1,006 ANSWERS INSIDE

THE MAGAZINE THAT FEEDS MINDS

HOW IT WORKS

REVEALED

INSIDE THE XBOX 360 S

Microsoft's cutting-edge console taken apart

SCIENCE ENVIRONMENT TECHNOLOGY TRANSPORT HISTORY SPACE

MASS VS WEIGHT

Understand the scientific difference between the two

RADIATION

From creating superheroes to battling cancer

SOLAR VEHICLES

Cars, boats and planes that run on the power of the Sun!

PUFFERFISH

What makes this the world's most poisonous fish?

DR ALICE ROBERTS INTERVIEWED INSIDE P14

WORLD'S FASTEST ANIMALS!

HOW THE QUICKEST CREATURES REACH AMAZING SPEEDS

SATURN

Fascinating facts on the planet that can float on water

HOW DOES GOOGLE WORK?

What really happens after you hit the search button?

+ LEARN ABOUT

- TESLA COILS
- SINKHOLES
- THE BENDS
- GREEK TEMPLES
- STOMACH RUMBLES
- CONCORDE
- THE WATER CYCLE
- GLUE
- GLIDERS
- EARDRUMS
- PREGNANCY
- CRANES

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HOW IT WORKS
WELCOME
The magazine that feeds minds! ISSUE TWELVE

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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Twitter: http://twitter.com/HowItWorksmag
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"FEED YOUR MIND!"

Meet the experts

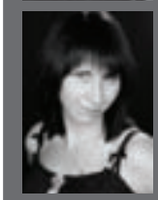
"Written by experts to be enjoyed by everyone" is how we roll, so meet the people that bring you each issue...

Dave Roos
Radiation

Dave's a farmer and a freelance writer who's been with us since issue 1. He's as great with research as he is with a plough and he turned in an excellent article on radiation, found over on page 46.

Adrian Bridgwater
Google

Adrian's a technology journalist who specialises in web-based tech. He's written some great articles for our sister mags so we drafted him in to explain how Google works.



Josie Reavely
Camera lenses

Josie is reviews editor on Digital Photographer magazine, which lives in the same spacious office as us. So she didn't have far to come to deliver her article on how camera lenses work on page 32.

Nigel Watson
Space junk

Nigel's interest in ufology meant he was well suited to explaining the identifiable flying objects that are in orbit around Earth. You can find his article on space junk over on page 62.

Dr Bridget McDermott
Greek temples

Recently returned from a trip to the desert, Bridget hydrated herself enough to write an explanation of Greek temples to accompany the amazing cutaway illustration found on page 78.

Shanna Freeman
Saturn

Shanna is another How It Works veteran. Space is her thing and you can read an excellent and thorough explanation of the planet Saturn and its rings starting on page 70.

With thanks to

How It Works would like to thank the following organisations for their help

sciencemuseum
2010
DK
NASA

So what's the fastest animal on Earth? It is not – contrary to a popular anecdote – a cow that has been dropped out of a helicopter. Such a cow would allegedly have a top speed of some 120 feet per second, or 80mph. This doesn't come close to the top speed of a diving peregrine falcon, which can hit a staggering 200mph. It does, however, just nose ahead of a cheetah at full pelt, which tops out at 75mph in short bursts... so it would depend on the height of the helicopter when the cow was tipped out. A sailfish would probably come in just behind the cheetah, leaving Usain Bolt – the fastest man on Earth – coming in last, and no doubt appalled by the senseless cruelty of the helicopter's occupants.

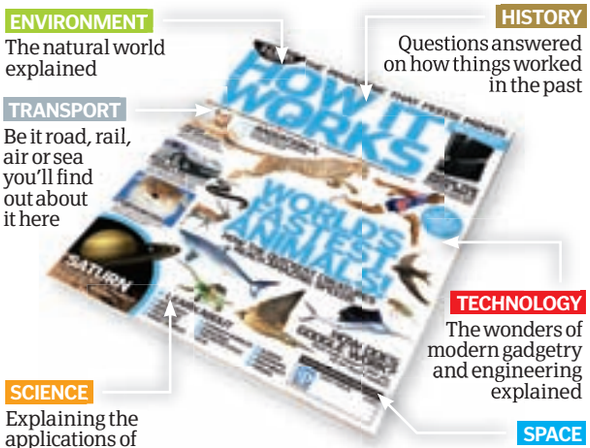
The fastest animals on Earth is the topic of our main cover feature this month and you can read more about a hypothetical race between the species on page 22, so whiz over there without delay to discover more about the quickest creatures on the planet, from fish to frog to fowl to fella...

If you think that speed isn't the key to a great issue of How It Works then there's still plenty to stuff your hungry mind with. You can find out about the solar-powered vehicles that are trying to go around the Earth powered only by the Sun, or discover the breathtaking amount of man-made trash and junk that's floating in space. We also explain the water cycle, Saturn, the Xbox 360 S and laser eye surgery, plus loads of other cool stuff too. And if that doesn't whet your appetite for knowledge, we even tell you why your stomach rumbles over on page 40.

Dave Harfield
Editor in Chief

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

What you're saying about How It Works

I absolutely love How It Works! Your articles are very simple to read and my brother and I really enjoy reading it (I am 12 and he is 9). Some articles I think would be good to have at some point include spy equipment, Nintendo Wiis and all the land speed records that have been set in cars.
Jack Philipson

Both my seven-year-old son, Aidan, and I love your magazine. I don't always know the answers to his questions so we enjoy reading it together.
Lucinda Kidney

Editor's pick

Imagine what your life would be like without Google. What would it be like planning a holiday? Booking a flight? Checking the weather? We take a simple white search box with two buttons for granted, so it was fascinating to discover what actually happens after you click "search". Find out for yourself on page 34.

HOW IT WORKS

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The magazine that feeds minds!

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Because enquiring minds want

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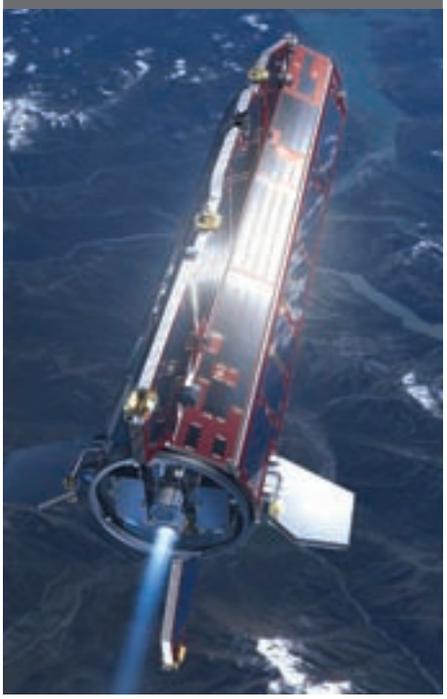
All that's interesting from the world of science, technology and the environment in six pages of photography and stories



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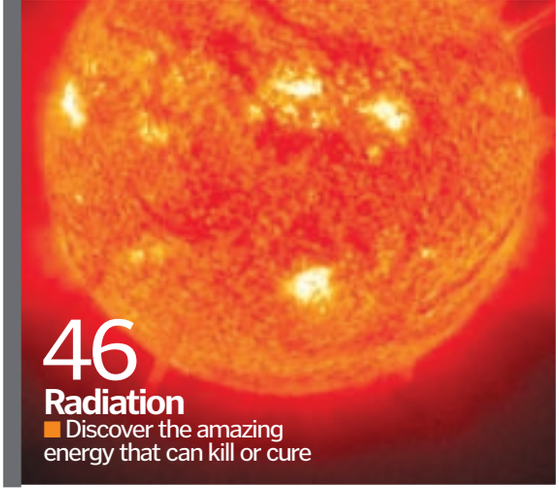

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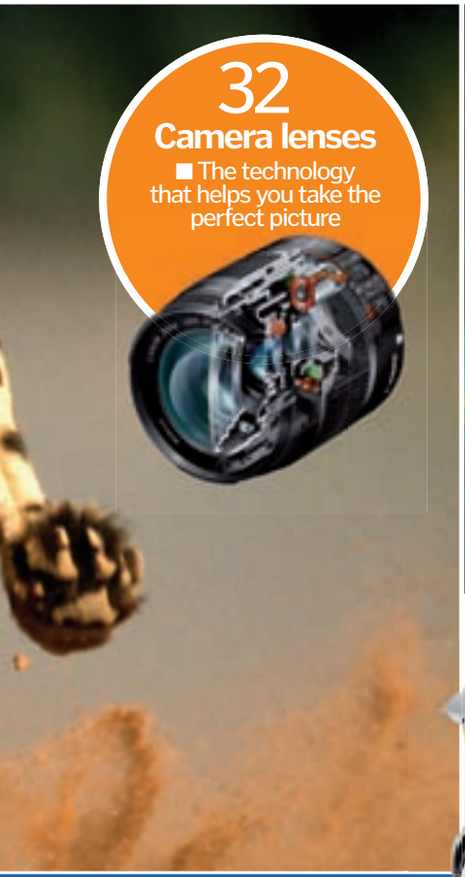
80 Expert answers

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

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

Adam Boal
Science Museum Family Programmes Developer
Adam studied Physics at York University and now writes and performs family events at the Science Museum.

Alison Boyle
Curator of Astronomy and Modern Physics
Alison Boyle is responsible for a range of collections spanning most of the space-time continuum.



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How It Works talks to Dr Alice Roberts about bones, books and digging for Britain

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For connoisseurs of kit and savants of stuff

86 The latest reviews

Which of our favourite gadgets and gizmos made it into the kit reviews this month?

94 How to make

This month discover how to make an origami glider

96 How It Works – Inbox

Your thoughts and opinions about How It Works

The Earth's magnetic field interacted with the charged particles in the solar storm cloud, creating an impressive light show

Solar slumber disturbed

Incredible SDO imagery of a recent solar event that plunged Earth's magnetic field into disarray

The unusually ferocious solar storm recorded in this ultraviolet image of the Sun, taken by the Solar Dynamics Observatory (SDO) on 1 August, produced some significant aurora displays here on Earth.

A C3-class solar flare launched two coronal mass ejections (CME) in the direction of Earth at speeds exceeding 1,000km per second, resulting in a 12-hour long geomagnetic storm that was lighting up the night skies in Europe and North America by 3 August.

CMEs are large clouds of charged particles (magnetic field) ejected from the Sun at millions of miles per hour. If such a wind reaches Earth – and they occasionally do – the charged particles blow across our planet's magnetic field, exciting the oxygen and nitrogen atoms in our own atmosphere. These excited gas particles glow to produce the famous aurorae visual phenomenon.

On this occasion the increased solar activity, which took place across the majority of the Sun's Earth-facing hemisphere, resulted in bursts of intense solar flares, a solar tsunami, filaments of magnetism from the surface, radio bursts, large-scale shaking of the solar corona, and powerful CMEs. The CMEs that reached our magnetic field on 3 August were so powerful they broke the Earth's magnetic field lines, causing aurorae that spread further from the poles than usual. This meant that the Aurora Borealis was visible much further south than usual over Europe and North America.

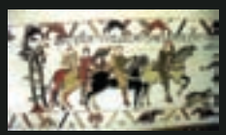
The Sun's activity is cyclical, with a solar maximum (the period of highest activity) and a solar minimum (the period of least activity) repeating in a cycle that lasts roughly 11 years. The last solar maximum was in 2001 while the next is expected to occur in around 2013. This latest bout of disturbance is evidence that the Sun is reawakening.

© NASA

This day in history

9 September: How It Works issue 12 goes on sale, but what else happened on this day in history?

1087 William the Conqueror dies after falling off his horse in Normandy.



1543 Infant monarch Mary, Queen of Scots, is crowned on this day at just nine months old. She was six days old when her father James V died.

1585 French clergyman Armand Jean du Plessis de Richelieu is born. You may recognise the name from *The Three Musketeers*.

1839 Englishman Sir John Herschel takes the very first glass plate photograph.

Blood test breakthrough

The team have created a way to measure blood glucose levels without using a needle

Scientists have developed a new method for testing blood glucose levels... without drawing blood

The team at MIT's Spectroscopy Laboratory have finally discovered a way for type one diabetes patients to control their condition without having to puncture their own skin.

After 15 years of research by the team, lab students Ishan Barman and Chae-Ryon Kong developed a tabletop machine that uses non-invasive light technology to test blood glucose levels by scanning a patient's arm or finger with near-infrared light. The machine can distinguish the chemical compounds in a substance by identifying the frequency of vibrations of the bonds holding a molecule together.

However, near-infrared light penetrates less than a millimetre below the skin's surface and so only measures the glucose levels in the interstitial fluid surrounding skin cells, not in the blood. To overcome this, the team produced an algorithm to compare the amount of glucose in the blood and the amount of glucose in the interstitial fluid, enabling them to use the result for one to predict the other.

The final breakthrough came when they conquered the last hurdle in the quest to test blood accurately. That being the fact that there's a lag between when a patient eats something sugary and when it shows up in their interstitial fluid reading. Barman and Kong have developed a new calculation method, dubbed Dynamic Concentration Correction, for working out the rate of glucose diffusion from blood to interstitial fluid.

The method has been tested and has improved the accuracy of measurements by up to 30 per cent. This could mean the end of painful blood testing for millions of people worldwide.

Greenland goes into meltdown

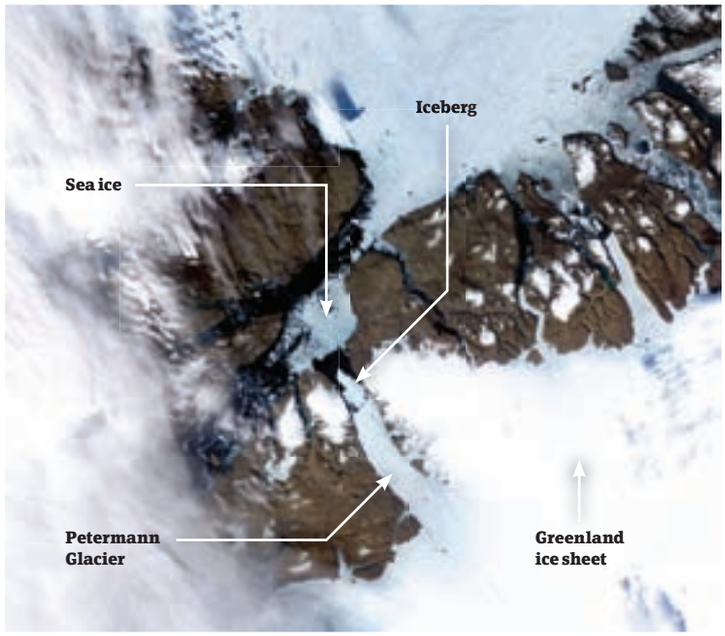
The largest chunk of ice to break away from Greenland since 1962 sparks concern

On 5 August a slab of glacial ice with an area of 97 square miles broke away from the Petermann Glacier in northwest Greenland.

According to the University of Delaware, this chunk of ice now represents the largest iceberg formed in the Arctic for 48 years. The slab came free and floated towards the straits separating Greenland and Canada.

At 40 miles long and ten miles wide, the Petermann Glacier is the largest ice shelf in the northern hemisphere and the section of ice that calved away from it accounted for around a quarter of the whole glacier. While seasonal thawing of the ice in Greenland is expected, this enormous calving has alarmed a panel of geoscientists who suggested that Greenland's ice could recede completely if temperatures were to rise by 2°C.

Pennsylvania State University's Richard Alley warned that the possible effects of continued calving could result in a global rise in sea level that may be felt thousands of miles away from the Arctic.

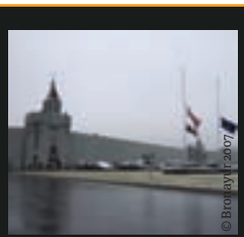


1850
California joins the Union as the 31st of the United States.

1926
America's radio and television network National Broadcasting Company – now better known as NBC – is founded.

1940
Inventor George Stibitz first demonstrated the remote operation of his "complex number calculator", or the modern digital computer.

1971
Prisoners at the Attica Correctional Facility near Buffalo, New York, seized control of the maximum-security prison for four days until state troopers regained control by force. The final death toll was 43.



1976
Chinese communist leader Chairman Mao Zedong dies aged 82 following a heart attack.

MONTH IN FACTS

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

Jumping the queues

■ Invented by engineer Mark Moore, the Puffin is a vehicle hoping to change the face of personal flight.

50 yrs

■ It's 50 years since the first successful launch of a communications satellite, the Echo 1A.

Eye of the storms

■ NASA will spend the next six weeks flying research vehicles – the DC-8 and the WB-57 – through storms around the Gulf of Mexico and Atlantic Ocean.

160,000km²

■ In Pakistan, around a fifth of the country has been affected by the worst recorded flooding in history.

10 years of Smart

■ September 2010 marks the tenth anniversary of the arrival of the right-hand drive Smart car in the UK.

Human ancestors' tool use pushed back 1m years

New bone find indicates that early humans used stone tools much earlier than believed

Researchers have found evidence that early human ancestors used stone tools to cleave meat from animal bones more than 3.2 million years ago, pushing back the earliest known usage by roughly 1 million years. Bones found in Ethiopia show cuts from stone and indications that the bones were forcibly broken to remove marrow.

Previous to this find in the Dikika region of Ethiopia, the oldest recorded use of stone tools was from 2.5 million years ago, a fact which suggested that it was members of our own genus Homo that were the first to use tools. However, this new find seems to show that it was in fact an earlier genus of hominin that first utilised tools to aid meat consumption.

Providing that the dating of the bones is accurate – something that is highly probable as they were dated against nearby volcanic rock – this means that it was in fact the hominin species *Australopithecus afarensis*, the species made famous by the 1974 discovery of the specimen nicknamed "Lucy" in Ethiopia's Awash Valley, that was the first to use tools in this fashion. Indeed, the arrival of the first human species, *Homo habilis*, was not until 2.3 million years ago, a whole million years after the species of the genus *Australopithecus* were roaming the Earth.

Shannon McPherron, an archaeologist at the Max Planck Institute for Evolutionary Anthropology and researcher on the Dikika Research Project, speaking on the find said:

"We were just walking along when we discovered the two bones. We picked up the rib fragment, flipped it over and there were these two, clear marks. Soon after, we found the second bone, also with a lot of marks on it. Right away we knew we had something potentially important."

The use of stone tools to remove meat from animal bones is postulated by scientists to be a crucial development in the evolution of the human, as when the ancestors of early humans turned to meat for sustenance, they were able to grow larger brains that enabled them to make more sophisticated tools.

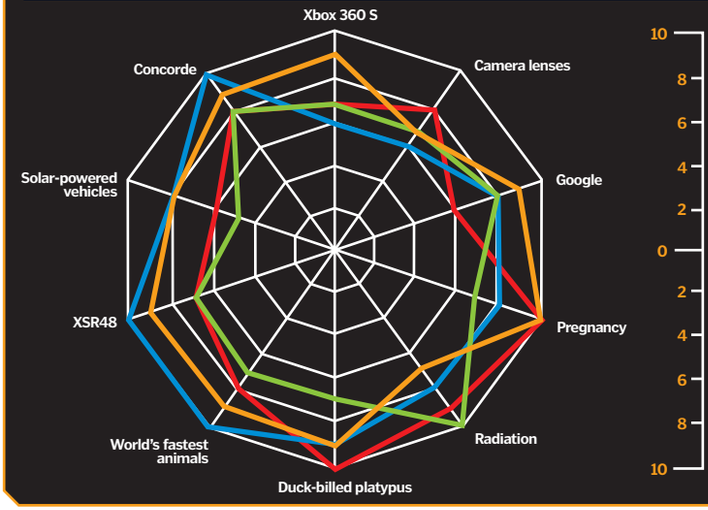
The bone find was discovered north east of Addis Ababa in central Ethiopia

The remains of the "Lucy" specimen of the hominin species *Australopithecus afarensis*

© 120

THE EXCITE-O-METER!

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



Dave

Ed in Chief

I'm trying to book a last minute, bank holiday camping trip right now and it would be much harder without Google giving me a hand. So I was excited to discover how the search engine finds all the campsites in the New Forest with toilets and a shower block...

Helen

Deputy Editor

Pregnancy and the development of human life in the womb (man, I hate saying that word). It affects us all: we all spent time in the womb and most women will experience the ordeal from a completely different perspective. What better reason to read on?

Rob

Staff Writer

Radiation stands out for me this issue, despite our look at Microsoft's new Xbox scoring highly also. How Google works is fascinating and more complex than you'd think, with a lightning fast chain reaction begun every time you hit the 'search' button.

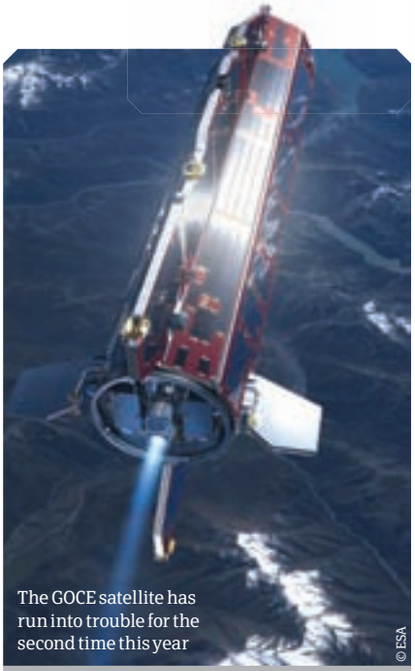
Jon

Senior Sub Editor

I went into excitement overdrive this month! The likes of the duck-billed platypus, Google and the world's fastest animal feature had me eager to read more, and with my fiancée being a midwife I had to be interested in pregnancy, seems I hear about it every day...

AND THE VERDICT IS...

Jon's excitement goes nuclear this month with a whopping 84 points out of a possible 100 placed onto the Excite-O-Meter. Helen, on the other hand, is more selective, with only duck-billed platypuses and pregnancy receiving top marks.



The GOCE satellite has run into trouble for the second time this year

© ESA

GOCE satellite

Europe's flagship Earth observation satellite taken offline

For the second time this year the European Space Agency's GOCE Earth observation satellite is drifting through space unable to beam any data back to Earth.

The satellite's emergency computer system has been struck by a glitch, a fact that after the system's primary system was taken offline due to a processor fault, leaves it unable to communicate with ground stations. Currently ESA engineers are working round the clock to get the system active once more, however the task ahead of them is daunting. Speaking on the mission to get the station fully functional again, GOCE mission manager Dr Rune Floberghagen said:

"There's no doubt about it: we're in a difficult situation, but we are not without ideas. If we have just two half-computers, we can stitch them together and get GOCE working again."

Luckily, regardless if the satellite was to be forever lost due to the current fault, GOCE has already collected two-thirds of the data it was originally due to ascertain – information regarding Earth's gravity and its variations. This data, it is hoped by scientists, will have multiple applications in the field of climate studies, potentially bringing new insights into the way ocean waters move and redistribute heat around the planet.

Presently a senior investigation board at the ESA is looking into the root causes of the computer failures.

© Keqs

God's number revealed

Fewest number of moves to crack Rubik's Cube determined by team of researchers

The 30-year quest to determine the fewest number of moves needed to solve any one of the Rubik's Cube's billions of possible configurations has been calculated by a team of international researchers.

Referred to as "God's number" – because an all-knowing entity would know the optimal number of steps needed to solve the puzzle – the magic number for which any puzzle can be solved was revealed to be 20.

To calculate this number the team had to run through all of the possible combinations of a Rubik's Cube, a task that Professor Morley Davidson – a mathematician from Kent State University and team member of the project – admits would have been "completely hopeless" if it wasn't for a timely intervention by Google, as there are quite literally billions of possible combinations and the computer technology the team had was inadequate to compute them.

However, thanks to Google's super computers the team were able to crunch through the numbers and by the end of the exercise the probability of there being a combination that required more than 20 moves to solve "dropped into the very low digits", before leaving Professor Davidson and his team with the number 20. Speaking at the close of the exercise, Professor Davidson stated, "It's come full circle for me. Rubik's Cube was an icon of the Eighties when I was growing up and was the reason I went into mathematics."

The *other* way to solve a Rubik's Cube

© Courtesy of Curis

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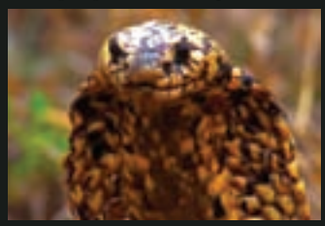
HOW IT WORKS TV

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

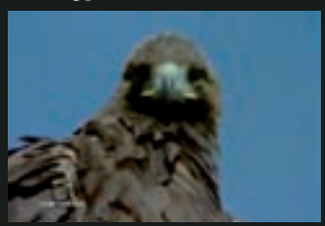
Cape Cobra

Learn about South Africa's deadliest snake, the Cape Cobra, and specifically how it can kill up to six people with a single bite.



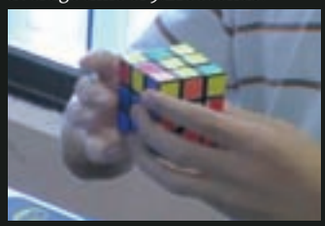
Golden eagle hunting

This is awesome! Check it out. A golden eagle hunts a mountain goat in an amazing display of hunting prowess.



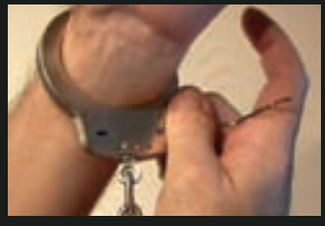
Speed cubing

Think you're an ace because you can solve a Rubik's Cube? Think again. Watch the former world champion complete five with an average time of 9.21 seconds.



Handcuff trick

Learn how to escape from a pair of professional double-lock handcuffs in less than 20 seconds with nothing more than a hairpin.



Dr Alice Roberts

From digging for ancient remains on *Time Team* to exploring the coastlines of the UK for the BBC's *Coast* series, Dr Alice Roberts has a passion for the world around her. Anatomy is threaded through almost everything she does, and with another book due out soon, we thought we'd find out more...

How It Works: Please tell us about your latest book *The Complete Human Body*.
Dr Alice Roberts: *The Complete Human Body* is a big book, crammed with fascinating facts and beautiful illustrations, revealing the structure and function of the human body, as well as a wide range of the diseases which afflict it. If you want one book as a guide to your body – this is it. And as you'd expect from DK, the illustrations are glorious – and accurate.

HIW: You're involved in a new BBC series called *Digging For Britain*, what can viewers expect to take away from this programme? And what did you learn during filming?
AR: Digging for Britain is a brand new archaeology series, which started on BBC2 just a while back. It's a fresh approach to archaeology on television, we set out to show British archaeology as it is – and as it's happening. We've travelled all over the UK, visiting everything from small scale research digs to community projects, to enormous excavations like the one at the site of the new road scheme in Kent. I've been to the beach where the evidence of the earliest humans in Britain – going back nearly a million years – came to light. I've seen the earliest rock art in the UK; I found out how archaeological science has been able to help identify an Anglo-Saxon princess, and I stood on the floor of Shakespeare's first theatre in London. It's certainly a series about archaeology and history, but what we're really doing is finding out about the people who inhabited Britain before us – and how we can find their traces and catch glimpses of their lives, hundreds, thousands of years later. What did I learn during filming? You'll have to watch the series to find out!

HIW: You have done much work on the migratory paths of early humans, as made famous by your television show *The Incredible Human Journey*. How clear-cut is the progression across the globe?
AR: Our understanding of how modern humans – Homo sapiens – spread across the globe is now quite detailed. Combining insights from archaeology, palaeontology, climate science and genetics, we can see where and when we emerged as a species, and track those ancient migrations that led to us colonising the globe. There are still some debates and controversies, as in any branch of science – and that's partly what makes it so exciting.

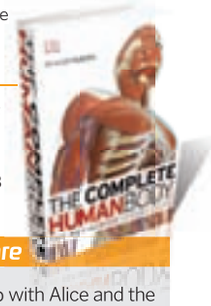
HIW: Over the years your work has taken you to some fascinating locations, what's your favourite? What sites would you like to visit in the future?
AR: Even though it was achingly cold, I loved visiting Siberia while filming *Human Journey*. I travelled out to a remote reindeer-herders' camp, where we stayed in tents (at -40°C!), with a herd of a thousand reindeer browsing in the snowy taiga around us.

HIW: What was it like working with the various experienced teams on *Time Team*, and what is the most exciting discovery that you made during your time on the programme?
AR: I enjoyed working on *Time Team* immensely. As an osteologist, or human bone expert, I was able to bring my own expertise and experience to the team, while working with a great bunch of experts in a number of other areas – including legends like Professor Mick Aston! I wrote up reports on the skeletons we found, but I also got a chance to be out in the field, helping with the excavation itself. I think my favourite dig is still the first one I went along to – an Anglo-Saxon cemetery site in Hampshire, where we found a range of grave goods alongside the skeletons – including metal parts of spears and shields, as well as some mysterious buckets.

HIW: We ask all our interviewees this one. If there is one gadget you wouldn't be without, what would it be – whether in the home or daily life, or while out and about in the field?
AR: My laptop. I love being able to write – as well as stay in touch with friends and family while I'm off on location. And at home, I like being able to work where I want – very useful when balancing my work with looking after a five-month-old baby!

HIW: What is next on your to-do list?
AR: I have a couple of ideas for books that I want to write, and a few television projects that I'm working on. We're currently filming series six of *Coast*!

Alice's outstanding new book *The Complete Human Body* will be available to buy from 23 September for £30.



Learn more

You can also keep up with Alice and the projects she's working on at her website www.alice-roberts.co.uk.

"I travelled out to a remote reindeer-herders' camp, where we stayed in tents (at -40°C!)"

Alice also works for the NHS Severn Deanery School of Surgery

Courtesy of Andrew Yarme

This month in **Environment**

Helping out with the curriculum this issue, we take an in-depth look at the hydrological cycle and explain how and why our precious water source moves around the Earth. We also take a close yet cautious look at some venomous nasties from the animal world – the pufferfish and the platypus, neither of which looks particularly threatening, but both of which can serve up a spiteful sting. We also thought you'd enjoy a high-adrenaline feature revealing how the planet's fastest animals are built specifically for speed on page 22.

18 Deadly pufferfish

19 Sinkholes

© Dr Philip Bentley, 1999

20 Duck-billed platypuses

ENVIRONMENT

The water

Rain falling today has spent billions of years travelling between Earth's clouds, oceans and ice

The water – or hydrological – cycle is the Earth's water recycling system. Since water rarely escapes the planet or arrives from space, the water cycle keeps rivers relentlessly flowing into the oceans and the atmosphere supplied with clouds and rain. Without it, life simply couldn't exist.

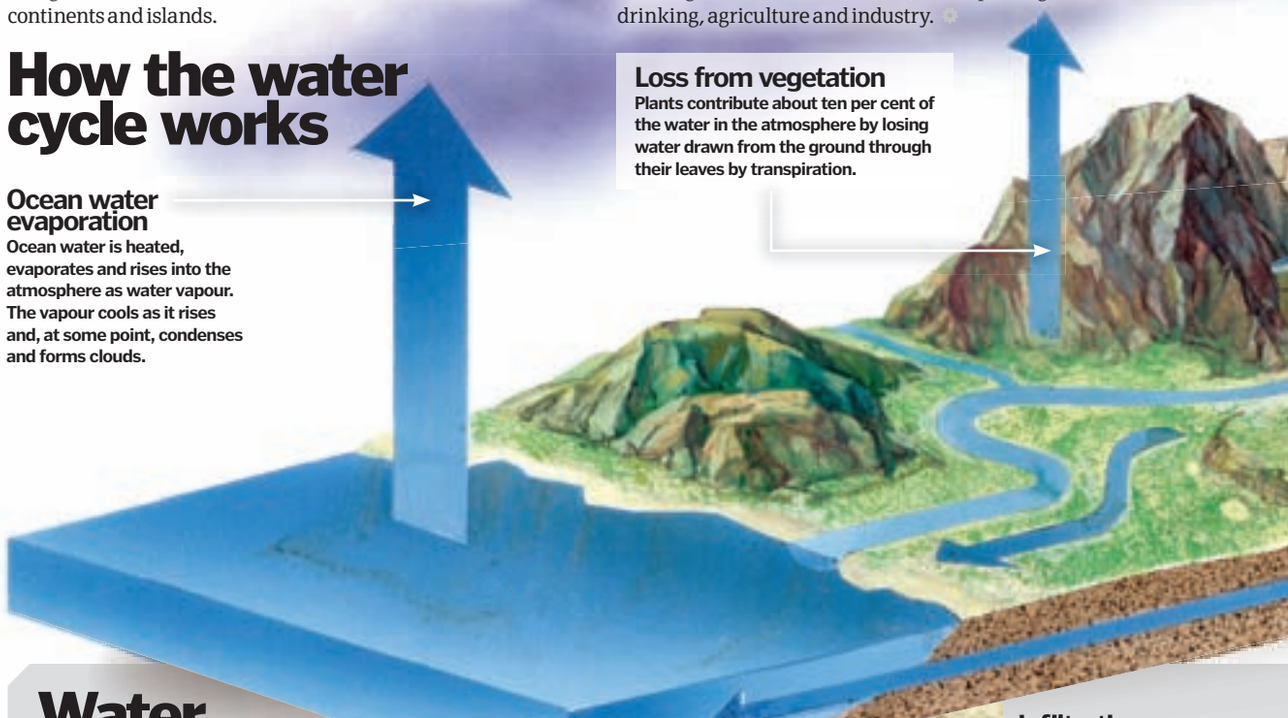
The water cycle circulates water between the oceans and atmosphere, sometimes via the land. When ocean water is heated, it turns into water vapour, which rises into the atmosphere and is carried by winds. The vapour cools at some point and forms clouds. Around 78 per cent of the rain, snow and other forms of precipitation falling from these clouds goes straight back into the ocean. The rest falls over the Earth's continents and islands.

Some of this water runs into rivers and lakes and is carried back to the sea. Water also seeps back to the oceans through deep soil and rocks, becoming the Earth's groundwater. Water falling as snow over the polar ice sheets can be buried, sometimes for millions of years, until it reaches the sea via slow-moving glaciers.

Water that stays in shallow soil can be lifted back into the atmosphere when it warms. Alternatively, plants may suck up soil water through their roots and return it to the atmosphere through their leaves. When animals eat plants, they take the water into their bodies and expel it into the air in their breath.

Humans are increasingly altering the water cycle on land by building cities and flood controls, and capturing water for drinking, agriculture and industry.

How the water cycle works



Ocean water evaporation

Ocean water is heated, evaporates and rises into the atmosphere as water vapour. The vapour cools as it rises and, at some point, condenses and forms clouds.

Loss from vegetation

Plants contribute about ten per cent of the water in the atmosphere by losing water drawn from the ground through their leaves by transpiration.

Water processes explained

Condensation

When you breathe on a cold window and it fogs up, you're seeing condensation in action. It's the process by which water vapour in the air turns back into liquid water when it cools down. Atmospheric water vapour condenses on salt, smoke and dust particles to form clouds.

Infiltration

Infiltration is where water seeps into the ground rather than running across it. Once in the ground, the water stays in shallow soil layers or moves deeper to form groundwater. Dry, loose soils on flat ground will absorb more water than steeply sloping hard surfaces or already wet soil.

5 TOP FACTS WATER CYCLE

Ancient science
1 People first mentioned the water cycle around 2,000 years ago. One of the oldest Hindu scriptures, the Chandogya Upanishad, said "rivers... lead from sea to sea".

Drop to drink
2 Most people get water from rivers and lakes, which form just 0.014 per cent of the world's water. The rest is mainly in the oceans (96.5 per cent), ice or underground.

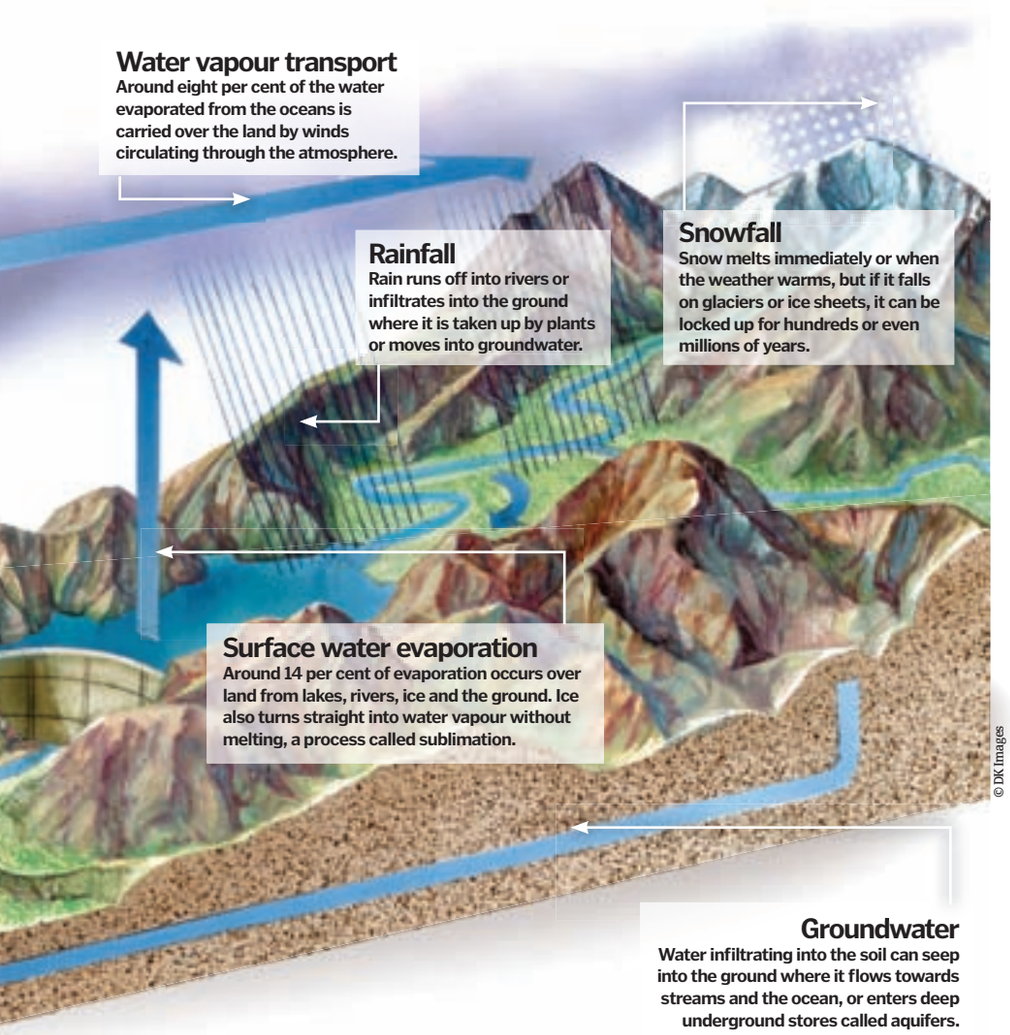
Olympic deluge
3 A small thunderstorm can produce, on average, 2,000 tons of rain in just 30 minutes. That's enough to fill an Olympic-sized swimming pool.

Earliest water
4 Liquid water may have existed on Earth for 4.4 billion years. The water in your glass is almost as old as our planet and significantly older than the dinosaurs.

Slow moving
5 Water can spend more than 10,000 years locked up in deep groundwater or the polar ice sheets, but just a few days in the atmosphere.

DID YOU KNOW? *The Sun powers the water cycle, moving around 15.5 million tons of water through the atmosphere every second*

cycle



Water vapour transport
Around eight per cent of the water evaporated from the oceans is carried over the land by winds circulating through the atmosphere.

Rainfall
Rain runs off into rivers or infiltrates into the ground where it is taken up by plants or moves into groundwater.

Snowfall
Snow melts immediately or when the weather warms, but if it falls on glaciers or ice sheets, it can be locked up for hundreds or even millions of years.

Surface water evaporation
Around 14 per cent of evaporation occurs over land from lakes, rivers, ice and the ground. Ice also turns straight into water vapour without melting, a process called sublimation.

Groundwater
Water infiltrating into the soil can seep into the ground where it flows towards streams and the ocean, or enters deep underground stores called aquifers.

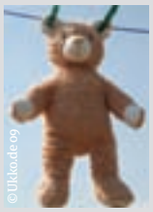
The River Indus is now some 30 kilometres wide in places

When the water cycle lets us down

Floods affect tens of thousands of people each year, as is evident from this year's devastating monsoon flooding across Pakistan. The flood, which has affected some 20 million people so far, was the result of the heaviest monsoon rains in the area for generations. On 8 August the River Indus burst its banks, sweeping away entire communities. While it's normal for Pakistan to receive half its annual rainfall (250-500mm) during the monsoon months of July and August, the country was reportedly bombarded with 300mm on 29 July alone. The Met Office suggests several possible reasons for the unusually heavy rains, including changes to upper atmosphere airflow, active monsoon systems, and La Niña (El Niño in reverse).

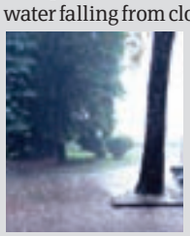
Serious floods, like those seen in Pakistan during July and August, can cause catastrophic destruction

Runoff
Water flowing down tarmac roads into curb-side drains after a storm is an example of the process of runoff. Rain that doesn't evaporate or infiltrate into soil or rock also flows down small channels as runoff. The channels merge into streams that, eventually, join rivers flowing downhill to the sea.



Evaporation
Wet clothes hung outside dry by evaporation, the process by which liquid water turns into vapour when heat energy breaks bonds between its water molecules. Soaking a T-shirt keeps you cool on a hot day because since evaporation uses up heat energy from the air, it reduces nearby temperatures.

Precipitation
Precipitation is a catch-all term for water falling from clouds to the earth.



It covers rain, snow, hail and so on. Precipitation happens when water vapour condenses on airborne particles as droplets. These grow bigger by, for example, collisions until they become so heavy they fall to the ground.

Transpiration

Plants – like humans – breathe out water vapour, a process called transpiration. During transpiration, water drawn into a plant's roots is carried to the leaves where it evaporates. How much plants transpire varies depending on air temperature, humidity and incoming sunlight. Higher temperatures and stronger sunlight mean more transpiration.

"The poison is produced as part of a mutually beneficial relationship"

The deadly pufferfish

A look at why, despite its size and timid appearance, one type of fish can be extremely deadly when it comes to defending itself

The pufferfish is a group of over 100 species that are so-named for their unique line in defence. When cornered, a puffer's last gasp is to draw in water (or sometimes air) and pump it to the stomach, expanding to three times its normal size; deterring potential predators and when possible, affording it the vital seconds necessary to escape.

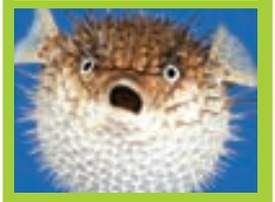
To achieve this with the required efficiency and speed, once the puffer has taken on water its gills clamp shut and a powerful bow-door-like valve closes over the inside of the mouth. Once the mouth's cavity is compressed, this forces the water into its stomach.

Despite its resulting comic appearance, the tissues and organs of many a puffer are no joke, laced with the potent poison tetrodotoxin – a single pinhead of which could kill a grown man. This makes it ten times more deadly than the black widow spider. The poison is produced as part of a mutually beneficial relationship by common bacteria where nutrients are exchanged as payment for the ultimate deterrent.

Some species such as the porcupine puffer are more sporting than others, covered with spines that offer added protection and ample warning to any would-be attackers. Each spine is attached to the skin by an ingenious tripod-shaped bony base. When the skin stretches, one of the legs is pushed forward and two are pulled back to snap the spine outwards... a point well made in more ways than one.

