NEW

THE MAGAZINE THAT FEEDS MINDS

HOW IT WORKS™

SCIENCE | ENVIRONMENT | TECHNOLOGY | TRANSPORT | HISTORY | SPACE

INSIDE

INTERVIEW

PROF IAIN STEWART

The man behind the BBC series How Earth Made Us

ELECTRICITY EXPLAINED

Learn the shocking facts about everyday energy

THE FUTURE OF TELEVISION

From high def and Blu-ray to 3D and OLED

JOURNEY THROUGH THE SOLAR SYSTEM

How do orbits work? What are gas giants? How long would it take to drive to Saturn? How are planets measured?

923 FACTS AND ANSWERS INSIDE

+ LEARN ABOUT

- THE ATMOSPHERE
- FRACTALS
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- VIKING LANDER
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- WW2 TANKS
- CATS' VISION
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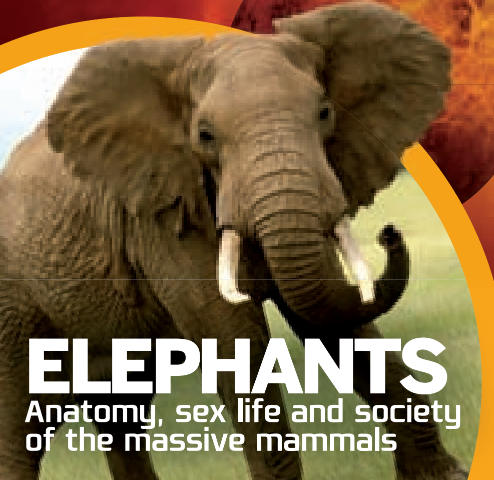
THE HUMAN SKELETON

Just how does the knee bone connect to the thigh bone?



ELEPHANTS

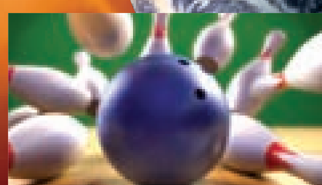
Anatomy, sex life and society of the massive mammals

VTOL AIRCRAFT

Straight-up information on the Harrier Jump Jet

CAFFEINE

Why does coffee perk you up in the morning?



BOWLING ALLEYS

Strrrrr-ike! We go behind the scenes at a bowling alley

www.howitworksdaily.com

IMAGINE PUBLISHING

WELCOME

The magazine that feeds minds! ISSUE SIX

Get in touch

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

Email: howitworks@imagine-publishing.co.uk
Web: www.howitworksdaily.com
Snail mail: How It Works
Imagine Publishing, 33 Richmond Hill
Bournemouth, Dorset, BH2 6EZ

"FEED YOUR MIND!"

What you're saying about How It Works

Hi guys, just wanted to say how great the magazine is. I've been waiting for something like this for years. I've already subscribed. I only wish it came out more than once a month. – **David Redfearn**

Hi there. First off, I would like to say how impressed I am with HIW, both the mag and the internet site, they make for great reading! Can you please show us how submarine torpedoes work in an upcoming issue? Thanks and keep up the good work! – **Mason Barker**

Thank you for such a broad series of articles featured in How It Works. As a pre-med college student, I found it useful to read about many real-world applications of information that I learned in class. I've shown the magazine to a few of my friends and they continue to thank me for showing them.

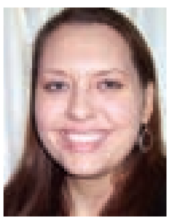
How It Works manages to help make science a universal language, providing clear and interesting articles that anyone can understand and enjoy! – **Joelle Gabet**

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…

Luis Villazon
Elephants

Luis is a zoologist and a freelance journalist so his name was first on the team sheet when we decided to explain the lives of elephants. You can find his article on these fascinating mammals over on page 14.



Shanna Freeman
The Space Shuttle

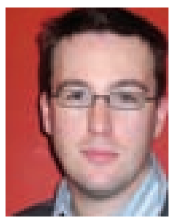
Shanna is our resident space cadet and as well as penning an excellent article on the Space Shuttle she's also just become a mum. Congratulations Shanna, shame we'll lose you for a bit. She'll be back!

