientific information, comprehensive text and audio descriptions, history and mythology about the target subject, as well as constellation lessons and whole field guides.

The unit itself is literally hand-held (2.5"x4.0"x7.4") and works through a combination of spotting scope and side-mounted LED display. The unit is rugged in build quality too, with strong rubberised buttons and a hard central casing.

To operate the SkyScout is easy. To detect a planet, star, etc, you simply point the device at the celestial object and click the target button, it will then tell you what you are looking at and provides a list of relevant and interesting information about it. If a target has already been chosen, say Jupiter for example, but you are not sure where it is in the night sky, you can also use the SkyScout to locate it. This is achieved thanks to the GPS positioning software housed within, and literally guides you as you look through the spotting scope – whose eyepiece is encircled by LED, 360-degree arrows – to the correct spot.

Verdict: ✪✪✪✪

Hannspree ST281 28" LCD HDTV



A 28" 1080p HDTV for under £270

Price: £269.99 / $299.99
Get it from: www.amazon.co.uk

IT IS A fact that any new form of technology when released is often prohibitively expensive, only then to drop in price over time allowing the average consumer to jump on board.

One of the most recent pieces of tech to adopt this inevitable trend is the HDTV, with televisions capable of full 1080p picture quality costing well over £2,000 just three years ago, only now, as can be seen with the Hannspree ST281 28", reduced to almost ten per cent of that figure. It is good news, of course, for the average consumer, but is this low price justified by the proliferation and availability of products, or by sub-standard parts and performance?

Well, it's six of one and half a dozen of the other. Firstly, out of the box, the styling of the ST281 is actually pretty pleasant, though the back housing is large making wall-mounting difficult. The speaker bar – which houses twin two-channel 10W speakers – fits in well enough, although the actual audio produced was not the best, with low frequencies prone to distortion and high frequencies coming out tinny at louder volume settings.

Picture quality was respectable when watching Freeview, but Blu-ray movies lost some of their detail and shine. Further, the colour palette of the television seemed off-balance in many of the films we played on the set, with skin tones varying and whites being over-exposed.

The broad range of inputs saves the set somewhat, but it is hard to recommend the ST281 as a main screen to all but those whose budget is restricted to under £270. If you are looking for a cheap second HDTV for a bedroom though, you could do worse.

Verdict: ✪✪✪

Cannondale Flash Carbon 3

A super flash bike from Cannondale

Price: from £2,699 / $3,699
Get it from: www.cannondale.com

THE LATEST AND arguably greatest hardtail from Cannondale yet, the Flash Carbon 3 offers the stiffest frame ever seen on one of its bikes. Indeed, the tough frame and tubing of the Flash 3 are optimised for off-road racing performance, providing a very light and dynamic ride with unparalleled support.

Furthermore, the Flash boasts Cannondale's new BB30 standard, which allows extra efficiency from the BB shells and crank sets, as well as sporting an oversized design that helps resist power loss from twisting.

The Flash also sports a radical new seat design, Shimano SLX and XTR front and rear derailleurs, Crank Brothers Eggbeater C pedals, twin Schwalbe Racing Ralph 2.1" EVO Triple Nano tyres, and Avid Elixir R Carbon SL 160mm rotor brakes. The styling of the bike is also suitably flash, with a cool, streamlined and understated look available in either blue or red.

Obviously, considering the rather large price tag that is attached to Cannondale's flagship bike, the performance is excellent, really allowing riders to 'point and go' down and over almost any mountainous terrain in their way, giving the experienced cyclist a tool to really push themselves and the bike hard. Quick, rapid directional movement changes were handled superbly, building confidence to tackle terrain at speed, and responsiveness and steering precision were top draw, offering a natural ride.

At £2,699, the Flash 3 is rather expensive, but certainly not overpriced considering the amount of tech that goes into it. However, while this would be a fantastic mountain bike for anybody, to get the best out of such a hi-end piece of kit, you would have to be a seasoned rider.