Fact File

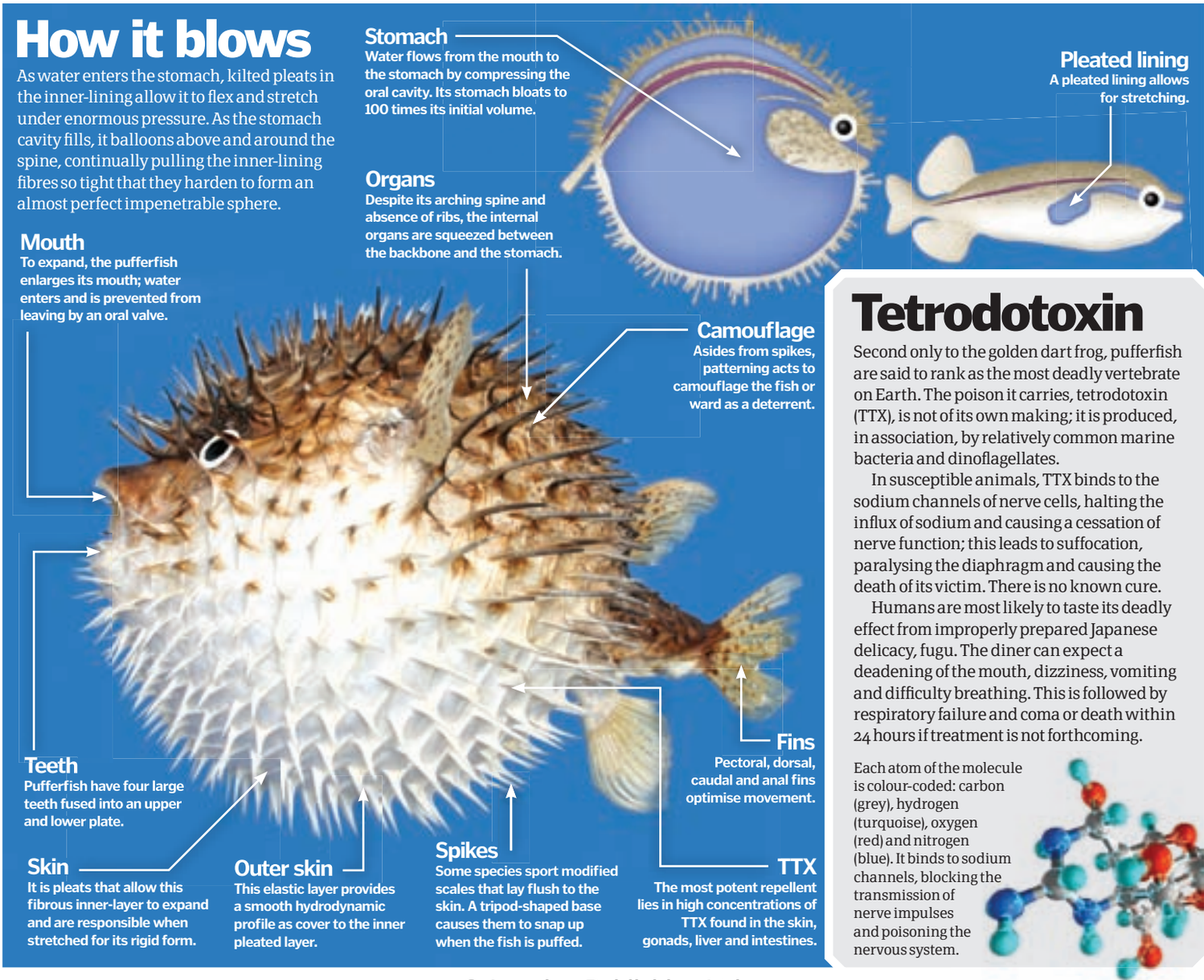
Pufferfish



Type: Fish
Diet: Omnivore: algae, molluscs, invertebrates and crustaceans
Average life span: 4-8 years
Power: Pressurised water reactor, fuelled for life
Weight: 150g-30lbs
Size: 1in-3ft
Habitat: Tropical/sub-tropical, saltwater, brackish, freshwater

How it blows

As water enters the stomach, kilted pleats in the inner-lining allow it to flex and stretch under enormous pressure. As the stomach cavity fills, it balloons above and around the spine, continually pulling the inner-lining fibres so tight that they harden to form an almost perfect impenetrable sphere.



Tetrodotoxin

Second only to the golden dart frog, pufferfish are said to rank as the most deadly vertebrate on Earth. The poison it carries, tetrodotoxin (TTX), is not of its own making; it is produced, in association, by relatively common marine bacteria and dinoflagellates.

In susceptible animals, TTX binds to the sodium channels of nerve cells, halting the influx of sodium and causing a cessation of nerve function; this leads to suffocation, paralysing the diaphragm and causing the death of its victim. There is no known cure.

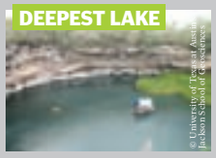
Humans are most likely to taste its deadly effect from improperly prepared Japanese delicacy, fugu. The diner can expect a deadening of the mouth, dizziness, vomiting and difficulty breathing. This is followed by respiratory failure and coma or death within 24 hours if treatment is not forthcoming.

Each atom of the molecule is colour-coded: carbon (grey), hydrogen (turquoise), oxygen (red) and nitrogen (blue). It binds to sodium channels, blocking the transmission of nerve impulses and poisoning the nervous system.

Head to Head MASSIVE SINKHOLES

1. Xiaozhai Tiankeng, southern China

At over 600m deep and wide, this gigantic sinkhole may be the world's largest. Tiankeng means 'sky hole'.



2. El Zacatón Cenote, Mexico

A 319m deep lake, this is the world's deepest water-filled vertical shaft – popular with divers and NASA explorers hoping to use research gained to search for life in space.

3. Great Blue Hole, Belize

The world's largest blue hole – otherwise known as an underwater sinkhole – lies off the Belize coast. It's almost perfectly round and 300m across.

DID YOU KNOW? *The ancient Mayan civilisation threw live victims into sinkholes to appease their rain god*

A near miss for these house owners in Kentucky, USA

How do sinkholes form?

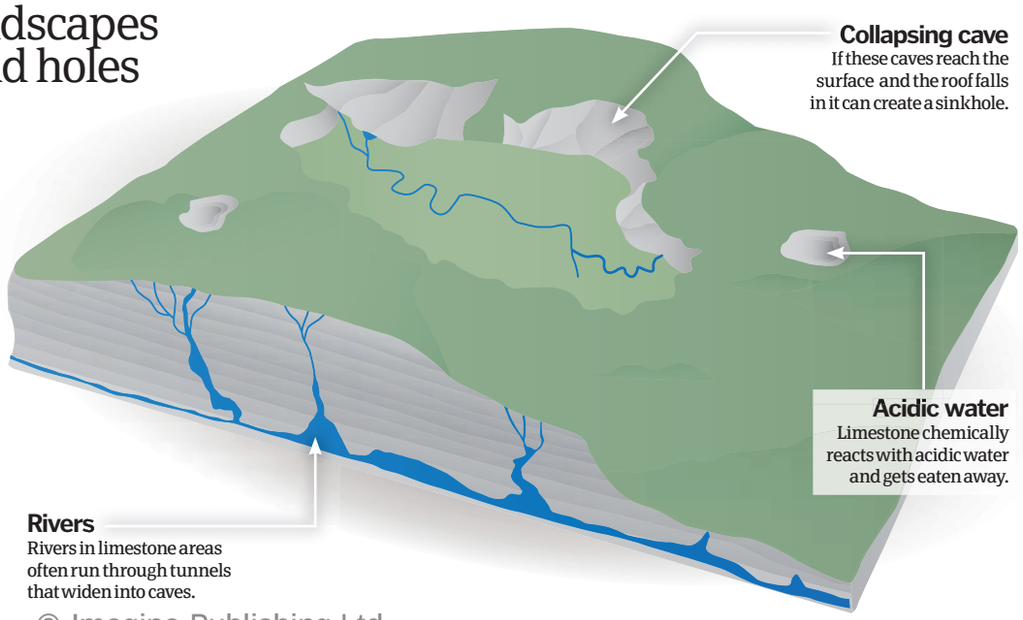
Discover why limestone landscapes are riddled with hollows and holes

Sinkholes, dolines, swallow or shake holes, or cenotes are bowl-shaped hollows created when limestone is eaten away by acidic groundwater. Limestone chemically reacts with acidic water because it's mostly calcium carbonate – the alkali used in some indigestion tablets to neutralise stomach acid.

Sinkholes form in two main ways. First, as acidic water seeps through and widens cracks in limestone. If the cracks are close together, a small hollow forms and grows bigger as rainwater flows into it.

Sinkholes also form when caves collapse. Rivers in limestone areas often run through underground tunnels that they widen into caves. If the cave reaches the surface and the roof falls in, it can create a sinkhole.

Holes in the ground in other rock types are sometimes called sinkholes. An enormous sinkhole that swallowed a Guatemala City clothing factory in May, for example, is in an area of volcanic rock and ash.



"The duck-billed platypus is a member of the class of primitive mammals called the monotremes"

Duck-billed pla

Is it a beaver? Is it a duck? Is it a lizard? No, it's something entirely different...

The duck-billed platypus is a member of the class of primitive mammals called the monotremes, which is a rare order that includes platypuses and just four species of spiny anteater.

Monotremes are oviparous, which means they reproduce by laying eggs that develop and hatch outside the mother's body, rather than giving birth. For around ten days, the mother incubates the egg alone in her burrow by keeping it warm in a pouch between her body and her tail. When the helpless, blind baby – commonly known as a puggle – hatches it will be hungry, and while female platypuses don't have teats like other mammals, they can still suckle their young. Milk glands that are tucked away in a groove inside the pouch on her abdomen produce pools of nutritious milk. The female nurses the puggle for several months until it can both see and swim independently.

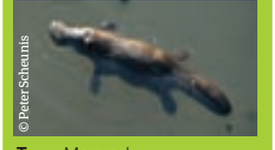
The platypus was built for underwater activities: it has a long streamlined body, waterproof fur, paddle-like feet as well as tricks for feeling around in the dark and remaining below the surface for as long as possible. While hunting in rivers and lagoons, the platypus uses its webbed front feet to propel itself through the water and its rear feet and flat, beaverish tail to steer. The creature can remain underwater for several minutes due to the folds of skin that form watertight seals over its eyes, ears and nostrils.

Another distinguishing feature of the platypus is the fact that adult males have a poisonous spur on the hind leg, which can deliver a nasty sting. The spur is used during tussles for territory or mates and in defence against predators, making the male platypus a very nasty adversary.


© Dr Philip Bethge

The Statistics

Duck-billed platypus


© Peter Scheunis

Type: Mammal
Diet: Carnivore
Life span in the wild: 10-15 years
Weight: 3lbs (1.4kg)
Size: Males up to 60cm Females up to 50cm
Habitat: Freshwater ponds, rivers and creeks

© DK Images

Platypus's lair

Platypuses make their homes in riverbank burrows with an opening just above water level. Once the female has mated – usually between July and November – she needs a quiet place to lay and incubate her eggs away from the males, and so she tunnels deep into the riverbank creating a lair for herself and her egg. At intervals between the nest and the riverbank, she creates blockages in the tunnel – which can be as long as 18m – to prevent any rising water from inundating her hideaway. The mother lines her nest with soft leaf matter, which she drags in behind her using her versatile tail.

Head to Head VENOMOUS MAMMALS

ELBOW SECRETION

1. Slow loris

The toxin produced by this primate is secreted from a gland in the elbow. It sucks the venom into its mouth and then either licks its babies to deter predators, or bites its foes.

NEUROTOXIN

2. Northern short-tailed shrew

This shrew can paralyse its prey with its venomous saliva. A neurotoxin, which acts on the nerves, is secreted from a gland in the mouth.

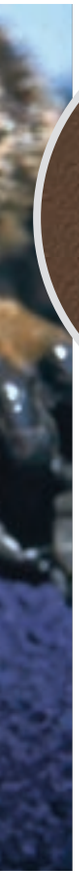
ACID

3. Pangolin

The scaly pangolin is another mammal that can emit a noxious substance in a similar way to the skunk. The pangolin gives off a foul-smelling acid from glands near its rear end.

DID YOU KNOW? *Platypuses can eat between 20 and 50 per cent of their own weight in food every day – more in winter*

typuses



Amazing platypus characteristics

Okay, so if you list the distinguishing features of our friend the platypus you have a medley of traits unique to only a few members of the animal kingdom. Take their webbed feet and rubbery bill, for instance – both examples of a duck's distinctive appearance. Or the beaver-like fur covering all but its bill and feet. And how about those legs, which protrude from the side of the body, giving the platypus a lizard's gait? Such borrowed characteristics make the platypus one of the weirdest animals waddling around the southern hemisphere. Many creatures all rolled into one quite curious mammal.

The male of the species is more deadly!

For self-defence, both sexes develop sharp calcaneus spurs on their hind legs. These growths are not fixed to the heel; they are attached to a separate bone that allows them greater freedom to move.

However, only the spurs of the males are venomous and capable of causing immobilising pain or death to small animals. The venom in the spur is unique to the platypus and is composed of special chemical proteins that can cause severe pain and swelling in the victim as well as lowering their blood pressure. The poison is produced in the crural venom gland in the upper thigh and is connected to the sharp end of the spur by way of a tiny duct. The female's spur, on the other hand, doesn't develop fully, and falls off after a year.

The duck-bill and electroreception

Because duck-billed platypuses are mainly crepuscular – that is, they're mostly active during the twilight hours of the early morning and late evening – you might assume they have excellent eyesight for hunting.

© Rainbow606

And you'd be right; despite the fact they have very small eyes, they do have very keen eyesight. However, the platypus actually keeps its eyes shut when hunting underwater. So to stalk its prey, a platypus instead uses its highly sensitive bill. Although this may resemble the bill of a duck, it's covered with soft leathery skin that contains approximately 40,000 tiny receptors that can detect the faint electric fields produced by small animals that are buried away in the riverbed.

By sweeping its bill from side to side, the duck-billed platypus can sense the direction of its lunch, which it will hungrily dig out of the mud with its spade-like bill.

Platypus anatomy

The body of the strangest creature on Earth!

Spurs
Male platypuses come with an added defensive feature: a poisonous spur located on the inside of the ankle on the hind legs.

Feet
A platypus's furless front paws consist of five webbed toes that act as very effective paddles for swimming gracefully through water. On land the platypus takes on a much more ungainly waddle. However, the webbing on their feet does retract to reveal a set of claws that enable it to run if needed. Platypus is Greek for flat feet.

Tiny eyes
The platypus is blind when born and even as an adult has tiny eyes located in a groove, set back from the bill. But the platypus doesn't require good eyesight to hunt for food; instead it uses that ultra-sensitive bill.

Fur
Thick, brown, waterproof fur grows all over the platypus's body – except for the bill and feet – to trap air to insulate the animal and keep it warm.

Mouth
Once the platypus has caught enough grub, it will return to the surface to feed. However, the adult platypus doesn't have any teeth; instead it has a mouthful of horny plates and gravel, which is used to grind the food. The young do have molars, but they fall out as they mature.

Nostrils
The nostrils are equipped with special flaps of skin that enable them to close not only their eyes, but also to form watertight seals over their ears and nostrils when diving.

Bill
Once the platypus has used its bill to locate and excavate its prey – that being worms, insect larvae and shellfish – it can scoop the food out of the mud and strain it through its bill. The platypus can then continue its hunt by storing food in its cheeks like a hamster.

© Rainbow606

ON THE MAP

Where the platypuses roam

Platypuses live in burrows in the freshwater creeks and lagoons the length of the eastern side of Australia and are also common throughout Tasmania.

Tail
The broad, flat tail makes for an excellent rudder, enabling the platypus to twist and turn in the water. The fat reserves are also stored here.

Cloaca
Monotremes have only one cloaca, which is the external opening on the body for reproduction and excretion.

© Stefan Kraft

"The cheetah is fast but that speed comes at a great price"

World's fastest animals

The arms race of hunter and hunted is a ferocious battleground, with different species furiously evolving to remain, literally, one step ahead of the competition. How It Works pits these speed demons against each other in the ultimate animal shootout

Cheetah

Accelerating to speeds of 70mph, the cheetah is the quickest on four legs!

Cheetahs are one of the fastest animals on Earth and have a terrifyingly quick 0-60 time of a mere three seconds. Cheetahs are unique in the fact they have evolved to such a degree in order to maximise their speed, that they regularly risk brain damage and starvation due to the great physical demands it places on their anatomy. The cheetah is fast, the fastest land animal on Earth, but that speed comes at a great price.

For example, lungs, nostrils and heart are all enlarged within the cheetah to ensure it can process enough oxygen and blood to maintain its explosive speed. However, it can only process this for short periods of time and at the close of a lengthy chase not only does it skirt dangerously close to oxygen deprivation but it must rest post-kill before it eats, leaving plenty of time for scavengers to surround it. In addition, while its muscle fibre is honed and holds superb elasticity, its physique is slender and lightweight, leaving it vulnerable to broken limbs and completely defenceless against a larger and heavier rival such as a lion or tiger.

Due to these facts – as well as through human-caused habitat loss and predation – cheetah numbers are dwindling and it is currently an endangered species in many African countries.

Tail
The cheetah's long tail acts as a counterweight, maintaining balance during sharp turns at high speed.

Paws
The paws are blunt and sport exposed claws that provide superior grip, increasing the forward thrust of each stride.

Lungs
Engorged lungs – and nostrils for that matter – allow for a fast and deep air intake. Maintaining a high level of oxygen is critical when the cheetah is on a chase as its breath-rate increases three-fold.

Heart
The heart is enlarged compared to other animals of its size, pumping a colossal amount of blood around the cheetah's body, especially during a chase.

Build
The average weight of a cheetah is 57kg (125lb) and its build is slender. It has a small head, flattened rib cage and long, thin legs that all minimise air resistance.

The Statistics

Cheetah

Family: Felidae
Genus: Acinonyx
Weight: 36-65kg
Height: 67-94cm
Length: 200-220cm
0-60mph: 3 seconds
Top speed: 70mph

5 TOP FACTS CHEETAHS

Lightweight
1 The average weight of a cheetah is 125 pounds. This is actually a fraction of the weight of other big cats, with an average lion weighing more than 400 pounds.

Threat
2 All over Africa, Asia and India cheetah populations are in sharp decline. In 1990 there was roughly 100,000 individuals worldwide, now there are roughly 10,000.

Sexist
3 Baby cheetahs are brought up solely by the female parent, who raises them in isolation from any male. It takes roughly 18 months for a cheetah cub to reach maturity.

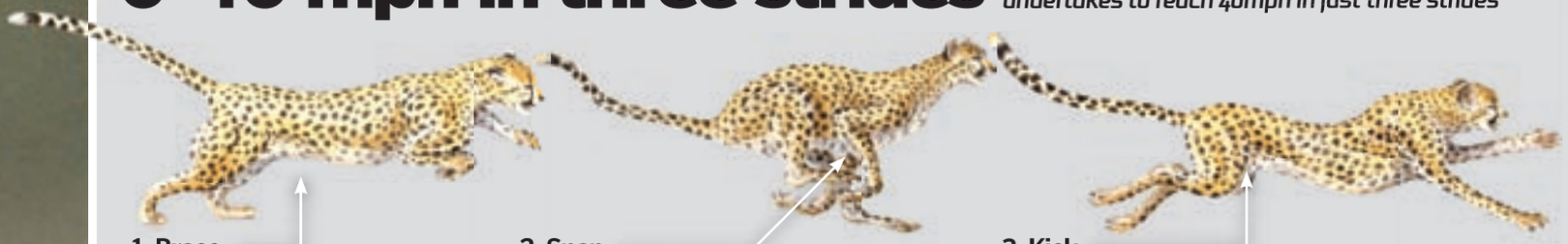
Hakuna matata
4 Cheetah's have a broad diet, ranging from antelope to springhare and game birds. However, one of their most common food supplies is the slow and fat warthog.

Habitat
5 Cheetahs tend to favour vast expanses of land where prey is abundant and easy to spot. However, cheetahs can be found in a variety of habitats including grasslands.

DID YOU KNOW? *Marine biologists postulate that the sailfish's large dorsal fin is used for cooling purposes as well as stability*

0-40 mph in three strides

Check out the three stages a cheetah undertakes to reach 40mph in just three strides



© DK Images

1. Brace
The cheetah employs its hard, ridged footpads and blunt, non-retractable claws to maximise traction with the ground. Its spine curves, coil-like, and head drops a fraction.

2. Snap
The spine uncoils and snaps straight, driving the hind legs into the earth and pushing the cheetah forward. The honed, slender muscles expand in conjunction, adding greater elasticity and drive to the forward thrust.

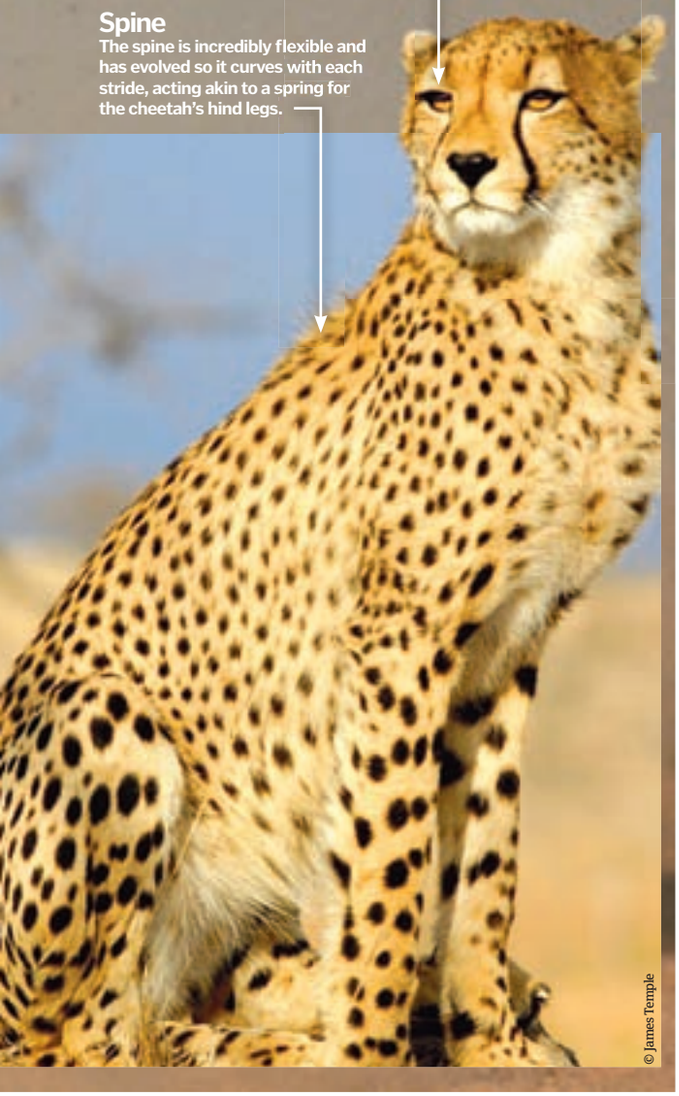
3. Kick
The combined spine and leg muscles give the cheetah an incredibly broad swing range and propel it 7.6 metres (25 feet) through the air in a colossal bound. At the culmination of the bound one foot is replanted onto the earth and the process is repeated. The cheetah completes three strides a second.

Cheetah anatomy

Just what makes it the fastest thing on four legs?

Eyes
The cheetah's eyes are long to provide a wide-angle view of its surroundings. This provides them with excellent vision when stalking and chasing prey in the native habitat of open plains.

Spine
The spine is incredibly flexible and has evolved so it curves with each stride, acting akin to a spring for the cheetah's hind legs.



© James Temple

The sailfish can rapidly turn its body light blue with stripes when excited, confusing its prey and making capture easier

Long nose
The sailfish's elongated bill is similar to a swordfish's and marlin's, placing it in the category of billfish.

Sailfish

Capable of swimming for long periods of time at over 40mph, and with a recorded top speed of over 70mph, the sailfish is the ocean's fastest animal

With a top speed on par with that of a cheetah, the sailfish is lightning fast and one of the most difficult-to-catch fish in the world. With its stiffened, tapered body and scissor-shaped caudal fin, the sailfish is built for speed – a speed that comes courtesy of a rapid and ferocious flicking of its tail. Indeed, during a chase to consume fish, crustaceans or cephalopods, the sailfish will flick its tail back and forth hundreds of times, utilising the powerful muscles which run down its compressed body.

As with the peregrine falcon, the sailfish's speed is also aided by its ability to retract parts of its body, in this instance its various fins (notably the large dorsal fin that adds over a foot on to its overall height). This feature helps it reduce the effects of drag and minimise resistance to its movements.

Its spine is also very flexible and as with the cheetah allows it to generate increased thrust through the rapid curves it bends its torso into while swimming.

The Statistics

Sailfish

Family: Istiophoridae
Genus: Istiophorus
Weight: 90kg
Height: 70cm
Length: 1.2-1.5m
0-60mph: Not recorded
Top speed: 70mph

Streamlined
Sailfish have an incredibly sleek and streamlined body.

© anon09

"The peregrine does not suffer damage from oxygen deprivation at the close of its stoop"

The fastest animals on Earth are...

Here's a the list of the most super-fast critters on the planet

FASTEST FISH	
Sailfish	68mph (110kph)
Marlin	50mph (80kph)
Wahoo	48mph (78kph)
Tunny	46mph (74kph)
Bluefish tuna	44mph (70kph)

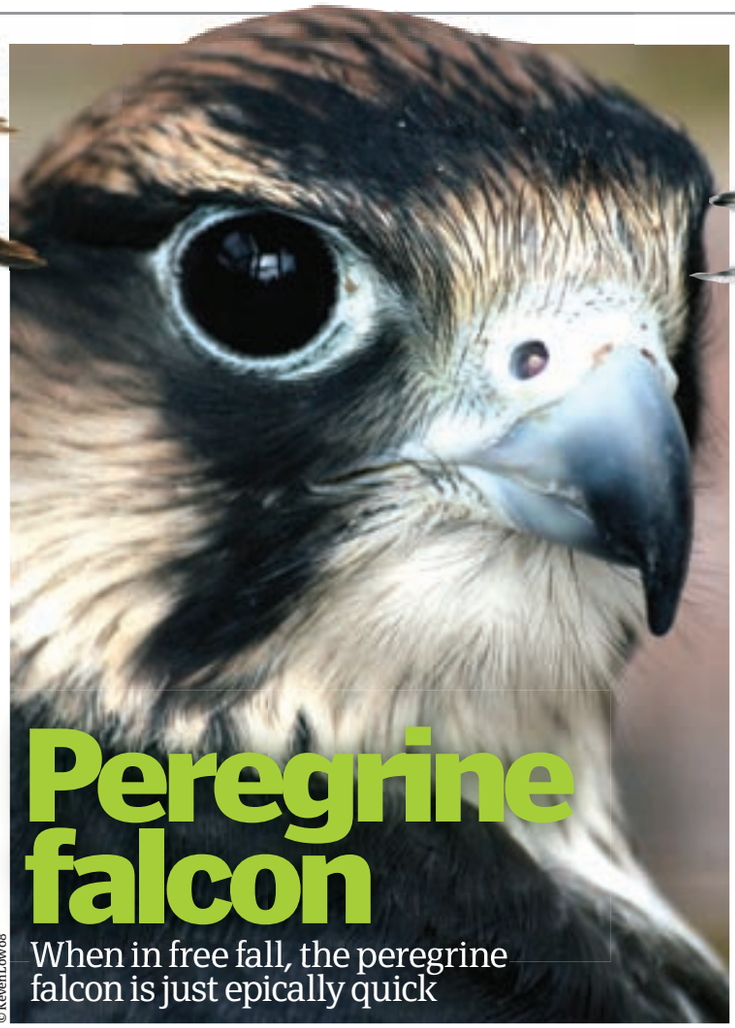
FASTEST LAND INSECTS	
Tiger beetle	5.6mph (8.4kph)
Cockroach	3.4mph (5.4kph)

FASTEST BIRDS	
Peregrine falcon	200mph (322kph)
Spine-tailed swift	106mph (171kph)
Frigatebird	95mph (153kph)
Spur-winged goose	88mph (142kph)
Red-breasted merganser	80mph (129kph)

FASTEST MAMMALS	
Cheetah	71mph (114kph)
Pronghorn antelope	57mph (95kph)
Springbok	50mph (80kph)
Blue wildebeest	50mph (80kph)
Lion	45mph (72kph)

FASTEST REPTILES	
Spiny-tailed iguana	21mph (34kph)
Black mamba	12mph (20kph)

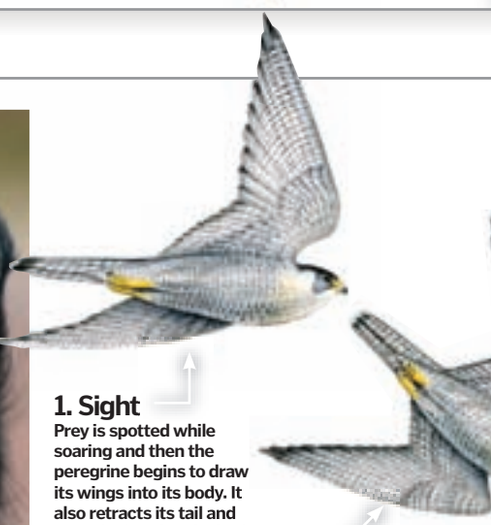
Sources: American Journal of Zoology, University of Michigan, Seattle Zoo, American Journal of Physiology, National Geographic, US Fish and Wildlife Service, Forest Preserve of Illinois



© KevenLow08

Peregrine falcon

When in free fall, the peregrine falcon is just epically quick



1. Sight
Prey is spotted while soaring and then the peregrine begins to draw its wings into its body. It also retracts its tail and tucks its feet into its body.

2. Streamline
The wings are brought right into the falcon's sternum and – thanks to their pointed, slim, stiff and unslotted feathers – begins to rapidly reduce its air resistance.

3. Velocity
Speed is increased as the falcon bombs down with little-to-zero drag, soon reaching speeds up to 200mph. Its strong keel helps maintain structural solidity during the dive and its eyes are kept clear by nictitating membranes, which act like a third eyelid.

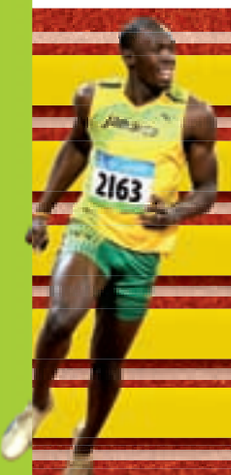
Diving to victory

Check out the four stages a peregrine falcon undertakes to reach 200mph when diving in for a kill

If you thought the cheetah was fast, then think again. The peregrine falcon blows its top speed out of the water by over 130mph. Capable of hitting a monumental 200mph during a stoop (dive), the falcon has the highest top speed of any animal on Earth.

The peregrine's speed is caused by a combination of factors. Firstly it makes use of gravity, diving upon its prey from great height, even when they themselves are airborne. Secondly, its anatomy – as with the cheetah's – has been finely honed to maximise speed, evolving over millions of years into the swift and efficient killer it is today. For example, the peregrine's keel – which is located at its breastbone – is significantly larger than average birds', allowing for bigger muscles and a greater number to attach its wings to its body. This allows it to generate far more power per thrust when building speed. Further, the peregrine's wings have evolved to be incredibly pointed, with slim, stiff and unslotted feathers, which helps streamlining and reducing air resistance significantly.

Unlike the cheetah, however, arguably the peregrine handles its awesome speed much better. Firstly, while having the same enlarged heart and lungs, the peregrine does



Usain Bolt 28mph 100m in 9.58 seconds

Sailfish 68mph Finishing time in 3.28 seconds

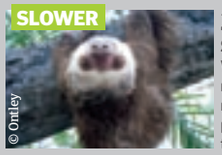
Cheetah 71mph Finishing time in 3.15 seconds

Peregrine falcon 200mph Finishing time in 1.12 seconds

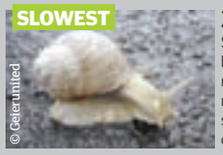
Tiger beetle 720mph Finishing time in 0.31 seconds

Head to Head
SLOWEST ANIMALS

1. Galapagos giant tortoise
With a top speed of 0.19mph the Galapagos tortoise is very slow. Luckily, it is protected by a shell to put off predators.



2. Two-toed sloth
With a top speed of just two metres per minute, they are nick-named "bicho-preguiça" in Brazil, which translates as "lazy animal".

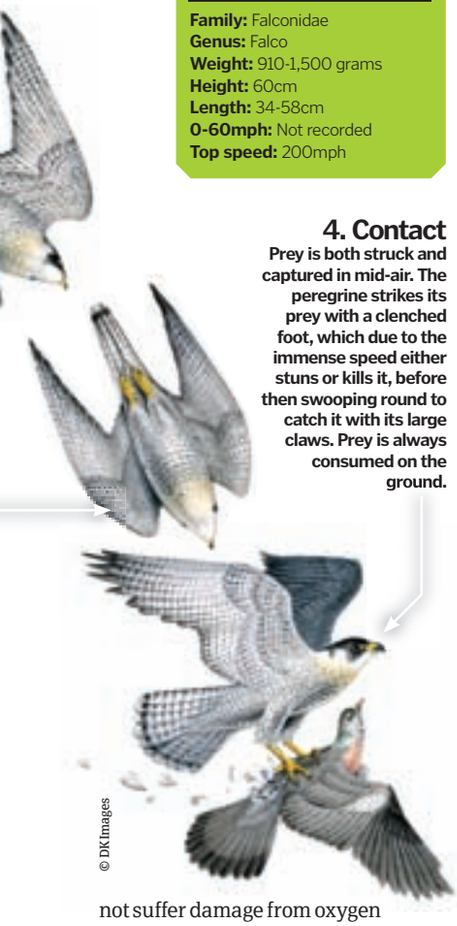


3. Snail
So slow that it was adopted by the Judeo-Christian religion as the physical manifestation of the deadly sin of sloth, the snail takes days to travel mere metres.

DID YOU KNOW? *Usain Bolt currently holds the world 100 and 200-metre records*

The Statistics
Peregrine falcon

Family: Falconidae
Genus: Falco
Weight: 910-1,500 grams
Height: 60cm
Length: 34-58cm
0-60mph: Not recorded
Top speed: 200mph

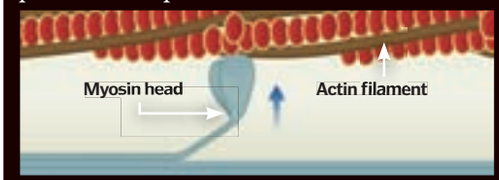


4. Contact
Prey is both struck and captured in mid-air. The peregrine strikes its prey with a clenched foot, which due to the immense speed either stuns or kills it, before then swooping round to catch it with its large claws. Prey is always consumed on the ground.

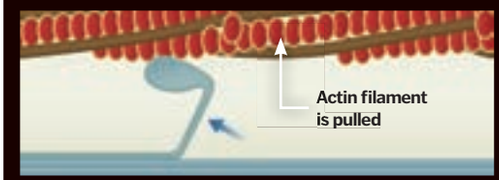
not suffer damage from oxygen deprivation at the close of its stoop. This is partly due to gravity's beneficial aid in generating its killer speed but also due to the peregrine's ability to absorb oxygen through its red muscle fibres, of which it has many. This allows it to keep a steady oxygen flow at all times and means that, consequentially, it does not need to rest post-kill, reducing its vulnerability to scavengers.

How muscles work – the contraction cycle

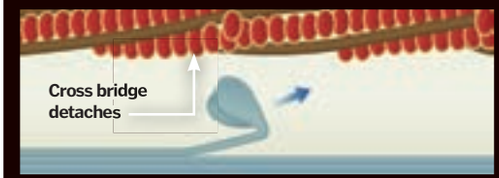
Muscle power is common to all these creatures so here's an explanation of how muscles provide the power that in turn provide the speed



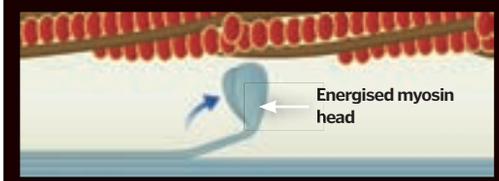
1. Attachment
Firstly a myosin head (akin to an organic hook) attaches itself to an exposed binding site on the muscle filaments, gripping it in a cross bridge.



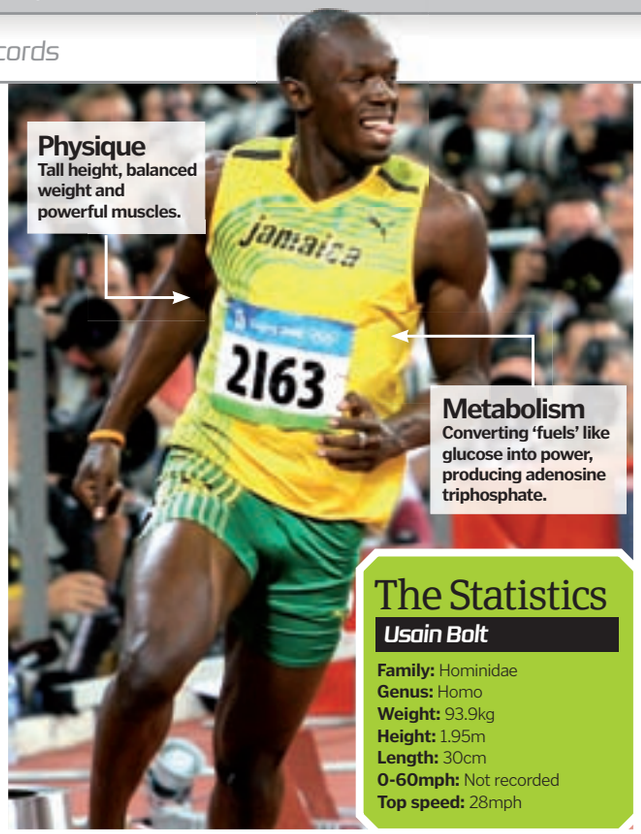
2. Power stroke
The myosin head then pulls the filament by pivoting backwards and dragging it into a compressed position.



3. Detachment
A molecule of ATP (adenosine triphosphate) then binds to the myosin, releasing its grip of the filament so that the cross bridge detaches.



4. Energy release
Finally, the ATP releases energy to convert the myosin head from its bent, low-energy position back to its initial high-energy configuration ready for the next cycle.



The Statistics
Usain Bolt

Family: Hominidae
Genus: Homo
Weight: 93.9kg
Height: 1.95m
Length: 30cm
0-60mph: Not recorded
Top speed: 28mph

Usain Bolt

The fastest human alive, Usain Bolt recently broke the world 100-metre record with a staggeringly quick time of 9.58 seconds

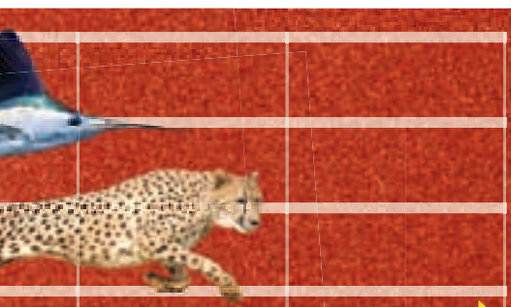
One of the most successful species of animal on the planet, Homo sapiens have evolved over the last 120,000 years into creatures with formidable physical abilities. Currently, the fastest human is Usain Bolt, a Jamaican-born sprinter who has won the world 100 and 200-metre gold medals.

Bolt epitomises the ideal human anatomy needed to produce such high speeds: a tall height (1.95m), balanced weight (93.9kg) and long, powerful muscles with an excellent metabolism – muscles cannot utilise energy-rich "fuels" such as glucose, instead they must convert it into ATP (adenosine triphosphate) with the amount of ATP a muscle produces directly correlating to the amount of power it can generate.

How It Works 100m final

So who would win in a 100-metre race?

NB: For the purposes of this illustration the peregrine falcon's speed is taken from a stoop and all animals begin the race at their top speed.



This is the speed a tiger beetle could get to if it were the same size as an average six-foot man!

This month in **Technology**

Take a look inside Microsoft's lastest addition to the Xbox clan as we explode the 360 S. Meanwhile, for a better understanding of the sophisticated kit in your camerabag, photographers should turn to page 32 to learn how various types of lens work. In other tech features, you can check out the cranes that can build themselves to stupid heights and find out exactly how Google can turn up 476,000,000 results in just 0.26 seconds.

29 Tower cranes

30 Central heating

34 Google's search engine

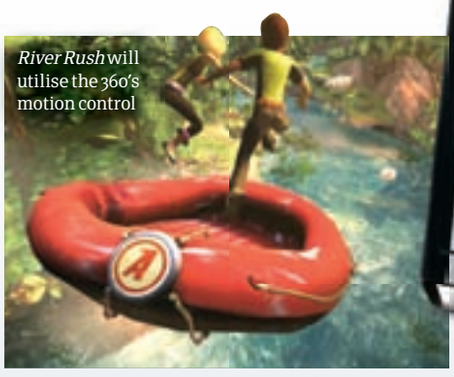
Xbox 360 S

Xbox has become one of the industry standards for console gaming, but what makes the new machine work?

The latest version of the Xbox, the Xbox 360 S, has just been unveiled and while it's not faster than its predecessor, it's fascinating to see how the console has been upgraded. For starters it only needs a 135 watt power supply, and uses two cooling fans instead of one. These factors combine to make the 360 S both quieter and cooler. It is also smaller and more versatile than its predecessor.

The 360 S ships with Kinect, Microsoft's motion control system that uses an infrared sensor and a multi-channel microphone to allow a player to act as their own controller, with the system monitoring your movements. It also has five USB ports, which not only makes the unit more versatile and eliminates the need for external hubs, but also allows the old Xbox Memory Units to be phased out.

The biggest changes, though, are actually inside the casing. The standard unit now ships with a 250GB internal hard drive which, while still removable, is a different design to its predecessors. The 360 S also comes equipped with built-in Wi-Fi, meaning that it can connect to a home hub and access Xbox Live very easily. All these features, combined with the Kinect system, make the 360 S a very powerful addition to the Xbox family and one that looks set to be the benchmark for improvements to come.



River Rush will utilise the 360's motion control

The end of the Red Ring of Death?

The Red Ring of Death refers to a ring formed by three status lights on the front of the machine. Normally green, if they go red it's usually because of either power fluctuations or by overheating damaging the motherboard, which will need to be replaced. Now, though, the Red Ring is no more according to Microsoft. This has been achieved by replacing the original 360's single fan with two smaller ones, making the machine quieter but also keeping it cooler.

A sight many Xbox owners have been too familiar with in the past

Head to Head
Innovative controllers

OLD

1. EyeToy
Released back in 2003, the PlayStation 2 motion control system needs a brightly lit room to work effectively, but has proved popular.

NEWER

2. Wii Remote
Originally designed to be used with the GameCube, the 'Wiimote' and nunchuk have helped popularise motion-control gaming.

NEWEST

3. PlayStation Move
The system is due out soon and even measures the unit's orientation relative to the Earth's magnetic field to work out how it's being moved.

DID YOU KNOW? *As of June 2010, over 41 million Xbox 360 consoles have been sold worldwide*

Gaming in motion

Kinect is Microsoft's new take on motion control. Containing a camera, depth sensor and multi-array microphone, Kinect allows a player tremendous freedom of movement.

The depth sensor throws an infrared 'net' out into the room which allows the sensor to sense not only that you're moving, but where in the room you are, and can be adjusted to take into account the size of the room and any obstacles. This sensor field means Kinect can track up to six people, including two active players, and pick up on movements in 20 joints per player.

Kinect's microphone also allows it to locate the player in the field, allowing for headset-free chat over Xbox Live.

Kinect will bring motion control to the Xbox 360 masses

The Statistics
Xbox 360 S

Manufacturer: Microsoft
Dimensions (height/width/depth): 264mm x 75mm x 209mm
Weight: 4kg
Processor/speed: 500MHz
Unit price UK/US: £189.99/$299.99
Memory: 250GB
Power: 135w
Graphics: 16:9 ratio widescreen and high definition
Sound: 48kHz 16-bit audio

Inside the Xbox 360 S

Optical drive
Where the fun begins; the games and movies are loaded and read here.

Wi-Fi board
Plugged into the machine's internal USB port, it allows the Xbox to connect to local Wi-Fi.

Fan
The S is much better ventilated than its predecessor, hopefully making the Red Ring of Death a thing of the past.

USB ports
These five ports make the S far more adaptable and eliminates the need for USB hubs.

Ventilation
The Red Ring of Death is no more, thanks to the extensive ventilation on the casing.

Heat sink
Vital in keeping the machine cool, the heat sink prevents overheating.

Logic board
The Valhalla motherboard is the versatile, powerful heart of the Xbox 360 S.

Power switch board
This controls the power button, so if it breaks, a replacement is a must.

Hard drive
The 250GB hard drive is no longer portable but it is replaceable, allowing you to upgrade if needed.

The hard drive

The major change with the 360 S is that the hard drive can't be pulled out and dropped into another Xbox 360. It can be removed, but the process is a lot more involved. While this cuts down on the system's portability and versatility, it's balanced by the fact the hard drive is replaceable and upgradeable. Microsoft's announced a 4GB version of the S and is selling the 250GB hard drive separately, meaning you can upgrade later.

Learn more

For more info and images of the exposed Xbox 360 S, visit the gadget surgeons at **ifixit.com** who kindly contributed the photos and findings for this article.

"Only when the correct key is inserted are the pins elevated into alignment"

Yale-style lock

Pin tumbler locks, as made famous by the Yale lock manufacturer, use a simple yet ingenious manner to form a secure locking mechanism that has evolved over thousands of years

A pin tumbler lock is a lock mechanism that uses pins of varying lengths to prevent the lock from opening without the correct key. The pin tumbler design is based on a main barrel that is drilled with five to six cylinder slots that are set close together in a line. Inside each cylinder a metal pin (tumbler) is fitted, with a second pin (driver) on top of it, pushed down by a tiny coil spring. This means that when no key – or indeed the wrong key – is inserted the pins are pushed down across the plug's shear line (the line where the plug is inserted into the outer casing) and it cannot rotate and open. Only when the correct key is inserted are the pins elevated into alignment with the shear line and the lock allowed to open.

A modern variant of a Yale pin tumbler lock

© Yale

DID YOU KNOW?

In the Netherlands there is a recreational society dedicated to the art of lockpicking.