Alasdair Stuart
Bike helmets

New addition to the freelance team, Alasdair has been writing about sci-fi but we gave him a tryout writing about bike helmets, breathalysers, clockwork radios, hubless wheels and speakers.

Helen Laidlaw
Television

As well as taking more of a front seat running the mag, Helen also found time to write one of our major features on television. Sadly though, she hasn't found a lot of time to watch much of it lately!



Rob Jones
Rob became a dad this month!

Congratulations! His sleep-deprived brain still managed to produce a couple of great articles on black holes, VTOL aircraft and Britain's ancient tribes though.

Editor's pick

It's hard not to be impressed by the largest mammals on Earth but there's so much more to these wonderful creatures than their size. Find out how they survive in one of the harshest environments imaginable in the excellent feature on page 14.

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 NSF JOHN DEERE NASA

And welcome to issue number six of How It Works. It's amazing how many marvels of modern science we take for granted and a large number of the gadgets and technology we cover in these pages wouldn't be possible if not for the steady supply of electricity that comes into our homes and offices 24 hours a day, seven days a week. For this reason we've decided to dedicate one of our main features to the topic of electricity, and be it AC or DC, ohms or amps or static or current you'll find answers and explanations of this fascinating source of power on page 58.

I'm a big fan of television. Despite many people claiming that it stunts the imagination and intelligence of adults and kids alike, I can't help think of the many excellent science and technology shows going out over the cable and satellite networks these days. Whether you think these outweigh the other dross that's on is up to you, but whatever your view you can discover the workings of television, cable and satellite on page 24. Enjoy the issue, and thanks to all of you who buy, read and subscribe to the mag.

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

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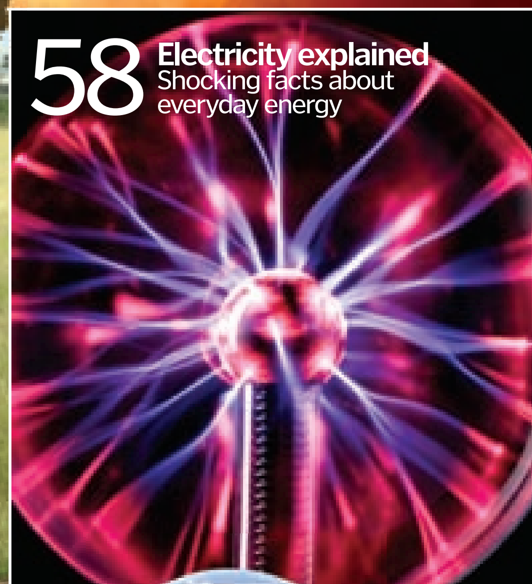
ISSUE SIX

The magazine that feeds minds!



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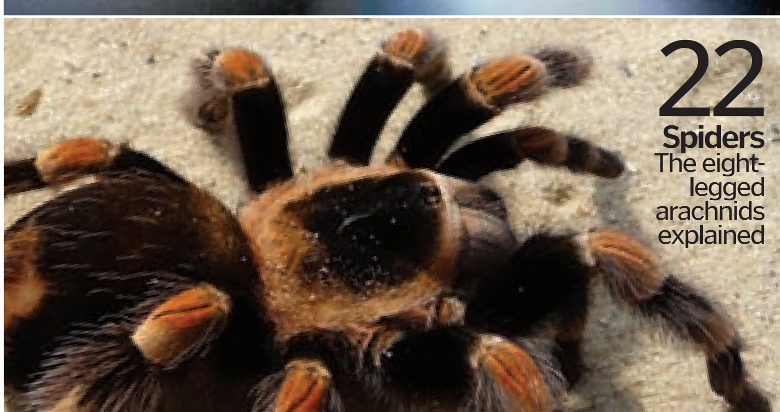

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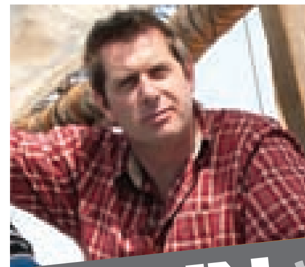
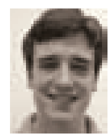
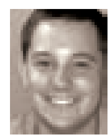


BRAIN DUMP
Because enquiring minds want to know...