Verdict:

Crystal Weather Station

Predict the weather in style

Price: from £99.99 / $139.99
Get it from: www.oregonscientific.com

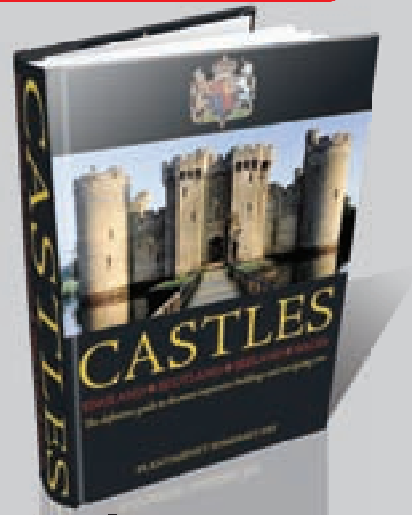
THIS IS JUST cool! Integrated into this sleek gloss black tower of the Crystal Weather Station are numerous sparkling Swarovski Crystal elements, shaped into three distinct forms – sun, cloud and rain – which dependent on the incoming weather pattern, are illuminated by different colours.

So, for example, if it is going to be sunny outside then the sun crystals are illuminated red, if cloudy the cloud crystals blue, and if rainy the raindrop crystals green. Further, on the side of the tower there is a super bright radio controlled clock, which can be turned on or off at the wave of a hand, or switched to display the current indoor temperature.

On test the Crystal Weather Station impressed, providing relatively accurate weather prediction and clear and concise time delivery. However, some may see the station as style over substance as sudden weather changes are not accounted for.

Finally, all those Swarovski Crystal elements embedded into the design don't come cheap, so you might balk at the cost, before you balk at the terrible approaching weather…

Verdict:

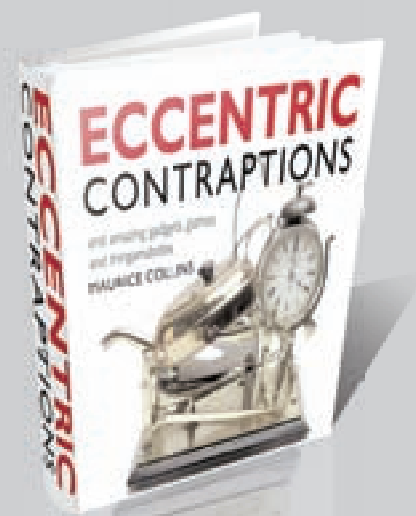


Castles

Price: £6.96 / $16.98
ISBN: 978-0715322123

A comprehensive if dry compendium of the castles of England, Scotland, Wales and Ireland, *Castles* is a good reference title for those who are intrigued by these ancient structures. Historical and contextual information is documented clearly, as well as interesting facts about the castles' architecture, highlighting anything of particular note.

Verdict:



Eccentric Contraptions

Price: £9.99 / $9.99
ISBN: 978-0715318217

Contrary to the high production values and quality found in *Kings & Queens*, this other postcard-sized title disappoints in its premise of presenting some of the world's most eccentric contraptions to date. Each double-page spread literally contains an image of a contraption on one side and 50 words – of which many are often wasted on irrelevant banter – about it on the other. Superficial, even for a coffee table book.

Verdict:

GROUP TEST

It's time to take to the skies and find the top remote-controlled chopper…

Mini RC helicopters

GROUP TEST WINNER

1 Micro Bladez 3D

Price: £49.99
Get it from: www.iwantoneofthose.com

Kicking off the group test this month is the Micro Bladez 3D, a futuristic mini remote control helicopter with three-channel control, adjustable speed and an auto balance system. This helicopter is one of the most impressively made on test this month, with the small mechanisms and gears clearly visible through its plastic body, as well as a multi-part, three-tier rotor system. The 3D handles well and has controls to adjust it on the fly, ensuring more time flying and less time crashing. The controller is also easily the most well built on test here, fitting very snugly in the hand and giving good feedback between its power and directional controls.

Verdict: ★★★★

2 SYMA S.026 Chinook

Price: £24.99
Get it from: www.amazon.com

The biggest but not quite the best helicopter on test is this S.026 Chinook from SYMA, the same guys who delivered the AH-64. The twin rotors of the chopper are large and well built, and make flying it a lot easier than any of its single-rotor counterparts. The body too is accurately modelled from its bigger, real-life variant, and it hovers superbly with little natural fluctuation. However, when in use it is incredibly noisy, sounding a lot like a hand-held vacuum cleaner as it drifts around, and it does not offer the speed or flexibility of movement that some of the smaller helicopters deliver.