5 TOP FACTS LOCKS

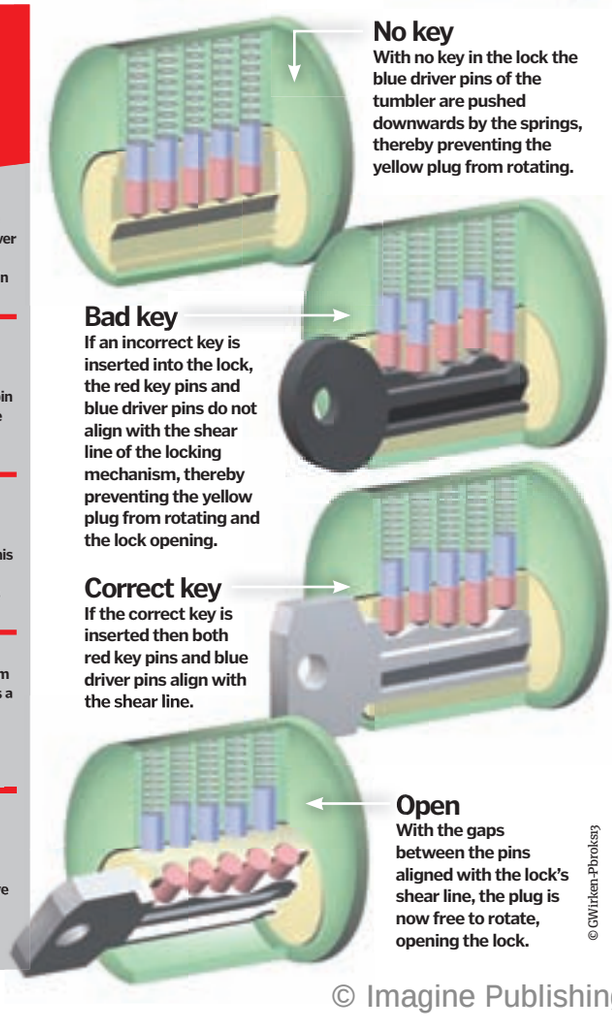
1 Ancient
The first pin tumbler locks were used by the ancient Egyptians over 4,000 years ago. However, they were much larger, non-uniform in shape and made of wood.

2 Senior
Linus Yale Snr, an American inventor and manufacturer of locks, invented the cylindrical pin tumbler lock in 1848. Linus Yale Snr was one of the founders of the Yale Lock Company.

3 Junior
Linus Yale Jnr, the son of Linus Yale Snr, set-up the Yale Lock Manufacturing Company with his father. He specialised in producing locking mechanisms for bank vaults.

4 Vault
The primary locking mechanism on many modern bank vaults is a dual-control, time-sensitive combination lock, requiring two people acting in unison to open it.

5 Dining
Old bank vaults were often built so secure and from such heavy, impregnable materials, that many still survive today even after the bank is closed. A number are now in use as restaurants.



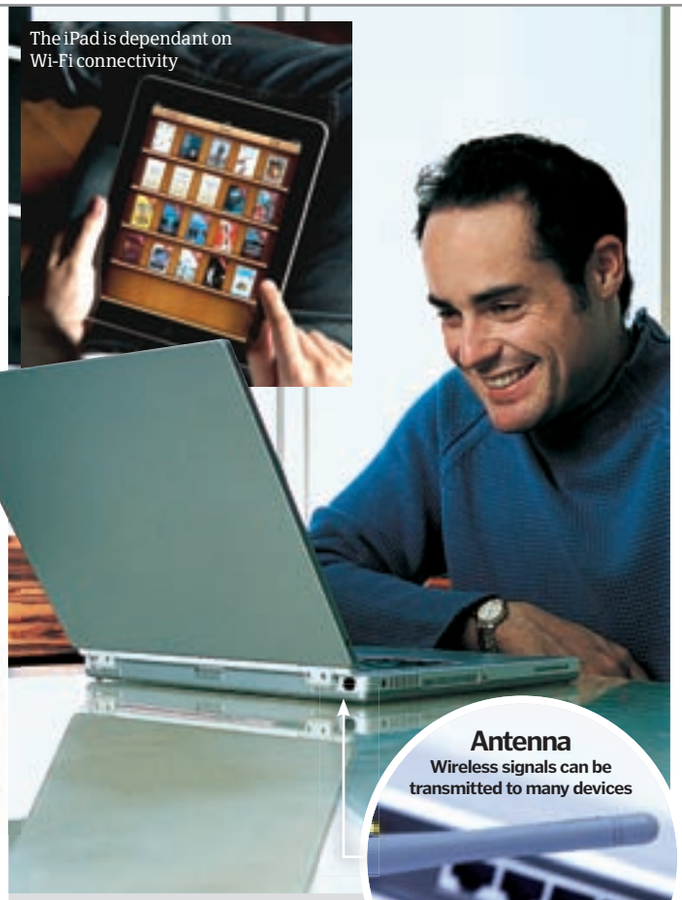
No key
With no key in the lock the blue driver pins of the tumbler are pushed downwards by the springs, thereby preventing the yellow plug from rotating.

Bad key
If an incorrect key is inserted into the lock, the red key pins and blue driver pins do not align with the shear line of the locking mechanism, thereby preventing the yellow plug from rotating and the lock opening.

Correct key
If the correct key is inserted then both red key pins and blue driver pins align with the shear line.

Open
With the gaps between the pins aligned with the lock's shear line, the plug is now free to rotate, opening the lock.

© GWirken-Pbroks13


The iPad is dependant on Wi-Fi connectivity

Antenna
Wireless signals can be transmitted to many devices

Wi-Fi explained

How can data be transferred wirelessly to your laptop?

Many electronic devices such as laptops, games consoles and mobile phones can be connected to the internet – or to each other – securely, quickly and wirelessly, using radio frequencies instead of cables to transmit data.

A wireless network comprises a source computer connected to the internet using an Ethernet cable, a router to translate data (1s and 0s) into a radio signal and an antenna inside the wireless device to pick up the signal. Like using a walkie talkie, sending information via radio waves requires the frequency bands to be broken down into channels to avoid outside interference.

To enable, say, a laptop to connect to a wireless network, the laptop requires a wireless adapter, which can both send and receive data to and from the network router, which can also send and receive data. Both devices are fitted with decoders, which convert radio signals into digital form. When you want to connect your laptop to the internet, the adapter communicates with the router via radio signals. The router decodes the signals and – via the Ethernet connection – fetches the relevant data from the internet. This info is converted into radio signals and sent to the laptop's wireless adapter where it is decoded, giving you the internet page you requested.

5 TOP FACTS CRANES

Mobile crane
1 The most versatile crane for both small and large jobs is simply a telescoping hydraulic boom attached to the bed of a heavy-duty construction vehicle.

Overhead crane
2 Shaped like an upside down 'U', this small but powerful crane rolls along tracks on factory floors to lift car engines and other heavy parts into place.

Self-erecting cranes
3 This crane rolls onto the work site as a compact, foldable unit only 13.6m long. The crane rises and extends its jib 32m out with a holding capacity of 4,000kg.

Luffing tower crane
4 The jib arm of this tower crane – which can still carry 35 tons – can be raised from a flat horizontal position to an 85-degree angle using a special jib cable and motor.

Hammerhead tower crane
5 The classic T-shaped tower crane with a fixed horizontal jib and counterweight arm. The hammerhead lacks freedom of movement, but can carry more weight.

DID YOU KNOW? *Tower cranes are designed to withstand wind gusts up to 150kph*

Load and stability

Hold a 10kg weight close to your body. Now try to extend your arms without tipping over. Tough, isn't it? Tower cranes have the same problem. A large tower crane can handle loads up to 16 tons, but that's only at a horizontal distance that's very close to the tower. At 80 metres out on the jib, the most that the same crane can carry is 3.9 tons. Tower cranes are preloaded with multiple slabs of concrete counterweights to maintain the overall equilibrium of the arm. A crane that carries heavy loads at 80 metres from the tower requires 31 tons of counterweight.

©Nebrot08

How tower cranes work

These big birds of sky-high construction are engineering marvels

Tower cranes flock to money. During the economic boom years, high-rise construction cranes migrated from Beijing to Shanghai to Dubai, where it was estimated in 2006 that there was one tower crane for every 44 residents of the desert boom-opolis.

Tower cranes are feats of structural engineering that often outshine their creations. They are designed to stand 80 metres tall and reach 80 metres out supported only by a narrow steel-frame mast, a concrete foundation and several counterweights.

The engineering principle that keeps the twiggy tower crane from tipping over is something called a 'moment'. If you hang a weight from the crane's jib arm, it exerts a rotational force or torque where the arm connects to the top of the mast. The magnitude and direction of this force (clockwise or anti-clockwise) is called the moment. If the weight is hung close to the mast, the magnitude of the moment is lower than if the weight is hung far out on the jib. To keep the crane upright, counterweights are used to create a moment of equal magnitude in the opposite direction, balancing out the rotational forces.

Once a tower crane meets its maximum unsupported height, it can be tethered to the building itself and continue to grow with the rising skyscraper. The tower cranes that rose with the construction of the record-breaking Burj Khalifa skyscraper in Dubai reached a truly dizzying height of 750 metres.

Self-assembling crane

One of the most remarkable engineering feats of tower cranes is that they can literally build themselves. With help from a large mobile crane, construction workers secure the base sections of the tower and assemble the top unit of the crane – the slewing unit, jib and machinery arm.

But before the top section of the crane is attached, workers slide a hydraulic climbing unit around the base of the tower. Once everything is in place, the hydraulic climbing unit lifts the entire top section of the crane (including the horizontal jib and operator's cab) just enough to slide in a new section of tower beneath. Once the new section is secured, the hydraulic unit continues to climb up, section by section, as the crane slowly builds itself higher.

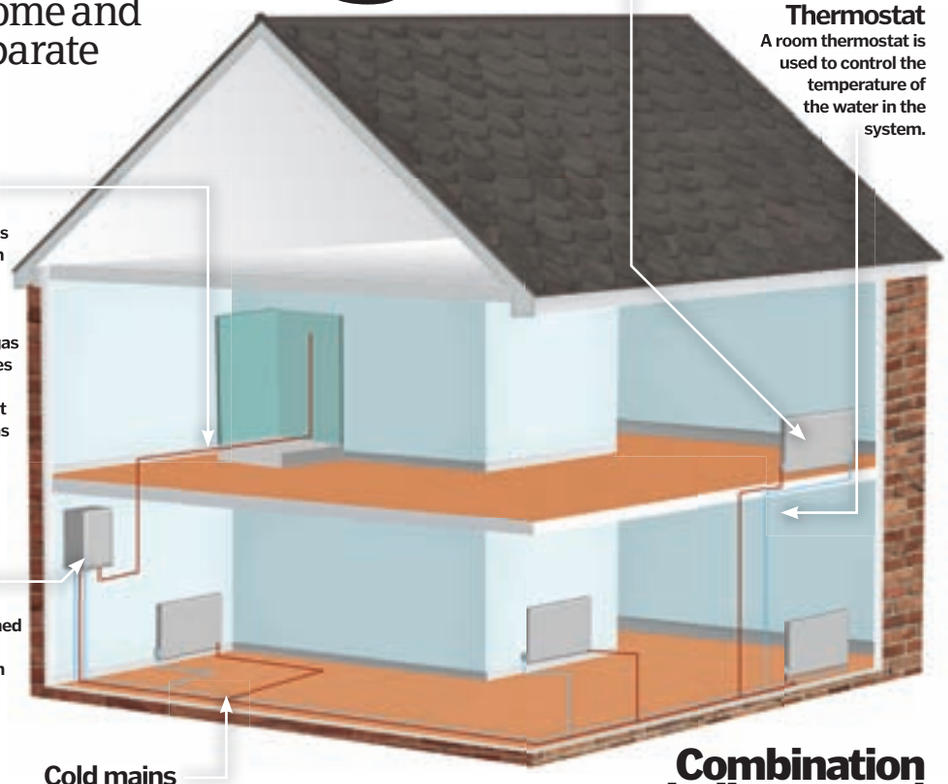
"A flap is sliced on the surface of the cornea and folded out the way"

Central heating

How a combi boiler heats your home and your water with no need for a separate hot water storage tank

The heat source for a central heating system is the boiler. 70 per cent of UK households now use a combination, or 'combi', boiler to heat their homes and their water – all in one compact unit. Inside the boiler, water is heated by a metal heat exchanger and pumped into a closed system of pipes that loop around the home to radiators in each room. By using a combi boiler, if you turn on your hot tap, water from the mains is heated as needed, with no need for a large and obtrusive storage cylinder.

All modern boilers fitted in the UK are condensing boilers, which are more fuel-efficient because they re-use the heat energy that, in a non-condensing boiler, would be expelled through the flue. The water is heated as it flows through the pipes inside one (or sometimes two) heat exchangers, which are suspended in hot gases over the burner's flames, maximising the heat transfer from the burner. In a combi, the temperature of the flue gases is reduced to 50-60°C (rather than the 120-180°C in a non-condensing boiler), and most of the gas leaves the flue as water vapour while the rest is drained away as condensate, or water.



Radiators
The temperature of a room's individual radiator can be controlled using a thermostatic radiator valve.

Thermostat
A room thermostat is used to control the temperature of the water in the system.

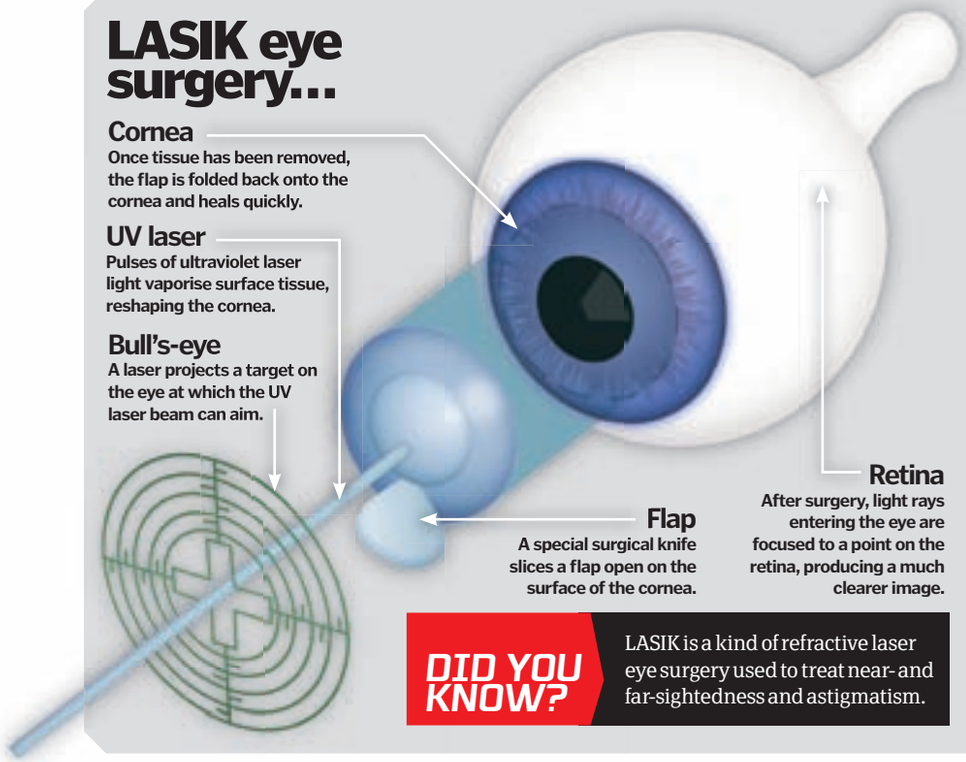
Hot water
Hot water is delivered at mains pressure. As soon as the hot tap is turned on, the water flow is detected by the gas burner, which uses electric sparks to ignite the gas that heats the water as it runs back and forth over a heat exchanger.

Boiler
The combi boiler can be programmed to switch the central heating on and off at desired times and at a specific temperature. A pump inside the boiler transports water through the radiators.

Cold mains
The combi heats water direct from the mains as and when it's required. There's no need for a coldwater storage tank.

Combination boiler central heating system

LASIK eye surgery...



Cornea
Once tissue has been removed, the flap is folded back onto the cornea and heals quickly.

UV laser
Pulses of ultraviolet laser light vaporise surface tissue, reshaping the cornea.

Bull's-eye
A laser projects a target on the eye at which the UV laser beam can aim.

Flap
A special surgical knife slices a flap open on the surface of the cornea.

Retina
After surgery, light rays entering the eye are focused to a point on the retina, producing a much clearer image.

DID YOU KNOW?
LASIK is a kind of refractive laser eye surgery used to treat near- and far-sightedness and astigmatism.

Laser eye surgery

How can a laser beam correct a patient's poor vision?

People with defective eyesight can undergo laser-assisted in-situ keratomileusis (LASIK) eye surgery to correct their vision. LASIK involves using an ultraviolet laser beam to remove tissue and alter the shape of the cornea at the front of the eye.

If, say, the cornea is not perfectly spherical, light rays entering the eye won't focus on a single point on the retina, causing diminished vision. However, by reshaping the cornea, light rays can be refracted (bent) as they pass through the cornea to focus light properly.

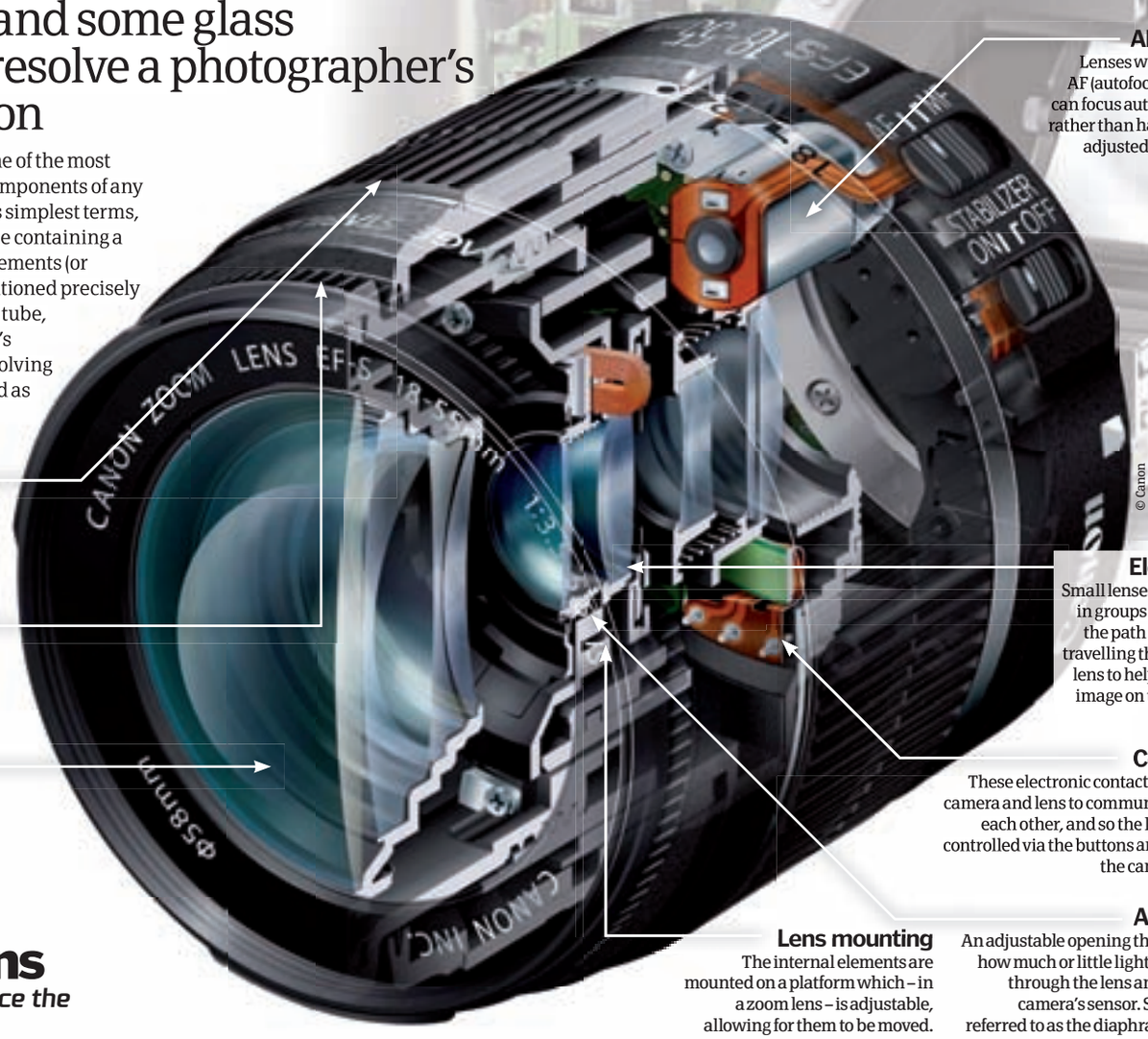
A computer maps the shape of the patient's cornea before calculating exactly how much tissue needs to be removed. Using a fine knife called a microkeratome, a flap is sliced on the surface of the cornea and folded out the way. The main laser light doesn't penetrate the eyeball, but rather it pulses, vaporising the tissue on the surface of the cornea. The flap is then folded back and heals without the need for stitches, resulting in instantly improved vision.

"In its simplest terms, a lens is a tube containing a set of glass elements"

Camera lenses

How a tube and some glass combine to resolve a photographer's creative vision

The lens is one of the most important components of any camera. In its simplest terms, a lens is a tube containing a set of glass elements (or lenses), each of which is positioned precisely to channel light through the tube, focusing it onto your camera's sensor or film plane, and resolving an image of the outside world as a result.



© Canon

Zoom ring
Only found on a zoom lens – rotating this moves the lens elements to increase or decrease the lens's magnifying power.

Focusing ring
The photographer turns this to fine-tune the space between the front and rear elements in order to focus the image.

Front element
The point where light enters the lens. Front elements often have a special coating to reduce problems like ghosting or flare.

AF motor
Lenses with built-in AF (autofocus) motors can focus automatically rather than having to be adjusted manually.

Elements
Small lenses arranged in groups that refine the path of the light travelling through the lens to help focus the image on the sensor.

Contacts
These electronic contacts allow the camera and lens to communicate with each other, and so the lens can be controlled via the buttons and dials on the camera body.

Aperture
An adjustable opening that controls how much or little light is allowed through the lens and onto the camera's sensor. Sometimes referred to as the diaphragm or iris.

Lens mounting
The internal elements are mounted on a platform which – in a zoom lens – is adjustable, allowing for them to be moved.

Inside a camera lens

The parts that produce the ideal picture

Optical vs digital zoom

If you look at any compact or superzoom digital camera's specifications, chances are it'll state values for both optical and digital zoom capability. Optical zoom refers to the ability of a camera's lens to shift its internal elements, magnifying the subject you're trying to photograph as the lens zooms to the telephoto (longest) end of its focal range. All non-fixed focal length DSLR lenses zoom optically. Digital zoom, on the other hand, involves no physical zooming mechanism at all; rather the camera crops into your image, making your subject appear to fill more of the frame. Overall image quality is reduced as the camera makes up (interpolates) pixels to create the impression of magnification, which may produce less-than-satisfactory results.

Wide
The wide-angled shot ready for some serious zooming!

Optical
Keeps quality high, found on all non-fixed focal length DSLRs.

3 x images © Josie Reavely

Digital
Focuses in-depth on a specific area, but loses overall quality.

GOOD

1. 18-250mm f/3.5-6.3 DC OS HSM
Costing £573, this lens covers a decent focal range but a non-fixed aperture means less light-gathering ability as you zoom.

BETTER

2. 50-500mm f/4.5-6.3 DG OS HSM
Priced at £1,400 this telephoto lens also spans a wide focal range, but it's heavy, and can suffer from loss of sharpness.

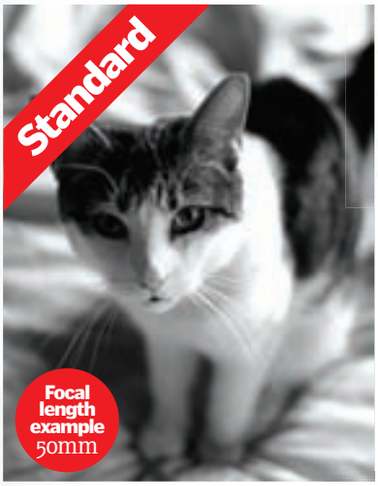
BEST

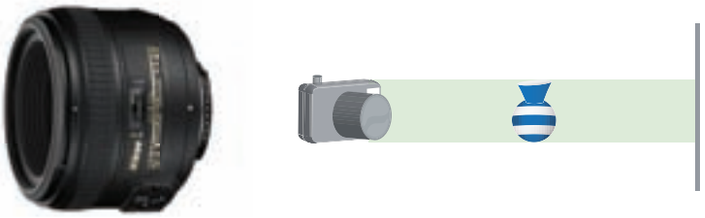
3. 70-200mm f/2.8 EX DG MACRO HSM II
This impressive lens costs £817 and has wide fixed maximum aperture, meaning it stays the same even if you zoom in.

DID YOU KNOW? *The glass used for lenses must be completely colourless*

Different lenses

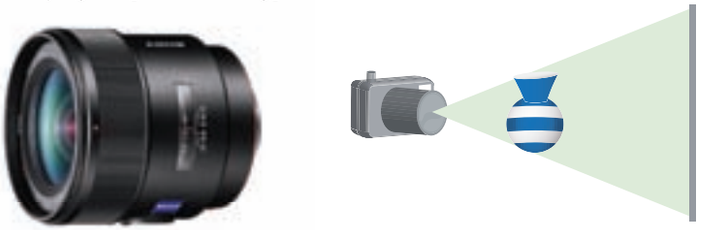
Knowing which lens to use for which shot is the key to a perfect picture





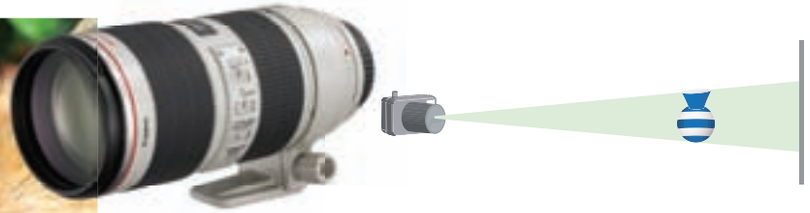
A standard or 'normal' lens typically has focal length equal to the diagonal of the focal plane, which is around 35mm on a 'cropped' (APS-C) sensor DSLR or 50mm on a full frame camera. The front element of a standard lens is fairly flat, so light is not significantly bent internally, and the image projected onto the sensor should roughly fill it, without any overlap. The standard lens is considered ideal for portraits as – when engineered correctly – they generate little, if any, distortion and tend to perform well in low light.

USE LENS IF/WHEN...
... trying to capture flattering portraits with minimal distortion.



Wide-angle lenses have a short focal length (roughly less than 35mm on a full frame camera) and have curved front elements, which give them a wide angle of view. The fact that the glass at the front of the lens is curved outwards means the light rays enter the front element at a sharper angle, spreading light across a smaller area of the camera's sensor and therefore producing a wider angle of view in your final image. This has the effect of allowing the lens to 'see' more around it and exaggerating the wide perspective of a scene.

USE LENS IF/WHEN...
... photographing groups of people, tall buildings or sweeping landscapes.



A telephoto lens covers the longer end of the focal ranges – with around 200-300mm being the most popular among enthusiasts, but professionals often use much longer optics. The front group of elements in a telephoto lens gather and project light onto a rear group of elements, which magnify the image transmitted and spread it across a wider area of the image sensor, creating a magnified version of your distant subject. This design allows the lens elements to be closer together, helping to keep the physical length of the lens barrel compact in relation to its focal length.

USE LENS IF/WHEN...
... you have to shoot from a distance, such as at sporting events or when photographing wildlife and candid portraits.

Other lenses

Macro

Macro optics are highly specialised lenses with powerful magnification capabilities. They feature a flat image plane and, usually, very high-grade glass elements which are highly corrected to minimise any distortion. Most produce a 1:1 (life-size) reproduction of a subject, although some can magnify by up to five times.

USE LENS IF/WHEN...
... you want to make small things look big.

Fisheye

A fisheye lens is an extreme version of a wide-angle lens. The front element is bulbous, literally like a fish eye, which diverges light. These lenses produce a great deal of distortion, with objects being 'pulled' away from the centre of the frame, but give a very wide angle of view – often around 180-degrees or more.

USE LENS IF/WHEN...
... you want everything in your shot, or for comic effect in portraits.

Teleconverter

Teleconverters are basically tubes that contain predominantly diverging lens elements. These are attached to your existing lens and increase its magnification power, allowing you to zoom further with a telephoto lens or magnify your subject more with a macro optic, for example. The downside is they reduce the lens's maximum aperture and can reduce image quality.

USE LENS IF/WHEN...
... your telephoto lens isn't quite long enough to fill the frame with your subject.

How a Google™ search works

How exactly does Google return all those search results?

Google Search | How It Works Search

Search: How It works pages from the web

Google's name is synonymous with internet search and browsing. The Google homepage has become the gateway into the world wide web and its plainly presented, mostly blank starting screen is no accident – it is meant to represent an open page just waiting to be filled with search results based on your area of query.

Google understands that cyberspace is massive and it is expanding just about as fast as the universe itself. Just like our own cosmos there are chunks of matter out there in the form of huge planets of data (let's call them web portals in this instance) with their own ecosystems inside of which users interact.

The problem is, no one has been able to create an accurate and definitive map of the universe, or cyberspace for that matter, due to the constantly changing dynamic shape of both worlds. But Google is there to guide us with some clever technologies and more than a couple of nifty tricks, which you may not even be aware of as you surf the web. Prepare for take-off.

What's really clever about Google's search function is that when most of us use it we think that we're searching the internet itself. In fact we're not. We're searching Google's index of the web. Google doesn't have connections to every single corner of the internet, but the company's indexes are pretty darn good. In fact, they are among the biggest databases on the planet. We're talking about many billions of webpages stored on thousands of machines around the world.

But how does Google build this index – and how does it 'populate' it with accurate and meaningful results data that will be useful to users? Even Google has to start somewhere, so it uses software programs known as spiders, also commonly referred to as crawlers or Googlebots. These useful little crawlers are sent out initially to the most logical places on the web. If you search for 'Marmite', most likely the first site the spider will have compiled your search results by visiting will be **www.marmite.com**, so no rocket science as yet. This first stage of website search is known as the 'seed' level.

After we pass the seed level we start to branch out. The spiders will then crawl outwards further and follow links from the initial pages that it finds and start to weave a web of interconnected websites that share relevance in terms of content. The spider builds up a pattern of pages linked to pages, which must be recursively revisited in order to ensure they ▶

NEW

1. Bing

Advertised as a 'decision engine', Bing is a search engine from Microsoft. It is currently the third largest search engine in use by query volume, with 3.24 per cent of the total share. This lags behind Google and Yahoo!.

BIG

2. Yahoo!

Now more of a web portal than mere search engine, Yahoo! was the first search engine to go massive and one of the largest companies to survive the dotcom crash in 2000. It currently lies in second place in total web queries.

NICHE

3. Ask

Set up by Garrett Gruener and David Warthen in 1996, Ask.com is a search engine that specialises in fetching results from everyday questions. In the UK it is known as Ask Jeeves, and has a butler persona mascot.

DID YOU KNOW? *Google was founded in 1996*

Visual guide to a Google search

What Google does to get your results

User logs on to Google.com or international country-specific site

User enters search term

User decides whether to use "quotation" marks or other tools

Google disregards short object words such as 'the' or 'at' unless the user inserts a "+" at the start of the term

Depending on the browser, Google may auto-complete some of the user's entry with commonly searched terms

User hits Return — Time taken for search: 0 sec

The user's search goes off to the nearest available Google web server to plug in to the catalogue of information

Google looks up relevant information related to your search by accessing its records of billions of webpages stored on thousands of its machines around the world

Google's query processor software then gets to work filtering through its indexes to decide which links to present

Google's query software asks over 200 questions to wade through vast lumps of data as it tries to apply almost human logic to reason why this search has been made

Depending on the language used to make the search, the analysis engines will be working away to check for possible synonym usage that might provide the user with a more useful and more accurate set of results

The "Did you mean?" spellchecker service will kick into gear at this point to look for misspellings

Sites found are then analysed for obvious spam, viruses and malware threats

Google checks through which 'file types' it will present back to the user

Pages are then classified by their 'page rank', a formula-based score derived from Google's own calculations

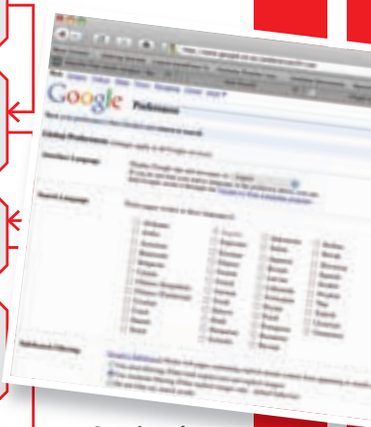
Google's PageRank formula goes to work
PR(A) = (1-d) + d(PR(t1)/C(t1) + ... + PR(tn)/C(tn))

Before live links are presented, Google prepares its 'cached' pages report where users can view the 'saved' version of the site, stored on Google's servers

Google will also prepare 'similar' results, derived using its own software to apply different logic to the search and find words that are related to the initial terms

The user can now click on the links, try a different search term – or possibly even play with Google's Options controls to change the how the search function operates

The user's search becomes one of 'hundreds of millions' of searches handled each day by Google alone — 0.5 sec

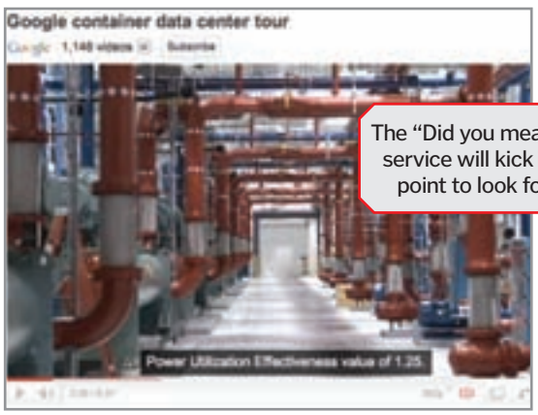


Search preferences can be tweaked to provide greater accuracy in results

Did you mean...

As detailed overleaf, our search here is for "Toasted Cheese Sandwich". However, if you type "taosyed cheeese samdwhich" the Did you mean... feature will offer suggestions based on the correct spelling. So how does it work?

Google engineer Noam Shazeer developed a spelling correction system that would form part of Google's core search software to perform this trick. He developed a system that would collate the most frequently misspelled words relating to real words. Consistently within the top ten search terms globally, "Britney Spears" has been searched for and misspelled so many times that there are now hundreds of listed misappropriations of her name – view them at www.google.com/jobs/britney.html.



Google's container data centre is responsible for a big chunk of the web's supporting data

"Google will also check for the presence of viruses and malware"

still contain content relating to the original search. Pages are revisited based on frequency 'policies' that are set by software that resides on Google's servers. But what we need to remember is that the web is so vast and changeable that no spider will ever capture all the information out there.

So let's start with a search. Say we want to look up 'toasted cheese sandwiches'. We type in those three words and press Return. Google's query processor software then gets to work filtering through its indexes to decide which links to present. But hang on – what's to stop me getting results on cheese making, results on toaster-buying advice and results on the Earl of Sandwich? Well, Google asks questions. More than 200 questions in fact. You could say that Google's software uses a little artificial intelligence here because it tries to apply human logic to the vast lumps of raw data that it has to wade through.

To decide which 'toasted cheese sandwich' website to present to us, Google asks whether the words appear in the website's title or URL. Google asks how many times the words appear in the correct order on any given website. Does the page include synonyms for 'toasted cheese sandwich' such as 'grilled cheddar buttie' or 'hot cheesy panini'. Discussing the mechanics of how to describe a toasted cheese sandwich might sound silly, but it's all logical to the guys who run Google's data centre.

As well as checking for poor design or poor content quality, Google will also check for the presence of obvious spam, viruses and malware. Our search process will then start to classify pages by their 'page rank', which is a formula-based score derived from Google's own calculations. A page rank score is obtained by analysing how many external pages point to a particular website or cite it as a reference or authority on a subject. All this is done in roughly half a second and your search term results will, depending on your web-connection speed, come back to you nearly instantaneously.

Now, of course Google could be on the pay roll of the international cheese sandwich society (for example) and so therefore be quite keen to present you with certain pages relating to that organisation's own interests. But it's not. Google's results are impartial and the company will not take payments from companies who want to push up their page-ranking results. Although there will be 'Google Ads' down the right-hand side of the page and sometimes on top, which have been classified as 'relevant' and 'supporting' to your search term.

So, how should you read a Google search result? Is it as simple as just clicking the top result on the page? Have you actually read down below the headline to look at some of the other information that Google is presenting to you? Right underneath your highlighted blue link you'll see a short description of the website's content. This is part of the metadata of the website itself – or to put it another way, it is information about information. Either way, it's your fastest route to getting a handle on what you're likely to find if you decide to click onwards.

Right underneath the website description is the site's cached results, which can be displayed if you want to be able to cross-reference exactly when the last time the Googlebots dipped onto the site in question for an update.

This version of the page will also give you colour-coded highlighted mark-ups of your search terms showing you exactly where they have been used. The cached version of the page is actually stored on Google's own servers and it is this content that the company uses to calculate and establish the site's page ranking. If the web server that hosts the 'live' version of the site you want to visit is acting up or working too slowly, you might like to remember that Google's servers are generally set to run pretty fast, so you could always use this version of the page instead.

Beside the 'Cached' link you'll see the 'Similar' link and this is pretty self explanatory. Part of the concept of web search is that we often don't really

Anatomy of a search result

Google's search results have evolved. Now we get relevant advertising slots at the top and down the right-hand side of our search page. As well as standard results (below) we'll also get location-based results that are tied in with Google Maps

She's delighted with the results for "best science and technology mag"!

PR(A) = (1-d) + d(PR(t1)/C

PageRank formula

Google uses its own page rank formula to decide which pages are likely to be most relevant to every search

5 TOP FACTS GOOGLE SEARCH ENGINE

Google is not the internet
1 Google is an index of the internet and the company says that it does not know about every single website out there. We wouldn't suggest trying to beat it though.

Quick, damn quick
2 Google typically returns your results to you in less than half a second. It uses immense server processing power at what it calls 'the back end' to be able to do this.

From noun to verb
3 Google is now a transitive verb and was officially added to the Oxford English Dictionary on 15 June 2006. Try it for yourself: I Google, he Googled, they are Googling and so on.

Millions and billions
4 Google currently runs over 1 million servers around the world and spends somewhere in the region of $200-250 million a year on various IT equipment alone.

Don't PANIC!
5 The word 'Google' occurs in the *Hitchhiker's Guide To The Galaxy* when the Deep Thought designer asks "And are you not a greater analyst than the Googleplex Star Thinker?"

DID YOU KNOW? *Google's data centers consist of servers housed in hundreds of shipping containers*

Google data centres

Google has always kept its data centres shrouded in mystery, almost as if it was hoarding the power of the internet away from us. But over time the search giant has allowed us to peak inside its 'container hangar' data centre in Mountain View, California. That's 'container', as in an eight-foot high ISO intermodal-shipping container.

Google has stacked 45 of these metal beasts into its huge 'container hangar' data centre and some of them are even housed up on a second-storey balcony. Whirring away inside each of these huge giant boxes is up to 1,160 servers using 250 kilowatts of power.

The use of shipping containers as data centre building blocks is something the US military have been doing for years, but Google has adopted this technique to give itself maximum portability – and it can easily switch out faulty servers this way too. With a power density of 780 watts per square foot, the cooling system is set to 81 degrees Fahrenheit inside the containers – and there's a whole heap of simple fans and complex air-cooling systems using heat dissipation techniques to keep this operation running smoothly.

The location of Google's data centres in the USA

know what we're looking for until we find it. Google can help here with some tangential results that you may not have considered searching for. Google uses its own server-based software to apply different logic to the initial search and find words that are related to the initial terms. You can play with this function more extensively if you use Google's Advanced search function or if you type 'related: URL' where URL is the full website address that you want to examine, as in 'related: http://www.howitworksdaily.com'.

Once you really dig into Google search you can start playing around with the user options, which are accessible right from the Google homepage. Not only can you change the language interface that is presented to you, but you can also change the native language that you are searching in and that you want results delivered back to you in. You can set the SafeSearch option to block pages with sexually explicit content and you can even change your search format to display preferences more suited to a mobile smartphone or PDA.

Search engine optimisation

Getting to the top of the list

Search engine optimisation (or SEO) is all about how a website owner tries to optimise and improve the visibility of their pages so that they feature among Google's (or another search engine's) search results. SEO is based upon the website's ability to be found organically and algorithmically without any paid-for marketing support.

Content is king!

It's all down to content on the internet, so if you 'populate' your website with words that are frequently used in search requests then your SEO score will improve.

Egg recall **Facebook** YouTube **Britney Spears** Pakistan floods Casey Johnson **Michael Jackson** **President Obama** Craigslist Weather **SmackDown spoilers**

Metadata matters

If you edit your website's metadata information to also include popularly searched-for terms then you become more prominent on the web as a whole.

Meta-tagging and release

Technologies such as a the 'Canonical meta tag' and the '301 redirects' URL redirect tools can improve your page ranking as they ensure that internal website pages (ie inside of and beyond your homepage) all go to add towards your score.

Don't get cross, get cross-linked

You can cross link less prominent pages within your total website's data stash to point to the most important pages with the most highly searched-for words and phrases to increase your overall ranking.

Use common sense

There are just certain words and phrases that you or anyone else would naturally associate with websites pertaining to every subject under the Sun. So use your common sense, look at what other successful sites have done and rework a few popular ideas in your own style.

(t1) + ... + PR(tn)/C(tn))

This looks complicated, but it's really very simple: PR(A) stands for the Google page rank of our arbitrary example page A. t1 – tn are the pages that link to page A. C is the number of outbound links that a page has and in this case our C variable is examining pages t1 to tn. d is a damping factor, which is usually set to 0.85 – this is a standard function used when working with numerical algorithms. It is likely that Google has progressed the form of this equation, but that it is still largely based on this initial form.

This month in **Science**

"The miracle of childbirth" is a phrase that can often sound overly sentimental. However, take a little time to consider what occurs during pregnancy and you'll realise the development of a new human being is a truly amazing process. Take a look at the article here to learn just how it occurs. Our main feature this issue explains radiation, another amazing process that has the power to both end human life and sustain it through the most serious illnesses.

Human pregnancy

Nine months of change and growth

Pregnancy is a unique period in a woman's life that brings about physical and emotional changes. When it occurs, there is an intricate change in the balance of the oestrogen and progesterone hormones, which causes the cessation of menstruation and allows the conditions in the uterus (womb) to become suitable for the growth of the fetus. The lining of the uterus, rather than being discharged, thickens and enables the development of the baby.

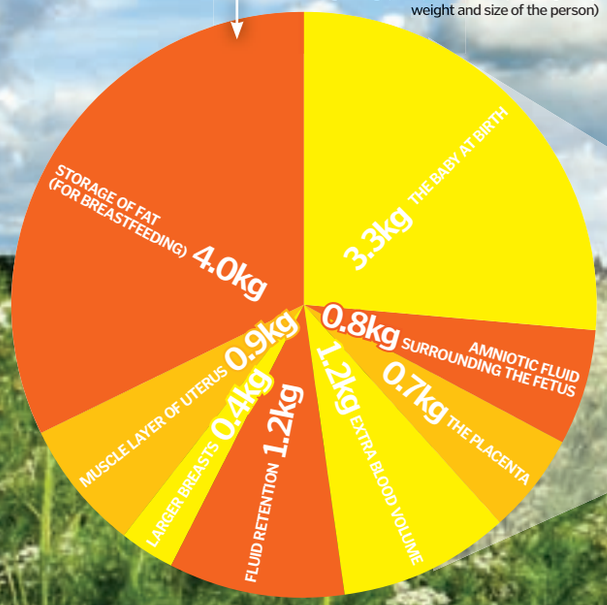
At first, it is a collection of embryonic cells no bigger than a pinhead. By week four the embryo forms the brain, spinal cord and heart inside the newly fluid-filled amniotic sac. Protected by this cushion of fluid, it becomes recognisably human and enters the fetal stage by week eight.

Many demands are put on the mother's body and she is likely to experience sickness, tiredness, lower-back pain, heartburn, increased appetite and muscle cramps, as well as the enlargement of her breasts and stretch marks. Her blood sugar levels, heart rate and breathing also increase to cope with the growing demands of the fetus.

As the date of labour approaches, the mother feels sudden contractions known as Braxton-Hicks, and the neck of her uterus begins to soften and thin out. Meanwhile, the lungs of the fetus fill with surfactant. This substance enables the lungs to soften, making them able to inflate when it takes its first breath of air. Finally, chemical signals from the fetus trigger the uterus to go into labour.

Weight gain

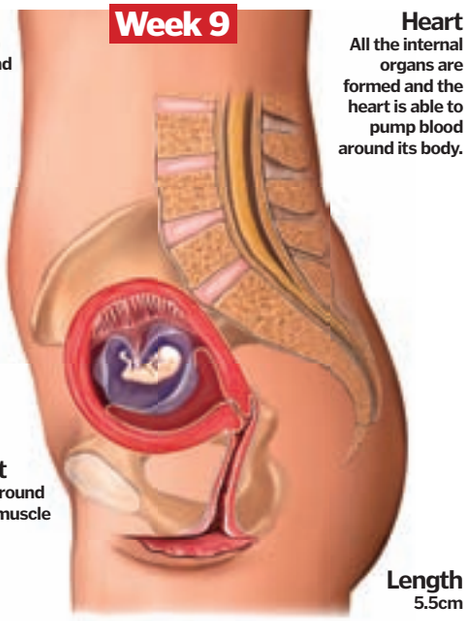
The average woman gains 12.5kg during pregnancy. This consists of...
(These figures vary according to several factors including the age, race, diet and the pre-pregnancy weight and size of the person)



FIRST TRIMESTER (0–12 weeks)

This begins after the last menstrual period, when an egg is released and fertilised. It takes about nine weeks for the resulting embryo to develop into a fetus. During this period, the mother will be prone to sickness and mood swings due to hormonal changes.