Alison Boyle
Astronomy Curator
Alison Boyle heads up our panel of experts once more



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



Mike Odd
Science Museum Explainer
New-boy Mike tackles all manner of queries

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

GLOBAL EYE NEWS

A fresh look at the world

Dark matter one step closer

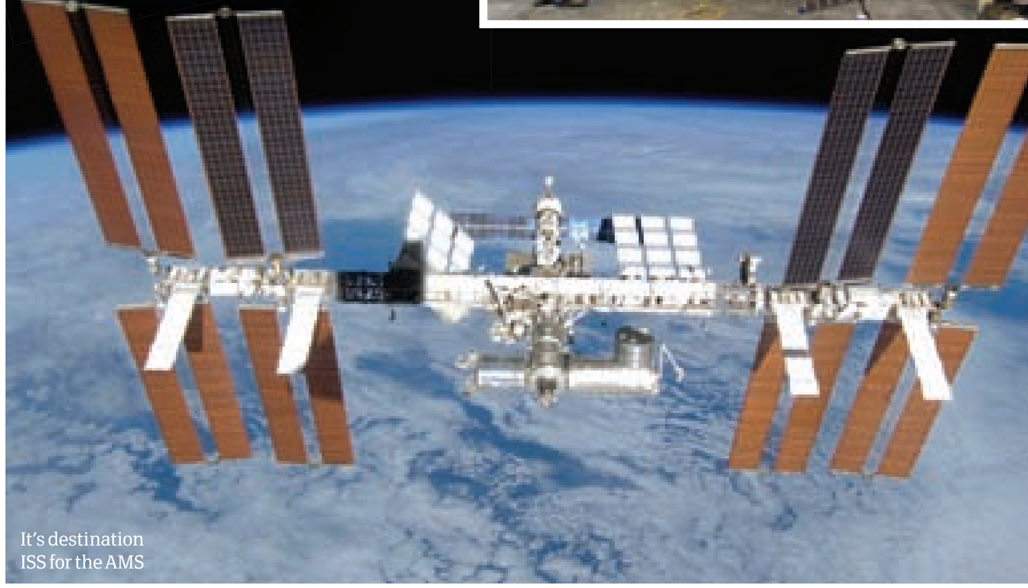
CERN's latest particle physics experiment begins its journey to the International Space Station

On 12 February, the European Organization for Nuclear Research (CERN) based in Geneva carefully packaged up and shipped out the prized Alpha Magnetic Spectrometer (AMS), its ultimate destination the International Space Station (ISS).

The super-advanced particle detector equipment is embarking on a breakthrough mission to the ISS in search of the positrons and electrons that could indicate evidence of dark matter in space and help us understand the origins of this universe of ours. Before the AMS can be launched into outer space, however, it must first undergo testing to determine its ability to endure a Space Shuttle launch, not to mention the equipment's ability to function in space. Before leaving CERN, the fully assembled AMS passed a series of checks to prove its ability to distinguish electrons from protons – vital for measuring cosmic rays.

Then, on 12 February the equipment embarked on a six-day convoy from CERN to the Netherlands where it is undergoing further testing at the European Space Agency's Research and Technology Centre (ESTEC) inside a special room that can simulate the vacuum of space thereby testing the functionality of the AMS's electronics and superconducting magnet.

CERN's fragile freight may well return to Geneva for a once-over before continuing its journey to the Kennedy Space Center in May. The precious payload is scheduled to lift off on board the orbiter Discovery – together with the Express Logistics Carrier, a platform for supporting ISS's external payloads – on 29 July 2010. Once docked, the AMS will begin its hunt for dark matter and antimatter, the data from which will be transmitted to Houston and on to CERN. This mission to the ISS will mark the Space Shuttle Program's second to last ever launch. A very exciting expedition indeed.



It's destination ISS for the AMS

Apple sues Nexus One manufacturer

HTC in trouble regarding 'stolen' iPhone tech says Steve Jobs

The aggressive world of smartphone marketing gets a jolt as Apple co-founder and CEO Steve Jobs accuses Taiwanese mobile manufacturer HTC of infringing several of the iPhone's patents. The interface of HTC's Nexus One handset is a bit too familiar for the folks at Apple.