Verdict: ★★★

3 SYMA AH-64

Price: £23.99
Get it from: www.amazon.com

Styled like its bigger and decidedly more deadly namesake, this mini variant of the Apache gunship brings a military slant to our micro RC helicopter bonanza. The rotors and controller of the AH-64 are identical to the Micro Bladez 3D reviewed earlier, and both sport the same great build quality. In addition, the body of the chopper offers good protection for the internal wiring and mechanics when you inevitably crash while learning the controls. In flight, the AH-64 has a level and sturdy countenance, which while not as nimble or agile as either the 3D or Heli Mission, is easier and more fun to fly thanks to its aerodynamic shell and military styling.

Verdict: ★★★★★

4 Picoz Heli Mission

Price: £59.95
Get it from: www.firebox.com

Breaking the rules slightly, the Picoz Heli Mission includes both a mini helicopter and also a truck to transport it. The helicopter itself flies well enough, even though its build quality is nowhere near that of the Micro Bladez 3D and is made mostly of polystyrene. However, the thing that saves the Heli Mission is the truck. It's a good addition that gives plenty of fun for younger users. Using the same controller as the helicopter, the futuristic truck is capable of carrying the chopper in a rear compartment as you move it around, before allowing you to open two top-mounted doors, raise the helipad up from its depths and then switch control to the helicopter and fly away.

Verdict: ★★

HOW TO MAKE
A pocket catapult concealed in a tin

A pocket catapult

Construction materials:

- 1x Sweet / mint box
- 1x Coat hanger
- 1x Elastic bands (different sizes)
- 1x Glue gun
- 1x Plastic spoon
- 1x Sheet of card
- 1x Tape
- 1x Wire cutter

This compact device can fire all manner of small missiles

Tired of your work colleagues stealing your chocolate digestives while your back is turned, only for them to then sit smugly across the office guffawing as they stuff themselves at your expense? Well, if so, get your revenge from afar with this small but deadly miniature catapult. Constructed from everyday household objects including a coat hanger, sweet tin and elastic band, and capable of firing lightweight projectiles like mints and sweets over a sizable distance, reigning mild annoyance on your foes has never been simpler. Further, thanks to its closed lid design, whenever your reign of terror is in danger of being discovered by the boss, the mini catapult can be transformed into an innocuous box of sweets.

By following these seven simple steps, you too can make your very own mini catapult.

Step 01

Empty the tin of sweets into a container and keep them safe, as these will provide an excellent form of ammunition for your upcoming reign of destruction. Then, clean the inside of the tin and put it to one side.

Step 02

Select your coat hanger and cut off either its head or, if a full-wire construction, a strip of wire roughly the width of the sweet tin. Once this is achieved bend and trim the wire until it fits snugly in a U-shape into the tin.

Step 03

Next, cut down the two tips until they are under the lid line of the tin when turned upright, ensuring there is a gap between the wire tips and the tin's walls. This is important as it is around the tips that the elastic band is positioned.

GET INVOLVED!
Made your own mini catapult? Why not tell us how far you've managed to launch your ammunition at howitworks@imagine-publishing.co.uk

HOW IT WORKS

Step 04
Glue the wire in place as shown with either a glue gun or a large quantity of superglue. This is to be the pivot point of the catapult, so make sure that the coat hanger is completely secured by the dried glue before continuing.

