NEW

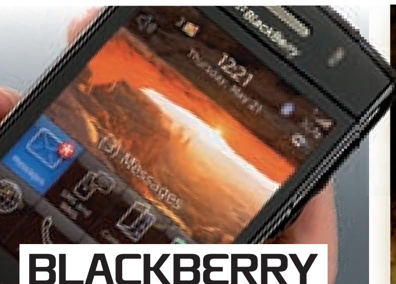
THE MAGAZINE THAT FEEDS MINDS

HOW IT WORKS™

SCIENCE ENVIRONMENT TECHNOLOGY TRANSPORT HISTORY SPACE

INSIDE

INTERVIEW
ADAM HART-DAVIS



BLACKBERRY
Discover the technology that's revolutionised communication

WASHING MACHINES
Explaining the everyday tech that cleans your clothes

DIGESTION
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On board the
WORLD'S LARGEST CRUISE SHIP

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- FLASH DRIVES
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"FEED YOUR MIND!"

What you're saying about How It Works

From what I have read so far, issue two is very good, has a wide range of features and is set to be as good as issue one. Loved the lions feature. – **cjayp33, forum**

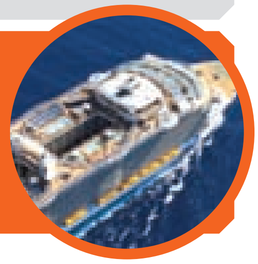
I just recently purchased your first issue of this magazine here in the United States. I absolutely love what I have read so far and plan on subscribing pretty soon. I learned so much still from this one issue, I can't wait for the next one to hit the shelves! Thank you! – **Paul Konomos, email**

The magazine seems to be continuing with its superb mix of articles and wonderful illustrations and photographs and I am looking forward to reading it thoroughly. I would also like to add that the subscription service so far has been faultless and the speed of delivery is fantastic, so well done. – **Dave H, forum**

Really loved the fantastic cutaway of the Rolls-Royce jet engine that was featured back in issue three and the article on the International Space Station. Here's hoping that you can bring us more interesting articles in 2010. Thanks! – **Brian Wallace, email**

The magazine is fantastic and I hope you get a chance to go over some more nanotechnology areas soon! – **Thom Newton, email**

Editor's pick



As many of you know by now, it's technology, gadgets and engineering that float my boat, and boats don't come much bigger than the Oasis of the Seas. There's some fantastic images and cutaways in my favourite article on page 44.

Meet the experts

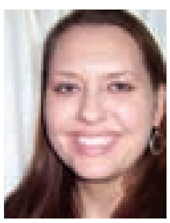
How It Works is created by a team of experts that's more like family than work colleagues, and it's a family that's growing all the time…

Helen Laidlaw
CGI

Helen worked all over her Christmas holidays to bring us an in-depth look at computer animation and the technology used to bring movies like *Avatar* and *Where The Wild Things Are* to our cinema screens.

Rob Jones
Dinosaurs

Rob turned virtual archaeologist this issue and unearthed all manner of dinosaur facts that populate the feature on page 72. Since he started working for How It Works he's become a master at quiz machines.



Shanna Freeman
Next-gen space craft

Shanna is our resident space cadet and we set her the task of researching how humankind will reach space after the Space Shuttle is retired later this year. You can find the fruits of her labours on page 34.

Dave Roos
The big bang

Dave is part farmer, part freelance writer and the latter part of this split personality took on the task of explaining the big bang and what happened in the first few seconds of the universe's life. No mean feat.

Lynsey Kay Porter
Human digestion

After completing an anthropology degree and travelling across the world in various different guises, Lynsey is now based back in the UK where she gets fed up with the weather and writes science articles for us.

With thanks to

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

sciencemuseum REUTERS DK BlackBerry NASA

Hello and may the fourth be with you! Yes, this is indeed the fourth issue of **How It Works** and after four issues we're pleased to report that the magazine is starting to get noticed by some big names in the world of science and technology. We've already hosted Sir James Dyson back in issue two and issue four sees an interview with scientist, author and broadcaster, Adam Hart-Davis. Adam approached us after issue one to tell us how impressed he was with the magazine and we're pleased to report that this interview kicks off a series of regular columns that Adam will contribute every month.

If you've yet to book your holiday then take a look at our lead feature on page 44 where we take a tour round the largest and most luxurious ocean liner to every to sail the seas. At three and a half football pitches long and featuring 21 swimming pools and jacuzzis, and even a park, this ship is a true technological wonder and we were amazed at the engineering that made it possible.

Once again, I'd like to sign off by saying a big thank you to all our readers, in particular the subscribers. Take a look at the deals on offer on page 80 if you want to join their ever-growing ranks.

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

HOW IT WORKS

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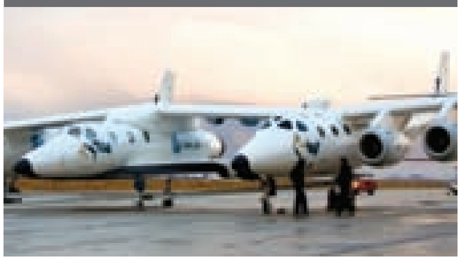
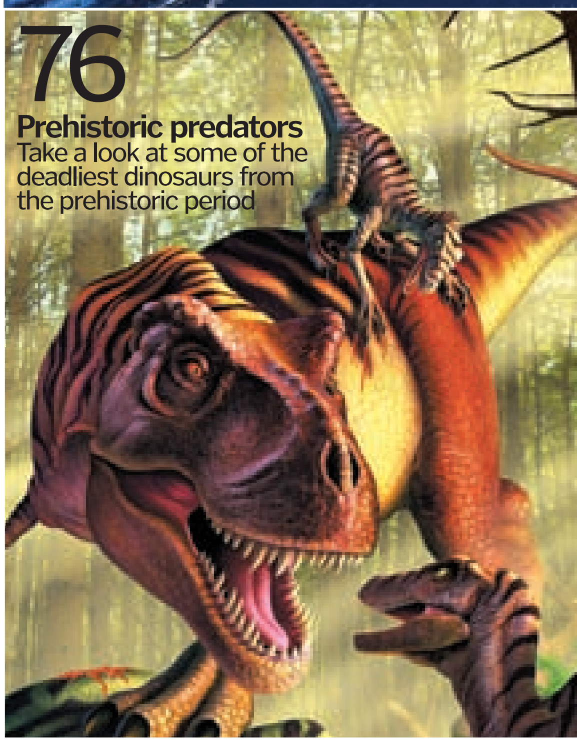
ISSUE FOUR

The magazine that feeds minds!



Sections



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Go to pg 80 for some great deals

E NOW!

Transport

Environment

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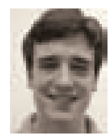
History

Regulars

BRAIN DUMP
Because enquiring minds want to know...

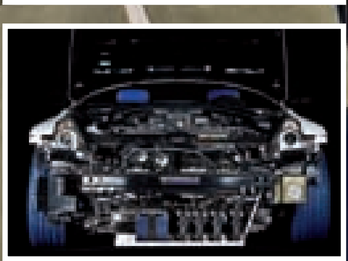
Doug Millard
Space Curator
Doug Millard answers all the space enquiries this issue



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

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

The Z-Hydro is a reworking of the Nissan 370Z R34 car but with major alterations to the body, engine, interiors, braking system and trim



Images courtesy of Marangoni Tyre

Driving hydro power forward

Z-Hydro uses energy from water to reduce emissions and fuel consumption

A new demo car from Italian tyre manufacturer Marangoni Tyre is pushing the boundaries of technological advancement and ecology with the Nissan Z-Hydro, a vehicle with a clever hydro system.

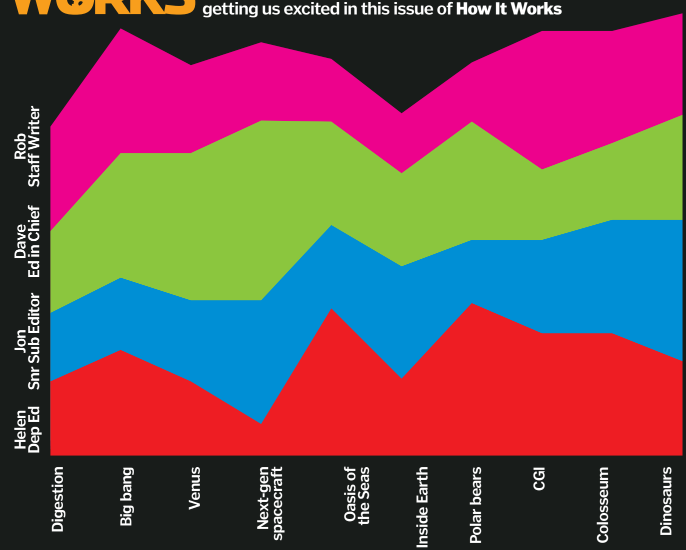
This tuning project, handled by Florence-based TRC Italia, features the body of Nissan's 370Z R34. However, under the hood of the Z-Hydro is an engine that boasts a highly innovative water system that produces a gas called oxyhydrogen. In harmony with the Nissan car's original engine, this oxyhydrogen works to minimise emissions and cut unburned hydrocarbons to almost zero. Unburned hydrocarbons are the hydrocarbons (or basic organic compounds containing only hydrogen and carbon) that are emitted when petrol is burned in an engine.

The oxyhydrogen gas is produced in water tanks above the central crossbar of the front bumper by a process of electrolysis, which uses electrical current to break the water molecules down into their component parts – oxygen and hydrogen. The gas is then injected into the engine's intake where it is combined with the regular fuel, reducing emissions.

The process, which is completely independent and can be deactivated via a switch on the dashboard, consumes about 500ml of water every 500km and can be refilled in the same way as you would the engine oil. Converting a car to run on oxyhydrogen partially replaces fuel, increasing the car's mileage by 40 per cent, thereby significantly reducing petrol bills.

HOW IT WORKS EXCITE-O-METER!

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

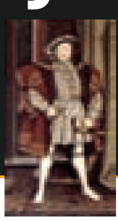


It's been a very cold issue for **How It Works** this month. The heating broke down in our office on the coldest day of the year, prompting us to consider a 'how do boilers work' feature as we sat with our hot water bottles and endless cups of tea to keep warm. And yet the cold did nothing to diminish Dave's perpetual excitement. This month we discovered that everyone's mad about dinosaurs except Helen – must be a girl thing. Plus we were surprised to see that the human digestive system got the least excited response from the team. It must be our delicate disposition.

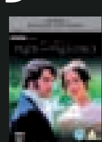
This day in history

28 January: How It Works issue four goes on sale but what else happened on this day in history?

1547 Obese serial divorcer Henry VIII dies, leaving his son Edward VI to take over as king.



1813 The novel that always seems to be getting a remake, Jane Austen's *Pride And Prejudice* is published.



1855 The first locomotive to travel from the Atlantic to the Pacific via the Panama Canal Railway crosses Central America.

1884 If you remember last issue's Mariana Trench article, you might recall the name Jacques Piccard. He built the Bathyscaphe Trieste submersible with his father, Auguste, who was born on this day in 1884. That's some coincidence.

1887 This is apt considering the weather we've been having: in 1887 snowflakes measuring 15 inches wide and eight inches thick fell during a snowstorm in the western US state of Montana.

Generation Nexus

Intended to bring the web to mobiles, Google's self-styled 'superphone' is finally unveiled

© Google Inc

The Statistics

Nexus One

Height: 119mm
Width: 59.8mm
Depth: 11.5mm
Weight: 130g with battery/100g without battery
Display: 3.7-inch touch screen
Processor/speed: 1GHz Snapdragon processor
Camera: 5 megapixels, auto focus, LED flash, location tagging from AGPS receiver
Memory: 512MB Flash, 512MB RAM, 4GB microSD card slot (expandable to 32GB)
Ports: 3.5mm stereo headphone jack with four contacts for inline voice and remote control
Battery: removable 1,400 mAh
Extras: GPS and compass, accelerometer, light sensor that changes screen brightness to conserve power, personalised laser engraving (up to 50 characters on the back of the phone)

Global internet phenomenon Google enters the consumer electronics market as a select audience is invited to witness the unveiling of the Nexus One mobile handset. On 5 January, members of the press gathered to catch a glimpse of the much-anticipated Nexus One that was finally revealed at Google's California HQ. Built by Taiwanese smartphone manufacturer HTC, the device runs on the Android 2.1 operating system with a 1GHz Snapdragon processor.

The handset will enable users to download and install applications onto target hardware with no need for a PC. Among many other features, the device boasts voice-recognition text entry, dynamic noise-cancelling technology, satellite-navigation system Google Maps Navigation, easy communication between social networking sites, access to over 18,000 applications, and a five-megapixel camera. It's a decent phone for sure, but whether it is an 'iPhone killer', as has been speculated, remains to be seen.

What's most interesting about Google's Nexus is what it represents for the company's long-term plans. Google is clearly aspiring to assume a prominent role in the mobile communications industry and is confident that this phone will bring the world of the internet and the mobile handset closer together, as VP of engineering Andy Rubin explains: "The Nexus One belongs in the emerging class of devices which we call 'superphones', with the 1GHz Qualcomm Snapdragon™ chipset making it as powerful as your laptop computer of three to four years ago. It's our way to raise the bar on what's possible when it comes to creating the best mobile experience for consumers."

In America, Nexus One will be available to buy straight from Google's online store for $529 (£330 approx) and then as part of a two-year T-Mobile contract from $179 (£112 approx). In the UK the Nexus will eventually be available through Vodafone.

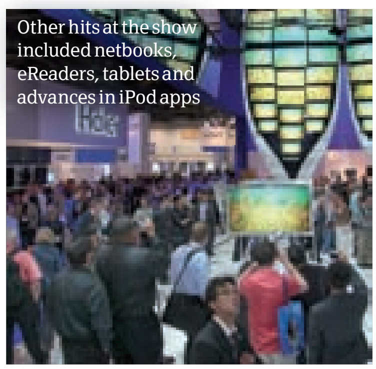
A new decade of innovation

Advanced tech and impressive new kit wows attendees at CES

The 2010 International Consumer Electronics Show (7–10 January) played host to over 20,000 new products as the biggest names in the business came together to showcase the latest technology.

Among the big developments was Microsoft's news that its controller-free gaming initiative Project Natal will be available by Christmas. Ford also revealed its myFord Touch venture that enables drivers to tweet via an in-dash interface. Intel displayed TV technology, including 3DTV and Wi-Di (or Wireless Display), enabling users to stream content by linking their PC to an HDTV.

These are exciting times for technophiles, as the president and CEO of the Consumer Electronics Associations, Gary Shapiro, confirms: "The innovations unveiled this week […] brought new optimism and opportunity to our industry and the global economy. This show exceeded expectations with its innovation and excitement. What a great way to kick off the new decade."



Other hits at the show included netbooks, eReaders, tablets and advances in iPod apps

1938 Surely contravening all road safety laws, the land speed record on a public road is exceeded by a Mercedes Benz W195, driven by German racing driver Rudolf Caracciola, who reached a speed of 268.9mph.

1958 Lego wisely patents the design of its popular coloured bricks.

1986 All seven of the crew on board Space Shuttle Challenger were tragically killed when the shuttle broke apart 73 seconds after lift off.

HOW IT WORKS TV

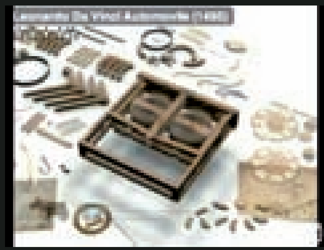
The How It Works website is regularly updated with the most amazing videos the net has to offer

Galactic dreams

Discover what it would be like to experience a suborbital spaceflight on Virgin Galactic's SpaceShipTwo in this rather impressive animation.

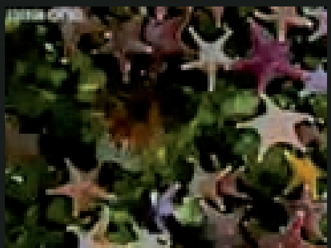
Da Vinci's automobile

A short clip revealing the components and mechanics of Leonardo Da Vinci's amazing automobile invention.



Time waits

Last issue we showed you a rather breathtaking video of high-speed footage, so this month we decided to slow it down a bit with some awesome time-lapse photography.



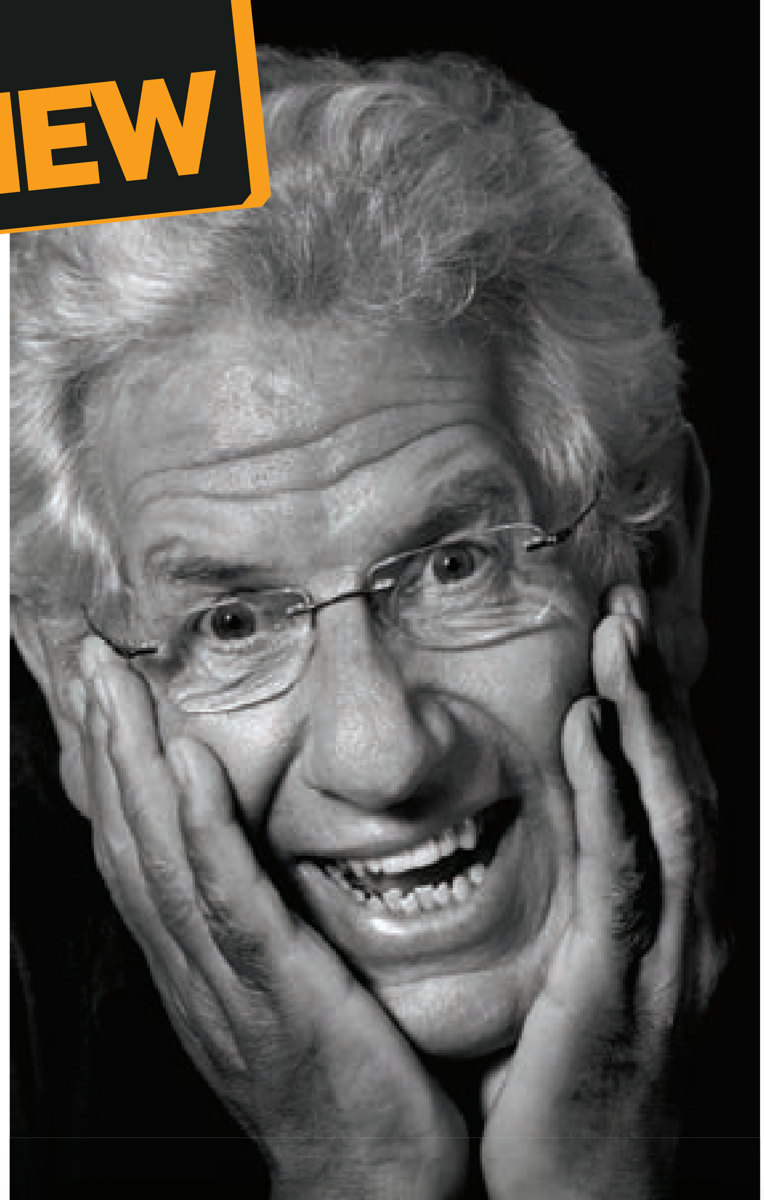
The Meissner effect

Watch as the Meissner effect causes a magnet to levitate when it is put opposite a super-cooled superconductor.

GLOBAL EYE INTERVIEW

A fresh look at the world

Adam Hart-Davis



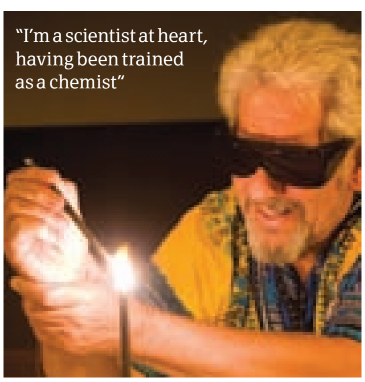
You might well recognise Adam Hart-Davis from presenting the BBC television series *Local Heroes* and *What The Romans Did For Us*. He's also a direct descendant of King William IV and is therefore fifth cousin once removed of Queen Elizabeth II. We caught up with him for a chat about what currently whets his appetite in the world of science and technology

HIW: You're described as a scientist, author, photographer, historian and broadcaster. Which order would you put them in to best describe yourself?

Adam Hart-Davis: I'm a scientist at heart, having been trained as a chemist, and so I look at the world with a scientific eye. I'm a broadcaster whenever anyone gives me the chance, because it's fun. I write books and articles to keep the wolf from the door – and because I enjoy writing. I am no historian, even though the BBC seems to think I am; my only qualification in history is that I failed O-level. I love taking photographs, but sadly don't often find time for photography.

HIW: In your TV series, *Just Another Day*, you investigated the fantastic inventions that made our daily lives easier from a cup of tea to the razor. Which invention do you consider to be the biggest unsung hero of our daily life?

AHD: Fundamentally the most important invention of all time was the Newcomen engine (1712), because that provided portable power for the first time – and it lies behind all the engines we have today. Probably the most useful invention that we all take for granted is the chair; are you sitting comfortably?



"I'm a scientist at heart, having been trained as a chemist"

HIW: Your latest book for Dorling Kindersley is simply titled *Science*. Can you tell us a little about the book and what it hopes to offer the reader?

AHD: *Science: The Definitive Visual Guide*, is a massive (5kg) volume that attempts to cover the whole of science and the whole of the history of science in one beautifully illustrated book. Each 'story' is covered in a single spread; so you can open the book at random and read about global warming, or Isaac Newton, or the development of the wheel, without having to turn a page. The ideas are grand, but the language is simple, and most of the book should be accessible to a bright ten-year-old.

HIW: Another of your recent books, *History*, attempts to summarise the world in one volume which seems an incredibly ambitious premise. How on earth did you go about co-ordinating such an massive project?

AHD: *History: The Definitive Visual Guide*, is an equally ambitious book, and splendid fun. I had nothing to do with the planning, but I did read all the spreads, in random order, and wrote hundreds of comments. I take little credit, but it's a lovely book.

HIW: What were some of the most mind-blowing facts to come out of both of the projects?

AHD: In both books I absolutely love the illustrations and the biographies: the awful pictures of the Lisbon earthquake and 'the gadget' (the first atom bomb), and the biographies from Alexander the Great and Genghis Khan, to Dorothy Hodgkin and James Lovelock.

"I am no historian, even though the BBC seems to think I am; my only qualification in history is that I failed O-level"

HIW: What projects have you got planned for 2010?

AHD: I am hoping to present a TV programme for BBC2 about John Harrison and his marine chronometers, write a book about time, and make a piano stool and a wooden clock.

HIW: How It Works magazine explains how everything we take for granted in the world actually works – all the way from the light bulb to the Bugatti Veyron. What is the one thing you have no idea how it works, but you would most like to know?

AHD: I have no real understanding about how computers work – especially complex software like Photoshop – but I don't really want to know. As Arthur C Clarke said, any sufficiently advanced technology is indistinguishable from magic, and even though I do understand them, I prefer to think of satnavs and iPods as magic. I would like to know how glue works – from Araldite to Post-it notes.

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

AHD: I was given an iPod shuffle recently, and I love it, but my most useful gadget is my computer.

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

AHD: I do a lot of green woodwork, and my next gadget, if I can find one, is a hand-brace with a three-jaw chuck, which should be capable of securely holding bits with hexagonal shanks.

CAREER

1943 Born on the fourth of July in Hertfordshire, Hart-Davis was the youngest child of his publisher father, Sir Rupert Hart-Davis.

1961 Reads chemistry at Merton College, Oxford, where he received a First, after being educated at Eton College in his teenage years.

1977 Begins 17 years of programme making at Yorkshire Television as a researcher with Magnus Pyke.

1985 Invents and produces the wildly successful *Scientific Eye*, which is used in 70 per cent of UK secondary schools.

1992 Moves to a presenting role in the successful television show *Local Heroes*, which sees Hart-Davis cycle around the country talking about science.

2000 Films the first of many acclaimed BBC history shows with *What The Romans Did For Us*.

2009 > PRESENT Continues as a popular face on the BBC, presenting *How Britain Was Built* among many other shows.

This month in Science

Ever wondered how it all began? This month's Science section sees us attempt to answer that question as we explain what scientists currently know about the big bang and the birth of the universe.

SCIENCE

Human digestion

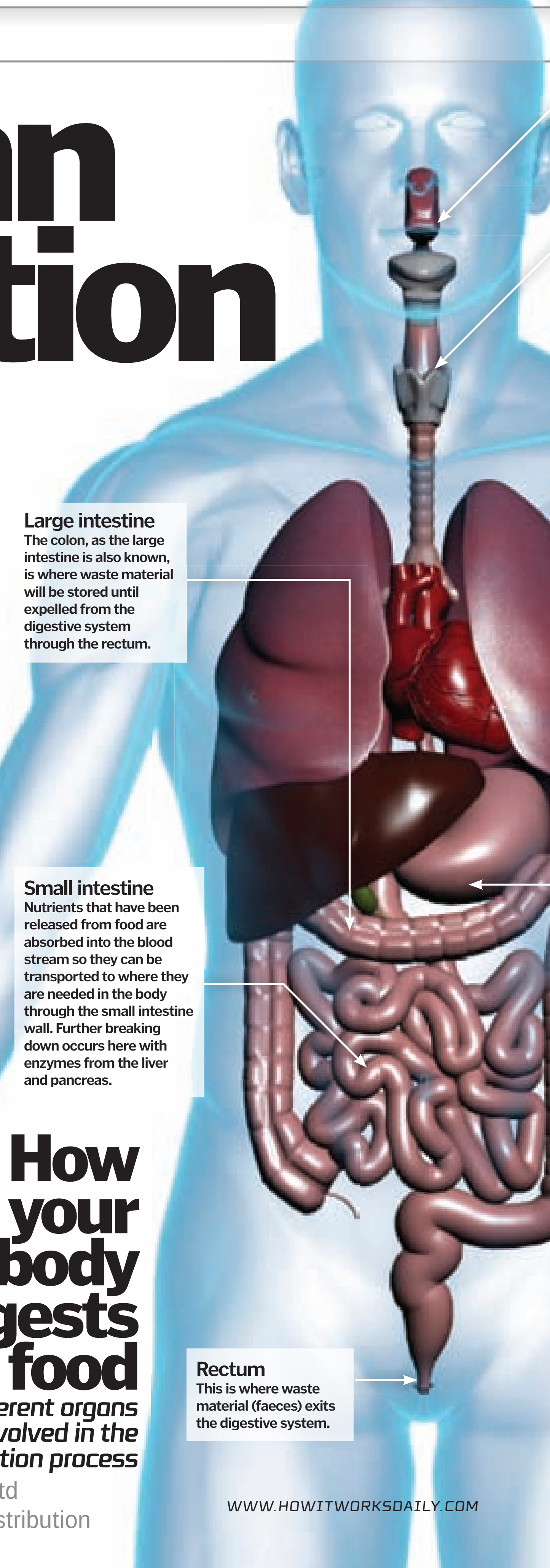
How does food get turned into energy?

The digestive system is a group of organs that process food into energy that the body can use to operate. It is an immensely complex system that stretches all the way between the mouth and the anus.

Primary organs that make up the system are the mouth, oesophagus, stomach, small intestine, large intestine and the anus. Each organ has a different function so that the maximum amount of energy is gained from the food, and the waste can be safely expelled from the body. Secondary organs, such as the liver, pancreas and gall bladder, aid the digestive process alongside mucosa cells, which line all hollow organs and produce a secretion which helps the food pass smoothly through them. Muscle contractions called peristalsis also help to push the food throughout the system.

The whole digestive process starts when food is taken into the body through the mouth. Mastication (chewing) breaks down the food into smaller pieces and saliva starts to break starch in these pieces of food into simpler sugars as they are swallowed and move into the oesophagus. Once the food has passed through the oesophagus, it passes into the stomach. It can be stored in the stomach for up to four hours. The stomach will eventually mix the food with digestive juices that it produces, and this breaks down the food further into simpler molecules. These molecules then move into the small intestine slowly, where the final stage of chemical breakdown occurs through exposure to juices and enzymes released from the pancreas, liver and glands in the small intestine. Nutrients are then absorbed through the intestinal walls and transported around the body through the blood stream.

After all nutrients have been absorbed from food through the small intestine, resulting waste material, including fibre and old mucosa cells, is then pushed into the large intestine where it will remain until expelled by a bowel movement.



How your body digests food

Many different organs are involved in the digestion process

5 TOP FACTS DIGESTION

Complete digestion takes time!
1 Generally, it can take between 24 and 72 hours for the food you eat to be fully digested, meaning you're constantly digesting food!

Some food for thought…
2 An average male will eat approximately 50 tons of food during his lifetime. That's the equivalent of ten African elephants.

The stomach can hold two litres
3 The stomach will normally feel full when it reaches a capacity of one litre, but ultimately it can stretch up to two litres.

We use pints of saliva a day!
4 Up to four pints of saliva can be produced by an individual each day and it helps to digest food and protect teeth and tissue inside the mouth.

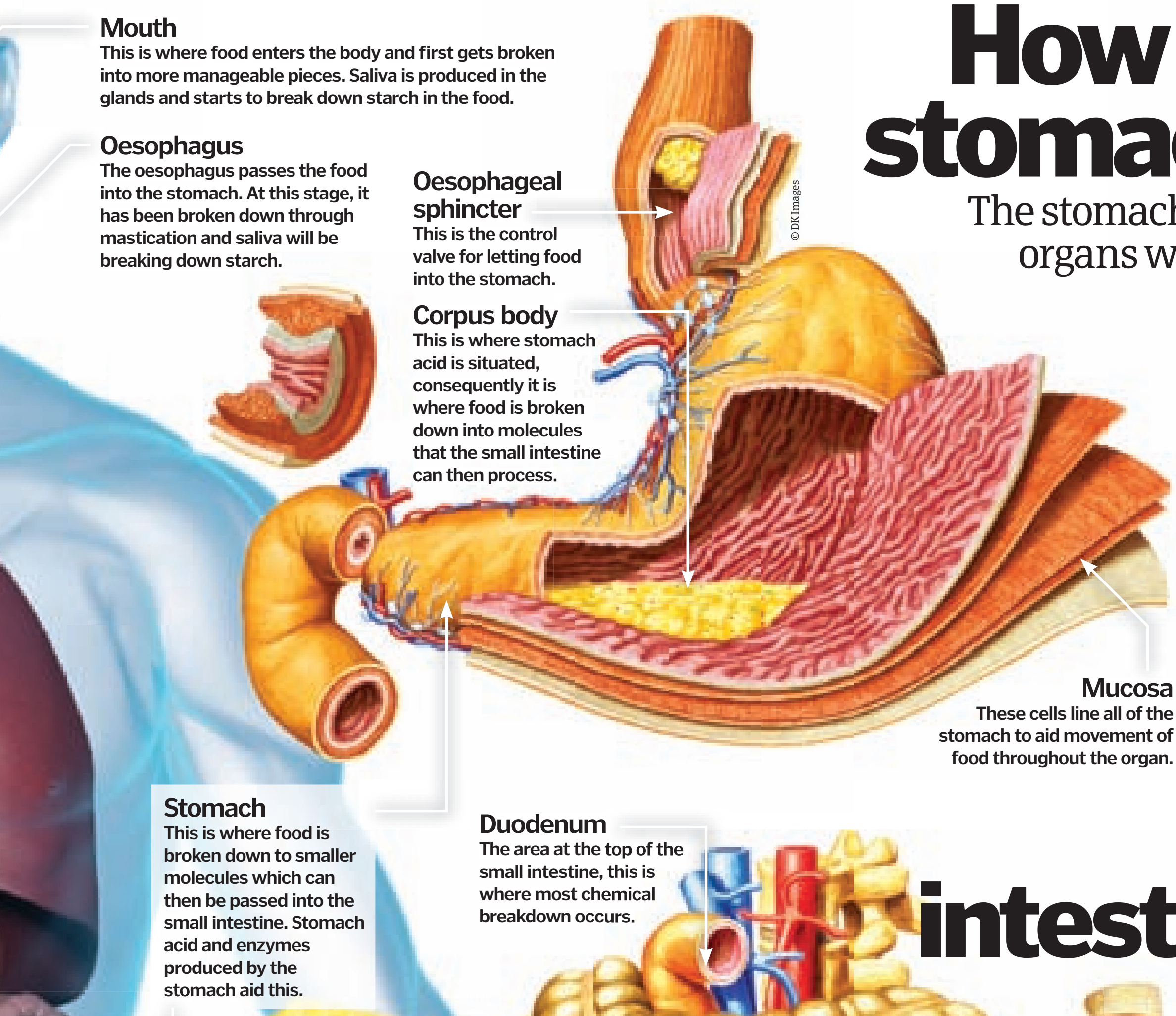
Enzyme production declines through age
5 Enzymes are crucial for digestion, but as we age, enzyme production reduces – at 70 a person may produce half what they did at 20.

DID YOU KNOW? *The human digestive system is between 20 to 30 feet long!*

How does our stomach work?

The stomach is one of the most crucial organs within the digestive system

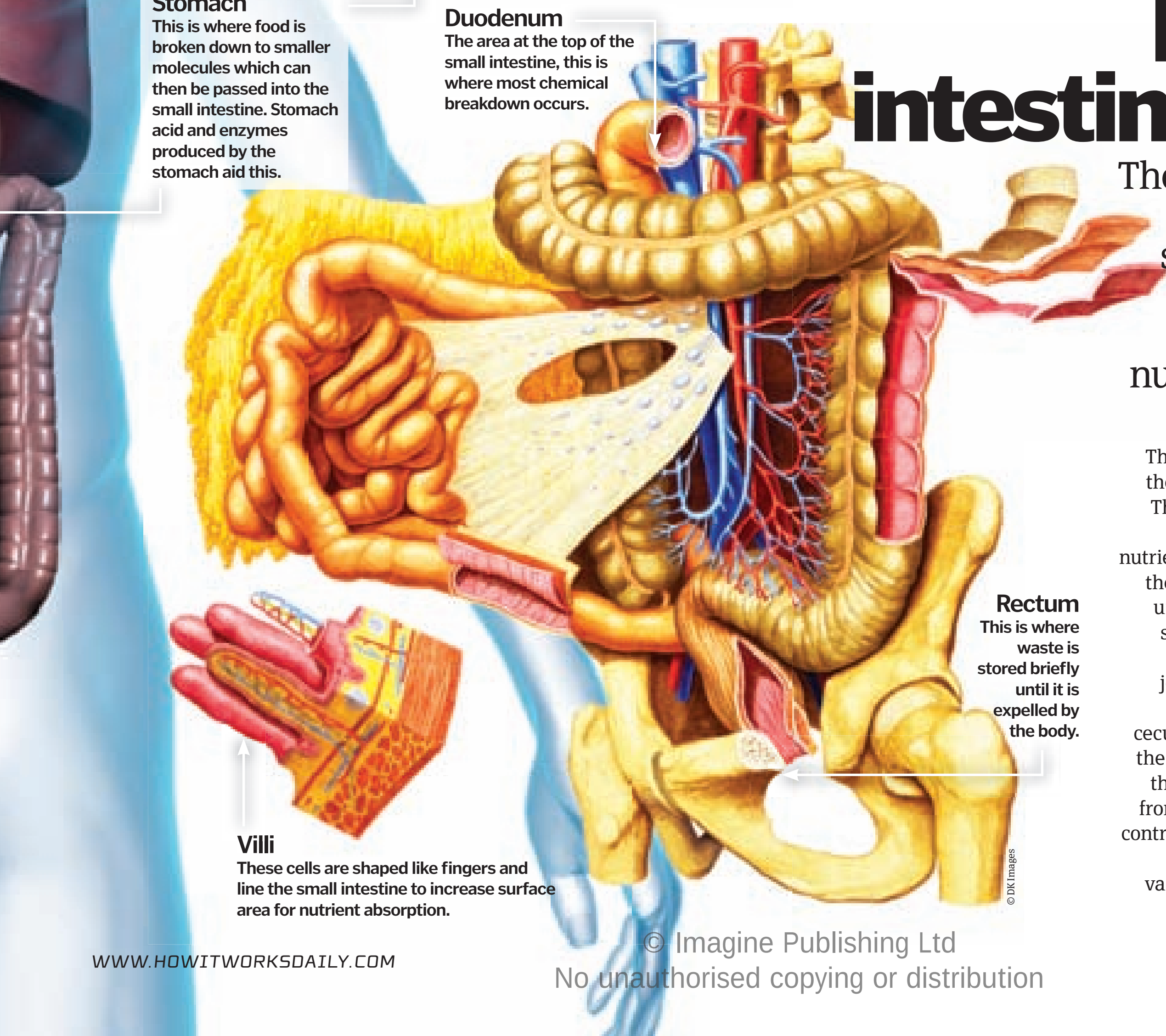
The stomach's function is to break down food into simple molecules before it moves into the small intestine where nutrients are absorbed. The organ actually splits into four distinct parts, all of which have different functions. The uppermost section is the cardia, where food is first stored, the fundus is the area above the corpus body, which makes up the main area of the stomach where food is mixed with stomach acid. The final section is the antrum, containing the pyloric sphincter, which is in control of emptying the stomach contents into the small intestine. Food is passed down into the stomach by mucosa and peristalsis through the oesophageal sphincter, and then mixed in the stomach with acids and juices by muscle contractions.



How the intestine works

The intestine is a crucial part of the digestive system that is heavily involved in breaking down and absorbing nutrients released from ingested food

The intestine splits into two distinct parts, the small intestine and the large intestine. The small intestine is where the food goes through final stages of digestion and nutrients are absorbed into the blood stream, the large intestine is where waste is stored until expelled through the anus. Both the small and large intestines can be further divided into sections, the duodenum, jejunum and ileum are the three distinct sections of the small intestine and the cecum, colon and rectum are the sections of the large intestine. As well as storing waste, the large intestine removes water and salt from the waste before it is expelled. Muscle contractions and mucosa are essential for the intestine to work properly, and we see a variation of mucosa, called villi, present in the lower intestine.



"Gyroscopes can be seen in practice everywhere"


Image © NASA

A gyroscope is even used to navigate the Hubble telescope

Gyroscopes

How does a gyroscope defy gravity?

Gyroscopes have their place in a wide variety of realms and have been utilised for a plethora of purposes from fascinating office toys to adrenaline-infused fairground rides to navigational equipment in space shuttles – gyroscopes can be seen in practice everywhere.

A gyroscope measures and maintains orientation based on the principles of angular momentum and appear to defy gravity – an effect know as precession. Precession occurs when you try to rotate its spin axis, and instead the gyroscope attempts to rotate about its axis at right angles to the external torque. Essentially this means the device is a spinning wheel with an axle that is free to take any orientation. When the gyroscope is spinning what happens to these parts follows Newton's first law of motion; ie a body in motion continues to move at constant speed along a straight line unless acted upon by an unbalanced force. Therefore the top point of the gyroscope is acted on by the force applied to the axle and begins to move. Precession causes the different sections of the gyroscope to receive forces at one point but then rotate to new positions, always remaining perpendicular to the 'spin axis'. The forces acting on the top and bottom of the wheel act against each other and force the wheel to spin, creating a gravity-defying illusion.

Gyroscopes are used in a huge variety of applications, including navigation when magnetic compasses do not work, such as those found in the Hubble telescope, or aviation where they are an integral part of any jet-powered aeroplane.

Barometers

It's not only the weatherman who can predict the weather

Barometers work by measuring air pressure, the force of the air pressing down on the Earth's surface and the key element in determining weather conditions. There are multiple types of barometer, however the traditional mercury-based device works by balancing mercury over a reservoir within a glass tube, against the acting atmospheric pressure. If the weight of the encased mercury is lower than the atmospheric pressure then it rises as it is pushed up the tube, higher than that of the mercury and it falls to fill the gap. This allows you to determine if the present weather system has high or low pressure, the crucial factor in predicting weather conditions.

Air pressure determines weather conditions as if the air temperature is high then it rises, creating a low-pressure region that expands and cools at altitude, with any water it contained being condensed into clouds. If the air temperature falls then its pressure will increase as it gets closer to the ground and instead of its water being condensed into clouds, it will be dispersed over the region as rain. Therefore, if the level of the mercury within the barometer's tube is high then the air pressure is low and rain is likely, while if the level is low then the air pressure is high and weather will be fair.


Mercury? Under pressure? There's a song in that

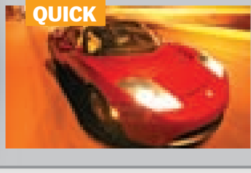
© Hannes Grobe

Lava lamps

Lava lamps, as well as being an icon of Seventies disco, are a hypnotic example of convection currents at work

Famed for the hypnotising ebb and flow of interesting-shaped blobs of heated wax, the lava lamp has fascinated generations, but how do they work? Well, the lamp is fitted with a halogen or incandescent bulb which warms the glass container – usually shaped in a tall tapered design. The glass bottle contains water and a glycerol derived additive and a portion of opaque lava – made of a mix of wax and carbon tetrachloride. The wax, denser than water at room temperature, loses some of its density as it is heated by the bulb, transforming it into a malleable fluid that ascends to the surface, as it moves away from the heat source it cools in the cooler water at the top, and so it becomes denser once more and sinks back to the bottom, where it starts the process over again.

Head to Head
SUPERCAR ACCELERATION



1. Tesla Roadster
Facts:
One of the world's fastest electric cars, the Tesla can accelerate to 60mph in four seconds.

2. Koenigsegg CCX
Facts:
Sharp by even Jeremy Clarkson's standards, the CCX hits 60mph in 3.2 seconds. Blimey!

3. Bugatti Veyron 16.4 Grand Sport
Facts:
The daddy of them all, the world's fastest car the Bugatti Veyron screams past 60mph in just 2.4 seconds!

DID YOU KNOW? *The cheetah is the world's fastest land mammal, accelerating to 60mph in just three seconds.*

Rollercoaster acceleration is typically measured against gravity, symbolised by the Roman unit g

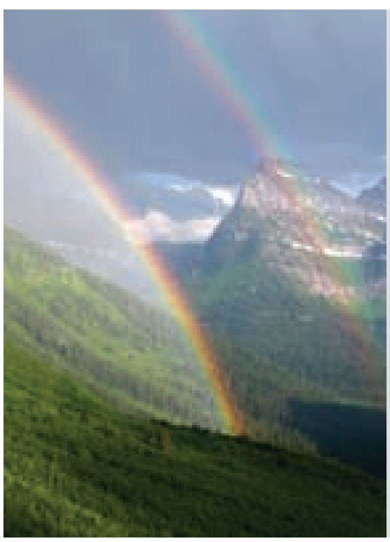
Acceleration and velocity

The relationship between acceleration and velocity is more complex than it first appears

Acceleration is the rate of change of velocity over time, with velocity being the rate of change of position. However, their relationship is not constricted, as is commonly understood, to merely increased mono-directional movement. This is because velocity is a vector physical quantity, requiring both speed and direction to define it. So absolutely any change in speed – including a decrease – is classed as acceleration, as is any change of directional motion, regardless of a speed increase or decrease. Therefore, it is not only a supercar that accelerates from 0-60, but also a spinning globe, dropped ball and rotating compass.

To attain an object's present acceleration its velocity should be divided by time, or in unit terms, by dividing metres per second by seconds. So if a ball is thrown across a room at a velocity of six metres per second into a container, and the whole action takes three seconds, then the ball's acceleration would be six divided by three and therefore two metres per second. However, as acceleration is a vector quantity (measured against both the rate of change in speed and direction), this figure is then squared to achieve the full measurement of 2m/s2. It is important to note, however, that acceleration can be measured as both average acceleration and instantaneous acceleration, the former being velocity divided by time, while the latter acceleration at any given point in time.

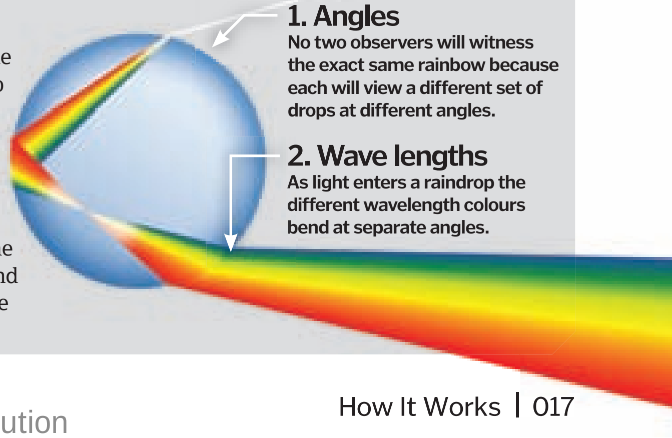
Acceleration can also be measured against gravity, symbolised by the Roman unit g, that in some situations – such as measuring the acceleration of rollercoasters – is a convenient benchmark where variations can be juxtaposed against it. For example, Earth's gravity is 1g, roughly 9.8m/s2, and if you drop an apple from your hand to the floor it accelerates at that speed. Rollercoasters – which provide their thrills by exposing people to large bursts of acceleration – increase and vary g from the natural 1g we are used to. This is why when riding a rollercoaster you can feel increased and decreased pressure on your body and also why, despite travelling often at no greater speed than 30mph, rides feel dangerous and fast.



I can see a rainbow

A meteorological phenomenon – we investigate how rainbows take shape

Marvelled for their beauty, rainbows have been inspiration for folk tales, but how are they made? Well, rainbows are refractions of light and are made of a series of colours: red, orange, yellow, blue, green, indigo and violet. As light travels in waves the colour of light that is emitted depends on the light's wavelength. When light travels through an object such as crystal or an individual raindrop, it bends and refracts. As light hits the water it bends according to its wavelength and refracts at separate angles. Drops at different angles send different colours to the eye. To see a rainbow you must have your back to the Sun and rain must be falling nearby – since each raindrop is lit by the white light of the Sun a spectrum of colours is produced.



1. Angles
No two observers will witness the exact same rainbow because each will view a different set of drops at different angles.

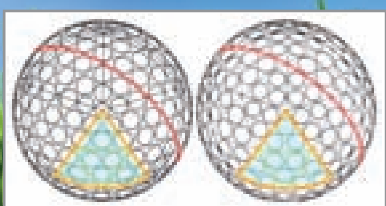
2. Wave lengths
As light enters a raindrop the different wavelength colours bend at separate angles.

How golf balls work

Golf balls can travel extreme distances thanks to a century of design evolution

The key to how a golf ball can fly such a massive distance lies in its hundreds of cover dimples. These dimples act as turbulators (a turbulator is any factor that increases the rate of turbulence involved with an object), creating a boundary layer cushion between the ball and the surrounding air, reducing drag while stabilising its flight path. By reducing drag on the struck ball, resistance to lift is also minimised and therefore the ball travels higher and further.

Modern golf balls are formed from multiple layers of synthetic materials, formed around a pressurised rubber core. This rubber core is encased in two half-circle thermoplastic shells within a compression mould to form the cover. It is during the compression process that the dimples are also added to the cover, of which there are typically 250 to 450 split into multiple triangular sections.



Magnetic attraction

Why is it some poles attract and others repel? Find out here

Magnetism is the force of attraction or repulsion – the 'pull' or 'push' that occurs due to a magnetic field. The action is caused by moving electrically charged particles in a magnetic field, which is an area consisting of lines of flux coming from spinning and moving electrically charged particles. These lines flow from one end of the object to the other – the magnetic field. Scientists have termed these ends 'poles'. The magnetic field of an object can create a force on other objects with magnetic fields too and this force is called magnetism. Attraction is what happens when two magnets or magnetic objects exhibiting opposite ends are close another together that there is a force that attracts the poles together. Repulsion happens when the two magnetic objects exhibit the same poles to each other and the magnetic force pushes them apart.

A magnetic force attracts an opposite pole of another magnetic object but repels a similar pole

Nuts and bolts

What are they and why do we use them?

A bolt or screw is characterised as a cylindrical fastener wrapped around by an external thread. This external thread is cut into the screw/bolt to either fit into a nut's internal thread (a nut being characterised as a fastener with a threaded hole), or to drive internal threads into other materials. The standard nut and bolt work by joining two overlapping materials while maintaining or providing structural integrity. For example, if you were joining two metal bars, a nut and bolt would need to provide enough friction/strength when tightened to prevent them from being pulled apart longitudinally.

Importantly, while the bolt and the screw are essentially the same in construction, they differ in definition. A bolt is an externally threaded fastener for use through holes in assembled parts and closed with a nut, while a screw is an externally threaded fastener for use where a nut is not necessary, being tightened and released by rotating its head.