Week 9



Head
Face begins to look human and the brain is developing rapidly.

Heart
All the internal organs are formed and the heart is able to pump blood around its body.

Movement
Fetus moves around to encourage muscle development.

Weight
10g

Length
5.5cm

SECOND TRIMESTER (13–27 weeks)

The fetus grows rapidly and its organs mature. By week 20 its movements can be felt. At week 24 it can suck its thumb and hiccup, and can live independently of the mother with medical support.

Week 16

Hair and teeth
At 16 weeks, fine hair (lanugo) grows over the fetal body. By 20 weeks, teeth start forming in the jaw and hair grows.

Movement
By week 16 the eyes can move and the whole fetus makes vigorous movements.

Sound and light
The fetus will respond to light and is able to hear sounds such as the mother's voice.

Vernix
By 20 weeks, this white, waxy substance covers the skin, protecting it from the surrounding amniotic fluid.

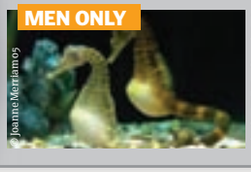
Sweating
An increase in blood circulation causes mother to sweat more.

Weight
Week 16: 140g
Week 20: 340g

Length
Week 16: 18cm
Week 20: 25cm

4x trimester images © Science Photo Library

Head to Head ANIMAL PREGNANCIES



MEN ONLY

1. Seahorses

The female seahorse deposits her eggs in the pouch of the male seahorse. He fertilises the eggs and carries them for the full term of three weeks.

VIRGIN BIRTH

2. Komodo dragons

Female komodo dragons can give birth to male babies without fertilisation from a male partner. This is known as parthenogenesis.

JUST PLAIN WEIRD

3. Spotted hyenas

Female spotted hyenas have genitalia like a penis. It stretches to allow the insertion of the male penis during copulation, and stretches again when giving birth through it.

DID YOU KNOW? *200 extra calories a day are needed in mid-pregnancy, which is 10 per cent more than the usual daily requirement*

The placenta

The placenta is an essential interface between the mother and fetus. When mature it is a 22cm diameter, flat oval shape with a 2.5cm bulge in the centre. The three intertwined blood vessels from the cord radiate from the centre to the edges of the placenta. Like tree roots, these villous structures penetrate the placenta and link to 15 to 20 lobes on the maternal surface.

The five major functions of the placenta deal with respiration, nutrition, excretion of waste products, bacterial protection and the production of hormones.

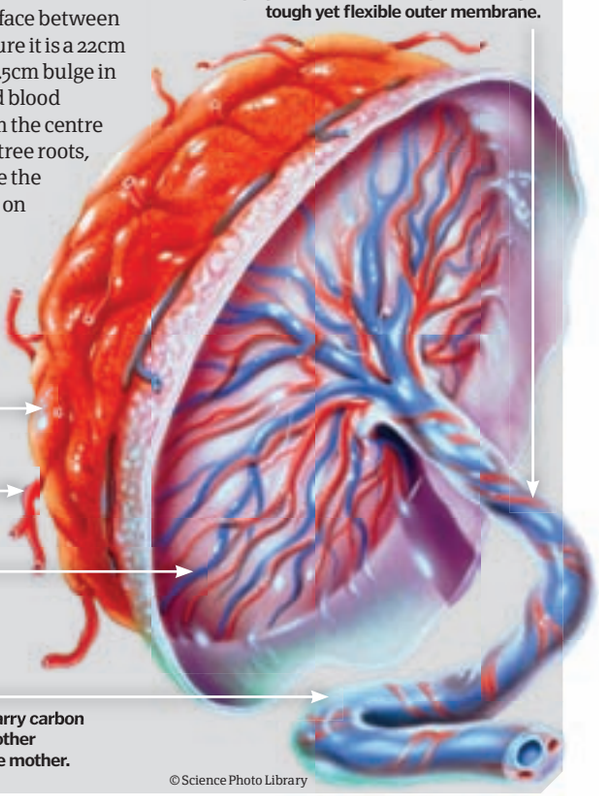
Placenta body
Is firmly attached to the inside of the mother's uterus.

Maternal surface
Blood from the mother is absorbed and transferred to the fetal surface.

Fetal surface
Blood vessels radiate out from the umbilical cord and penetrate the placenta. The surface is covered with the thin amnion membrane.

Umbilical cord
Consists of three blood vessels. Two carry carbon dioxide and waste from the fetus, the other supplies oxygen and nutrients from the mother.

Wharton's jelly
The umbilical blood vessels are coated with this jelly-like substance and protected by a tough yet flexible outer membrane.



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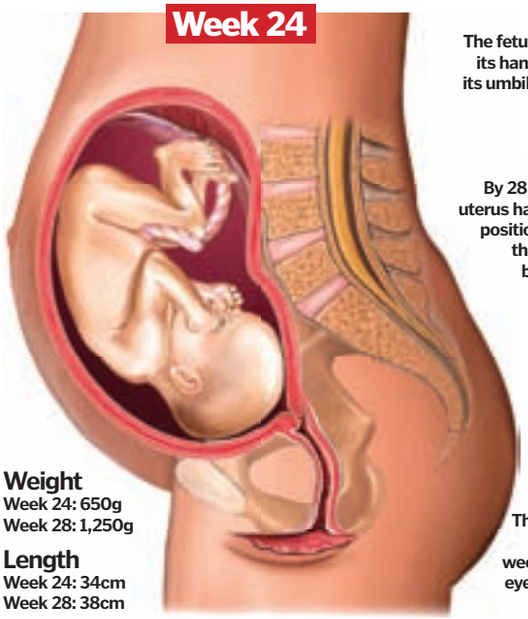
THIRD TRIMESTER (28–40 weeks)

Now almost at full term, the fetus can recognise and respond to sounds and changes in light. Fat begins to be stored under the skin and the lungs are the very last organs to mature.

Ultrasound scans can monitor the fetus's progression

Week 24



Breathlessness
The increased size of the fetus by 24 weeks causes compression of rib cage and discomfort for mother.

Movement
By the 28th week, due to less room in uterus, the fetus will wriggle if it feels uncomfortable.

Hands
The fetus can move its hands to touch its umbilical cord at 24 weeks.

Position
By 28 weeks, the uterus has risen to a position between the navel and breastbone.

Weight
Week 24: 650g
Week 28: 1,250g

Length
Week 24: 34cm
Week 28: 38cm

Head
The head can move at 28 weeks and the eyes can open and see.

Week 32

Weight
1,500g

Length
41cm

Under pressure
Pressure on the diaphragm and other organs causes indigestion and heartburn in the mother. She will find it difficult to eat a lot.

Position
Head positions itself downwards, in preparation for labour.

Sleep patterns
Fetus will sleep and wake in 20-minute cycles.

"It's this combination of liquid and gas in a small space that causes the gurgling noise"

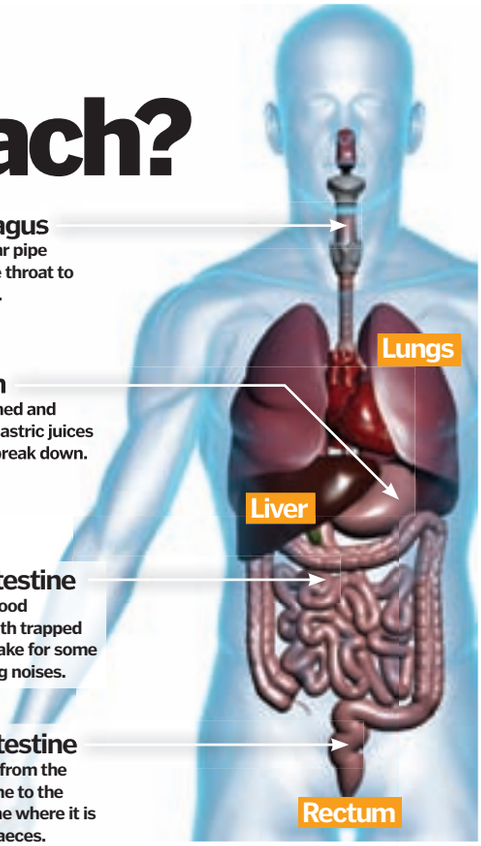
What causes a rumbling stomach?

Discover how the small intestine is really to blame...

Waves of involuntary muscle contractions called peristalsis churn the food we eat to soften it and transport it through the digestive system. The contractions are caused by strong muscles in the oesophagus wall, which take just ten seconds to push food down to the stomach. Muscles in the stomach churn food and gastric juices to break it down further.

Then, after four hours, the semi-digested liquefied food moves on to the small intestine where yet more powerful muscle contractions force the food down through the intestine's bends and folds. This is where the rumbling occurs. Air from gaseous foods or swallowed when we eat – often due to talking or inhaling through the nose while chewing – also ends up in the small intestine, and it's this combination of liquid and gas in a small space that causes the gurgling noise.

Rumbling is louder the less food present in the small intestine, which is partly why people associate rumbling tummies with hunger. The other reason is that although the stomach may be clear, the brain still triggers peristalsis at regular intervals to rid the intestines of any remaining food. This creates a hollow feeling that causes you to feel hungry.



5 TOP FACTS INTESTINES

1 It's all good
Noises coming from your intestines is quite normal. In fact, an absence of bowel growls could indicate an intestinal obstruction.

2 Break it down
Each day the average human stomach secretes three litres of gastric juice, which is used in the breakdown of food.

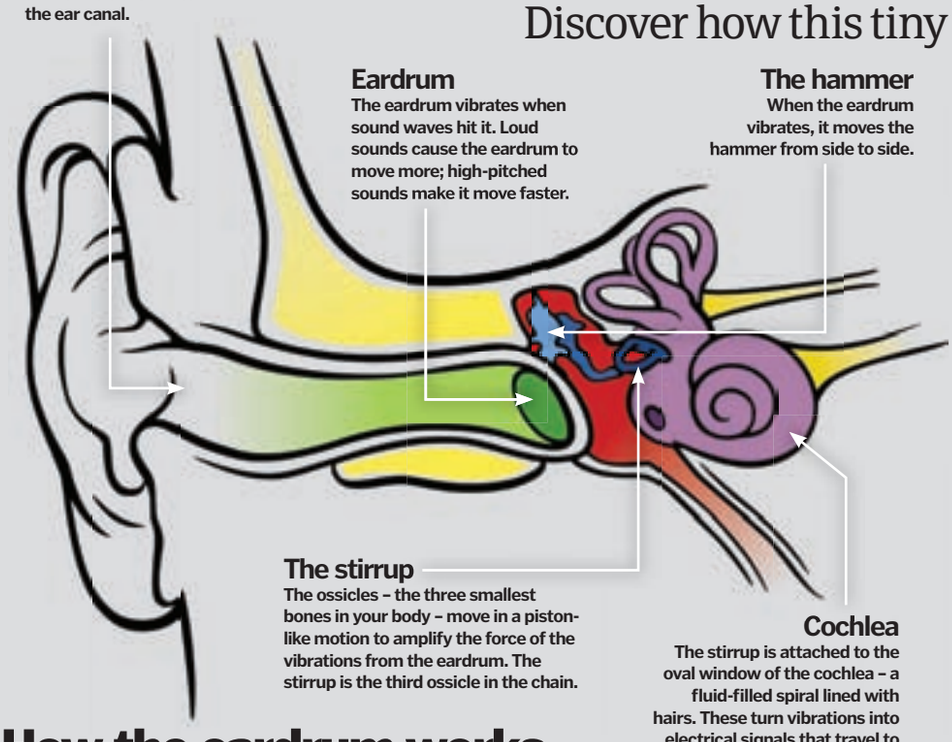
3 What's in a name?
Despite the name, the small intestine is actually five metres long – that's 3.5m longer than the large intestine.

4 Massive absorption
The surface area of the small intestine is the size of a tennis court. Millions of projections called villi – each 0.5-1mm long – on the inside wall absorb vital nutrients from food.

5 Getting gassy
Foods naturally containing more gas and therefore leading to more rumbling – not to mention other sorts of bodily noises – include fibre-rich fruits and vegetables, such as beans.

Your eardrums explained

Discover how this tiny flap of skin helps you hear



How the eardrum works

The eardrum is a thin, cone-shaped piece of skin around a centimetre across that separates the outer and middle ear. Sound waves entering the ear canal push the eardrum backwards and forwards. These vibrations travel towards the inner ear where they get turned into messages that your brain interprets as sound. The eardrum also stops foreign objects like bacteria and dirt getting into the middle ear.

The eardrum – or tympanic membrane – is attached to a ring of bone and tilted at a steep angle inside the ear canal. Within the membrane are radial fibres. These fibres, the steep angle and the shape of the eardrum increase its sensitivity to sound.

5 TOP FACTS EFFECTS OF THE BENDS

Skin pain
1 A red rash on the shoulders or chest is often a clear indication of bubbles residing in the capillaries of the skin. Though painful, it is not in itself serious, but may infer underlying issues.

Joint and limb pain
2 In three quarters of DCS cases bubbles growing in and around the ligaments, tendons and muscles are said to occur and signal a common cause of joint and limb pain.

Neurological: paralysis
3 Bubbles can grow in nervous tissue or clog up venous flow and so impinge on arterial supplies to affected areas. Numbness and paralysis can soon spread.

Pulmonary: the "chokes"
4 When bubbles in the pulmonary capillaries can't diffuse to the alveoli sufficiently, a jam may ensue; this can interfere with gas exchange and reduce oxygen to the tissues.

Cerebral: stroke
5 A blockage of blood flow to the brain can lead to a blurring of vision, strong headaches and migraines and unconsciousness, which in the end could lead to death.

DID YOU KNOW? *Astronauts prevent the 'bends' by purging their bodies of nitrogen before slipping into low-pressure suits*

The bends

When you're out of your depth, rising too fast could have a devastating effect on your body

Despite its appearance, the air we breathe has mass. Consisting of nitrogen (78 per cent), oxygen (21 per cent) and trace gas constituents, the action of gravity on these molecules around us result in atmospheric pressure. While the body's chemistry is in a constant state of equilibrium with this surrounding (ambient) pressure, in water it is a totally different kettle of fish.

At 33 feet deep, the ambient pressure is twice that at the surface, and a diver's body must attempt to redress this balance. Breathing apparatus regulates air to the lungs at ambient pressure. To achieve equilibrium, the partial pressure of gas in the lungs must ultimately equal, and so diffuse to, the tissues and blood. Unlike oxygen, which is constantly being used, nitrogen will build in the tissues until saturated in line with the ambient pressure.

If the descent continues so too does nitrogen absorption, in tune with the continuing rise in ambient pressure; ultimately this leads to nitrogen narcosis. Only upon the diver's ascent and a subsequent fall in ambient pressure will the gradient reverse, leading to excess nitrogen being released. This is not without danger.

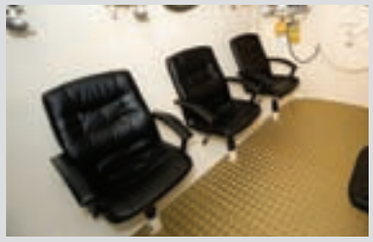
At a gradual ascent, nitrogen is exhaled from the body. Surfacing too rapidly will force the nitrogen out of solution, like the carbon dioxide distilled in a bottle of soda when the cap is removed too quickly. These bubbles cause decompression sickness (DCS) and, depending on where they form, all manner of 'bends' ranging from headaches and muscular weakness to paralysis and even death.

Hyperbaric chambers – getting round the 'bends'

Hyperbaric oxygen therapy administers 100 per cent oxygen at upwards of three times atmospheric pressure. Monoplace and multiplace steel tanks allow single or multiple occupancy during treatment and are air-sealed and pressurised throughout.

Once the requisite pressure is reached, oxygen is served by flooding the single-occupancy chamber or via oxygen masks when more than one patient is treated.

Elevating the ambient pressure increases the rate at which oxygen is absorbed by up to 20 times, saturating the bloodstream; aiding nitrogen exhalation by way of the lungs and improving white blood cell function so as to speed up recovery time to damaged tissues.



Why penguins don't p-p-pick up the bends

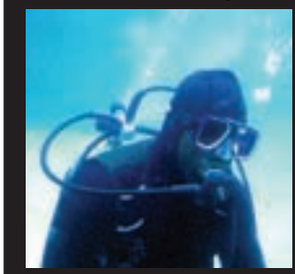
The blood and muscles of some marine mammals conserve oxygen extremely well. As a response, they have evolved to collapse their lungs while diving. This prevents nitrogen from the lungs further diffusing into the body during descent with increasing ambient pressure, and so from diffusing out upon ascent to potentially cause the bends.

Penguins do not have this option. They may limit dive time to reduce the window during which nitrogen may be absorbed. On deeper dives they may bypass the bends by slowing the ascent, allowing natural buoyancy to return. This allows nitrogen time to diffuse from the blood and into air inside the body cavities.

The nitrogen diving cycle

Henry's law
It is accepted that the human body will dissolve nitrogen in line with and dictated by the prevailing surrounding (ambient) pressure.

At sea level
The body is in equilibrium, or 'saturated' in respect to the ambient atmospheric pressure, ie it contains as much nitrogen as it can hold in solution at surface pressure.



Beginning the descent
During descent, the ambient pressure increases in relation to the diver's body. The two are no longer in equilibrium.

Nitrogen makes its move
Nitrogen in the lungs moves down the pressure gradient, diffusing across the alveoli of the lungs and into the tissues and blood.

Regaining equilibrium
At a stationary depth ambient gases continue to diffuse into solution (in the body) until the tissues and blood are saturated.

Super-saturation
During ascent, pressure surrounding the diver falls and is lower than tissue pressure. This is known as super-saturation.

Outgassing
A super-saturated state acts in reverse. Nitrogen diffuses from tissues and blood into the alveoli, which is then vented by pulmonary exhalation.

Bubble trouble
If the ascent is too swift then nitrogen is forced to come out of solution too quickly, leading to the formation and build up of bubbles in the tissues and blood.

All about location
The resulting condition is something of a lottery and is dependent upon the extent and location of bubble formation.

Symptoms by degree
Where bubbles arise they cause varied degrees of physiological angst and distress.

"This is because most masses on Earth have proportional"

Mass versus weight

Commonly grouped under the generic term 'weight' in everyday society, the properties of mass and weight are actually completely different

Outside of the world of physics 'weight' is a generic term used to refer to an object's mass – the amount of matter an object has, directly dictated by its amount of and type of atoms – and its weight, the force created when a mass is acted upon by a gravitational field. This is because most masses on Earth have weight and the relationship between the two factors is directly proportional – ie, the more massive an object is, the greater its weight. However, in the world of physics – which deals with objects of infinite mass under wildly varying forces, not just the relatively stable force of Earth's gravity – mass and weight are distinct.

To understand the distinction fully between mass and weight it is important to understand their fundamental principles. Newton's law of universal gravitation states that every massive particle in the universe attracts every other massive particle to some extent, and considering the size of Earth it has a pretty big pull. On Earth this resultant force is gravity (g) and its average numerical value is 9.81m/s² – meaning that, ignoring air resistance, the speed of an object falling freely near the Earth's surface increases by about 9.81 metres per second every second. However, gravity pulls down on both airborne and ground-based objects and this force acting upon a mass is an object's weight.

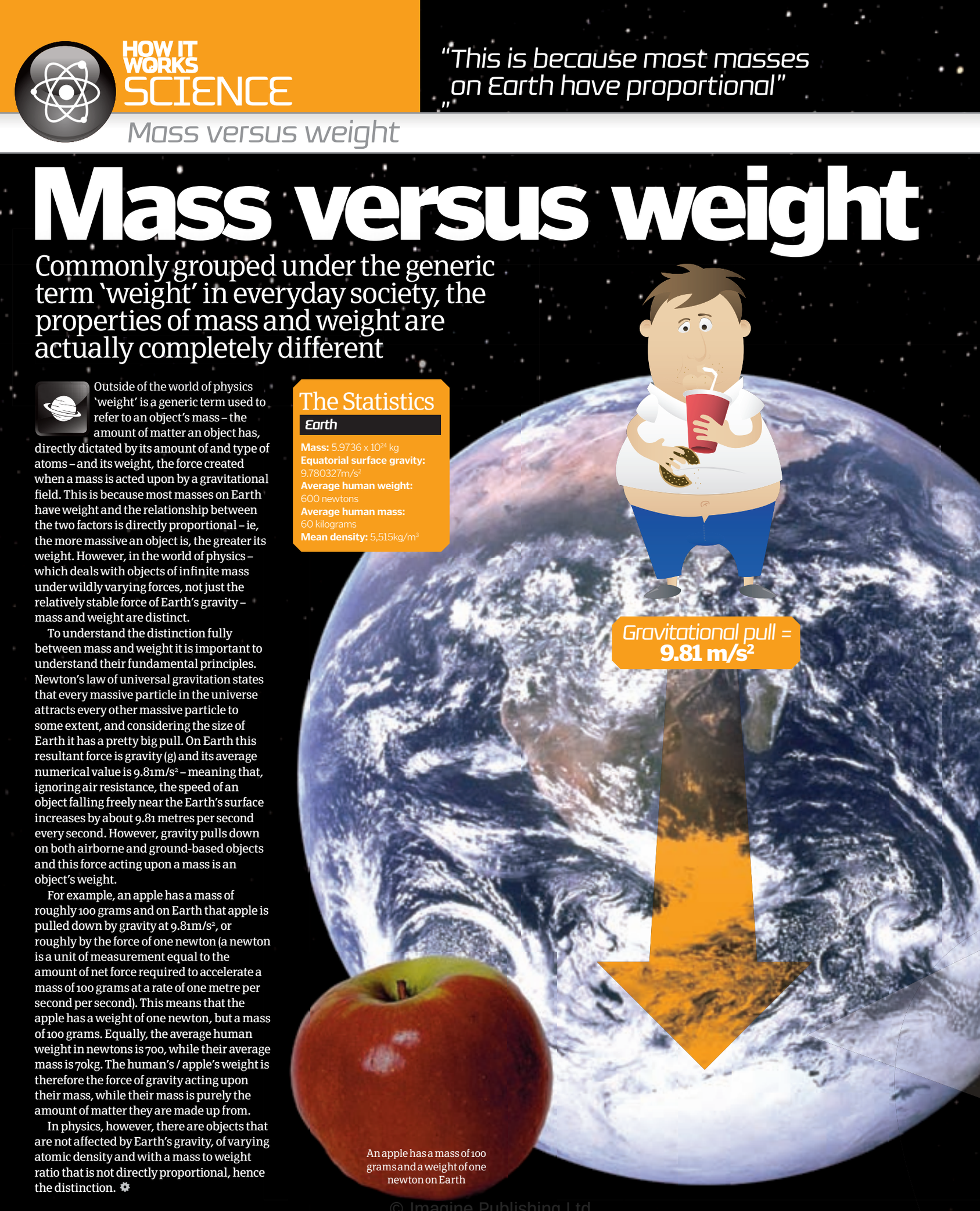
For example, an apple has a mass of roughly 100 grams and on Earth that apple is pulled down by gravity at 9.81m/s², or roughly by the force of one newton (a newton is a unit of measurement equal to the amount of net force required to accelerate a mass of 100 grams at a rate of one metre per second per second). This means that the apple has a weight of one newton, but a mass of 100 grams. Equally, the average human weight in newtons is 700, while their average mass is 70kg. The human's / apple's weight is therefore the force of gravity acting upon their mass, while their mass is purely the amount of matter they are made up from.

In physics, however, there are objects that are not affected by Earth's gravity, of varying atomic density and with a mass to weight ratio that is not directly proportional, hence the distinction.

The Statistics

Earth

Mass: 5.9736 x 10^{24} kg
Equatorial surface gravity: 9.780327m/s²
Average human weight: 600 newtons
Average human mass: 60 kilograms
Mean density: 5,515kg/m³



An apple has a mass of 100 grams and a weight of one newton on Earth

5 TOP FACTS
MASS & WEIGHT

Fruitful
1 The force of gravity acting on a mass of 100 grams is called one newton, roughly the weight of an apple. When one falls to Earth under the force of gravity, it is falling under the force of one newton.

Microgravity
2 Astronauts taking part in a spacewalk are capable of holding a multiple ton satellite because it is weightless, a feat that would be impossible on Earth.

Inertia
3 Mass itself is an inertial property – the resistance of any physical object to a change in its state of motion – that when static is represented numerically.

Little g
4 The gravity of Earth has an approximate value of 9.81m/s². This means that the speed of an object falling near the Earth's surface increases by about 9.81m per second every second.

Justice
5 The scales that are held by the blind figure of Justice, as with all balance-type scales, measure mass rather than weight.

DID YOU KNOW? *Mass and weight are not always proportional*

The ultimate diet plan

If you're missing any pies, this guy ate them

When a person is overweight they are referred to as having a 'weight problem', when they really have a mass problem, as the force of gravity acting upon them is consistent across Earth. The amount of matter the obese person has is just larger than that of a comparatively skinny person, who has less mass but the same force of gravity acting upon them. Therefore, to lose mass a person needs to eat less, while if they wish to lose weight they should travel to the moon, where the force of gravity acting upon that mass is 1/6th of that of the Earth. If they did this, they'd instantly have a weight of 1/6th of what they had on Earth, even though their mass would remain the same.

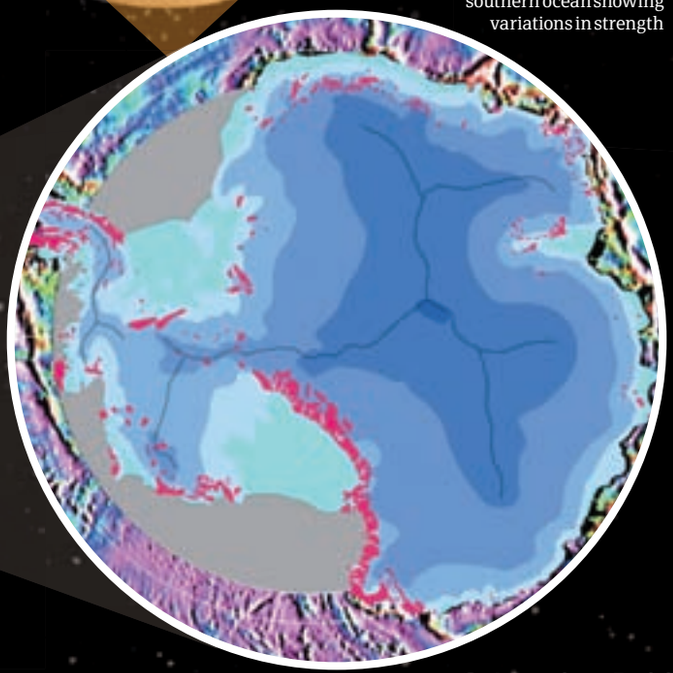
The Statistics

Moon

Mass: 7.3477 x 10^{22} kg
Equatorial surface gravity: 1.622m/s²
Average human weight: 100 newtons
Average human mass: 60 kilograms
Mean density: 3,346.4kg/m³

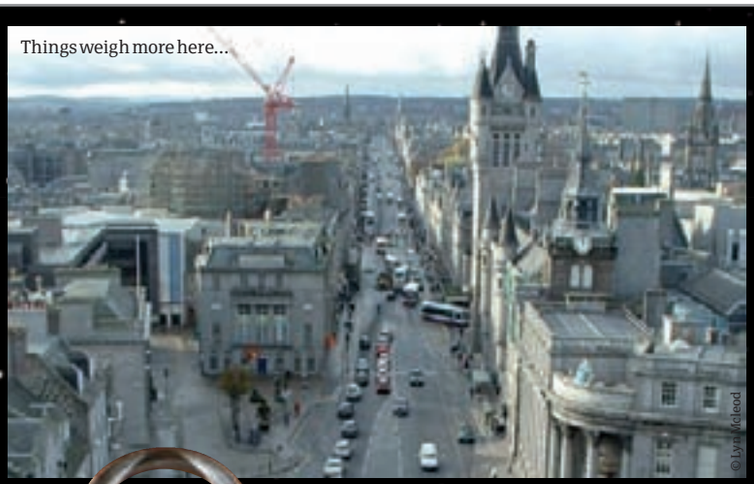
Gravitational pull = **1.65 m/s²**

Although your mass would be the same on the moon as on Earth, your weight would be a lot less



A gravity map of the Earth's southern ocean showing variations in strength

Things weigh more here...



© Lyn Adelead

Newton spring scale

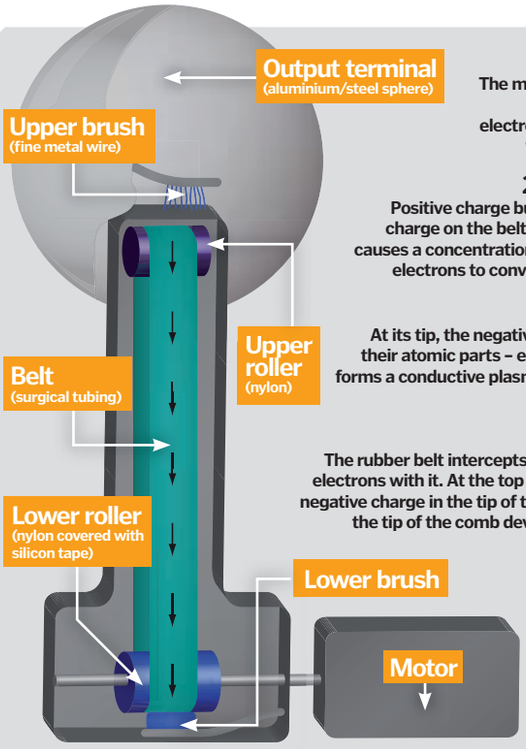
As weight is technically a force – the force of gravity acting upon a mass – a different device is used to measure it accurately. The newton spring scale works by the principle of Hooke's Law (the extension of a spring is in direct proportion to its load) and unlike a traditional set of scales, allows for the Earth's gravitational pull on an object's mass to be accurately determined.

Interestingly, however, because Earth's gravitational field can vary depending on where you are (see the nearby map of the Earth's southern ocean) and that weight is used generically on Earth to ascertain mass, industrial spring scales – which measure local weight – must be individually calibrated to be legally accepted in commerce. For example, at the Earth's equator, acceleration due to gravity is measured at 9.7803, while in Aberdeen, Scotland, it is measured at 9.8322. This means that a produce's mass would technically weigh more in Aberdeen than at the equator, making fine measurements difficult to attain.

...than here. This is due to the Earth's density and gravitational field varying

© Michael J Lowe

"The glue and the surface react to form a new chemical compound"



1. Generating a charge
The motor turns the nylon roller, whose atoms are more prone to give up electrons than those of the rubber belt, which is more inclined to receive.

2. Charge concentration
Positive charge builds on the roller, with a negative charge on the belt. The roller's smaller surface area causes a concentration of positive charge, which draws electrons to converge at the tip of the lower comb.

3. St Elmo's fire
At its tip, the negative charge tears air molecules into their atomic parts – electrons and positive nuclei – and forms a conductive plasma. Freed electrons of the plasma are drawn to the positive roller.

4. Electron transport
The rubber belt intercepts this passage and carries the free electrons with it. At the top of the belt, this charge repels the negative charge in the tip of the upper metal comb resulting in the tip of the comb developing a strong positive charge.

5. Feeding the dome
This charge tears ambient air molecules apart by attraction (of electrons) and repulsion (of positive nuclei). The positive air attracts to and neutralises the returning belt while free electrons transfer to the comb and coat the outside dome.

Van de Graaff generators

Learn how this invention gained universal appeal for a generation of shocking hairstyles…

Atoms consist of nuclei housing positively charged protons, middling neutrons, and a surrounding shell of negatively charged electrons. A material may be measured by its atomic tendency to gift or receive electrons.

The Van de Graaff generator exploits this principle using a base roller and belt that exchange electrons in a direction dependent upon their material nature. The positive or negative charge that is carried by the belt to the dome is ultimately dependent upon this exchange.

Assuming a person is insulated from the ground while touching the dome, the charge builds on the body causing the follicles on the head to take on the same charge. As like charges repel, this leads each hair on the head to recoil its neighbour, causing them to stand up.


The quick way to get an Eighties hairstyle

What makes glue stick?

Think you know how glue works? Well stick around to find out

For glue to stick, a substance must have cohesion – that is, it should be able to stick to itself. Adhesion must also apply so that the properties of a substance and surface relate by way of a physical and/or chemical engagement.

Even the smoothest surfaces have microscopic fissures and cracks. The key to mechanical binding is seen where the substance can seep or is pressed into these pores, hardening and locking itself into place.

Binding a non-porous surface most often relies upon chemical bonding where the glue and the surface react and 'interlace' to form a new, and invariably strong, chemical compound. The component parts of epoxy resins – which are chemical compounds that start off as liquid and then harden through the process of curing – may be modified to affect their ability to adhere to a variety of surfaces by mechanical and chemical treatment.

Subtle Van der Waals forces – which dictate whether molecules are attracted or repulsed by each other – may act as an adhesive, where weak polar opposing electrostatic charges of surface and glue molecules attract. Alternatively, Post-it notes deliver their strength by virtue of tiny bubbles that burst to form a vacuum and seal when pressed to a surface.

5 TOP FACTS AMAZING GLUE

1 Bacterial glue
Caulobacter crescentus boasts the strongest grip in the natural world. This stalk tipped with sugary molecules can withstand a force of five tons per square inch.

2 Gecko glue
A gecko's foot is covered in microscopic hairs, each of which bristles with even smaller hairs. Electrostatic bonds between the hairs and the surface allow the gecko to stick to polished glass.

3 Marine glue
Mussels can adhere to rocks and boats due to protein fibres created by a gland in the foot. These fibres anchor via wire bundle proteins that build into a cohesive blob.

4 Geckle glue
Bioengineers have fabricated silicone pillars to imitate a gecko's grip and coated them in a layer of synthetic protein to mimic that of mussels to provide adhesion on land and in water.

5 Nosferatu glue
Optics and dentistry employ an epoxy resin that is cured by the addition of UV light. This allows time to position the materials without the glue going off.

"Radiation isn't 'good' or 'bad', it's simply a scientific reality"

© Science Photo Library

Nuclear radiation

We explain the misunderstood process that has the power to kill and to cure

Radiation is both a blessing and a curse. In the hands of a highly trained physician, targeted blasts of radiation can destroy cancer cells and save lives. But that same radiation, in much higher doses, can be catastrophic. Think of the fallout clouds descending on Japan during World War II or the lingering effects of the Chernobyl disaster.

In truth, radiation isn't 'good' or 'bad', it's simply a scientific reality. Radiation is all around us. Over 80 per cent of the radiation absorbed annually by the human body comes from natural sources like the Sun, minerals in the Earth and radon, a heavy gas that seeps up from the ground. The other 20 per cent comes from periodic exposure to medical x-rays, consumer products like smoke detectors and even food. Normal levels of radiation exposure, estimated as 360 millirems/year, do not result in higher instances of cancer or other diseases.

By definition, radiation is nothing more than a form of energy that either travels in waves or particles. The intensity of radiation depends on its position on the electromagnetic spectrum. Generally, when we talk about the radiation that kills cancer cells and powers nuclear reactors — not the kind emitted by mobile phones and microwaves — we're talking about extremely high-energy particles and waves called ionising radiation.

Ionising radiation gets its name from the effect that it has on individual atoms. When a particle or wave of ionising radiation strikes an atom, it has enough energy to bounce an electron out of its orbit. Since electrons carry a negative charge, the resulting atom now has a net positive charge and is called an ion. Some ionising radiation is powerful enough to cut right through the nucleus of an atom.

There are three major types of ionising radiation: alpha particles, beta particles and gamma rays. Alpha and beta particles are the result of a process called radioactive decay. The atoms within heavy, unstable elements like uranium and radium contain an imbalance of protons and neutrons in their nuclei. Each atom requires a certain amount of protons and neutrons to be stable. For example, a stable form of

5 TOP FACTS RADIATION USES

1 Smoke detectors
Smoke detectors contain a americium-241, which helps create an electrical current between two charged plates. Smoke particles disrupt the current, triggering the alarm.

2 Static eliminators
Some industrial processes generate huge amounts of static electricity. Radioactive polonium-210 emits positively charged alpha particles that neutralise static electricity.

3 Natural illumination
Wristwatch dials and emergency-exit signs use gaseous tritium, a radioactive isotope that emits fluorescent light (through beta decay) when it reacts with a phosphor layer.

4 Dating organic matter
Trace amounts of carbon-14 are present within all plant and animal life. As we know it has a half-life of 5,730 years, scientists can determine a material's relative age.

5 Food safety
The irradiation of fresh foods with gamma rays from radioactive isotopes like cobalt-60 is controversial, but results in the destruction of potentially deadly food-borne bacteria.

DID YOU KNOW? *Tobacco is a sponge for radiation, storing radioactive isotopes of lead and polonium*

lead has 82 protons and 124 neutrons. Radioactive decay is the process by which atoms alter their nuclear structure on the path to stability. The half-life of a radioactive element is the time it takes for exactly half of its atoms to decay into a more stable form.

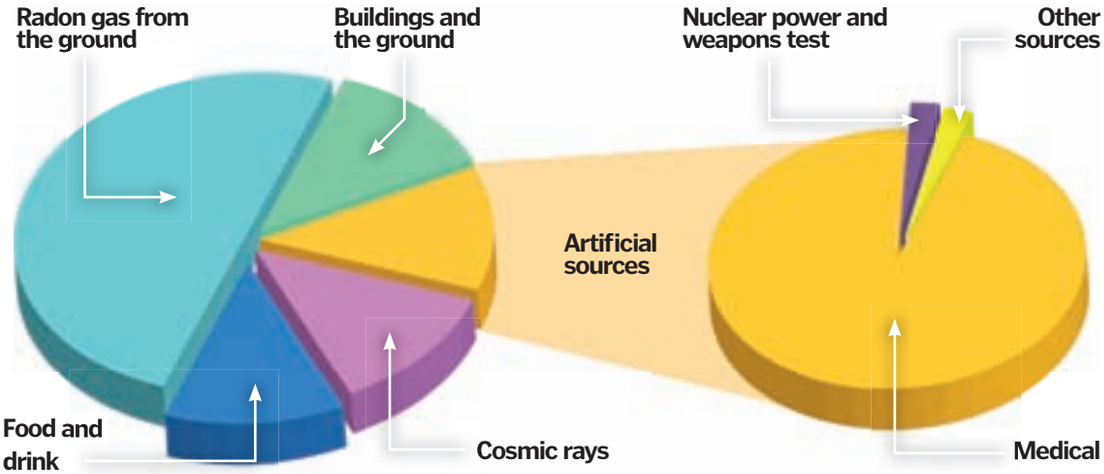
Atoms have different ways of compensating for instability, all resulting in the emission of ionising radiation. If an atom has too many protons, for example, it emits an alpha particle containing two protons and two neutrons. By lowering the total number of both particles, it slightly lowers the proportion of protons in the nucleus. Alpha particles have a mass, a positive charge, and carry energy – although very weakly. A piece of paper is enough to block an alpha particle.

Beta particles are very similar. If an atom carries too many neutrons, it can change a neutron into a proton. In the process, a spare electron is also created, which flies off as a loose beta particle. Beta particles have a negative charge and carry more energy, but can be stopped by a thin piece of aluminium.

Gamma rays aren't particles, but rather high-energy photons (waves of light). Gamma rays are emitted when the nucleus of an atom has excess energy to shed. The most common trigger is after the emission of a beta particle. If not enough energy is released with the creation of the spare electron, the nucleus emits a gamma ray – no mass, no charge, just pure energy – which travels at the speed of light and passes straight through most materials, including human tissue. The only effective barrier is lots of lead.

Background radiation

Where everyday radiation comes from




The remnants of the gym in the Palace of Culture, Prypiat, a ghost city since the Chernobyl disaster

© Tim Seuss


The Sun is a huge source of radiation that has an effect on our everyday lives

© NASA

Types of radiation

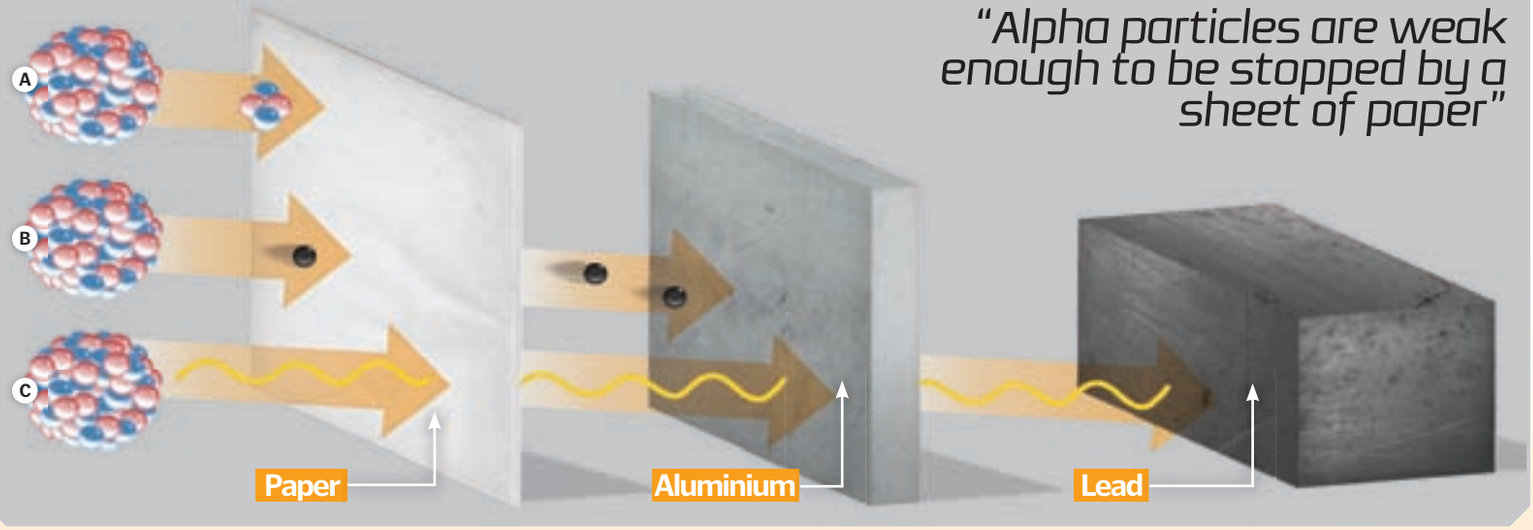
The differences between alpha, beta and gamma

A. Alpha decay
Heavy, unstable elements like uranium and radium emit alpha particles – nuggets of nuclear material containing two protons and two neutrons – to balance the ratio of neutrons to protons in their nuclei. By losing these particles, the 'decayed' atom becomes a new element with a new atomic number. Alpha particles are weak enough to be stopped by a sheet of paper.

B. Beta decay
Beta decay occurs in unstable atoms when a neutron turns into a proton, emitting an electron in the process. The loose electron is the beta particle (β-), whose energy and momentum is shared by a massless neutrino (ν). Since the atom loses a neutron and gains a proton, it decays into a different element. Beta particles can be effectively blocked by six millimetres of aluminium.

C. Gamma decay
Gamma rays are high-energy photons with no mass, no charge, but intense power. The power comes from the exponentially short wavelength of the photon, which is measured in tiny fractions of nanometers. Gamma rays are emitted in the wake of beta decay, if the transformed nucleus still has excess energy to shed. Lead is the only effective barrier to gamma rays.