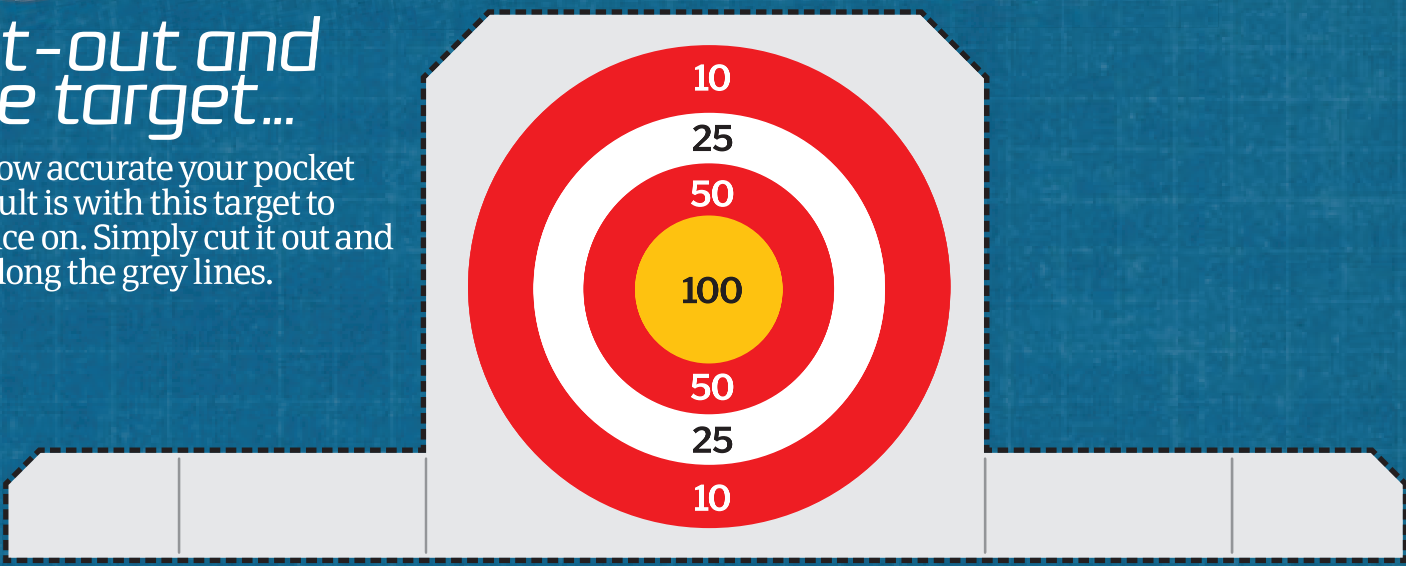
Step 05
Cut down your plastic spoon at the handle end until it fits into the tin. Cut a strip of cardboard and wrap it around the handle, before taping in place. You'll need to take the spoon out of this pouch so do not glue or tape the spoon to the pouch.

Step 06
Wrap the elastic band around both of the two coat hanger tips, creating an elastic line between them. Once achieved, insert the pouch between the elastic strands and turn it over and over towards the top end of the tin until held under tension.

Completed!

Step 07
Finally, insert the spoon back into the pouch. You should now have a taught, wound-up pouch with inserted spoon that can be hidden by shutting the lid. Now simply place some ammunition into the cup of the spoon, pull down and release.

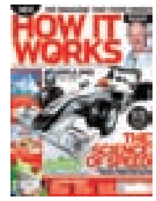
Cut-out and use target…
See how accurate your pocket catapult is with this target to practice on. Simply cut it out and fold along the grey lines.



HOW IT WORKS

INBOX

Feed your mind. Speak your mind



Get in touch!

If you've enjoyed this issue of How It Works magazine, 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. We'd love to hear from you. There are several easy ways to get in touch…

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 pen-and-paper method of communication, and you can send your letters to How It Works Magazine, Richmond House, 33 Richmond Hill, Bournemouth, Dorset BH2 6EZ.

Letter Of The Month

Britain didn't build much of this

High five!

Just bought your magazine for the first time. You guys have some great stuff going on and I really like it. High five! I've read most of it, but now my eyes hurt, and at 3:50 in the morning I feel I have to email you.

One thing I've noticed is that a few articles use some fancy units but give no explanation for them. For example, what measure is 3.3 bushels of grain equivalent to, what are 100,000 SHUs equivalent to? It would be super if you could include some sort of key to explain what the units stand for. Or even better, include a formula page like in science exam papers. Or at the back of the magazine include all the units featured in that month's issue and any related formulae with page references, maybe even monolithic words like 'ovoviviparity'.

On a separate note, on seeing the 'who built the ISS' diagram I was more than disappointed with Europe's pathetic green cylinder of an excuse of a contribution to the station? Britain's new space agency better pull its trousers up because I feel ashamed.