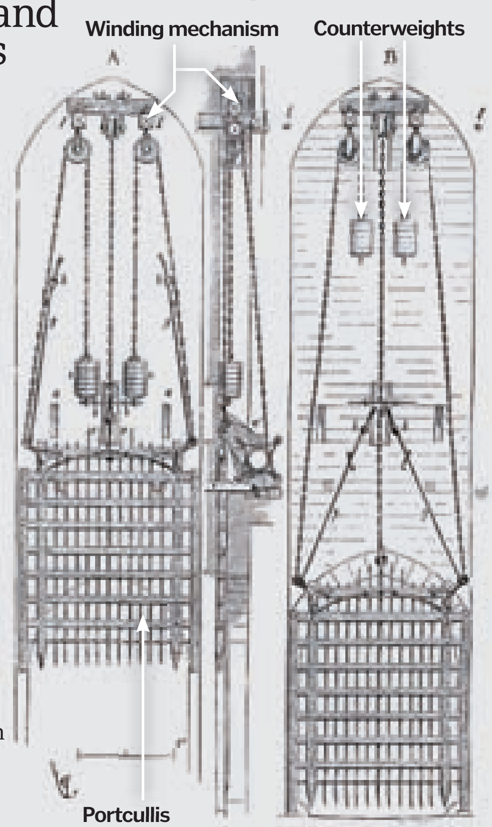
The proliferation worldwide of the nut, bolt and screw can be attributed to their small sizes, simplicity of use and colossal load-bearing potential.

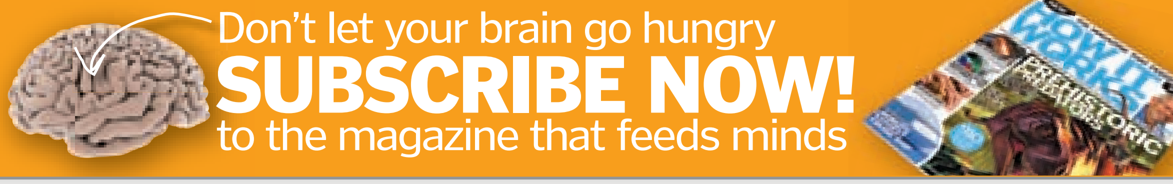
Counterweights

Used in cars, elevators and cranes, counterweights are all around us

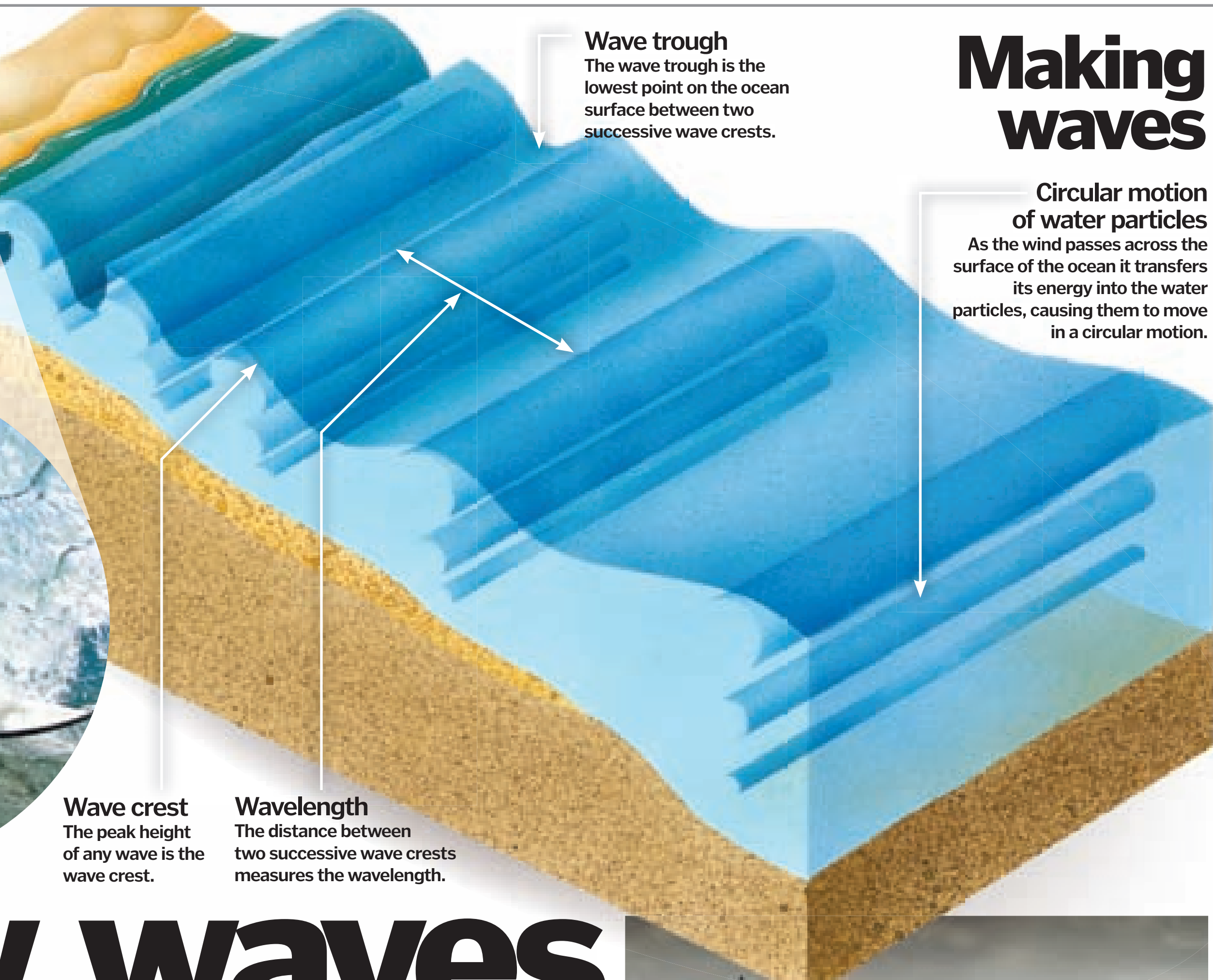
Counterweights work by the simple principle of equilibrium, cancelling out an equivalent weight over a pivot to balance a load. A good visual example of a counterweight system in its purest form can be seen in mechanical cranes, with its long working arm balanced out the other side of the shaft by the shorter, weight-carrying arm.

Counterweight systems have been prolific throughout history, from tremendous systems utilised in siege engines, to ingenious floating gate portcullises. Their success lies in the simplicity of their design but the potentially massive return in function. The portcullis for example, allowed just a couple of men to lift a gate of stupendous weight. This is because the counterweights balanced out the weight of the gate over a pivoted winding mechanism, meaning no energy was required to actually lift the gate other than that needed to operate the turn wheel. An example of early design can be seen in the diagram on the right.





Making waves




Surfing is a good way to wash off the smell of Old Spice

How waves are formed

Born out of transference of energy from wind to water, waves are a powerful and dangerous natural phenomenon


Waves carry tremendous amounts of energy over large distances

Waves are mainly formed across the surface of the sea through high winds transferring their energy into water particles. This transference of energy causes water particles to move in a repetitive circular motion, merge and then form an ocean swell which, when passed over the steeper gradient of the shore, forces it up to a point where it cannot support its own weight and breaks. Wave formation is effected by factors including current speed, water depth and wind speed.

Waves are also formed through vertical water displacement, the most devastating example of which can be seen in tsunamis. This mass water displacement – generally created by earthquakes or underwater landslides raising the seabed – transfers energy in a different way, passing energy to water particles so their resulting motion isn't circular but consistently forward. This causes tsunami waves not to roll back on themselves when forced over shallow terrain such as shoreline and creates a wave of tremendous length and shallow depth, as well as containing massive stored energy capable of devastating levels of destruction.

An individual wave is characterised through two parts, the trough (the low gap between two vertical waves) and the crest (the peak of a wave). The distance between two subsequent wave crests is the wavelength and the gap between each successive wave is called the wave period. Waves fall into two categories, with the distinction dependent on the ratio between length of wave and depth of water. If the water depth is shallow and the wavelength long, then the wave is classed as a shallow water wave. If it is the inverse of the latter, then it is classed as a deep water wave.

"Photosynthesis, simply put, is the process plants use to make food to live"

Photosynthesis

Plants need to eat but how do they do it?

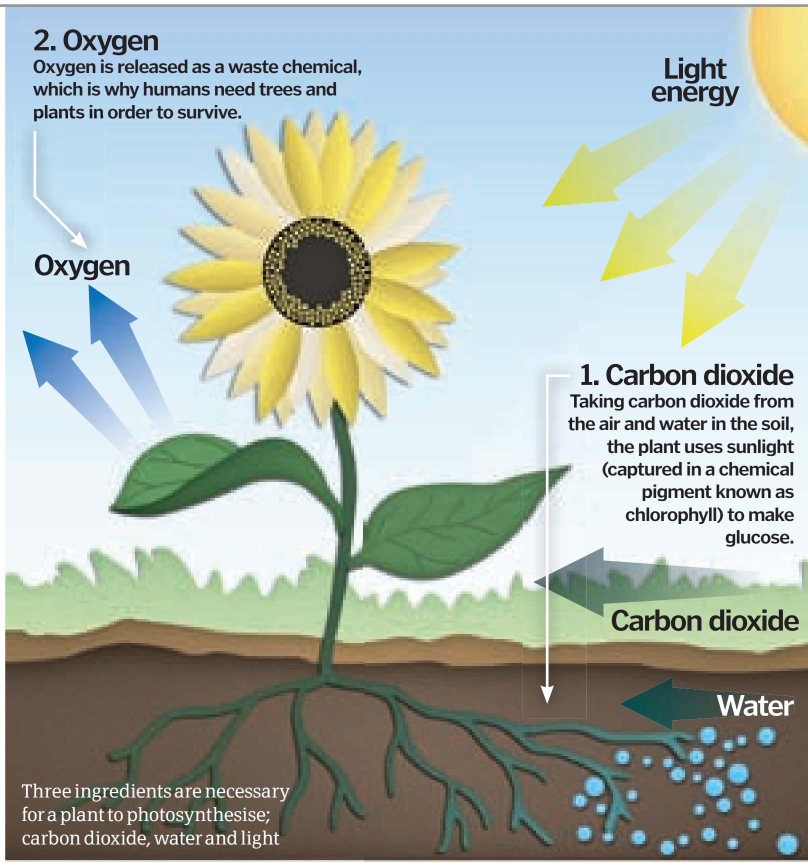
Photosynthesis is the process plants use to make food to live. Plants take carbon dioxide from the air and water (from rain) to make an organic chemical glucose – a food which plants absorb to survive. The process requires an input of energy and that is where sunlight comes in. Plants capture the energy from sunlight using a pigment called chlorophyll which converts light energy into chemical energy. Oxygen is released as a waste chemical. The formula is noted as:

Carbon dioxide + water – (sunlight) – Glucose + Oxygen, or:

$6CO_2 + 6H_2O$ – (sunlight) – $C_6H_{12}O_6 + 6O_2$

The process occurs in the leaves of the plant and each variety has evolved to make sure as much photosynthesis happens as possible, because the more a plant photosynthesises, the more food it can make and the faster and stronger it will grow – optimising its chances of survival. The leaf exhibits a waxy outer shell to restrict the loss of water as this is a crucial substance in the process.

The three ingredients a plant needs for photosynthesis to occur are carbon dioxide, water and light. The three factors which affect the rate at which a plant can produce glucose via this method is the concentration of carbon dioxide, temperature and light intensity. A plant will use glucose as a storage food substance such as starch – as in the case of potatoes or rice, or lipids in the case of seeds. It may convert the glucose into cellulose to make or repair cell walls and in other cases it forms amino acids which are used to produce proteins or chlorophyll to trap more sunlight to perpetuate the cycle.



Three ingredients are necessary for a plant to photosynthesise; carbon dioxide, water and light

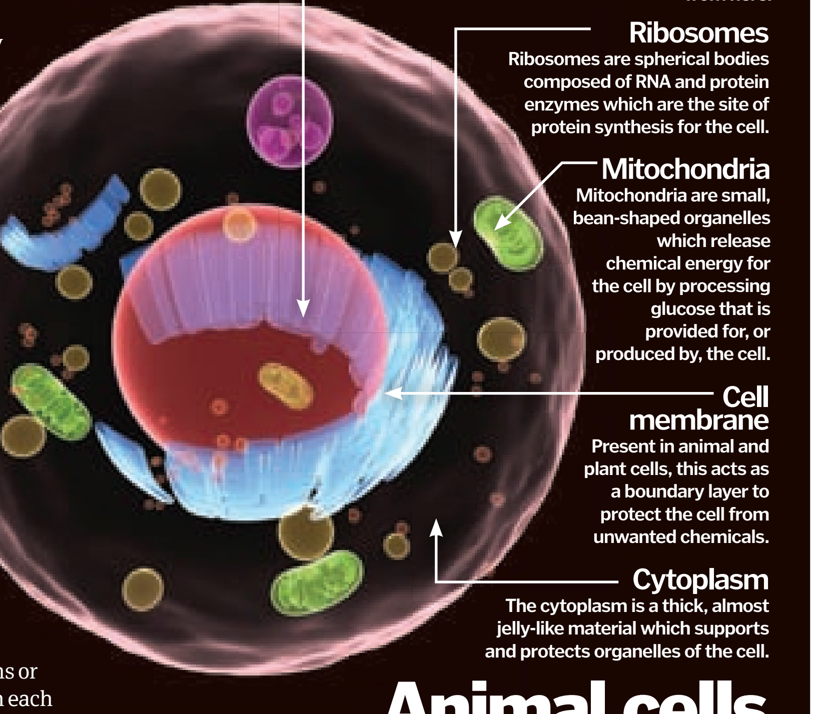
How cells work

The building blocks of life explained

Cells are the building blocks of all living organisms. Individual cells are classified as living things, and there are millions of organisms which are unicellular across the planet.

As they are living units, cells consequently need energy, and therefore respire to survive. Parts of the cell, called organelles, work like organs of a body. Energy for the cell to process can be provided by the cell, such as through photosynthesis in plants, or absorbed into the cell through cell membranes and then processed within it by the mitochondrion. Single cells operate like this, and there are billions of unicellular organisms that survive independently or within multicellular organisms. These single cell organisms are generally prokaryotic cells, which are much smaller and have fewer organelles, most importantly lacking a nucleus. Multicellular organisms are primarily made up of eukaryotic cells which are more complex and can therefore specialise so the organism can become more complex. They do this by grouping together to form tissues, which then group to form organs within the organism.

Cells reproduce to replace old, damaged cells in an organism, to allow growth or growth of a new individual. In unicellular organisms, cell reproduction is obviously the only way a population will grow. Prokaryotes favour binary fission, where all genetic information is doubled and then the cell divides into two new, identical cells. Eukaryote cells use either mitosis, which results in two identical organisms or cells, or meiosis, which results in each new cell having half the number of chromosomes of the original cell.



Animal cells

A typical, non-specialised animal cell

Bacteria thrive on human skin
1 Every square inch of skin has an average of 32 million bacteria on it… no matter how many baths or showers you have a day!

You shed skin every day!
2 Every 24 hours, you will lose your uppermost layer of dead skin cells, helping to keep your skin fresh and clean and able to breath.

Skin varies drastically in thickness
3 Skin is around 1mm thick on your eyelids, but on your feet this thickness increases to 3mm, giving you much more protection where needed.

As we age, skin thins
4 Skin thins over time and begins to loosen, which is where wrinkles come from, and why people opt for plastic surgery in later life.

We have billions of sweat glands
5 Each square inch of healthy skin contains close to 650 sweat glands, which are essential for keeping you cool.

DID YOU KNOW? *All mammals have hair on their skin, including marine mammals which appear hairless*

Under the skin

Find out more about the largest organ in your body…

Our skin is the largest organ in our bodies with an average individual skin's surface area measuring around two square metres and accounting for up to 16 per cent of total body weight. It is made up of three distinct layers. These are the epidermis, the dermis and the hypodermis and they all have differing functions. Humans are rare in that we can see these layers distinctly.

The epidermis is the top, waterproofing layer. Alongside helping to regulate temperature of the body, the epidermis also protects against infection as it stops pathogens entering the body. Although generally referred to as one layer, it is actually made up of five. The top layers are actually dead keratin-filled cells which prevent water loss and provide protection against the environment, but the lower levels, where new skin cells are produced, are nourished by the dermis. In other species, such as amphibians, the epidermis consists of only live skin cells. In these cases, the skin is generally permeable and actually may be a major respiratory organ.

The dermis has the connective tissue and nerve endings, contains hair follicles, sweat glands, lymphatic and blood vessels. The top layer of the dermis is ridged and interconnects securely with the epidermis.

Although the hypodermis is not actually considered part of the skin, its purpose is to connect the upper layers of skin to the body's underlying bone and muscle. Blood vessels and nerves pass through this layer to the dermis. This layer is also crucial for temperature regulation, as it contains 50 per cent of a healthy adult's body fat in subcutaneous tissue. These kinds of layers are not often seen in other species, humans being one of few that you can see the distinct layers within the skin. Not only does the skin offer protection for muscle, bone and internal organs, but it is our protective barrier against the environment. Temperature regulation, insulation, excretion of sweat and sensation are just a few more functions of skin.

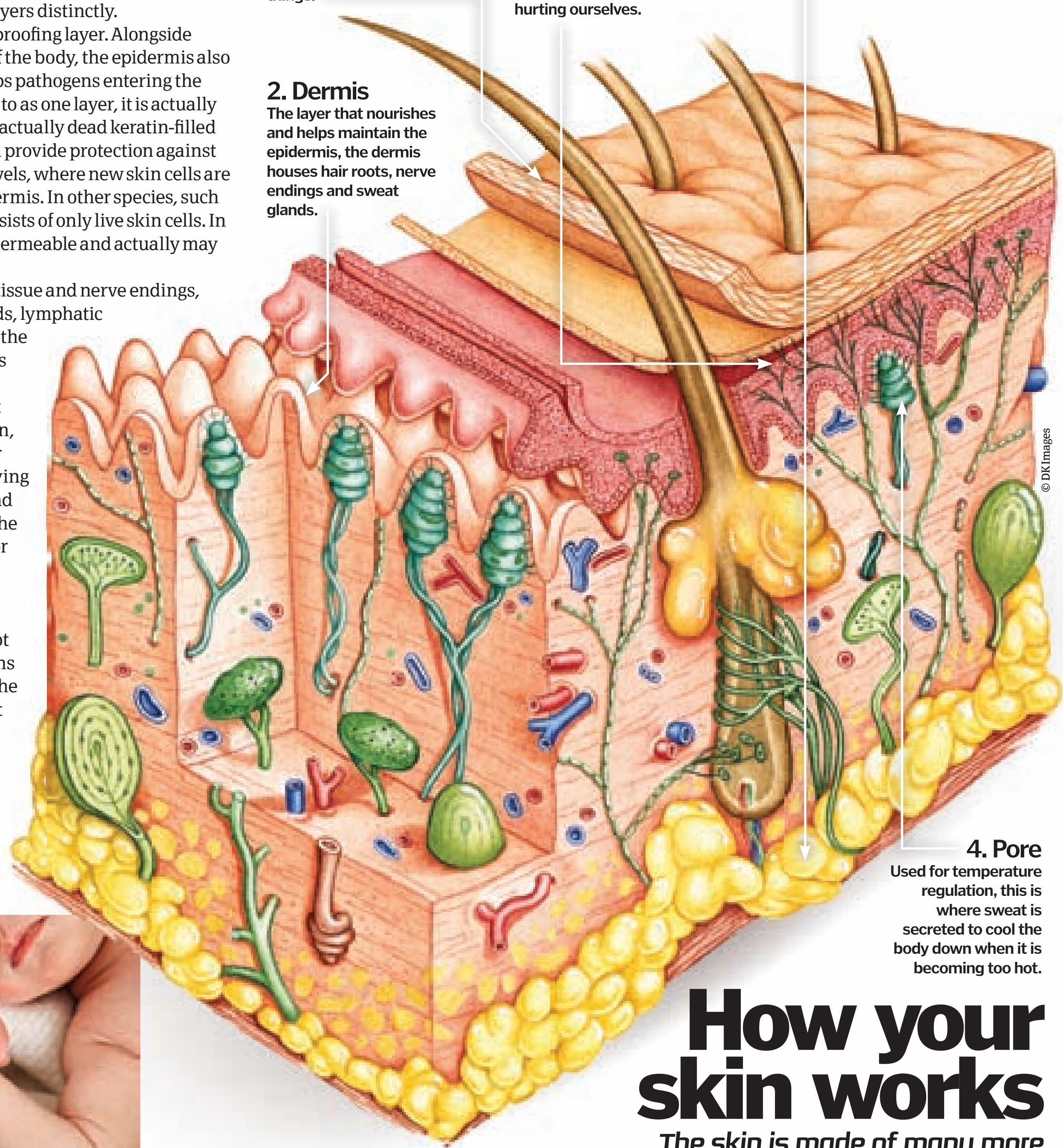

Baby-soft or old and wrinkly, skin is the largest organ in the body

1. Epidermis
This is the top, protective layer. It is waterproof and protects the body against UV light, disease and dehydration among other things.

2. Dermis
The layer that nourishes and helps maintain the epidermis, the dermis houses hair roots, nerve endings and sweat glands.

3. Nerve ending
Situated within the dermis, nerve endings allow us to sense temperature, pain and pressure. This gives us information on our environment and stops us hurting ourselves.

5. Subcutaneous tissue
The layer of fat found in the hypodermis that is present to prevent heat loss and protect bone and muscle from damage. It is also a reserve energy source.



4. Pore
Used for temperature regulation, this is where sweat is secreted to cool the body down when it is becoming too hot.

How your skin works

The skin is made of many more elements than most people imagine

"The bubble, many times smaller than a single proton, contained all matter and radiation in our current universe"

The big bang

As an elegant explanation of the origins of both atoms and galaxies, the big bang is the ultimate theory of everything

The big bang theory begins with a simple assumption: if the universe is expanding and cooling – something Edwin Hubble and company proved at the beginning of the 20th Century – then it must have once been very small and very hot. From then on, the simple becomes infinitely complex. Big bang theory is nothing less than the summation of everything we've learned about the very big (astrophysics) and the very small (quantum physics) in the history of human thought.

Cosmologists – people who study the origin and evolution of the universe – theorise that 13.7 billion years ago, a bubble formed out of the void. The bubble, many times smaller than a single proton, contained all matter and radiation in our current universe. Propelled by a mysterious outward force, the bubble instantaneously expanded (it didn't explode) by a factor of 1,027, triggering a cosmic domino effect that created the stars, the galaxies and life as we know it.

The Planck era

Time: Zero to 10^{-43} seconds

The Planck era describes the impossibly short passage of time between the absolute beginning of the universe (zero) and 10-43 seconds (10 trillionths of a yoctosecond, if you're counting). In this fraction of an instant, the universe went from infinite density to something called Planck density (1093g/cm3), the equivalent of 100 billion galaxies squeezed into the nucleus of an atom. Beyond the Planck density, rules of General Relativity don't apply, so the very dawn of time is still a complete and utter mystery.

ERA

TIME

Inflation era

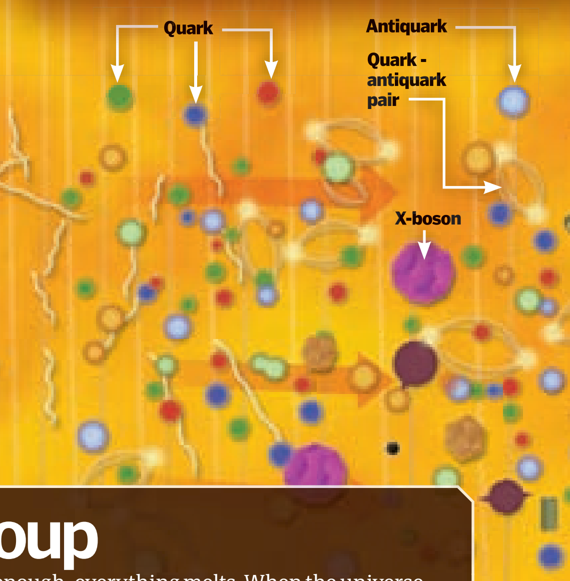
10^{-36} to 10^{-32} after big bang

In the Eighties, cosmologists theorised a period of spontaneous expansion in the very early moments of time. Instantaneously, every point in the universe expanded by a factor of 1,027. The universe didn't get bigger, it just was bigger. Because the universe got so big, so fast, its naturally spherical shape appeared flat to objects on the surface, solving one of the early problems with big bang theory.

Quark era

10^{-32} to 10^{-12}

After the explosive inflation period, the universe was a dense cauldron of pure energy. Under these conditions, gamma rays of energy collided to briefly form quarks and anti-quarks, the fundamental building blocks of matter. Just as quickly, though, the quarks and anti-quarks collided in a process called annihilation, converting their mass back to pure energy.

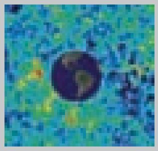


Particle soup

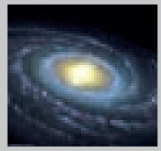
If you turn the heat up high enough, everything melts. When the universe was 10-32 seconds old, it burned at a magnificent 1,000 trillion trillion degrees Celsius. At this remarkable temperature, the tiniest building blocks of matter – quarks and anti-quarks, leptons and anti-leptons – swirled freely in a particle soup called the quark-gluon plasma. Gluon is the invisible 'glue' that carries the strong force, binding quarks into protons and neutrons.

3 TOP FACTS EVIDENCE FOR THE BIG BANG

Background radiation
1 Cosmic microwave background radiation – which fills the universe uniformly – is the super-cooled afterglow from the original big bang.



Expanding universe
2 Galaxies outside of the Milky Way move away from us at a rate proportional to their distance from us, pointing to a continual expansion from a single source.



Big bang nucleosynthesis
3 Big bang theory predicts that the earliest atoms to emerge from the dense particle soup were hydrogen and helium in a 3:1 ratio. Using powerful telescopes and spectrometers, cosmologists confirm that the observed universe is 74 per cent hydrogen, 25 per cent helium and one per cent heavier elements.

DID YOU KNOW? *None of the essential elements of human life (carbon and oxygen) were created during the big bang*

Let there be light

The primordial soup of the early universe was composed of pairs of particles and anti-particles (mostly quarks, anti-quarks, leptons and anti-leptons). Picture this ultra-hot, supercharged environment as the original super collider. Particles and anti-particles smashed together in a process called annihilation, producing beams of photons (light radiation). As more particles collided, more light was generated. Some of those photons reformed into particles, but when the universe finally cooled enough to form stable atoms, the spare photons were set free. The net result: the universe contains a billion times more light than matter.

X-bosons

A funny thing happened at 10-39 second after the beginning of time. The universe produced huge particles called X-bosons (1,015 times more massive than protons). X-bosons are neither matter nor anti-matter and exist only to carry the Grand Unified Force, a combination of the electromagnetic, weak and strong forces that exist today.

The Grand Unified Force drove the early expansion of the universe, but rapid cooling caused X-bosons to decay into protons and anti-protons. For reasons that aren't clear, a billion and one protons were created for every billion anti-protons, creating a tiny net gain of matter. This imbalance, forged during a short blip in time, is the reason for our matter-dominated universe.

Recreating the big bang

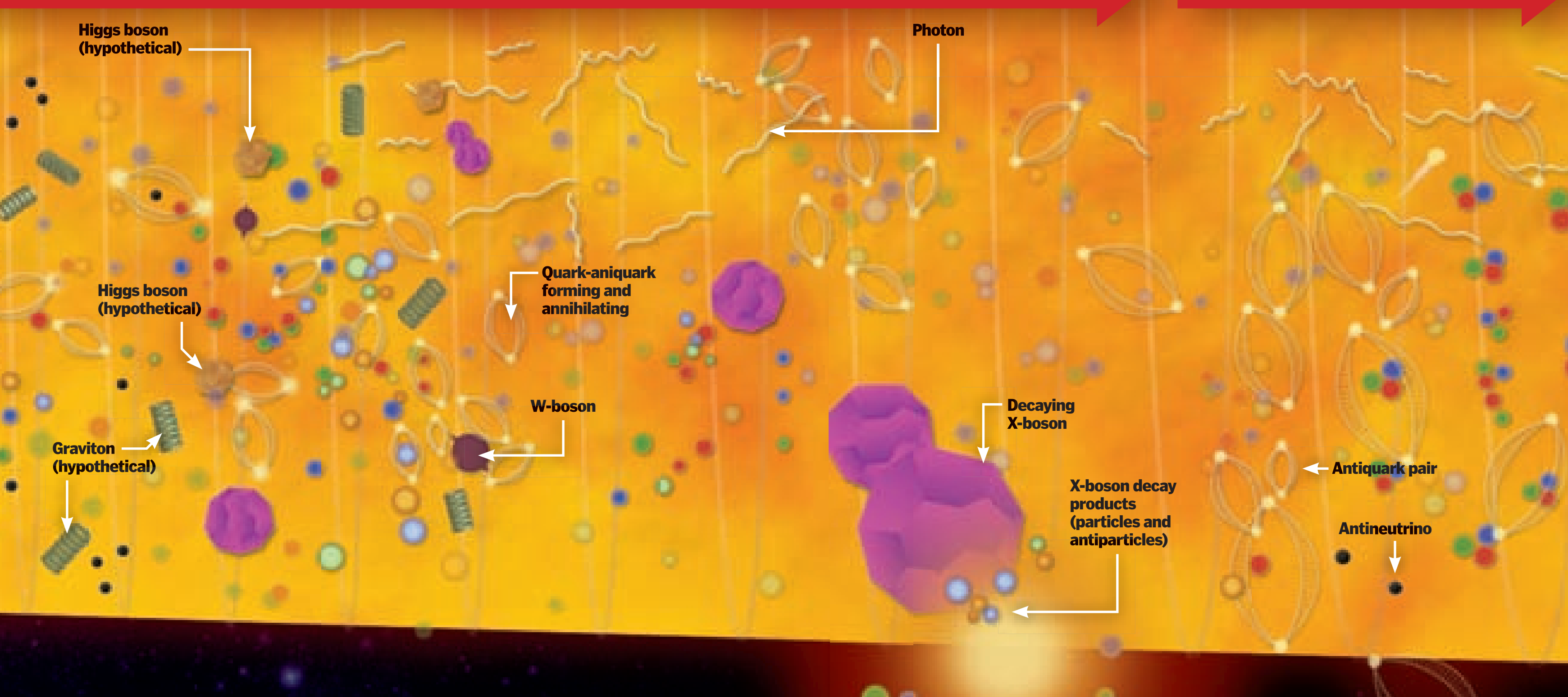
CERN's Large Hadron Collider (LHC) is the world's largest particle accelerator. At full power, trillions of protons will travel at near light speed through super-cooled vacuum tubes buried 100 metres below the surface. As the protons smash into each other – at a rate of 600 million collisions per second – they will generate energy 100,000 times hotter than the Sun, a faithful recreation of the cosmic conditions milliseconds after the big bang. Using ultra-sensitive detectors, scientists will scour the debris trails for traces of quarks, leptons and even the Higgs boson, a highly theoretical particle believed to give mass to matter.

A computer simulation of the decay path of a Higgs boson after two protons collide in the LHC

Separation of the Electroweak force

During the Planck era, the four forces of nature were briefly unified: gravity, the strong force, electromagnetism and the weak force. As the Planck era ended as the universe cooled, gravity separated out, then the strong force separated during the inflation. But it wasn't until the end of the Quark era that the universe was cool enough to separate the electromagnetic and weak forces, establishing the physical laws we follow today.

110^{-9} to 10^{-62}



"72 per cent is dark energy, a bizarre form of matter that works in opposition to gravity"

The origins of matter

Everything in the universe – the galaxies, the stars, the planets, even your big toe – is made of matter. In the beginning (roughly 13.7 billion years ago), matter and radiation were bound together in a superheated, super-dense fog. As the universe cooled and expanded, the first elemental particles emerged: quarks and anti-quarks. As things cooled further, the strong force separated, pulling together clumps of quarks into protons and neutrons, building the first atomic nuclei. Half a million years later, conditions were finally cool enough for nuclei to pull in free electrons, forming the first stable atoms. Small fluctuations in the density of matter distribution led to clusters and clouds of matter that coalesced, over hundreds of millions of years, into the stars and galaxies we explore today.

Dark forces

So what is the universe made of? Well, there is more to the universe than meets the eye. Cosmologists have proven that the visible or 'luminous' portions of the cosmos – the stars, galaxies, quasars and planets – are only a small fraction of the total mass and composition of the universe. Using super-accurate measurements of cosmic microwave background radiation fluctuations, scientists estimate that only 4.6 per cent of the universe is composed of atoms (baryonic matter), 23 per cent is dark matter (invisible and undetectable, but with a gravitational effect on baryonic matter), and 72 per cent is dark energy, a bizarre form of matter that works in opposition to gravity. Many cosmologists believe that dark energy is responsible for the accelerating expansion of the universe, which should be contracting under its own gravitational pull.

Hadron era

When the expanding universe cooled to 1,013K (ten quadrillion degrees Celsius), quarks became stable enough to bond together through the strong force. When three quarks clump together in the right formation, they form hadrons, a type of particle that includes protons and neutrons. Miraculously, every single proton and neutron in the known universe was created during this millisecond of time.

Lepton era

During this comparatively 'long' era, the rapidly expanding universe cools to 109K, allowing for the formation of a new kind of particle called a lepton. Leptons, like quarks, are the near massless building blocks of matter. Electrons are a 'flavour' of lepton, as are neutrinos.

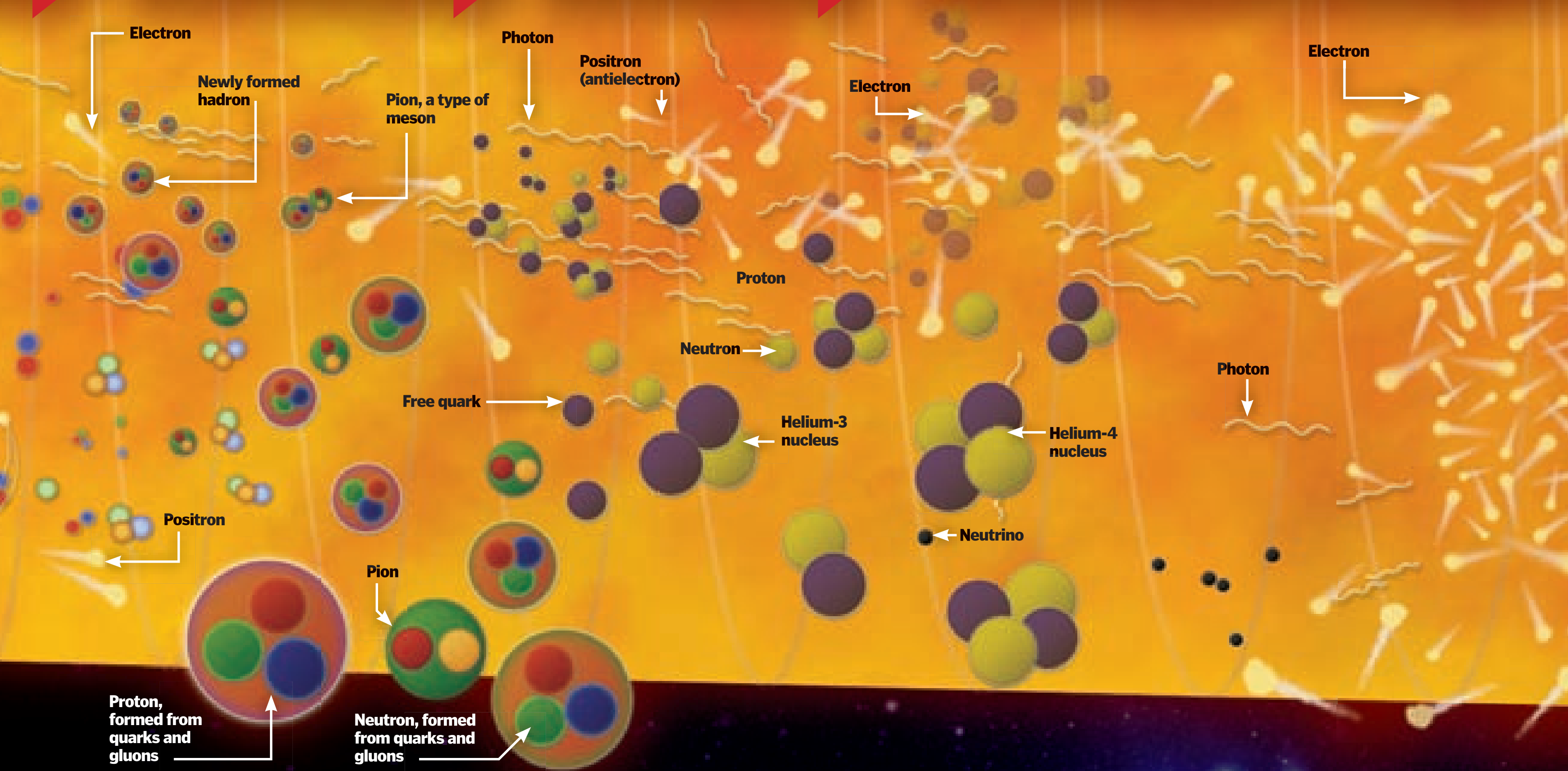
Nucleosynthesis era

For 17 glorious minutes, the universe reached the ideal temperature to support nuclear fusion, the process by which protons and neutrons bond together to form atomic nuclei. Only the lightest elements have time to form – 75 per cent hydrogen, 25 per cent helium – before fusion winds down.

10^{-6} to 1 second

1 second to 3 minutes

3 minutes to 20 minutes



Head to Head Scientists

MOST FAMOUS

1. Albert Einstein
Einstein's revolutionary Theory of General Relativity paved the way for the idea that all matter in the universe was uniformly distributed from a common source.

LESS FAMOUS

2. Edwin Hubble
Calculated that galaxies moved away from one another at a rate relative to the distance between them, first proving that the universe was expanding.

LEAST FAMOUS

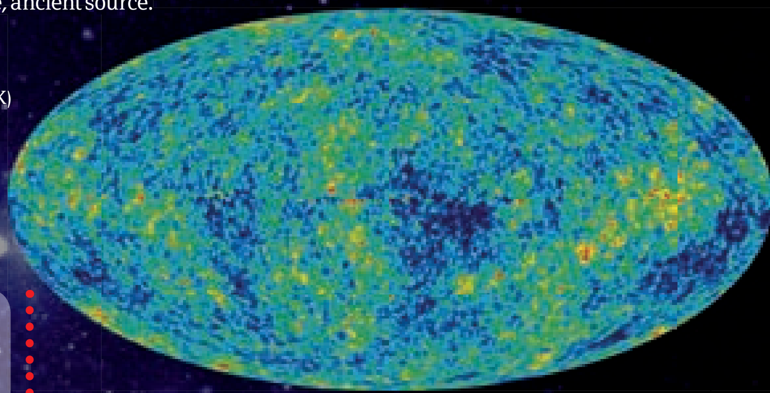
3. Gamow, Alpher & Herman
In the Forties, these three analysed the creation of elements from the big bang's fallout, discovering that only hydrogen and helium could've been produced in large quantities.

DID YOU KNOW? *If there were more matter in the universe, its mass would be too great and it would collapse on itself*

Cosmic microwave background radiation

The residual heat from the big bang can give us a clue to the origin of the universe

As the universe expands, it also cools. The inconceivable heat released during the big bang has been slowly dissipating as the universe continues its 14 billion-year expansion. Using sensitive satellite equipment, cosmologists can measure the residual heat from the big bang, which exists as cosmic microwave background radiation (CMBR). CMBR is everywhere in the known universe and its temperature is nearly constant (a nippy 2.725K over absolute zero), further proof that the radiation emanated from a single, ancient source.



Minute differences in microwave background radiation levels (+/-0.0002K) reveal fluctuations in the density of matter in the primitive universe

Opaque era

These are the 'dark ages' of the universe, when light and matter were intertwined in a dense cosmic fog. Photons of light collided constantly with free protons (hydrogen ions), neutrons, electrons and helium nuclei, trapping the light in a thick plasma of particles. It is impossible for cosmologists to 'see' beyond this era, since there is no visible light.

Balance of elements

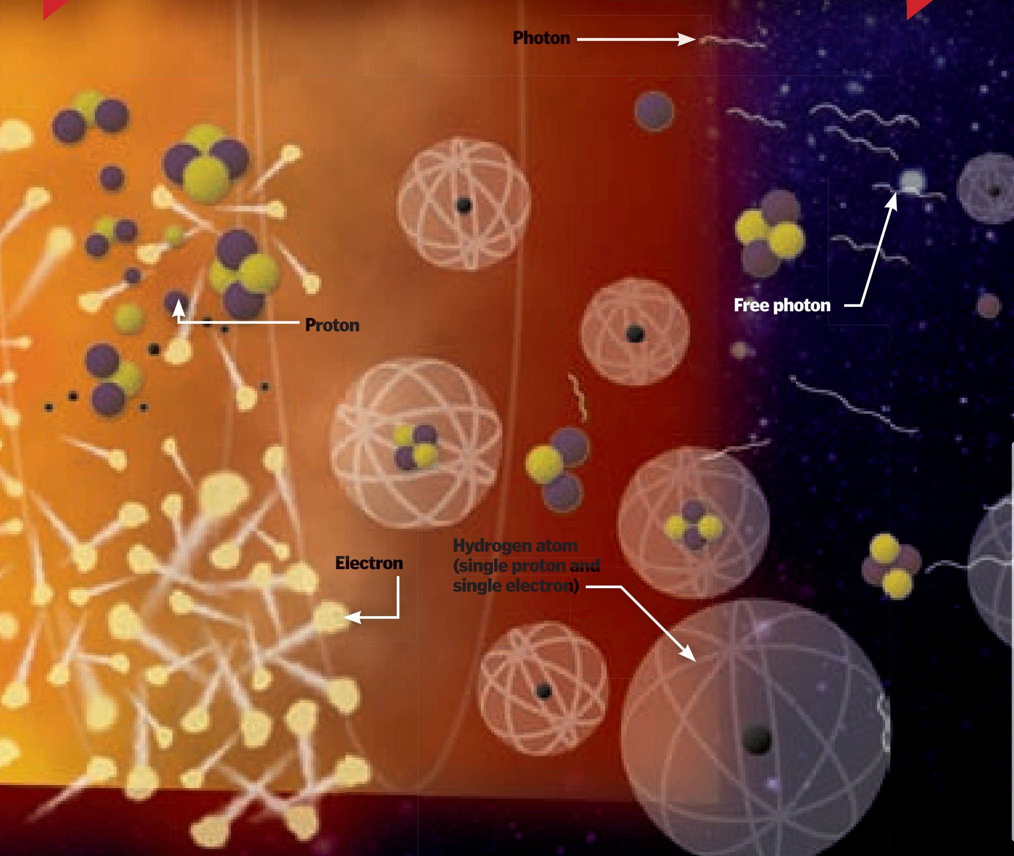
When the temperature dropped to 10,000K, electrons slowed down enough to be pulled into orbit around atomic nuclei, forming the first stable, neutral atoms of hydrogen, helium and other trace elements. As atoms started to form, photons were freed from the cosmic fog, creating a transparent universe. All cosmic background radiation originated with this 'last scattering' of photons.

Matter era

During the Opaque era, matter and light were stuck together as plasma. Photons of light applied radiation pressure on matter, preventing it from bonding together to form atoms and larger particles. When light and matter 'decoupled', the radiation pressure was released as light, freeing matter to clump and collect in the first clouds of interstellar gas. From there, the first stars were born around 400 million years after the big bang.

20 minutes to 377,000 years

500,000 to the present



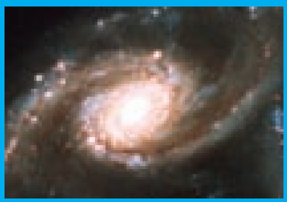
The 'God' particle

We take for granted the idea that if something is made of protons, neutrons and electrons, then it inherently has mass. But cosmologists now believe that no particle has mass simply by merit of its existence. Instead, mass is bestowed on particles as they pass through a Higgs field, a theoretical quantum field named after British physicist Peter Higgs. Imagine the Higgs field as a bowl of honey and quantum particles as a string of pearls. As you drag the pearls through the honey, they are imbued with mass. Every quantum field has a fundamental particle, and the particle associated with Higgs field is the Higgs boson. One of the goals of the Large Hadron Collider at CERN is to prove the existence of the elusive Higgs boson once and for all.

This month in Space

Any idea what this picture is? It's M42, otherwise known as the Orion Nebula, and it is one of the most famous nebulae known to man. And we can see it thanks to the Hubble telescope, which has been providing stunning images of space for the past 19 years. This issue, we've taken a look at just how it provides us with a God's-eye view of the universe.

29 Hubble telescope



30 Types of galaxies

33 Asteroids

SPACE

Venus: Earth's sister planet

Discovering just how similar this planet actually is to Earth…

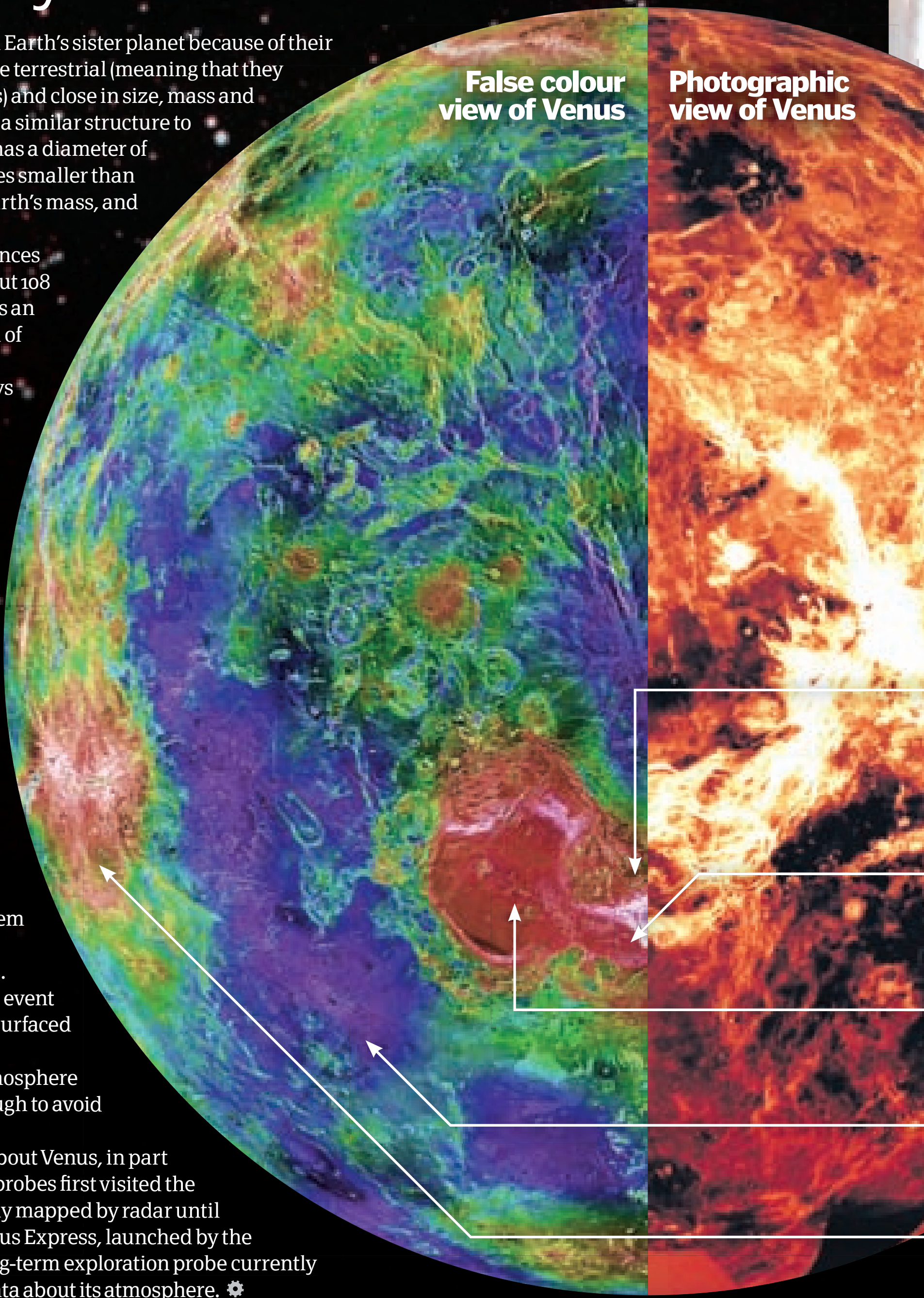
Venus has often been called Earth's sister planet because of their similarities. Both planets are terrestrial (meaning that they are made up of silicate rocks) and close in size, mass and gravity. Venus probably has a similar structure to Earth, with a crust, mantle and core. It has a diameter of around 12,000 kilometres, 650 kilometres smaller than Earth. Its mass is about 80 per cent of Earth's mass, and its gravity 90 per cent of Earth's gravity.