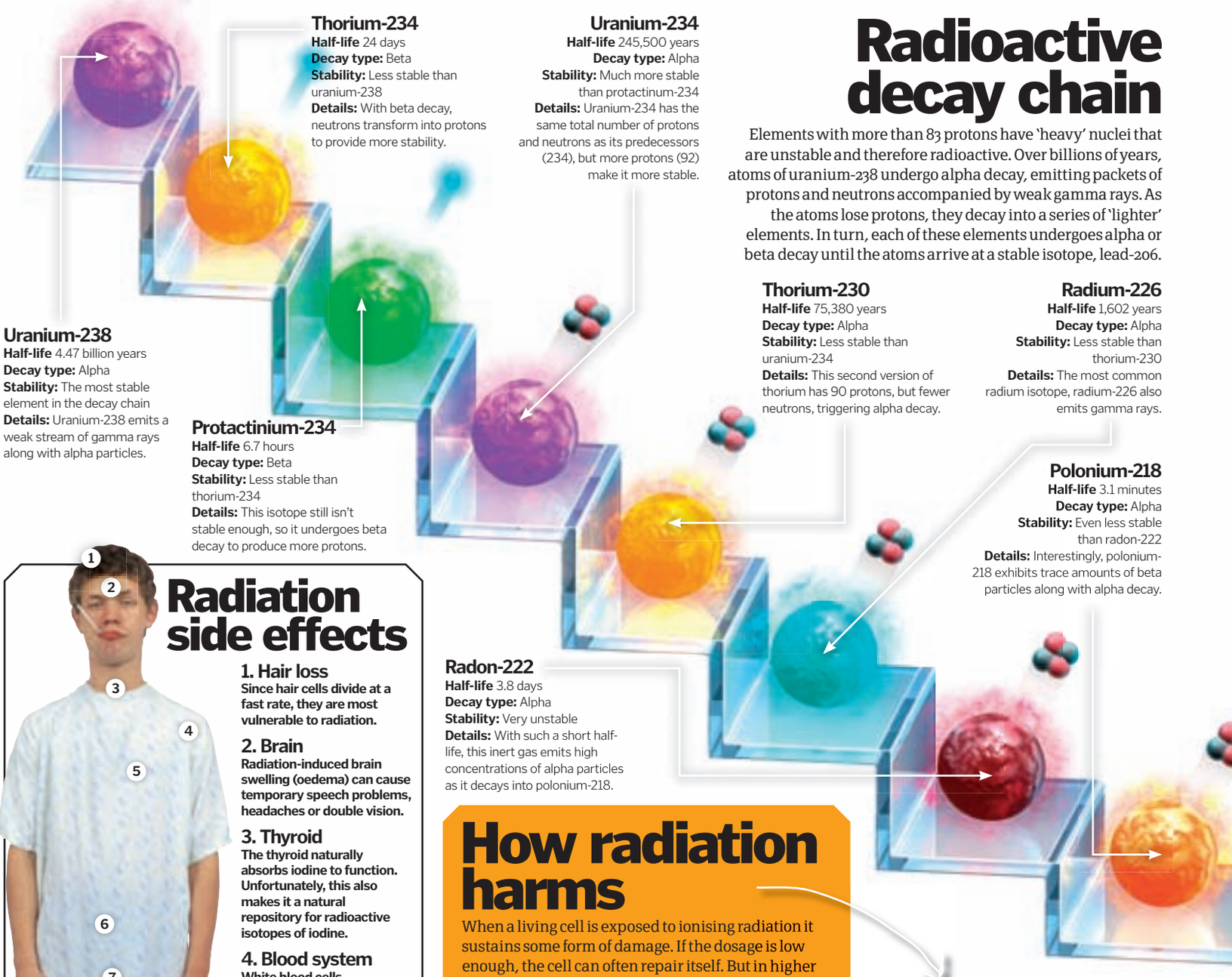
"Alpha particles are weak enough to be stopped by a sheet of paper"



"Photons are only one weapon in the fight against cancer"

Radioactive decay chain

Elements with more than 83 protons have 'heavy' nuclei that are unstable and therefore radioactive. Over billions of years, atoms of uranium-238 undergo alpha decay, emitting packets of protons and neutrons accompanied by weak gamma rays. As the atoms lose protons, they decay into a series of 'lighter' elements. In turn, each of these elements undergoes alpha or beta decay until the atoms arrive at a stable isotope, lead-206.



Uranium-238
Half-life 4.47 billion years
Decay type: Alpha
Stability: The most stable element in the decay chain
Details: Uranium-238 emits a weak stream of gamma rays along with alpha particles.

Thorium-234
Half-life 24 days
Decay type: Beta
Stability: Less stable than uranium-238
Details: With beta decay, neutrons transform into protons to provide more stability.

Protactinium-234
Half-life 6.7 hours
Decay type: Beta
Stability: Less stable than thorium-234
Details: This isotope still isn't stable enough, so it undergoes beta decay to produce more protons.

Uranium-234
Half-life 245,500 years
Decay type: Alpha
Stability: Much more stable than protactinium-234
Details: Uranium-234 has the same total number of protons and neutrons as its predecessors (234), but more protons (92) make it more stable.

Thorium-230
Half-life 75,380 years
Decay type: Alpha
Stability: Less stable than uranium-234
Details: This second version of thorium has 90 protons, but fewer neutrons, triggering alpha decay.

Radium-226
Half-life 1,602 years
Decay type: Alpha
Stability: Less stable than thorium-230
Details: The most common radium isotope, radium-226 also emits gamma rays.

Radon-222
Half-life 3.8 days
Decay type: Alpha
Stability: Very unstable
Details: With such a short half-life, this inert gas emits high concentrations of alpha particles as it decays into polonium-218.

Polonium-218
Half-life 3.1 minutes
Decay type: Alpha
Stability: Even less stable than radon-222
Details: Interestingly, polonium-218 exhibits trace amounts of beta particles along with alpha decay.

Radiation side effects

1. Hair loss
Since hair cells divide at a fast rate, they are most vulnerable to radiation.

2. Brain
Radiation-induced brain swelling (oedema) can cause temporary speech problems, headaches or double vision.

3. Thyroid
The thyroid naturally absorbs iodine to function. Unfortunately, this also makes it a natural repository for radioactive isotopes of iodine.

4. Blood system
White blood cells (lymphocytes) are constantly regenerating, making them highly sensitive to radiation.

5. Heart
Damage to valves and ventricles can lead to stiffening of heart muscles and congestive heart failure.

6. Gastrointestinal tract
The GI tract is very sensitive to radiation. Widespread cell damage can lead to internal bleeding and death.

7. Reproductive tract
Damage to reproductive cells can result in DNA mutations that are passed on to the next generation.

How radiation harms

When a living cell is exposed to ionising radiation it sustains some form of damage. If the dosage is low enough, the cell can often repair itself. But in higher doses, radiation will either kill a cell immediately or alter its DNA so significantly as to trigger mutations.

Severe exposure to radiation, like the dosages absorbed by atomic bomb survivors, leads to widespread cell death called radiation poisoning. The intestinal lining withers, causing internal bleeding, or the central nervous system collapses – death is inevitable within hours.

Lower doses of radiation have more long-term effects. A cell damaged by ionising radiation will attempt to repair itself. Mistakes can be made, resulting in an altered DNA sequence called a mutation. Sometimes the genes controlling cell division are damaged, leading to cancerous growths. If a foetus is exposed, the damaged DNA can lead to developmental mutations like small head size. If an adult is exposed, the DNA within reproductive cells can sustain mutations that are passed on to the next generation.

Potentially deadly mutations can be formed because of contact with radiation

Head to Head RADIATION DISCOVERIES

SIGNIFICANT

1. Antoine Henri Becquerel
Documented spontaneous natural radiation when he placed uranium salts near a photographic plate and saw the plate became 'fogged'.

MORE SIGNIFICANT

2. Marie and Pierre Curie
The winners of two Nobel prizes, the Curies expanded on Becquerel's discovery, isolating radioactive isotopes like polonium.

MOST SIGNIFICANT

3. Ernest Rutherford
His discovery of alpha particles in 1898 led him to postulate the existence of a nucleus, an invaluable contribution to science.

DID YOU KNOW? *Brazil nuts are the most radioactive snack, containing 1,000 times the average radium content of other foods*

How radiation heals

Radiation therapy is a form of controlled cell death. The method is to use focused beams of radiation to kill cancer cells while limiting the exposure of healthy cells nearby. Radiation therapy kills cancer cells by destroying or damaging their DNA through a process called ionisation.

When a high-energy beam of ionising radiation – usually x-rays or gamma rays – passes through an atom, it dislodges electrons, creating positively or negatively charged ions. These ions, not the beam of radiation itself, are what damage the DNA of cancer cells. Cell death is not always immediate, but any damage sustained by the DNA is usually enough to prevent the cancer cell from dividing and the tumour from growing.

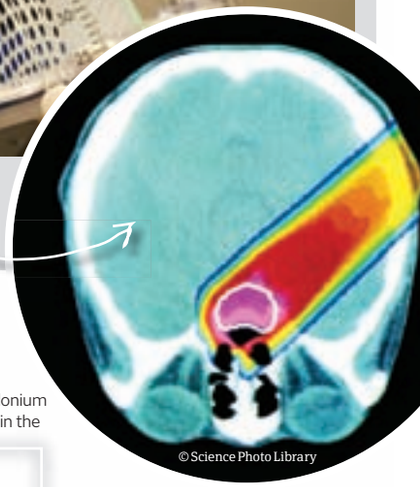
Ionising radiation is most effective at killing cells when they are in the process of actively dividing. Cancer cells divide like crazy, while normal cells spend most of their life cycle in a rest state. That's why radiation therapy is such a common treatment for tumours and other localised (non-metastasised) cancers. Radiation can be tightly focused on the tumour, targeting the fast-dividing cells, while limiting collateral damage to healthy, non-dividing cells.

Radiation oncologists, doctors trained in the use of radiation to treat cancer, have several tools in their arsenal. The most common treatment is to attack the tumour externally. Oncologists use high-energy photons produced by radioactive elements like cobalt and caesium or a machine called a linear accelerator. As the patient lies motionless, doctors use powerful computers to map and target the tumour in 3D. Then they bombard the cancerous cells with hundreds of simultaneous beams of radiation.

Photons are only one weapon in the fight against cancer. Other accelerators fire streams of protons, which limit the damage to healthy cells by saving their energy until they arrive at their destination, the tumour itself. Proton accelerators aren't as common in cancer treatment centres because of their staggering cost. Electron beams are another type of radiation used to treat superficial tumours like skin cancers.

Tomotherapy is radiation delivered in slice by slice ('tomo' being Greek for slice). This patient is being prepared for tomotherapy radiation treatment, which delivers high-dose radiation while reducing the exposure to healthy surrounding tissue. Plastic webbing holds the head in place.

During proton therapy, the cancerous brain tumour (pink) is targeted with a stream of protons (red). The precision of the proton beam makes this the best treatment for cancers near to delicate organs.



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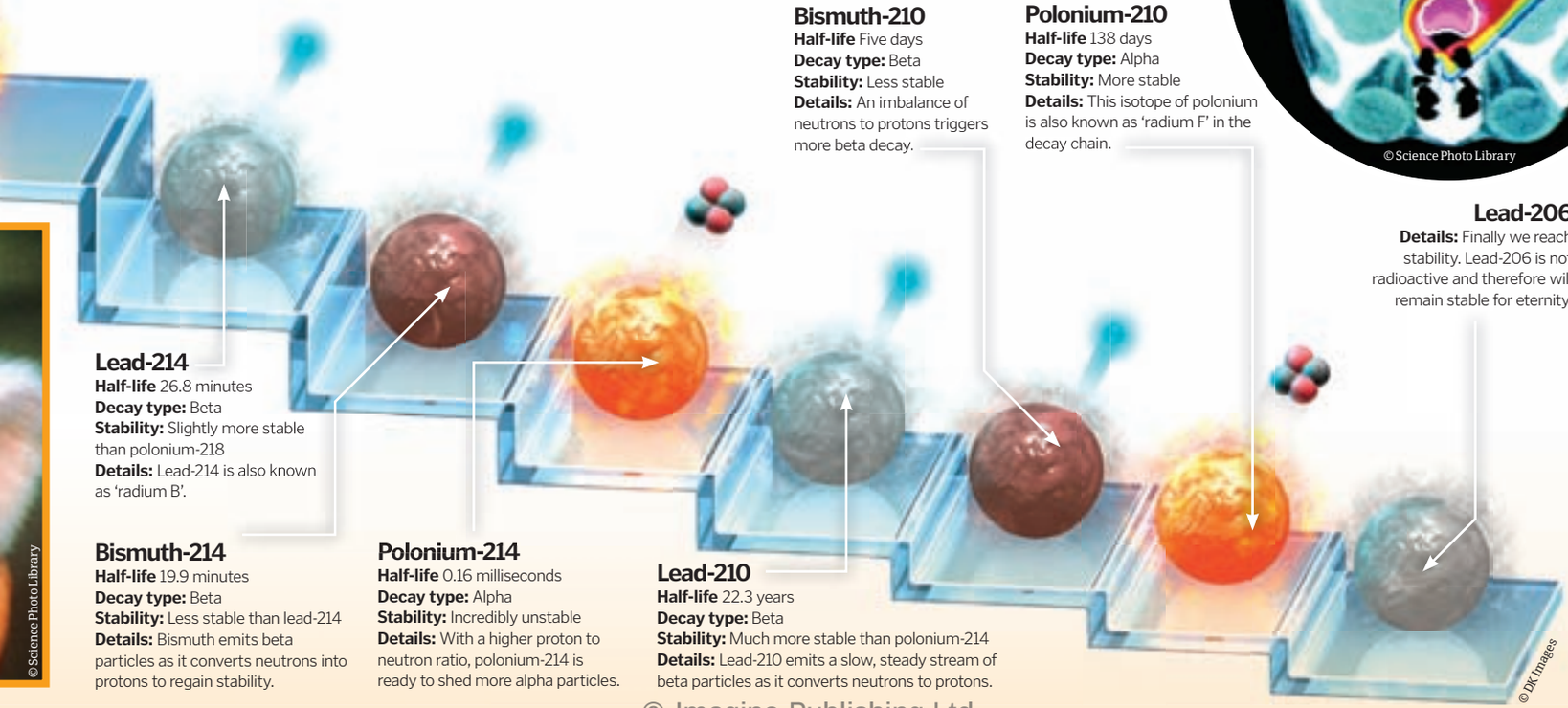

Lead-214
Half-life 26.8 minutes
Decay type: Beta
Stability: Slightly more stable than polonium-218
Details: Lead-214 is also known as 'radium B'.

Bismuth-214
Half-life 19.9 minutes
Decay type: Beta
Stability: Less stable than lead-214
Details: Bismuth emits beta particles as it converts neutrons into protons to regain stability.

Polonium-214
Half-life 0.16 milliseconds
Decay type: Alpha
Stability: Incredibly unstable
Details: With a higher proton to neutron ratio, polonium-214 is ready to shed more alpha particles.

Lead-210
Half-life 22.3 years
Decay type: Beta
Stability: Much more stable than polonium-214
Details: Lead-210 emits a slow, steady stream of beta particles as it converts neutrons to protons.

Bismuth-210
Half-life Five days
Decay type: Beta
Stability: Less stable
Details: An imbalance of neutrons to protons triggers more beta decay.

Polonium-210
Half-life 138 days
Decay type: Alpha
Stability: More stable
Details: This isotope of polonium is also known as 'radium F' in the decay chain.

Lead-206
Details: Finally we reach stability. Lead-206 is not radioactive and therefore will remain stable for eternity.

© Dk Images

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This month in **Transport**

Check out the vehicles harnessing the Sun's energy to circumnavigate the globe. Discover the hurdles they face and how they overcome them. And from solar power to no power – learn how gliders can soar like a plane and yet don't have an engine. Also see how life-saving side impact protection systems work, and how Bentley is using 3D virtualisation and simulation technology to design its new models.

TRANSPORT

XSR48 superb

Unique glass roof
The triple layer roof is made from a polymer and glass mix. It is tinted and heat reflective to keep cabin temperatures under control.

Tested to extremes
Developers tested the XSR48 at speeds in excess of 100mph – in the most extreme sea conditions.

STABility
A patented STAB stabilisation system counteracts unsettling roll and pitch by means of hydrofoils.

F1 on water
There is an F1-style fly-by-wire hand throttle, remote trim tabs using touch sensors, and helicopter-style headset communication units.

The world's first superboat is a £1.2 million pound masterpiece. As you'd expect, only super-level engineering has been used to create it…

No speedboat like the XSR48 has ever existed. It is such a revolutionary machine, a new term had to be invented: meet the world's first superboat! It is a true groundbreaker. Two world powerboat champions conceived it, and developed it with experts in naval architecture, hydronamics, aerodynamics, aesthetics, ergonomics and propulsion technology.

XSMG used expertise from leading yacht designers and marine structure experts. High power is essential; the minimum output of the XSR48's twin turbodiesel engines is in excess of 1,600bhp. Countries outside Europe can also have supercharged petrol engines that give out well in excess of 2,000bhp. A 1,000-litre fuel tank carries enough diesel for a cruising range of 250 nautical miles – and this is at the XSR's cruising speed of 50-plus knots. That's more than 60mph…

This drive is delivered through a reinforced ZF gearbox to a ZF surface drive system. The surface-piercing propellers are by Rolla and made from stainless steel. Only this sort of system can withstand the potentially crushing forces propellers could be subjected to; XSR has verified this by testing the superboat at speeds in excess of 100mph.

Given such extremes of force, shock mitigation technology had to be standardised in every seat: various configurations of race-style budget seat are on offer to secure passengers, all of which are fitted with full race harnesses.

It's not all about speed, though. Because it uses a composite monocoque, the additional strength has been used to create more space inside – and the interior is overflowing with luxury. Buyers can choose, for example, a wetroom-style bathroom itself constructed from carbon fibre.

BY SUN

1. PlanetSolar

The world's first solar-powered yacht aims to cross the globe by the power of the Sun, via 500 square metres of photovoltaic panels.

BY SURFACE AND BENEATH

2. Hyper-Sub™ Submersible Powerboat

40 knots on water, but this powerboat can also dive to 250 feet, and then hit over 3.5 knots underwater!

THREE BY THREE

3. Austal 102 Trimaran

This 1,165-passenger trimaran can hit 39 knots yet maximises fuel thanks to a patented trimaran hull form.

DID YOU KNOW? *100,000 man hours were spent developing the XSR48, to create the world's first superboat*

oat

Interior
Car designers who worked for Rolls-Royce, Bugatti and Bentley worked on the boat's interior.

Hull and deck
These are made from Kevlar and carbon fibre. This makes it very strong and rigid, and enables it to have the full-length glass roof.

Speedy
A high deadrise hull means high speeds can be achieved even in high wave seas; it stops the XSR48 launching off one wave and crashing hard onto the next.

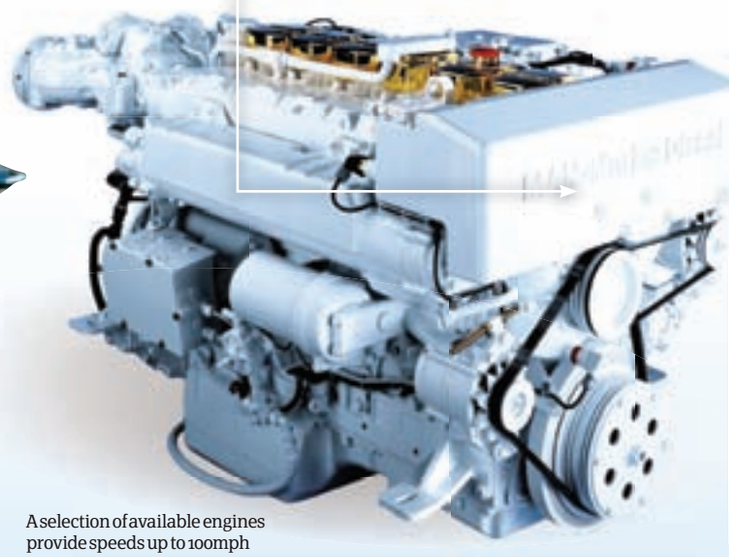
Engine
Various engines are offered. Seatek 820 Turbo engines are six cylinders, four valves per cylinder, direct injection and boast a very good reliability record.

Surface drives
The very high speeds of the XSR48 mean surface drives are the best solution for transmitting power.

The Statistics

XSR superboat

Manufacturer: XSMG World
Unit price: £1.2 million
Dimensions: Length: 14.6m, beam: 3.19m, height overall: 3.1m, height above water: 2.2m
Displacement: 8,750kg
Engine: Two 10.3 L Seatek 820 Plus Turbo – 603 kW
Fuel: Diesel, capacity 1,000 litres
Top speed: 70 knots
Horsepower: 1,640bhp (standard), 1,900bhp (max)



A selection of available engines provide speeds up to 100mph

Interview
Ian Sanderson
CEO of XSMG

Described by Jeremy Clarkson as "the most beautiful thing created by man", the idea for the XSR48 came from CEO of XSMG Ian Sanderson. He is a speedboat master, with ten UIM international endurance powerboat records, two world titles and three European titles. "I felt that there was a huge gap in the market for an F1 car-type powerboat that could be positioned as a supercar of the sea. A 'superboat', it would be the marine equivalent of a Bugatti Veyron."

His general intent was to produce a powerboat with the technology, performance and driving experience of an F1 car. To do this, he based it on a hull that, in full racing form, can run at an incredible 140mph.

"I felt that there was a huge gap in the market for an F1 car-type powerboat that could be positioned as a supercar of the sea"

Sanderson explains carbon fibre monocoque construction was used to lower the centre of gravity, provide massive strength and durability, and increase internal cubic capacity by 40 per cent compared to traditional designs. This means the cockpit and cabin are larger, fuel tanks bigger – even comfort is improved, as more equipment such as fridges and air conditioning units can be fitted.

"The hull has three transverse steps that introduce air under the boat to help her break away from the friction of the water. At each step, the V-shape of the hull is decreased from bow to stern. This means that the hull has a deep sharp V at the bow, which cuts through the waves and the back the boat runs on at high speed."

"The sails, in theory, are positioned 45 degrees to the direction of the wind"

Side impact protection systems

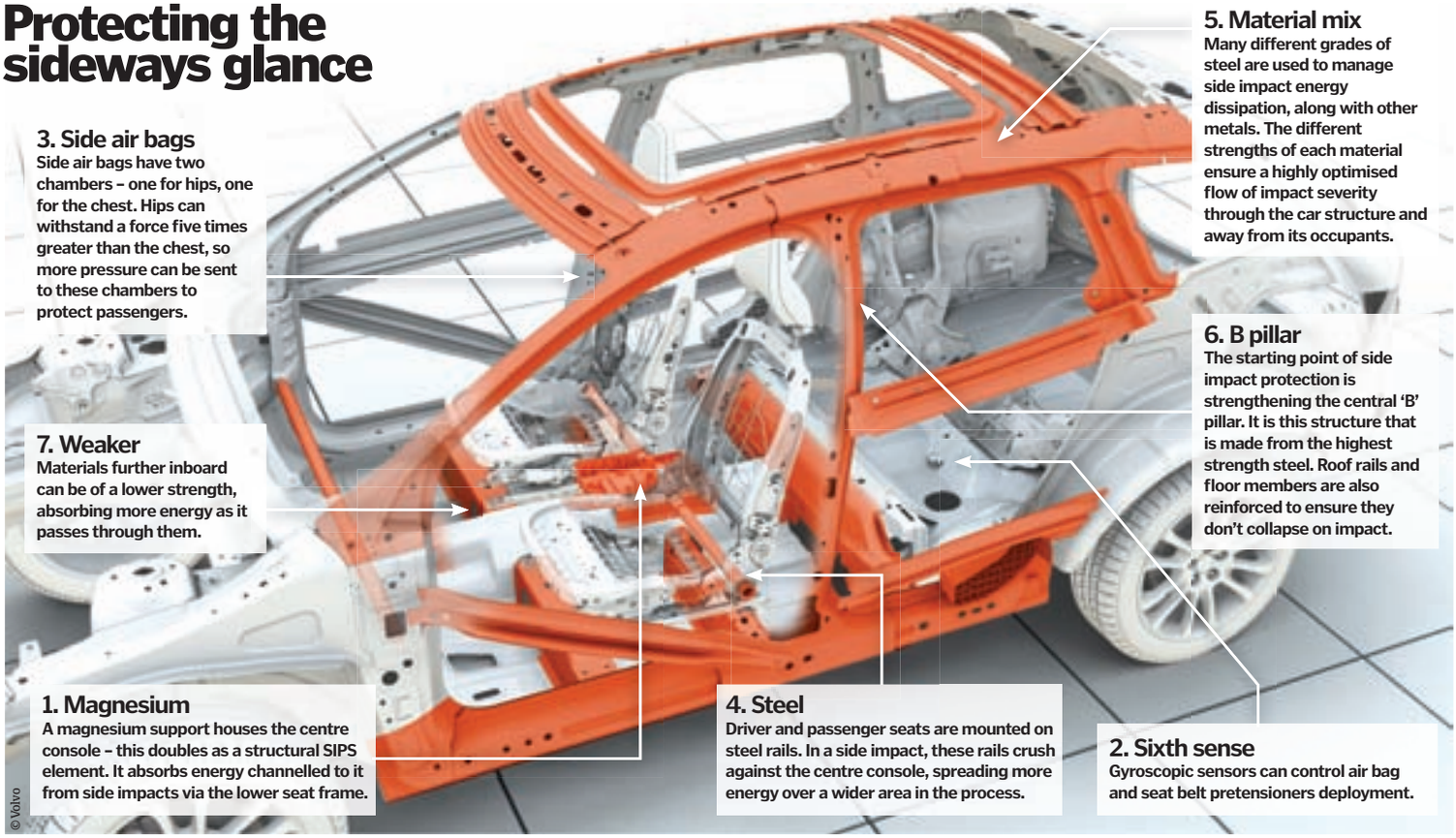
Passengers are susceptible in side impacts due to the small gap between them and the other car, so carmakers work hard to overcome physics and protect the occupants

Side impacts are a headache for designers. Crumple zones, like those that absorb energy in front impacts, are much reduced in side impacts. Here, energy must be dissipated in another way. Cars today do this through scientific calculation of load dissipation paths. The car body is then designed and engineered to maximise energy absorption before it reaches the occupants.

It is not just a matter of making the body sides as heavily reinforced as possible. Energy flow is a scientific process: simply fitting lots of 'ultra high strength' steel will risk 'stalling' this energy flow and therefore not absorbing as much. Carmakers are also under pressure to make cars as light as possible – not least because over-reinforced doors would be impossible to open!

The car manufacturer Volvo led side impact safety in the Nineties with its SIPS – side impact protection system. This has developed over the years to combine safety restraints such as air bags with well-managed crumple-zone-equivalent side impact safety. Current models can even communicate with electronic stability systems for a holistic system.

Protecting the sideways glance



3. Side air bags
Side air bags have two chambers – one for hips, one for the chest. Hips can withstand a force five times greater than the chest, so more pressure can be sent to these chambers to protect passengers.

5. Material mix
Many different grades of steel are used to manage side impact energy dissipation, along with other metals. The different strengths of each material ensure a highly optimised flow of impact severity through the car structure and away from its occupants.

6. B pillar
The starting point of side impact protection is strengthening the central 'B' pillar. It is this structure that is made from the highest strength steel. Roof rails and floor members are also reinforced to ensure they don't collapse on impact.

7. Weaker
Materials further inboard can be of a lower strength, absorbing more energy as it passes through them.

1. Magnesium
A magnesium support houses the centre console – this doubles as a structural SIPS element. It absorbs energy channelled to it from side impacts via the lower seat frame.

4. Steel
Driver and passenger seats are mounted on steel rails. In a side impact, these rails crush against the centre console, spreading more energy over a wider area in the process.

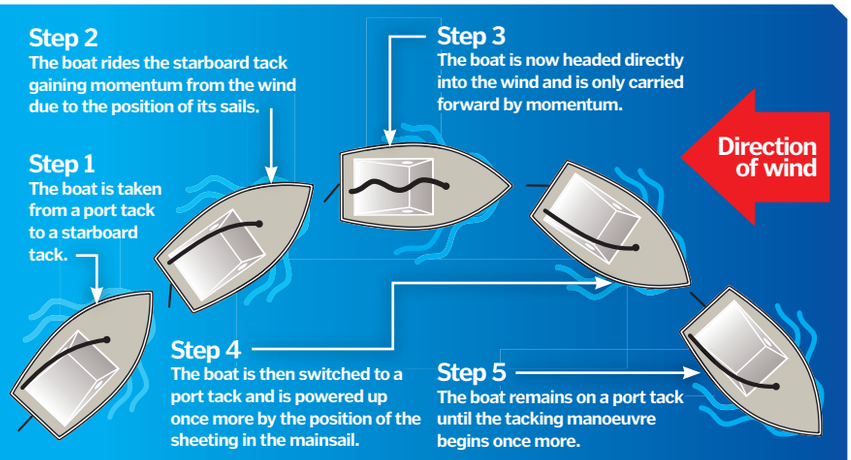
2. Sixth sense
Gyroscopic sensors can control air bag and seat belt pretensioners deployment.

© Volvo

Tacking

What is tacking and how does it allow sailing boats to travel into the wind?

Whenever a sailboat needs to progress in a direction heading into the wind, the operation required to do so is referred to as tacking. Tacking requires the boat to keep turning its bow through the wind and alternately filling the sails from one side and then the other (the sails, in theory, are positioned 45 degrees to the direction of the wind each time). In essence, to tack is to zigzag the boat and sails into the wind, which obviously requires the boat to cover more distance but the payoff is progress directly against the wind's direction.



DID YOU KNOW? *The famous monk Eilmer broke his legs after gliding 200 metres from the roof of Malmesbury Abbey*

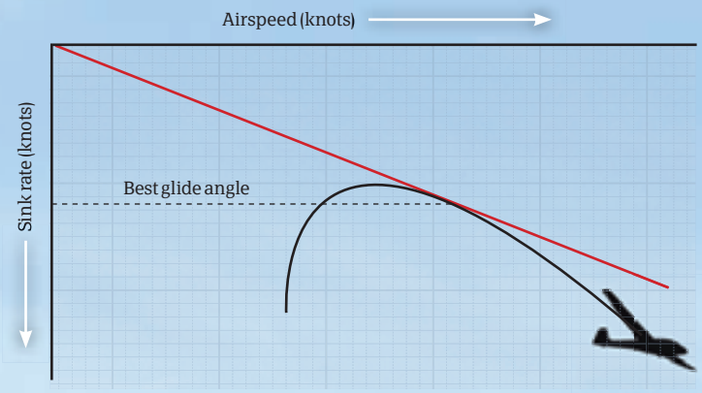
Gliders

How do these engineless aircraft stay airborne?

Gliders work by maximising the dynamic properties of air to remain airborne for long periods of time. To do this they optimise their lift-to-drag (L/D) ratio – the amount of lift generated by a wing or vehicle, divided by the drag it creates by moving through the air – by extending the surface area of their lifting surfaces, ie their wings, streamlining their physical construction and utilising the lightest possible construction materials.

The glide ratio – the distance a glider falls for the distance it travels forward – of any glider is also reliant on its airspeed and the prevalence of rising air in the aircraft's vicinity. For example, if a glider is too light then its fall rate will be low but its travel distance forward will also be low, meaning high speed and long distance glides are impossible, as it will never reach the next area of lift. However, if a glider is weighted correctly, then the polar curve of distance travelled to distance fallen is optimised, carrying the glider between areas of uplift.

A trainer and pupil in a dual-seated trainer glider



"Weighted correctly, the polar curve of distance travelled to distance fallen is optimised"

5 TOP FACTS GLIDERS

1 Recreational
Modern gliders were developed post World War Two, mainly by enthusiasts just to have fun during their time off work. Back then they were made primarily out of wood, not fibreglass.

2 Tow
Gliders were used in the Second World War to drop soldiers and equipment into war zones. The gliders would be towed half the way and then left to glide to a set drop-off point. They were considered expendable.

3 Cheat
Not all gliders are engineless, with many fitted with one to allow them to take-off on their own, removing the need for them to piggyback on another aircraft in order to get airborne.

4 Boom
The principles of gliding have been extrapolated to the armament industry, where numerous companies make gliding bombs designed to travel great distances without needing any propellant.

5 Training
Many gliders are used by instructors to educate amateur pilots in the basic principles of flight before they are given an engined aircraft. Trainer gliders contain a dual-seated cabin.

The Wright brothers' aircraft without motor in 1911 successfully gliding

Experiments with gliding

Gliding isn't a new pursuit of humans, although it only reached substantial success in the 20th and 21st Centuries. In fact, the first record of someone attempting to glide through the air occurs in a 17th Century account of a 9th Century attempt by Abbas Ibn Firnas of Cordoba, Spain. Unfortunately for Firnas – who was a respected polymath and inventor – the attempt was reliant on covering himself with vulture feathers and ended in bad back injuries. Where Firnas failed, though, the Wright brothers succeeded, and in 1911 they successfully glided in a modified, engineless variant of their famous aircraft. Since then the engineless glider has evolved into the sleek, streamlined aircraft we see today.

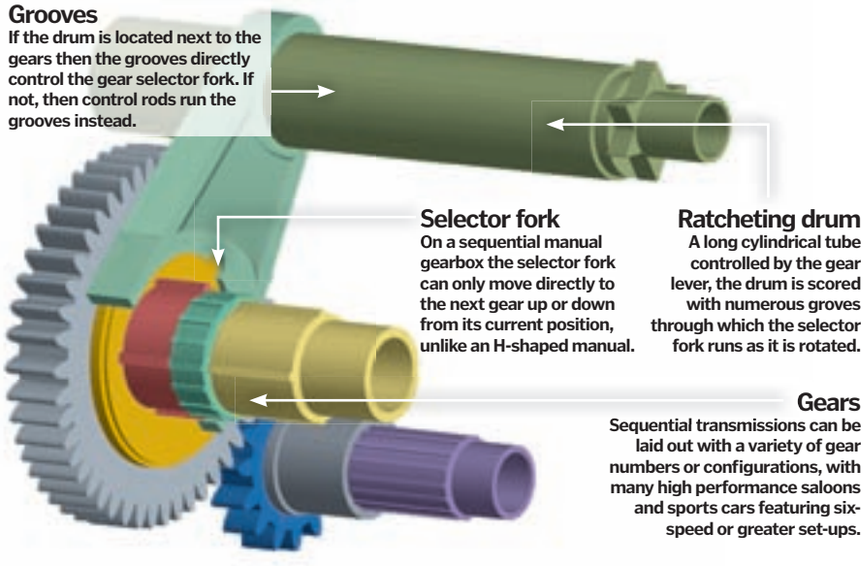
Both the Aston Martin DBR9 Gulf and Jaguar XKR GT3 use manual sequential racing gearboxes

Sequential gearbox

Favoured on racecars, the sequential gearbox allows more efficient gear changes

Sequential gearboxes work by replacing the standard H-shaped gear layout – found on most modern vehicles – with a straight ratcheting drum, a cylindrical tube scored with multiple grooves. This drum removes the need for a gear lever to move in more than one direction when selecting gears, allowing the gear lever instead to select gears simply by being pushed up or down.

This is because when the gear lever is pressed upwards or downwards it rotates the drum, causing the gear rods and selector forks to move according to its grooves, changing the present gear configuration. In essence, the drum converts the fore and aft motion of the shift lever into a rotary motion, while reducing the gear selection procedure into a linear process in order to speed up shift time and allow for a one-position user-end set-up.



Grooves
If the drum is located next to the gears then the grooves directly control the gear selector fork. If not, then control rods run the grooves instead.

Selector fork
On a sequential manual gearbox the selector fork can only move directly to the next gear up or down from its current position, unlike an H-shaped manual.

Ratcheting drum
A long cylindrical tube controlled by the gear lever, the drum is scored with numerous groves through which the selector fork runs as it is rotated.

Gears
Sequential transmissions can be laid out with a variety of gear numbers or configurations, with many high performance saloons and sports cars featuring six-speed or greater set-ups.

Sequential gearbox advantages

Speed

A sequential shift is considerably faster than a standard H-type shift as it requires the gear lever to be simply pushed up, instead of up, sideways and up again (or, of course, the reverse procedure). This becomes incredibly important when every second counts, such as in Formula 1, where a podium finish is often differentiated from the rest of the pack by merely a couple of seconds.

Consistent

With a sequential gearbox the gear lever is consistently in the same position, with its only movement coming in the brief upwards and downwards pushes the user inflicts on it. With a standard H-type gearbox configuration this is not the case, requiring the user to remember where the gear lever is in the set-up and adjust their hand positioning accordingly when changing gears.

Damage

Sequential gearboxes also help mitigate the damaging effects of missing a gear when shifting. On manual H-type configurations if a user misses a gear – for example, going from 5th to 2nd – then they can damage the gearbox and engine. On sequential gearboxes, however, users can only ever shift to the gears directly above and below the gear they are presently in.

A good example of a traditional gear stick being used on top of a sequential gearbox

"Problems with parts and design can be addressed and rectified before any physical products even exist"

Designing a Be

Thanks to 3D virtualisation and simulation tech from Dassault Systèmes, the design of Bentley's new flagship has been honed like never before

Virtualisation and simulation software works by allowing a company to create designs, build orders, and parts without any valuable time and money been spent in the real world. In the case of the Mulsanne, for example, this allowed Bentley to model all of its 10,500 parts, all 831 of its build operations and complete the entire build process in 3D virtualisation.

This is arguably an important step for the automotive industry – which previously had to physically build parts and test their assembly on a trial and error basis – and has optimised the Mulsanne's design and manufacturing significantly, reducing its production costs and build time. Now any problems with parts, build order and overall design, can be addressed and rectified before any physical products even exist. Aided by a central data hub that manages all virtual information and designs for the Mulsanne live, this means workers can plan and simulate manufacturing build processes in parallel with the cars' design evolution.

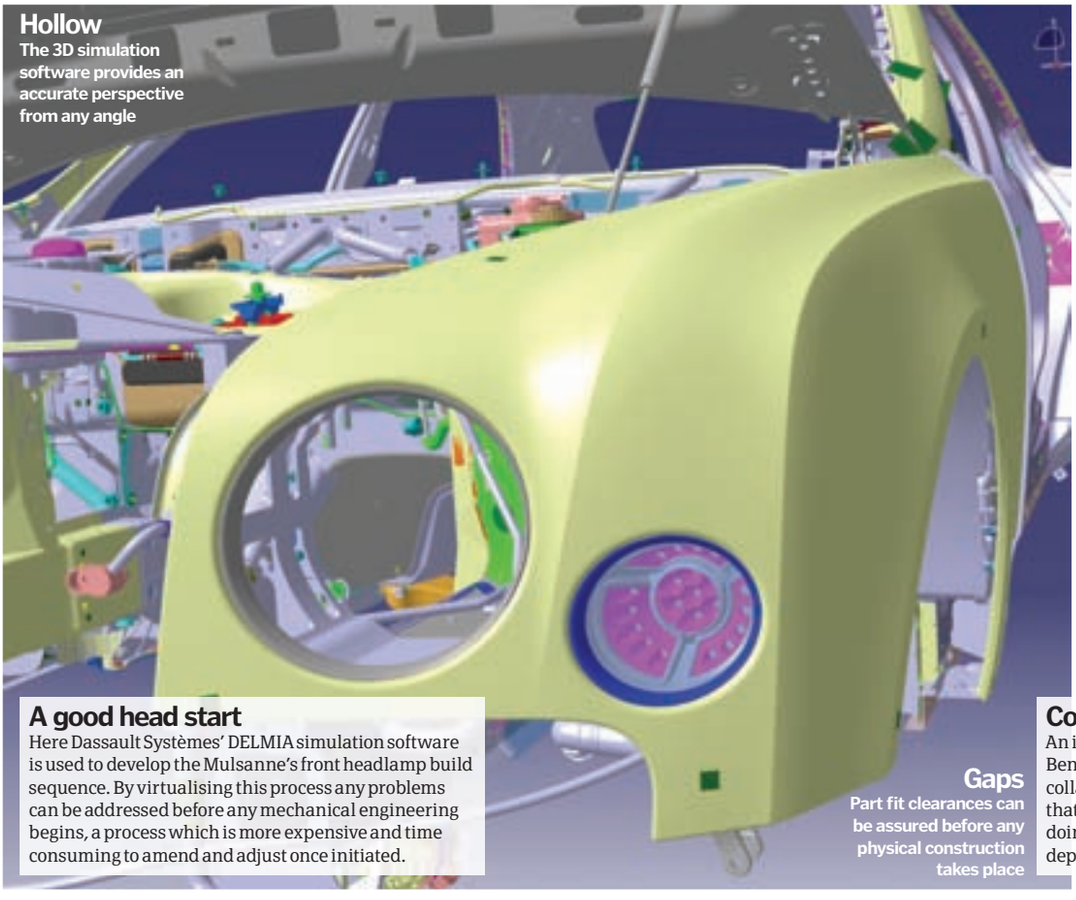
A good example of the benefits that the virtualisation process has brought to Bentley is in the design and manufacture of its doors. Here 204 individual parts had to be efficiently assembled into each aluminium skinned door assembly, so 3D simulation software was used to define an optimised assembly sequence and that was then shared concurrently with all departments who added to it and fine tuned it over time. In doing this, the final design of the door was optimised for function and production and meant that parts fitted properly and tool and hand access could be ensured 100 per cent.

Before this virtualisation, this direct line progression would not have been possible, with much time and money spent altering the designs after the physical parts had become available due to the assembly order or part designs were found to be wanting.

The Statistics

Bentley Mulsanne

Length: 5,575mm
Width: 1,926mm
Height: 1,521mm
Weight: 2,585kg
Engine: Twin-turbocharged 6750cc V8
Power: 505bhp
Torque: 1,020Nm
Gearbox: ZF 8-speed automatic
0-60mph: 5.1 seconds
Max speed: 184mph
Wheel size: 20in



Hollow
The 3D simulation software provides an accurate perspective from any angle

A good head start
Here Dassault Systèmes' DELMIA simulation software is used to develop the Mulsanne's front headlamp build sequence. By virtualising this process any problems can be addressed before any mechanical engineering begins, a process which is more expensive and time consuming to amend and adjust once initiated.

Gaps
Part fit clearances can be assured before any physical construction takes place

Detail
Every part of the door, down to individual screws and washers, is modelled

Co-operation
An important part of the virtualisation software that Bentley is using is that it allows the departments to collaborate, create and adjust designs on the go, with that information available to everyone at all times. By doing this, less time is spent sending work to and from departments and no one is working on outdated stats.

5 TOP FACTS BENTLEY

24

1 The Mulsanne is named after the famous Mulsanne corner of the Le Mans racetrack where the Le Mans 24-hour race is held. Bentley has won the competition six times.

History

2 Bentley Motors Limited was set up in 1919 by Walter Owen Bentley, who had previously produced a range of rotary aero-engines in World War One.

Rival

3 Bentley's main rival in the early 20th Century was Rolls-Royce, who bought the company in 1931 through a deal where it posed as an entity called the British Central Equitable Trust.

Hollywood

4 Various models of Bentleys have appeared in numerous Hollywood movies since the Fifties. Recently Bentleys have appeared in the films *The Dark Knight* and *2012*.

Rare

5 The traditional veneered wood common to many Bentleys is variable from vehicle to vehicle, with customers able to choose from a variety of rare woods.

DID YOU KNOW? *Bentley Motors Limited was bought by the Volkswagen Group in 1998 for £430m*

entley

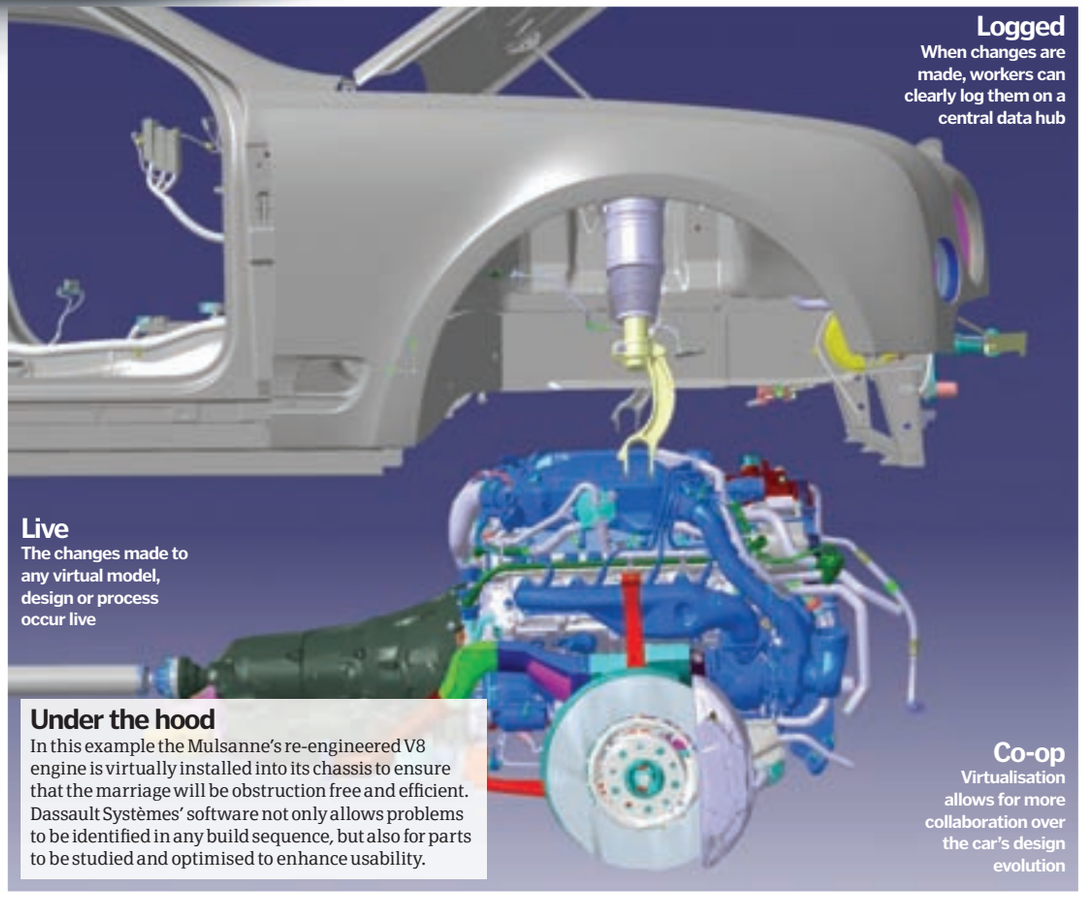
Rare wooden panelling and hand-stitched leather is standard

The Mulsanne is currently in pre-production at Bentley's headquarters in Crewe, Cheshire

The Bentley Mulsanne's powerful twin-turbocharged V8 engine

© Bentley / Dassault Systèmes

Wires
Wiring can be mapped accurately, however presently the virtualisation software presents wires as solid objects



Logged
When changes are made, workers can clearly log them on a central data hub

Live
The changes made to any virtual model, design or process occur live

Co-op
Virtualisation allows for more collaboration over the car's design evolution

Under the hood

In this example the Mulsanne's re-engineered V8 engine is virtually installed into its chassis to ensure that the marriage will be obstruction free and efficient. Dassault Systèmes' software not only allows problems to be identified in any build sequence, but also for parts to be studied and optimised to enhance usability.