In a lawsuit filed with the US International Trade Commission and the US District Court in Delaware, Apple Inc claimed HTC has infringed on some 20 patents owned by Apple. Apple is seeking an injunction that will prevent the Google-branded pretender to the iPhone crown from being sold or imported. Jobs has issued a statement in which he declares: "We can sit by and watch competitors steal our patented inventions, or we can do something about it."

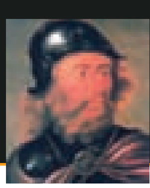
As we go to press, HTC has so far declined to comment on the legal action itself, stating it has neither been served any papers nor had time to investigate the claims. However, a spokesperson for the company said: "We respect and value patent rights but we are committed to defending our own innovations."

The iPhone architecture and hardware is a much sought-after commodity – for both consumers looking for an ultra-functional piece of kit and for manufacturers hoping to occupy a larger area in the smartphone market currently dominated by Apple's iProduct.

This day in history

25 March: How It Works issue 6 goes on sale, what else took place on this day in history?

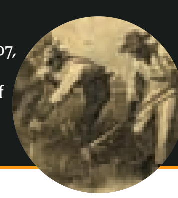
1306 The coronation of Robert the Bruce as King of Scotland.



1655 Dutch astronomer Christiaan Huygens discovers Titan, Saturn's largest moon, using his refracting telescope.

1807 The Swansea and Mumbles Railway, which ran until 1960, becomes the first passenger railway in the world.

1807 Also in 1807, slavery is abolished with the enforcement of the Slave Trade Act by the British Empire.



1865 The Battle of Fort Stedman takes place during the American Civil War. Confederate forces temporarily seize the Union Army's fortification in Virginia.

© CERN

© NASA

Robot patients make perfect practice

Meet Simon, the medical robot complete with blood, sweat and tears

© Images courtesy of Laerdal Medical

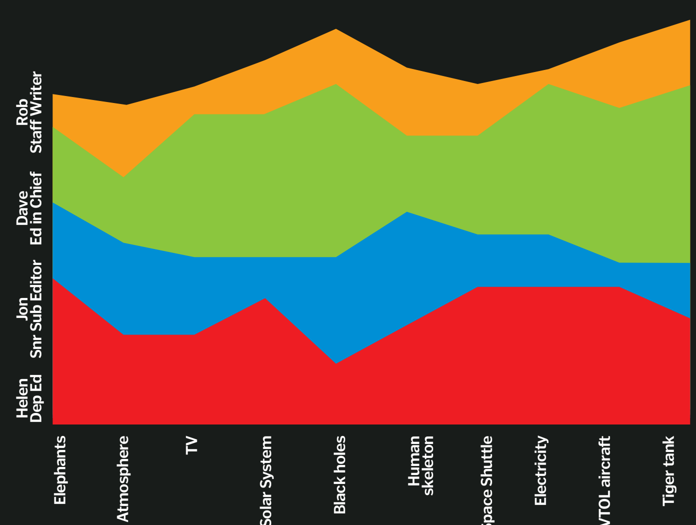
Gone are the days when a half-dehydrated frog and a scalpel were your only educational aids. Today, pharmacy students at the University of Bath have access to a life-sized robotic model that is helping train them to treat patients.

Simon, or the SimMan 3G, is a completely wireless robotic patient who can be programmed to simulate specific medical conditions and then respond to treatment like a human casualty. He can speak and breathe, his pupils constrict when exposed to light, he has a pulse, and he can even become a girl if necessary. Give him the wrong drugs, however, and he'll recognise this and may have a fit or throw up. He can also secrete fluids that represent blood or sweat from the skin, eyes and other orifices. Simon's medical conditions can also be altered to suit each examination to test different levels of ability.

Trainee doctors already use SimMan 3G in medical schools, but Bath's students are the first trainee pharmacists to witness the effects of the medicine they administer, in a safe environment. As the role of pharmacist broadens from merely dispensing prescriptions to also diagnosing and prescribing medicine themselves, pharmacy students will require more sophisticated training methods such as the SimMan 3G robot.

How It Works EXCITE-O-METER!