However, there are also many differences between Venus and Earth. Venus is about 108 million kilometres from the Sun and has an almost perfectly circular orbit, while all of the other planets have elliptical orbits. Venus completes one orbit every 225 days and has one of the slowest rotations of any planet, with one every 243 days. Venus's consistently high temperature means that it has no surface water.

The planet also has more than 1,500 volcanoes, many of which are more than 100 kilometres across. Most of the volcanoes are extinct, but some believe that there has been recent volcanic activity. Because Venus doesn't have rainfall, lightning could have been caused by ashy fallout from a volcanic eruption. These eruptions have created a rocky, barren surface of plains, mountains and valleys.

Venus is also covered with more than 1,000 impact craters. While Earth and other planets also have craters, Venus's are unusual because most of them are in perfect condition. They haven't degraded from erosion or other impacts. Venus may have experienced a massive event as much as 500 billion years ago that resurfaced the planet and changed its atmosphere completely. Now bodies entering its atmosphere either burn up or are slowed down enough to avoid making a crater.

It has proven difficult to learn more about Venus, in part due to its dense atmosphere. Although probes first visited the planet in the early Sixties, it was not fully mapped by radar until the 1989 NASA Magellan probe. The Venus Express, launched by the European Space Agency in 2005, is a long-term exploration probe currently orbiting the planet and sending back data about its atmosphere.



5 TOP FACTS VENUS

Venus has phases like a moon
1 When closest to the Earth, Venus appears bright and crescent-shaped. When it is further away, the planet is dim and round.

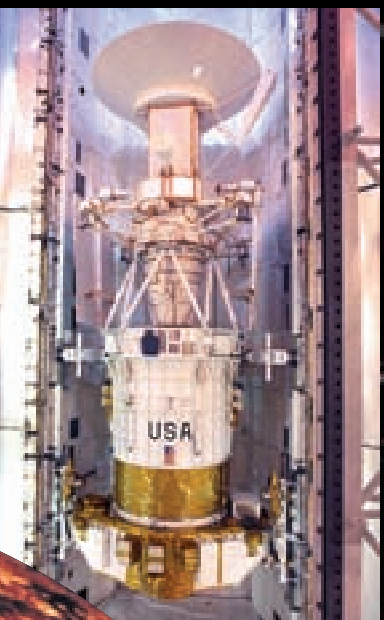
Venus rotates backwards
2 Venus has a retrograde, or west to east, rotation. This is actually the opposite direction of its revolution around the Sun.

Venus was the first 'probed' planet
3 NASA's Mariner 2 probe was launched in 1962. It passed within 30,000 kilometres of Venus and took microwave and infrared readings.

Venus has no moons
4 Venus probably had a moon billions of years ago, but it was destroyed when the planet's rotation direction reversed.

Venus is brighter than the stars
5 Venus is brighter than any star and can be easily seen in the middle of the day, especially when the Sun is low in the horizon.

DID YOU KNOW? Because Venus shines so brightly, it has often been misreported as a UFO



The NASA Magellan spacecraft

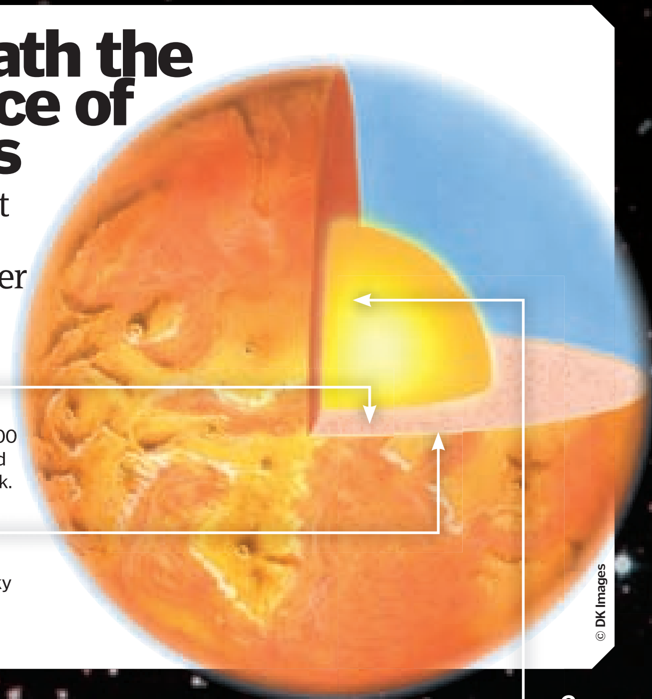
Venus' atmosphere

Immense pressure of the atmosphere

Venus's atmospheric pressure is greater than that of any other planet – more than 90 times that of Earth's. This pressure is equivalent to being almost one kilometre below the surface of Earth's oceans. The atmosphere is also very dense and mostly carbon dioxide, with tiny amounts of water vapour and nitrogen. It has lots of sulphur dioxide on the surface. This creates a Greenhouse Effect and makes Venus the hottest planet in the solar system. Its surface temperature is 461 degrees Celsius across the entire planet, while Mercury (the closest planet to the Sun) heats up to 426 Celsius only on the side facing the Sun.

Beneath the surface of Venus

What lies at the core of Earth's sister planet?



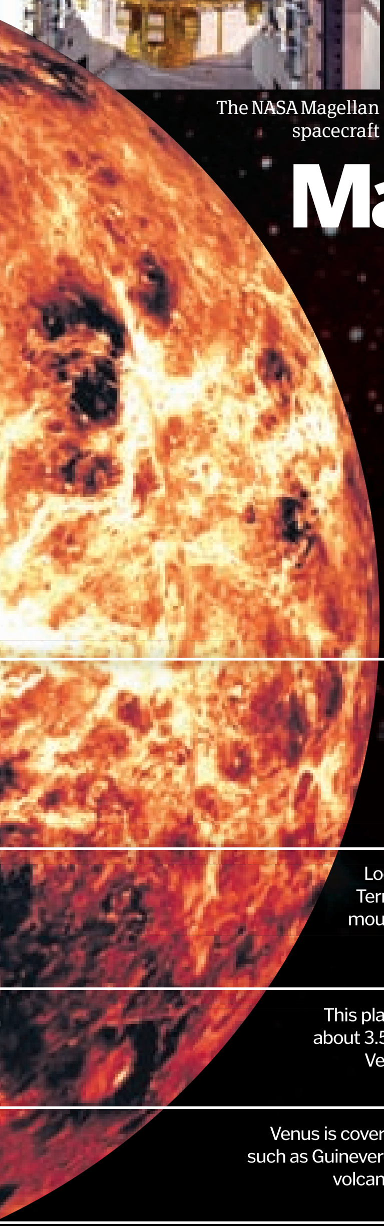
Mantle
Venus's mantle is probably about 3,000 kilometres thick and made of silicate rock.

Crust
Venus likely has a highly basaltic, rocky crust about 100 kilometres thick.

Core
Scientists believe that Venus's core is a nickel-iron alloy and partially liquid, with a diameter of 6,000 kilometres.

© DK Images

Mapping Venus



Red indicates highland areas and blue indicates lower elevations in the false-colour view of Venus

1. Ishtar Terra
One of two 'continents', or major highland areas, on Venus, Ishtar Terra is located at the planet's North Pole. It is a little smaller than the continental United States.

2. Maxwell Montes
Located on the north edge of Ishtar Terra, Maxwell Montes is the largest mountain range on Venus at nearly 11 kilometres high.

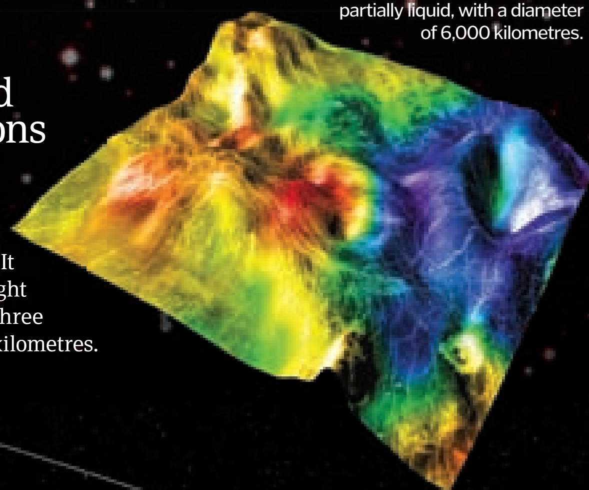
3. Lakshmi Planum
This plateau in western Ishtar Terra rises about 3.5 kilometres above the surface of Venus. It is covered with lava flows.

4. Guinevere Planitia
Venus is covered with regions of lowland plains such as Guinevere Planitia, which contains several volcanoes, impact craters and fissures.

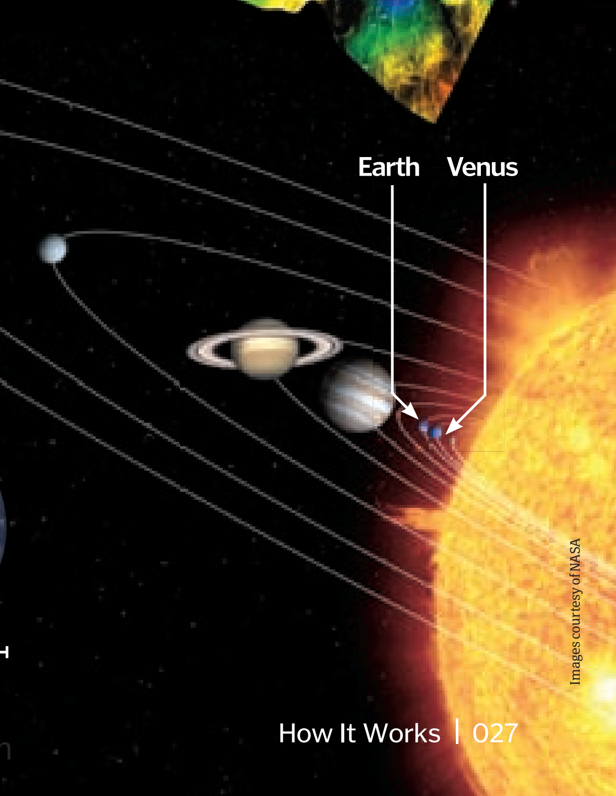
5. Beta Regio
Beta Regio is one of several volcanic rises on Venus's surface, more than 1,000 kilometres wide.

The surface of Venus

Venus is covered in broad plains and elevated regions dotted by volcanoes



This computer-generated image shows a 7,500-kilometre-long region on the northern hemisphere of Venus known as Eistla Regio. It contains two volcanoes, Gula Mons on the right and Sif Mons on the left. Gula Mons is about three kilometres high and Sif Mons stands at two kilometres.



Sizes…

Venus and Earth are very similar in size. Venus's diameter is only 650km less than that of Earth, and the mass is 81.5 per cent of Earth's.

Images courtesy of NASA

"They have to be built tougher and more rugged than the hardiest black box recorder"

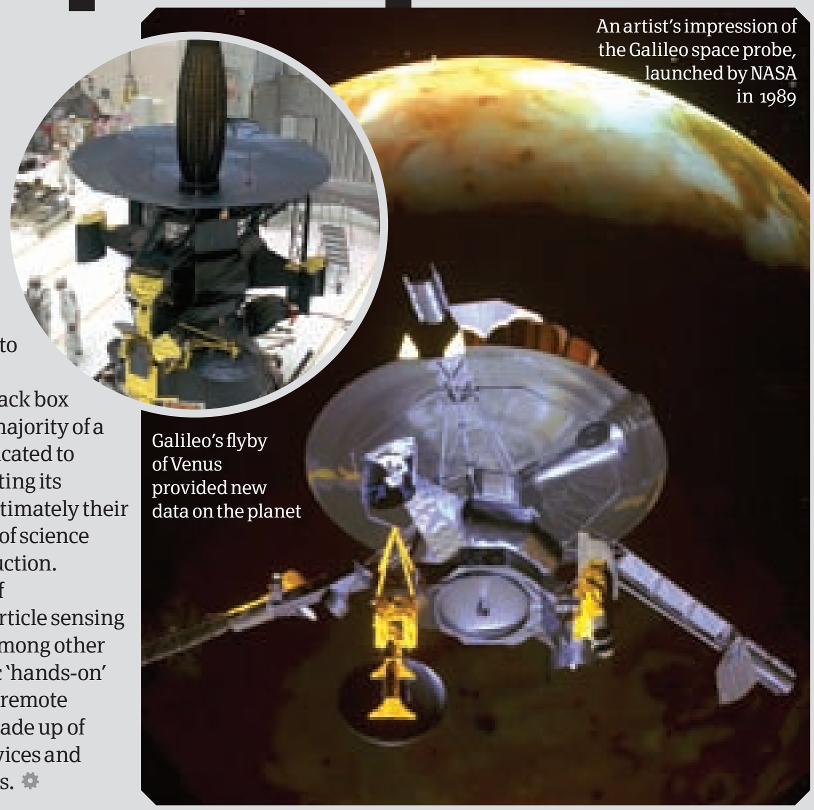
Unmanned space probes

They have made some of the most fundamental discoveries in modern science, but how do space probes work?

On 4 October 1957 the former Soviet Union launched the world's first successful space probe, Sputnik 1, heralding the start of the space race between Russia and the USA. In the initial ten years the vast majority of man's efforts to conduct scientific experiments in space were failures, and it wasn't until the late Sixties that successes were achieved. While many were chalked up to launch failures, most couldn't weather the harsh realities of space.

Withstanding temperature extremes is a monumental task in itself. Of course, it's not temperatures that pose problems for probes wanting to land in alien environments, they must also be capable of putting up with intense radiation and atmospheric pressures which fluctuate from pure vacuum to 90 times that of Earth's surface pressure and beyond. Russia's 1970 Venera 7 probe successfully landed on the surface of Venus and managed to send data back for just 23 minutes before being crushed under the immense pressure.

Not only do space probes have to act as highly sensitive scientific instruments, but they have to be built tougher and more rugged than the hardiest black box recorder. As such, the vast majority of a space probe's design is dedicated to sustaining itself and protecting its mission-critical systems. Ultimately their makers consider four fields of science while they're under construction. Engineering (ultimately self sustainability), field and particle sensing (for measuring magnetics among other things), probing (for specific 'hands-on' scientific experiments) and remote sensing, which is usually made up of spectrometers, imaging devices and infrared among other things.



An artist's impression of the Galileo space probe, launched by NASA in 1989

Galileo's flyby of Venus provided new data on the planet

Whether a spacecraft is manned or unmanned will affect how it reaches the moon's surface

Image courtesy of NASA

DID YOU KNOW? If for any reason the spacecraft is not slowed then it will impact upon the moon at over 2,500 miles per hour.

How spacecraft land on the moon

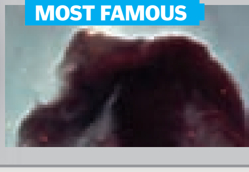
Unsurprisingly, it's not as easy as Wallace and Gromit made it look

For any spacecraft to land successfully on the moon many factors need to be considered, however, the most critical of these is deceleration. To carry a spacecraft out of the gravity well of the Earth's atmosphere, massive upward thrust is necessary, a force only currently possible with a rocket. However, when approaching the moon the massive velocity caused by the rocket (which has by now been detached), as well as the moon's gravitational attraction, means that the spacecraft's velocity is so high that any sort of safe landing is impossible. Therefore, in order to land, the spacecraft needs to decelerate massively. To achieve this, the spacecraft uses additional braking rockets to change its velocity as it nears the moon's orbit, slowing its speed of impact in order to land.

Landing even with these velocity-altering rockets is not as straightforward as it may appear. Even with the reduced speed of the craft, in order to be classed as a successful landing all operational ability needs to be maintained after the impact, both in terms of onboard technology and any astronauts. If the spacecraft is unmanned then the speed of impact can be higher, up to 100 miles per hour, but if there are astronauts on board then that speed needs to be much reduced. If for any reason the spacecraft is not slowed – due mainly to technology malfunction – then it will impact upon the moon at over 2,500 miles per hour, destroying it completely and killing all on board.

Unfortunately, even if the landing is successful there is still then the problem of returning back to Earth after the mission. In order to achieve this yet another transported rocket is needed with enough power to counteract the escape velocity of the moon and break free, providing enough thrust to match the kinetic energy of the craft to its gravitational potential energy.

MOST FAMOUS



1. Horsehead
The most impressive image of the Horsehead Nebula which is part of M42, located just below the star Alnitak.

MOST IMPRESSIVE

2. M42
M42, otherwise known as the Orion Nebula is one of the most beautiful and most famous nebulae known to man.

MOST AMAZING

3. Eagle Nebula
Often described as the pillars of creation since it depicts a large region of star formation. This image was created from Hubble images in 1995.

DID YOU KNOW? *The Hubble Space Telescope can be seen with the naked eye on a clear, dark night*

The Hubble telescope

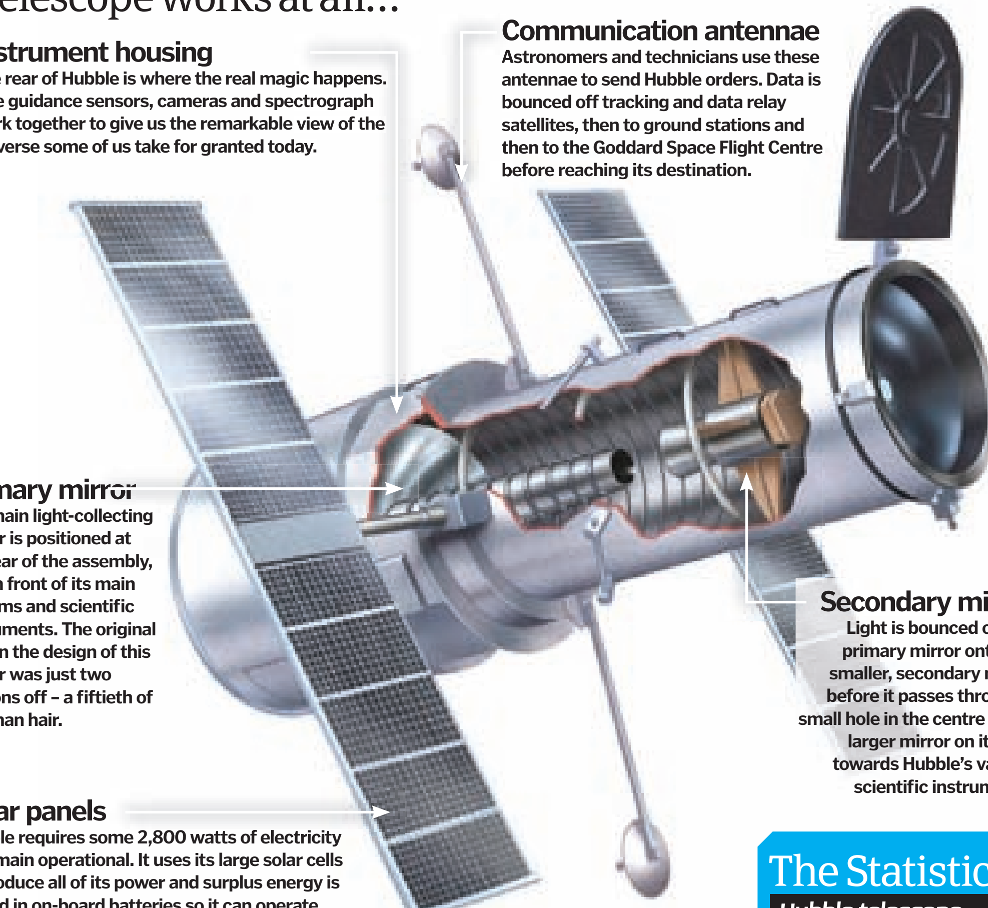
After a false start and 19 years of faithful service it's a wonder the Hubble space telescope works at all…

Lyman Spitzer Jr was one of the 20th Century's leading scientists. He was also the first person to consider the idea of putting a giant telescope in space and not only lived to see the launch of the Hubble Space Telescope (HST) in 1990, but witness seven years of its incredible contribution to modern science.

Buy why space? Compared to many of the world's most powerful Earth-bound telescopes the HST's optics are actually quite small. Bar obvious payload limitations, in space the required optics of a telescope are smaller since the 'seeing' is always perfect. Looking through Earth's atmosphere is not unlike trying to watch TV through a desert mirage – the seeing is hindered by a constant shimmer produced by the atmosphere. In space the HST's resolution is so great that it's the equivalent of us being able to distinguish a car's two separate headlights from 6,000 miles away.

Hubble didn't have the smoothest of starts however, and for the first three years of its life was partially sighted due to an error in the manufacture of its 2.4-metre primary mirror. Thankfully, upon its first servicing mission in 1993 its optics were corrected.

With 19 years service already under its belt you may wonder how much longer Hubble is due to be with us. It's most recent scheduled servicing mission took place in May 2009 and should allow Hubble to continue its work into 2014, when its successor – the James Webb Space Telescope – is due to launch.



Instrument housing
The rear of Hubble is where the real magic happens. Fine guidance sensors, cameras and spectrograph work together to give us the remarkable view of the universe some of us take for granted today.

Communication antennae
Astronomers and technicians use these antennae to give Hubble orders. Data is bounced off tracking and data relay satellites, then to ground stations and then to the Goddard Space Flight Centre before reaching its destination.

Primary mirror
The main light-collecting mirror is positioned at the rear of the assembly, just in front of its main systems and scientific instruments. The original flaw in the design of this mirror was just two microns off – a fiftieth of a human hair.

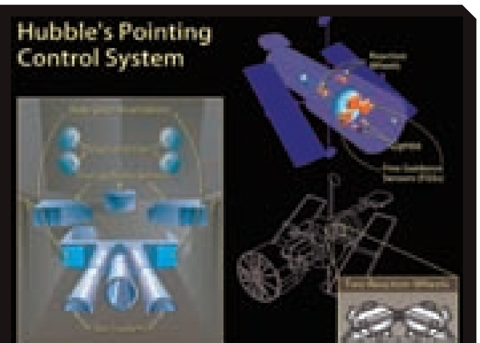
Secondary mirror
Light is bounced off the primary mirror onto this smaller, secondary mirror before it passes through a small hole in the centre of the larger mirror on its way towards Hubble's various scientific instruments.

Solar panels
Hubble requires some 2,800 watts of electricity to remain operational. It uses its large solar cells to produce all of its power and surplus energy is stored in on-board batteries so it can operate from inside the Earth's shadow (around a third of its complete orbit time).

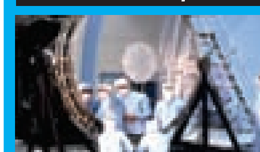
© DK Images

Hubble's control system

To accurately point this bus-sized piece of technology properly requires gyroscopes. They sense its motion and help it to find its target by acting as a reference point. Next come the reaction wheels which steer it towards its next target. Finally come the fine guidance sensors of which there are three. They pinpoint the aim by using star trackers to lock onto bright guide stars.



The Statistics
Hubble telescope



Service: 19 years (and counting!)
Mass: 11,110kg
Orbital velocity: 7,500 metres per second
Orbit period: 97 minutes
Diameter: 2.4 metres
Telescope focal length: 57.6 metres
Due to be de-orbited: >2021

All images © NASA

Hubble service record

The Hubble telescope was designed to be serviced by astronauts, here's its service history

DEC 1993 The most important part of the first servicing mission (SM1) was to correct the lens abortion. New systems were also installed including the Wide Field Planetary Camera 2.

FEB 1997 Besides important maintenance routines, Hubble's abilities were again upgraded with a new spectrograph able to collect 30 times more data than its predecessor.

DEC 1999 After the forth of six gyroscopes failed in 1999 Hubble was effectively put offline. Luckily, what was planned as a simple servicing mission turned into a successful rescue.

MAR 2002 Much of the work planned for 1999 was carried out in this mission. A new solar panel array was fitted, and despite being 1/3 of the size of the original provided 30 per cent more power.

MAY 2009 The fifth and final servicing mission. Two new scientific instruments were installed and two previously failed instruments were fixed. Hubble is in the best shape it's ever been in.

"Becoming denser and denser to the point where its very electrons become smashed together"

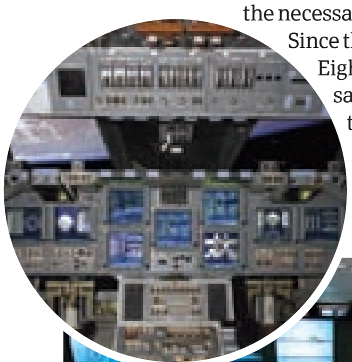
How NASA communicates with space shuttles

Through a fast relay of information, NASA's Mission Control can send and receive data from orbiting shuttles

NASA communicates with orbiting space shuttles through its Tracking and Data Relay Satellite System, a series of communication filters that allow vessels to remain in contact with ground-based controllers the majority of the time when in orbit.

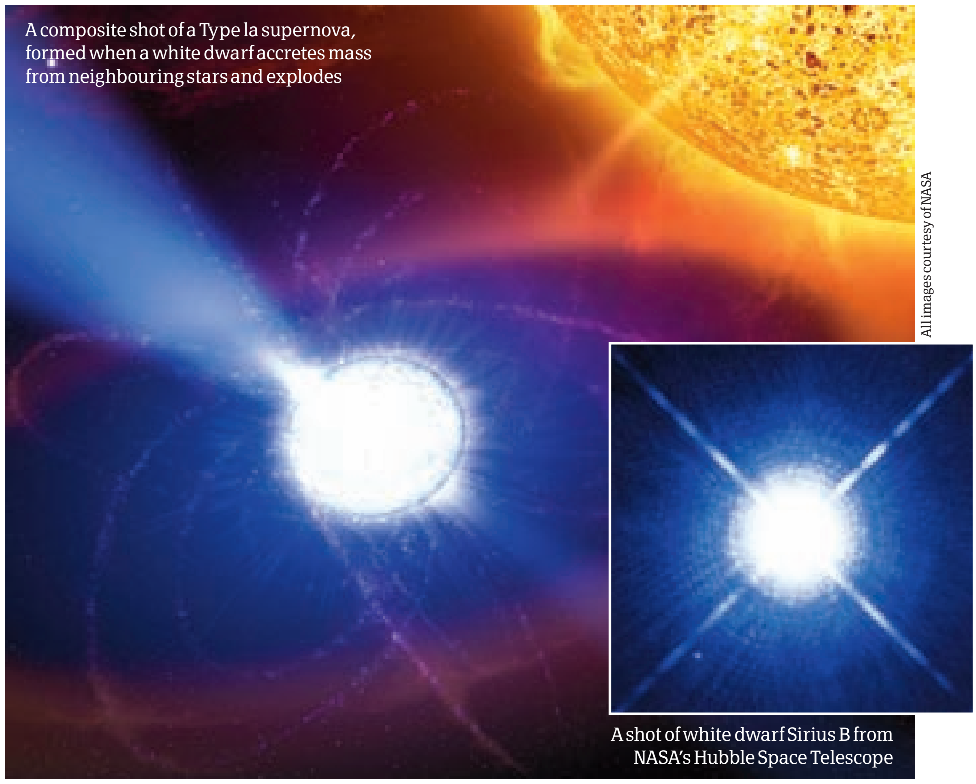
Mission Control, which is based at the Lyndon B. Johnson Space Center, is the data-hub for all NASA space flights, as well as the US section of the International Space Station. All instructions for space shuttles and astronauts originate from Mission Control, and all data sent from space is received and processed here.

The White Sands Test Facility – nestled in the foothills of Organ Mountains, New Mexico, is a communications base run by Lyndon B. Johnson Space Center. Here, out-going and incoming information from and to Mission Control is relayed through multiple large antennas in and out of space. The space-based transfer of data from White Sands is dealt with by multiple Tracking and Data Relay Satellites. These communication-orientated satellites redirect information to the necessary space shuttle or space station. Since their launches back in the Eighties and Nineties, these satellites have greatly increased the amount of time spacecraft remain in communication with Mission Control.



Mission Control – the most complex call centre on Earth

DID YOU KNOW? The second of ten Tracking and Data Relay Satellites was destroyed when the Challenger exploded in 1986.



A composite shot of a Type Ia supernova, formed when a white dwarf accretes mass from neighbouring stars and explodes

A shot of white dwarf Sirius B from NASA's Hubble Space Telescope

All images courtesy of NASA

White dwarfs

With a mass comparable to the Sun, white dwarfs are an intriguing space phenomenon

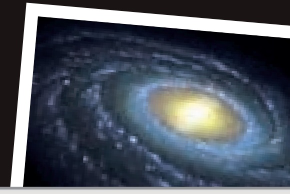
White dwarfs are small stars in the last throes of their life span, degenerate plasma centres of matter that are no longer creating energy through nuclear fusion. To understand how a star enters its white dwarf state, it is best to chart its progress from birth.

Stars are formed when clouds of space dust build in knots under internal turbulence to the point in which they collapse under their own gravitational attraction. As the cloud collapses a dense, hot core is formed which continues to collect dust and gas before turning into the heart of a protostar. Over millions of years this star continues to gather material and mass before entering its main sequencing stage where it fuels its expansion by the nuclear fusion of hydrogen into helium within its core. This is the main stage of any star (the stage our Sun is presently in) and is when the star is most stable, fusing hydrogen into helium while transferring heat outwards via radiation.

After billions of years hydrogen reserves within the core run out, slowing fusion and causing a massive reduction in energy. This lack of energy stops the star from pushing its multiple layers outwards and, under the force of gravity, slowly starts to collapse upon itself. Under this increased pressure the central temperature of the star rises to a critical point where helium, stored internally from the hydrogen fusion, starts to fuse together in the core, creating carbon and oxygen. Due to this increased core temperature the force of expelled radiation becomes so great that it forces the star's photosphere outward by a colossal distance, turning it into a red giant, and then due to the now weak gravitational pull on the outer layers, causes colossal mass loss to stellar winds.

After the star has exhausted its helium supplies and lost its outer layers, it enters the white dwarf stage. With no fuel left to burn in its core and the pressure of outbound radiation reducing, the star is compressed by gravity continuously, becoming denser and denser to the point where its very electrons become smashed together. Finally, the compression of these electrons cause every energy level available within the individual atoms to be filled and are left with nowhere else to go, stabilising the newly formed white dwarf. The dwarf is now comparable to Earth in volume and our Sun in density, with only two courses of action left – slowly dissipate any remaining energy until all that remains is an inert lump of astronomically dense matter, or continue to collect mass from a companion star pushing itself over critical mass and explode in a Type Ia supernova.

DIAMETER (LIGHT YEARS) 100,000 STARS 200 billion
AGE (YEARS) 13.2 billion THICKNESS (LIGHT YEARS) 1,000



DID YOU KNOW? *Galaxy classification is notoriously difficult due to its highly subjective nature*

Different types of galaxies explained

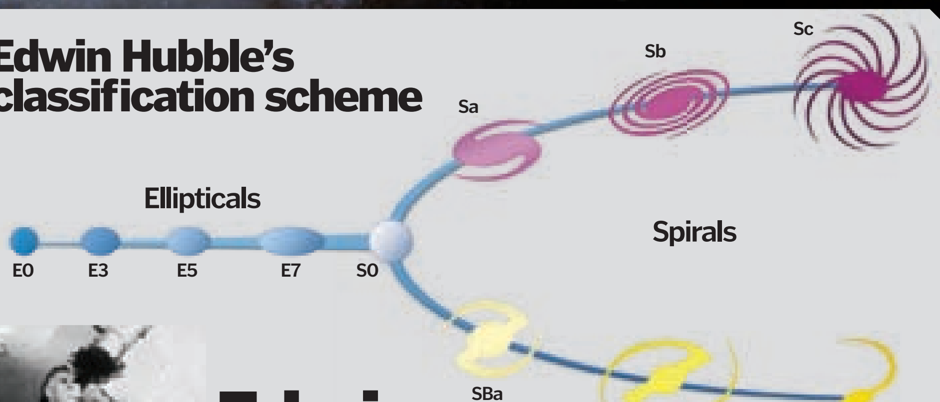
They might be grouped like a galactic tuning fork, but galaxy types don't always sing from the same hymn sheet

There are several galaxy classification systems, but the most widely used is the Hubble Sequence, devised by the great Edwin Hubble in 1926 and later expanded upon by Allan Sandage among others. It's more commonly known as the Hubble tuning fork due to the shape the system represents in diagrammatic form.

Hubble's system was designed to demonstrate the various classifications of three main classes of galaxy broken down into elliptical, spiral and lenticular shapes. The latter is essentially an intermediate of the other two types. The tuning fork was erroneously thought that each galaxy type represented snapshots of the entire life span of galaxies, but it has since been demonstrated that this is not the case.

The most recent version of Hubble's tuning fork comes courtesy of the Spitzer Space Telescope's infrared galaxy survey made up of 75 colour images of different galaxies and includes a new sub-section of irregular galaxy types. You can find a full resolution image of this remarkable accomplishment at http://sings.stsci.edu/Publications/sings_poster.html. Thanks to the internet, anyone can try their hand at galaxy classification and further the science – simply go to www.galaxyzoo.org and join in alongside 150,000 other volunteers.

Edwin Hubble's classification scheme



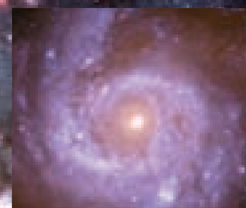
Edwin Hubble Pioneer to the stars

No person in history has had a greater impact in determining the extent of our universe than Edwin Hubble. From proving that other galaxies existed to giving evidence that galaxies move apart from one another, Hubble's work defined our place in the cosmos. Shown above posing with the 48-inch telescope on Palomar Mountain, the Orbiting Space Telescope was named in memory of his great work.

Today a great controversy rages on about the rate of the universe's expansion, parameterised by a quantity known as Hubble's constant.

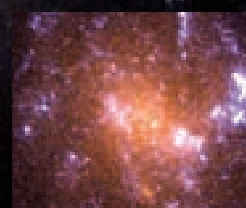
Types of galaxies

Galaxies can be categorised into these types…



Elliptical galaxies

On the far left of the Hubble Sequence lies the elliptical galaxy types. They show no defined features like the intricate dust lanes seen in classic spiral galaxy types, besides a bright core. Ellipticals are represented by the letter E, followed by a number that represents the ellipticity of its shape.



Spiral types

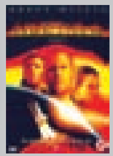
Appearing flatter on the sky than an elliptical galaxy, spiral galaxies feature two or more spiral 'arms' that wrap around the galaxy core and are made up of vast lanes of stars. The upper half is populated with the standard spiral type, while the lower half contains 'bar' spirals. The twist of the spiral begins at the end of an extended bar.

Lenticular galaxies

Where the handle of the tuning fork and the two spiral arms meet lie the lenticular galaxies. These galaxies feature aspects of both spiral and elliptical galaxies and didn't actually feature on Hubble's original sequence. They have a bright central bulge like an elliptical galaxy, but are surrounded by a structure not unlike a disc.

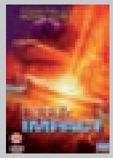
All images © NASA

Head to Head
Bad asteroid movies



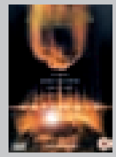
BAD

1. Armageddon
An asteroid is making a beeline for Earth in this blockbuster that sees Bruce Willis make the ultimate sacrifice for mankind. Hollywood at its cheesiest.



BADDER

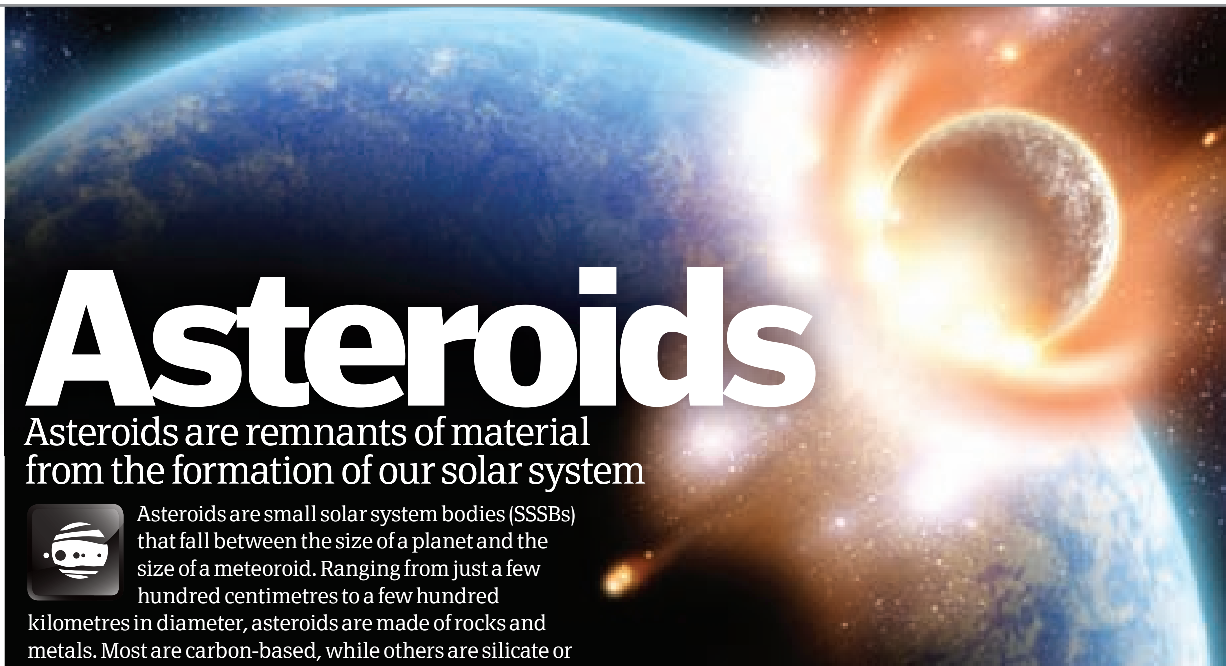
2. Deep Impact
Okay, so technically *Deep Impact* is about a comet, not an asteroid, but it's still a lump of rock and it's still heading for Earth as Téa Leoni and Morgan Freeman discover.



BADDEST

3. Asteroid
Maybe not the baddest but certainly the most unimaginatively titled. First aired as a mini-series for US TV in 1995, the asteroid of note is heading for Dallas.

DID YOU KNOW? For half a century Ceres was classified as the eighth planet

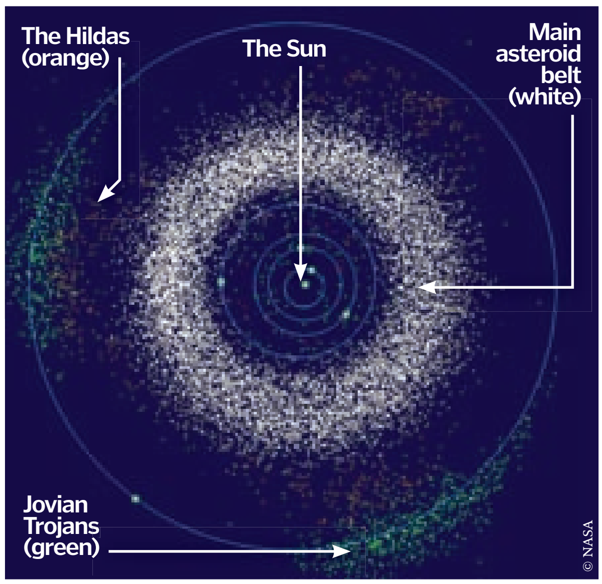


Asteroids

Asteroids are remnants of material from the formation of our solar system

Asteroids are small solar system bodies (SSSBs) that fall between the size of a planet and the size of a meteoroid. Ranging from just a few hundred centimetres to a few hundred kilometres in diameter, asteroids are made of rocks and metals. Most are carbon-based, while others are silicate or metal-based. They are left over from the formation of the solar system more than 4 billion years ago.

Millions of asteroids orbit the Sun in the Main Asteroid Belt, a massive ring between 300 and 600 million kilometres in diameter between the orbits of Mars and Jupiter. Most asteroids have elliptical orbits and take a few years to orbit the Sun. Some astronomers think the Asteroid Belt comprises remnants from a planet that was destroyed during a collision, while others believe that they are material left over from a planet that never formed due to Jupiter's strong gravitational pull. ✪

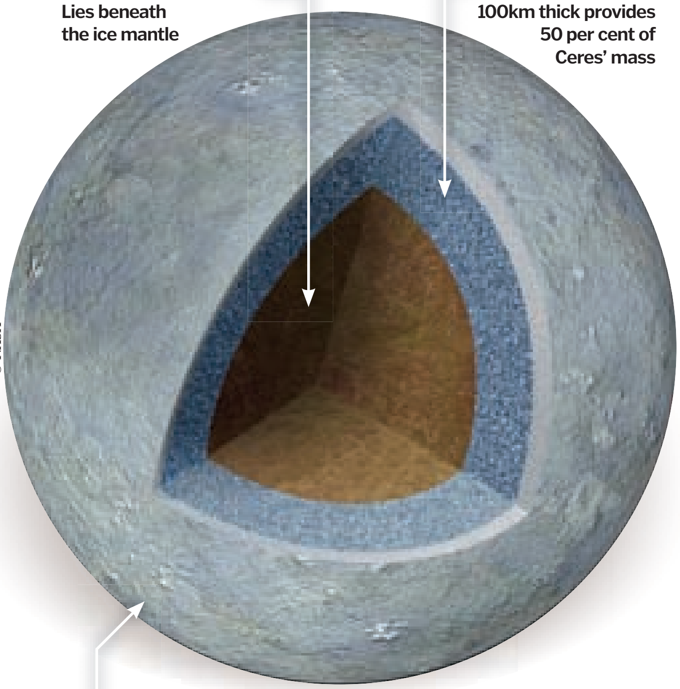


Where to find them

The Asteroid Belt isn't the only group of asteroids. The Hildas have orbits just inside of Jupiter's orbit. Another group, called the Jovian Trojans, share Jupiter's orbit at areas called the Lagrangian points. The group 60° ahead of Jupiter's orbit are the Greeks, while the group trailing by 60° are the Trojans.

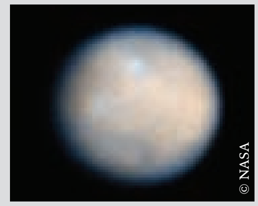
Will one ever hit Earth?

Some asteroids do break free from their normal orbit, either due to Jupiter's gravity or collisions with other asteroids. When they come within 1.3 AU (195 million kilometres) of the Sun, they are known as near-Earth asteroids (NEAs). Astronomers theorise that an asteroid impact 65 million years ago could be responsible for the extinction of the dinosaurs. The possibility of an asteroid hitting Earth and causing catastrophic damage is very low, although close calls happen on a regular basis. In March 2009, a small asteroid (about 60 metres wide) passed within 66,000 kilometres of Earth.

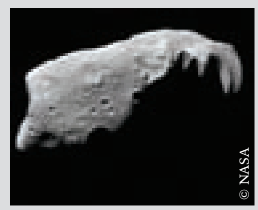


Inside Ceres
The largest body in the asteroid belt explained

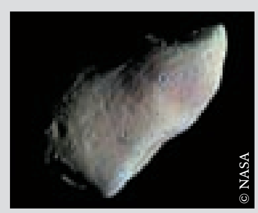
Know your asteroids
OUT OF THE MILLIONS OF ASTEROIDS, THERE ARE A FEW MAJOR STANDOUTS


© NASA

1. Ceres
Diameter (miles): 605
Orbital period (years): 4.6
Distance from the Sun (AU): 2.767
Date discovered: 1 January 1801
Facts: Ceres is the largest object in the Main Asteroid Belt, and the smallest dwarf planet in our solar system. It is spheroid with clay and icy crust, an icy mantle and a rocky core.


© NASA

2. Ida
Diameter (miles): 33.3 x 15 x 9
Orbital period (years): 4.84
Distance from the Sun (AU): 2.86
Date discovered: 29 September 1884
Facts: Ida was the first asteroid found to have its own moon, Dactyl. It has an elongated crescent shape covered in craters, and is likely made of silicate rocks like iron, feldspar and olivine.


© NASA

3. Gaspra
Diameter (miles): 12 x 7.45 x 6.83
Orbital period (years): 3.29
Distance from the Sun (AU): 2.209
Date discovered: 30 July 1916
Facts: The very first asteroid to be closely approached by the Galileo spacecraft, Gaspra is an irregularly shaped asteroid covered in small craters. It is likely made of metal silicates because it has a reflective surface.

"It would be more cost-efficient to develop a completely new system"

How will we get to space when the Shuttle is retired?

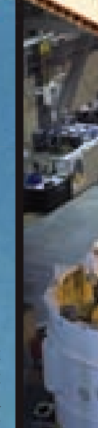
Scheduled for retirement in 2010 based on directives issued by President George W. Bush, NASA's Space Shuttle programme has just a few flights left before it ends for good. NASA hopes to sell the three remaining shuttles – Atlantis, Discovery and Endeavour – to museums, schools or other institutions for more than £26 million each. Originally the shuttles themselves were only supposed to last for a decade, but the programme has been going for nearly 30 years.

Unfortunately, NASA doesn't have its next space exploration programme lined up just yet. Now there will be a gap of at least a few years until the next vehicle is ready to go. While there are a few replacement options in the works with the title of Project Constellation, NASA isn't the only agency looking for new and improved ways of exploring space. Let's take a look at the next generation of spacecraft from around the world.

So why junk the Space Shuttle?

NASA's Space Shuttle programme began in 1972 and truly took off with the launch of the Space Shuttle Columbia on 12 April 1981. It was designed to be a flexible, efficient and relatively cheap way to explore space. While the programme has made some amazing strides and discoveries, critics say that it hasn't quite lived up to its original promise. It's not only been very expensive and difficult at times, it has also resulted in serious problems and tragedies. Many scientists believe these problems have been due in part to flaws in the original Space Shuttle design, as well as its out-of-date, aging technology. It would be more cost-efficient to develop a completely new system rather than try to update the Space Shuttle. This is why NASA is developing ways of not only getting in and out of Earth orbit, but also returning to the moon and exploring other planets such as Mars.

Next-gen spacecraft



This simulator was built to test the launch abort system of the NASA Ares I rocket

5 TOP FACTS
NASA'S CONSTELLATION PROGRAM

Innovation isn't cheap

1 Getting to space costs money, lots of money, and the Constellation Program has an estimated total cost of more than £130 billion through to 2025.

Inspiration from Apollo

2 There's a lot to be learnt from the past. In October 2008, scientists at NASA working on the Orion began studying heat shields used on the Apollo capsules.

Rollercoaster of rescue

3 NASA engineers designed a rollercoaster-inspired system that would remove astronauts from the Orion in the event of a launch pad emergency.

An extended moon stay

4 A colony on the moon has long been the subject of science fiction and NASA's goal is for astronauts to set up outposts on the moon and stay for up to 180 days.

Visiting the Red Planet

5 NASA's proposed Mars mission would require a six-month journey there and back, as well as a 500-day stay on the planet. That's a hell of a business trip.

DID YOU KNOW? *The space agencies of Japan, India and China (CNSA) all have goals of manned lunar missions in the 2030s*

The Statistics
Ares rockets

Ares I
Estimated development cost: more than £25 billion
Height: 94 metres
Diameter: 5.5 metres
Payload: 25 metric tons

Ares V
Estimated development cost: $350m to $500m per vehicle
Height: 116 metres
Diameter: 10 metres
Payload: 188 metric tons to low-Earth orbit; 71 metric tons to the moon

Nationality: United States
Estimated first mission: 2014 for Ares I, 2018 for Ares V

The Ares I-X NASA test rocket, had a successful launch on 28 October 2009

The Ares rockets

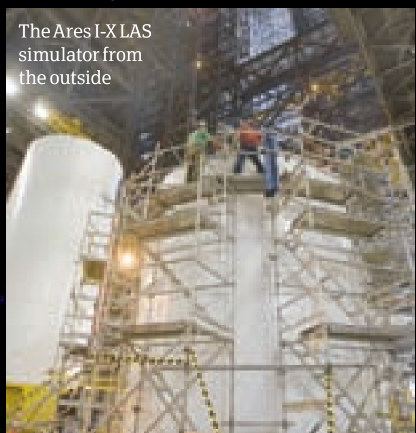
Meet NASA's most immediate replacement for the shuttle


Inside the Ares I-X launch abort system simulator

The Ares rockets are part of NASA's Project Constellation, and there are plans for two different rockets that can also work together. One rocket will be primarily to transport crew, while the other will be used to transport cargo. The Ares I is a two-stage rocket configuration. Its first rocket stage is reusable, and will launch the vehicle into low-Earth orbit before separating. The second, upper stage is a J-2X engine that will launch the rocket into a circular orbit. The Ares I will be topped by the Orion Crew Vehicle.