"If electricity is the power of the future, sourcing and managing solar energy will become key to this"

Solar-powered vehicles

Discover the planes, boats and cars that run on Sun power

The Sun is a bounty of free energy – harnessing its power has been a challenge occupying inventors for years. Now, though, new machines are being developed that are powered by only energy from the Sun: the best are capable of some remarkable feats.

It has long been the dream to utilise this democratic energy of the Sun. It costs nothing, is available to everyone across the planet, and makes consumers independent of fossil fuels. Unlike oil or gas, the Sun will never run out. This is why there is a growing determination to crack the solar code.

Vehicles are ideal objects to be powered by the Sun. They do not stay static in one location so they can avoid shade and even angle themselves for best solar capturing. They can also utilise other energy-generation methods such as kinetic regeneration to supplement solar power.

There is an obvious downside to solar power too, though. What do you do when it gets dark? Or if it's cloudy? The problem of managing motion when the Sun is in has long been the challenge. Until now. Would you believe there is now a solar plane that can fly around the globe? Or solar cars that can travel from one end of Australia to the other?

If electricity is the power of the future, sourcing and managing solar energy will become a key part of this. Will these planes, boats and cars be shooting you round the globe in years to come?

The Statistics

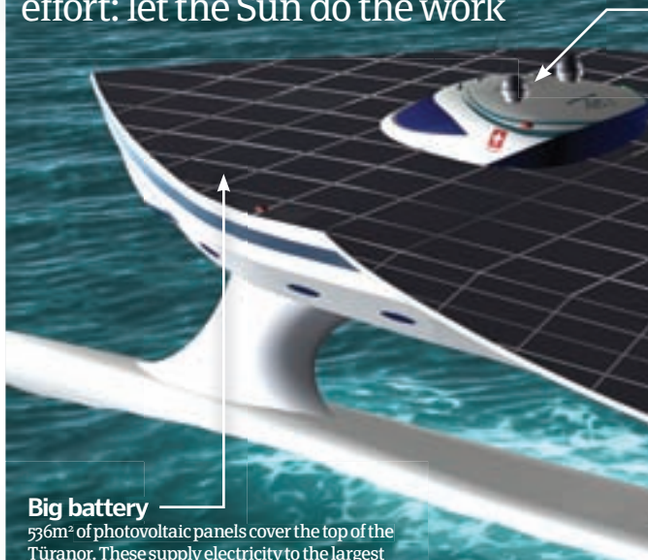
The Türanor

Length: 31m
Width: 15m
Height: 6.1m
Weight: 85t
Surface of solar panels: 536m²
Power from solar energy: 93.5kW
Solar panel efficiency: 18.8 per cent

The propeller will be steering the Türanor forward

The Türanor

Sailing boats have always relied on 'free' power: the Türanor aims to replicate this with far less effort: let the Sun do the work



Big battery
536m² of photovoltaic panels cover the top of the Türanor. These supply electricity to the largest lithium-ion battery in the world! The yacht can carry up to 40 people but four people will board to cross the world.

The sheer size of the Türanor is impressive

5X Images © PlanetSolar 2010

5 TOP FACTS SOLAR CONCEPTS

Solar ferry
1 The only ferry allowed to carry people across Hyde Park's highly protected Serpentine is the Solar Shuttle. Solar panels on the roof power a lead acid battery.

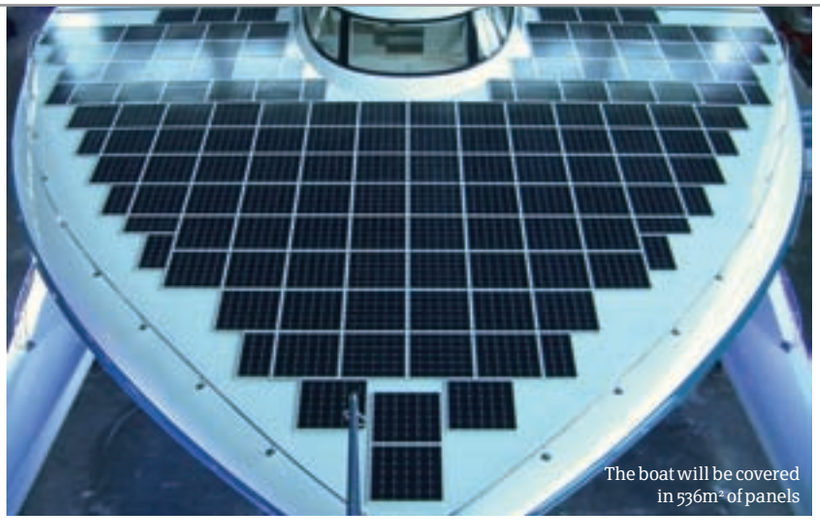
Auriga
2 Toyota cars carried by container ship across the globe are done so using solar-assisted vessels. The Auriga has enough photovoltaic cells on its deck to supply 40kW of electricity.

Stanford Solar Car Project
3 A student-run organisation that was set up in 1989 to help members learn and develop solar car theories. On two-year cycles, students design and build their own solar car.

Power of One
4 This Canadian one-seat electric car weighs 300kg, is five metres long and has a top speed of 75mph. It has set a distance record of 16,000km and is 'open source'.

Prius roof
5 Toyota fits a solar panel on the roof of the Prius Hybrid. When the car is parked, this powers the ventilation system, so the car remains cool inside on a hot day.

DID YOU KNOW? *Space vehicles combine solar power and electrical propulsion (such as ion drives) for high exhaust velocity*



The boat will be covered in 536m² of panels

Electric range beyond belief
Batteries can store enough energy to drive the Türanor for three days – and that's at a speed of 7.5 knots. Go slower and it can run for up to 15 days. Circumnavigating the Earth will see it cover 34,000 miles!

Carbon fibre for light weight
The Türanor weighs 85 tons – by boat standards, this is very light. It is because the hull is constructed from a carbon fibre sandwich. This is made up of 20.6 tons of carbon fibre, 23 tons epoxy resin and 11.5 tons of structural foam.

Low drag, high speed
The Türanor is a multihull catamaran yacht. This helps it slice through the water using as little energy as possible; it is an efficient, low hydropneumatic drag method. Catamarans can also help reach higher speeds.

The route...
Efficiently circumnavigating the globe in a boat means working with the waves. Energy can be conserved if you go with the tides rather than against them, so following the path of 'least resistance' around the world is the way to go.

To maximise publicity, the Türanor will stop over in cities such as New York and Abu Dhabi. The route therefore hugs the US coast and takes a direct route across the Atlantic to minimise distances.

How does a solar cell work?

The theory of solar electricity generation is 'literally' exciting – it's all thanks to the effect of light on certain elements and was investigated by several physicists, including Einstein

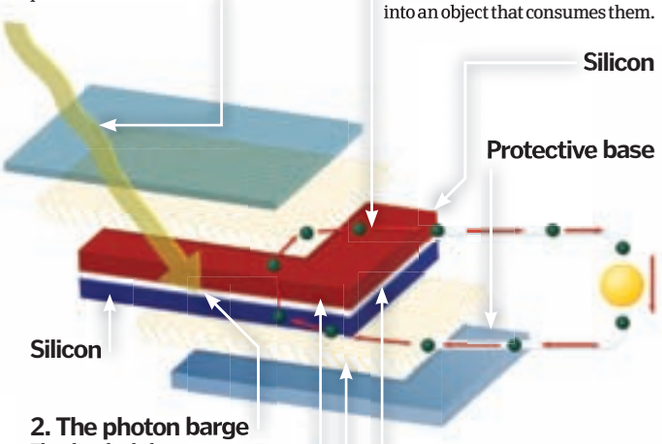
Solar cells convert sunlight into electricity through the photovoltaic effect on a semiconductor. This is where electrons are emitted from a material that has absorbed energy from electromagnetic radiation such as sunshine. These are photoelectrons. Photovoltaic cells work on the same principal, but work on any light source, not just sunlight.

Individual solar cells are connected together in a module. These are then interconnected to other modules, forming an array. This is covered by a protective material to create a solar panel. Depending on the materials used, such panels can be highly flexible.

Electricity produced is used to power most objects that run on electric – from lights to cars. Consumer solar panels are often connected to batteries. This ensures the power that is not immediately used can be stored for later use, so it is not wasted. Efficiency of today's solar panels is, however, only around 10-20 per cent. This will improve in the future.

1. Photon of the Sun
Sunlight contains photons: these hit the solar panel and are absorbed by the semiconducting materials it is constructed from – a common product here is silicone.

3. One-way road
The composition of the p-n (positive-negative) junction means electrons can only flow in one direction. The arrangement of the solar cells channels these atoms into an object that consumes them.



2. The photon barge
The absorbed photons 'knock loose' negatively charged electrons from atoms within the structure.

4. Semiconducting solar
Electron transfer occurs at the p-n junction. This is what makes the solar cell a semiconductor.

5. Influential doping
A p-n junction is created within the silicon lattice by 'doping' – that's introducing a section of impurity within the otherwise pure structure. This changes the electrical composition and is where the electronic action occurs.

6. Digging the hole
The work of the photons creates a 'hole' in the covalent bond between atoms. Atoms therefore move sideways to fill this hole. This flows through the lattice.

Solar Impulse

The Solar Impulse has been designed to fly around the globe under solar power alone – day AND night

As wide as an Airbus

The wingspan of the Solar Impulse is so broad, it equals an Airbus A340. There are 12,000 photovoltaic cells covering a 200m² area: they boast an efficiency rating of 12 per cent. The energy density of the battery is 240kWh/kg. The accumulators weigh 400kg: more than a quarter of the entire plane!

The Impulse's wingspan compared to that of an Airbus

The Statistics

Solar Impulse

Length: 21.85m
Wingspan: 63.40m
Height: 6.40m
Weight: 1,600kg
Motor power: 4x10hp electric engine
Solar cell count: 11,628
Average flying speed: 70kph
Max altitude: 8,500m

Constant watch

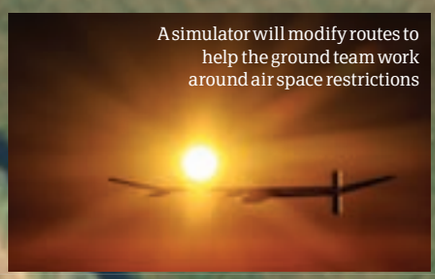
The batteries need thermal insulation to retain its heat: at 8,500 metres, it can be subjected to a temperature of –40°C. The plane is in constant air-ground communication and hundreds of parameters are observed by the management system.

Electric motor props

Propulsion comes from four pods beneath the wings, each containing a 10hp electric motor and polymer lithium-ion batteries. A gearbox limits the rotation of each 3.5m twin blade propeller to 400rpm.

Carbon fibre rich

Carbon fibre is an integral construction material. The upper wing is a skin of encapsulated solar cells, using 145-micron monocrystalline silicone. Beneath the wing there is a flexible film: these two surfaces encase 120 carbon fibre ribs, which give the aerodynamic profile.



A simulator will modify routes to help the ground team work around air space restrictions

The route...

The route is essential to ensuring the plane finds itself in clear, cloud-free skies at sunrise, to charge the batteries. The exact route will only be decided a few days before the run, based on meteorological information. A simulator will examine 5,000 key parameters – winds, temperatures, air humidity and turbulence – before selecting the route. The simulator will propose modified routes for the plane in 'real-time'.

5x photographs © Solar Impulse

DID YOU KNOW?

Solar-powered car (plant)

Seat plans to design a car plant that could one day be entirely powered by solar energy. The roof of the Martorell plant is covered in solar panels as Spain looks to become independent of fossil fuels by harnessing the Sun's energy.

DID YOU KNOW? *The hemp used to construct the Eco Elise is grown near Lotus's East Anglia factory*

Solar cars

Cars have used all sorts of energy sources, but the Sun hasn't been one of them. Until now...

Solar-powered cars don't offer the flexibility of battery-electric or hydrogen power, but they are a tantalising prospect. If structures can be made light enough, and solar panels efficient enough, solar power could provide a useful complementary source to other means. This has been driving enthusiasts for decades, but now, international competitions have reached the mainstream.

Australia's World Solar Challenge, for example, has been running since 1987 and demands competitors cover 1,877 miles between Darwin and Adelaide. Battery capacity is limited to 5kWh, and the PV area to 6m². Batteries can weigh no more than 21kg and the cars are run on public highways so must be fast enough!

NLV Quant

The electric car with the self-charging body!

Solar ability
The body is covered in pyrite solar film, which harnesses electricity to power the operating electronics and recharge the battery.

Solar efficiency
Using digital prototyping, NLV invented an iron-sulphur semiconductor. This offers an average efficiency of 38 per cent and peak efficiency of 50 per cent.

Luxury car
The four-seater Quant will soon start trials.


© Quant

In-wheel electric motors
Four 150kW in-wheel electric motors are powered by a modular battery running down the centre of the car – various chemistries can be installed.

© Quant

The Statistics

NLV Quant


© Quant

Manufacturer: Koenigsegg
Weight: 1,680 kg
Class: Electric vehicle
Body style: Gullwing
Power: 600kW (4x150kW), 800bhp
Top speed: 377kph (234mph)
Price: TBA

Lotus Eco Elise

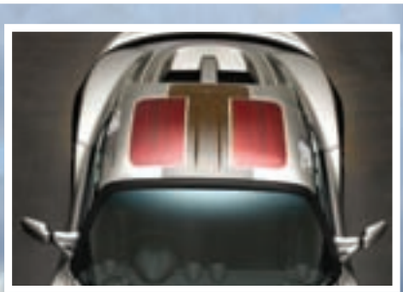
Innovative sports car maker British Lotus is thinking green with the Eco Elise

The Statistics

Lotus Eco Elise


© Lotus

Manufacturer: British Lotus
Weight: 828kg
Class: Sports car
Body style: Roadster
Power: 134bhp
Top speed: 204kph (127mph)
Price: TBA



Flexible solar panels
Two solar panels on the hemp roof power the electrical systems (heater and air con), so charge doesn't have to be drawn from the battery.

Petrol engine
It uses a conventional petrol engine but weight reductions mean it is more efficient.

The plan
In time, the whole combustion engine could be replaced by a battery-electric setup.

Get the hemp
Most of the body panels are made from renewable hemp while all paint is water-based.

© Lotus

This month in Space

Unlike this issue's opening space feature on the junk littering low Earth orbit, this section isn't a load of rubbish. You can discover the awe and beauty of the Heart and Soul nebulae, and find out how and why they create such a vibrant spectacle in the sky. Our guide to Saturn, one of the most recognisable planets in our solar system, is definitely worth a look. Did you know that if you could find a big enough bath tub, Saturn would float? We also have facts on Halley's Comet and the border between Earth and space, the Kàrmàn line.

68 Halley's Comet

68 Earth's thin blue line

70 The guide to Saturn

SPACE

© NASA

Space junk

The space age junk that pollutes our planet

Since the launch of Sputnik I, which was the first man-made satellite to orbit the Earth in 1957, a vast amount of space debris has accumulated in its wake. This consists of anything from flecks of paint to discarded rocket boosters, 'dead' satellites that no longer function and equipment lost by astronauts during space walks.

The scale of the problem can be grasped by the fact that there are estimated to be several hundred million items of space junk less than 1cm in size, several hundred thousand items between 1cm to 10cm and at least 19,000 objects larger than 10cm.

In low Earth orbit (LEO) this junk travels at an average speed of 7.5km/s, which is ten times faster than a bullet. This means that even the smallest objects can damage the subsystems of a satellite. Objects from 1cm to 10cm are part of a 'lethal population' because they are big enough to do considerable damage to a satellite, but are too small to be tracked. Larger debris is tracked and can be avoided; in the case of the International Space Station, it makes at least one manoeuvre a year to divert it from potentially lethal collisions.

Last year there were 13,000 near misses and by 2059 it is predicted that there will be as many as 50,000. The increased need to use rocket fuel to avoid these hazards shortens the life of satellites, and increases the cost of launching satellites that need to carry extra fuel.

1,400 items of space junk were created when the first ever collision between two satellites occurred on 11 February 2009.

DID YOU KNOW?

Is there junk on Mars?

Space junk is littered over Mars. In 2004, NASA deliberately crashed a heat shield protecting a Mars rover vehicle into the planet. The rover vehicle was then sent to examine the type of impact crater the shield created.

DID YOU KNOW? *Villagers near the Plesetsk spaceport are allowed to collect, use or sell the junk metal of spent rocket boosters*

A propellant tank from the Delta II launch vehicle that landed in Texas in 1997

© Science Photo Library

"Last year there were 13,000 near misses and by 2059 it is predicted that there will be as many as 50,000"

This was between the Iridium 33 US communications satellite and a defunct Kosmos 2251 Russian satellite, 790km over Northern Siberia.

Even worse, 150,000 pieces of junk were deliberately created when China destroyed an inactive Fengyun-1C weather satellite with a missile, as part of an anti-satellite test.

Radar systems are used to track LEO junk, and telescopes are employed to track objects from 2,000km to 36,000km in medium Earth orbit (MEO) and geostationary orbit (GEO) at 36,000km. Telescopes, however, are only capable of tracking objects that are 1m or more in size. Radio frequency technology can also be used to discover if satellites are operating or not.

Tracking helps warn of possible collisions, but measures that are more drastic are being employed, before it is impossible to launch manned flights, or operate the satellites that provide us with TV signals, weather forecasts, mobile phone networks and global positioning systems.

LOST IN SPACE

What's floating around in the LEO?

Glove

Lost by Ed White, the first American astronaut to take a spacewalk on 3 June 1965, during the Gemini 4 mission

Ed White's first space walk

Cameras

Lost during the Gemini 10 and a Discovery space shuttle mission in December 2006

200 rubbish bags

Produced when the upper stage of a Pegasus rocket exploded in 1996

Tool bag

Worth $100,000 containing grease guns lost by Heide Stefanyshyn-Piper during a shuttle spacewalk in 2008. It re-entered the atmosphere in August 2009

The extravehicular activity tool bag floats away from the International Space Station

128kg of nuclear reactor coolant

Leaked from inactive Soviet Radar Ocean Reconnaissance Satellites

480 million copper needles

Launched in 1963 as part of Project West Ford to create an artificial ionosphere, it encircled Earth at 3,700km. Most re-entered the atmosphere in the Seventies

Metallic spherical drinking water spheres

Started a UFO scare when they crashed in Western Australia in 1965, but were identified as coming from the Gemini spacecraft

Gene Roddenberry

His ashes were released in a small capsule by a Pegasus XL rocket in 1997

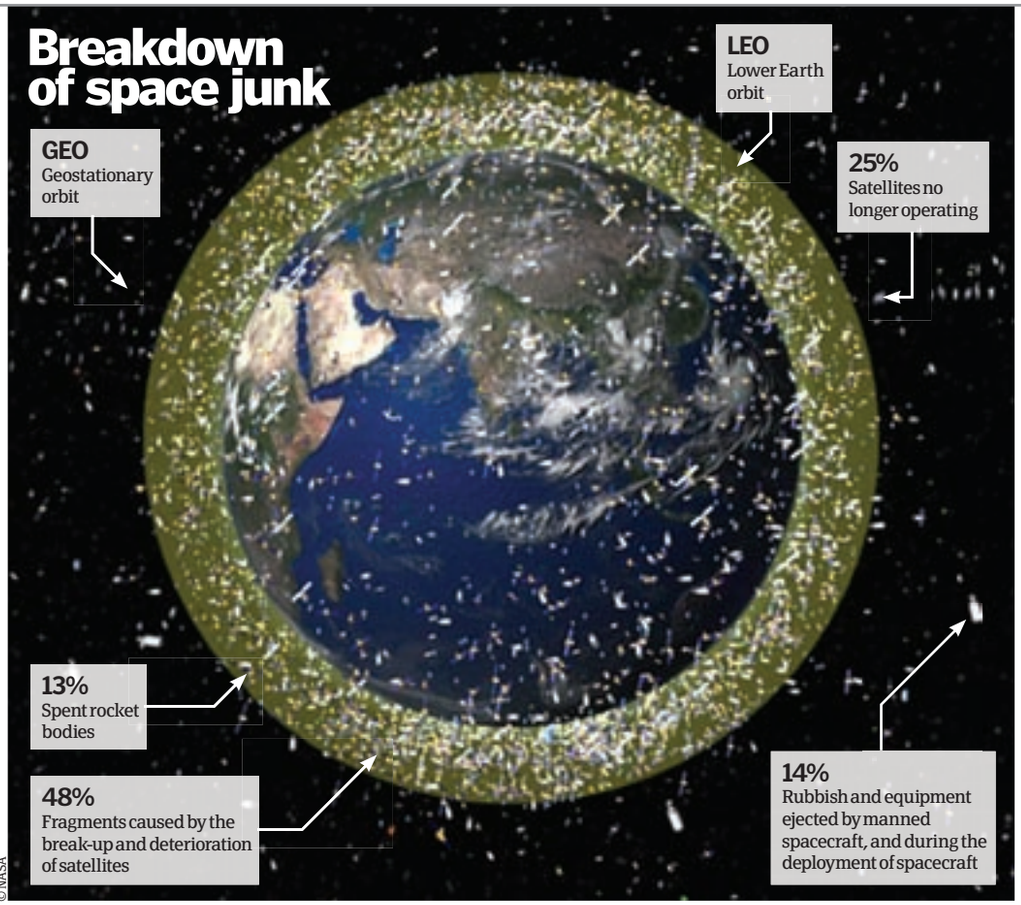
Gene Roddenberry and the cast of *Star Trek* attending the roll out of the Space Shuttle Enterprise in 1976

4x images / starybackground © NASA

300,000 fragments

Produced when the upper stage of a Pegasus rocket exploded in 1996

"In 2001, the Russian Mir space station was deliberately made to crash into the southern Pacific Ocean"



© NASA

Debris in low Earth orbit

A snapshot of the junk orbiting Earth

Objects in low Earth orbit (LEO) are between 160km and 2,000km above the Earth. Military satellites, Earth monitoring satellites and communications satellites operate at these orbital altitudes.

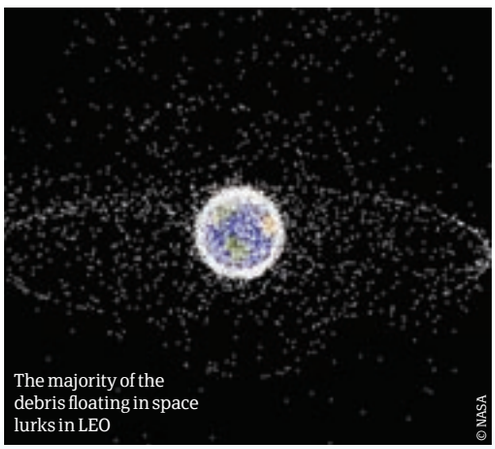
LEO satellites pose a problem because they orbit the Earth at least 15 times a day along different orbital planes to provide global coverage. This gives them more chance of hitting other satellites in contrast to those that keep to the elliptical plane of the Sun. In addition, they have shorter battery lives and are more vulnerable to the gravitational pull of the Earth than higher satellites.

The so-called Kessler Syndrome proposes that as collisions multiply they create even greater numbers of fragments that will start an unstoppable chain reaction of collisions. In this process, the debris will increase more than the amount of debris burnt-up by orbital decay, and will make the use of low Earth orbits impossible.

Most objects that go beneath LEO, through orbital decay or due to a collision, fall back to Earth and harmlessly burn-up in the atmosphere. Larger space junk is more of a problem. This was emphasised by the accidental crash of Cosmos 954 in January 1978. The Soviet reconnaissance satellite carried an onboard nuclear reactor, which instead of reaching a safe orbit fell over northwest Canada. A huge recovery operation found 12 large pieces, ten of which were radioactive and one that carried a lethal radiation level of 500r/hr.

In 2001, the Russian Mir space station was deliberately made to crash into the southern Pacific Ocean. The re-entry of the 130,000kg station created a spectacular display, and metal fragments from it were recovered and sold on eBay.

So far, such crashes have been in oceans or remote parts of the world but certainly, there is a risk of a rogue piece of space junk causing serious damage to a highly populated area.

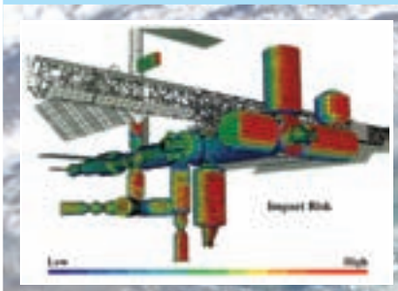

The majority of the debris floating in space lurks in LEO
© NASA

How the ISS dodges the debris

Orbiting at 350km in low Earth orbit, the ISS is particularly vulnerable to damage from space debris. Manned modules and other vulnerable areas have been fitted with protective aluminium shields – both during and since construction.

The ISS also carries out Debris Avoidance Manoeuvres (DAMs) to dodge space junk or micrometeorites. When warned of such dangers, the ISS is sent a few kilometres higher or lower, using a short engine thrust from a docked Automated Transfer Vehicle (ATV) or Progress spacecraft. The ATV is fitted with an automatic system that during docking procedure will abort the procedure if it detects any danger from debris.

If any debris comes within 0.75km above or below, or within 25km around it that cannot be avoided, the ISS is put into unmanned mode and the astronauts have to seek protection in a spacecraft docked with the station. In 2008 and 2009, astronauts had to seek refuge in a Soyuz craft, due to such warnings.


One line of defence for the manned modules is aluminium shielding

© NASA

5 TOP FACTS SPACE JUNK

First and oldest
1 Vanguard 1, launched by the USA back in 1958, is the oldest piece of space junk. It stopped operating in 1964, but will continue orbiting Earth for 240 years.

Long-term problem
2 The length of time junk stays in orbit before re-entering the atmosphere is only a few days when it's below 200km, but increases to a few years between 200 and 600km.

Working
3 The 902 operational satellites that were orbiting Earth in 2009 are dwarfed by the vast amount of junk debris and dead spacecraft that surrounds them.

Lethal
4 A 2mm piece of debris can rip a lethal hole in an astronaut's spacesuit. The chance of such an object hitting an astronaut during a six-hour spacewalk is 31,000 to one.

Hit
5 The chance of being hit by space junk on Earth is 20 billion to one. Unlucky Lottie Williams was hit but unharmed by a 13cm piece of a Delta II rocket in 1997.

DID YOU KNOW? *More than 178,000kg of hardware has been junked on the moon, including Apollo's Lunar modules*

Damages

The relative velocity of a space vehicle and a piece of junk can be 10km/s, making a collision very damaging. In the case of manned flight, it is even more threatening. The US space shuttles often encountered debris, causing NASA to regularly replace cabin crew windows and thermal tiles damaged by flecks of paint or micrometeorites.

A more threatening incident happened to the Columbia shuttle in 1995, when an object penetrated the protective layers of its payload bay door. Another collision, between a circuit board and an Atlantis shuttle payload door in September 2006, created a 12mm deep hole. To reduce such impacts Shuttles flew tail-first in orbit, or when docked to the ISS they were positioned so that the station took the worst impacts.

Whipple shields that absorb debris impacts before they can do any significant damage can protect manned and unmanned spacecraft. Unfortunately, such shields cannot protect vital solar panels or stop the impact of larger debris. To tackle large debris, spacecraft have to manoeuvre out of the way to avoid a collision.

The orbital debris hole made in the panel of NASA's Solar Max experiment

© NASA

One idea for ridding space of detritus is using satellites to destroy the litter with lasers

© Science Photo Library

Dealing with the space junk

The European Space Agency is currently building a radar system to catalogue and track hazardous objects in Earth orbit. At the moment, the US military Space Surveillance Network (SSN) tracks 19,000 objects and its Space Fence radar system scheduled for 2015 expects to track as many as 100,000 objects.

To mitigate the problem of space junk the Inter-Agency Space Debris Co-ordination Committee (IADC) was formed in 1993 to produce a set of guidelines. It advocates several preventative measures, including reducing the amount of hardware ejected or rendered inoperative by a space mission. Since accidental orbital explosions have accounted for at least 200 incidents, it is recommended that explosive gases or fuels be vented to stop this happening. The deliberate explosion of satellites should be stopped, and where possible satellites should be steered clear of debris. As LEO satellites are the biggest culprit, they should be designed to only have an orbital life of 25 years, and carry drag devices or a propulsion system to send them into re-entry if its orbit is not low enough for it to naturally re-enter. Higher satellites should be designed to enter a 'graveyard' orbit at the end of their operating life.

Several ideas have been proposed to dispose of existing junk. They range from shooting it down using lasers, scooping it up with Aerogel material or netting it with 'trawler' satellites. For the smallest debris, large panels of porous foam could slow down junk that passes through it, making it re-enter the atmosphere. For larger debris, it could be collected by the robotic arm of an unmanned spacecraft.

The Hypervelocity Ballistic Range at NASA's Ames Research Center simulates orbital debris hitting a spacecraft by launching a projectile at speeds of up to 17,000mph at a solid surface. This image shows the resulting energy flash.

Hypervelocity picture and stary background © NASA

"These clouds form visible parts of the interstellar medium called nebulae and it's here that star formation begins"

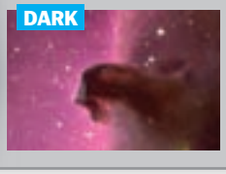
The Heart and Soul nebulae

How clouds of gas and dust create the most spectacular vistas in the universe

The space between stars, consisting mainly of hydrogen and helium gas, is the interstellar medium. Most of this space is extremely thin, but there are clouds of denser material containing heavier matter such as molecules of carbon dust and silicates (silicon and oxygen). These clouds form visible parts of the interstellar medium called nebulae and it's here that star formation begins.

This striking image from NASA's Wide-field Infrared Survey Explorer reveals a pair of emission nebulae called Heart and Soul. The 'heart' nebula on the right-hand side is so-named for its likeness to an anatomical human heart while the 'soul' nebula, on the left, is more akin to a traditional two-lobed heart shape. They're located 6,000 light years from Earth in the Perseus Arm of the Milky Way. So far, WISE has captured three quarters of its infrared survey of the entire sky, and continues to bring us incredible imagery to marvel at.

Head to Head
TYPES OF NEBULA



1. Horsehead Nebula
Dark nebulae, such as the famous Horsehead, are only really visible when they are silhouetted against a bright background.

2. Witch Head Nebula
The blue light of the Witch Head is a result of its constituent dust grains scattering the starlight reflected from the nearby star Rigel.

3. Rosebud Nebula
Intense light from nearby stars heats the interstellar medium, causing hydrogen to ionise, which frees electrons that are then absorbed and re-emitted by the cloud.

DID YOU KNOW? *The different appearances and processes within a nebula are defined by temperature variations in the gas*

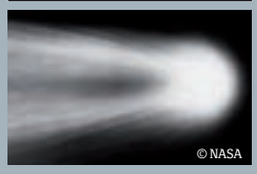
The Statistics
Heart and Soul nebulae

Location in Milky Way: Perseus Arm
Constellation: Casssiopeia
Diameter: 580 light years
Distance from Earth: 6,000 light years
Nebula type: Emission

"As it comes closer, it heats up and spews out dust and gas to form a glowing cloud – the coma"

The Statistics

Halley's Comet



Closest approach to Sun: 88 million km (55 million miles)
Furthest distance from Sun: 5.3 billion km (3.3 billion miles)
Orbital period: About 76 years
First recorded: 240 BC
Last recorded: 1986
Next appearance: 2061
Diameter: 16 x 8 x 7km
Mass: 2.2 x 10^{14} kilograms

Halley's Comet

What is this fiery ball and why does it return to the night sky?

Comets are dirty snowballs made of dust and ice left behind when our solar system formed. Halley's Comet is the best-known short period comet – a comet that has orbited around the Sun more than once in recorded history.

Comets' orbits can be tilted at a large angle relative to the orbits of the planets. Halley's Comet's orbit is so tilted it looks to orbit backwards compared to the planets. Its orbit is also very elongated so the distance between Halley's Comet and the Sun changes dramatically as it travels.

When the comet is far from the Sun, it's a frozen ball called a nucleus. As it comes closer, it heats up and spews out dust and gas to form a glowing cloud – the coma – and long tail. Each time Halley's Comet returns towards the Sun, it loses more ice until, eventually, there will be too little to form a tail.


We'll have to wait until 2061 to see this sight again, by which time we'll be celebrating our 670th issue!

DID YOU KNOW?
Over the centuries, Halley's Comet has been blamed for earthquakes, the births of two-headed animals and even the Black Death.

5 TOP FACTS COMETS

1 Dinosaur extinction
A comet hitting the Earth 200 million years ago could have cleared the way for dinosaurs to rule the world until another comet wiped them out 135 million years later.

2 Lightweight
A person weighing 45kg on Earth would weigh 0.005kg on a comet and could jump off into space. A comet's small size gives it little gravity to hold objects down.

3 Gushing gas
Comet Hale-Bopp could have lost 250 tons of dust and gas every second as it swung by the Sun in early 1997 – more than 50 times greater than most comets.

4 Time capsule
Comets could hold a deep-frozen record of the early solar system. Scientists think they formed 5 billion years ago and have remained almost perpetually frozen since.

5 Seeding life
Dust collected from comet Wild 2 in 2004 contained a chemical, glycine, used by living organisms. Scientists think some building blocks for life could have arrived from space on comets.

What is the Kármán line?

Want to turn from an aeronaut into an astronaut? Just cross the Kármán line

The Kármán line is an official boundary between the Earth's atmosphere and space, lying 100km (approximately 62 miles) above sea level. The governing body for air sports and aeronautical world records, Fédération Aéronautique Internationale (FAI), recognises it as the line where aeronautics ends and astronautics begins.

The line is named after aeronautical scientist Theodore von Kármán. He calculated that approximately 100km above sea level it was more efficient for vehicles to orbit than fly. The air thins with increasing altitude and aircraft rely on air flowing over their wings to keep them aloft so must move faster with increasing height. Above 100km they'd have to move faster than the velocity satellites orbit around the Earth.

Thin air also explains why the Earth's sky looks blue and space is black. Atmospheric gases scatter blue light more than other colours, turning the sky blue. At higher altitudes, less air exists to scatter light.

The layers in Earth's atmosphere

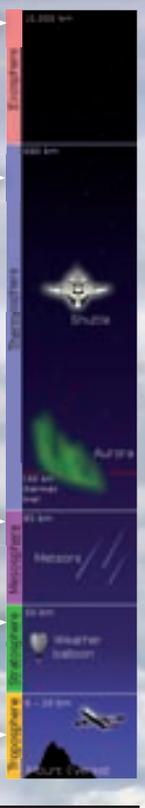
Exosphere
Many satellites orbit in the exosphere – the highest atmospheric layer. It extends to 10,000km above sea level and gets thinner and thinner until it becomes outer space.

Thermosphere
'Thermos' means hot. Air molecules in this layer can be heated to over 1,000°C by the Sun's incoming energy, but we would feel cold because there is so little air.

Mesosphere
Meteorites entering the Earth's atmosphere normally burn up in the mesosphere, the coldest layer in the atmosphere that lies 50 to 80km above sea level.

Stratosphere
The stratosphere stretches from around 12km to 50km above sea level. This layer contains the ozone layer, which shields us from the Sun's potentially harmful ultraviolet radiation.

Troposphere
The atmosphere's lowest layer contains 75 per cent of its mass and almost all its weather. It varies from around 8km high at the poles to 20km over the equator.



DID YOU KNOW?
The first man-made object to cross the Kármán line was a German V-2 rocket during a 1944 test flight.

THE STATS THE OORT CLOUD

MIN. ORBIT **200 yrs** TEMP **-270° Celsius** MASS **5 x Earth**

CONTAINS **Up to 2 trillion comets** MAX. ORBIT **+1 million yrs**

DID YOU KNOW? *The outer extent of the Oort Cloud is viewed as the edge of our solar system*

The Oort Cloud

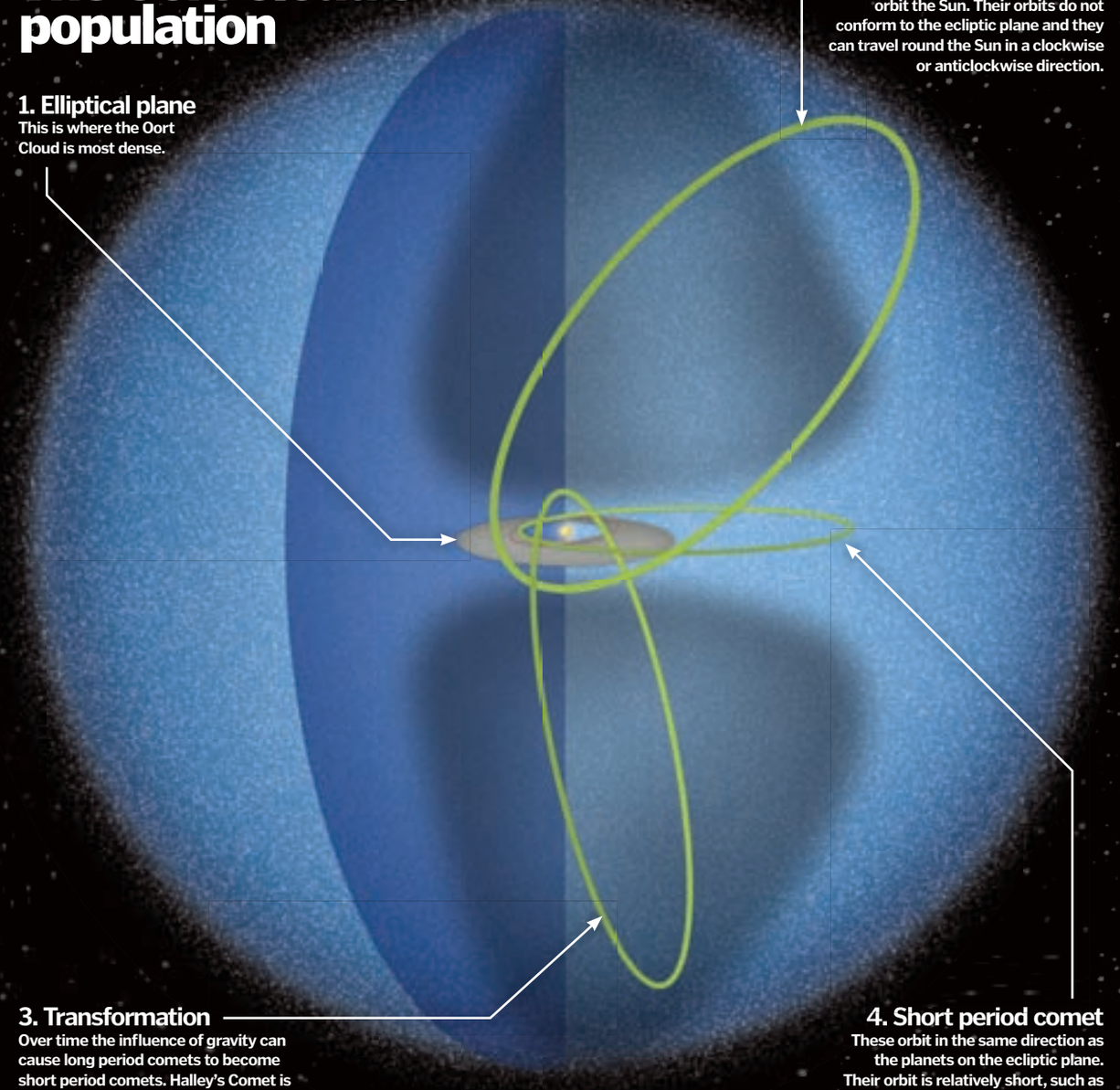
The home of comets

The Oort Cloud is a giant sphere of icy cometary nuclei that surrounds our solar system. Its maximum distance is 1.9 light years away from the Sun, which is as far as the Sun's gravitational influence extends.

In 1950, Dutch astronomer Jan Oort developed the concept of this cloud as the origin of comets. It was created during the formation of the solar system, when planetesimal bodies gathered to form planets or moons. The gravitational influence of Uranus and Neptune sent some of these planetesimals outwards to form the Oort Cloud.

Over time the gravitational effects of the Sun, planets in the solar system and even nearby stars have caused objects to actually leave the Oort Cloud. They then either turn up in the form of comets in the inner solar system, or they are sent completely out of our system's influence altogether. Just as objects are lost from the cloud, new ones from outside the solar system can also be attracted into it.

The Oort Cloud's population

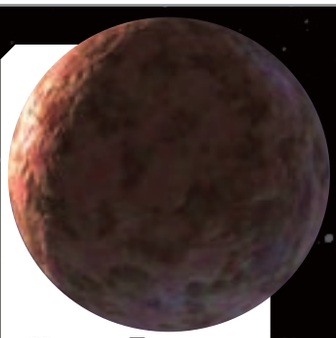


1. Elliptical plane
This is where the Oort Cloud is most dense.

2. Long period comets
These can take thousands of years to orbit the Sun. Their orbits do not conform to the ecliptic plane and they can travel round the Sun in a clockwise or anticlockwise direction.

3. Transformation
Over time the influence of gravity can cause long period comets to become short period comets. Halley's Comet is thought to have originated from the Oort Cloud as a long period comet.

4. Short period comet
These orbit in the same direction as the planets on the ecliptic plane. Their orbit is relatively short, such as Halley's Comet, which takes 76 years to orbit the Sun.

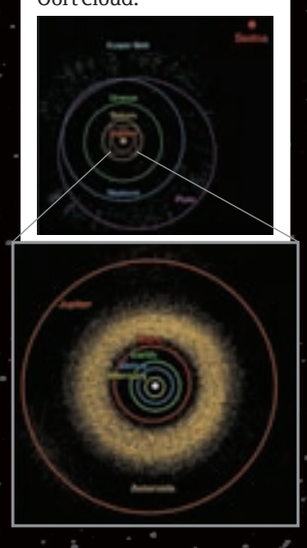


Sedna

Evidence of the Oort Cloud's existence is supported by the discovery on 14 November 2003 of the furthest object in the solar system. Named Sedna, it is currently 13 billion kilometres away from Earth. Its highly elliptical orbit around the Sun takes 11,250 years and to a maximum distance of 130 billion kilometres.

Sedna has a diameter of between 1,180 to 1,800 kilometres, making it larger than an asteroid but smaller than a planet. It is the second reddest object in the solar system after Mars, and its surface temperature is a very cold -240° Celsius.

A sticking point is that it is much closer than the predicted position of the Oort Cloud. One suggestion is that millions of years ago a rogue star passed by, causing comets and bodies like Sedna to form an inner Oort Cloud.



"Each ring contains billions of chunks of dust and water-ice"

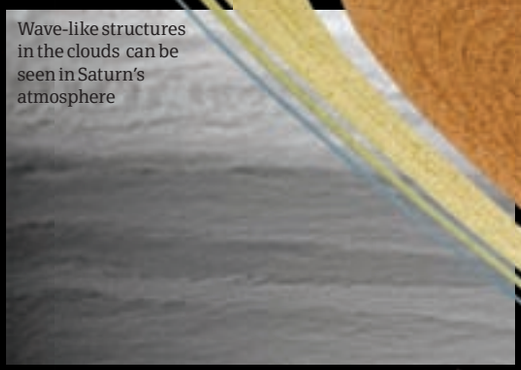
Saturn

Only Jupiter is larger than this gas giant, best known for its ring system

We've been viewing Saturn with the naked eye since prehistoric times, but the planet's most unique feature – its ring system – wasn't discovered until 1610. Each ring contains billions of chunks of dust and water-ice. Saturn has about 14 major ring divisions, but there are also satellites and other structures within some of the rings and gaps. Saturn's rings are believed to have come from the remains of moons, comets or other bodies that broke up in the planet's atmosphere.

The rings aren't the only fascinating thing about Saturn, however. This gas giant is less dense than any other planet in our solar system and has a mostly fluid structure. It radiates a massive amount of energy, thought to be the result of slow gravitational compression. Saturn takes about 29½ years to revolve around the Sun, and its rotation is a bit more complex – different probes have estimated different times, the latest estimate is ten hours, 32 minutes and 35 seconds. The variations probably have something to do with irregularities in the planet's radio waves, due to the similarities between its magnetic axis and its rotational axis.

Saturn has a cold atmosphere comprising layered clouds of both water-ice and ammonia-ice. It also has winds of up to 1,800 kilometres per second. Occasionally Saturn has storms on its surface, similar to those of Jupiter. One such storm is the Great White Spot, a massive storm in the planet's northern hemisphere that has been observed about once every Saturnian year since 1876.