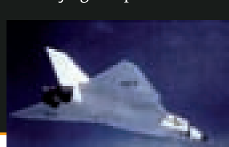
Every issue we offer this visual guide to what's been getting us excited in this issue of **How It Works**



Considering staff writer Rob's wife gave birth to a beautiful baby girl this month his excitement levels were exceedingly low. We guess all his energy has been sapped after becoming a dad. That, or he's contemplating the next few years of his life being dedicated to nappies and crying. Still, he did have time to bring us some wonderful articles on the Tiger tanks and VTOL aircraft. In other news, elephants topped the excitement poll while the atmosphere's struggled to get us going.

1957
The Treaties of Rome were signed by Belgium, France, Italy, Luxemburg, West Germany and the Netherlands, establishing the European Economic Community to bring economic harmony between European nations.

1958
On 25 March 1958 Canada's Avro Arrow (AKA Avro CF-105) completed its debut flight. Soon after, the military fighter plane – intended for intercepting and destroying enemy aircraft – was cancelled, causing political controversy.



© Canada Department of National Defence

1979
Columbia, the earliest functional Space Shuttle orbiter, is delivered to the Kennedy Space Center for its first launch. Find out what's inside an orbiter on page 42.

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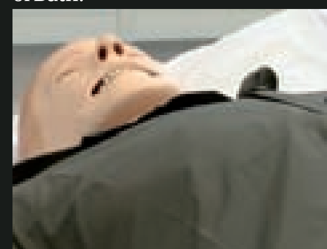
HOW IT WORKS TV

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

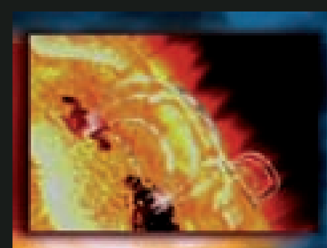
SimMan 3G in action

See the SimMan 3G robotic patient at home in the new pharmacy suite at the University of Bath.



NASA's SDO

An entertaining insight into NASA's Solar Dynamics Observatory, which can take images of the Sun that are ten times better than HD.



Prof Cox on LHC

Large Hadron Collider frontman Professor Brian Cox explains, in layman's terms, what the LHC is all about.

Hadrian's history

Step back in time with this video exploring the amazing history of the famous Scotland/England border Hadrian's Wall.

"It would take the Earth 3 million years to make enough oil for just one year of our consumption"

Professor Iain Stewart

Discover the amazing stories behind the adventures of the man from Scotland who has taken many of us – albeit from the comfort of our armchairs – on a spectacular tour of some of the most spectacular corners of the globe

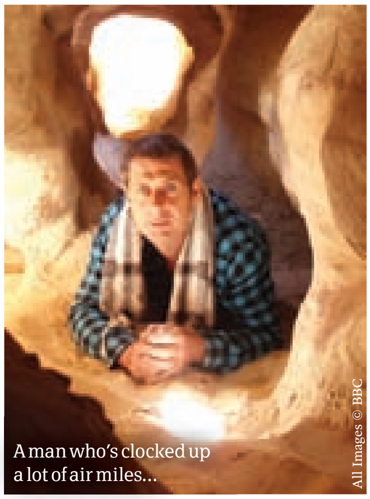
How It Works: Tell us about your latest series for the BBC, *How Earth Made Us*…
Iain Stewart: It is a sideways look at history through the lens of geology, taking our modern understanding that the planet is in a constant state of flux and that its forces can effect dramatic change over human timescales and exploring what that has meant for us in the past. For some this is Big History, but for me it is about emphasising the human face of geological change. What I hope it offers is to encourage people to think more broadly about just what the planet means to us and what our responsibilities are.

HIW: Do you think it will help viewers appreciate where we've come from as a result of the planet's awesome power?
IS: Well, more than anything, I hope it reminds them of what an amazing planet we live on. The inter-connected nature of our planet's machinery – links between its interior, oceans, ice sheets, and atmosphere – are constantly surprising us, which makes the Earth fantastically exhilarating to study. But, at the same time, the fact that many of those surprises have big implications for our future gives earth science a growing sense of real purpose.

HIW: You have been described as a geologist, a television presenter, and 'Earth Man' among others. Which title best describes you?
IS: I'm an earth scientist. That's the day job. The television presenting is great fun but it's just the chance to communicate on an enormous scale the same stuff that I do in the lecture rooms at Plymouth.

HIW: What was the most thrilling new fact that you discovered on this latest adventure?
IS: I like how geology offers an alternative angle on the contemporary world, like the fact that it is estimated it would take the Earth 3 million years to make enough oil for just one year of our consumption. Now that is living beyond our means.