Ares V is an unmanned rocket used to transport heavy items such as the Altair Lunar Lander, building materials, supplies and hardware. The core stage consists of reusable boosters that burn at the same time to propel the rocket into low-Earth orbit. The next stage, or Earth Departure Stage (EDS), allows the Ares V rendezvous with Ares I. It can hook up the Altair Lunar Lander with the Orion so astronauts can descend to the moon.

On 28 October 2009, a version of the Ares I rocket, called the Ares I-X, had a successful two-minute test flight. NASA hopes that data from the flight will help them continue to improve the Ares rocket design.


The Ares I-X LAS simulator from the outside

All images © NASA

Ares V rocket

Composite shroud
This shroud protects the Altair Lunar Lander during its flight aboard the Ares V.

Altair Lunar Lander
The Altair Lunar Lander is launched initially on the Ares V, and then meets up with the Orion to travel into lunar orbit.

Earth Departure Stage
This stage steers the Altair Lunar Lander into low-Earth orbit. It also propels the Altair and Orion to the moon and can haul cargo into low-Earth orbit.

J-2X engine
This engine powers the Earth Departure Stage. It is propelled by liquid oxygen and hydrogen, and is an upgrade from engines used on Saturn rockets.

Interstage
The interstage connects the J-2X engine to the core stage and contains motors to separate the rocket boosters from the core.

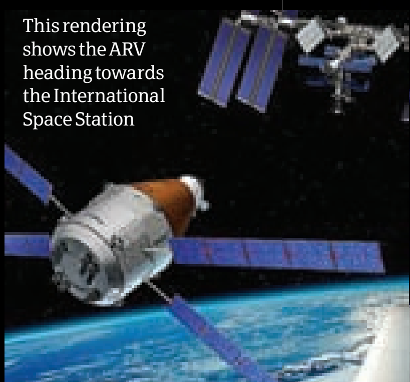
Core stage
This stage contains six RS-68B rocket engines along with tanks containing liquid oxygen and liquid hydrogen propellants.

Two 5.5 segment RSRBs
These two segmented reusable solid rocket boosters are similar to the single booster used on Ares I. They are upgrades of the shuttle RSRBs.

> "The Altair lands on the moon while the unoccupied Orion remains in orbit'"

Advanced Re-entry Vehicle

The ESA is working on a next-gen reusable vehicle for manned space flight



This rendering shows the ARV heading towards the International Space Station

In March 2008, the ESA launched its first ATV (Automatic Transfer Vehicle), the Jules Verne. This unmanned disposable spacecraft brought supplies and experiments to the International Space Station. While more ATVs are in the works, the ESA is also working on a manned version called the Advanced Re-entry Vehicle. Currently European astronauts get to the ISS via the Russian Soyuz or a NASA Space Shuttle, but the ARV would mean independent European spaceflight.

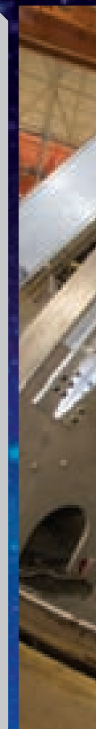
The ARV design is in its preliminary stages, but the aerospace company EADS Astrium unveiled a potential concept model at the International Aerospace Exhibition in May 2008. This model would involve transforming current cargo hold of the ATV into a four-man crew compartment and otherwise upgrading it for flight safety, while using existing avionics and propulsion technology. Like the ATV, the ARV would launch on the Ariane 5 rocket.

The Altair Lunar Lander

NASA is planning to build a new lunar spacecraft called the Altair Lunar Lander

Man has not set foot on the moon in more than 30 years, and NASA believes that a return is long overdue. The Altair is planned as a two-stage spacecraft that will probably be similar in some ways to the Apollo Lunar Module, but much larger. It will have a descent and an ascent stage – the former will contain equipment such as power supplies, while the latter will house up to four astronauts and their life-support system.

The Altair will launch on the Ares V rocket into low-Earth orbit. Then it will rendezvous with the Orion, which launches on the Ares I rocket. The Altair will dock with the Orion, and then the combined spacecraft journeys to lunar orbit. After undocking, the Altair lands on the moon while the unoccupied Orion remains in orbit. Once landed, the Altair can serve as a base for the astronauts for up to a week.



The Statistics

Altair Lunar Lander

Height: 9.7 metres
Diameter: 7.5 metres
Volume: 31.8 cubic metres
Nationality: United States
Estimated first mission: 2018 unmanned, 2020 manned

This rendering shows the Altair Lunar Lander serving as a base for astronauts on the moon

FIRST SATELLITE

1. Sputnik 1
The space age started on 4 October 1957 when the first artificial satellite was launched by the Soviets. It orbited Earth every 96 minutes.

FIRST RENDEZVOUS

2. Apollo 18
America's Apollo 18 completed the first international space rendezvous when it docked with the Soviet Soyuz 19 in 1975.

FIRST RE-USABLE

3. Space Shuttle Columbia
Columbia was successfully launched on 12 April 1981. It flew a total of 27 times before being destroyed during re-entry on 1 February 2003.

DID YOU KNOW? Twelve people have walked on the moon. The last was Eugene Cernan on 14 December 1972

The Statistics

Orion

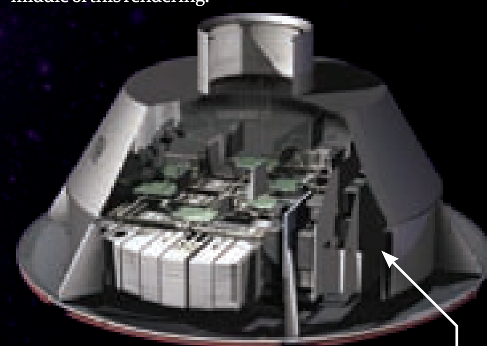
Diameter: 5.02 metres
Length: 3.3 metres
Mass: 8.5 metric tons
Nationality: United States
Estimated first mission: 2014 unmanned, 2015 manned

Orion

The Orion Crew Exploration Vehicle takes NASA spacecraft back to a capsule design

At first glance, the Orion looks much like the capsule-type spacecraft last used by NASA during the Apollo space programme, and it does use some of the same technology. However, the design will also include successful elements of the Space Shuttle programme as well as the most up-to-date heat shield, waste-management, atmospheric and computer technology. It comprises of three different elements: a crew module, a service module, a launch abort system and a spacecraft adapter. The plan is for NASA to have a fleet of several reusable Orion vehicles, with each holding four to six astronauts but also with the capability for unmanned flight. They will be launched by the Ares I rocket into low-Earth orbit. From there, the Orion can dock with the International Space Station, the Altair Lunar Lander or other future vehicles.

1. Six seater
The Orion will hold up to six astronauts, who will be oriented horizontally in the seats in the middle of this rendering.



2. Under pressure
This cutaway of the Orion shows the inner pressure vessel, which contains the crew cabin.

3. Equipment
This cutaway concept of the Orion shows equipment between the outer shell and inner pressure vessel.

4. Exterior
This concept image represents the exterior of the Orion crew exploration vehicle module.

All images © NASA

http://www.buran-energia.com/kliper-clipper-shuttle/kliper-desc.php

The Statistics

Kliper

Nationality: Russia
Estimated first mission: 2012 initially, now unknown

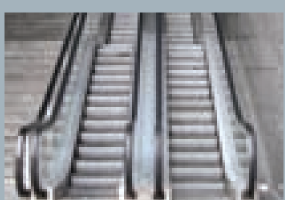
One that didn't make it… the Kliper

Russia's Kliper shuttle has yet to make it off the drawing board

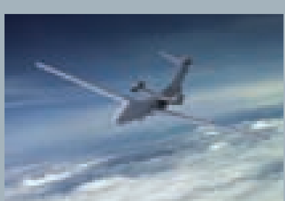
In 2004, the Russian Federal Space Agency (FSA) began working on a spacecraft to replace the Soyuz. The Kliper was a winged shuttle that could carry up to six cosmonauts to and from the ISS and appeared to potentially be safer, more easily controlled and more flexible than the Soyuz. The FSA hoped to forge an international partnership to fund and build the Kliper, but this did not materialise. Currently, FSA officials aren't saying much about the future of its spacecraft. There has also been talk of a different design, closer to NASA's Constellation Program, called the PPTS (Prospective Piloted Transport System).

This month in **Transport**

The freezing January weather made us think of travelling to warmer climates and the largest cruise ship on Earth, Oasis of the Seas, looked like just the vehicle to get us there. With 21 swimming pools and jacuzzis it's hard to think of a better or more luxurious way to get some winter sun. Find out all about it on page 44.



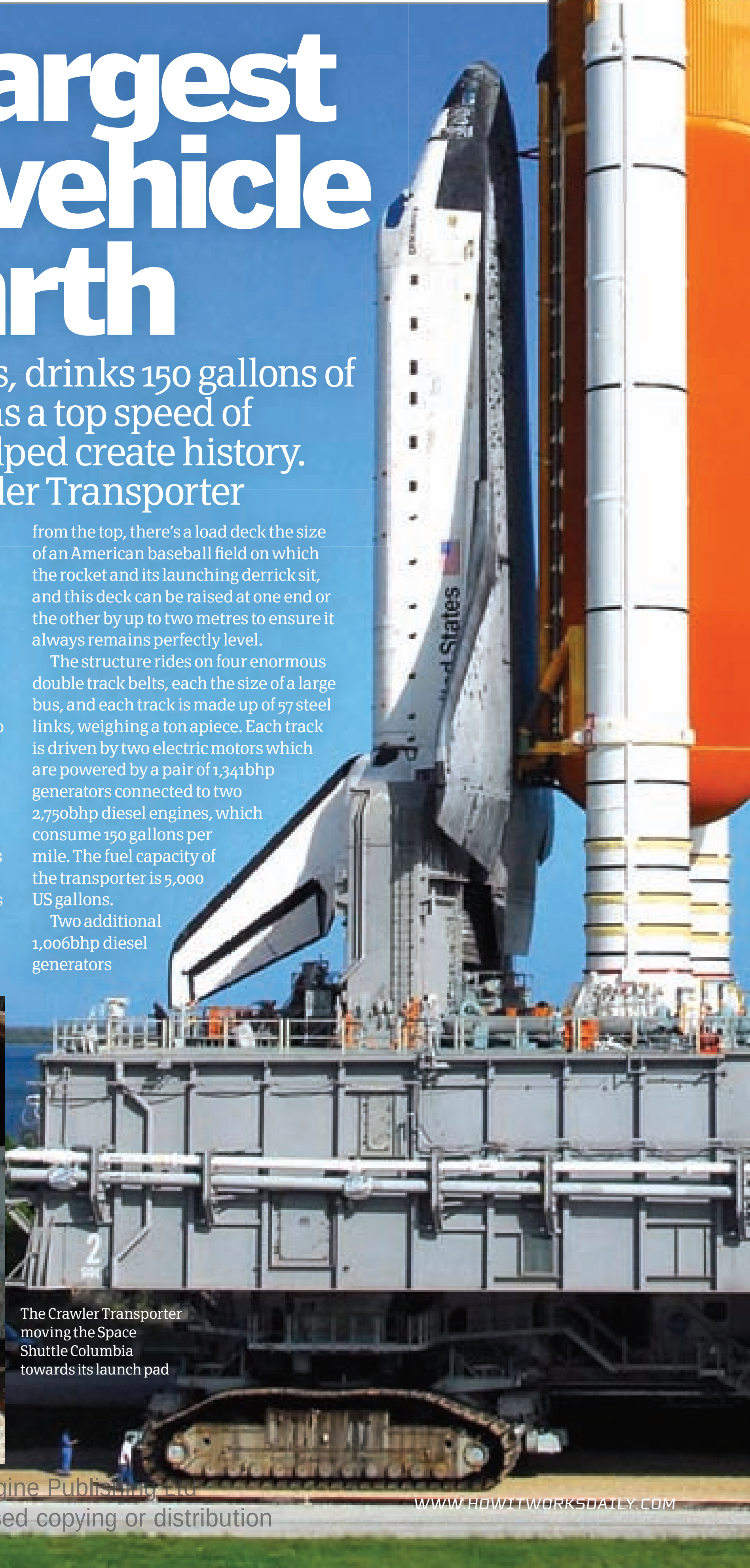
40 Escalators



40 Spy planes

41 Air traffic control

TRANSPORT



The largest land vehicle on Earth

It weighs 2,721 tons, drinks 150 gallons of fuel every mile, has a top speed of 2mph, and has helped create history. Meet NASA's Crawler Transporter

Think space travel and what comes to mind is Dan Dare, gleaming rockets, super-high speeds and the ultimate adventure. You certainly don't think of gargantuan, extremely slow-moving equipment built by a mining company and driven by guys in overalls and hard hats. Yet such a machine was essential to the Apollo missions and is still used for today's Shuttle flights and other numerous launches.

We're talking about the Crawler Transporter, the world's largest self-powered vehicle, which for over 40 years has carried spaceships from NASA's Vehicle Assembly Building the five miles to the launch pad.

Everything about the 2,700-ton Crawler Transporter is huge. Starting from the top, there's a load deck the size of an American baseball field on which the rocket and its launching derrick sit, and this deck can be raised at one end or the other by up to two metres to ensure it always remains perfectly level.

The structure rides on four enormous double track belts, each the size of a large bus, and each track is made up of 57 steel links, weighing a ton apiece. Each track is driven by two electric motors which are powered by a pair of 1,341bhp generators connected to two 2,750bhp diesel engines, which consume 150 gallons per mile. The fuel capacity of the transporter is 5,000 US gallons.

Two additional 1,006bhp diesel generators

Try kicking the tyres on this then!

The Crawler Transporter moving the Space Shuttle Columbia towards its launch pad

Image: Martin Roell, 2006

1. Krupp Bagger 288
Facts: The world's largest machine, this mining excavator is 95 metres high and weighs 45,500 tons.

2. JCB Backhoe
Facts: Construction machines aren't usually designed to be fast, but in the Eighties JCB built an astonishing 150mph backhoe digger.

3. Mammoet MoMo
Facts: The largest mobile crane in the world, with a maximum lifting capacity of 1,600 tons and a height of 180 metres.

DID YOU KNOW? In 1977, the Crawler Transporter was named as a National Historic Mechanical Engineering Landmark

power the vehicle's jacking, steering, lighting and ventilation systems, while a pair of smaller 201bhp units are used to power the 16 hydraulic systems that raise and lower the load deck.

Keeping the load deck level as the Crawler Transporter ascends the five-per cent incline to the launch pad is essential if its tall payload is not going to topple over. A laser guidance system monitors this to such accuracy that the spacecraft moves less than 1/6-degree from vertical. What's more, the guidance systems ensure that the gargantuan vehicle, which moves at just 1mph when loaded, can be steered to an accuracy of within 50mm.

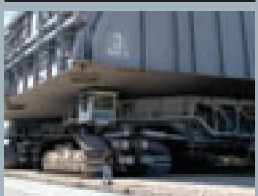
As it lumbers slowly along its five-mile journey, the Crawler Transporter is controlled by a highly trained crew of 11. There is a driver in one of the two cabs, four observers at different points along the route to advise the driver, and six technicians looking after the vehicle's many control systems.

Although not the most glamorous machine, the Crawler Transporter is an astonishing feat of engineering and has carried seven different types of launch vehicles, including Apollo's Saturn V rockets, the Space Shuttles and the new Ares 1 rocket. What's more, there are no plans to retire the big machine so, just maybe, it will one day carry a spaceship destined to take man to Mars.

Oh, and if one Crawler Transporter isn't impressive enough, there are actually two of them!

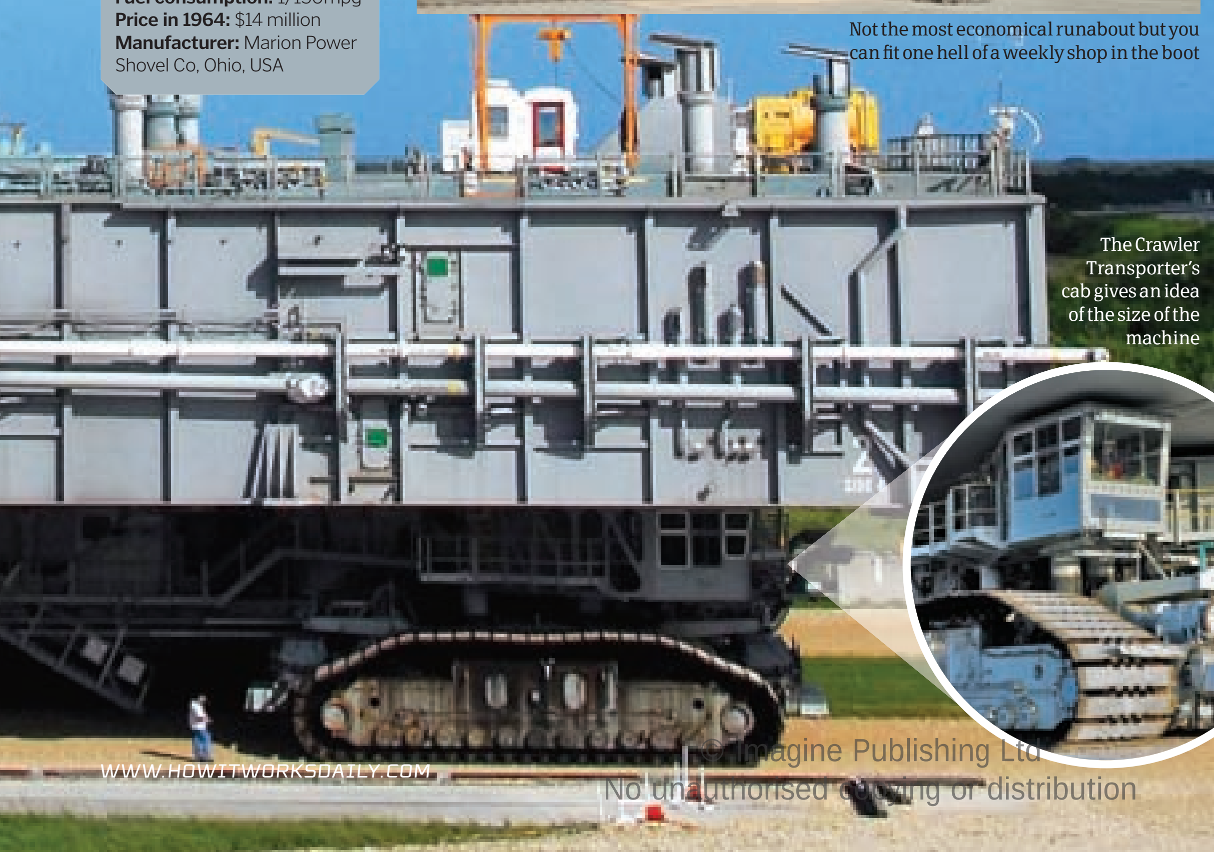

A relatively light load for the Crawler Transporter – a pair of Shuttle booster rockets. The launch pad is visible on the horizon

The Statistics
The Crawler



Length: 40 metres
Width: 35 metres
Height: varies from 6-8 metres
Load deck size: 27 metres square
Weight: 2,721 metric tons
Maximum speed: 1.0mph (loaded); 2.0mph (empty)
Fuel capacity: 5,000 US gallons (diesel)
Fuel consumption: 1/150mpg
Price in 1964: $14 million
Manufacturer: Marion Power Shovel Co, Ohio, USA


Not the most economical runabout but you can fit one hell of a weekly shop in the boot


The Crawler Transporter's cab gives an idea of the size of the machine

Building the crawler

Huge hurdles had to be overcome to transport the Saturn V rockets

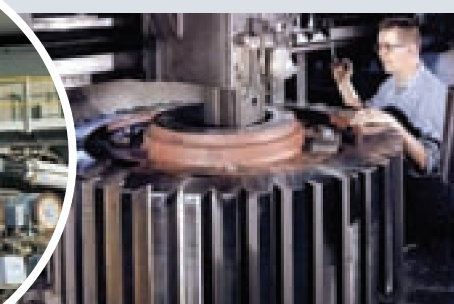
When NASA began its space programme, it created the huge Vehicle Assembly Building in which to build the massive Saturn V rockets used by the Apollo missions. It then needed a way of transporting the completed rockets and their derricks the five miles to the launch site .

Various solutions were considered, but because of the weights involved it was decided that a tracked vehicle was the best option, because a number of massive caterpillar tracks would spread the weight over a specially built twin road with two-metre deep foundations.

Another problem to overcome was the fact that there was a five per cent incline to the launch pad, and the rocket had to be kept perfectly upright if it wasn't going to topple over. The answer to this was to make the load platform vary in height, front to back, so it could always remain level.

Bids were tendered for the design and construction of a new transporter and the winning idea came from engineer Philip Koehring of Bucyrus International. However, the contract to build the machine was then awarded to a competitor, the Marion Power Shovel Company in Ohio (which, ironically, Bucyrus later took over).

It wasn't to be straightforward, though, but finally the hurdles were overcome. The Crawler Transporter may not have the 'wow' factor of the actual rockets that ride upon it, but without it man would never have left the Earth and started the race into space.



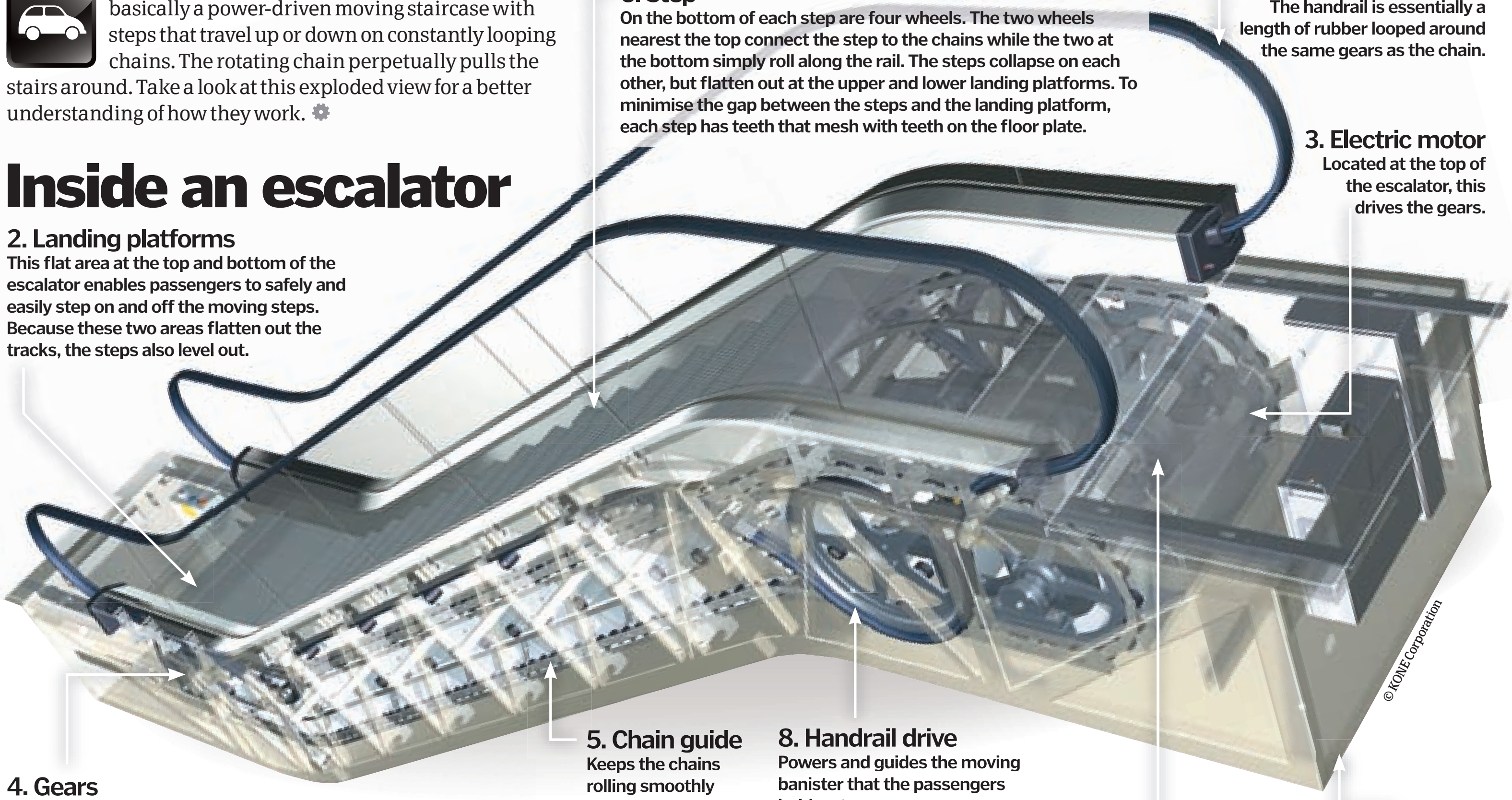
All images © NASA

How do escalators work?

Though a simple mechanism, these moving staircases are a brilliant feat of engineering

Used for conveying people quickly, an escalator is basically a power-driven moving staircase with steps that travel up or down on constantly looping chains. The rotating chain perpetually pulls the stairs around. Take a look at this exploded view for a better understanding of how they work.

Inside an escalator



© KONE Corporation

Spy planes

Why the military use unmanned aerial vehicles to patrol the skies

In combat zones, military forces need to be aware of what the enemy is up to, and the best way to do that is to send in reconnaissance aircraft to survey them. However, this immediately puts a pilot and crew at risk of being spotted and fired upon. One way of avoiding this potentially dangerous situation is to use remotely controlled spy planes – also known as unmanned aerial vehicles (UAVs) – to monitor enemy activity while putting no one at risk. UAVs are becoming increasingly autonomous, which means they can function with the minimum of human intervention.

With a wingspan of 20 metres, BAE's Mantis is the biggest fully autonomous UAV built in the UK. It's all-electric and carries sensors for gathering intelligence at long range. Though most UAVs are used purely for recon missions, the larger kind have the potential to carry and drop weapons.

BAE's Mantis UAV requires little human intervention as it understands and reacts to its environment, enabling the people on the ground to get on with analysing the information being collected.

© BAE Systems

1. Charles de Gaulle
Paris's Charles de Gaulle conducts over 600,000 aircraft movements per year.

2. London Heathrow
Deals with over 65 million passengers per year the world's second busiest in total passenger traffic.

3. Atlanta International
151 domestic gates, 28 international gates, produces over 980,000 aircraft movements per year.

DID YOU KNOW? The universal air-traffic control language is English

Air traffic control

How the latest tech orchestrates airspace

Symbolised by the imposing control tower at any airport, air traffic control plays an absolutely fundamental part in launching, landing and guiding planes when airborne. However, there are multiple differing disciplines within the air traffic control system, with the control tower being the hub for this information to disperse.

The overall method of controlling aircraft within a 10km radius of the airport is dealt with by the air traffic control tower. Here aircraft separation (ensuring that flight paths don't converge), organisation of aircraft flow traffic (keeping inbound and outbound aircraft movement efficient) as well as providing flight awareness information to the pilots, is undertaken by three separate but interlinked control areas. To accomplish this, controllers use a mixture of radar and visual information, as well as radio feeds from the aircraft and airport staff. These methods provide the controller with information on the plane such as speed, altitude and direction, in addition to weather conditions such as wind shear and velocity, as well as runway and taxiing information that will directly benefit the pilot and staff.

The first of these control areas is ground control and is the first port of call for any departing aircraft. All operations on the ground, including boarding areas, holding areas and taxiways, are dealt with by ground control. This division of air traffic control delivers clearance to all vehicles performing movement on the ground, ensuring safety and efficiency for departing or landed planes and airport staff. Ground control is also responsible for the ordering of queued aircraft, with a visual map of the airport displaying the exact position and movement of all grounded aircraft at their fingertips.

Once on the runway, control of the aircraft is handed over to local tower control. This second area of the air traffic control system is responsible for take-off and landing clearance, aircraft stacking, plane movement authorisation on the runway and deliverance of contextual information to the pilots. Tower control is also responsible for providing flight data, such as the flight path the plane is going to follow on its journey as well as modifying any pre-delivered plan in order to mitigate any congestion areas or weather hazards in the airport's immediate vicinity.

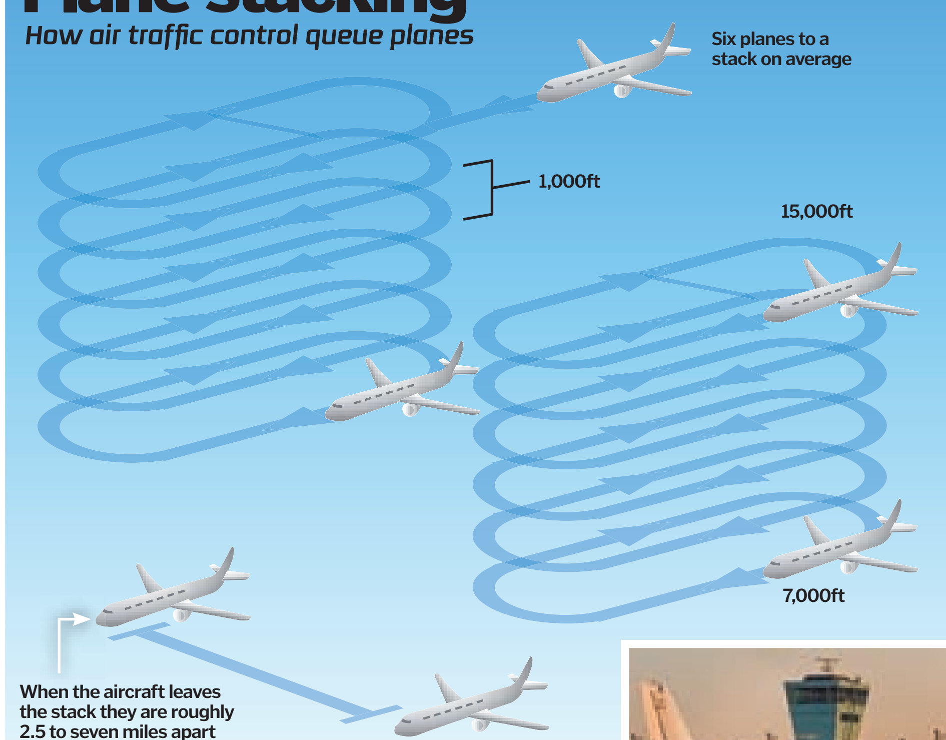
In the air, notably around large metropolises where there may be multiple airports, aircraft are monitored and supplied with information by terminal control. This third element of the air traffic control system acts in a similar manner to tower control but on a much larger scale. Covering areas of out to 200 kilometres and up to 20,000 feet, terminal control acts as an overseer of all air-traffic movement in and around multiple airports.

This allows controllers to inform pilots early on their approach to certain areas if there are any flow, weather or technical issues to be wary of. These approach control stations also undertake an important role in guiding and transferring aircraft from differing airspaces, acting as a middleman between country-to-country flights, where many aircraft may be purely passing through to an airport in a successive country.

"That's not the red-eye from Boston, you just sneezed on the monitor!"

Plane stacking

How air traffic control queue planes



"Do we have clearance tower? The hostess is dying for the loo"

How does a helicopter fly?

These vehicles have amazing manoeuvrability in the air, but how?

Helicopters are incredible flying machines – indeed, the great Da Vinci himself almost had the right idea with some of his early drawings – they can take off and land vertically, and, unlike other aircraft, they can hover.

Getting any vehicle off the ground requires lift, which is basically achieved by the downward deflection of air. While a typical fixed-wing plane uses forward movement to create downward air deflection, a helicopter uses the rotating motion of a central rotor powered by an engine. As the rotor blades turn, the effect of lift eventually overcomes the weight of the helicopter and it takes off – vertically.

The problem is that as soon as the vehicle leaves the ground, Newton's third law of motion – the one that says that for every action there is an equal and opposite reaction – steps in and forces the fuselage to rotate in the opposite direction to the blades. The only way to hold the body still is to apply another force to counteract this torque effect, and so a second rotor, at the end of the helicopter's tail, produces sideways thrust.

Now the helicopter has stopped spinning wildly, you must control it. To propel a helicopter in a given direction, the pilot can tilt the main rotor axis by a swashplate that adjusts the angle of the rotor blades with each turn of the central hub.

Snowboard construction

How does layering produce a strong, fast snowboard?

Snowboards are constructed with a thin wooden core to absorb vibrations. The core is planed to the desired thickness and the edges are rounded to create the perfect shape. Holes are then bored into the wood where aluminium inserts will later secure the bindings, these holes are positioned with a template so they can be located after being covered up during the production process.

To stiffen the board, large, thin sheets of fibreglass are glued above and below the wooden core with an adhesive called epoxy. The top of the board is made from resistant plastic applied by silkscreening, which spreads ink over the board. One colourful layer is applied at a time, but the ink must be left to dry for several hours before the next colour can be applied.

To give the board its curvature, it is placed in a mould and heated, which sets the adhesive. Another lot of silkscreening adds the finishing touches to the final design on the surface of the board, and then for protection it gets a thin coat of varnish before the edges are sanded smooth.

The inserts installed at the beginning of production have by now been covered up, so new holes must be drilled in the exact position so the snowboarder can locate them, attach their bindings and hit the slopes.

FAST

1. Siemens Transrapid 08 (China)
In 2003 the Transrapid 08 maglev train, which connects the rapid transit network to the Shanghai Pudong International Airport, hit a rather tasty 501km/h.

FASTER

2. TGV V150 (France)
In 2007 a specially configured, one-off variant of the TGV train hit a scorching 574.8km/h on a stretch of track running between Strasbourg and Paris.

FASTEST

3. JR-Maglev MLX01 (China)
Officially the fastest train on Earth, the MLX01 currently holds the world record after boasting an epic 581km/h top speed.

DID YOU KNOW? *A prototype AGV travelled at 357mph on a test track in Czech Republic, making it the world's fastest train*

© ALSTROM Transport P.Sautelet

Not a train you want to play chicken with at the railway crossing…

© ALSTROM Transport/TOMA C.Sasso

The Statistics

Alstom AGV train

© Alstrom 2008 Lefranc David

Top speed: 224mph
Power: 6,000 to 12,000kW
Power to weight: 22.6kW per ton
Number of carriages: 7 to 14
Carriage length: 17.3 metres
Train length: 130 to 250 metres
Width: 2.9 metres
Gauge: 1.435 metres
Seats: 250 to 650
Weight: 270 to 510 tons

Alstom's AGV train

This train of the future is capable of speeds of over 200mph yet isn't pulled by an 'engine'

France's TGV high-speed trains have been in service for over 20 years and they are currently seen as the benchmark for modern railway transport. Now, though, a potential successor is in the pipeline and it promises to be even faster, more economical and more futuristic.

The AGV (automotrice à grande vitesse, or high-speed self-propelled carriage) is at the prototype stage and is set to be in service by 2011. Ever since Richard Trevithick built the first steam locomotive in the early 19th Century, trains have relied on an 'engine' at one end pulling (or pushing) a train of carriages. Not any more, though – the AGV does not have such an engine. Instead, each of its carriages have relatively small electric motors mounted directly to the bogies under the floor, therefore freeing up space for more passengers.

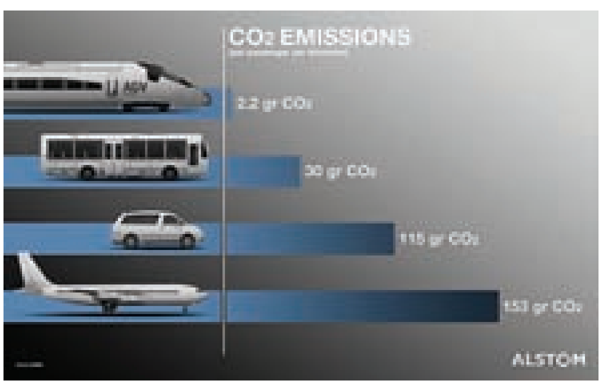
Furthermore, instead of the carriages being 'coupled' together in the conventional way, they are 'articulated'. In other words, the bogies are located between the carriages, linking them together. This is a stronger and safer method of linkage and, because they are shared between carriages, less bogies are required, saving both weight and money.

This, combined with the use of lightweight materials, means that the AGV is much lighter than its predecessor which makes the train remarkably efficient. For instance, it generates just 2.2 grams of CO_2 per passenger per kilometre, which compares favourably to figures of 115 grams for a typical car and 152 grams for an airliner. Put another way, the new train uses 30 per cent less energy than the TGV.

The AGV is also remarkably comfortable. Its body is three metres wide and clever design means that all but 25cm of this is available internally, making the carriages more spacious than before. Also, the carriage floors are 10cm lower, so the train is easier to board. Finally, the windows are 15 per cent larger than on the TGV, letting in plenty of light and allowing passengers to enjoy the ever-changing scenery.

This remarkable train will be available in sets of between seven and 14 coaches, which equates to a capacity from 250 to 650 passengers. The first order for the AGV has been placed by the Italian NTV company, a new organisation that hopes to have the super-fast trains running by the summer of 2011 on various routes across Italy.

It looks like the future is bright for railways but perhaps less so for railway engines!



Proving that speed can also be good for the environment, the AGV's average CO_2 emissions per passenger are lower than that of a passenger jet, a car and even a bus

How the 'engineless' train works

Eliminating the engine saves both space and weight

Having electric motors under the carriages is called a distributed drive. Not only does this arrangement negate the need for a separate and bulky power car, locating the motors on the bogies means that the transmission from motor to wheel is much simpler. Noise and vibration is also reduced.

Half the bogies on the AGV are powered, and each motor is relatively small and low powered. However, they combine to propel the train at impressive speeds.

The motors are high-tech synchronous permanent magnetic items that work with a variety of voltages, from 1,500 to 25,0000, therefore allowing the trains to operate in different countries. What's more, when the train is braking, the motors act as generators and the power created can then even be fed back to the national grid, via the overhead pantographs.

Back in the Forties the Chicago, North Shore & Milwaukee Railroad ran its Electroliner, a train with electric motors positioned in its bogies, and this reached speeds of up to 110mph.

© ALSTROM Transport P.Sautelet

You certainly wouldn't want the train company's electric bill!

The world's larg cruise ship

Evolving out of the transatlantic crossing tradition, cruise liners have developed exponentially since their creation in 1900. The Oasis of the Seas is the latest and arguably greatest variant sailing today

The design of the cruise ship has changed wildly in the past 100 years, from the compact passenger ship designed to carry a small number of passengers across the Atlantic, to the Oasis of the Seas, a massive floating city resplendent with parks, theatres, restaurants, golf ranges, swimming pools and shops. Indeed, the Oasis of the Seas is truly a monumental feat of engineering and its lineage can be traced through several iterations of the cruise ship over the past 20 years, culminating in the creation of an entirely new category of liner (Oasis Class).

The Oasis of the Seas was built by Royal Caribbean International to replace its previous top-of-class liner, the Freedom Class. In order to build such a colossal ship, over 37 design firms, 20 architectural firms, the full 130 members of Royal Caribbean's Newbuilding & Fleet Design group, and the entire staff of STX Europe's Finnish shipyard were needed. The fine honing of 15 separate ship configurations, as well as the pioneering inclusion of a split-superstructure design, were also undertaken in a design and build process that would take almost six years.

Upon completion in October last year, the Oasis of the Seas was over seven times bigger than the Titanic – the world's most famous cruise liner – and twice as heavy as its predecessor Freedom Class liner at a displacement weight of an estimated 100,000 tons. In addition, the Oasis is now the largest passenger ship and cruise liner in the world, with a total capacity of 6,296, incorporating a zonal design for its seven on-board neighbourhood areas.

The Oasis' primary role is as an all-in-one floating vacation, one in which the journey is part of the holiday just as mush as the actual destination. Registered at the port of Nassau in the Bahamas, and sailing from Fort Lauderdale, Florida, to multiple destinations around the Caribbean, the ship specialises in touring passengers in ridiculous comfort and with an unequalled level of amenities.

THE STATS OASIS OF THE SEAS

WEIGHT 225,282 tons LENGTH 360 metres SPEED 22.6kn CREW 2,165 BUILD TIME 3 years

DID YOU KNOW? The Oasis of the Seas' displacement weight is roughly 100,000 tons

gest

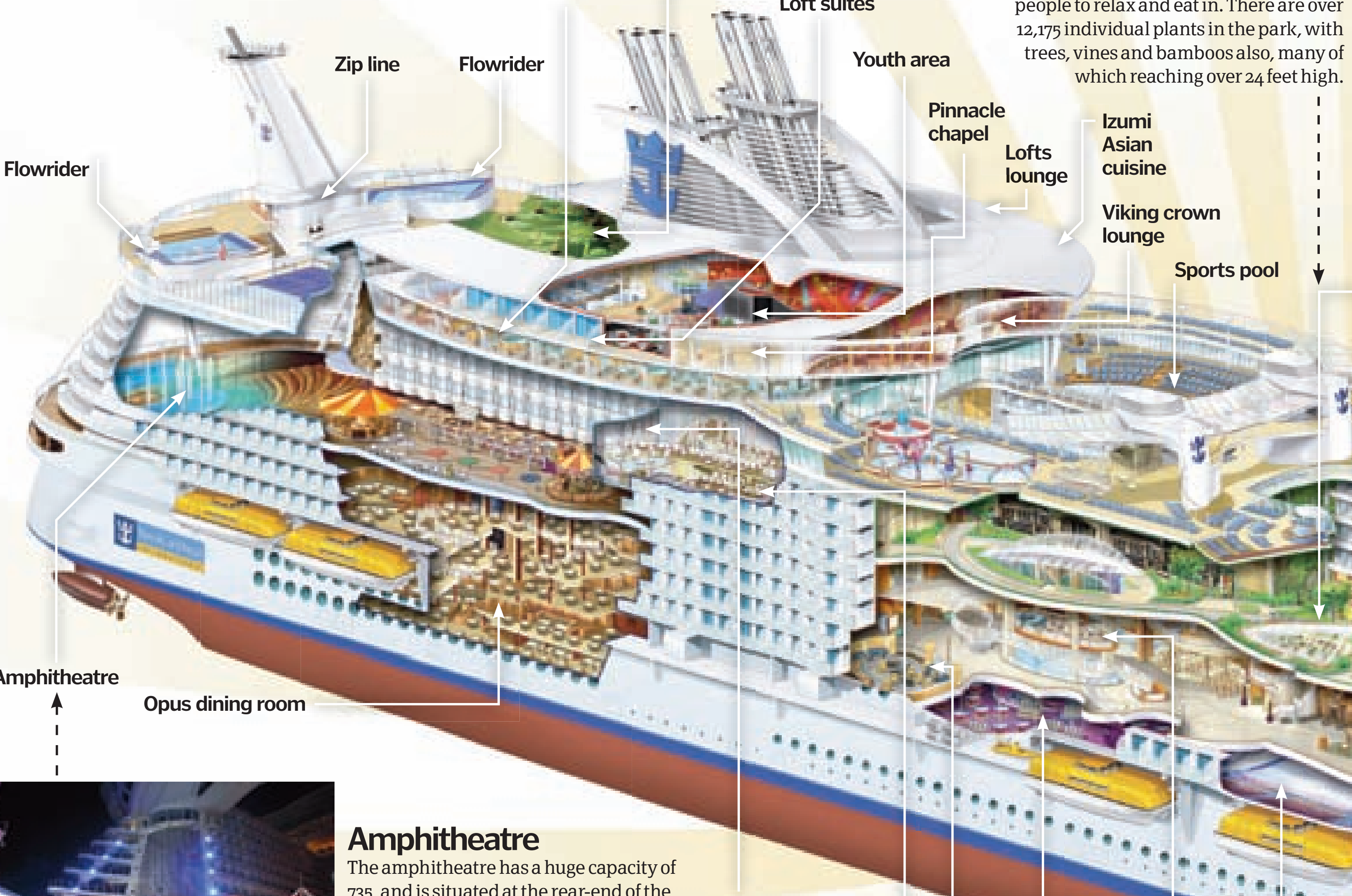
An under-construction shot of the ship's Central Park

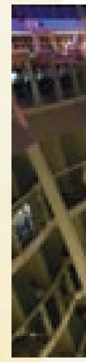
"Upon completion in October last year, the Oasis of the Seas was over seven times bigger than the Titanic"

The physical building of the Oasis of the Seas took over three years

All pictures © Royal Caribbean International

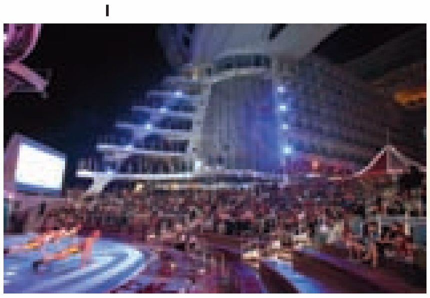
"It sounds more like a collection of city centre amenities to those traditionally found on a ship"





Central Park

Central Park is a purpose-built park area for people to relax and eat in. There are over 12,175 individual plants in the park, with trees, vines and bamboos also, many of which reaching over 24 feet high.



Amphitheatre

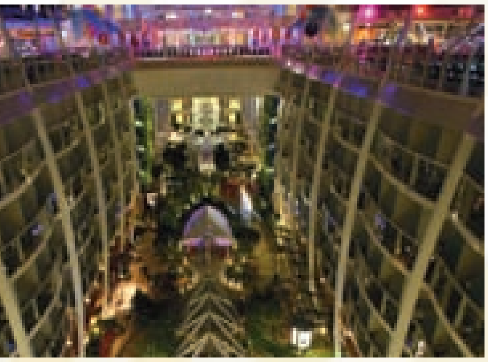
The amphitheatre has a huge capacity of 735, and is situated at the rear-end of the Oasis. This oceanfront theatre hosts a wide-variety of shows and entertainment, including live music, fountain shows, themed events and cabarets as well as high-dive performances.

On board the Oasis of the Seas

Take a look at the amenities that make this the world's most decadent cruise ship

The facilities available to those who travel on the Oasis of the Seas are quite staggering, sounding more like a collection of city centre amenities to those traditionally found on a ship. Split into seven distinct neighbourhoods, including Central Park, Pool and Sports Zone, Spa and Fitness Centre, Boardwalk, Royal Promenade, Youth Zone and Entertainment Place, no matter what your fancy, the Oasis in all probability can provide. From numerous restaurants, coffee houses, bars and high street shops, to a full theatre, casino, park and amphitheatre, the term 'floating city' has never been more apt.