Wave-like structures in the clouds can be seen in Saturn's atmosphere

Inside Saturn

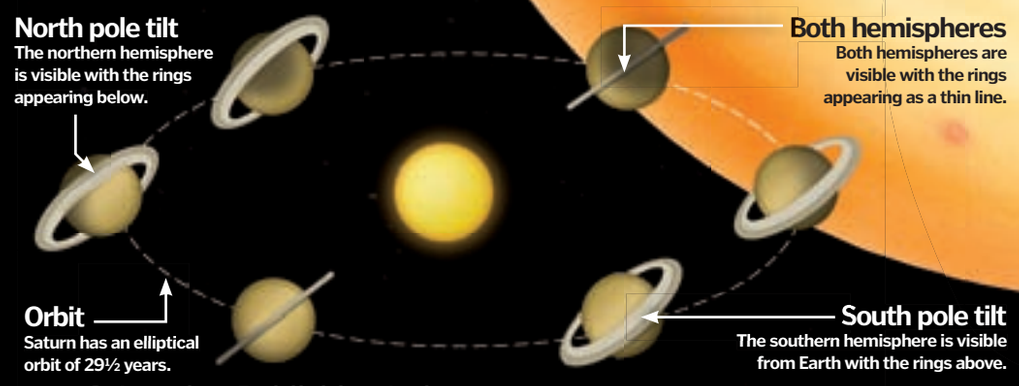
Saturn is believed to have a small rocky core, with a temperature of more than 11,000°C. It is surrounded by a layer of gases and water, followed by a metallic liquid hydrogen and a viscous layer of liquid helium and hydrogen. Near the surface, the hydrogen and helium become gaseous. Saturn has no solid surface.

Inner layer
This thickest layer surrounding the core is liquid hydrogen and helium.

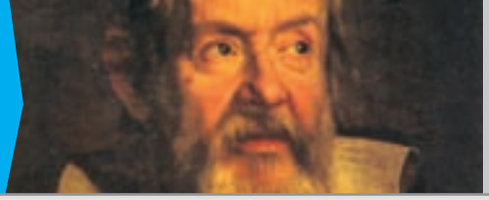
Outer layer
The outer layer is gaseous hydrogen and helium, blending with its atmosphere.

Rings in view

Saturn takes 29½ years to orbit the Sun, and it has an elliptical orbit like most planets. The closest Saturn comes to the Sun is 1.35 billion kilometres, while at its furthest, Saturn is 1.5 billion kilometres away. Saturn has a tilt of 26.7 degrees relative to the orbital plane. During half of its orbital period, the northern hemisphere is facing the Sun, while the southern hemisphere faces the Sun during the other half. When viewing Saturn from Earth, this impacts whether we can see the rings full-on or as a thin line.



DID YOU KNOW?



Discovering the rings

Galileo thought that he was seeing moons orbiting Saturn instead of rings because his telescope was not powerful enough. Astronomer Christiaan Huygens observed the rings in 1655, but thought they were a single ring.

DID YOU KNOW? *Images from the Cassini probe show that Saturn has a bright blue northern atmosphere*

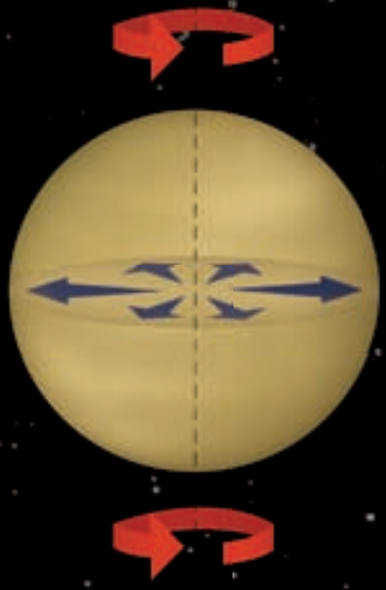
The Statistics

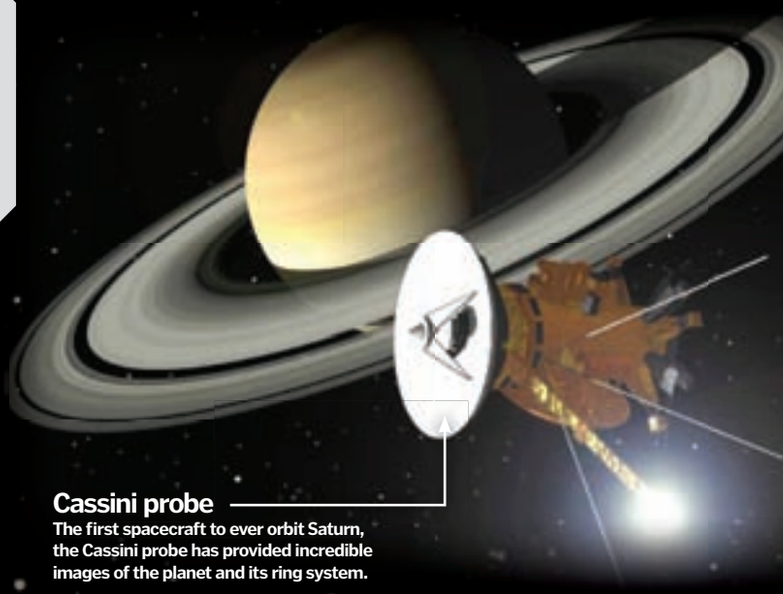
Saturn

Diameter: 120,535 km
Mass: 5.6851 x 10^{26} kg
Density: 0.687 grams per cm^3
Average surface temperature: -139°C
Core temperature: 11,000°C
Moons: 62
Average distance from the Sun: 1,426,725,400km
Surface gravity: 10.44 metres per second squared

Extreme bulge

Saturn is an extreme example of an oblate spheroid – the difference between the radius of the planet at its poles and at its circumference is about ten per cent. This is due to its very short rotational period of just over ten hours.





Cassini probe
The first spacecraft to ever orbit Saturn, the Cassini probe has provided incredible images of the planet and its ring system.

Inner core
The inner core is likely very small and contains silicate rock, much like Jupiter's core.

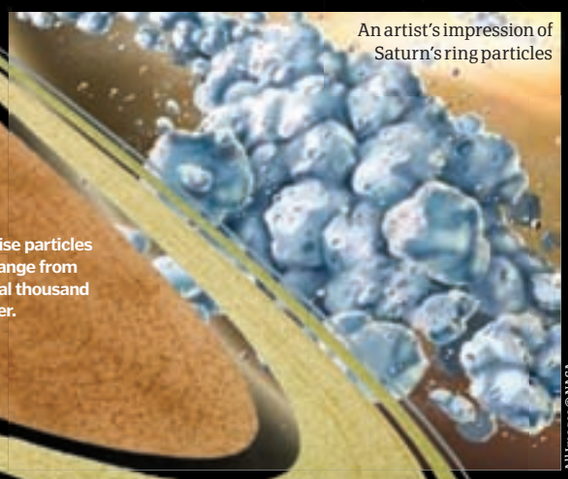
Float that planet

If we had a big enough pond, we could float Saturn on its surface. Although Saturn is the second-largest planet as well as the second-most massive, it's the least-dense planet in our solar system. Its density is just 0.687 grams per cubic centimetre, about one-tenth as dense as our planet and two-thirds as dense as water.

Outer core
Saturn's outer core is much thicker than its inner core, containing metallic liquid hydrogen.

Saturn's southern storm

In 2004, the Cassini space probe discovered a massive, oddly shaped convective thunderstorm in Saturn's southern atmosphere. Dubbed the Dragon Storm, this weather feature emitted strong radio waves. Like storms on Earth, the Dragon Storm emits flashes of lightning that appear as white plumes. Scientists believe it exists deep in the atmosphere and can occasionally flare up.



An artist's impression of Saturn's ring particles

Rings
Saturn's rings comprise particles of ice and dust that range from microscopic to several thousand kilometres in diameter.

This month in **History**

Floppy disks, remember them? We take a look inside those prehistoric data storage devices and find out how they served us so well since their invention in the Seventies. Step even further back in time – several thousand years, in fact – to discover the incredible engineering behind Greek temples. These structures are so impressive some have stood the test of time and are still around today. We also take a look at the Tesla coil, an invention that took wireless to the next level well ahead of its time.

76 Tesla coil

77 Floppy disks

77 Anderson shelters

HISTORY

Intake system
The intake ramps and spill door were so effective they could almost completely offset an engine failure and keep the aircraft aerodynamic.

Wing fuel tanks
Concorde, like many aircraft, stored its fuel in its wings. However, it also used its fuel as a heat sink, drawing heat away from the passengers.

Inside Concorde
What's under the wings?

Rolls-Royce/Snecma Olympus 593 engines
Concorde's afterburning engines were a development of engines originally designed for the Avro Vulcan bomber.

Ogival wings
Concorde's 'double delta' wings helped its aerodynamic profile and speed.

Lighter, stronger components
Concorde was constructed using 'sculpture milling', a process that reduced the amount of parts required while making those that were necessary lighter and stronger.

© John Batchelor / www.johnbatchelor.com

Concorde

An aircraft that could fly across the Atlantic in less than three hours seemed as impossible as it was desirable

Flying faster than the speed of sound has always been the sole proviso of the military, but in the late-Sixties, Russia, France, the UK and the US were all working on the idea of supersonic commercial travel. Faster planes meant shorter travel times, increased demand and higher prices.

Concorde was the result of France and the UK combining their efforts to produce a supersonic airliner and, even now, it's impossible not to be impressed by its pioneering stature.

Its ogival or double-curved wings kept it aerodynamic and dictated much of the plane's shape, as they forced the nose up on taxiing, take off and landing. To help minimise drag on the aircraft as well as improve visibility, the nose cone could move, dropping down to improve visibility then straightening out in flight to improve the aerodynamic profile.

Concorde's engines also had to be modified for extended supersonic flight. Jet engines can only take in air at subsonic speed so the air passing into the engines had to be slowed when flying at Mach 2.0. Worse, the act of slowing the air down generated potentially damaging shock waves. This was controlled by a pair of intake ramps and an auxiliary spill door that could be moved during flight, slowing the air and allowing the engine to operate

Head to Head SUPERSONIC PLANES

1. Bell X-1
As well as being the first aircraft to break the speed of sound, the X-1 was the first in a long line of experimental, pioneering aircraft.

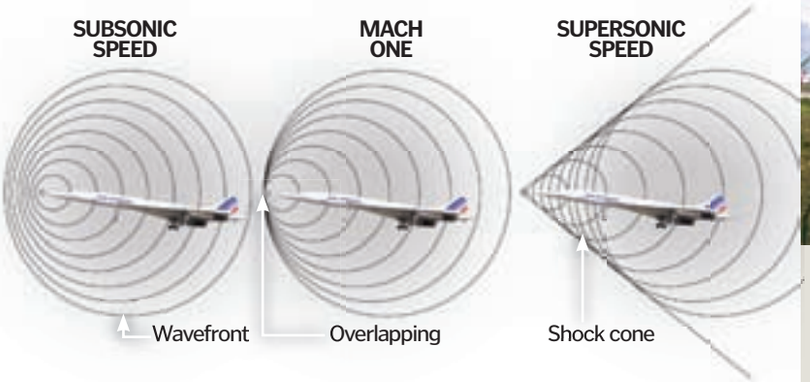
2. SR-71 Blackbird
A futuristic, high-altitude reconnaissance aircraft, the SR-71 was capable of up to Mach 3.35, or 2,275 miles per hour.

3. Tupolev-144 (NATO code name – Charger)
The TU-144 flew two months before Concorde in December 1968 but was ultimately scrapped due to lack of demand.

DID YOU KNOW? *The first Concorde test flight took place from Toulouse on 2 March 1969*

The sonic boom

Sonic booms are generated by the passage of an object through the air. This passage creates pressure waves that travel at the speed of sound. The closer the aircraft gets to the speed of sound, the closer these waves become until they merge. The aircraft then forms the tip of a 'Mach cone', the pressure wave at its nose combining with the fall in pressure at its tail as it passes to create the distinctive 'boom' sound.




This Concorde is on display at Paris-Charles de Gaulle airport

End of an era

On 25 July 2000, Air France Flight 4590 crashed in Gonesse, France, killing all 100 passengers and nine crew as well as a further four on the ground. Although the crash was caused by a fragment from the previous aircraft to take off, passenger numbers never recovered and were damaged still further by the rising cost of maintaining the ageing aircraft and the slump in air travel following the 9/11 attacks.

As a result, on 10 April 2003, Air France and British Airways announced their Concorde fleets would be retired later that year.

Despite an attempt by Richard Branson to purchase BA's Concorde fleet for Virgin Atlantic, the planes were retired following a week-long farewell tour that culminated in three Concordes landing at Heathrow. BA still owns its Concorde fleet: one is on display in Surrey, a second is being kept near-airworthy by volunteers at the Le Bourget Air and Space Museum, and a third, also at that site, is being worked on by a joint team of English and French engineers. The plan is to make it air worthy and have the aircraft form part of the 2012 Olympics opening ceremony.

Passenger cabin
Concorde could carry 92 passengers or be reconfigured internally to carry up to 120.

The interior of a British Airways Concorde

Undercarriage
The undercarriage was unusually strong due to the high angle the plane would rise to at rotation, just prior to take off, which put a tremendous amount of stress on the rear wheels in particular.

Cockpit
Concorde's were the last aircraft BA flew that required a flight engineer, seated in the cockpit with the pilot and copilot.


Mike Bannister (top left) piloted the first Concorde flight following the Gonesse disaster

Thrust-by-wire
Concorde was one of the first aircraft to use an onboard computer to help manage its thrust levels.

Nose
Concorde's nose drooped to help visibility on take off and landing and straightened in flight.

efficiently. This system was so successful that 63 per cent of Concorde's thrust was generated by these intakes during supersonic flight.

And yet Concorde still had to contend with the heat generated by supersonic flight. The nose – traditionally the hottest part of any supersonic aircraft – was fitted with a visor to prevent the heat reaching the cockpit while the plane's fuel was used as a heat sink, drawing heat away from the cabin.

Even then, owing to the incredible heat generated by compression of air as Concorde travelled supersonically, the fuselage would extend up to 300 millimetres, or almost one foot. The most famous manifestation of this was a gap that would open up on the flight deck between the flight engineer's console and the bulkhead. Traditionally, engineers would place their hats in this gap, trapping them there after it closed.

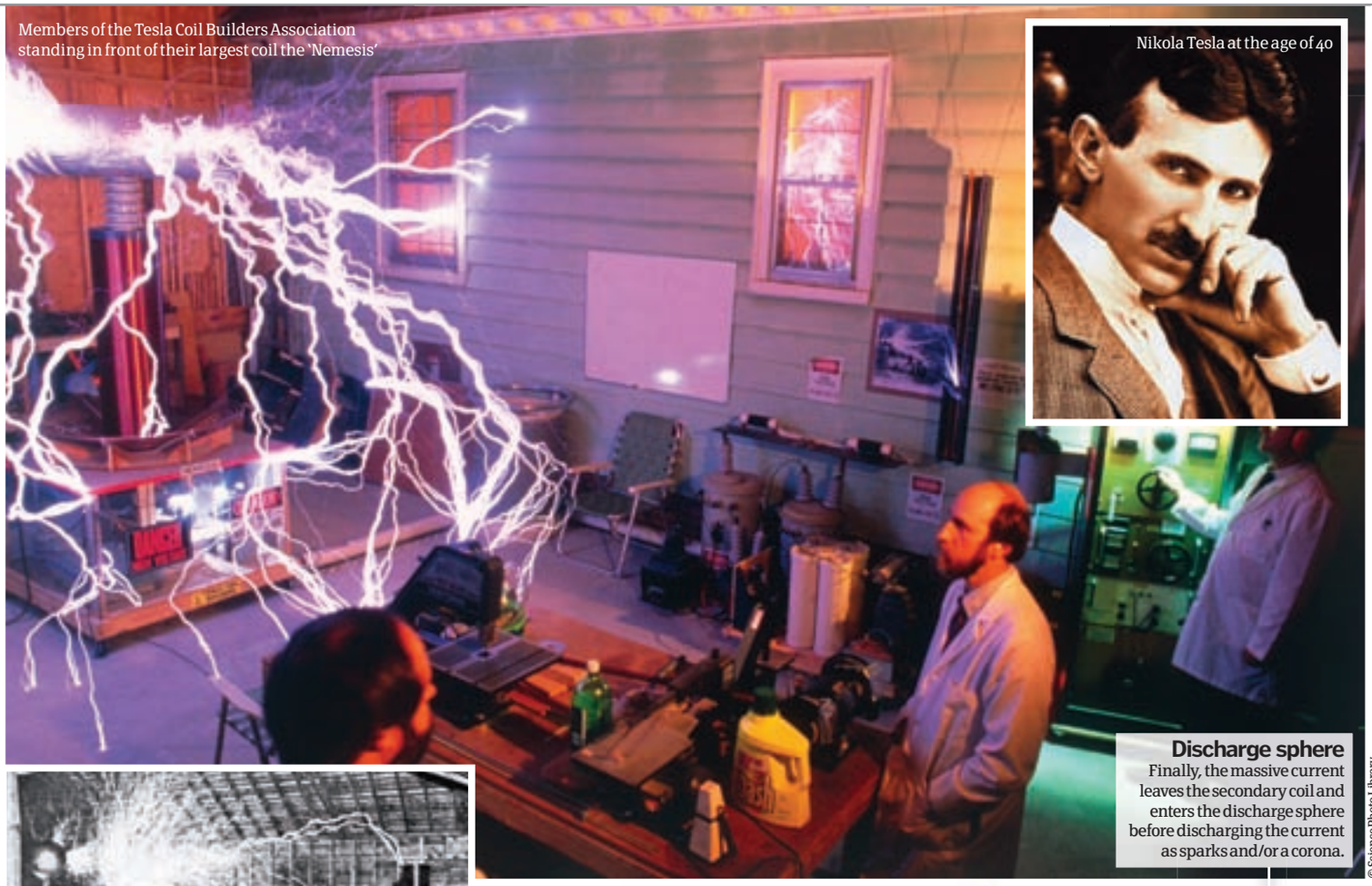
The Statistics

BAC/Aerospatiale Concorde

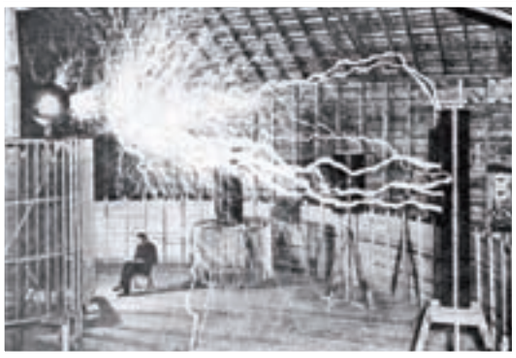
Manufacturer: BAC (Now BAE Systems) and Aerospatiale (Now EADS)
Year launched: 1976
Year retired: 2003
Number built: 20
Dimensions: Length: 61.66m Wingspan: 25.6m Height: 3.39m
Capacity (passengers): Up to 120 passengers
Unit cost: £23 million in 1977
Cruise speed: Mach 2.02 (1,320mph)
Max speed: Mach 2.04 (1,350mph)
Propulsion: 4x Rolls-Royce/ Snecma Olympus 593 engines
Ceiling: 60,000ft

"Nikola Tesla's coil worked by stepping up a current exponentially"

Members of the Tesla Coil Builders Association standing in front of their largest coil the 'Nemesis'



Nikola Tesla at the age of 40



Discharge sphere
Finally, the massive current leaves the secondary coil and enters the discharge sphere before discharging the current as sparks and/or a corona.

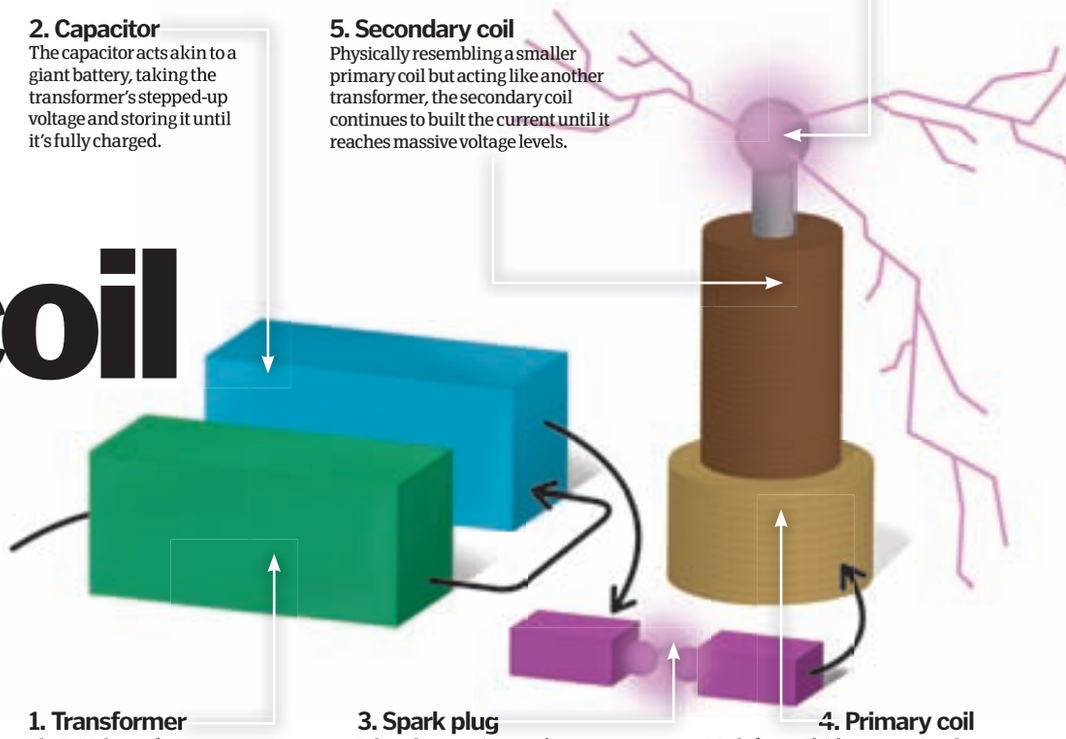
2. Capacitor
The capacitor acts akin to a giant battery, taking the transformer's stepped-up voltage and storing it until it's fully charged.

5. Secondary coil
Physically resembling a smaller primary coil but acting like another transformer, the secondary coil continues to built the current until it reaches massive voltage levels.

Tesla coil

The Tesla coil was one of the first and most theatrical resonant transformer circuits

An early type of resonant transformer – a device that facilitates the wireless transference of energy between two similarly tuned coils – Nikola Tesla's coil worked by stepping up a current exponentially to produce high voltage, high current and high frequency alternating current electricity. During the operational life span (1890s – 1920s) Tesla coil circuits were primarily used commercially in radio transmitters for wireless telegraphy and medical devices for electrotherapy. Follow our step-by-step guide to see how the famous coil worked.



1. Transformer
The initial transformer takes a low level current and steps it up to thousands of volts.

3. Spark plug
When the capacitor reaches 100 per cent, the spark plug fires releasing its contents into the large primary coil.

4. Primary coil
Made from a thick copper wire, the primary coil produces a strong magnetic field as the current released by the spark plug flows through it.

DID YOU KNOW? *The floppy disk was invented by IBM and became commercially available in 1971*

Anderson shelter

Named after the head of British Air Raid Precautions during WWII, the Anderson shelter was built to protect civilians from German bombs

Anderson shelters worked by absorbing the blast and ground shocks from bomb explosions throughout their curved steel sheeting, diverting the potentially dangerous levels of energy released into mere plastic deformation, rather than widespread destruction.

This differed massively from the existing concrete bunkers that had been in use during the early 20th Century as they were especially prone to collapsing if exposed to the effects of a close explosion (both walls and ceiling would collapse if the other was disturbed). Importantly, however, the new shelter was one for the general population and not just the wealthy, with Andersons being released for free if a person earned under £250 a year.

DID YOU KNOW?

The Anderson shelter was designed in 1938 by William Paterson and Oscar Carl Kerrison.

© Ceridwen

A preserved Anderson shelter from 1941

Steel panels

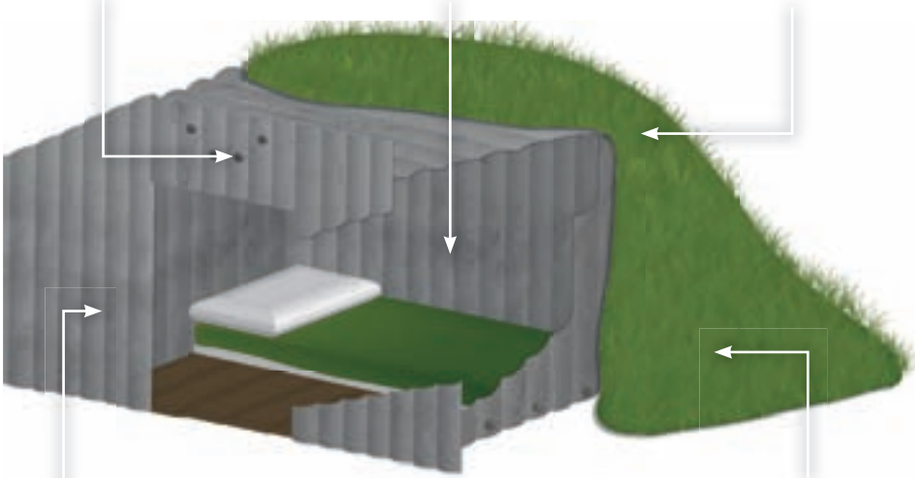
Made from six curved sheets of steel bolted together and with steel plates at either end, the shell of the shelter was 1.95m by 1.35m and could accommodate six people.

Interior

The interior of all Anderson shelters was bare, leaving its furnishing to the owner. Because of this, the level of luxury varied massively from shelter to shelter.

Earthen roof

Added as another layer of defence but also to provide camouflage from German bombers, each shelter was, if possible, covered with a great mound of earth.



Blast wall

At the entrance end of the shelter there was both a steel blast sheet and earthen wall to protect it from any debris caused by an explosion to the owners' main dwelling.

Entrenched

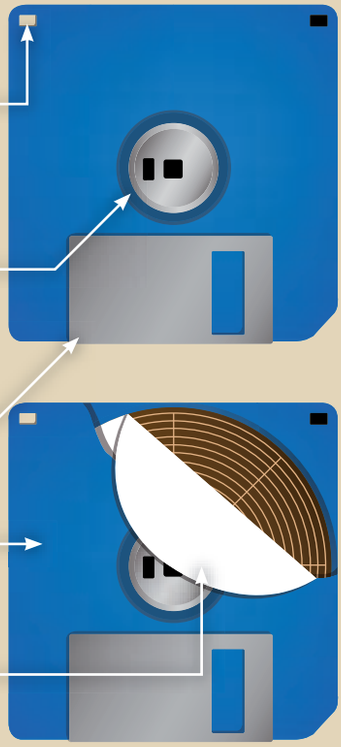
Anderson shelters were entrenched 1.2 metres down into the earth to provide extra protection from explosions and to enhance the stability of the steel-sheeted chassis.

Floppy disks

We take transferring huge amounts of data for granted, but without the floppy disk your USB drives would never have existed

Inside the plastic casing, floppy disks are made from a thin piece of plastic with magnetic material on both sides, arranged in concentric circles like a record, which is in turn divided into sectors. When information is copied to the disk, it spins while a 'stepper motor' matches the rotation and moves a read/write head into place over the correct sector of the disk. Once in place, an erase coil clears the sector of the disk and the read/write head records information onto the disk by magnetising minute, bar-magnet particles embedded in the disk's surface.

What's inside?



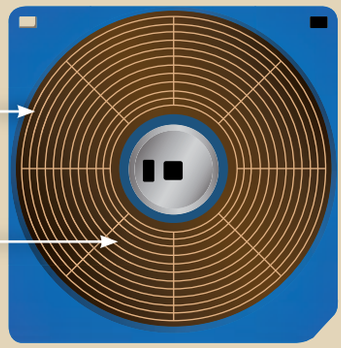
Capacity indication
If this hole is present, it means the disk can hold up to 1.4 megabytes.

Hub
This slots on to spokes in the drive to hold the disk steady.

Shutter
This metal shutter protects the disk when not in use.

Plastic housing
The hard outer casing protects the fragile floppy disk interior.

Paper ring
Glued in place, these keep the disk clean as it is spun.



Magnetic disk
This ferromagnetic disk is where the information is recorded.

Disk sector
Each piece of saved information is stored in a different sector of the disk.

"It housed important official offices and acted as a storage centre and a treasury"

Greek templ

Inside these multi-use architectural marvels

The temple acted as a cosmic generator. It was regarded as a dwelling designed for the gods and was also seen as a reception area for prayer, magical petition and divination. It also became a political symbol that emphasised the might and power of the state through ancient architectural achievement. The temple, now the most famous symbol of ancient Greece, was also functional – it housed important official offices and acted as a storage centre and a treasury.

The Doric temple of Segesta

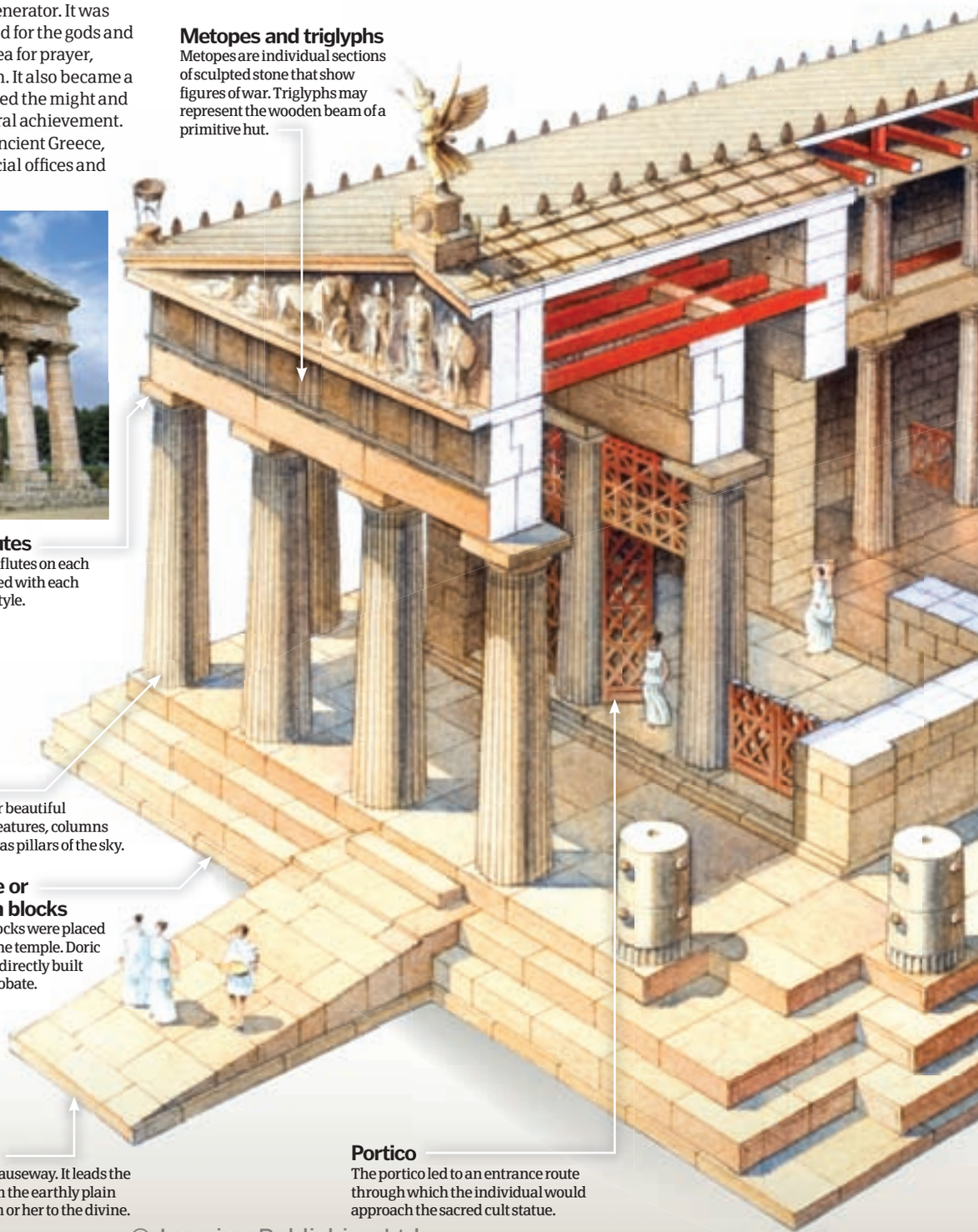
The Statistics

The Parthenon

Location: Athenian Acropolis, Greece
Length of construction: 447 BC – 438 BC
Designer: Phidias
Type of building/purpose: Temple and treasury
Type of architecture: Classical – Doric
Cost of construction: In modern terms, it is estimated that the Parthenon cost over £3 million
Architects: Ictinos and Callicrates
Area coverage: 69.5m x 30.9m

Learn more

For a fantastic video on the building, history and secrets of the Parthenon, visit our website and click on the history section **www.howitworksdaily.com**.



Metopes and triglyphs
Metopes are individual sections of sculpted stone that show figures of war. Triglyphs may represent the wooden beam of a primitive hut.

Column flutes
The number of flutes on each column changed with each architectural style.

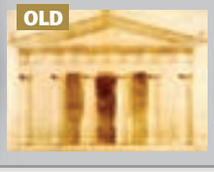
Columns
Valued for their beautiful architectural features, columns were also seen as pillars of the sky.

Stereobate or foundation blocks
Foundation blocks were placed at the base of the temple. Doric columns were directly built upon the stereobate.

The ramp
A ceremonial causeway. It leads the individual from the earthly plain and guides him or her to the divine.

Portico
The portico led to an entrance route through which the individual would approach the sacred cult statue.

Head to Head DORIC TEMPLES



1. Temple of Delians
Delos, Greece, 478 BC
This temple was founded on the island of Delos – as Delos was the birthplace of Apollo, the temple is dedicated to Apollo and Artemis. This temple was never finished.

2. Temple of Poseidon
Paestum, Italy, 470-460 BC
This temple dedicated to the Goddess Hera was described as "oppressive" by the philosopher Goethe.

3. Temple of Hephaestus
Athens, Greece, 447 BC
This elaborate temple, which was built on the tip of the Agoraios Kolonos Hill, was used (until 1834) as a Greek Orthodox church.

DID YOU KNOW? *The Parthenon has been used as an early Christian church and the site of a Turkish mosque*

es

Doric architecture

The temple was entered from a ceremonial ramp, allowing the individual to approach the portico. Once inside, you faced a narrow corridor decorated with pillars. Although the temple was annexed by official offices and storerooms, it was designed so that the individual had a sense that he or she was entering a holy space – with the narrowing of the corridor you were gradually drawn inwards as if about to experience the sacred presence of the gods. At the heart of the temple there was the cella, the home of the cult statue.

Building the temple

The temple was viewed not only as an edifice of marble, wood and stone, but a magical structure that was designed on astronomical principles. With this in mind, early construction of the temple began with the foundation ceremony, creating a base that is known as a stereobate. This consisted of several layers of stone blocks, their tips protruding above ground.

The workers employed simple tools of bronze and copper. During construction they also used mallets, chisels and ropes to create a further foundation block called a crepidoma, which acted as a base for the columns and walls. The columns, which were made of several drums of fluted stone, supported the entablature, which consisted of the architrave and the frieze which lay below the cornice. Temple construction could take over a decade, the building often covered 115m x 55m of land and boasted columns that reached 15m to 20m in height. On completion, the temple was decorated by craftsmen.

Types of... GREEK COLUMNS

How to identify Greek columns

DORIC

These columns are short, heavy structures with plain capitals. They have no base and their height measures only four to eight times their diameter. The columns are decorated with 20 flutes. The base of the column was placed directly on the stylobate (or the foundation stone), its capital can be seen as a square abacus that connected it to the entablature.

IONIC

Ionic columns are graceful and slender – they differ from the Doric in that they are designed with a large base for extra support. They are easily distinguished by their large scrolled features. The Ionic column has 24 flutes. The frieze above them is often designed with carved figures.

CORINTHIAN

The Corinthian column is ornate and elaborate, and is often more appealing than the Doric and Ionic columns described above. The column is tall and slim. Designed with 24 flutes it is crafted with a scrumptious capital, which is sculpted with scrolls and acanthus leaves. The column is often measured at ten metres high.

BRAIN DUMP

Because enquiring minds want to know...

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HOW IT WORKS EXPERTS

sciencemuseum

Adam Boal
Family Programmes Developer

Adam studied Physics at York University and now writes and performs family events at the Science Museum. He enjoys playing computer games and football and is scared of heights.

Ernestina Asare
Science Museum Explainer

A student in Engineering Design at University of Bristol, Ernestina's favourite part of being a Science Museum Explainer is learning and explaining the science behind everyday things.

Rik Sargent
Science Museum Explainer

Rik is an Explainer in the Science Museum's Launchpad gallery. When Rik isn't blowing up stuff or putting people in giant bubbles he trains the Explainer team in the principles of science.

Alison Boyle
Curator of Astronomy and Modern Physics

Alison Boyle is responsible for a range of collections spanning most of the space-time continuum. She is currently researching particle accelerators.

How does toothpaste for sensitive teeth work?

Barry Green

■ Imagine one of your teeth. It has two main sections: the crown above the gum line and the root below it. The crown comprises the following layers from top to bottom: enamel, dentine and the pulp gum. Nerves branch up from the root to the pulp gum. The dentine runs down to the root and contains a large number of tubules or microscopic pores, which run from the outside of the tooth to the nerve in the pulp gum.

People with sensitive teeth experience pain when their teeth are exposed to something hot, cold or when pressure is applied. Their layer of enamel may be thinner and they may have a receded gum line exposing more dentine. Therefore, the enamel and gums offer less protection and this is what makes their teeth sensitive.

Sensitive toothpaste works by either numbing tooth sensitivity, or by blocking the tubules in the dentine. Those that numb usually contain potassium nitrate, which calms the nerve of the tooth. The toothpastes that work by blocking the tubules in the dentine usually contain a chemical called strontium chloride. Repeated use builds up a strong barrier by plugging the tubules more and more, leading to less-sensitive teeth.

Ernestina Asare

Why do we get stitch?

Simon Walsh

There are many theories about what causes that horrible side pain we commonly know as a stitch, but almost all the theories point towards the diaphragm as the main cause. The diaphragm is a sheet of muscle that sits below the rib cage and plays a big part in respiration. Attached to the diaphragm are various ligaments that connect to different organs – one of which is the liver. It's thought that as you exercise, the liver moves around, as does the diaphragm due to breathing. This movement causes the connecting ligaments to stretch which gives rise to a sharp pain, a 'stitch'.

Another notable theory is that a stitch occurs due to an inadequate blood supply to the breathing muscles, which may explain why we often get stitches upon doing exercise after eating as there is an increase in the blood supply to the digestive system.

Rik Sargent

What is a memory?

Kirsty Stockton

Memory is the brain's ability to recall information from the past and it generally falls into three categories – sensory, short-term and long-term.

Take a look at this page then close your eyes and try to remember what it looks like. Your ability to recall what this page looks like is an example of your sensory memory. Depending on whether or not this page is important to you will determine how likely it is that it will get passed on to your short-term memory.

Can you remember the last thing you did before reading this? That is your short-term memory and is a bit like a temporary storage facility where the less-important stuff can decay over time, whereas the more important stuff can end up in the long-term memory.

Our senses are constantly being bombarded with information. Electrical and chemical signals travel from our eyes, ears, nose, touch and taste receptors and the brain then makes sense of these signals. When we remember something, our brain refires the same neural pathways along which the original information travelled. In this way, you are almost reliving the experience by remembering it.

Rik Sargent

What is a slipped disc, and why does it hurt so much?

Geoff Poore

Your spine consists of 33 bones called vertebrae. In-between each vertebra are circular pads, or discs, of connective tissue, which protect the vertebrae against shocks. The discs have tough cases that contain a gel-like substance.

A slipped disc occurs when the gel protrudes outwards between the vertebrae. A damaged disc can put pressure on the entire spinal cord or on a single nerve fibre. This means that not only will a person with a slipped disc feel pain around the disc, but they could potentially also feel pain in every area a nerve fibre controls.

Ernestina Asare

How do boats brake, do they just pedal backwards?

Iris French

You're correct, though only for boats with pedals and propellers. Different types of boat use different ways to propel themselves through the water. For boats with propellers, like motorboats and pedalos, the spinning propeller pushes water back and this pushes the boat forwards. You can slow them by stopping the propeller spinning. If you spin the propeller backwards, the boat will push water forwards and this will start to push the boat backwards and it will slow down a bit faster.

Sail boats are different. If you want to completely stop your boat then don't forget an anchor or you'll drift away with the wind and currents.

Adam Boal

What's on?

NEW! Fly Zone

WHAT: Visit the new Fly Zone simulator area and take control in 360° flight simulators or fly with the Red Arrows in our sensational 3D motion effects theatre. And don't forget to visit Fly Café to refuel.
WHERE: Science Museum, 3rd floor
WHEN: On now
PRICE: Charges apply

Legends Of Flight 3D

WHAT: A captivating new film showcasing some of history's most amazing aircraft. Soar over the highest peaks, feel the gut-wrenching force of take-off, and loop and roll above the ocean.
WHERE: Science Museum, IMAX 3D cinema
WHEN: On now
PRICE: Charges apply

Who Am I?

WHAT: Who Am I? presents the latest in brain science and genetics through a mixture of interactive exhibits and object-rich displays. Find out what makes you… you, and discover how your genes impact on your brain, your actions, your thoughts and your appearance.
WHERE: Science Museum, 1st floor
WHEN: On now
PRICE: Free

Trash Fashion: Designing Out Waste

WHAT: We're buying a third more clothing than we did a decade ago. But fast-changing fashions mean over 1 million tons of textile waste every year. Discover how new technology will help create wear without waste. How can we reduce the impact of throwaway fashion?
WHERE: Antenna Gallery, G floor
WHEN: On now
PRICE: Free

sciencemuseum

COMING SOON...

Atmosphere: Exploring Climate Science

WHAT: Atmosphere combines interactive exhibits with objects from the museum's collection and around the world. Discover the science of the climate system, how climate has changed, and how scientists are improving our understanding of it.
WHERE: Wellcome Wing, 2nd floor
WHEN: Winter 2010
PRICE: Free

Psychoanalysis: The Unconscious In Everyday Life

WHAT: Explore the unconscious mind with an exhibition to celebrate psychoanalysis. Discover the broad contemporary relevance of psychoanalysis in an accessible way. The exhibition focuses on how the unconscious can be interpreted through everyday experiences.
WHERE: Science Museum
WHEN: 13 Oct – April 2011
PRICE: Free

SCIENCE MUSEUM LATES

Music Of The Mind

WHAT: A night of musical performance and science with musician Finn Peters. Discover the innovations in brain-computer technology that allow us to compose music from our own brain waves.
WHERE: The Dana Centre
WHEN: 17 September
PRICE: Free

For further information visit the What's On section at www.sciencemuseum.org.uk/centenary.

Visit the Museum

Exhibition Road, South Kensington, London SW7 2DD.
Open 10am – 6pm every day.
Entry is free, but charges apply for the IMAX 3D Cinema, simulators and some of the special exhibitions.

Not a good day to leave your space suit at home...

©NASA

How long could a human survive unprotected in outer space?

Sam Barnes

■ You might be able to survive in space for over a minute, so long as you got back to safety and medical care immediately. Following a sudden exposure to the vacuum of space, the first thing to do would be breathe out – if you held your breath, the gas expanding in your lungs due to the reduced external pressure would cause them to rupture (it's a bit like ascending after a scuba dive).

Around ten seconds in, you would start to lose consciousness and vision due to oxygen depletion. In the low-pressure environment, your body fluids would begin to vaporise, causing tissue to swell up. If you were in the sunlight, without the protective effect of the Earth's atmosphere, serious sunburn would occur.

Experience from training accidents suggests that if astronauts are returned into a pressurised oxygen environment within 90 seconds, injuries are reversible. However, with so many factors at play, the survival limits are not well known.

Alison Boyle

FROM THE FORUM

*Every month we'll feature a reader's question from our fantastic forum at **www.howitworksdaily.com/forum***

What is the difference between 'rain' and 'showers'?

AndrewGear111

■ Rain is water falling from the sky that is bigger than 0.5mm in diameter. Anything smaller is called drizzle. However, rain is then divided into different types so that you know what to prepare yourself for. One type of rain is showers. This is where the rain starts and stops suddenly, like your shower at home when you turn it on or off.

Adam Boal

Some would call this puppy love...

What is love, and what triggers it?

Annie

■ Love is the emotion of strong affection and personal attachment. Love comes in many forms varying from the generic and platonic type such as 'I love that film' and 'I love my friends', to the more personal, intense, romantic love.

Love is seen as a mammalian drive similar to hunger or thirst as it activates the same area of the brain as these cravings. It is speculated that romantic love evolved to enable us to focus our mating energy on one partner long enough to stay together and rear young.

There are many different triggers for love: specific chemicals being released in the brain, meeting someone who you are compatible with and so on. As long as we are surrounded by other people it would be near impossible to prevent love from eventually happening in some way or another.

Rik Sargent

Butterflies' wings are made up of timy scales

What are butterflies' wings made of?

Dorothy Burns

Butterflies are from the order of insects known as Lepidoptera. A butterfly has four wings; two forewings and two hind wings. Each wing is made up of thousands of tiny scales that sit in overlapping rows over a framework of veins – a bit like tiles on the roof of a house. Some scales contain colour pigments, whereas others are translucent and create colour by refracting and diffusing light.