James Measures

HIW: Thanks for your charismatic letter, James. This is exactly the kind of feedback we look forward to reading, and you have a valid point about the use of unusual measurements so we'll look into finding a way to make strange units easier to understand – be that in the form of a glossary, key or just incorporating it into each article as necessary. So thanks for a great comment.

You're clearly itching to air your views about the 'limited' European contribution to the building of the International Space Station so why not start some debate and jump on to the How It Works forum and share your disappointment with other readers. The ISS is currently the world's largest multinational co-operative programme in science and technology and no matter how small the contribution may appear on the diagram, the European Space Agency did play a part. What's more exciting is the news of a dedicated British space agency, so that should be more impressive!

The original V-22 Osprey

In your recent magazine you covered an article on the V-22 Osprey, describing it as 'new technology'. This is not new technology to me. When I was in the forces in 1957, I was stationed in Basingstoke and nearby was an Army Air Corp called Middle Wallop, where an aircraft identical to the V-22 was flying regularly and I used to watch this quite often. Its name was the Fairey Rotodyne of Fairey Gannet fame.

James Britton

The Fairey Rotodyne, early forerunner of the V-22?

HIW: We were interested to hear your account of the Fairey Rotodyne, which does indeed share incredible similarities with the V-22 Osprey. Both vehicles are a hybrid of plane and copter with a snazzy combination of rotors and wings. We're not surprised that the Fairey Rotodyne caught your attention as it is said to have been an extremely noisy beast – perhaps one reason why it never 'took off' commercially. It was hoped that the Fairey would be a successful vertical take-off and landing (VTOL) passenger liner, but ultimately it failed due to limited funding and not enough prospective customers. Had it succeeded, we may have seen heliplanes like the Fairey Rotodyne flying about long ago. As you rightly say, James, this is clearly not a new concept, but there's no denying the advanced technology employed in the newer model we featured in issue three – take the state-of-the-art tilting rotor engines developed by Rolls-Royce, for example. Great spot though, and thanks for writing in.

How To Make…

Me and my friend read your mag and liked in issue one where you showed how to make a paper plane. We would like to request that you do some more of them.

Harry Tomlinson

Hollow Victory

Firstly, all hail to you and your excellent publication. Informative, clear, eye-catching, expert insights into all manner of things that reach all ages of people with a thirst for knowledge. Brilliant stuff.

However, one thing dear to my heart after serving 38 years in the Navy and being a proud Englishman is HMS Victory. I also have the good fortune to work very near to it in Portsmouth Naval Base. At the end of issue two, you stated that next month would be a chance to learn about HMS Victory. Now, I know the eyes aren't what they used to be, but I can find no reference or feature at all. Where was it? More importantly, will it be featured in a future issue? I'd like to say I'm so angry that I'll never buy your magazine again, but that's impossible; it's too damn good! Please, if you get the chance, direct me to the bit I've missed about the ship or please do a feature on it in the future. Many thanks for your attention in this matter.

Terry McCormack

HIW: Terry, no one was more disappointed than us that HMS Victory did not appear in issue three. While we do try our best to bring you everything listed on the next month page, the content is subject to change because we insist on providing our readers with the finest illustrations, diagrams and photography available. In this case, we would like to have provided you with a cross-section or cutaway illustration of the great ship. So when these resources aren't available we won't fob you off with inadequate visuals. As soon as we can arrange for some top-notch Victory artwork, we've no doubt you'll see a feature on it in a future issue of the magazine.

HIW: Hey Harry, thanks for your request. We suspect you're writing from abroad, in which case you may be a bit behind on the issues. So we'll catch you up: in our launch issue we featured How To Make… the perfect paper plane. We didn't do one for issue two but were bombarded with requests to do more. So you'll be pleased to hear that we plan to keep the How To Makes coming as long as they're fun and that you guys at home give them a try.

Do send in any photos you take of yourselves and your perfect planes, DIY litmus paper, or secret safes, we may even feature them on our website. And we recommend you give this issue's pocket catapult a go as we had loads of fun flicking vitamin tablets at each other across the office! It really works.

Good illustrations of HMS Victory's innards are hard to find…

Can't get enough of How It Works?

www.howitworksdaily.com/forum

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 from all around the world will be on hand to answer your questions and initiate debate. So get online and start feeding your minds.

HOW IT WORKS

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