DID YOU KNOW? *The Oasis of the Seas is the first ever ship to have a park built in, containing a whopping 12,175 plants*

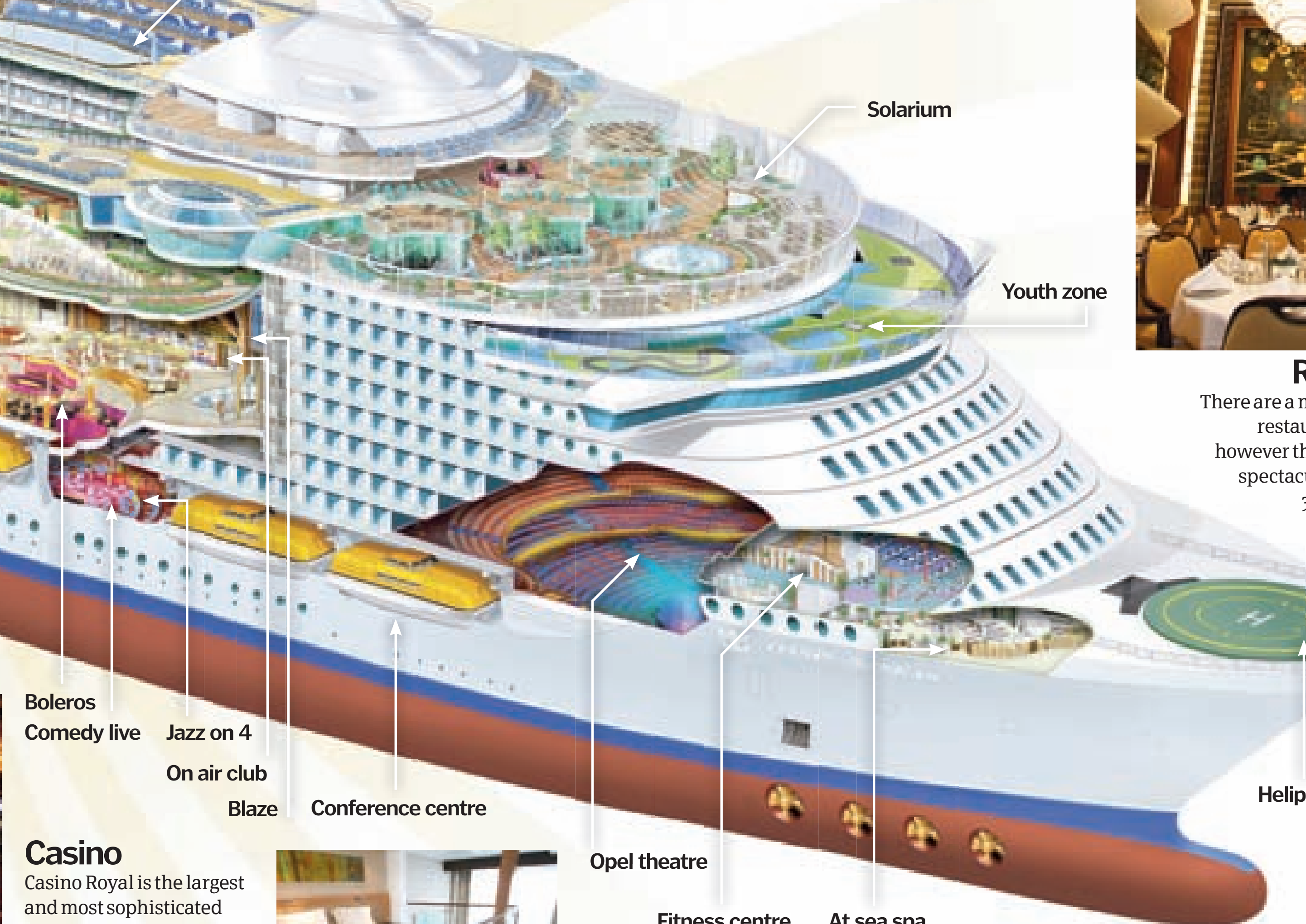


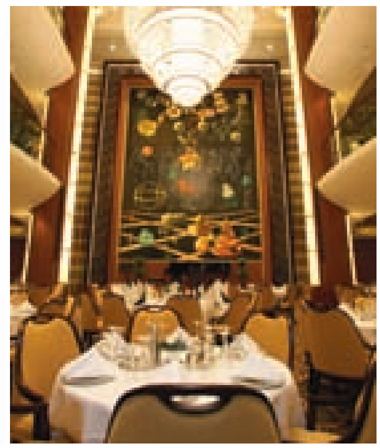
Bars

Dotted around multiple neighbourhoods are over 35 drinking establishments, each differing in theme, style and service from the last. There is even a traditional English pub.

OASIS OF THE SEAS VS FREEDOM OF THE SEAS

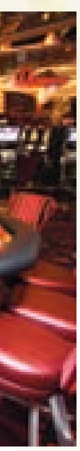
	Oasis of the Seas	Freedom of the Seas
Cost:	$1.6 billion	$800 million
Power:	3 x 18,590hp, 3 x 24,780hp	3 x 17,000hp
Capacity:	6,296	4,375
Decks:	16	15
Speed:	22.6 knots	22.6 knots
Length:	360 metres	339 metres
Weight:	225,282 gross tons	154,407 gross tons





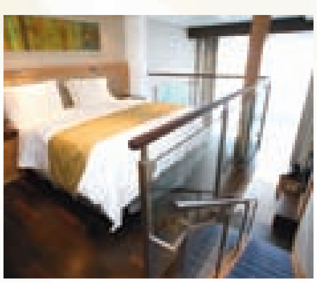
Restaurants

There are a massive selection of restaurants on the Oasis, however the biggest and most spectacular is arguably the 3,056 capacity Opus dining room.



Casino

Casino Royal is the largest and most sophisticated casino at sea, with over 450 slot machines, table games and separate bar and lounge. The casino is served by two main walkways that display the history of gaming.



Accommodation

The Oasis of the Seas has a grand total of 2,706 staterooms, including 1,956 with a balcony, 254 outside and 496 in the interior. In addition, the ship also has a selection of luxury two-storey loft suites, with floor-to-ceiling views of the sea and promenades.

The technically advanced bridge control room of the Oasis

The king of all cruise ships

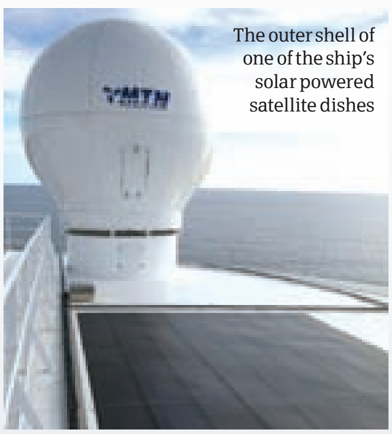
Exploring the statistics, performance and equipment of this oceanic behemoth

Despite a smorgasbord of amenities and its new class-creating size, the Oasis of the Seas is designed largely in the same way as any other ship, with performance and stability ultimately driving its design and construction.

For example, in order for any ship to float it must displace an equal amount of water to its weight, if it can't do this before it is submerged then it sinks as it is too dense. All ships accomplish this mainly through their hulls; the lightweight, watertight part of the ship that sits below the waterline. Considering that the Oasis has a displacement weight of over 100,000 tons its hull is therefore super-wide to maintain stability (66 metres) and to minimise drag, while its magnificent size and shape (nine metres deep with rounded edges) are tailored to disperse weight while maintaining smooth sailing.

The large, traditional hull of the Oasis however, has an increased burden when compared to its predecessors, as it has to accommodate the split-superstructure of the ship. The Oasis's superstructure is split right down its middle to minimise the amount of interior areas with no access to the exterior – an issue that has grown in parallel with ship size over the last 20 years. By splitting the superstructure however, the complexity and weight distribution of the ship is altered dramatically from previous liners and the hull's construction – notably its colossal width – is modified to account for this.

Due to the ship's gargantuan physical characteristics – over 360 metres long, 66 metres wide, 65 metres high from the water line and a draft of nine metres – it is



The outer shell of one of the ship's solar powered satellite dishes

5 TOP FACTS OASIS OF THE SEAS

Whale of a size
1 With an incredible displacement weight of 100,000 tons, the Oasis of the Seas weighs more than 500 blue whales, the largest known animal.

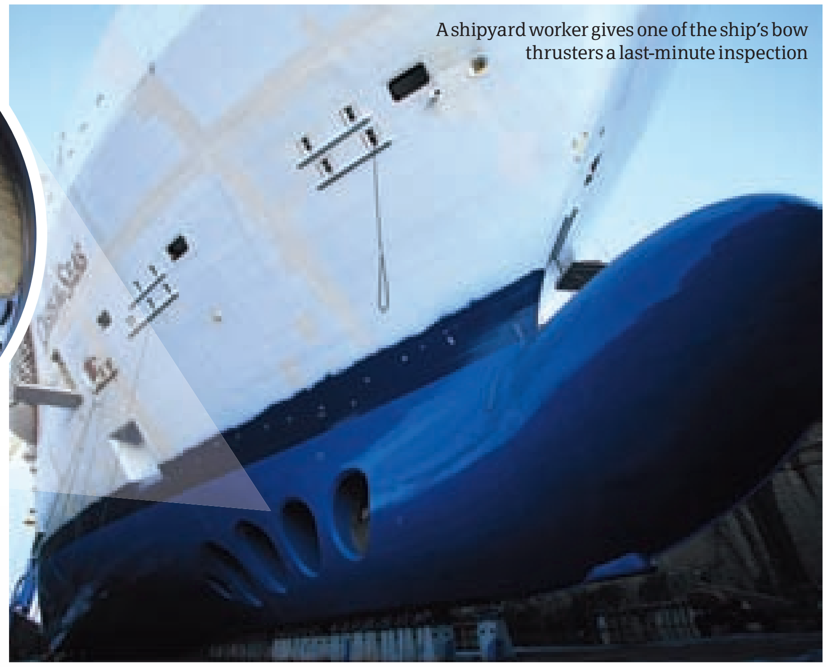
A ship in bloom
2 The massive Central Park area on board the Oasis of the Seas contains approximately 12,175 plants, 62 vines and 56 trees and bamboos.

Plenty of power
3 The Oasis of the Seas' total power output is over 130,000hp… which is 130 times that of the world's fastest car, the incredible Bugatti Veyron.

Steering
4 No rudders are needed to steer the Oasis of the Seas, instead the action is performed by a series of 20-foot propellers suspended under the stern.

A mighty crew
5 The ship has a crew of over 2,100, which is not surprising considering its sheer size and the activities and amenities that are on offer.

DID YOU KNOW? *The Oasis of the Seas is so wide at 66 metres that it cannot fit through the Panama Canal*



A shipyard worker gives one of the ship's bow thrusters a last-minute inspection

limited to certain ports. This is not surprising considering that the Oasis is four times the length of a football pitch and over 20 stories high.

The juice for such a leviathan comes courtesy of six engines, three Wärtsilä 12-cylinder diesels producing 18,590hp each, and three Wärtsilä 16-cylinder diesels producing 24,780hp each – a combined total power output of over 130,000hp. Amazingly, this massive power is entirely justified as, once converted into electricity, it is used all over the ship, from the operation of individual lights and elevators, to the running of the on-board water treatment plant and ship's control room. Propulsion is also powered by these engines and is handled by three 20MW ABB Azipod electrically driven, rotatable propellers. In addition, to aid docking, the ship is also fitted with four 7,500hp bow thrusters.

Horse power

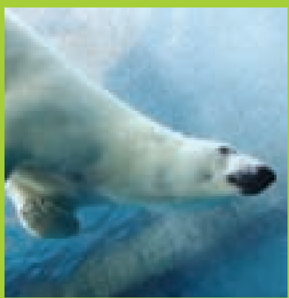
A look at the world's first carousel at sea

With a weight of 11,000 pounds, a height and diameter of seven metres as well as containing 21 handcrafted wood figurines, the Oasis of the Seas boasts the world's first carousel at sea. Constructed over eight months, the centrepiece of the ship's Boardwalk area needed 31 gallons of paint, 130 square feet of real gold leaf gilding, 1,800 feet of wiring, 200 light bulbs and 21 sets of glass eyes.

The showpiece hand-made carousel is positioned in the centre of Boardwalk

Learn more

For more information about the Oasis of the Seas – and her sister ship – head to **www.oasisoftheseas.com/** where you can watch videos and read about the history of the ship that could change the face of cruise liners forever.



This month in **Environment**

Polar bears are a fascinating juxtaposition of a cute, cuddly and not to mention endangered bundle of fur and an ice-cold killer. The largest carnivore in its habitat and king of the arctic. You can find out just how these fantastic creatures hunt, breed and survive in the frozen wastes by turning to page 56 right now. Take a look below to find out what else is on offer.

52 Clouds

54 Metamorphosis

55 Beaver dams

The Earth's

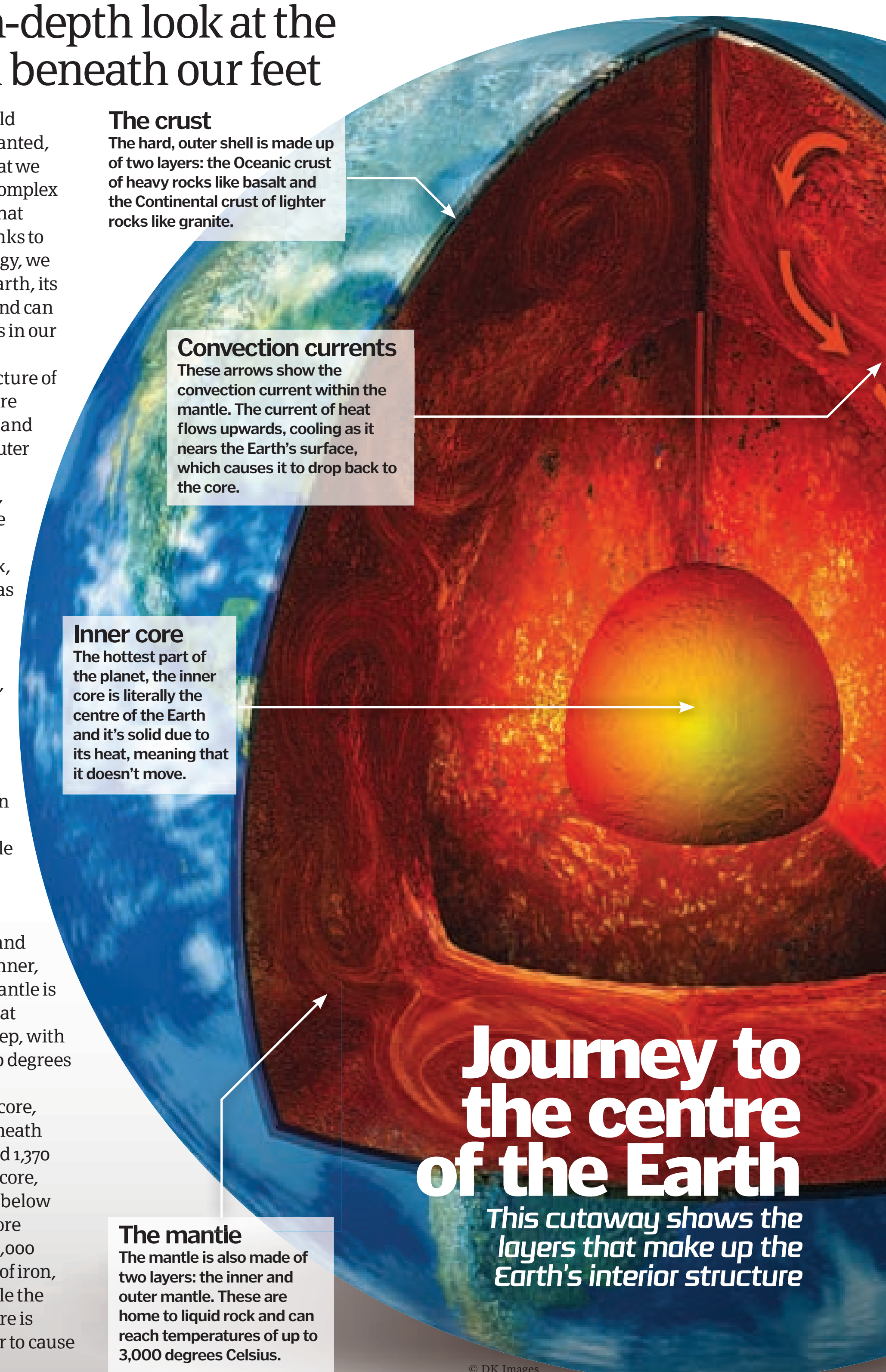
We take an in-depth look at the hidden world beneath our feet

We take the world around us for granted, but the Earth that we walk upon is a complex blend of layers that together create our planet. Thanks to research in the field of seismology, we now know the makeup of the Earth, its distances and measurements and can even compare it to other planets in our solar system.

Essentially, the internal structure of the Earth is made up of three core elements: the crust, the mantle and the core. The crust is the hard outer shell that we live on, split into Oceanic and Continental crusts, and it is comparatively thin. The first layer, the Oceanic crust, is around four to seven miles thick, made up of heavy rocks, whereas the lighter Continental crust is thicker, at approximately 19 miles.

Below the crust is the mantle, and again this is divided into two distinct layers: the inner and outer mantle. The outer mantle is the thinner of the two layers, occurring between seven miles and 190 miles below the Earth's surface. The outer mantle is made up of a bottom layer of tough liquid rock, with a temperature of somewhere between 1,400 degrees Celsius and 3,000 degrees Celsius, and a thinner, cooler upper layer. The inner mantle is deep into the Earth's structure, at between 190 and 1,800 miles deep, with an average temperature of 3,000 degrees Celsius.

Finally, we reach the Earth's core, which is 1,800 to 3,200 miles beneath our feet. The outer core is around 1,370 miles thick, encasing the inner core, which falls down to 3,960 miles below the Earth's surface. The inner core reaches a temperature high of 6,000 degrees Celsius and is made up of iron, nickel and other elements. While the outer core is liquid, the inner core is solid, and the two work together to cause the Earth's magnetism.



Journey to the centre of the Earth

This cutaway shows the layers that make up the Earth's interior structure

© DK Images

Day and night
1 During Earth's year-long orbit round the Sun, it also rotates once a day round its axis, an imaginary line passing through the North and South Poles, creating day and night.

The seasons
2 Earth's axis tilts at 23.5°. When Earth orbits the Sun, the North Pole spends six months leaning towards the Sun and six months leaning away from it.

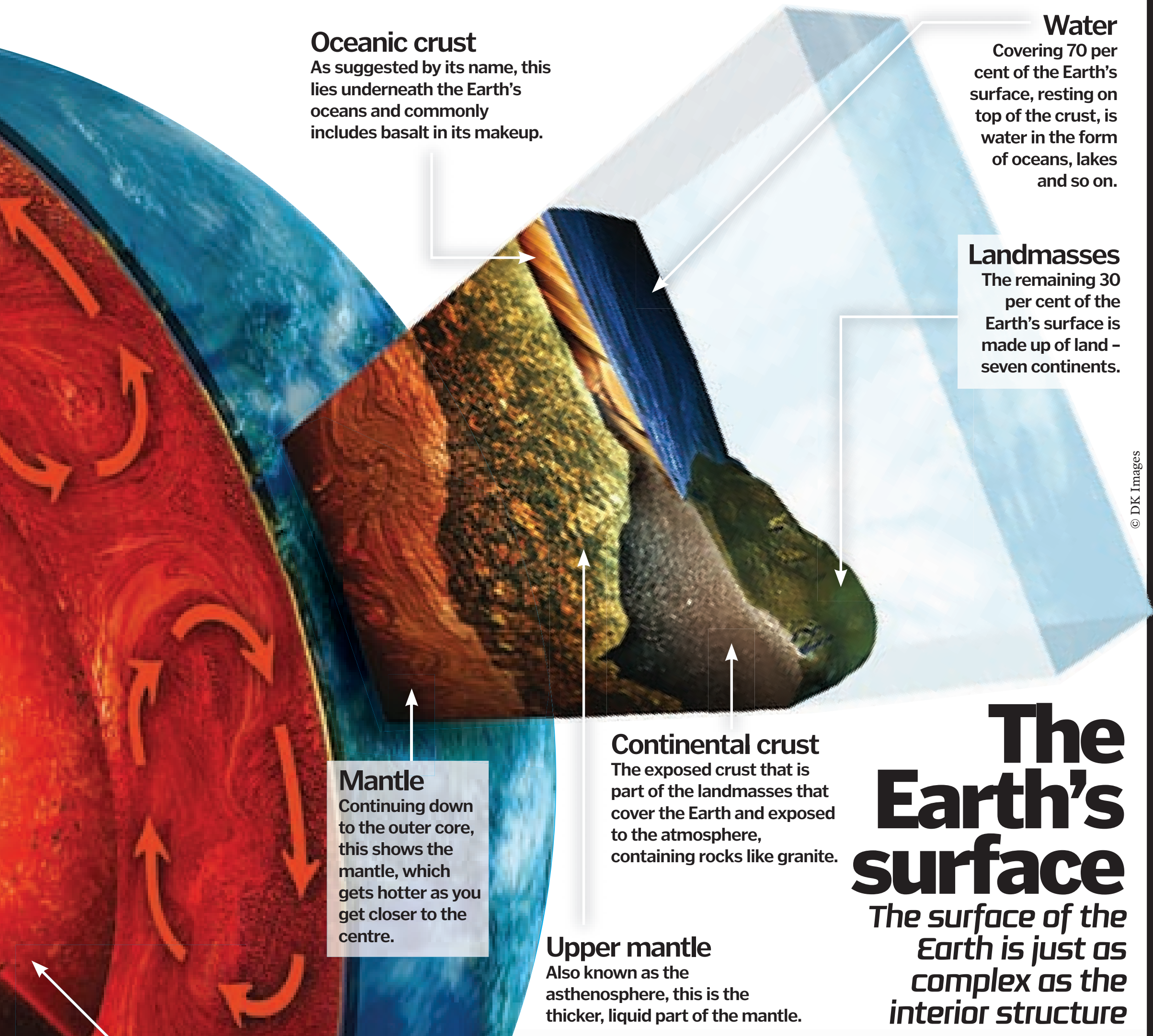
The tides
3 The Earth's tides are caused by the gravity of the Moon. The Earth's water on the side nearest to the Moon is pulled causing the water to bulge, this is known as a high tide.

Spring tide
4 The Sun also affects the tides, and when the Sun and Moon are aligned with the Earth, their combined gravities create the highest tide, called spring tide.

Neap tide
5 When the Sun and Moon are not lined up but are instead at right angles to each other, their gravities cancel each other out, creating the Earth's lowest neap tides.

DID YOU KNOW? 70 per cent of the Earth's surface is covered in water

structure



Oceanic crust
As suggested by its name, this lies underneath the Earth's oceans and commonly includes basalt in its makeup.

Water
Covering 70 per cent of the Earth's surface, resting on top of the crust, is water in the form of oceans, lakes and so on.

Landmasses
The remaining 30 per cent of the Earth's surface is made up of land – seven continents.

Mantle
Continuing down to the outer core, this shows the mantle, which gets hotter as you get closer to the centre.

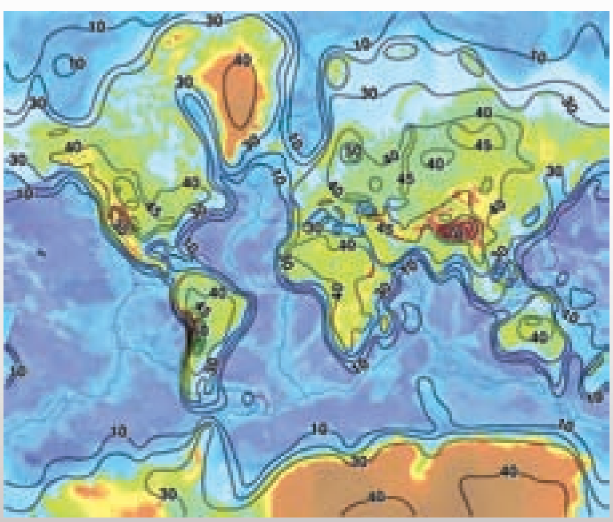
Continental crust
The exposed crust that is part of the landmasses that cover the Earth and exposed to the atmosphere, containing rocks like granite.

Upper mantle
Also known as the asthenosphere, this is the thicker, liquid part of the mantle.

Outer core
The liquid, outer core is made up of iron, nickel, sulphur and oxygen. This outer core spins as the Earth rotates.

The Earth's surface

The surface of the Earth is just as complex as the interior structure

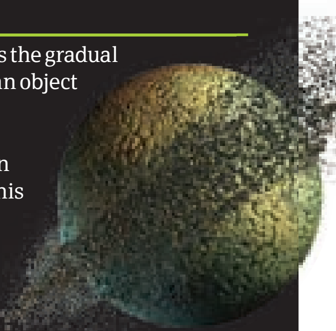


Crust thickness
A contour map of the globe, showing the thickness of the Earth's crust, with the numbers in kilometres.

How the Earth formed

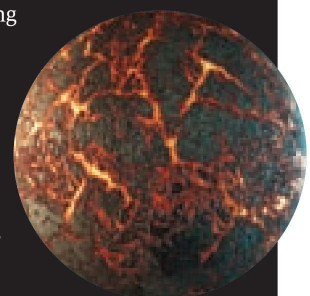
A complicated procedure brought together the many elements of the Earth and even today the planet is adapting and changing

Accretion



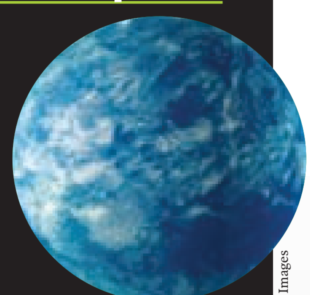
Accretion describes the gradual increase in size of an object through the accumulation of additional layers. In the case of Earth, this is how rocks and metals built upon each other to form the core.

Heating and cooling



The process of creating planets via accretion causes friction and collisions that create a heat, which partly explains the temperature at the Earth's core. As this cooled in the planet's formation, the crust hardened.

Oceans and atmosphere



Steam from the crust combined with gases from volcanoes to create the atmosphere and water. As the planet cooled, clouds formed, causing rain, which in turn caused the oceans.

Today's Earth

Though we rarely see the results, the Earth's surface continues to change as landmasses collide and break apart, thanks to the dynamic properties of the Earth's interior structure, which can move land by centimetres each year.

"Lightning, hail and violent tornadoes are associated with Cumulonimbus clouds"

Influencing cloud formation

We explore elemental factors influencing varying cloud types

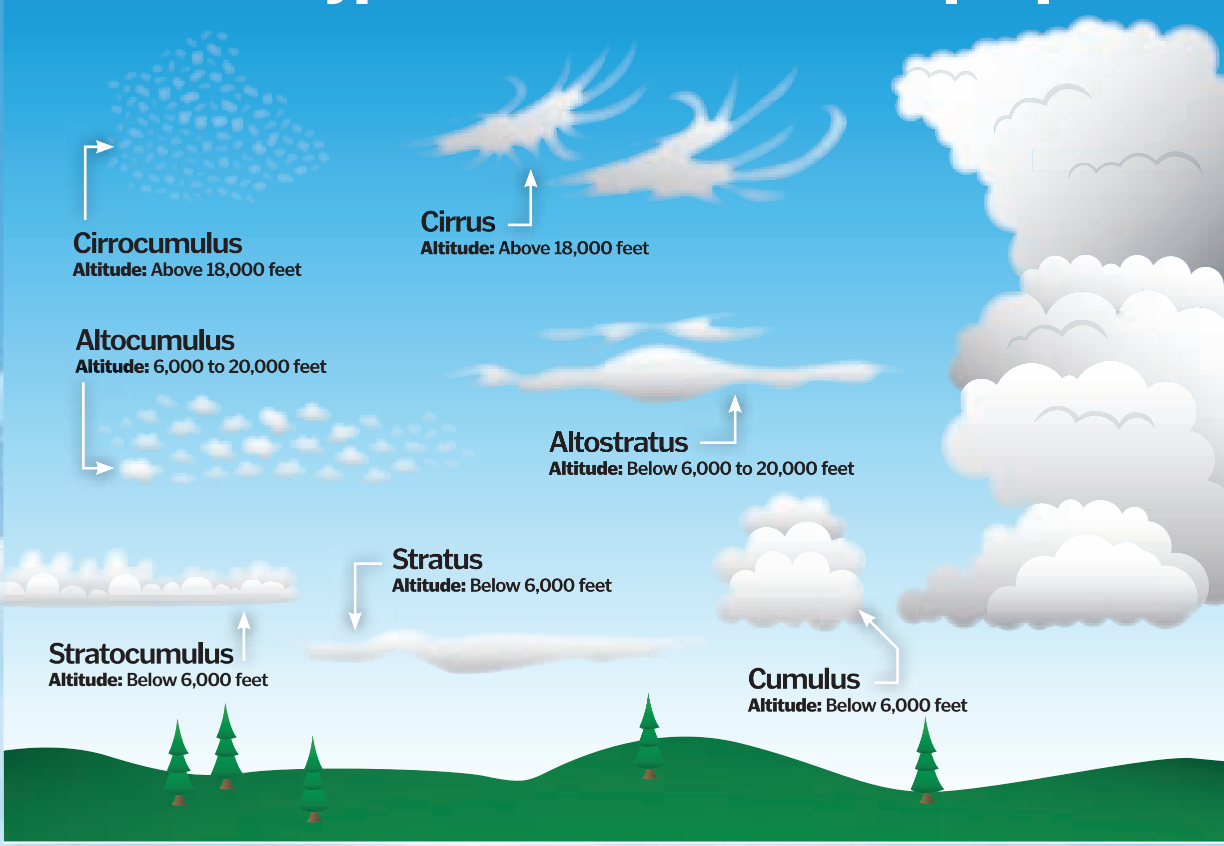
Look up into the sky above and you will notice that clouds constantly shift in shape and size. This is due to there being numerous common types of cloud formation, with each performing a natural role, which is determined by external factors such as altitude, condensation and disposition. These include stratus, cumulus, stratocumulus, altocumulus, cirrus, cirrocumulus and cumulonimbus.

Most cloud formations are produced in environments that are saturated, or where relative humidity is at 100 per cent. Varying mechanisms can activate this process. For example orographic uplift, which occurs as air is forced up due to the physical presence of elevated landmass. As air rises it cools as a result of adiabatic expansion, at a rate of approximately ten degrees Celsius per every 1,000 metres, until saturation occurs. Stratus clouds, for example, form when minimal upward vertical air currents lift a thin layer of air high, which is enough to initiate the condensation of excess water vapour.

Altocumulus clouds are part of the middle order of formations, appearing greyish with dark patchy areas. Often these clouds precede a cold front, and on a warm humid morning indicate approaching thunderstorm activity. Altocumulus clouds are often produced due to turbulent updrafts of air, uplifted by terrain barriers such as mountains, composed of super-cooled water, below freezing, which has not yet crystallised around a condensation nucleus.

There are several cloud formations at high altitude. Most notable are cumulonimbus, which form if cumulus congestus clouds continue to grow vertically. Ranging from near ground level up to 50,000 feet, this formation releases enormous amounts of energy by condensed water vapour. Lightning, hail and violent tornadoes are associated with cumulonimbus clouds. During the formation, condensation carries droplets up and down several times before being released and combining to form raindrops. In larger specimens up-currents become extremely severe, splitting raindrops and ice crystals, before re-combining and falling to the ground. This contributes to a build up of electrical charges and therefore the occurrence of lightning.

Common types of clouds in the troposphere

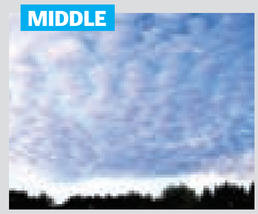


Head to Head
CLOUD FORMATIONS

LOWEST

1. Low-level clouds
Facts: Including stratus, stratocumulus and cumulus formations, these types appear below 6,000 feet and are composed mostly of water droplets.

MIDDLE



2. Mid-level clouds
Facts: These typically appear between 6,500 and 20,000 feet, including altocumulus, altostratus, cirrocumulus and cirrus. These consist of water droplets, but when temperatures are cold enough display ice crystals.

HIGHEST

3. High-level clouds
Facts: These formations, including cirrocumulus and cirrus, appear above 18,000 feet. The latter are composed from ice crystals that originate due to the freezing of super-cooled water droplets. Appearing in fair weather, these clouds indicate the direction of air current.

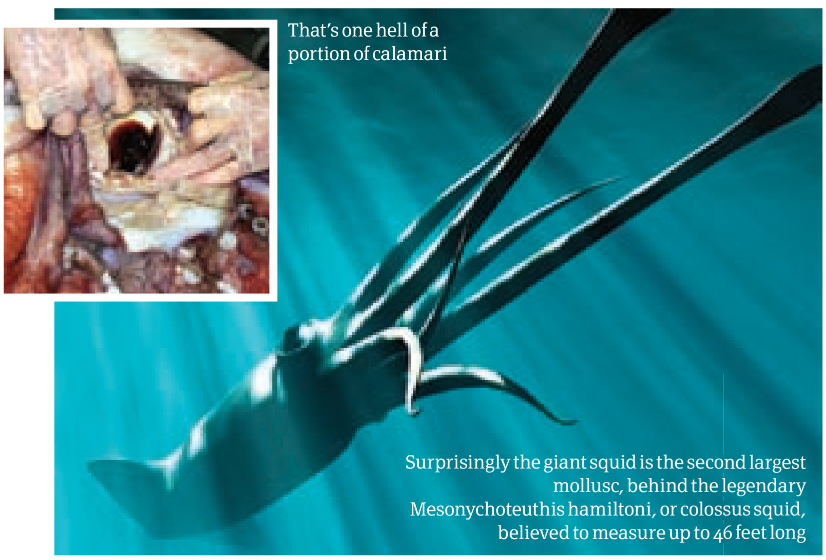
Do giant squid exist?

Yes they do. A species of squid can reach up to half a ton!

Fiction is commonly built upon myth, however in the year 2007 the tales of maritime folklore were revealed to be true. Exciting the zoological world, a half-ton Architeuthis, or giant squid, was discovered by fishermen in Antarctic waters south of New Zealand. This female measured 33 feet in length and weighed exactly 1,089lbs.

This discovery was significant, as scientists determined the species lives up to 3,000 feet below the surface, descending deeper to 6,500 feet to aggressively hunt prey, with eyes 11-inches wide – useful at depths where light is scarce. Anatomically, this species is found to be a keen predator, with its tentacles all containing swivelling hooks. Further up these limbs are three razor points, all helping it to attach to prey, including deep-sea fish and other squid species.

Amazingly, after comparing this sea creature's beak with specimens found in the stomachs of sperm whales, researchers believe that Architeuthis can reach up to 46 feet in length.



That's one hell of a portion of calamari

Surprisingly the giant squid is the second largest mollusc, behind the legendary Mesonychoteuthis hamiltoni, or colossus squid, believed to measure up to 46 feet long

© Science Photo Library

How do fireflies produce light?

Understanding this natural phenomenon

Lampyridae, or fireflies, are not flies at all. This beetle species is celebrated at many cultural festivals for their ability to produce biological lights. They are able to achieve this through a natural heat-resistant substrate enzyme known as luciferase. The cells in the insect's tail produce this enzyme, which chemically reacts with oxygen; the fuel that allows them to produce this natural phenomenon.

But why do they create light? Fireflies are noted for blinking their lights and the female of the species does this, alternating the rate and wavelength of each flash, to attract fertile males. This is a fundamental interaction, due to the fact that varying species of Lampyridae will occupy the same space. This flashing can distinguish appropriate mates. Firefly larvae are also capable of creating this bioluminescent spectacle, hence the affectionate nickname glowworm.

Image: Art Farmer 2006

Metamorphosis

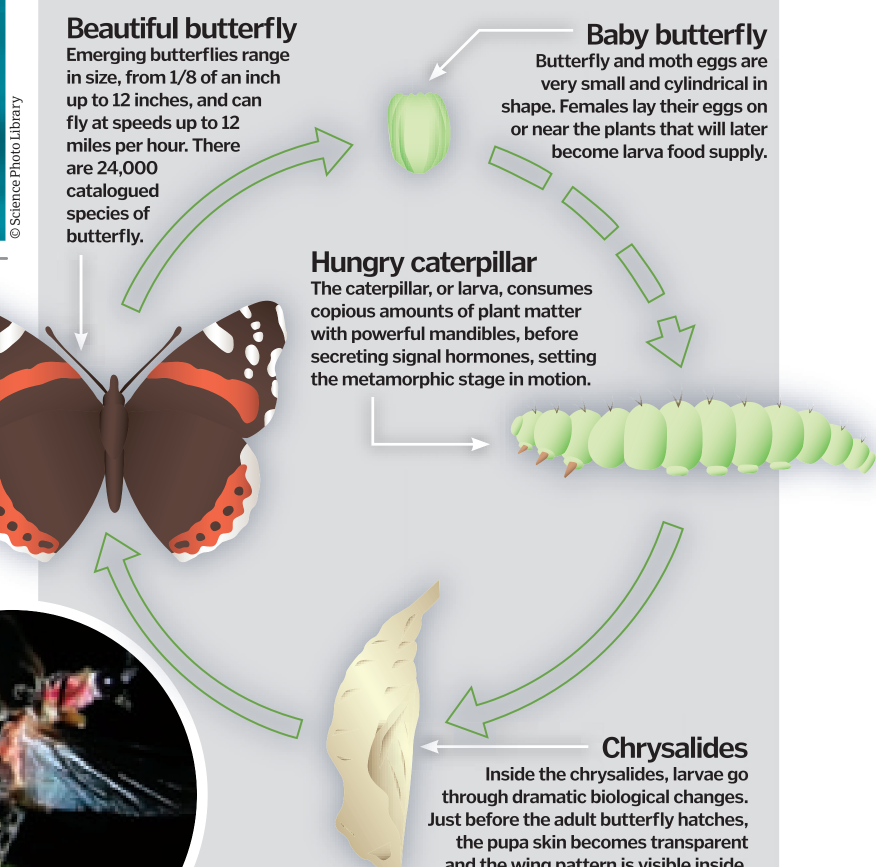
We explore how Lepidoptera metamorphosis takes shape

Belonging to the Lepidoptera family, butterflies are insects that achieve four life stages before turning into all manner of beautiful specimens, including the Hesperiidae, Papilionidae and Nymphalidae. This amazing journey sees Lepidoptera begin life as a plain egg that hatches into a larva, or caterpillar, after a period of six days.

The caterpillar is an eating machine, consuming for up to four weeks constantly until pupation takes place. The caterpillar's anatomy makes it adept at consuming plant matter. Using its three pairs of true legs and five further pairs of 'prolegs' – sucker-like structures with hooks on the end – it grips to leaves and plant stems, munching away with powerful mandibles. The caterpillar has 4,000 muscles to compliment these feeding habits and a long gut track to quickly digest foodstuff.

As these creatures feast this fuels their tremendous growth and a caterpillar will shed its husk several times, becoming stronger and larger with each turn. At this stage larvae begin to secrete signature hormones, which instinctively kick in its need to produce a protective silk cocoon – known as pupa or chrysalides – and initiate the metamorphic stage. They achieve this by using their modified set of salivary glands, known as spinnerets. This cocoon may take the form of a small hollow in the earth lined with silk, or a roll of leaves, camouflaged to deter predators.

What really goes on inside this cocoon is fascinating. Larva anatomy and organs are rapidly dissolving and re-forming into new tissue, limbs and wings of the adult butterfly. This process varies from species to species, some taking no more than two weeks, others over winter, but eventually emerging as a butterfly. Blood is pumped into the insect wings, making them expandable and ready to fly.



DID YOU KNOW? *The beaver is an obligate monogamous species, which means both parents are needed to raise offspring*

Beaver dams

We explore how these aquatic mammals design and construct their habitats

Home sweet home
A beaver's lodge, often found in the middle of a pond, is accessible only by water. These dwellings are home to extended families.

Standing tall
The average height of a beaver lodge reaches up to six feet tall, with an average depth of water behind the dam of four to six feet. This makes it a great place to look out for predators, and keeps it a safe distance from shore.

Made to last
The thickness of the dam can measure up to five feet or more. The length depends on the width of the habitable stream, averaging 15 feet. This makes for a very sturdy home in all weather conditions.

Safe depths
Winter seasons are perilous for all aquatic creatures. To stop the hazard of ice blocking the dam entrance at this time of year, beavers will submerge its foundations three feet beneath surface level.

Rodent renovation
Renovation is the name of a beaver's game. Apart from building dams, they can gnaw at trees and felling, creating large log and branch obstructions that turn fields and forests into large ponds to build their habitat.

Food fuel
Beavers are among the largest rodents on Earth. They live on a herbivore diet, eating leaves, bark, twigs, roots and aquatic plants.


© DK Images

Beavers are aquatic mammals with a keen affection for engineering, demonstrated in the construction of their artificial dam habitat. This ingenuity is one of nature's greatest wonders, and has been happening for well over 10 million years. Fundamentally, the building of a dam suits the natural instinct of this species. The beaver is an adapted swimmer, that is fairly immobile upon land. This makes it susceptible to predators such as the bear.

Their strong aquatic skills make deep water habitats far more secure. Skilled teams of constructer beavers, usually working in pairs, can build a dam in a matter of days. The dam itself is constructed from an eclectic mix of natural materials, including rocks, wet grass, wood and mud to build the superstructure. A minimum level of three feet is required to keep the dam's underwater entrance from freezing over in winter. A beaver's dam will vary in construct and design, dependent on water speeds in the river. If the dam is straight, then the water current is slow. If it's curved, the water current is fast moving.

Bats' ultrasonic sonar system

We reveal how Chiroptera's supersonic hearing happens

Contrary to belief, bats (Chiroptera) do demonstrate an acute sense of vision, however this is accommodated during daylight conditions. When night falls, these small mammals are more inclined to use their heightened sense of hearing when hunting prey and manoeuvring around habitats, never being at a disadvantage. This is complemented by their incredible biological sonar navigation system.

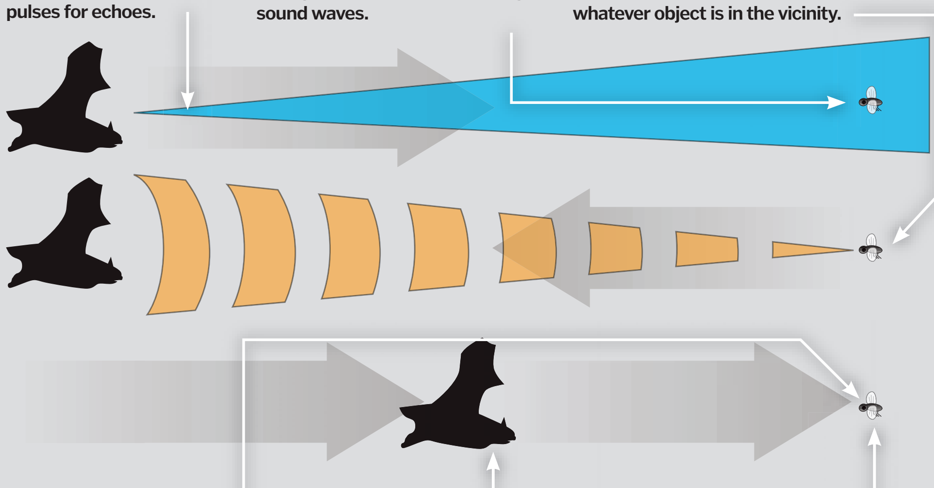
But how does this work? Well, bats are inclined to emit ultrasonic sounds, with a frequency of between 50,000 and 200,000 vibrations per second, too high-pitched for human ears to comprehend.

These sound are emitted 20 to 30 times each second in all directions, with the bat listening between pulses, scanning for echoes with its head in perpetual motion. Bats separately perceive and process overlapping echo delays, arriving as little as two microseconds apart, that's an impressive two thousandths of a second. The bat's own nervous system supports this fined-tuned capability, allowing Chiroptera to identify echo-reflecting points on an object the width of a pen line on paper, or objects as close together as three-tenths of a millimetre.

Emitting sound
Bats emit ultrasonic sounds 20 to 30 times each second, listening between pulses for echoes.

Timing and direction
The bat then registers distance and location of prey through the timing and direction of returning sound waves.

Translating echo
The time between sending out a cry and then receiving a response is translated by the bat into distance, between itself and whatever object is in the vicinity.



Moving prey
The bat realises moving prey through delayed sound and a slightly lower or higher pitch, due to the Doppler effect.

Sourcing insects
Echoes from prey such as mosquitoes, moths and butterflies reveal fluctuations, which are caused by the flutter of their wings, easily recognised by the bat.

Stationary prey
Stationary objects are instantly recognisable, as these yield an echo that is a replica of the pulse sent out by the bat.

“The bear’s sense of smell is extremely acute, and becomes the most important sensory for detecting land prey”

Kings of the

How polar bears hunt and survive

The polar bear may seem cute and cuddly, but these mammoth mammals of the Arctic are a hardened species, set out to survive in these subzero temperatures, plunging to as much as -45° Celsius.

The polar bear, or Ursus maritimus – which means sea bear – have been recorded to weigh as much as 2,209 pounds, and can grow to as big as ten feet tall, when standing on their hind legs. That’s a massive body mass, which includes a thick layer of blubber nearly 4.5 inches thick. Wrap this up with two additional layers of fur, which covers all of the bear’s anatomy except their nose and foot pads, and Ursus maritimus stays as snug as a bug. Pure white to creamy yellow/light brown in colouration, depending upon season and angle of light, makes for a perfect combination for surprising prey.

Other essential parts of the anatomy, such as the paws and snout, help them thrive in these harsh conditions. Polar bears’ paws are large compared to its body size. Measuring 12 inches, they include thick, curved, non-retractable claws, essential for catching large prey, as well as for traction when running on ice.

A family of polar bears receive a surprise visit from a Russian sub

Polar bears are animals without boundaries, padding across the ice from Russia to Alaska, from Canada to Greenland and onto Norway’s Svalbard archipelago

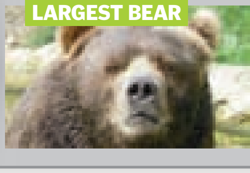
© Ansgar Walk 1996

ON THE MAP

Where can you find the king of the arctic?

Found throughout the Arctic circle, polar bears can be found in five countries: Denmark (Greenland), USA (Alaska), Canada, Norway (Svalbard) and Russia. Estimates suggest that only 20,000-25,000 polar bears remain worldwide.

LARGEST BEAR

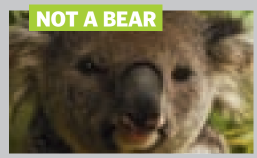


1. Brown bear
The largest member of the bear family, they can weigh up to 1,500 pounds. They live across northern Eurasia and the USA.

MEANEST BEAR

2. Polar bear
Rival in all but size to the brown bear and much more deadly, polar bears are claimed to have actively hunted humans.

NOT A BEAR



3. Koala bear
Contrary to its misleading name, the cuddly Koala is not a bear at all but a marsupial, an infraclass of mammals.

DID YOU KNOW? *Polar bears enjoy a relatively extended life span, most dying at a ripe age of 25 years old*

e Arctic

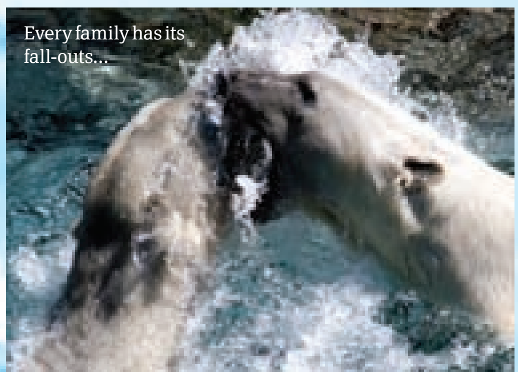
Small bumps, known as papillae, are also present and these help them keep their grip when manoeuvring slippery ice. Up to half the length of the bear's toes is covered with a swimming membrane, which enables them to swim at a rate of six miles per hour, and they're known to be competent swimmers as far as 320km from shore.

The bear's sense of smell is extremely acute, and becomes the most important sensory for detecting land prey. Able to smell a seal from over one kilometre away, under three feet of snow, this is extremely important to this species' survival, as snowy weather conditions impair its eyesight, which is no better than that of a normal human being. These factors firmly put Ursus maritimus at the top of the Arctic food chain.

Unfortunately, despite their great prowess, the polar bear population is dropping quickly, mainly due to the damaging effects of global warming. As the Earth heats up, larger quantities of ice are melting earlier in the year, removing the vital hunting platforms which polar bears use to hunt seals. This habitat loss is preventing polar bears from building up the requisite fat reserves to survive in the harsher and leaner parts of the year, with many succumbing to malnutrition. In addition, the loss of ice is forcing the bears to swim further and further between landmasses, draining energy that is vital for healthy reproduction, body conditioning and general survival.

It'll take more than a baby wipe to clean up those two…

A sperm whale provides a nutritious and hearty meal



Every family has its fall-outs…

5 TOP FACTS
POLAR BEARS

1 Diving depths
The polar bear makes shallow dives to catch prey, but can stay submerged for up to two minutes, in depths of up to 15 feet.

2 Female of the species
A female polar bear can bare offspring as young as four or five years old. Cub litters are most commonly twins.

3 Boys are bigger
The male is the larger of the two sexes, growing up to ten feet tall and weighing in at over 1,400 pounds. The female is a little more slender, at seven feet tall and only 650 pounds.

4 Translucent fur
Ever wondered why a polar bear looks white? Well, each hair is a transparent and pigment-free hollow tube, reflecting the light around it. Perfect camouflage for hunting prey.