The front and back of the wings usually have different patterns. The undersides are often designed to help the butterfly camouflage to its surroundings when it is resting – like the mottled leafy green on the Orange-tip, and butterflies rest with their wings closed. If you see a butterfly sitting with its wings open it will be absorbing sunlight to raise its body temperature. peacock butterflies use the eye patterns on their wings to scare off predators when they are basking.

Butterfly wings are very delicate and often tear, but it would take a lot of damage to stop them from flying. Scales containing colour pigment can also fade in sunlight. If a butterfly looks pale it could mean it's nearing the end of its life. Sometimes the pigments mutate and rare variations occur like copper butterflies with white wings instead of orange ones. There are often ultraviolet patterns in the wings that we cannot see, but which may possibly be seen by other butterflies.

Dr Martin Warren, chief executive, Butterfly Conservation

How do owls turn their heads 360°?

Alison Whitman

With 14 vertebrae in its neck – twice that of a human – an owl has more flexibility and can turn its head through 270 degrees without moving its body. This adaptation is necessary because owls' eyes are almost completely fixed in their sockets. Being able to move its head allows the owl to focus its vision and hearing towards its prey, often with deadly results.

Grahame Madge, conservation spokesman, RSPB

Who needs eyes in the back of their head?

HOW IT WORKS EXPERTS

Dr Robert Bloomfield
Director IYB-UK/Head of Innovation and Special Projects, Natural History Museum

Bob is Head of Innovation and Special Projects at the Natural History Museum where he has delivered Darwin200 and is now directing IYB-UK during 2010. With a PhD in Genetics, Bob has pursued a career in science and public engagement, leading major science communication projects. In 2002 Bob was awarded a NESTA Dream Time Fellowship, which he used to retrace the first voyage of Captain James Cook.

What's on?

Butterfly Explorers

WHAT: Journey through the Natural History's Museum's magnificent butterfly house and discover the many habitats and butterflies living there. Spot different species at various stages in their life cycles, and learn which are under threat, as well as those you might see in your garden.
WHERE: Natural History Museum
WHEN: 8 April – 26 Sept
PRICE: Charges apply

From Another Kingdom: The Amazing World Of Fungi

WHAT: This major multimedia exhibition at the Royal Botanic Garden in Edinburgh explores the amazing world of fungi and their relationship with humans.
WHERE: Royal Botanic Garden, Edinburgh
WHEN: 31 July – 21 Nov
PRICE: Audio guide £2.50 adults, £1.50 for children

Big Batty Walks

WHAT: Explore London's WWT reserve with a bat detector to see and hear bats swooping overhead. Times vary with sunset. Children should be accompanied by an adult. Call 020 8409 4400 to book.
WHERE: Wildfowl & Wetlands Trust
WHEN: 9 and 16 Sept
PRICE: £10 admission fee

Autumnal Migration in North Kent

WHAT: The autumn migration season is a great chance to learn about the UK's waders and migrant birds. Oare Marshes and the Elmley RSPB reserve sites in Kent are the perfect setting to discover more about these amazing birds. You can also observe birds of prey at one of the best sites in the UK, led by warden Tony Swandale and ornithologist Rob Clements. To book, call 01622 662012.
WHERE: Elmley RSPB Reserve and Oare Marshes, Kent
WHEN: 10 September
PRICE: £25

Blue Ribbon Village at the Mayor's Thames Festival

WHAT: Blue Ribbon Village is the interactive river and environment zone at the Mayor's Thames Festival. The Village features stalls and activities provided by a range of organisations promoting biodiversity within urban, rural and marine environments. From bee keeping to pond-dipping, wild-flower cooking to amphibian and reptile conservation there's lots to try your hand at.
WHERE: Potters Field Park and the Riverside Walkway between City Hall and Tower Bridge, London
WHEN: 11 and 12 September
PRICE: Free

The Secret Life Of Seals

WHAT: Join the Cornwall Wildlife Trust for an exciting illustrated talk from renowned seal expert Sue Sayer from the Cornwall Seal Group. Learn all about these beautiful creatures with which we share the Cornish coastline. Discover how you can help protect these remarkable animals. For more information, call 01872 552 428.
WHERE: Meet at Driftwood Spars, Trevaunance Cove, St Agnes
WHEN: 14 September
PRICE: Free

Why do birds sing so loudly at dawn?

Danielle Street

At dawn, the air is calm and other noises, such as traffic, are low. Birdsong travels further and has more impact. Studies suggest a song sung at dawn is around 20 times more effective than one at midday. Females tend to lay eggs in the morning so it makes sense for males to attempt to attract mates just before. The chorus of song also reveals which birds are perching where and whether any territories have become vacant overnight.

The best time to hear a dawn chorus is the first hour before sunrise – which means getting up early or staying up really, really late! The Wildlife Trusts usually have special events happening up and down the UK on the first Sunday in May to celebrate International Dawn Chorus Day. You can contact your local Wildlife Trust to find out more.

Paul Wilkinson, head of living landscape, The Wildlife Trusts

© Kevin King 09

The Bengal tiger (pictured) is among the most endangered species

What's the most at-risk species in the world?

Hayley Parsons

According to the World Wildlife Fund, the tiger is among the most at-risk species on the planet. Studies suggest that there may be just 3,200 wild tigers left in the world.

Tigers are the largest of Asia's big cats, and they're hunted and traded illegally for their pelts, bones and even their heads. In several countries, such as Indonesia, tigers are protected by law in an effort to prevent such illegal trade, and yet still more needs to be done to protect this majestic creature and its habitat.

By the end of the 20th Century, the Bali, Javan and Caspian tigers were all extinct, and the six remaining sub species – Amur, Bengal, Indochinese, Malayan, South China, and Sumatran – are all at risk of the same fate through poaching, illegal trading and loss of habitat.

How It Works

How come some animals can change colours?

Rob King

There are two answers to this – a 'why' and a 'how'. Flatfish take only a few seconds to change colour to blend with their background. Many other animals change colour to communicate. Chameleons are very good at this. They change to express sexual interest, readiness for a fight, etc. Some chameleons also change colour to help them maintain their body temperature.

Cuttlefish are masters of rapid colour and texture change, which means they can 'disappear' against their background, as well as communicate complex messages. Their skin can change colour so rapidly they produce waves of colour controlled both on speed and in detail of the patterns that they can produce.

Frogs generally don't change colour like this, though a few tropical species change colour as chameleons do to maintain a constant temperature.

As for the how: some animals change very slowly to match a seasonal change in surroundings, simply by moulting and then growing different coloured hair. The rapid changes, however, are achieved with 'chromatophores' in the skin. In the cuttlefish, there are tiny pockets of pigment such as melanin. These pockets are like pixels on an LCD screen. Simply by expanding or contracting these 'pixels' they can create almost endless blends of colours and patterns at will.

Simon Garrett, head of learning, Bristol Zoo Gardens


Forget a fishing line, this way's much more productive!

© Teddy Llovet 08

How do birds catch fish?

Georgina Foster

It's a big question because different species use different tactics. Fish-eating birds of prey, like the osprey, plunge feet-first into the water to catch live fish from the surface with their talons. Other birds such as the heron, stand motionless at the water's edge, wait until a fish comes close and then use their bill as a spear. Mergansers and auks dive for fish from the water's surface using their wings to 'fly' underwater. Kingfishers sometimes hover and dive, and at other times will dart from a perch to catch fish unawares. These birds and others have clever adaptations to help them catch their food. The osprey, for example, has a reversible outer toe, allowing it to grasp its fishy prey while a pelican scoops up fish in its expandable throat pouch. There is even speculation that deep-diving cormorants wintering north of the polar circle in West Greenland can switch from using their eyes to feeling, or even using acoustics, to catch fish underwater in the very low light during the winter months.

Nigel Jarrett, head of conservation breeding, Wildfowl & Wetlands Trust (WWT)

Which pollination technique is best: abiotic or biotic?

Pete Morris

If a flower pollinates without the help of an organism it's an abiotic pollinator, but if it pollinates with their help it's a biotic pollinator. Of all of Earth's flowers, only 20 per cent are abiotic – 98 per cent of which use wind to achieve pollination. Statistically it's harder to reproduce in this way due to increased points of failure and dependence on weather, proximity etc.

The other 80 per cent of plants are biotic pollinators, relying mainly on insects and birds to carry their pollen from one plant to another. This system is statistically more successful, with plants and birds/insects often co-evolving to – unconsciously – get the best for each other. The plants get pollinated, while the organisms get energy from their nectar.

How It Works


Biotic pollinator heliconias has co-evolved with hummingbirds to maximise pollination rates


Cuttlefish can quickly change their colour

© Silke Baron 2010

© Rikard 06

Galapagos Day

WHAT: Galapagos Day is an annual event organised by the Galapagos Conservation Trust, the UK's only charity dedicated to raising funds and awareness of these incredible islands.

Speakers include travel writer and conservationist Stanley Johnson (father of the London mayor); H E the Ambassador of Ecuador, Mrs Ana Albán Mora; the great great granddaughter of Charles Darwin, Dr Sarah Darwin; and executive director of the Charles Darwin Foundation in Galapagos, Dr J Gabriel Lopez. They will discuss their experiences of one of the world's most iconic natural wonders. Call 020 7629 5049 to book.

WHERE: Royal Geographical Society, London

WHEN: 15 September

PRICE: £30


© Haplochromis 2008

Priorwood Garden Apple Day

WHAT: 21 October marks Apple Day across the UK. Events are being held at National Trust properties in England and Scotland. The Priorwood Garden event offers visitors the chance to buy fruit from the orchard, which has a growing selection of apples since it re-planted 25 new varieties. Call 0844 4932257 to book.

WHERE: Priorwood Garden and Dried Flower Shop, Melrose, Scotland

WHEN: 9 Oct

PRICE: Entry is included in the admission price

Visit the website

For more information on these events and more across the UK visit www.biodiversityislife.net

This website is the UK partnership supporting IYB. It's a great source of news and events concerning biodiversity and the environment.

IYB-UK is made up of over 400 major organisations, charities, universities, businesses, schools, museums and arts practitioners. Dr Robert Bloomfield, the director of International Year of Biodiversity in the UK, will be marshalling a range of experts from across the partnership to answer your questions.

2010 has been declared the International Year of Biodiversity (IYB) by the United Nations.

THE HOW IT WORKS KNOWLEDGE

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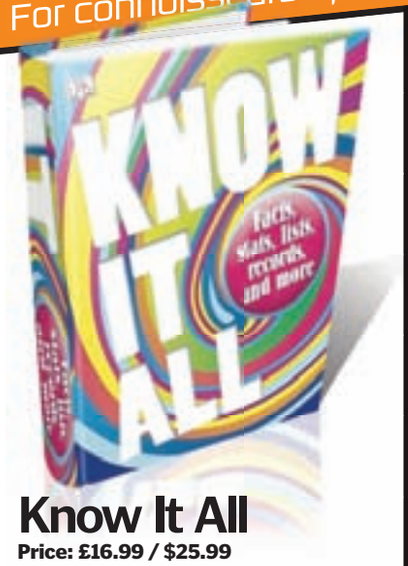
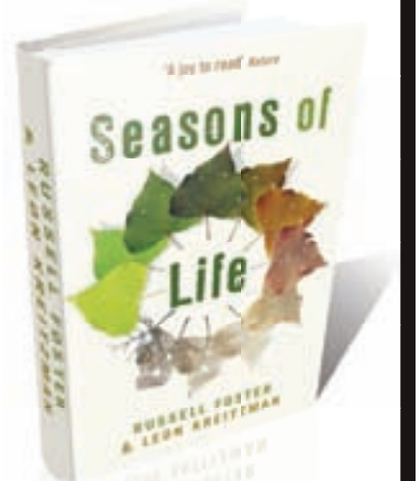


Know It All

Price: £16.99 / $25.99
ISBN: 978-1-4053-5533-9

A sort of compendium of random, albeit awesome science trivia from DK. *Know It All* takes its reader one step closer to true omniscience with lists of the weirdest beetles, the fastest jet aircraft and stupidest dinosaurs, as well as presenting pictorial galleries, timelines and 'how to' boxes instructing you how to land on a comet and drink from a cactus.

Verdict: ✪✪✪✪



Seasons Of Life

Price: £9.99 / $14.99
ISBN: 978-1-8619-7969-8

A new title exploring the upcoming field of chronobiology, *Seasons Of Life* explains why the seasons occur, the impact of seasonal change and how organisms have evolved to anticipate these changes. Exploring questions such as "how does the season in which we are born affect our subsequent life chances?", this is an intriguing book.

Verdict: ✪✪✪

Princely underwater propulsion

Bladefish Seajet 3000

HOW IT WORKS EDITOR'S CHOICE AWARD ✪✪✪✪✪

Price: £399.99 / $620.00
Get it from: www.bladefish.net

WITH THE SUMMER holidays coming to an end, and the decent weather gradually slipping away, some of you may be looking for a last-minute holiday, or simply a trip to the coast to enjoy the September sun. Regardless of where you live, where you go or what you decide to do, if it involves any underwater-based activity then you should do well to consider the new Seajet 3000 from Bladefish, a steering-wheel-sized handheld device that propels you through the water at up to 4.25kph with zero physical exertion.

Aimed firmly at snorkellers and scuba divers (there are different models that cater to the different activities, the Seajet 1000 being the most basic model while the Seajet 5000 the most advanced), the Bladefish range is designed to take a lot of the effort out of fish hunting/coral reef viewing, with the units easily controlled while drifting through the water. This, the 3000 and more heavy-duty variant, allows for underwater action down to a maximum depth of 30 metres and will last roughly 40 minutes powered by its 18V Li-ion battery.

In addition, this model will recharge back up to 80 per cent capacity in only one hour, making reuse easy and fast, and it weighs only 4.7kg, making its transportation easy in its carry case.

Verdict: ✪✪✪✪✪

Blobo

Disappointingly, it's not a wind-up clown

Price: £69.99 / $109.99
Get it from: www.blobo.co.uk

JUMPING IN LATE to the whole *Wii Fit*, peripheral-based, casual videogame market is the Blobo for PC, a golfball-sized six-axis wireless game controller. The Blobo works by measuring the users' motion, rotation, squeeze force, air pressure and magnetic field when it is held in the hand, before decoding that data and transferring the information into a range of virtual games including: archery, skiing, running, basketball and baseball among others.

Overall, the Blobo does what it says on the tin well and is a neat product. At a penny shy of £70, however, it is pretty expensive, and with the device only compatible with PC it is important to weigh-up its practicality and accessibility – is your PC connected to your big screen TV for example? – for the younger users it is aimed at.

Verdict: ✪✪✪

Paper Jamz Instant Rockstar

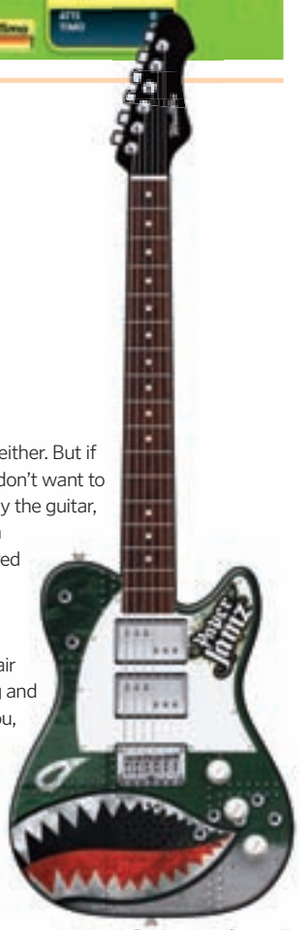
No talent? No matter!

Price: £21.49 / $34.99
Get it from: www.amazon.co.uk

WANT TO ROCK out like Jon Bon Jovi? No, we didn't either. But if you do want to rock out to other good rock music but don't want to go through that troublesome process of learning to play the guitar, then Paper Jamz is for you. Each Paper Jamz guitar is a lightweight plastic and card construction that is powered by three AAA batteries and uses touch sensors to play songs or chords.

The guitars (there are different variants) come preloaded with different songs and allow their user to air guitar along to the music. In addition to merely miming and strutting along while the guitar does all the work for you, users can also opt to switch the guitar off the 'Perfect Play' setting and onto either 'Rhythm Play' – allowing for the music's rhythm to be either sped up or slowed down – or 'Freestyle Play' where real chords can actually be played to form your own music. Luckily for parents, each guitar comes with a headphone jack.

Verdict: ✪✪✪✪



Game reviews

Halo: Reach

- **Price: £37.99 / $59.99**
- **Format: X360**

Halo: Reach returns the franchise to form after *Halo: ODST* received mixed reviews critically. Cherry-picking the best parts from the entire *Halo* canon to form the new single-player campaign mode and retuning the great multiplayer experience users are familiar with already, *Reach* delivers on both fronts and makes this the definitive, and maybe last, *Halo* game. To be compared in certain respects to a band's 'best of' album.

HOW IT WORKS EDITOR'S CHOICE AWARD ✪✪✪✪✪

Verdict: ✪✪✪✪✪

Dead Rising 2

- **Price: £36.99 / $55.99**
- **Format: PS3**

Dead Rising 2 sees the user play as protagonist Chuck Greene as he brutally fights off waves of the undead in Fortune City. Raising the amount of zombies that can be on screen at any one time and providing a cavalcade of new weapons to ensure their destruction, *Dead Rising 2* does little to change its core gameplay. This all means that if you like beating zombies back to death with nothing other than a plastic toy Lightsaber, this is the game for you.

Verdict: ✪✪✪✪

Spider-Man: Shattered Dimensions

- **Price: £39.99 / $59.99**
- **Format: PS3**

Throwing together four different Spider-Man universes from the Marvel Comics multiverse, including: Amazing, Noir, 2099 and Ultimate, *Spider-Man: Shattered Dimensions* delivers an action-adventure platformer in which the gameplay varies from dimension to dimension. Noir, for example, relies on stealth to beat opponents, while 2099 features more combat-heavy gameplay. Fans of the franchise are duly served.

Verdict: ✪✪✪

Tom Clancy's H.A.W.X 2

- **Price: £36.99 / $49.96**
- **Format: X360**

H.A.W.X returns for a second outing with this follow-up to the 2009 original. *H.A.W.X 2* sees the player re-adopt their role in the famous squadron as it is sent to the Middle East to investigate the mysterious disappearance of Russian nuclear weapons. Gameplay remains arcade-focused in the flight style, favouring intense dog-fighting action over realism. Benefits this time round include a more accurate damage model, better graphics and improved AI.

Verdict: ✪✪✪✪

THE HOW IT WORKS KNOWLEDGE

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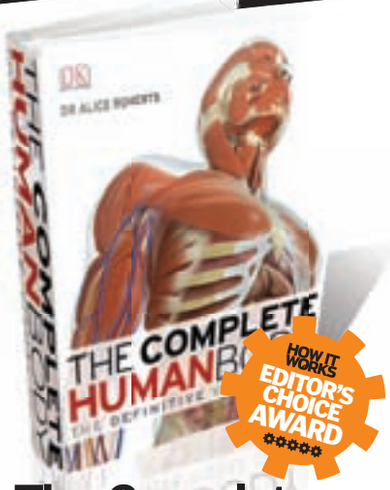


The Complete Human Body

Price: £30.00 / $45.99
ISBN: 978-1-4053-4749-5

Using the latest data from medical and microscopic imaging, *The Complete Human Body* covers the development, form, function and disorders of the human body, all brought to life by state-of-the-art 3D computer-generated artworks. Detailing everything from respiratory systems to how over 200 diseases afflict the human body, this title is ideal for students, families and even professionals.

Verdict: ✿✿✿✿✿

A Brief Guide To Cloud Computing

Price: £8.99 / $13.99
ISBN: 978-1-84901-406-9

A glance into the future of the IT industry, this book explains how more and more computing applications will be accessed online, with the web rather than individual hard disc drives at the heart of everything we do. This is a handy, progressive and knowledgeable guide.

Verdict: ✿✿✿

Plantronics Explorer 395

A simple, effective headset

Price: £30.00 / $46.71
Get it from: www.plantronics.com

THE EXPLORER 395 is a Bluetooth headset aimed at first-time users. As a result it is simple to set up and stripped back in functionality, but this does not compromise on quality. The device is lightweight and conservative in design – it is not as discreet or stylish as some headsets, but is reasonably comfortable to wear. It is a superior entry-level headset, and though you'll get more if your budget stretches further, for its target market it does its job well.

Verdict: ✿✿✿✿

Massive and stylish portable power

Powergorilla

Price: £150.00 / $234.99
Get it from: www.powertraveller.com

FOLLOWING ON FROM the Solargorilla last month we have the Powergorilla from Powertraveller, a lightweight, hardback book-sized battery that specialises in delivering huge amounts of juice while on the move. Capable of powering any device that requires up to 24 volts to work – pretty much any modern portable device – the Powergorilla charger specialises in extending your device's running time no matter where you are and for lengthy periods of time. Indeed, with a touted two-to-five extra hours of laptop power and over 20 hours for other smaller electronics, it's easy to see this device powering weekends away from home.

On test this claim was ratified fully, with the Powergorilla adding an extra one hour 35 minutes onto **How It Works'** Rock Xtreme CTX Pro laptop – which famously has a shocking stock battery life and is extremely power hungry – taking its total idle running time from 35 minutes to two hours ten minutes.

Verdict: ✿✿✿✿

Optoma PK201

A powerful pocket projector

Price: £299.00 / $464.99
Get it from: www.optoma.com

THE PK201 IS the latest in Optoma's line of Pico Pocket Projectors. The pocket-sized device – measuring roughly the same size as a mobile phone – can be connected to an external device in order to project images, movies or presentations onto the nearest wall, wherever you are.

The PK201 comes with several input methods, including Composite, VGA and Mini HDMI, enabling you to use content from products ranging from an iPhone (with a non-supplied adapter) to a TV or games system. In addition you can simply pop in a microSD card and use it as a standalone device. Being able to use the system free from any external device is perhaps the most welcome new feature.

The number of file formats supported is vast too. You can show full PowerPoint presentations, watch videos in 14 formats including AVI and MP4, and view ten different types of image file. The device is controlled via a series of buttons on the top of the unit that navigate you through the UI projected onto a wall and the display stretches to a massive 70-inches with WVGA resolution, which theoretically enables the device to be used as a portable cinema system.

The technology in the PK201 is undeniably impressive, although it does inevitably come at quite a price. While the addition of a memory card slot is also welcome, the drive to make the Pico Pocket Projector a portable system has not quite come off. Movies will be a secondary feature on this device, whose primary place will still be firmly rooted in the office.

Verdict: ✿✿✿✿

Luxa2 H1-Touch

Standing out from the rest...

Price: £28.99 / $45.14
Get it from:
www.luxa2.com

If you're in the market for a stand that can hold a number of products then we urge you to take a look at this cool effort from Luxa2. The stand takes obvious design cues from the iMac, which we're a big fan of – but rather than using a fixed system to hold an iPhone or iPod, like some other cases, the H1 has a flexible system that will allow you to use not only an iPhone or iPod touch, but also most other iPods and any other small computing device that will fit. It uses a swinging arm system that lets you fit the protruding rubber points to the outside of the device and then close them in around it in a spider-like grip. The arms are connected to a flat metal plate, and that plate is then attached to the aluminium stand.

Construction of the H1 is very rugged and the arm system feels safe and secure. The rubber points keep the stand from causing any scratches on the devices you put in there, and you can tilt the screen back and forth as well as rotating it 90-degrees should you wish to watch a video on the iPhone. Despite being useable for other devices, the H1 has obviously been designed with the iPhone in mind and it's even suitable for iPhone 4. When the iPhone is in the cradle you still have access to all the buttons and controls, as well as having the space to connect the cable too. This is not only a very suitable and practical stand, but it also looks cool with your iPhone sat in it.

Verdict: ✪✪✪✪

Jivo Elements

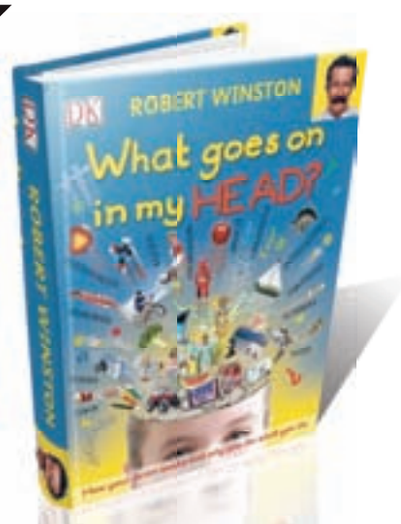
Eco-inspired earbuds

HOW IT WORKS EDITOR'S CHOICE AWARD ✪✪✪✪✪

Price: £25.00 / $38.99
Get it from: www.jivo.co.uk

We are fans of any tech product doing its bit for the environment, and can understand when the result has an adverse effect on the product. Luckily Jivo needn't worry about this in the slightest, as its eco-inspired earbuds are nothing short of exceptional. Crafted using rosewood because of its traditional use in instrument building, these Element buds seriously rock. Hang on, we're not sure that does them justice – they seriously rock! The wooden enclosure must do some kind of magic because the sound these beauties deliver is on a par with the majority of £80-£100 earphones we've tested. For the price point these are without a shadow of a doubt the best earphones we've ever tested.

Verdict: ✪✪✪✪✪

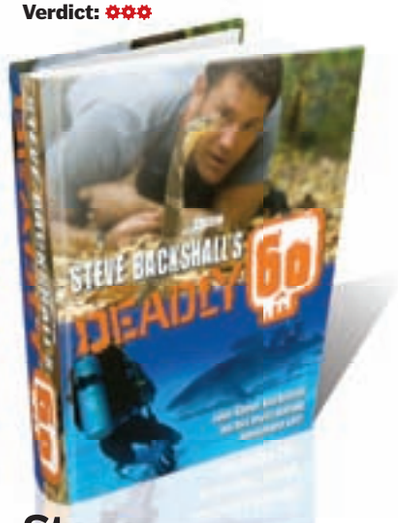


What Goes On In My Head?

Price: £11.99 / $18.49
ISBN: 978-1-40535-373-1

Professor Robert Winston takes younger readers on a tour of their own brain, covering its different parts, how it evolves, and why it is the most powerful computer network on Earth. The title is well illustrated and easily approachable – taking complex subjects and simplifying them – and is filled with entertaining brainteasers to test its readers' memory, perception and reactions.

Verdict: ✪✪✪



Steve Backshall's Deadly 60

Price: £9.99 / $11.99
ISBN: 978-1-8477-3430-3

Six months, six continents and 60 of the world's deadliest creatures sums up this title from naturalist and TV presenter Steve Backshall. A tie-in title to his BBC series where he traverses the globe in order to hunt down the world's most deadly creatures, it brings those creatures into your own home thanks to an array of facts and glossy pictures.

Verdict: ✪✪✪✪

GROUP TEST Coffee machines

A personal Starbucks in your very own home...

Krups Nescafé Dolce Gusto

Price: £80.99 / $139.95

Get it from: www.amazon.co.uk

This stylish coffee maker from Krups delivers a decent selection of coffees (latte macchiato, cappuccino, espresso, caffè lungo, cappuccino ice and mocha) and does so at a fast speed. Further, the unit is very simple to use with just a couple of button presses needed for any action and it doesn't need to be cleaned after every use. However, its build quality is mainly plastic – making us question its durability – and the packs of coffee pods are pretty expensive unless you shop around. For the price it is retailing for, though, it offers a decent price to performance ratio.

Verdict: ✿✿✿

Pros:
- Stylish design
- Decent drink range
- Fast cycle

Cons:
- Plastic build materials
- Expensive coffee pods

HOW IT WORKS GROUP TEST WINNER

Dualit Espressivo

Price: £149.95 / $229.99

Get it from: www.amazon.co.uk

Retailing for almost twice the price of the Dolce Gusto, the Espressivo from Dualit offers slightly better coffee, but considerably better features and build quality. The unit is constructed out of stainless steel and is finished in either shiny chrome or a cream matte, with the front adorned with a series of chunky, easy-to-use buttons and dials, and the top covered with a warming plate. Further, the Espressivo is fitted with a 15 BAR pump and Thermobloc water heating system, the latter enabling the unit to deliver hot water and steam instantly on demand. Bad points centre on the weak taste of the crema and average espresso strength.

Verdict: ✿✿✿✿

Pros:
- Classic design
- Sturdy and well-built
- Good price to performance

Cons:
- Overly aerated crema
- Average strength espresso
- Weak warming plate

Bosch Tassimo T40

Price: £99.99 / $146.99

Get it from: www.amazon.co.uk

Slotting in snugly between the other two, the T40 provides a rock-solid, sub-£100 coffee machine. The range of coffee is excellent and includes espresso, cappuccino, decaffeinated and crema intenso among others, with Tassimo's website allowing you to purchase the 'discs' easily. The build quality is above average and it comes fitted with a flow heater that speeds up its cycle time. The main minus point here, though, is how the T40 is locked-down to just one expensive brand of disc/pod, which it ensures is used by reading a barcode on each one before making the drink.

Verdict: ✿✿✿

Pros:
- Wide coffee range
- 60-second cycle
- Good drink quality

Cons:
- Locked down
- High pod cost
- Noisy

HOW TO MAKE
A tumblewing

GET INVOLVED!
Have you created the ultimate tumblewing that defies gravity? Why not send your pictures to howitworks@imagine-publishing.co.uk and we'll show it to the world!

A tumblewing

Defy gravity with this simple-to-make paper plaything

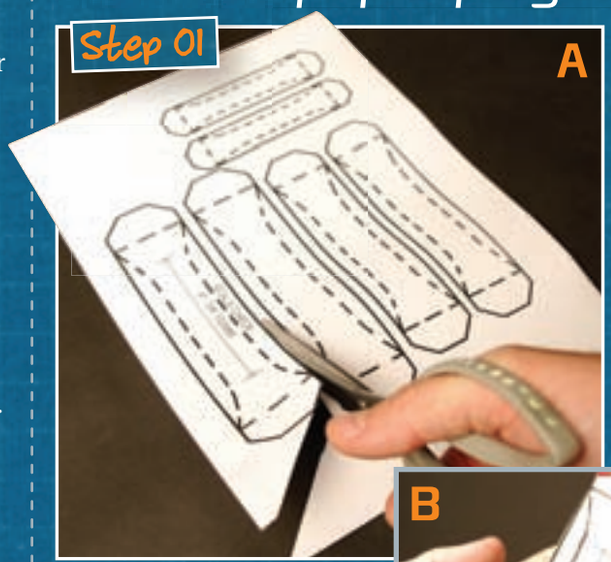
Humanity's quest to defy gravity sans power source has never ended well. In Greek mythology Icarus attempted to escape Crete with a pair of wings made for him by his father, only to fly too close to the Sun, burn them and fall back to Earth and his death. The historian Eilmer of Malmesbury, jumped from the top of Malmesbury Abbey with fixed wings attached to his feet and hands made from bird feathers, only to fall to earth breaking both his legs.

However, while How It Works cannot grant the human body independence from gravity's all-encompassing reach, it can grant it for the ingenious tumblewing, a paper construction that by simply harnessing the power of aerodynamics, can defy gravity. Simple to make, even the most junior scientist can quickly be drifting the tumblewing around the house with just a little practise.

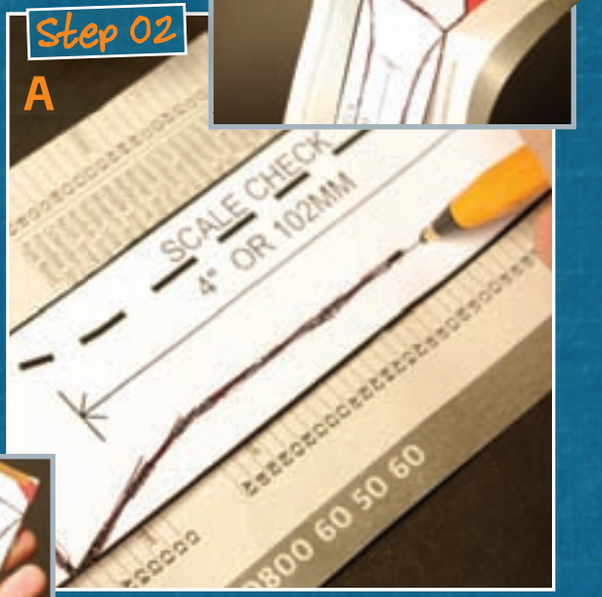
Construction materials:

- 1 x A4 paper
- 1 x Scissors
- 1 x Pen
- 1 x Phone book / newspaper
- 1 x Sellotape
- 1 x Cardboard sheet

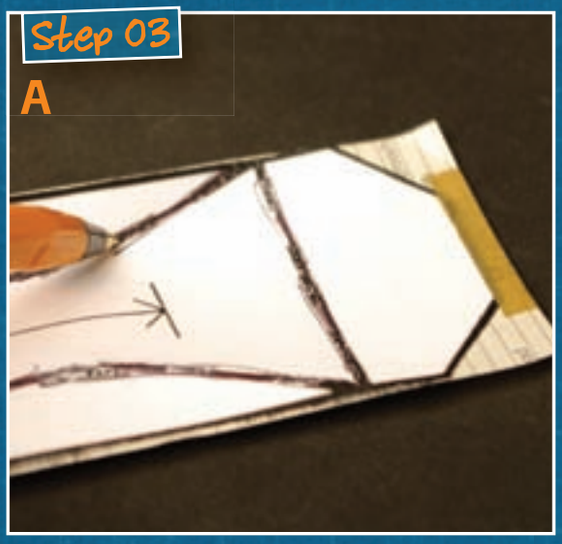
All construction materials can be acquired from Hobbycraft.



1. Cut out the template (right) and stick it with some Sellotape to a piece of phone book paper at each of its ends (A). Then cut around the template to replicate its shape on the phone book paper. At this point keep the two pieces of paper taped together (B).



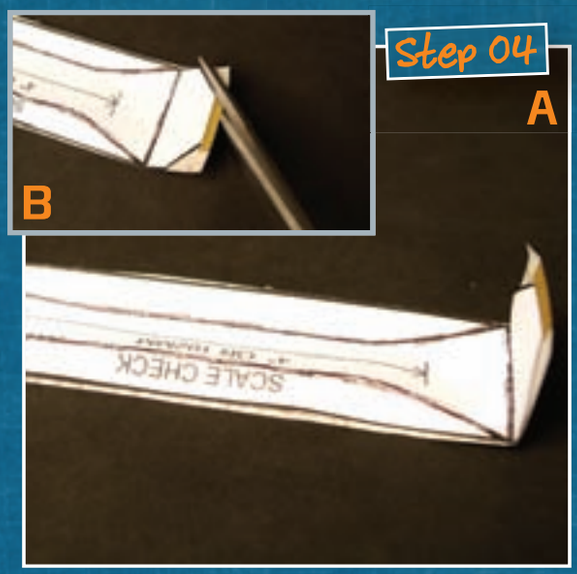
2. Now take the tumblewing outline and score along each of its fold lines with a ballpoint pen (A). In doing this you will make folding the tumblewing much easier, as the paper fibre will have been compressed along the fold lines, making it more malleable to alteration of position (B).



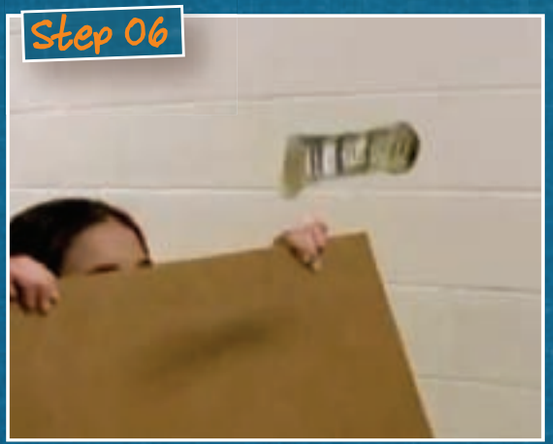
3. Once this is achieved you can fold both the angled sides of the tumblewing. One must be folded upwards, the other downwards. It is important that you do not fold the creases to the end tips of the tumblewing but follow the curved dotted line faithfully (A). Once complete you should have something that looks like this (B).

HOW TO MAKE
A TUMBLEWING

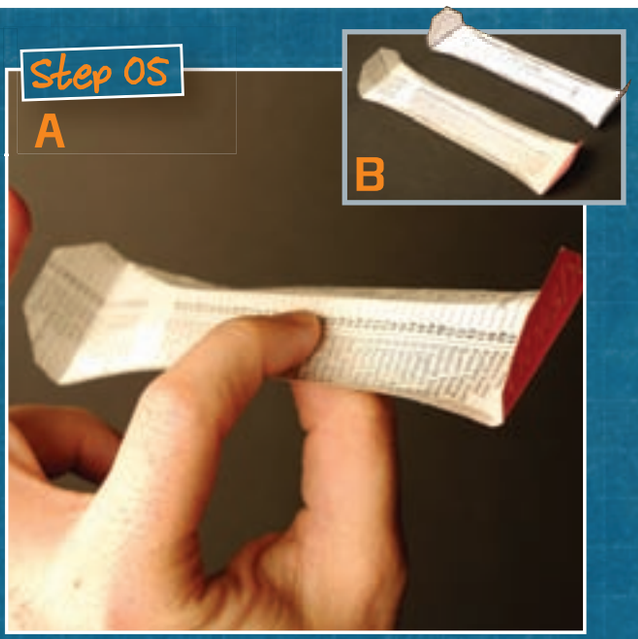
TUMBLEWING TEMPLATE



4. You will now notice that the tumblewing has rigidity when held, instead of drooping under its own weight. Now take the two end tips and fold them vertically, ensuring that neither is out of kilter, as this will effect how straight and true the tumblewing will fly (A). You can now cut the Sellotaped ends of the paper and separate the A4 from the phone book paper (B).



6. Lastly, once released, follow your tumblewing around with your piece of cardboard, holding the board on a near vertical trajectory. By doing this you will produce a controlled updraft and ensure your tumblewing remains airborne. For more help on attaining perpetual, fuel-less flight, see the "Tumblewing tips and tricks" boxout.



5. Your tumblewing is now ready to fly, however, to get it to work properly you need to release it in a certain way. Gripping the centre of its main body like this (A), ensure that the flap facing upwards is pointed towards you (B). Now flick your hand gently forward and down, releasing the tumblewing and setting it on a backwards 360 rotation. This is perhaps the most crucial part to achieving perpetual flight, so practise the release until you get a straight and true flight.

7. Congratulations! You have created and flown your very own tumblewing.

Tumblewing tips and tricks:

Turn from a schoolboy to professional tumbler with a few helpful hints:

1. Sheepdog – If your tumblewing begins to veer off a straight flight path, do not follow it directly with your board as this will just increase its rate of turn and soon you will end up like a dog chasing its tail. Instead, act like a sheepdog would and, while continuing to push forward, nudge the tumblewing back inwards with the outer edge of the board. By doing this you will guide it back onto a nice, straight course.

2. Angles – If your tumblewing begins to dip while flying, do not raise the angle of the cardboard paddle towards the horizontal. This is because, contrary to what appears to be a way of raising the tumblewing's altitude, this will only serve to increase its descent. To increase altitude, maintain the cardboard at a near vertical position but increase the speed at which you move forward. This will generate more of an updraft running up the outside of the card and lift the tumblewing higher in the air.

HOW IT WORKS INBOX

Feed your mind. Speak your mind

1,000mph here we come!

Letter Of The Month

Bloodhound gang

I've been following the progress of the Bloodhound SCC since reading about it in issue 9 of How It Works and the news story in the last issue prompted me to write this letter. While some may query the government funding of this project in these times of public sector cutbacks, I think such criticism is short sighted and counter-productive in the long term. In my opinion the Bloodhound project is the perfect vehicle (pun intended) to inspire young people to get involved with engineering and will prove far more effective in encouraging them into apprenticeships and degree-level courses than 100 career officers could ever be. So while it might seem an expensive folly to some, "glamorous" engineering projects like these are the best way to ensure the engineering and manufacturing industry survives in the UK by attracting the brightest young minds to key positions. Really love the magazine by the way, so keep feeding those minds.
Alex MacDonald

HIW: Fine sentiments well expressed Alex, hence you occupy the letter of the month slot this issue. The Bloodhound's quest to top 1,000mph is exciting enough and the educational side adds a whole extra level of opportunity to boot. Inspiration and excitement through technology and engineering is close to our hearts and we'd suggest that anyone who wants to learn more about the Bloodhound heads to www.bloodhoundssc.com for all the info they need.

Get in touch!

If you've enjoyed this issue of How It Works, or have any comments or ideas you'd like to see in a future edition, why not get involved and let us know what you think. There are several easy ways to get in touch...

Found what she's been looking for

I am a middle-aged lady who is not into fashion or celebrity but who loves learning new things and finding out how things work. Up until your magazine, finding something worthwhile to read was extremely difficult. Now I have discovered How It Works I can't wait for each issue. Thanks for producing something that really does feed the mind.
Sally Adams

Early-edition How It Works articles available soon

Will you do a rerun of the first few issues for those of us who missed them as I believe there could be quite a few people like myself who never knew this existed until later issues came out? I would rather pay you a bit more for the past issues if you did a reprint than pay the stupid prices they are asking on eBay.
Garry Murphy

HIW: Garry, many people missed our early issues, which then went out of stock with readers keen to obtain the full back catalogue. Although it's simply not feasible to reprint entire issues at this stage, we have launched our range of How It Works PixelMags available for iPads and iPhones, which enables you to buy every single issue so far.

However, we do understand that many readers still want a hard copy of our early articles that they can keep, and so we're well on the way to bringing you a solution, which we will reveal very soon. Keep watching our information channels – Twitter, Facebook, and of course the How It Works Daily website and forum. We'll disclose our exciting plan of action as soon as we're allowed.

OMNI present

I wanted to let you know that I have thoroughly enjoyed each issue of How It Works that has made its way to the US. Your magazine sparks my curiosity the same way that *OMNI* did many years ago. If you want to get a better idea of my opinion of How It Works, I wrote a review of it and you can find it here: http://purpleranger.livejournal.com. Looking forward to the next issue.
Johnny Carruthers

Future feature suggestions

I love How It Works. I always like the Global Eye part and enjoyed the issues on

How to contact us

Facebook: search for 'How It Works'

Email: howitworks@imagine-publishing.co.uk

Twitter: http://twitter.com/HowItWorksmag

Web: www.howitworksdaily.com

We aim to cover topics that compliment school subjects

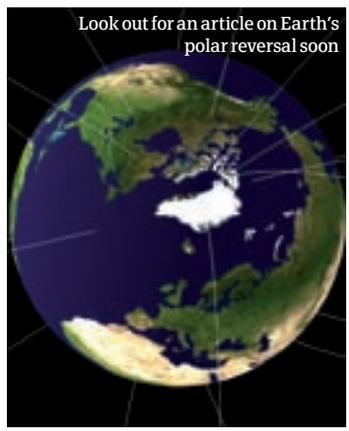
the iPad and iPhone 4. Please could you write more features on one specific animal like when you did the pages on elephants. Also, please could you include some of the facts that most people wouldn't know about St Peter's in Rome in one of your future issues. I hope you continue with the fantastic topics and keep it enjoyable to read. Thank you.
James Wass, 13

Thank you

■ Dear team. I would just like to say thank you for making this exciting magazine. Not only is it a good read, but it also helps me at school, as I am in secondary school. Well done for making this magazine so interesting. When I am older I hope that I can write for a magazine like this one, to make people aware of simple objects!
Jade

Young reader request

■ My name is Adair and I am nine years old. I love your magazine. I think it would be great if the magazine could write an article on how and why the Earth's magnetic poles swap places.
Adair



Look out for an article on Earth's polar reversal soon

Practical help

■ I am currently doing some A-level Physics coursework on exoplanets. As a subscriber, I was very excited when I found your article on it in issue 9. I was wondering if you could tell me the author so I can put them in my sources. Thank you very much.
Joseph Williams

HIW: It's great to hear that How It Works is proving useful to your own work. Our exoplanets article was written by one of our regular space cadets Nigel Watson. Nigel's a huge fan of the cosmos and has a particular passion for ufology. He's even written a number of books on the subject.

Next month...

■ In issue 8 of HIW you said that in issue 9 there would be an article on Google and cranes. Are they coming up or are you not doing them? Thanks.
Sean Morris
PS: I love your magazine.
PPS: Please could you do an article on jet boats, LCD TVs and diggers. Thank you.

HIW: Hi Sean. You're in luck. As you can see, this issue we have Google's search engine, cranes and the fastest speed boat in the world, and in issue 11 we brought you a six-page feature on diggers (well, massive mining machines) and jet skis.

Our next month page is always subject to change due to unforeseen circumstances. However, where possible we do endeavour to get all promised articles (and those suggested by readers) into the magazine at some stage.

"I'd rather pay you more for the past issues if you did a reprint than pay the stupid prices they are asking on eBay"

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For all subscription enquiries
☎ 0844 826 7322
Overseas +44 1795 414779
Email: howitworks@servicehelpline.co.uk
13 issue subscription (UK) – £41
13 issue subscription (Europe) – £50
13 issue subscription (USA) – £50
13 issue subscription (ROW) – £60

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Distributed in the UK & Eire by : Seymour Distribution, 2 East Poultry Avenue, London, EC1A 9PT. ☎ 0207 429 4000

Distributed in Australia by : Gordon & Gotch, Equinox Centre, 18 Rodborough Road, Frenchs Forest, NSW 2086.
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Distributed in the Rest of the World by : Marketforce, Blue Fin Building, 110 Southwark Street, London, SE1 0SU.
☎ 0203 148 8105

ISSN 2041-7322