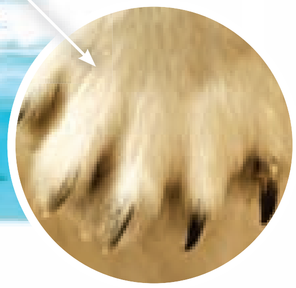
5 Bear on standby
The polar bear can slow down its own metabolism, which enables it to conserve energy at any time of the year.

On the hunt
Land or sea, nothing stops the polar bear

Locating prey
To catch prey, polar bears wait in silence outside seal breathing holes in the ice, before dragging them out when they surface to breathe. They then crush the seal's skull to kill it.

Big diet
Polar bears' diet consists mainly of land-caught seals and their pups. During the summer months they also eat a plethora of sea creatures and fish.

Devouring prey
Polar bears tend to be selective in what parts of their prey they consume, focusing on the calorie-rich skin and blubber.



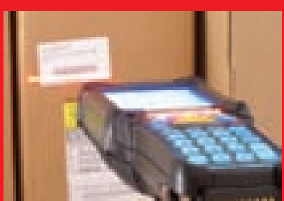
© DK Images

Learn more
For more information about polar bears head over to **polarbearsinternational.org/** where you can learn more about these incredibly cute but ultimately deadly beasts, and even adopt your very own cub!

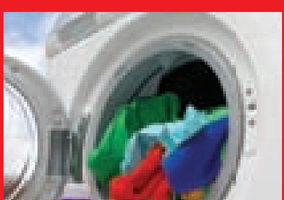
categories explained
Computing | Electronics | Gadgets | Engineering | Communication | Domestic | Entertainment | Medical | General

This month in **Technology**

From everyday domestic items to the latest in cutting-edge advancements, the technology section seeks to explain the most fascinating kit from the spheres of computing, engineering, communication, medicine and electronics.



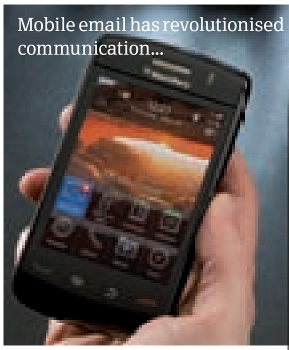
60 Barcodes



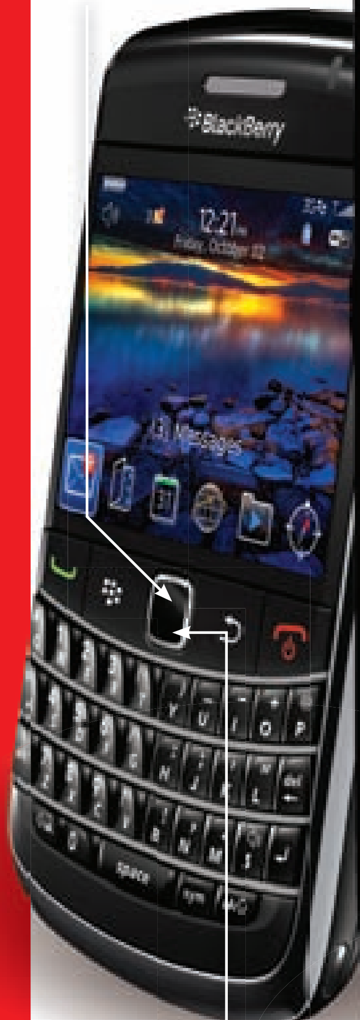
61 Washing machines

62 Solar panels

TECHNOLOGY



Mobile email has revolutionised communication...



Highlight text
Hold Shift and move trackball

Copy text
Press Alt and click trackball

NUM Lock
Alt+Left shift

BlackBerry shortcuts

How the BlackBerry keyboard makes typing easier

Auto full stop
Press the spacebar twice

Insert @ symbol
Press spacebar (in email field)

Paste text
Hold Shift and click trackball

CAPS Lock
Alt+Right shift

5 TOP FACTS BlackBerry

An app for everything
1 The BlackBerry App World has around 10,000 programs that can be installed, enabling the BlackBerry to perform almost any function you can imagine.

50 million BlackBerrys
2 As one of the biggest phone platforms in the world the BlackBerry has sold over 50 million units to businesses and ordinary consumers alike.

Four ranges
3 There are four distinct ranges of BlackBerry handset: Bold, Storm, Pearl and Curve. The newest, the Storm, features fully touch-screened devices in the style of the iPhone.

SureType keyboards
4 The Pearl range of BlackBerrys include a SureType keyboard which combines a Qwerty layout with the more traditional numeric keypad.

Shortcuts
5 The BlackBerry keyboard is packed full of shortcuts. For example, hitting the spacebar in an email address will automatically insert the @ symbol.

DID YOU KNOW? *The first BlackBerry was launched back in 1999, not as a phone, but as a pager*

Inside the BlackBerry

They are the must-have gadget for the discerning business user, but what is it that makes the BlackBerry such a popular phone?

Originally launched back in the Nineties as a simple paging device, the BlackBerry has grown into one of the biggest and most recognisable mobile phone brands, the pride and joy of business users the world over. The secret of its success was simple: the BlackBerry completely rewrote the rules on how we use email. No longer did you need to be tied to a desk, and a desktop computer, to check your inbox, you could do it on the go. Even more importantly, through the BlackBerry's revolutionary 'push email' concept you could read your messages instantly.

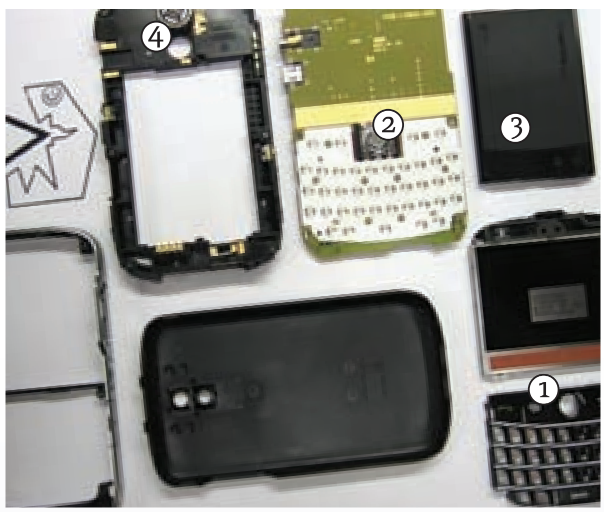
Push email works by routing your traditional inbox via the BlackBerry servers, accessed by signing up to either the BlackBerry Enterprise Service (BES) for businesses or the Internet Service (BIS) for individual users. As soon as a new mail drops into your inbox, BIS (or BES) instantly 'pushes' it to the BlackBerry handheld associated with the account. There's no clicking of a Send/Receive button in the mail client, no waiting for 15 minutes for the email app to poll your inbox. With a BlackBerry email is instant - more akin to the immediacy of text messaging than the email we are more used to on a PC. It's this instant delivery that sold the BlackBerry concept to businesses, while in the last couple of years the simplicity of the service combined with more attractively designed hardware has increased its appeal to ordinary consumers as well. Now, a fifth of all the smartphone users in the world carry a BlackBerry.

Of course, a pocket-sized email device would be useless without the BlackBerry's second point of genius, the thumb keyboard. The trademark Qwerty keyboard that sits below the handset's screen seemingly defies the laws of engineering. It's tiny, cramped and should be impossible to use with any comfort, yet with subtle design touches and intelligent shortcuts it is somehow possible to type even lengthy emails at fast speeds. Other phone manufacturers have tried to replicate this, but the BlackBerry is still well ahead.

Now your office can reach you wherever you are. Er, hurray?

How it works

What's under the skin of the BlackBerry…



1. The keyboard
The 35-key thumbboard comes in the normal Qwerty layout similar to any desktop keyboard. Despite its compact size it enables the user to type quickly and at some length.

2. Trackball
The trackball offers the quickest way of navigating. You can control how fast you scroll through webpages or documents simply by changing the speed at which you move the trackball.

3. Large capacity battery
The 1500mAh battery is as large as in any mainstream device, and delivers a couple of days' use on a single charge, unlike many devices that need a daily charge.

4. Two megapixel camera
Although not a major focus of the BlackBerry range, the camera is good for snapshots, and the always-on internet connection on the phone makes it easy to share them.

Screen:	3.5 inches
Processor:	600MHz
Memory:	up to 32GB
Apps:	100,000
Camera:	3MP autofocus
Battery:	5 hours 3G

iPHONE 3GS VS BLACKBERRY STORM2

Screen:	3.25 inches
Processor:	528MHz
Memory:	up to 16GB
Apps:	10,000
Camera:	3.2MP flash
Battery:	6 hours 3G

Learn more

For more information about BlackBerry and other mobile devices, head over to **www.smartphonedaily.co.uk** where you can catch up on all the latest smartphone news and reviews.

© Images from ifixit.com

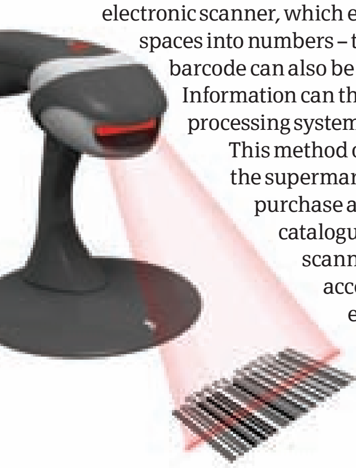
Using barcodes

How this printed version of Morse code has revolutionised the checkout

A simple enough concept, the barcode is a kind of Automatic Identification Technology (Auto ID) that stores real-time data. Consisting of a series of vertical bars of different widths, it can encode numbers and letters that represent a unique identifying code: the universal product code (UPC).

The barcode can then be read and interpreted by an electronic scanner, which electro-optically converts bars and spaces into numbers – the alphanumeric version below the barcode can also be read by the human operator. Information can then be transferred to a data-processing system directly.

This method of representing data has automated the supermarket checkout so that whenever we purchase an item, all the product details are catalogued every time a product's barcode is scanned. This allows retailers instant access to information about the item, enabling them to keep track of prices and price changes, product descriptions, stock levels and automatic re-ordering. A very useful everyday cryptogram.



Stun guns

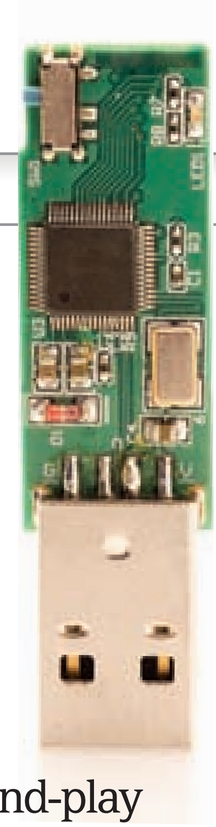
What happens if you're zapped by one of these electrifying weapons?

A stun gun is a non-lethal personal protection device that generates a high-voltage, low-amperage electrical charge. Stun guns operate on nine-volt batteries and have the power to deliver up to 300,000 volts to the body. It sounds like a lot, but our nervous system creates natural electrical impulses that enable us to move, think and feel – the electrical charge of a stun gun simply over-stimulates these nerves.

The battery sends power to a circuit, consisting of transformers that transfer electrical energy from one circuit to another. The transformers boost the voltage and yet reduce the amperage as an oscillator varies the current, creating pulses of electricity. The pulsed current charges a capacitor that builds the charge released to a pair of electrodes. These are spaced apart so the current doesn't flow until a conductor completes the circuit. Humans can conduct electricity so if the electrodes make contact with a person, the circuit is complete and the shock delivered.

© Junglecat 2008

Impressive technology that we take for granted



How do flash drives work?

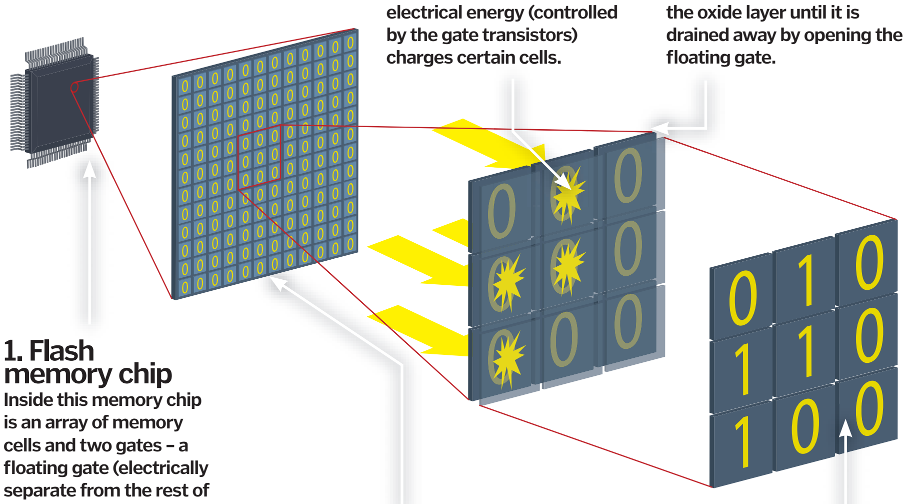
Find out how these versatile plug-and-play devices can store your data

Similar in nature to a conventional hard drive, a flash drive is a very convenient device capable of not only storing data, but also transferring it quickly between computers and digital devices. A form of solid-state storage (electronic, with no moving parts), flash drives are both robust and small enough to fit in your pocket and yet can hold vast quantities of data – up to 16GB – depending on how great their storage capacity. Flash memory is a type of EEPROM (Electrically Erasable Programmable Read-Only Memory) stored as small blocks. The chunks of data stored using flash memory can be erased and re-programmed electronically, making it a quick, effective way of transferring files.

Insert the flash drive into the computer's USB port and the computer will automatically detect the device. It will then act like an external hard drive, allowing you to immediately begin storing and retrieving data. The internal workings of a flash drive consist of a small printed circuit board (PCB) that features some power circuitry and a few mini integrated circuits: one of these circuits provides an interface to the USB port, one drives the memory, and another – perhaps the most important – is the flash memory as you can see from our annotation.

How the flash memory chip works

Inside your storage device



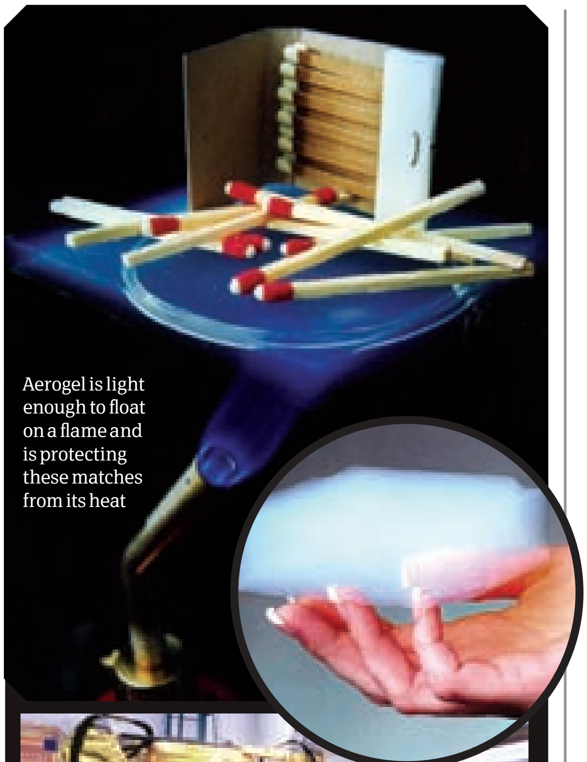
1. Flash memory chip
Inside this memory chip is an array of memory cells and two gates – a floating gate (electrically separate from the rest of the device and surrounded by a thin oxide layer) and a control gate transistor that affects the flow of electricity.

2. Enlarged memory cell
Each memory cell contains binary code in the form of 0s and 1s. When no data is stored, the cells are all set to 0 because the voltage on the gate is blocked.

3. Electrical charge
Once data enters via the USB, electrical energy (controlled by the gate transistors) charges certain cells.

4. Thin oxide layer
The electrical charge pierces the oxide layer until it is drained away by opening the floating gate.

5. Stored data
The charge becomes trapped on the oxide and the cells become 1s. This pattern of 0s and 1s are stored as data in the memory.



Aerogel is light enough to float on a flame and is protecting these matches from its heat

All images © NASA

What is aerogel?

The strongest, lightest material known to man is just three times the density of air

Aerogel is a highly porous sponge-like solid, usually formed from silica gel. In 1930, American chemist Samuel Kistler created the world's first aerogel using a process called supercritical fluid drying, during which the liquid part of the gel is carefully transformed into gas. Sometimes referred to as frozen smoke, aerogel is surprisingly strong considering it has an extremely low density. Such porous substances are often exploited for their useful insulating properties.

NASA's Stardust spacecraft even used aerogel to catch tiny interstellar dust and comet particles from the Comet Wild 2. When a particle strikes the aerogel, it is slowed to a gradual stop and becomes buried in the incredibly light yet incredibly durable material. Scientists are then able to locate and examine the tiny comet particles upon their return to Earth.

In the spin

How do washing machines clean our clothes?

Most homes are lucky enough to have one, but have you ever wondered how a washing machine works? After separating your laundry into whites and colours – so as to protect your whites from colour run – load your clothes into the main drum and close the door. Once you've programmed the machine to tell it what sort of wash you require – temperature, speed, length and so on – the machine then adds water and detergent and sloshes the clothes around. After a time, the drum will spin really fast – up to 80mph – creating a centrifugal force that extracts most of the water out of the clothes and out through the holes in the inner drum where it is then pumped away.

Inside a washing machine

1. Water inlet
Water enters the machine via inlet pipes. Modern machines endeavour to use as little water as possible in order to be environmentally friendly. Some models even have the capacity to weigh the load to assess how much water is required.

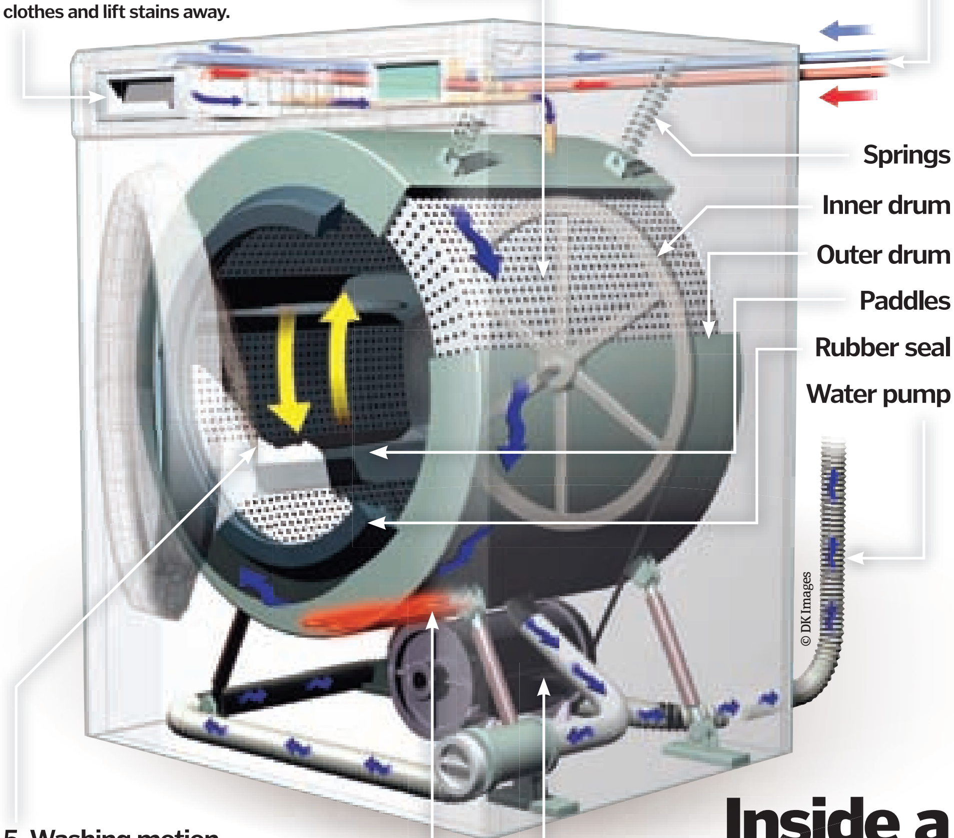
2. Detergent
The water washes through a tray containing detergent. Laundry detergent contains surfactant molecules, which are attracted to water, reducing the water's surface tension. This allows the soap to better penetrate the clothes and lift stains away.

3. Heating element
The soapy water then drains into the outer drum and through tiny holes down the sides of the inner drum where it collects at the bottom. Here the water is heated by a heating element. As less water is used in modern machines, less electricity is needed to heat it.

4. Motor
Once the water is the right temperature – as indicated by the program selected – a motor then drives the inner drum round inside the larger outer drum. The motor is attached to a large wheel at the back of the machine.

5. Washing motion
The cyclical motion of the spinning drum ensures the clothes get good and soapy, and paddles around the sides of the drum scoop up the soapy water and distribute it all over the clothes. The spinning creates a lot of vibration, which can be partly absorbed by the springs located between the main drum and the outer structure.

6. Centrifugal rinsing
A pump then extracts the dirty water, and the clothes are then rinsed. The drum then spins up to 1,400 times per minute, extracting as much water from the load as possible before the cycle finishes.



© DK Images

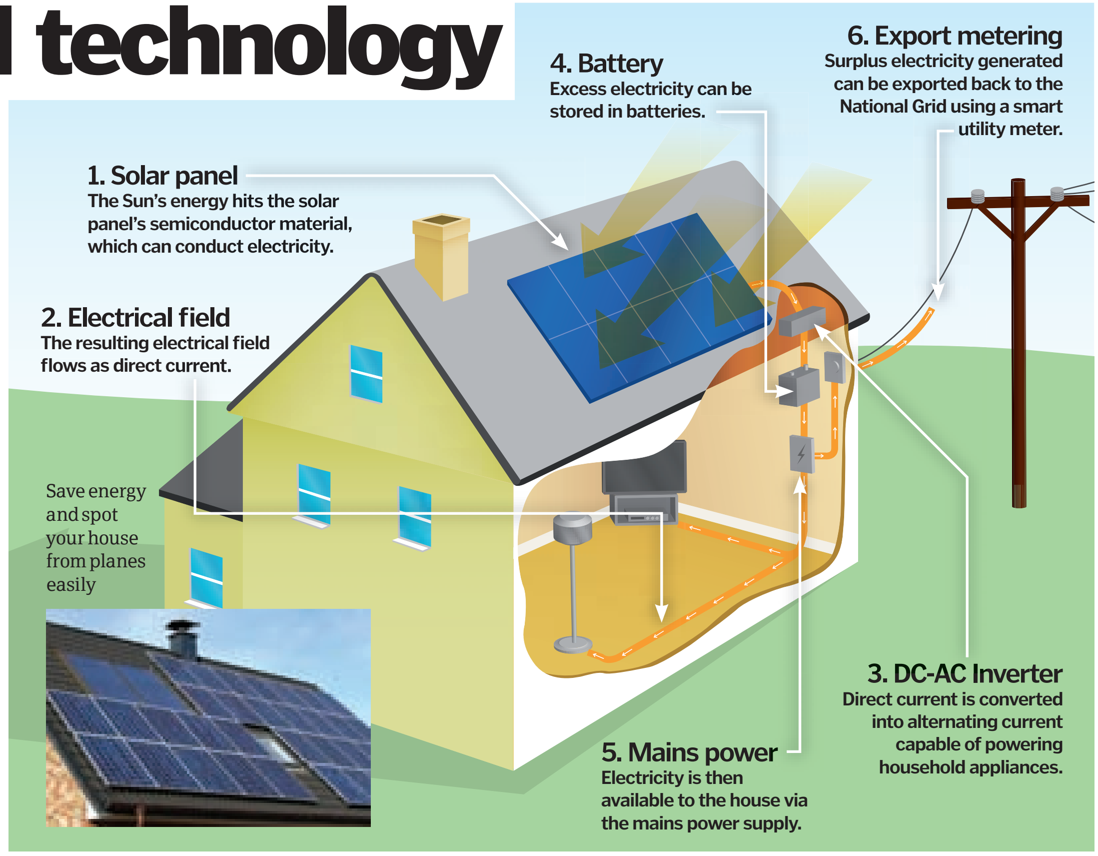
Solar panel technology

How sunlight is transformed into electrical energy

Solar panels – also known as photovoltaic (PV) cells – convert the Sun's energy into electricity, which is a great alternative to costly, less environmentally friendly methods of powering your home. PV cells consist of two layers of a semiconductor material, such as silicon, and when sunlight shines on the cell it creates an electrical field between the layers.

This amazing conversion of sunlight into electricity takes place because when the Sun's energy hits a cell, some of it is absorbed – and transferred – into the semiconductor material. The energy loosens the electrons in the material, which, due to the electric fields, flow as electrical current. An inverter then converts this direct current into alternating current so it can be used in the home.

To be able to store all this lovely solar energy for a rainy day would require batteries, which are pretty expensive to buy and maintain. So one solution is to hook up with the National Grid and buy power from there when you need it but sell it back when you're producing more than you can use.



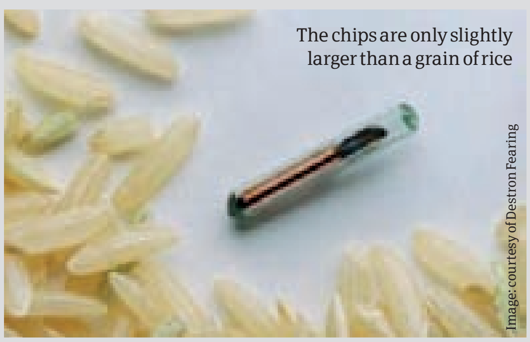
Save energy and spot your house from planes easily

Pet ID chips explained

If Lassie had one of these she'd have come home a lot sooner…

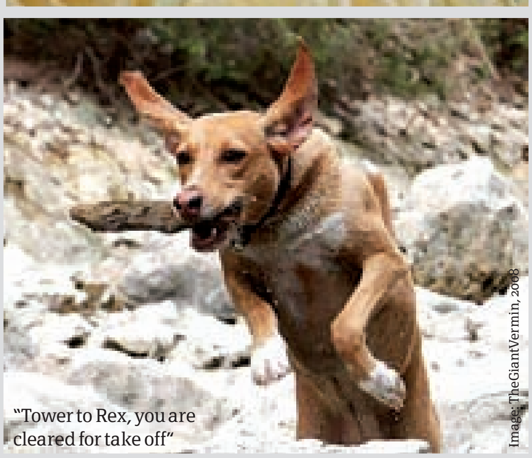
When a cherished pet goes missing, any caring owner will do all they can to get their beloved animal back. And a popular way of improving your chances of seeing old Fido again is getting him chipped – that is, having a tiny microchip implanted just under the skin between the shoulder blades. The chip is programmed with a unique identifying number that refers to the owner's details stored in a nationwide database. This ID number will permanently identify the pet and its owner. So, should a chipped pet end up at an animal rescue shelter, it will be scanned revealing the unique number.

Identification chips use passive (ie no power source) radio frequency identification (RFID) technology. They consist of a silicon chip, containing the ID number and a circuit that relays information to the scanner, a coil inductor (or radio antenna) to receive the signal from the scanner, and a capacitator, which – together with the inductor – picks up the signal from the scanner.



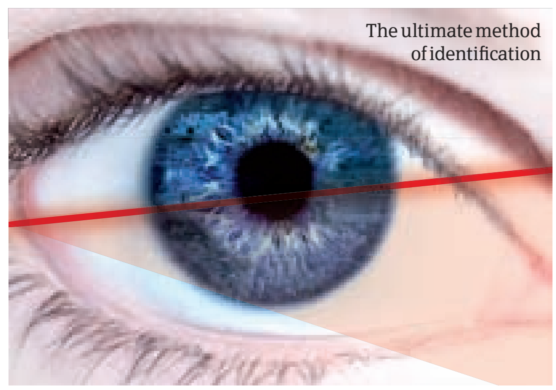
The chips are only slightly larger than a grain of rice

Image: courtesy of Destron Fearing



"Tower to Rex, you are cleared for take off"

Image: TheGiantVermin, 2008



The ultimate method of identification

Iris scanning

Why iris scanning is more secure than fingerprint recognition systems

Iris scanning is the latest buzzword in biometrics for fast, secure identification. It's so accurate – 1,000 times more so than fingerprint scanning – that the UK Border Agency is introducing the Iris Recognition Immigration System (IRIS) where people can enter the UK through barriers equipped with scanners.

Iris scan cameras are used to take digital high-resolution images of the iris with visible and infrared light, which are then converted via a computer into a digital template, known as an IrisCode, which stores the exact position of unique patterns and features.

Everyone displays different iris patterns and the first time you have your eyes scanned, an IrisCode will need to be generated. Future scans will be compared to a database and your digital template is located in seconds.

DID YOU KNOW? Whenever a dive is in progress a diver down flag must be flown for safety purposes

Diving equipment explained

The apparatus that keeps you alive underwater

How a deep-sea diver operates

Deep-sea diving requires specialist training, equipment and physical conditioning

Diving from the surface with a snorkel is an easy and relaxing way to see the many forms of life that inhabit the shallow waters of the ocean. However, in order to remain underwater for a lengthened period or to dive to deeper depths, specialist training and equipment is necessary.

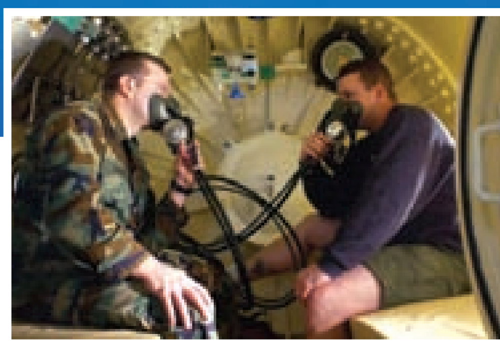
A standard dive usually operates from out at sea off a boat or a floating platform. When diving, the first thing a pair of divers (diving is always, apart from with the most seasoned divers, performed in pairs or groups, with at least one person remaining above water in communication with land) do is to fly a diver down flag, which alerts all vessels to the fact that there are divers in the water. The flag also acts as a guideline in the water, helping divers to maintain situational awareness when they are beneath the surface.

Underwater, divers descend slowly, utilising the equipment on their Scuba suit (Self Contained Underwater Breathing Apparatus) to manoeuvre and maintain buoyancy. Once the dive is complete, divers ascend slowly in order to escape the effects of decompression sickness (the precipitation of dissolved gases into bubbles inside the body on depressurisation), emerging as close as possible to the boat or platform.

Underwater diving training is vigorous and strictly controlled, as there are many pitfalls that the uninitiated and untrained can be privy to, as well as a wealth of knowledge that must be imparted. Diving physics is central to this teaching regime (the effects that divers and their equipment are subject to underwater), with laws of buoyancy, pressure, temperature and light refraction playing large roles in any dive.

Equipment is also analysed and familiarised during training. Diving signals are learnt as well, as communication in all but the most expensive suits is not possible under the water.

The Ood lookalike competition was a bit of a disappointment…



A popular form of deep-sea diving is salvage operations

Go-faster swimwear

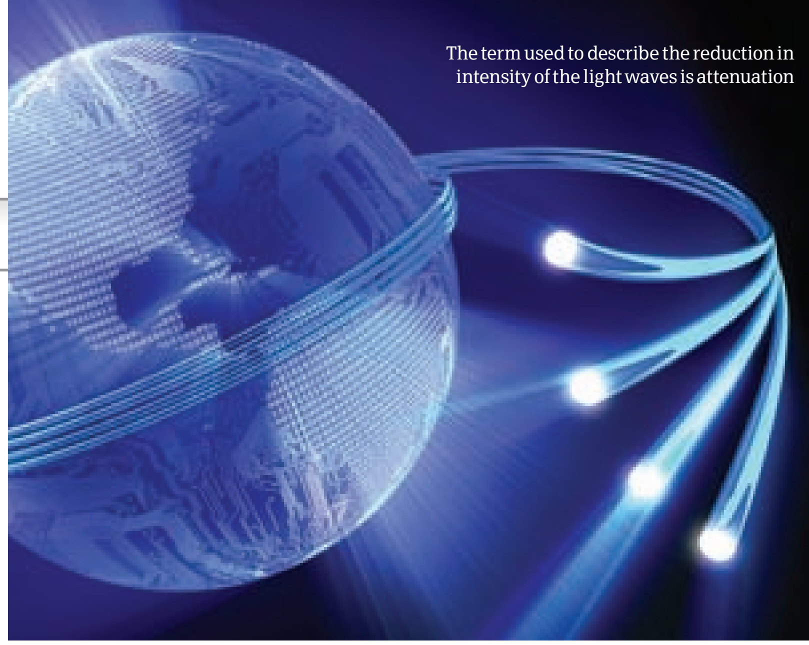
How mimicking sharkskin can give Olympic swimmers the edge

For Olympic competitors, the slightest millisecond can mean the difference between winning and losing. So if there's any legal way to enhance their performance, an athlete is going to do it.

Speedo's Fastskin technology applies some of Mother Nature's niftiest principles to cutting-edge swimwear design. Real sharkskin is covered with what are known as dermal denticles, which are tiny, grooved tooth-like projections. Using computer simulation technology called computational fluid dynamics (CFD), these ridged denticles have been proved to reduce the amount of water that comes into contact with the skin, therefore reducing the drag factor on the shark. And this is the principle behind the fabric used in Fastskin.

The Fastskin suits are also intentionally tight-fitting in order to minimise the amount of water that gets between the swimsuit and the wearer, further improving the hydrodynamics. Each seam and panel on the suit has been carefully positioned to maximise the flow of water across the body, reducing drag and promoting speed through the water.

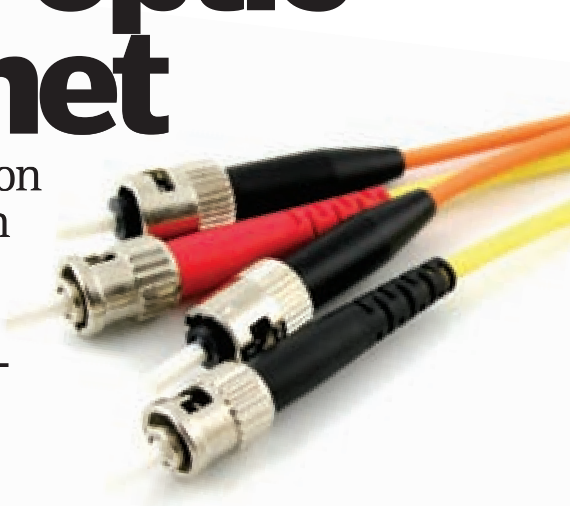
This magnified section of sharkskin reveals that the dermal denticle projections form tiny grooves, which have been proved to reduce drag in wind tunnel tests



The term used to describe the reduction in intensity of the light waves is attenuation

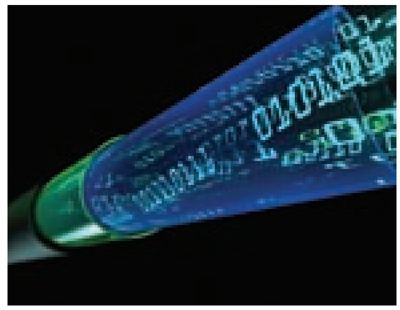
Fibre-optic internet

The next generation of communication will speed up download times using state-of-the-art fibre-optic technology



In today's culture of internet TV and streaming media there's a growing demand for extremely high transmission speeds to allow for such data-intensive services. Although traditional copper wire has served internet users well until now, it may just have run its course. A more reliable and efficient system of fibre-optic internet is now providing ultra-fast connection speeds while also solving the problem of increased internet traffic.

The main problem with copper wire is that the speed of data transmission is rapidly reduced as the length of the wire increases, meaning connection speeds can vary depending on how far away from a telephone exchange the user is located. Fibre optics, meanwhile, have no such restrictions: as you'll remember from our article on how fibre optics work in issue three, optical fibre sends information by a process called total internal reflection. Each fibre is made up of a transparent inner core, along which the signals are transmitted, and a casing of reflective material that bounces the signals back into the core whenever they hit the wall of the outer casing. The optical signal is neither distorted nor dramatically weakened as it travels along the fibre because the reflective casing absorbs none of the light from the core – this means the light wave can travel great distances without losing much speed or clarity.



The so-called 'last mile' of the content delivery from the provider to the consumer will likely still be copper wire, rather than fibre optic cable, negating some of its advantages.

DID YOU KNOW?

An optical fibre can carry 2.4 million phone calls simultaneously, while a single copper wire can carry just six phone calls.

5 TOP FACTS COMPUTER-GENERATED ANIMATION

Uncanny Valley
1 Animating photoreal humans is tricky because we are all programmed to spot if something about a human face is amiss: this phenomenon is called the Uncanny Valley.

Scale of the project
2 Staff are brought on to a project as and when they're needed. The size of the team usually swells gently, then rapidly, and then contracts quickly towards the end.

Personality traits
3 According to *Golden Compass* visual effects supervisor Alex Rothwell, the perfect CG animator, is "An Olympic gymnast with a Masters in fine art and a PhD in maths."

Childs' play
4 In 1995 *Toy Story* became the first fully CG feature film, with a duration of one hour 21 minutes. Directed by John Lasseter, it grossed $361,958,736 worldwide.

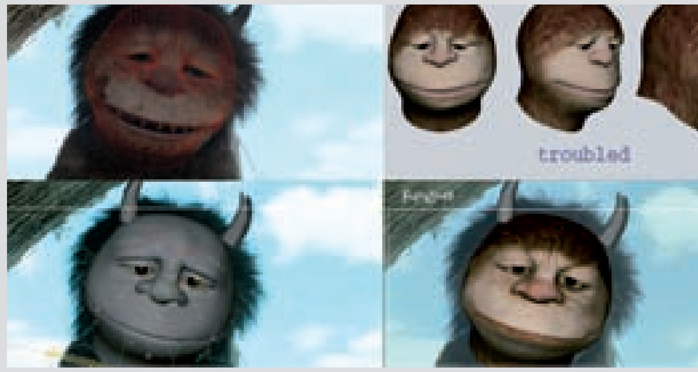
Early CG
5 In the late-Seventies it was discovered that computer-aided design provided a short cut to hand-painting individual animation cels, kick-starting a surge in development.

DID YOU KNOW? For the soldiers movements, Toy Story's team glued shoes to a sheet of wood and walked around on them

1 The character model

The blank canvas upon which the character animation begins

At the heart of every 3D character is a basic 3D model. Artists create a model on screen by taking and modifying an ordinary shape, but for intricate creations a clay sculpture called a maquette is made. Translating this sculpture onto the screen involves using a laser to pinpoint areas on the surface of the maquette and scan them into the computer: this is cyberscanning. The surface of the model is made out of polygons and at each corner of every polygon is a vertex, pinpointing the exact co-ordinates of that point on the model. Knowing the position of these vertices changes the position of the character when it's later manipulated by the animator.

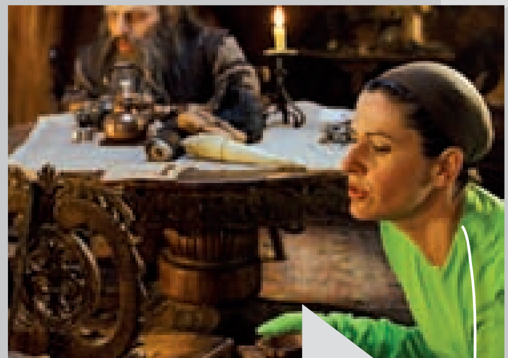


Where The Wild Things Are images: Warner Bros Entertainment Inc

2 Rigging the model

Developing the main skeleton and control of the animated character

The next step in animating a 3D character is generating a skeletal structure inside the model on screen. Known as the rig, this structure is designed to move in the same way as an animal's skeleton and it enables the animator to adjust movement frame by frame. The rigger gives the skeleton pivot points and hinges (just like human ball-and-socket joints) to define how it moves and to enable the animator to manipulate the model into the desired pose using handles and controls, and each character can have several rigs for muscles, bones and skin. To create a good rig requires an excellent understanding of anatomy and how different creatures move, so watching videos of animals or humans moving, walking and talking is a great way to appreciate the intricacies of movement. And in order to create believable facial expressions, using a mirror to scrutinise how their own skin, mouth and eyes move is essential for the rigger.



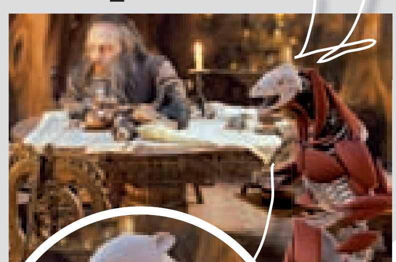
3 Keyframing, tweening and motion capture

Making the character rig move… one frame at a time

A rig can be animated either by motion capture, keyframing, or a combination of both. Motion capture is a technique for gathering rig data by recording an actor's movements, using sensors attached to their body. The data is then applied to the 3D character and the rig replicates the movement.

Most movies are filmed at a rate of 24 frames per second, so for every single second's worth of film a viewer sees, 24 individual screens have passed before their eyes.

Fortunately, today's software allows animators to use a technique called keyframing, which means they don't have to animate every frame individually. A process called 'tweening' means the CG software essentially fills in the gaps. The artist must select the most important, or 'key' frames in a sequence and position the model where it needs to be on those particular frames. Tweening then produces the images on the intervening frames.



How do animators create the fantastic feature films we all know and love?

The history of animation, in its various guises, is extensive. From early Chinese toys, such as the zoetrope, to basic flip books, the art of making pictures move has long been a human fascination. Here you will discover the various stages of a computer-generated (CG) film's journey to the big screen.

First, let's explain what we mean by computer-generated imagery. Unlike a live-action movie, which is performed by actors, filmed by camera operators, and lit by lighting crews, a computer-generated film is produced by creative artists and their mega-powerful computers.

The collaborative process of making an animated feature film is known as the pipeline, and much like the production line in a factory, an animated film is the result of many different disciplines that all steer a project towards completion. Every department is just as important as the next and if any one element fails, the team will not convince the people viewing that they are looking at something credible.

The badger character in *Prince Caspian* was developed with different rigs for skin, muscle and bones

"The movement may look perfect, but if the shading is wrong you'll notice immediately"

4 Rendering

Once the character model is moving realistically, it's time to add some aesthetic finery, including colour, lighting, texture and shaders

Texturing the polygonal model includes painting in colours and other details. The character's vertices will help identify the areas that needs texturing. To paint in the colours, the animators use cloning techniques to help make surfaces look real. As well as colours and textures, a mini program called a shader runs on every single pixel of an image. It's a simple program that takes all the information and calculates the final colour. The movement may look perfect, but if the shading is wrong you'll notice immediately. Equally the shading may look perfect, but the movement could be clunky. The shader program knows the position of lights and cameras; it knows the base colour of the model; and it knows how much subsurface scattering (SSS) is required.

SSS refers to the glowing effect you see when you shine a torch behind your finger. Light enters the finger, bounces around and is either absorbed or reflected out again. Calculating this effect wasn't feasible until four or five years ago, but today programs can recreate this effect, helping to produce organic-looking skin that doesn't look plasticky.

On the subject of lighting, once the shader program and texturing is sorted, the lighters can take virtual lights in the scene and move them around to create a well-balanced image. To do this they must consider the colour of the skin and how the light moving changes its appearance. Lighters also need a good understanding of composing an image, and should know how to emphasise certain aspects of an image.

The Chronicles Of Narnia: Prince Caspian images: Walt Disney Pictures

Due to the marvel of green screens, actors rarely need to be filmed on location

King Arthur images courtesy of Cinesite/ Touchstone Pictures/Jerry Bruckheimer Films

5 Compositing

Now it's time to compile the individual CG elements

Compositing involves putting the character, environments and special effects into finalised sequences. The compositor takes the CG and background plates and merges them, while also applying any necessary colour correction, painting out errors or adding shadows. Compositors basically put the polish on the shots and iron out any creases that may have appeared.

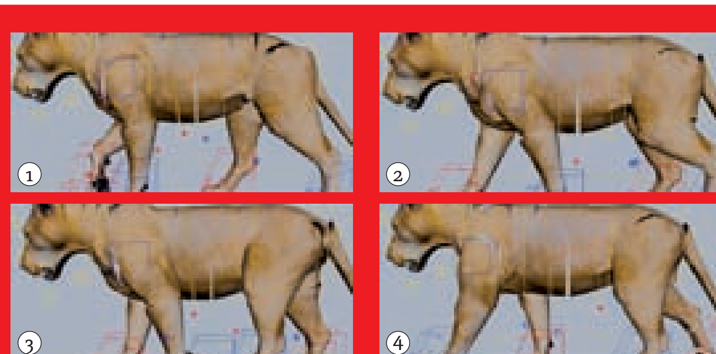
Compositing is more an effects discipline that incorporates the use of green screens to mask out the elements and their positions in the frame. Say your character is on a spaceship with a window behind them, through the window you should see space whizzing by. Compositors mask out the area through which sky should be seen, and place the moving sky sequence behind it. Space will appear only in the masked-out area of the frame.

The compositor takes images and works out how to combine them. Like Photoshop, you can cut bits out of one image and stick them onto another. It's a powerful technique when dealing with huge volumes of data, because there are thousands of frames to perfect, not just a single image.

Walk this way

The mark of a good animator is their ability to create a good walk cycle, whereby a CG character simply walks from A to B. Because it would be time-consuming to animate each step individually, the animator ideally wants to generate a right foot landing followed by a left foot landing and then just repeat that motion over and over. They can then draw a path on the ground for the character to follow and repeat the walk cycle over and over again till the character reaches its destination. A walk shouldn't look too perfect and so variation can be added to individual steps.

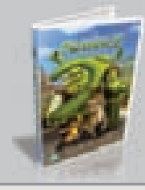
To generate a convincing walk cycle is one of an animator's key skills. If you can't make a character walk realistically, there's little hope for you. It's the same principal with flying and the up-and-down movement of wings.



The Chronicles Of Narnia: Prince Caspian images: Walt Disney Pictures

BIG
1. Toy Story
Total lifetime gross: $191,796,233
Opening weekend: $29,140,617
Release date: November 1995
Distributor: Walt Disney Pictures

BIGGER
2. WALL·E
Total lifetime gross: $223,808,164
Opening weekend: $63,087,526
Release date: June 2008
Distributor: Walt Disney Pictures



BIGGEST
3. Shrek 2
Total lifetime gross: $441,226,247
Opening weekend: $108,037,878
Release date: May 2004
Distributor: Dreamworks

DID YOU KNOW? The world's centres for the animation industry are LA, Vancouver, Wellington, Sydney, NY and London

Tools of the trade

Liam Stacy is the MD for leading 3D graphics software developer Maxon. We asked how today's software helps animators create breathtaking backdrops to films

HIW: CG has advanced leaps and bounds over the last decade, what are the main changes in technology/software that have facilitated this?
Liam Stacy: Reasons why CG is getting so good include that the price of cutting-edge software is less, enabling more artists to take advantage; the software is more powerful; computers are much more powerful than they were ten years ago; the internet has made it easier to find out about 3D software and to learn it; and new techniques have made it easier to get quality results.

With 3D software you have complete control over the reflections, shadows, lighting, and more. If a client wants you to change something, such as to try a different material on a product or to show a completely different camera angle, it's much quicker to make these changes in 3D software than with 2D software or photography. With 2D software, if the client wants to see your product visualisation from a different angle, it can mean a complete redraw. With 3D, you just move your camera to the new position and click a button to render again.

> "With 3D software you have complete control over the reflections, shadows, lighting, and more"

HIW: Is the available software intuitive enough to enable animators to let their creative juices flow, or do they have to be technically skilled first and foremost?
LS: Technical skills can be useful, but artistic skills are key and what gives you the edge. And artistic skills are becoming more important as the 3D software gets easier to use. Some 3D apps are easier to learn than the others, so if you are less technically minded, it's important to test the various tools and see which one you click with.

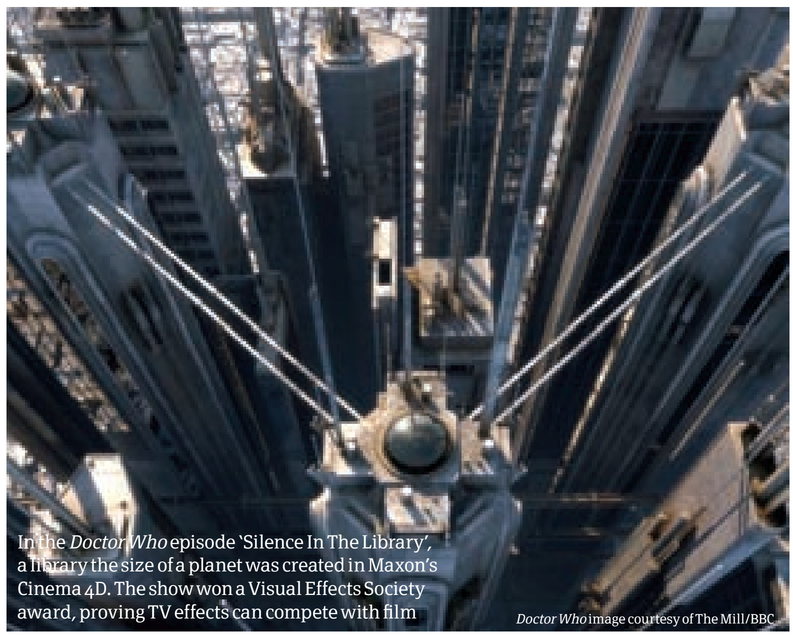
HIW: Lighting seems to play an increasingly important role in making 3D animation appear realistic. Can the software keep up with the demands of animators?
LS: Lighting can be crucial in creating realistic images, and here things have been changing for the better. For some years, 3D software apps have offered a feature called Global Illumination (GI), which makes it relatively easy to create realistic lighting. GI simulates how real light behaves, where some of the light bounces off objects to create very complex lighting.

For example, in the real world, if you shine a torch in an otherwise unlit room, you can still make out some features in the room that are not directly within the beam of light. This is because some of the torchlight bounces off the objects it illuminates, such as walls, and this bounced light then illuminates other objects in the room.

Although you can 'fake' this bounce lighting in 3D without using GI by placing a low intensity light near a wall to simulate the light that would bounce off the wall and back into the room, you need a good understanding of how real light behaves to pull off the effect. And this 'fake GI' can take hours to set up and requires many test renders. GI, on the other hand, will do all the light bouncing for you, making it easier and quicker to create realistic lighting.

HIW: If a reader bought an animation software package, would they be able to achieve similar effects to those seen in their favourite films?
LS: The tools are there to do it, [but] whether what you produce will be close to or as good as film quality will come down to your ability. If readers want to find out more and give 3D a go, a demo version of Cinema 4D software, which allows saving for 42 days, is available from www.maxon.net.

We also have a DVD that includes the demo as well as amazing artwork and animation from many different industries, and easy-to-follow tutorials to get you started. If you are in the UK or Ireland, you can order a free copy at www.maxonuk.com/.



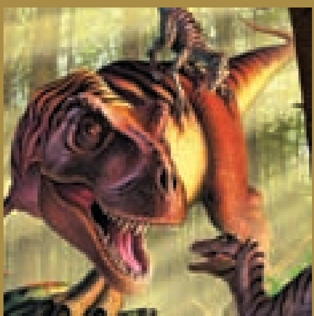
In the *Doctor Who* episode 'Silence In The Library', a library the size of a planet was created in Maxon's Cinema 4D. The show won a Visual Effects Society award, proving TV effects can compete with film

Doctor Who image courtesy of The Mill/BBC

Matte painting by Bob Scifo for *Van Helsing* in co-operation with Illusion Arts

Maxon's Cinema 4D excels at creating spectacular CG locations (animated 'matte paintings'), including environments like this scene from *Van Helsing*

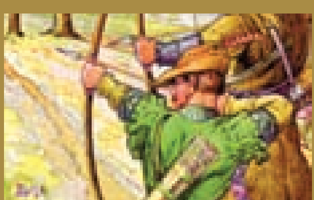
Building up a complex scene can be a painstaking process



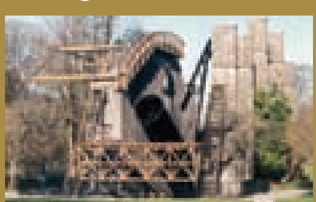
This month in History

Dinosaurs continue to fascinate us, despite having been extinct for millions of years and, let's face it, it's the big, bad carnivores that are by far the most exciting. The lead history feature this issue takes us back to prehistoric times to take a long look at the baddest predators to ever walk the planet, and it's on page 76. Beyond the prehistoric, there's something of a Roman feel to this issue with a look at soldiers and the Colosseum.

72 Roman soldiers



74 Longbows



75 Leviathan telescope

HISTORY

Inside the C

The Colosseum was the icing on the lavishly decorated Roman Empire, and still stands as one of the most iconic thumbprints of Imperial Rome

Unlike many other amphitheatres, the Colosseum was constructed in the city centre, placing it as the literal and symbolical heart of Rome.

Originally the construction was called the Amphitheatrum Flavium deriving from the Flavian dynasty, as it was built during the reign of Vespasian between AD 70 and 72 on land that Nero had seized following the mass destruction caused by the Great Fire of Rome in AD 64, which he used to create his own personal haven, the Domus Aurea. Vespasian's decision to build the Colosseum on the site of Nero's lake and gardens was interpreted as returning the land back to the citizens of Rome.

Work on the stadium had been completed up to the third storey at the time of Vespasian's death, with the upper level completed under his son Titus's reign. The gallery at the top and the hypogeum (a series of underground tunnels used to hold slaves and animals) were added years later by Emperor Domitian, Titus's brother.

Its capacity stood at approximately 50,000 spectators and was used for gladiatorial combat, games and other public spectacles. In the medieval era it was no longer used for entertainment but rented out for housing, storage and religious premises until the 12th Century at which point the Frangipani family fortified the exterior and used it as a castle. A religious order moved in mid-14th Century, and inhabited the site until the early 19th Century.

Today it stands as a battered relic of the monument it once was. It was first devastated by fire in 217 and earthquakes in 443 and 1349 caused more damage. Over the last few hundred years the interior has been stripped of stone, the marble facades burned to produce quicklime and the bronze clamps which secured the stonework have been hacked out of the walls, scarring the face of the building.

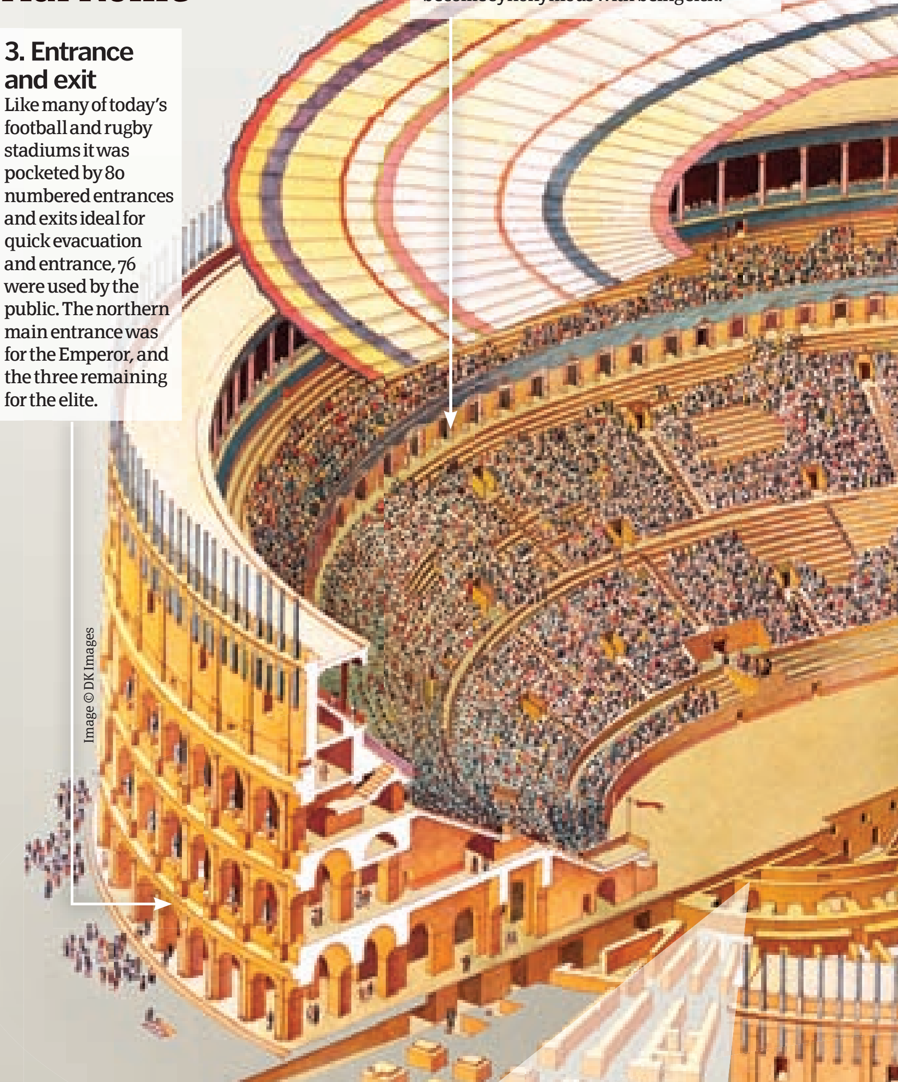


Image © DK Images

3. Entrance and exit

Like many of today's football and rugby stadiums it was pocketed by 80 numbered entrances and exits ideal for quick evacuation and entrance, 76 were used by the public. The northern main entrance was for the Emperor, and the three remaining for the elite.

4. Passageways

Spectators accessed their seats via 'vomitoria' – passageways that opened into a tier of seats from below or behind. The name vomitoria derives from the Latin 'rapid discharge', today this word has been become synonymous with being sick.

9. Hypogeum

Today a wooden walkway runs over the hypogeum (underground), which would have originally been concealed by an arena wall. The substructure was partially excavated in 1810-14 and fully exposed under Benito Mussolini in the Thirties. Today the hypogeum remains unveiled and consists of a two-level subterranean network of tunnels and caves beneath which slaves, gladiators and animals were held before the contests.

5 TOP FACTS THE COLOSSEUM

What's in a name
1 The name 'Colossuem' is believed to have derived from a bronze statue of Nero, erected nearby. It was later remodelled into the likeness of Helios/Apollo the Sun god.

Size
2 The elliptical stadium is 189 metres (615 feet) long and 156 metres (510 feet) wide with a base area of an impressive 24,000 metres squared (six acres).

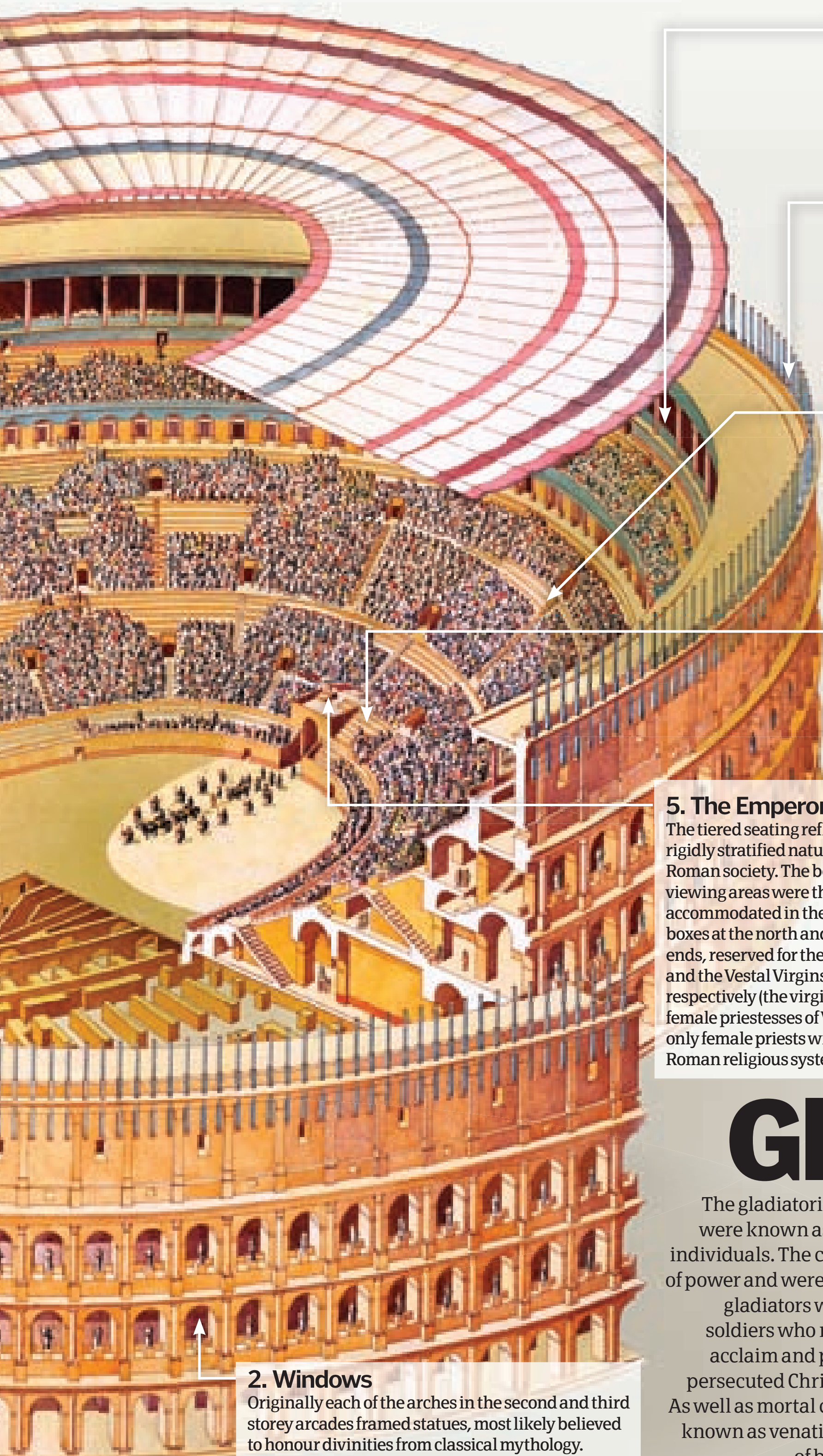
Wonder of the world
3 On 7 July 2007 the Colossum was voted as one of the New Open World Corporation's New Seven Wonders of the World (along with the likes of the Taj Mahal, and Petra).

Anti capital punishment
4 In irony of its bloody heritage, the site stands as a symbol of the anti-death penalty movement after a demonstration took place there in 2000.

Velarium
5 The Velarium was a popular Roman invention that was used inside the Colosseum as an awning to protect against any rain and to provide shade.

DID YOU KNOW? *Not everyone was welcome at the Colosseum. Those excluded were former gladiators and actors*

Colosseum



8. Domitian's addition
Another level known as the 'maenianum secundum in legneis', was built at the top during the reign of Domitian, which accommodated women (who were not of an elite standing), the poor and slaves, with standing room only.

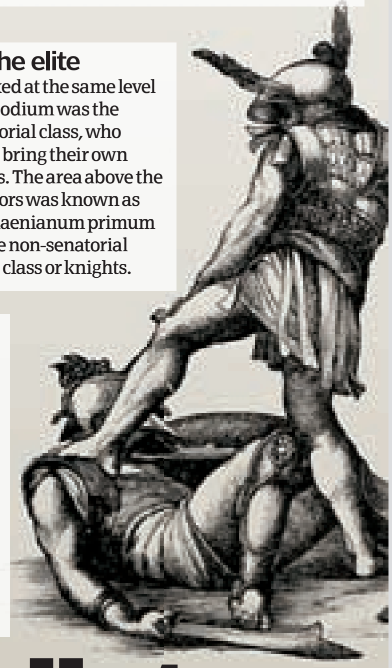
1. Surviving wall
The surviving part of the outer wall is made up of three stories of arcades surmounted by a podium on which stands a tall attic, featuring huge windows interspersed at regular intervals.

7. Roman citizens
Above the maenianum primum, was the maenianum secundum reserved for the ordinary Roman citizens (plebeians) and was halved into two sections. The lower segment (the immum) for wealthy folk, the upper part (the summum) was used to segregate the lower class citizens.

6. The elite
Flanked at the same level by a podium was the senatorial class, who could bring their own chairs. The area above the senators was known as the maenianum primum for the non-senatorial noble class or knights.

5. The Emperor
The tiered seating reflected the rigidly stratified nature of Roman society. The best viewing areas were those accommodated in the ornate boxes at the north and southern ends, reserved for the Emperor and the Vestal Virgins respectively (the virgin holy female priestesses of Vesta, the only female priests within the Roman religious system).

2. Windows
Originally each of the arches in the second and third storey arcades framed statues, most likely believed to honour divinities from classical mythology.

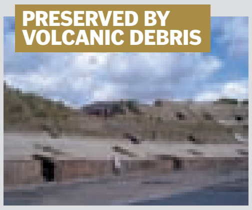


Gladiators

The gladiatorial battles that were carried out in the Colossuem were known as munera and were usually organised by private individuals. The combat was seen as the ultimate demonstrations of power and were hugely popular with the citizens of Rome. Some gladiators were burly volunteers, likely to have been former soldiers who risked their social standing in pursuit of popular acclaim and public admiration. However, most were slaves or persecuted Christians, who had no choice in their participation. As well as mortal combat, gladiators would fight animals in shows known as venatio, and would depict the fighter hunting a variety of beasts imported from Africa and the Middle East.

Head to Head AMPHITHEATRES

PRESERVED BY VOLCANIC DEBRIS



1. Flavian Amphitheatre of Pozzuoli
Location: Pozzuoli, Italy
Built: During the reign of emperor Vespasian, between AD 69 and AD 79
Capacity: 20,000
Design features: The construction is one of two surviving amphitheatres in Pozzuoli, the smaller and older has almost been completely destroyed by the creation of the Rome-Naples railway line.
Fact: Thought to be designed by the same architects associated with the Colosseum.

FIRST KNOWN

2. Theatre of Dionysus
Location: Athens, Greece
Built: 325 BC
Capacity: 14-17,000
Design features: Built at the foot of the Acropolis.
Fact: The restored amphitheatre will include both modern additions and restored surviving elements such as the marble seats.

BEST CONDITION TODAY

3. Pula Arena
Location: Pula, Croatia
Built: 27 BC-AD 68
Capacity: 23,000 (one of the six largest surviving Roman arenas)
Design features: An outside ringed wall of limestone. The section that confronts the sea exhibits a three-storey design with the other side featuring as it's on a slope.
Fact: The building was pictured on the reverse of the Croatian ten kuna bank note, last issued in 2004.

Life as a Roman soldier

Despite the long hours, low pay and high mortality rate, soldiers were always the backbone of the Roman Empire

For nearly 500 years, one of the most sought after jobs in the world was that of a Roman soldier. Not because of the conditions – which were brutal – or the pay – which was infrequent – but because soldiers were Roman citizens, entitled to retire with a state pension or land and a rare chance for foreigners to become part of the greatest empire on Earth.

Soldiers had to be at least 20 years old, serve for at least 25 years and were not allowed to marry. Although their training and formations changed, they were trained as infantry (either light known as Velites or heavy known as Hoplites) or cavalry and organised into legions of up to 5,000 infantry and 250 cavalry each.

When not on military exercises, soldiers spent their days training and patrolling, marching up to 20 miles a day in full armour before having to make or secure camp – digging and staking out the perimeter and protecting it with walls of wooden stakes, that also had to be carried when the unit decamped. Their diet consisted of unleavened bread, vegetables or porridge with wine where the location permitted, although this and fresh meat were usually reserved for centurions and generals.

However, it was in battle that the soldier earned his reputation, thanks to the years of training and discipline that inspired fear in all but the later Barbarian hordes that faced them. Armed with shields, swords, daggers spears or javelins, soldiers typically fought in lines, forming a wall of shields against the enemy. They had to do precisely as they were told or face flogging, losing limbs and, for the crime of desertion, beheading.

Helmet
The helmet was made from iron, brass or bronze and lined with leather to prevent bruising the skin.

A soldier's kit

When not in battle, Roman soldiers carried basic provisions with them. This included a dish, a cooking pan, and up to three days' rations. Sometimes, they carried extra clothing and an axe to help set up camp…

Sword
Soldiers usually carried a gladius – a short iron weapon designed for rapid stabbing movements.

Shield
Shields were usually made from wood and could be circular, oval or rectangular.

Breastplate
Breastplates and armour were made from metal strips held together with metal iron or leather ties. They were so heavy, soldiers had to help each other into them.

Tunic
Woollen tunics were worn to prevent chafing from the heavy metallic armour. They covered most of the torso.

Shoes
Sandals and leg-guards were made from leather. Required to survive battle as well as daily marching, sandals were often reinforced with metal studs to make them last longer.

© MatthiasKabel 2005

5 TOP FACTS THE ROMAN SOLDIER

1 First among equals
According to the historian Livy, Rome was originally defended by 1,000 men raised from the city's three founding tribes.

2 The Tortoise
Soldiers could adopt their trademark Tortoise formation by locking the edges of their shields together. It allowed them to advance while under fire from arrows, rocks and burning oil.

3 Punishment
In the early Empire, if an entire unit deserted in battle, one in ten of them would be put to death. Soldiers could also be beheaded, tortured, fined or deprived of citizenship.

4 Gladiators
Captured enemy soldiers of suitable age and physique were trained to be Gladiators – effectively an extended death sentence played out for public entertainment.

5 Weaponry
Romans (and Greeks before them) used 'bullets' – usually made from lead, stone or clay and fired by a sling, not a gun.

Shropshire's Iron Bridge

Coalbrookdale's Iron Bridge was a prime example of the transforming power of British engineering

The town of Coalbrookdale today might seem an unlikely choice for a construction that came to define Britain's industrial potential, but in the 18th Century it was a very different place. Shropshire was one of the UK's leading producers of coal with a nearby blast furnace recently built, but only six ferry crossings in the immediate area. As a result, in 1779 a team of entrepreneurs led by architect Thomas Farnolls Pritchard, proposed initial designs for what came to be the world's first cast iron bridge.

Needing to span 120ft of the River Severn with a single arch, it cost around £6,000 (over £1.5 million in today's money). It also went through several designs before Pritchard died a month into its construction. And although the detailed history of its construction has largely been lost, we do know the impact Iron Bridge had on the town and its surroundings, with a tourist and business population growing rapidly after its opening. It also became the design model for cast iron bridges and aqueducts that followed.

DID YOU KNOW? In 1986 the Ironbridge Gorge, the area that was spanned by the Iron Bridge, became one of the first seven UK sites to be awarded World Heritage status by UNESCO.

With his trusty longbow he exacted revenge on those who referred to him and his men as 'merry'.

The longbow

For nearly 50 years, the backbone of English military might was the longbow

Although first depicted in Stone Age cave drawings, the English longbow slowly and surely became the dominant weapon of medieval warfare. Typically about 6.6-feet long and made from yew, longbows developed from the earlier short bows and warbows and by the time of the 100 Years War they were more than proving their merit. Capable of shooting up to seven arrows a minute and from a distance of nearly 250 yards, longbows provided the crucial advantage at the battles of Crecy (1346) and Agincourt (1415).

As the century progressed, however, their limitations were exposed by the need to penetrate ever stronger armour. As battlefield tactics developed they were first outmanoeuvred and then rendered obsolete by muskets and other gunpowder-based weapons.

5 TOP FACTS LONGBOWS

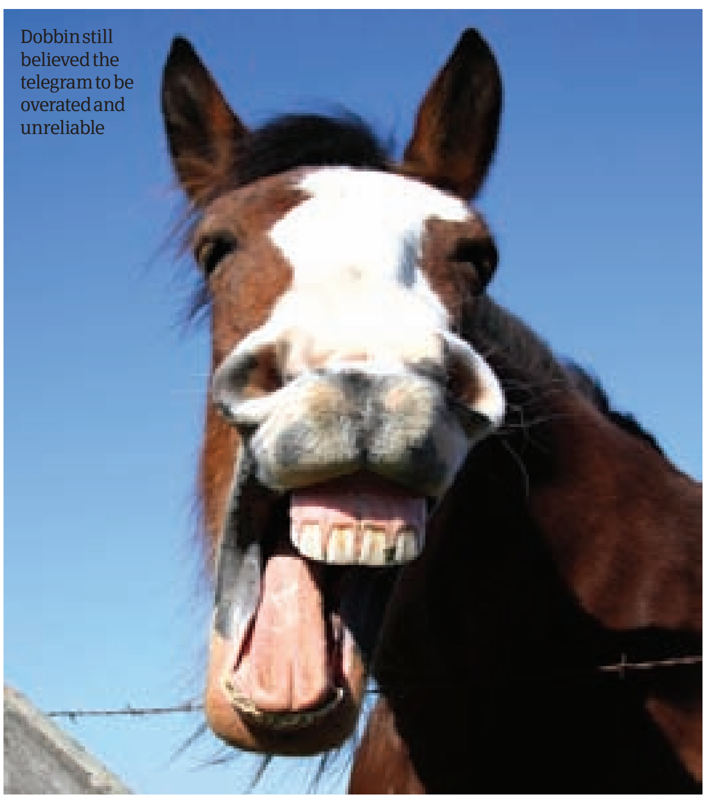
1 Dimensions Measuring over six feet in length, the longbow required considerable strength to master.

2 Construction After felling, drying and working from selected yew branches, a longbow took up to four years to craft.

3 Firepower Archers were capable of firing up to seven arrows per minute.

4 Range With a top range of nearly 250 yards, longbowmen enjoyed unparalleled range advantage until the advent of rifles.

5 Tactics Typically archers had two tactics; ranged volleys to cut down static enemies at the start and precisely aimed shots for advancing targets.



Dobbin still believed the telegram to be overated and unreliable

The Pony Express

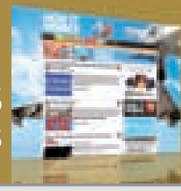
Although only in existence for 16 months, the Pony Express's impact on American culture was huge

The Pony Express began in April 1860, its modest objective to beat the slower and less frequent stagecoach mail deliveries and prove that a single, transcontinental mail system could actually work. In both these respects, it proved a resounding success, albeit only for a while.

Pony Express was the idea of a group of businessmen, including Alexander Majors who acquired the 400 horses that were required to run it. The route began in St Joseph, Missouri and ended in Sacramento, California nearly 2,000 miles away. Along the way it took in Fort Bridger, Salt Lake City, Carson City and the Sierra Nevada hills. In addition to their precious mail, riders carried a water sack, bible, gun and a horn in order to alert the next rider. For a while, Pony Express was the fastest way to communicate messages over distance, reducing the mail times between the Atlantic and Pacific coasts to around ten days. This new speed proved critical in the Civil War, particularly by providing rapid communication between the Union strongholds of California and Washington.

Unfortunately, technology was moving even faster and within months the transcontinental telegraph had reached Salt Lake City, creating an East/West communication link no pony could match. Pony Express closed a mere two days later in October 1861.

DID YOU KNOW? At the time of closing Pony Express had made around $90,000 but lost nearly $200,000. Despite proving a commercial failure, the Pony Express was sold in 1866 to Wells Fargo for a staggering $1.5 million.



DID YOU KNOW? Leviathan's original mirror, the world's largest until 1971, can still be seen at London's Science Museum

The Leviathan

Leviathan, once the world's largest telescope, was recently restored to its former glory after years of neglect. But what is this unique structure's place in history?

It may have taken four people to reposition and a hefty ladder to use, but the Leviathan telescope was the world's largest for nearly 70 years. Built in 1845 by William Parsons, Third Earl of Rosse, in his grounds at Birr Castle, County Offaly, the device took two years to build and its unusual design (suspended between two walls) soon made it a popular tourist attraction.

However, it was also at the forefront of astronomy, able to see farther than any telescope of its time. The device's main mirror alone weighed over three tons and was originally made of speculum, but replacement silver on glass mirrors were later developed that required less polishing.

Leviathan's main task was to look at nebulae, but its biggest discovery came when Parsons used it to inspect the M51 galaxy (known today as the Whirlpool Galaxy), previously thought to be little more than a gas cloud but on closer inspection it was revealed to possess a distinctive spiral structure that was later regarded as a key indicator of a galaxy.

This importance as a serious scientific tool made Leviathan's slide into disrepair after the Third Earl's death all the more surprising. By 1914 it was derelict and unused, which is how it remained for 65 years. However, since restoration was completed Leviathan has once again become Ireland's largest working telescope.

Images courtesy of Birr Scientific and Heritage Foundation

As in 1840, using Leviathan today still requires climbing a ladder to reach the eyepiece and several people to move it to inspect different portions of the night sky

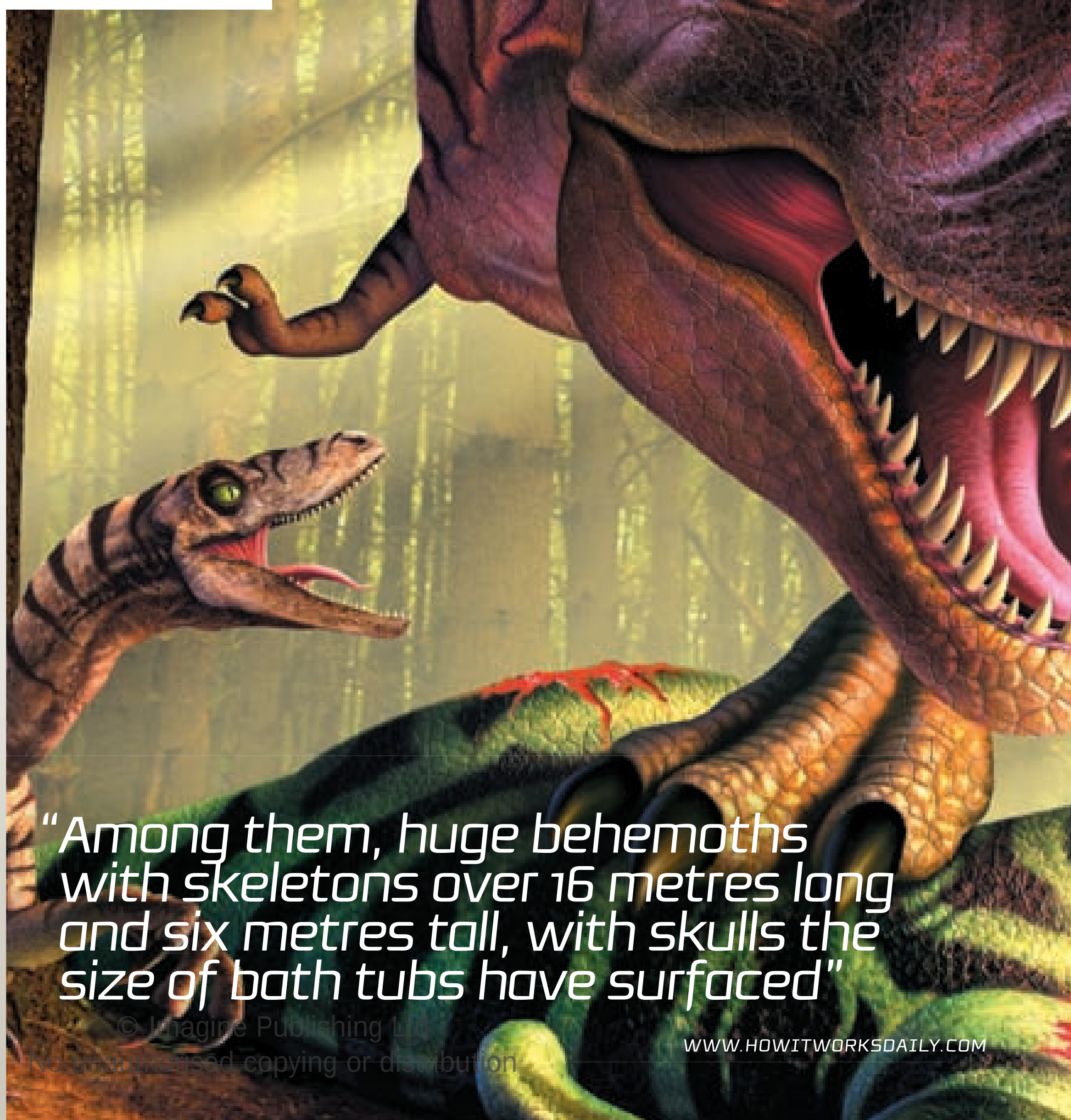
Prehistoric predators

Until they were wiped out 65 million years ago dinosaurs ruled the Earth. Among them, monstrous beasts stamped their authority over the menagerie, devouring all who stood in their way. These were the dinosaur kings, the largest carnivores the world has ever seen

Evolving from archosaurs (large lizards) in the latter part of the middle Triassic period, dinosaurs quickly gained a strong and prolific foothold all over Pangaea, the super continent which all our continents were once part of. Indeed, as the dominant terrestrial vertebrates through the Jurassic and Cretaceous periods, thousands of species of dinosaur have been unearthed as fossils by palaeontologists all over the world, with new discoveries being presented every year. Among them, huge behemoths with skeletons over 16 metres long and six metres tall, with skulls the size of bath tubs have surfaced and delivered a scary and disturbing glimpse into the creatures that once prowled the countries we still live in today.

Among the largest of these giants, a group of massive carnivorous theropods (bipedal dinosaurs) emerged throughout the Jurassic and Cretaceous periods, casting a shadow over the rest of the dinosaur population. The most famous of these is the Tyrannosaurus Rex, as made popular by the *Jurassic Park* films, however this type of theropod was but one of a host of killers and, amazingly, not the largest! Historically, of course, the reign of these carnivorous kings was cut short in the mass-extinction of the dinosaur population at the close of the Cretaceous period, when a 110-mile radius asteroid crashed into the Yucatán Peninsula, setting off a chain-reaction (tsunamis, dust clouds, temperature variation, food-chain collapse) of events that eventually led to their extermination.

Here, though, we explore the giddy heights of the pinnacle of dinosaur evolution, the time when nothing living on Earth could match these beasts for size and strength. Better run for cover then, as things are about to get prehistoric…



"Among them, huge behemoths with skeletons over 16 metres long and six metres tall, with skulls the size of bath tubs have surfaced"

5 TOP FACTS DINOSAURS

Long neck

1 The tallest of all the dinosaurs was the giant Brachiosaurus, mainly thanks to its giraffe-like neck, which stood at a rather impressive height of 50 feet.

The shortest

2 In contrast, one of the smallest dinosaurs to roam the Earth was the Compsognathus, standing at a measly 1.5 feet tall and four feet long.

The fastest

3 Two of the quickest of all dinosaurs were the Ornithomimus and Gallimimus, which are estimated to have been able to reach speeds of 70mph.

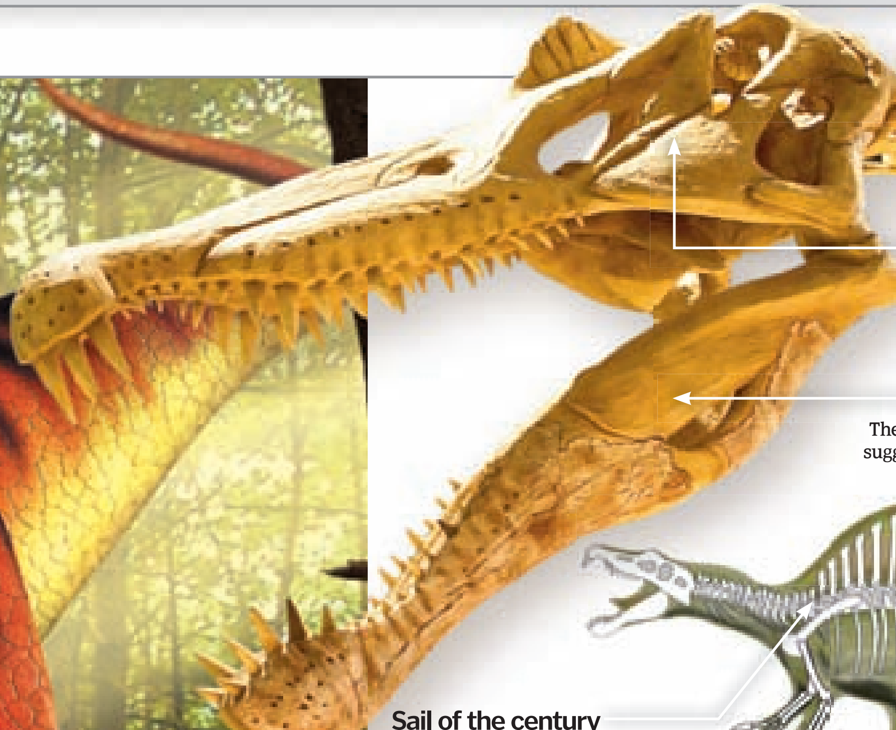
Feathered

4 Contrary to their portrayal in films, many dinosaurs were actually feathered like birds, with the Sinosauropteryx being the first to be un-earthed by palaeontologists.

Velociraptor

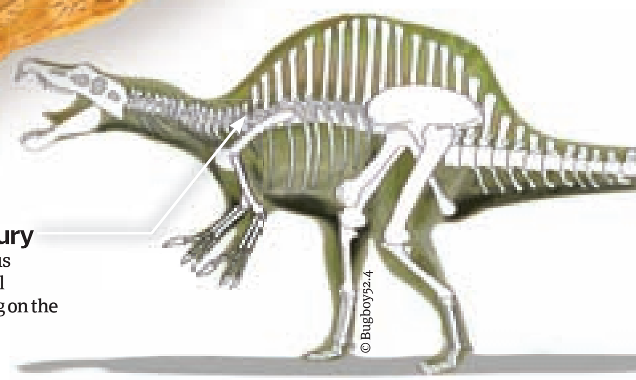
5 The Velociraptor, made famous by the *Jurassic Park* films, was not actually as big as it was portrayed, standing at six feet long and only 1.9 feet high.

Image used with kind permission of Jerry Lofaro



Why the long face?
Spinosaurus had one of the longest skulls of any carnivore, some 1.75m long

Snout and about
The long, crocodile-like snout suggests it plunged its jaw into water to catch fish



Sail of the century
The sail of Spinosaurus was formed of very tall neural spines growing on the back vertebrae

© Bugboy52.4

CARNIVORE 1

Spinosaurus

Step aside T-Rex, this was the ultimate theropod…

Bigger and arguably meaner than the Tyrannosaurus Rex, the Spinosaurus is thought to be the largest theropod dinosaur to ever roam the planet. Over 16 metres long, six metres high and weighing a monumental 12 tons, the Spinosaurus was a relatively common animal in the late Cretaceous period. Palaeontologists have found fossilised remains of the Spinosaurus in Morocco, Libya and Egypt, including a well preserved but now destroyed (blown-up in a World War II bombing run) specimen that included the lower jaw and vertebrae with complete spines.

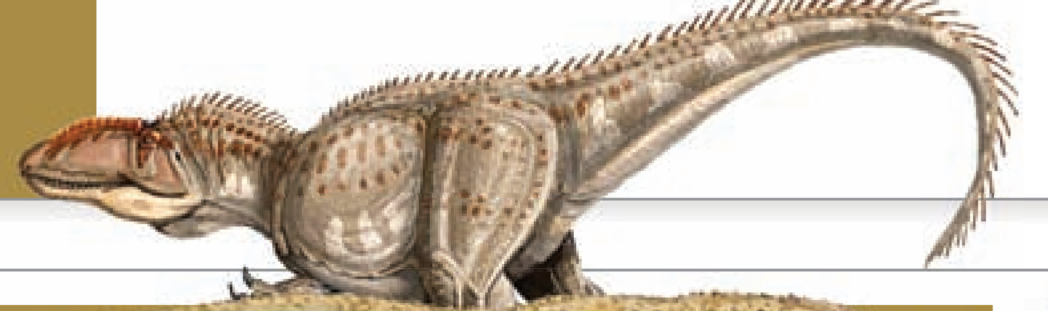
Spinosaurus was typical for a large theropod but differed in its skull and vertebrae construction. The snout of the 1.75-metre skull was long like a crocodile, with the nostril openings placed well back from the tip. Its teeth were also conical, rounded in a cross section and did not contain any serrations – these features suggest that the Spinosaurus plunged its jaw into water in order to catch fish. However, considering its size, jaw strength and number of teeth, it equally had no trouble in hunting small, medium and other large dinosaurs on land.

Not a dinosaur you'd want to meet down a dark alley…

The Statistics

Spinosaurus

Height: 6 metres
Length: 16 metres
Weight: 12 tons
Head size: 1.75 metres
Interesting fact: The spines on the Spinosaurus grew up to two metres tall
Fear factor: 9/10



CARNIVORE 2

Giganotosaurus

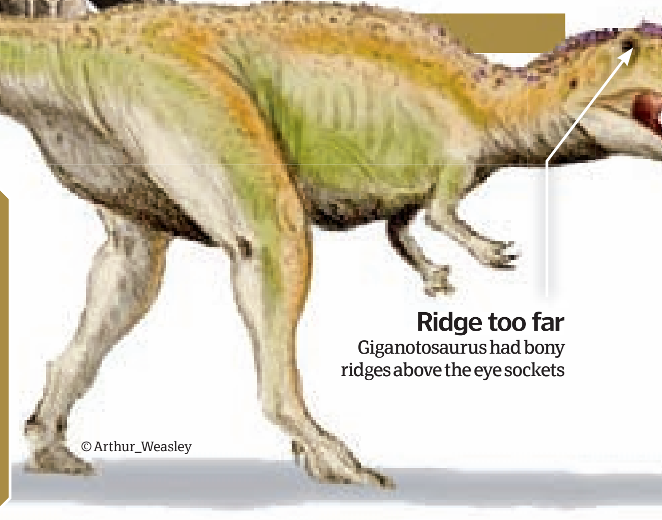
The dinosaur with a big name to live up to, but was it as colossal as it sounds?

Meaning 'giant southern lizard', the Giganotosaurus was roughly the same size as the largest Tyrannosaurus Rexs, measuring over 12 metres long, five metres tall and weighing over eight tons. The skull of the Giganotosaurus was adorned with shelf-like bony ridges, notably above the eye sockets and had low horn-like projections, while the neck was considerably thicker than that of the Spinosaurus, with a stout and powerful head supported by it. Giganotosaurus remains have been found in Argentina and it has been postulated by palaeontologists that it dined mainly on medium-sized dinosaurs such as Andesaurus.

The Statistics

Giganotosaurus

Height: 4.5 metres
Length: 12 metres
Weight: 8 tons
Head size: 1.80 metres
Interesting fact: The Giganotosaurus had a brain half the size of the Tyrannosaurus
Fear factor: 7/10

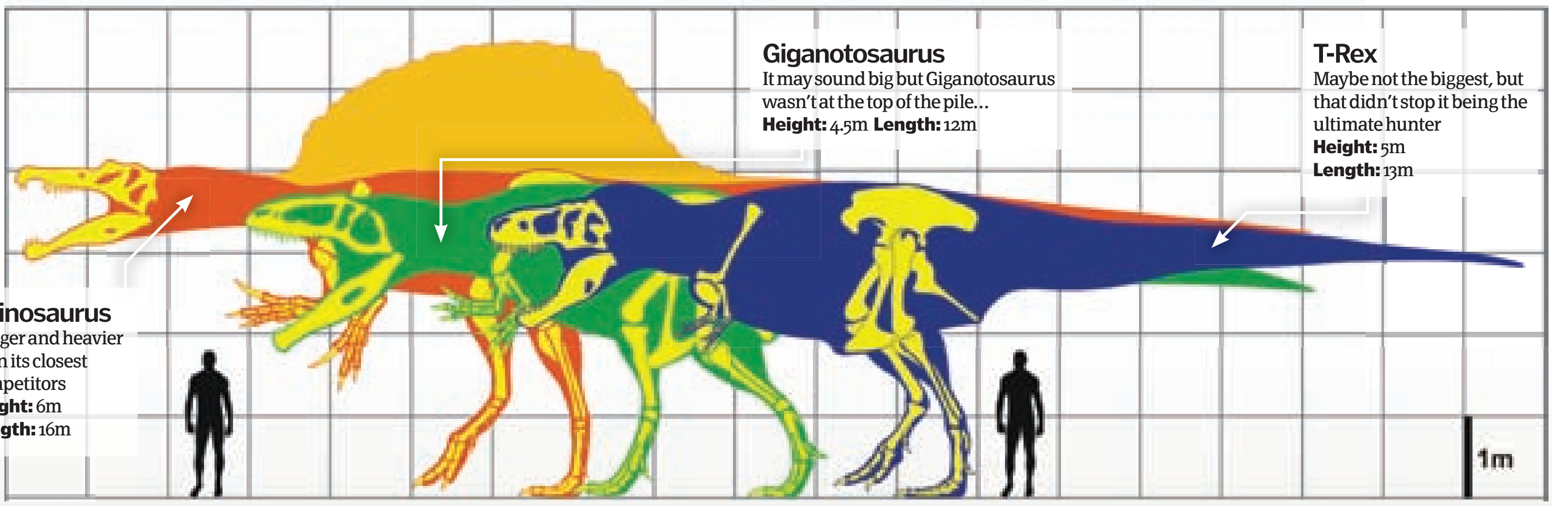


Ridge too far
Giganotosaurus had bony ridges above the eye sockets

© Arthur_Weasley

Size comparison

Who was the real king of the dinosaurs…



Giganotosaurus
It may sound big but Giganotosaurus wasn't at the top of the pile…
Height: 4.5m **Length:** 12m

T-Rex
Maybe not the biggest, but that didn't stop it being the ultimate hunter
Height: 5m
Length: 13m

Spinosaurus
Longer and heavier than its closest competitors
Height: 6m
Length: 16m

CARNIVORE 3

Carcharodontosaurus

Not the world's easiest name to pronounce…

Named in 1931, the African Carcharodontosaurus was a huge theropod with serrated teeth similar to the great white shark. The skull of the Carcharodontosaurus was very narrow although it reached up to 1.6 metres in length, while its body was taller at the back than at the front, giving it a low, streamlined physicality. The thigh muscles of the Carcharodontosaurus were some of the largest of any dinosaur and this, in partnership with its narrow streamlined frame and ferocious sharp teeth, made chasing down and devouring prey elementary. Arguably the quickest of the carnivorous theropods, the Carcharodontosaurus was a fearsome predator. Fossilised remains have been found in Morocco, Tunisia and Egypt

© Didier Descovens 2010

This incredible beast was named after its deadly serrated teeth

Shark-like teeth
The serrations in the teeth are very similar to a shark's

© F.Fonseca

The Statistics

Carcharodontosaurus

Height: 4 metres
Length: 11 metres
Weight: 6 tons
Head size: 1.60 metres
Interesting fact: The Carcharodontosaurus could run over 20mph
Fear factor: 8/10

© Arthur_Weasley

DID YOU KNOW?

The biggest bite
The strength of the Tyrannosaurus's bite is estimated by palaeontologists to be greater than that of any other animal ever to live on Earth.

© Arthur_Weasley

CARNIVORE 4

Mapusaurus

The Statistics

Mapusaurus

Height: 4 metres
Length: 12 metres
Weight: 4 tons
Head size: 1 metre
Interesting fact: Unlike other large theropod dinosaurs, Mapusaurus' would often hunt in groups
Fear factor: 6/10

The dinosaur that proved teamwork can be the best way to get a good meal

Dating from the late Cretaceous period and stalking the area that is now Argentina, the Mapusaurus was a close relative of the Giganotosaurus. Despite being one of the smaller giant carnivores, with a length of 12 metres, height of four metres and weight of four tons, it was still a fearsome predator. Interestingly, palaeontologists believe that the Mapusaurus would engage in group hunting activity, allowing groups of them to take down larger foes than they would be able to achieve on their own. The remains of the Mapusaurus were first excavated between 1997 and 2001 and now complete the majority of a full skeleton. Due to its connection to the Giganotosaurus, it shares many of the same characteristics.

Leg up
Researchers believe that the structure of the femur suggests a close relationship to Giganotosaurus

CARNIVORE 5

Tyrannosaurus Rex

The most famous dinosaur of them all and the ultimate predator

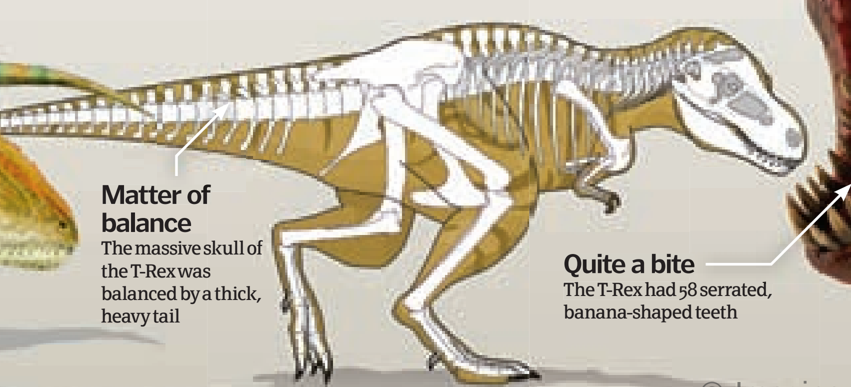
A nice bit of colour... in case you didn't spot it running at you!

The T-Rex was one of the largest terrestrial carnivores in the world, with the estimated strength of its bite greater than that of any other animal that has ever existed on Earth. Standing at a height of five metres, measuring over 13 metres in length and weighing over nine tons, the T-Rex is considered to be one of the most fearsome hunters ever.

The body of the T-Rex was perfectly balanced, with a horizontal backbone positioned above the hips giving completely equal weight distribution. The head was also colossal, measuring 1.6 metres long and far bulkier than any other theropod, containing 58 serrated teeth and large forward-facing eye sockets giving it acute binocular vision. From fossilised remains of Tyrannosaurus faeces, palaeontologists have discovered that the T-Rex crushed bones of the prey it consumed. The T-Rex was prolific over the entire western North America.

Good eyes
The T-Rex had binocular, colour vision

Quite a bite
The T-Rex had 58 serrated, banana-shaped teeth



Matter of balance
The massive skull of the T-Rex was balanced by a thick, heavy tail

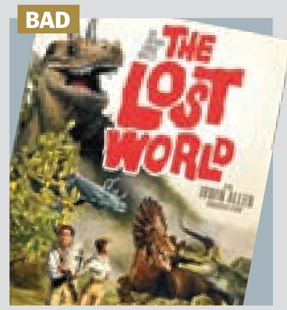
The Statistics

Tyrannosaurus Rex

Height: 5 metres
Length: 13 metres
Weight: 9 tons
Head size: 1.6 metres
Interesting fact: The Tyrannosaurus Rex could consume 230kg of meat in a single bite
Fear factor: 10/10

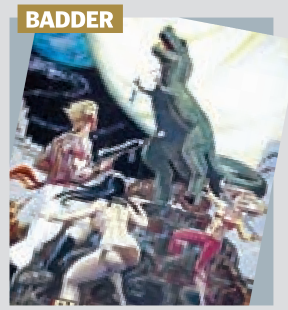
Head to Head
WORST DINOSAUR MOVIES

BAD



1. The Lost World
When: 1960
Facts: Due to massive late-in-production funding cuts, *The Lost World* had to abandon stop-motion photography to bring its dinosaurs to life, opting instead to film lizards with glued-on horns and gills.

BADDER



2. Planet Of The Dinosaurs
When: 1978
Facts: Following a group of space adventurers who get stranded on a planet inhabited by dinosaurs, the film features lines such as, "We can't risk lives trying to tame dinosaurs!"

BADDEST

3. Carnosaur
When: 1993
Facts: With the poster tagline stating, 'Driven to extinction. Back for revenge', *Carnosaur* begs the question, revenge against whom? The giant meteor that wiped them out over 65 million years ago?

BRAIN DUMP

Because enquiring minds want to know...

Send us your questions!

The How it Works experts are ready and waiting to answer your questions so fire them off to...
howitworks@imagine-publishing.co.uk

HOW IT WORKS EXPERTS

How It Works is proud to welcome the curators and explainers from the National Science Museum to the Braindump panel

Alison Boyle
Curator of Astronomy

Alison Boyle graduated in Experimental Physics from the National University of Ireland, Galway, in 1998. She completed a European Master's Degree in Astronomy at the Universidade do Porto, Portugal, and the University of Oxford. Alison joined the Science Museum in 2001 as part of the Antenna Science News team.

Doug Millard
Space Curator

Doug Millard is Senior Curator of ICT and Space technology. He has worked at the Science Museum for many years and contributed to a large number of exhibitions and publications on the exploration of space. Doug is currently working on a proposal to bring the treasures of the Russian space programme to the Museum.

Rik Sargent
Science Museum Explainer

Rik is an Explainer in the Science Museum's interactive Launchpad gallery. When Rik isn't blowing up stuff or putting people in bubbles he trains the Explainer team in the principles of science.

Flying's as simple as A, bee, C...

Just because they can fly doesn't mean they won't get stuck!

If bees are too heavy to fly, how come they can?

John Griffin, email

■ The idea that bees shouldn't be able to fly has been around since the Thirties when a scientist attempted to calculate the lift generated by a bee based on their wing size with relation to body mass. The calculations were based on aircraft lift which describes lift for a fixed wing design. Bees wings are moving in a complex arrangement so trying to quantify this with calculations based on aircraft proved to be a big mistake.

High speed photography has shown us that the bee's ability to fly comes from the exotic way in which they flap their wings. The wings do not just go up and down, the root of the wing also moves the wing forwards and backwards so the tips of the wing moves in an oval-type way. The incredible speed at which the wings perform this complicated movement creates air currents which are strong enough to allow for the bee to fly.

Rik Sargent

At what temperature is water at its densest?

Cliff Garside

■ Density is a measure of how much mass a material has in a specific volume of space. Therefore the more atoms per unit volume a material has and the more mass those atoms have, the higher the density will be.

When you heat something up, it takes up more space and therefore becomes less dense. Most materials will be at their densest when they are a solid, ie when their atoms are closest together. Water does not follow this rule as we all know that ice floats on water therefore ice is less dense than water! So when is water at its densest? Well, it turns out this happens to be around 4°C. This is when the water molecules are closest together. Cooling water further than 4°C causes the density to decrease up to the point where it becomes a solid which is less dense than the liquid. This happens due to the unusual way that the water molecules arrange themselves when turning into a solid, it is known as a crystalline structure and it is such an arrangement that the molecules are further apart from each other as a solid than when they were a liquid.

Rik Sargent

Why and how does hot honey and lemon help your throat when it's sore?

Aaron Brouard

■ Honey and lemon can be drank warm as a comfort remedy when suffering from a sore throat or cold. The idea behind this is that honey coats the throat and therefore any inflamed or sore areas will become 'protected' by a layer of honey. This means it will feel less painful when these areas come into contact with other surfaces like when you eat a meal or swallow.

Lemon helps to settle the stomach as it contains acid, this can be particularly helpful when experiencing an upset stomach from the effects of a cold.

Rik Sargent

How can they make railway lines without them buckling?

Ronald Charmers

■ Expansion joints are structures placed at points along a railway track in order to cope with expansion and contraction of the rails due to changes in the temperature. When it gets hot the rails get longer as the metal expands, if this was just one long track then it would create a problem so the track is divided up into sections separated by these expansion joints.

These joints pose another problem, however, in that they become areas of weakness along the track and require lots of maintenance and can eventually lead to deformations in the track. Not good news in times of rising ticket prices for passengers.

The most common type of track now in use is called continuous welded rail. In this type of rail, the rails are welded together to form one long continuous rail which may be up to several kilometres in length. They are bolted into place using a series of sleepers that are made from concrete or timber.

So how does this type of rail cope with the expansion and contraction problem? Well, because there are less joints, the track is stronger and gives a smoother journey. This allows for less friction and trains can consequently go faster.

When the tracks have just been laid down, they are heated up to a high temperature which causes expansion. They are then fastened to their sleepers in their expanded form and upon attempting to contract as they cool down they simply can't. In essence they are like a piece of stretched elastic which is fixed down firmly.

Rik Sargent

What's on at the Science Museum?

1001 Inventions

■ 21 Jan - 25 Apr ■ FREE

1001 Inventions will trace the forgotten story of a thousand years of science from the Muslim world, from the 7th Century to the modern day.

Launchpad Science Shows

■ On now ■ FREE

The largest free interactive science gallery in the UK, Launchpad is packed with exhibits which will allow visitors to launch a rocket, turn their head into a sound box and control a magnetic cloud. Catch one of the spectacular science shows performed by Explainers throughout the day. Ideal for children aged 8-14 years old.

A 4,000-Year History of Science

■ 8 Feb, 7.30pm ■ £7

How do you fit 4,000 years of science into one talk? Prepare for some unexpected answers as Patricia Fara, distinguished historian and author, tackles the when, who and how of the history of science.

Change in the Air

■ 9 Mar, 7.30pm ■ £7

Come along to hear James Lovelock, famous originator of the Gaia hypothesis, talk about his life and work in science. Find out how his early work on the Earth's atmosphere helped change our views of human impact on the environment.

Time and the Moon

■ 1 Feb ■ £7

The moon has been important to cultures and religions around the world since humankind began. Explore its relationship with time with our experts.

Space… A Real Frontier?

■ 4 Feb, 7.00pm ■ FREE

How have international collaborations shaped the fields of astronomy and space exploration over the years? We discuss past, present and future with curators and other experts.

For further information visit the What's On section at www.sciencemuseum.org.uk/centenary.

BRAIN DUMP

Because enquiring minds want to know...

"The sky is blue because of the way light interacts with gases in our atmosphere"

Next time someone trots out the oft repeated platitude, you'll know the answer!

Why is the sky blue and the grass green?

Julie Howard, email

This is a good question as it's often quoted by folk in response to a question that they deem either unimportant or unanswerable or both, so it's good to have a scientific answer in your locker to fire back at them, so here goes.

Grass is green because it contains a pigment known as chlorophyll which is used in the process of photosynthesis where a plant produces sugar in the presence of sunlight. Now this leads to the question as to why chlorophyll is green? Well, this is because the arrangement of the atoms in chlorophyll means it absorbs every colour from the Sun except green, which it reflects. Our eyes see this green light and therefore grass is green!

The sky is blue because of the way light interacts with gases in our atmosphere. Light from the Sun is made up of many different colours, these all travel as waves and each colour has an associated wavelength. Our atmosphere is filled with atoms and molecules of gas, mainly nitrogen and oxygen.

When light hits these gas molecules some of it may get absorbed and then released again in a different direction. The colour which is radiated will be the same colour that was absorbed, however some colours are more susceptible to this absorption and re-emission. It turns out that the wavelength of light corresponding to the colour blue is absorbed more often than any of the other colours. This process is called Rayleigh scattering (after the physicist Lord John Rayleigh). The reason we see a blue sky is because the shorter wavelength 'blue' light is scattered in all directions whereas the other colours are scattered much less. This blue light is travelling in more directions than the other colours and whichever direction you look, some of this blue light will be reaching you. Next time someone asks you, you'll know.

Rik Sargent

FROM THE FORUM

*Every month we'll feature a reader's question and a reader's answer from our forum at **www.howitworksdaily.com/forum***

How do propellers drive boats and ships?

Lady Lightning, forum user

Contrary to common belief, a propeller doesn't push a ship through the water – it 'lifts' it. Take a close look at the shape of a propeller. With its thicker leading edge, concave underside and precise pitch (or angle), it looks just like an aeroplane wing. That's because both aeroplane wings and propellers are types of aerofoils.

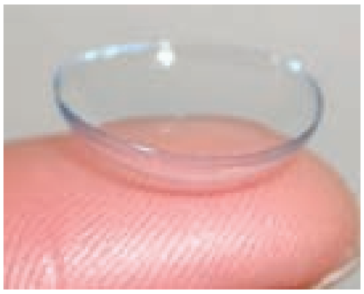
When an aerofoil passes through a fluid, the fluid is forced to move faster along the curved top surface, creating a drop in pressure. With less pressure on top of the aerofoil and more pressure below, it lifts. That's exactly what happens when a boat propeller cuts through the water. As it slices vertically in a circular motion, it creates horizontal 'lift' at right angles to the motion, pushing the boat or ship along.

Choosing the right size of propeller for the boat is very important, get the size wrong (eg too high a pitch for the engine power/boat speed) and the risk of cavitation is increased. Cavitation is caused when the surface of the blades become covered in tiny vacuum bubbles. A smaller degree of cavitation will cause vibration and if left in this condition for long periods will cause 'cavitation burns' which is where the vacuum bubbles implode with enough force to start sucking metal off the blade surface. Severe cavitation can cause the propeller to break away completely, leaving the boat stranded and offering the possibility of a long row home.

gangees

How do lenses magnify or minimise things?

Theo Climby



■ A lens is a transparent piece of glass or plastic with at least one curved surface. Light moves faster in air than it does through glass or plastic. So, when a beam hits a lens, it slows down. And when a beam enters glass at an angle, the part of the beam that hits the glass first slows down sooner making the beam turn. Once the beam hits the air again, it speeds up and completes the trajectory. In this way, a lens can focus the light from an object into an image of the object on the other side.

Convex lenses (sometimes called positive lenses) which are thick in the middle and curve out on one or both sides, take the light beams and redirect them towards the centre. Convex lenses are also called converging lenses. Concave, or diverging lenses, are thick at the edges and curve inward on one or both sides. Concave lenses take light beams and redirect them away from the centre. Concave lenses are used in things like TV projectors to make light rays spread out into the distance.

HIW

Watch the skies! They're coming for your cows...

If intelligent life existed outside Earth, wouldn't they already be here by now?

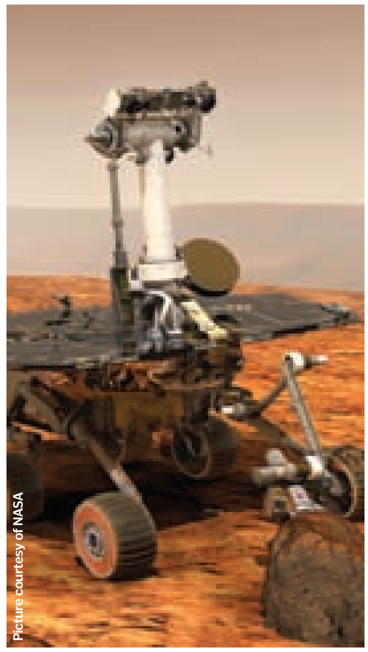
Colin Edwards, email

■ The question presupposes much. For example, would such intelligence be capable of bridging the vast distances of interstellar space? Why should 'it' or 'they' develop the capabilities of building spacecraft? Perhaps the technical know-how is there but the money, or extraterrestrial equivalent is not; maybe ET can't afford the trip!

What if the intelligent aliens simply don't want to visit: 'too dangerous', 'what's the point'? Of course, they may not be contacting us because they do not know we exist: if their awareness of us depends on picking up our radio and TV transmissions that have been spilling out into space then they have only a century's worth to listen out for so far – that's a mighty small target in the space-time continuum! But what if they have made the journey from the stars?

Arthur C Clarke placed his extraterrestrial artefact on the moon, his aliens only wishing to make contact once we had developed interplanetary flight. What if extraterrestrials really have left a calling card but somewhere else in the solar system: on an asteroid; in a crater on Callisto or in a pool of liquid methane on Titan. It will be many years before we send humans to these distant worlds.

Doug Millard



Picture courtesy of NASA

Why are we so keen on getting to Mars and not the other planets?

Noel Featherstone, email

■ There was a time, as telescopes were first turned to space, when some thought that the moon and planets were populated. Creatures on Mars, Venusians on Venus, even civilisation on Saturn. Some watchers thought we might one day travel and meet these extraterrestrial peoples.

Of course, we now know far more about such planets and the possibility of sending humans to the acidic, burningly hot plains of Venus seems very remote, while Saturn's rocky surface is buried beyond our reach at the bottom of its abysmal and crushing atmosphere. But reaching out to Mars remains a realistic possibility, albeit a distant one. As we have continued to probe the solar system with instruments and spacecraft we have learned that while Mars is cold – yes; has a thin, asphyxiating atmosphere – yes; offers little protection from the hazardous solar and cosmic radiation – yes, it is nevertheless a world that we could reach and actually live on, if only we could afford the price tag of doing so.

Mars is the only other planet we are likely to get to for some time. And lest we forget this possibility, we need only do as our ancestors did and gaze up at the blood red planet as it continues to beckon.

Doug Millard

sciencemuseum

What's on at the Science Museum?

Blind Data: Celebrating Science and Design

■ 10 Feb, 7.00pm ■ FREE

A year ago 30 scientist-designer pairs were asked to brainstorm ways to celebrate and communicate science. Come and explore the resulting interactive designs. The winning ideas fuse webcams, computers and camel hair with ancient games.

Blind Data: SEED Dating

■ 10 Feb, 7.00pm ■ FREE

Scientist or designer? Or maybe you're just curious. Come and discover SEED dating where you can brainstorm what science and technology can do for design. What ideas can you come up with in three minutes?

Fast Forward: 20 ways F1™ is changing our world

■ Until spring 2010 ■ FREE

A new free exhibition at the Science Museum showing how Formula 1™ technology can be applied to different fields of research and innovation to offer new solutions to our everyday lives. Find out how sophisticated composite materials, telemetry systems and rigorous pit-stop strategies devised by British teams are currently applied to improve safety and efficiency in our hospitals, homes and work places.

Dan Dare and the Birth of Hi-Tech Britain

■ Until March 2010 ■ FREE

Parents and grandparents can enjoy a nostalgic hour looking back at an era when Britain was at the forefront of technological innovation after World War II. Alongside seminal objects of the time is a collection of Eagle comic artwork and Dan Dare memorabilia reflecting the optimism of the post-war years.

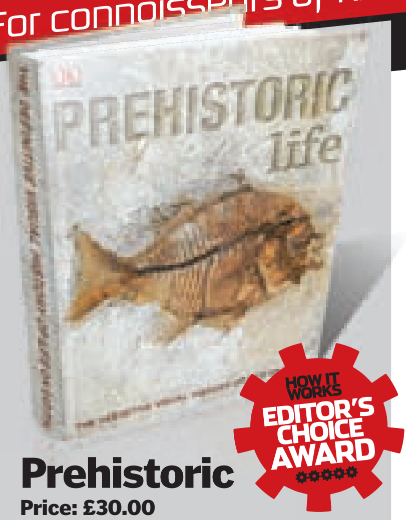
Visit the Museum

Exhibition Road, South Kensington, London SW7 2DD. Open 10am – 6pm every day. Entry is free, but charges apply for the IMAX 3D Cinema, simulators and some of the special exhibitions.

THE HOW IT WORKS KNOWLEDGE

For connoisseurs of kit and savants of stuff

DVDs/Blu-ray • Books • Gadgets • Videogames • Toys



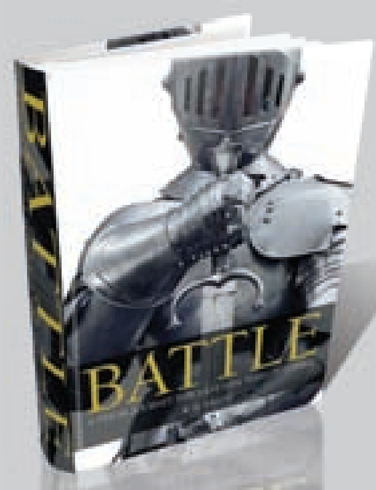
Prehistoric

Price: £30.00

ISBN: 978-1405337045

Kicking off this month's book reviews in style, *Prehistoric* is, as it boasts on the cover, the definitive visual guide to the history of life on earth. Stuffed with high-calibre glossy pages full of information and images on invertebrates, vertebrates, dinosaurs, the Earth, fossils, plants, and plate tectonics to name but a few, *Prehistoric* charts the development of life on Earth.

Verdict: ★★★★★



Battle

Price: £20.00

ISBN: 978-1405316392

This authoritative hardback explores the last 5,000 years of combat across the world. From the first recorded battle fought between the Canaanites and the Egyptians at Megiddo, to the modern era of Mutually Assured Destruction, *Battle* provides an in-depth analysis of the men, armies, tactics, weapons and causes that have led to warfare.

Verdict: ★★★★

It's enough to get your heart racing…

A netbook with real pedigree

Acer Ferrari One

Price: £399

Get it from: www.acerdirect.co.uk

COMING IN ANY colour you wish, providing it's red of course, the Acer Ferrari One bucks the trend of non-computing endorsed products with a fantastic netbook with laptop-humbling specifications. Performance, speed and prestige is what we associate with Ferrari and for once these qualities are simply what is delivered in the actual product.

The Ferrari One includes AMD's latest mobile processor technology – a true dual-core processor with 64-bit capabilities – 4GB of RAM, 250GB of SATA storage and 1366x768 of desktop real estate to play with. Furthermore, besides the impressive mobile CPU technology, the Ferrari One is fitted with ATI's Radeon HD 3200-series integrated GPU, which offers full HD support should you want to run advanced 3D applications or compatible games.

If there were any criticism to throw at the Ferrari One it would be its less-than-stunning battery life, which suffers in comparison to its peers at the top-end of the netbook range due to its tasty video and processing power. On test, the 4.45 hours of running time quoted by Acer was fair, only providing you turned off the wireless adapter, put the screen on its lowest brightness and let it idle on a low-power application such as Mail. In reality, however, this is not the usage we would expect from a netbook of this calibre, and the six-cell 4400mAh battery simply will not last anywhere near as long as other less-powerful competitors with normal use. This minor grumble aside though and you have Acer's greatest netbook to date that matches many full laptops for speed and performance, while obliterating them in style, value for money and portability.

Verdict: ★★★★★

Sony Alpha 850

A chunky, studio-friendly, full-frame DSLR

Price: £1,449
Get it from: www.crazycameras.co.uk

PUNCHING ABOVE ITS weight in terms of value for money, the Sony Alpha 850 provides most of the features of Sony's flagship Alpha 900, but for £500 less. Designed very much to appeal to the advanced amateur, the 850 provides 24.6MP, a 35mm full frame CMOS image sensor, internal image stabilisation, dual processors, ultra-bright glass pentaprism viewfinder, 3.0-inch display and nine-point AF system. All this tech is housed in a hardened and bulky casing, which while rather heavy provides great protection and is well laid out.

On test the Alpha 850's image quality was extremely impressive. The vibrancy of the oranges and reds were particularly eye-catching, though not to the extent where they seemed artificial. In the studio, the 850 continued to impress with great shots easily and quickly achieved thanks to the dexterous shooting modes and options, as well as the now user-friendly menu/display system that allowed the ability to immediately alter values as seen.

In terms of criticism, the Alpha 850 did not match other offerings in terms of on-location speed shooting, with its burst mode not quite matching up to the speeds we have seen elsewhere.

Verdict:

Dolland 3.5" Brass Sundial

Quite simply when a watch won't do…

Price: £29.99 / $47.99
Get it from: www.curiousminds.co.uk

IF YOU ARE the outdoors type and fancy a slower and statelier manner in telling what time it is, then this nifty and well-made portable sundial is for you.

Measuring in at a tiny 3.5 inches and coming in a four-inch square wooden box – great for protecting the delicate and shiny innards – the sundial is well made and, providing it is set-up correctly, measures the passing of time by the position of the Sun. Of course, in order for the sundial to work a requisite amount of actual light is necessary, which in countries with cloudier climates reduces its usefulness. This is the smallest of a few portable sundials produced by Dolland, however, this variant get our vote as its smaller size aids its portability.

Verdict:

Where The Wild Things Are: The Game

- **Format: PS3**
- **Price: £15.95 / $39.95**

Rated as a 12, *Where The Wild Things Are: The Game* is a simplistic collect-'em-up that should really be played by no one older than seven. With its slow, placid atmosphere, limited choice, melodious collecting and mellow music, this title feels like children should play it before bedtime. This is not surprising considering that this game is based on a movie based on a children's picture book. But of course, children under 12 can't buy this game, and parents who take these ratings seriously won't buy it for their underage child. This leaves *Where The Wild Things Are: The Game* sitting in limbo.

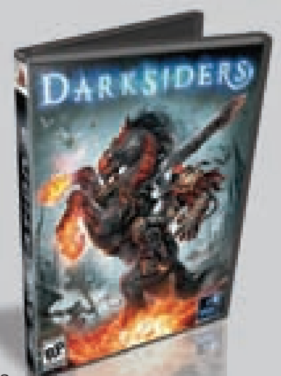
Verdict:

Lego Indiana Jones 2

- **Format: PC**
- **Price: £14.99 / $27.99**

The original Lego titles tapped into the spirit of wonder that the films on which they were based delivered so well, and, as a result, their simple platforming mechanics and clever puzzles were elevated to an entirely new level. They were funny too. Unfortunately, as with the fourth Indy film, a lot of the magic has long since dissipated from *Lego Indiana Jones 2: The Adventure Continues*. The title is now cluttered with options, characters, special abilities and other additions, that while adding variety, offers little to the game mechanics while taking away any remnant of the simplicity these titles once boasted.

Verdict:



Darksiders

- **Format: PS3**
- **Price: £39.99 / $54.99**

Arguably heavily influenced by the very successful *God Of War* series, *Darksiders* is an epic third-person action/adventure journey where War – one of the Four Horsemen of the Apocalypse – is stripped of his powers and must return to a war-ridden, human-extinct Earth to regain them. Gameplay-wise it is a surprisingly cohesive mish-mash of the best elements from other genre outings, throwing together open-world, hack-and-slash fighting, a decent combo system and the ability to upgrade War. However, while it plays brilliantly, the design of characters and environments can look a tad dodgy.

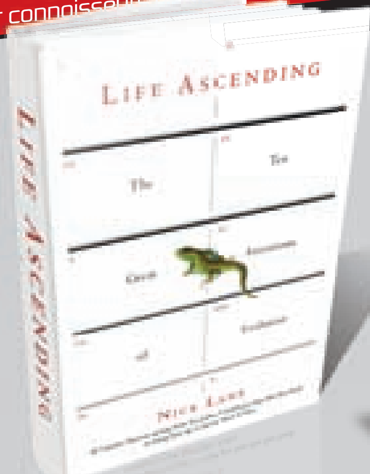
Verdict:

Legend Of Zelda: Spirit Tracks

- **Format: DS**
- **Price: £26.87 / $24.99**

Following on from *Phantom Hourglass* comes *Spirit Tracks*, a brand new adventure set in Hyrule but following a distinctly different storyline. Building on the flaws of the original, Nintendo has created an adventure experience that is decidedly more tight and enjoyable this time round, with increased variety, challenges and mini-games that add plenty to the brilliant game mechanics that make the most of the DS's unique controls. So, this is another *Zelda* title in a long canon of largely brilliant titles – not the Second Coming, but a thoroughly enjoyable romp.

Verdict:

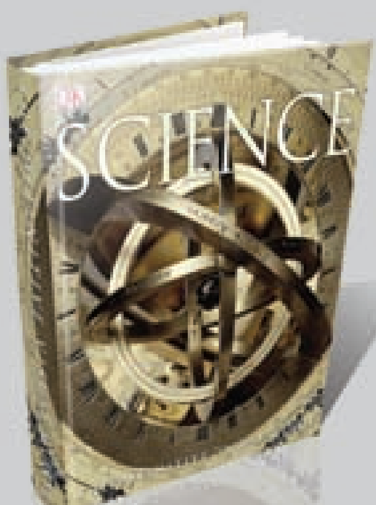


Life Ascending

Price: £9.99
ISBN: 978-1861978189

A solid and thought-provoking title that explores many of the most important questions in biology, *Life Ascending* reaffirms Darwin's theory of evolution by drawing upon groundbreaking new research into the molecular make-up of life. Nick Lane, a biochemist and the author of *Life Ascending*, is clear and concise in his writing, delivering concepts and ideas with ease and enthusiasm.

Verdict: ★★★★



Science

Price: £30.00
ISBN: 978-1405322478

A monster of a book, *Science* is basically a secondary school education in its own right, delivering on every need-to-know topic under the wide-reaches of science. From pages dedicated to explaining our solar system and astronomy to an exposition on the states of matter and the fundamental laws of physics, through to the behaviours of animals and the theory of evolution, there isn't much that this title doesn't cover.

Verdict: ★★★★

The show left these cheeky chaps rather red-faced...

Life is just spectacular in high-definition

HOW IT WORKS EDITOR'S CHOICE AWARD

David Attenborough: Life (Blu-ray)

Price: £29.98 / $48.99
Get it from: www.amazon.co.uk

BUILDING ON THE wildly successful *Planet Earth* and the *Blue Planet* series, *Life* is the latest ten-part epic from the BBC's Natural History Unit as narrated by David Attenborough. Filmed in high-definition and utilising numerous state-of-the-art filming and cinematography techniques, *Life* provides a definitive exploration of the multitudinous and diverse forms of life that inhabit planet Earth and their quests to survive.

Brutally vivid in its portrayal of the actions and behaviours that organisms undertake in order to live and reproduce, watching *Life* is an insightful and often shocking experience, one which shows nature in the cold light of day though an unprecedented all-encompassing perspective.

This, the Blu-ray addition of the series, delivers all ten episodes in stunning high-definition, as well as a ten-minute making-of diary for each episode.

Verdict: ★★★★★

Acer Liquid

An understated and classy smartphone from Acer

Price: £330
Get it from: www.acer.co.uk

RATHER A DARK horse in the world of Android-powered handsets, the Acer Liquid is not the first name that springs to mind when smartphones are mentioned. This is not surprising either considering the on-paper specifications, with the Liquid running Android 1.6 rather than the newer 2.0, basic social networking support compared to other offerings, pegged Snapdragon processor running at 768MHz rather than 1GHz and sub-par widget augmentation.

Indeed, when compiling a list of current smartphones, the Liquid would struggle to slip into the top ten. However, the Liquid is not only saved by a few key features, it's actually propelled into the upper echelons of the current generation of smartphones.

First, it is the only Android device to have a WVA display (800x480 pixels) and boy is it a stunner. Bright, clear and vibrant, it's an incredibly attractive feature and, thanks to its capacitive layer and the phone's processor, is very responsive and easy to use. Second, the design of the Liquid is extremely elegant and understated, coming in a range of colours each appearing classy rather than gaudy. Third, the functionality of the Liquid is top-drawer with the unit light on buttons and external clutter. The front itself is button-free, with responsive touch-sensitive panels beneath the screen. There's no D-pad or trackball either as on other Android handsets, however, the snappiness of the system means it isn't missed one jot.

Considering this, as well as the Liquid coming in at a firmly mid-range price, it is not hard to recommend. In fact, we would be inclined to say that this is our favourite Android smartphone to date.

Verdict: ★★★★

Onkyo DS-A3

A remote interactive dock for iPod

Price: from £75.60 / $114.98
Get it from: www.amazon.co.uk

AS iPOD DOCKS go, the Onkyo DS-A3 is a serious piece of kit, allowing users to connect their device through the stylish shiny black base station to any television, hi-fi or device with audio or video outputs. Bundled with a small plastic but functional handset, the DS-A3 then allows remote, interactive playing of videos at resolutions up to 575p on larger screens, as well as any music stored on the device through the more ample speakers of the remote device. The sturdy build quality of the base station is good while the aesthetics blend a chunky masculine look with the smooth curves of the iPod itself. However, although compatible with almost all iPods, the DS-A3 is not compatible with the now prolific iPhone, which is a slight disappointment considering the high-end market the station is aimed at.

Verdict:

E-blue AIRHIFI

Stream music and banish wires

Price: £28.99 / $45.99
Get it from: www.orbitsound.com

THE E-BLUE AIRHIFI is a nifty little device that allows you to wirelessly stream and enjoy music through a Bluetooth connection. The device itself is a small, lightweight curved box, slightly larger than a box of matches that is powered by an AC connection and plugs into any audio player or device with audio-outs. Music can then be streamed through it to any other device with a Bluetooth connection, perfect for running music in multiple rooms and reducing the amounts of wires around the house. With its white colouring and clean lines it looks the part too and blends in nicely with a minimal styling.

Verdict:

Garmin nüvi 1690

Garmin's first connected GPS device makes life easier

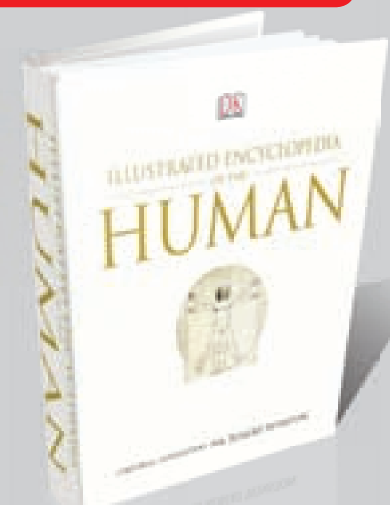
Price: £349
Get it from: www.garmin.com

THE 1690 IS the first Garmin nüvi GPS device we have seen that features the new nüLink over-the-air pan-European services such as traffic, camera updates and Google Local Search, bringing them into line with the recent high-end Live devices from TomTom. This variant's design is similar to previous remodelled devices from Garmin's nüvi range, though the 1690 is now gifted with a more attractive black finish.

On test the Garmin interface was quick and easy to use, and the new nüLink services are seamlessly integrated into the system and worked well. In addition, as part of a current deal, Garmin is including the first year of connected services for free as part of the 1690's package, making it a much more attractive proposition compared to TomTom's one month free subscription on its new GO 950 device.

Overall the Garmin 1690 is certainly an impressive device. While it is undeniably expensive – and aimed at high-mileage drivers – the nüLink services do work well and the lack of subscription costs in the first year certainly add appeal.

Verdict:

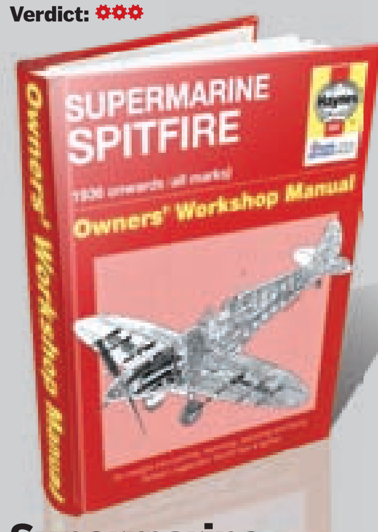


Illustrated Encyclopedia Of The Human

Price: £20.00
ISBN: 978-1405332699

If aliens landed here tomorrow, this is the book that the inhabitants of Earth should bequeath to them, providing all they would need to know about the human race. Covering our origins, bodies, cultures and societies, this is an interesting if sporadic title that will increase your knowledge of peoples from the other sides of the world.

Verdict:



Supermarine Spitfire: Owners' Workshop Manual

Price: £17.99
ISBN: 978-1844254620

Everything you ever need to know about the most iconic fighter plane of WWII, the Supermarine Spitfire, is accurately described and explained in-depth in this title. Indeed, with chapters on history, mechanics, ownership, restoration and flight, its authority is not in doubt. It can seem slightly heavy going at times though.

Verdict:

GROUP TEST

Block out the rest of the world and give your music the quality headphones it deserves

Noise-isolating headphones

1

Sennheiser CX 95

Price: £37.45 / $62.99
Get it from:
www.amazon.co.uk

The CX 95s from Sennheiser are one of the better offerings in this month's headphones group test. Delivering a stylish set of ear-canal headphones that provide well-balanced sound, notably in terms of bass for phones of this size, the CX 95s fitted snugly in the ears thanks to the interchangeable multi-size rubber tips as well as their light weight. The one complaint we could level at the CX 95s was that the initial cable leading from the phones is incredibly short, meaning we had to use the included extender at all times. Overall, however, a great set of headphones for the price, which boast excellent sound quality.

Verdict: ★★★★

2

Griffin TuneBuds

Price: £16.88 / $29.99
Get it from:
www.amazon.co.uk

Cheap and definitely cheerful, the Griffin TuneBuds deliver good overall performance for a very modest price point. The phones themselves come in a variety of colours to suit the individual, as well as providing a small zippered carry case to keep them well protected. On test, sound was good, with well-defined mid-tones and deep base, though it didn't match the richness of the Sennheiser CX 95s or CX 500s. However, for under half the price of the CX 95s, and considering they also include interchangeable silicone inserts to fit any ear shape, the TuneBuds offer a pretty good package overall.

Verdict: ★★★

3

Sennheiser CX 500

Price: £22.99 / $49.95
Get it from:
www.amazon.co.uk

Putting it bluntly, the CX 500s are the best overall headphones on test, as they deliver great sound quality at a super price point. While the CX 500s are slightly pipped to the post by the more expensive CX 95s in high-end audio performance, as a pair of everyday noise-isolating headphones there is virtually no difference and they are lighter and arguably more discreet. In addition, the CX 500s include a volume control that is integrated into the cable, various tips for maximum comfort, and a carrying pouch for keeping them in top nick.

Verdict: ★★★★★

4

Skullcandy INK'D

Price: £15.99 / $19.95
Get it from:
www.iheadphones.co.uk

Skullcandy has real pedigree in the headphone market, so hopes were high for the compact Skullcandy INK'D canal-style earphones. With standout, impulse packaging, as well as the trademark skull design adorning the phones themselves, the INK'D set look the business and fit comfortably in the ears thanks to their super light construction. Unfortunately, the stark and edgy look masks mediocrity in terms of performance, with the set only delivering average, treble-heavy sound. Further, the build quality of the INK'D doesn't match up to either of the Sennheiser sets of headphones, with thin and cheap-looking cabling.

Verdict: ★★

Red cabbage litmus paper

Try this cheap and easy way of testing whether a substance is an acid or a base

Test the pH of any substance you like, including **lemon/lime/orange/tomato juices**, **milk, soapy water, vinegar, household bleach** (warning: mixing bleach and ammonia will create toxic fumes so never mix household cleaning products)**, window cleaner, baking soda** (note: when testing solids or powders, you will first need to dissolve them in a small amount of water) or **powdered laundry detergent**.

Construction materials:

1x Small red cabbage
250ml Tap water
1x Grater or knife
1x Sieve
1x Bowl
1x Sheet of plain white paper
1x Scissors
1x Tweezers (optional)
1x Wire rack

Step 01
Chop

Take the red cabbage and finely slice or grate it. You won't need the whole cabbage, but slicing it thinly means the indicator molecules will be released quicker.

Step 02
Boil

Put the chopped cabbage into a pan containing about 250ml of boiling tap water and simmer for 20 minutes. The solution's concentration will be stronger if you use less water.

Step 03
Strain

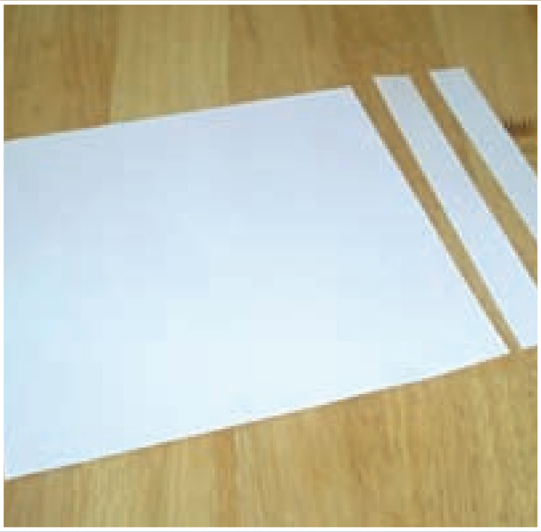
Now take the sieve and, while holding it over the bowl, pour the cabbage and the cooked water into the sieve. You can either discard the cooked cabbage or make a tasty treat with it.

Step 04
Cool

Leave the coloured cabbage water to cool. This will allow you time to prepare the paper for the test.

GET INVOLVED! Got any questions about this month's How To Make? Or do you have any other vegetable-related ideas? Why not tell us via howitworks@imagine-publishing.co.uk

HOW IT WORKS



Step 05

Paper

Take the sheet of paper and cut it into two-inch strips, then into half lengthways, just like the litmus paper you used at school all those years ago. Cut one strip for each substance whose alkalinity you would like to test.

Step 06

Soak

Now that the cabbage water has cooled, place the strips of paper into the bowl and leave them to soak up the purple dye. The longer you leave it the more colour will be absorbed so be patient.

Step 07

Dry

Once the paper has turned a good purple colour, carefully remove the strips from the water (we used tweezers to limit our messy fingerprints getting everywhere) and place them on a wire rack to dry.

Step 08 / Test

The dry strips will now look like proper litmus paper so now you can begin to test the pH of various substances. Take one strip and add a drop of your chosen substance, then watch to see what colour the paper turns. In the scale for this red cabbage litmus test, the pH for each colour is as follows

0-2: Pink

3-4: Dark red

5-6: Violet

7-8: Blue

9-10: Blue-green

11-12: Green

13-14: Yellow

The pH scale

What do the results tell us?

The pH scale measures the concentration of hydrogen ions in a solution, telling you whether it is an acid or a base. An acid has a high concentration of hydrogen ions while a base has a low concentration. The scale ranges from 0 to 14, and while a substance with a pH of seven is neutral, like distilled water, anything below seven is acidic, and anything above seven is alkaline, or basic. Each pH value below seven is ten times more acidic than the next highest value. pH4, for example, is ten times more acidic then pH5, and 100 times more acidic than pH6.

Table to show the pH scale

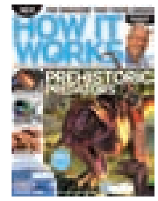
Concentration of hydrogen ions to distilled water	pH	Examples of solutions and their pH
1/10,000,000	14 Base	Liquid drain cleaner, caustic soda
1/1,000,000	13 Base	Bleaches, oven cleaner
1/100,000	12 Base	Soapy water
1/10,000	11 Base	Household ammonia (11.9)
1/1,000	10 Base	Milk of magnesium (10.5)
1/100	9 Base	Toothpaste (9.9)
1/10	8 Base	Seawater, eggs
0	7 Neutral	Distilled, pure water (7)
10	6 Acid	Urine (6), milk (6.6)
100	5 Acid	Acid rain (5.6), black coffee (5)
1,000	4 Acid	Tomato juice (4.1)
10,000	3 Acid	Grapefruit/orange citrus juices, soft drink
100,000	2 Acid	Lemon juice (2.3), vinegar (2.9)
1,000,000	1 Acid	Hydrochloric/sulphuric/nitric acids (1)
10,000,000	0 Acid	Battery acid

HOW IT WORKS

INBOX

Feed your mind. Speak your mind

Get in touch!



If you've enjoyed this issue of How It Works magazine, or have any comments or ideas you'd like to see in a future edition, why not get involved and let us know what you think. We'd love to hear from you. There are several easy ways to get in touch...

Forum

Those who like to spark debate and enjoy healthy discussions among like-minded individuals can visit www.howitworksdaily.com/forum and put their questions to the How It Works experts.

Email

If you'd like to contact us directly and perhaps even see your letter featured right here then get online and tell us what you think. Just email howitworks@imagine-publishing.co.uk

Snail mail

Yes, we even welcome the good old pen-and-paper method of communication, and you can send your letters to How It Works Magazine, Richmond House, 33 Richmond Hill, Bournemouth, Dorset BH2 6EZ.

Letter Of The Month

Educational entertainment

How It Works proved itself useful in the classroom for one reader

Hi there. I sent you guys a query via email, but then (sod's law) I discovered you have a forum just after I sent it. Is there a particular preference you have as to how we ask questions? Also, I missed issues one and two, but I loved issue three and I really like the way you pitch and explain things that teachers would be too reluctant to talk about – black holes, for instance – but not so much like a textbook that you're wading through reams of waffle just to know what a synapse is. Your articles on nuclear power and the nitrogen cycle helped me properly understand my GCSE topics and I have a funny feeling they may crop up again this year at A-level. Now I need not fear. Nice one.
Carol, forum

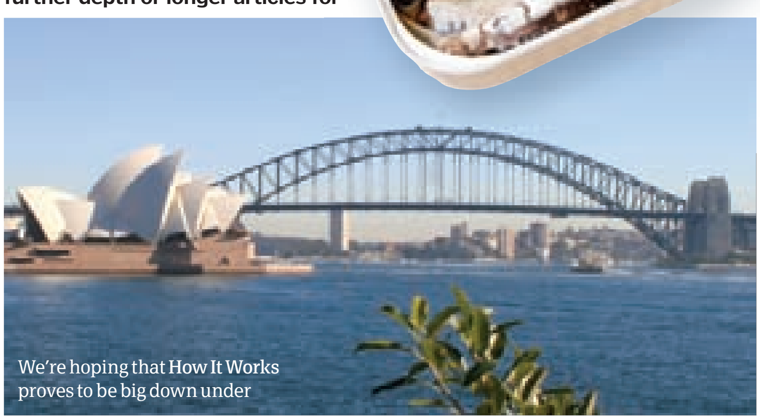
HIW: It's lovely to hear from you, Carol, and we honestly don't mind how you guys get in touch as long as you get involved and keep raising points and asking questions. As you'll see now that you've joined the forum, the most active way to get your ideas and wonderings out there is to get onto the buzzing How It Works forum, where eager-minded students like yourself are waiting to discuss people's questions and share the knowledge with other brainy boffins.

It's lovely to hear from students who have benefited from reading How It Works, an intelligent yet entertaining magazine, so if anyone else has any stories or questions they'd like to share with us about how the mag has helped them, just drop us a line in whatever form takes your fancy – be it via email, the How It Works forum, or good old pen and paper.

Size is everything

I picked up the first issue of How It Works and was fascinated by the magazine. I had gone into the bookstore with the intention of purchasing my usual selection of magazines, but upon scanning just the cover, I was hooked and decided to instead buy yours. I really have no complaints other than the fact that certain articles seem to be excessively brief, but other than that I must commend you on doing a fabulous job. The organisation and flow of the magazine from one topic to the next is so high quality that I am sure it will be copied. I look forward to picking up another issue. Thanks.
Chris Carter, email

HIW: We're pleased you're loving the magazine, Chris. And if we're tempting you to switch from other publications... even better! Your comment about the articles being brief has been echoed by a few readers who have been in touch to say that they would like to see further depth or longer articles for certain subjects. We actually make a conscious effort to keep some of the articles as short and concise as possible in order to squeeze as much delicious content into each issue as possible, while also covering all the essential facts. How It Works is really like two magazines in one; it's perfect for people to flick through when they're in a hurry, and it's great for people with more time to delve into and get absorbed in a particular subject.



We're hoping that How It Works proves to be big down under

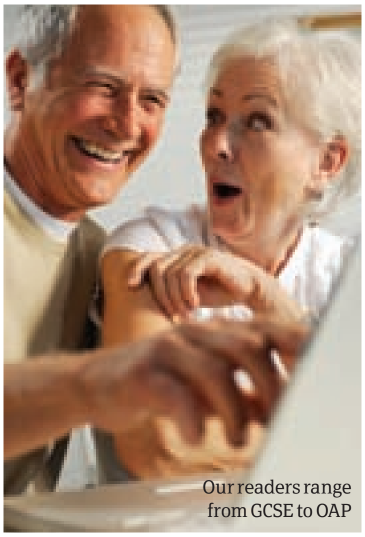
The whizz kids of Oz

G'day. Luckily, during my short stay in the UK I picked up the first edition of How It Works and was completely enticed by its in-depth, to-the-point explanations, its diversity, charming illustrations, the shear number of facts that bulge from its pages, and – easily the best part – learning. After returning I couldn't find it for sale anywhere in my home country, but fortunately I subscribed and will enjoy my next fix in a few weeks' time. Happy new year and all the best with the magazine for 2010.

May I suggest a layman's explanation of quantum physics and virtual reality for a future issue?

James Steele, website comment

HIW: James, we'd hate to be rude, but you didn't mention where your home country is. So, due to your greeting and the fact that your email address has the word Oz in it, we're going to assume you're from down under. If not we apologise, but if so, welcome to How It Works. We're delighted to see that the magazine is trotting the globe and feeding minds further afield. And while a layman's guide to quantum physics is a tall order, we'll see what we can do.


Our readers range from GCSE to OAP

It's never too late to learn

■ Saw this new magazine at my local newsagents and was intrigued by the title. At 72 years of age, I am still interested in the world we live in. I love the magazine so much that I have taken out a subscription. Keep up the good work.

Gordon Richards, website comment

HIW: We're delighted to hear that How It Works appeals to you, Gordon. And we should think so too; it's never too late to learn, especially when there are so many new discoveries still to make. We hoped the magazine would charm a wide audience and it's wonderful to hear that you're still fascinated about science, technology and the world in general in your seventies. Gordon, did you know that in the year you were born (supposing you haven't had a birthday since your post on the How It Works website), the world's first flying car, Waldo Waterman's Aerobile, took to the skies on 21 February 1937, and on 2 July Amelia Earhart disappeared while tying to become the first woman to fly around the globe? And even today the discoveries and inventions keep coming.

> *"I was completely enticed by the shear number of facts that bulge from the pages"*
>
> **Chris Carter, email**

Can't get enough of How It Works?

www.howitworksdaily.com/forum

Signing up to the forum couldn't be easier, just take a few minutes to register and then start sharing your questions and comments. The How It Works staff from all around the world will be on hand to answer your questions and initiate debate. So get online and start feeding your minds.

HOW IT WORKS

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