HIW: What, so far, is the most remarkable place you've seen on Earth?
IS: It has to be the Crystal Cave in Mexico – any geologist would give up their right arm to enter that wonderland. But other highlights were the methane-burping mud volcanoes of Azerbaijan, the singing sand dunes of the Libyan Sahara, and wallowing in brine pools in an Iranian salt cave. Oh, and playing five-a-side football (and pulling a hamstring) in a oil-drilling town built on stilts in the middle of the Caspian Sea. This really was a whirlwind tour through the planet's weird and wonderful.



A man who's clocked up a lot of air miles…

All Images © BBC

HIW: When you entered the Cave of Crystals in Mexico it looked otherworldly. As a lover of the environment and natural history, how did it make you feel to experience these extraordinary sights?
IS: It's oppressively hot and humid, you're weighted down with kit, and you dread losing your footing on the slippery sheen of the crystals, but none of that really mattered. It was the raw beauty of the place that took your breath away. You had to remember that you were in there to work, otherwise you'd just be entranced. The miners believe there are similar but bigger caverns deeper down, but because it's a working silver mine it would be too much effort and disruption to open them up. As it is, they plan to block and reflood this one, so the planet will get it back.

Maybe it's for the best – perhaps the Crystal Cave is best seen as a symbol of the innumerable remarkable worlds that lie hidden beneath our feet, just waiting for the time when humans seriously look to explore downwards rather than up to the heavens.

HIW: Is there one special gadget that you wouldn't leave for an expedition without?
IS: My standard geological compass-clinometer is invariably tucked away in the rucksack, but it is the MacBook and iPhone alongside it that ends up being essential for keeping up with the day job.

HIW: What is next on your to-do list?
IS: I'm off to Scotland for a BBC4 series that looks at how the roots of some of the most fundamental ideas about how the planet worked emerged from of a tiny but rich piece of geological real estate to the north of Carlisle. Geology is coming home!

How Earth Made Us is available on DVD from the BBC Shop, priced £17.00

CAREER

1964 Born in East Kilbride near Glasgow, Iain embarked on an acting career, which in 1978 saw him starring in the BBC series *Huntingtower.*

1986 A bright kid, Iain went on to graduate with a degree in geology and geography from Strathclyde University.

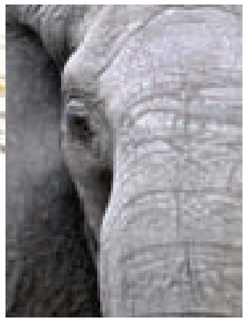
1990 Iain then went on to gain a well-earned doctorate in earthquake geology at the University of Bristol before heading to London to pass on his wisdom and teach geology and earth sciences at Brunel.

2002 He began a soon-to-be burgeoning television career, starting off as an expert on *Helike – The Real Atlantis*, a programme for the BBC series *Horizon.* The show looked at the earthquakes and tidal waves that drowned the Greek city of Helike in 373 BC.

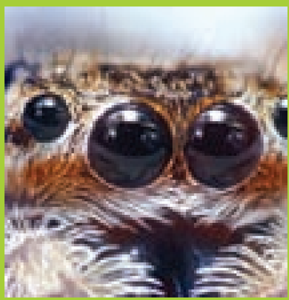
2004 > PRESENT In 2004 Iain fronted *Journeys From The Centre Of The Earth* for Discovery's Science Channel, marking the beginning of an extraordinary television presenting career. In the same year, he joined the University of Plymouth as a lecturer in geoscience communication.

How does the largest land mammal survive?

The life of

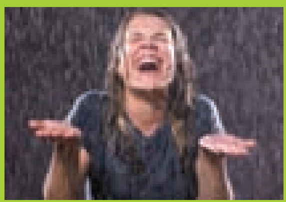


Elephants are big in every sense of the word, but they are also surprisingly sensitive animals. **How It Works** unpacks some of the myths and explains what makes them so special



This month in **Environment**

We've always said that no subject is too big or too small for **How It Works** to cover and this issue really is living proof. In the space of ten pages we go from telling you about the largest mammals on land to revealing some fascinating facts about many people's least favourite creepy-crawly the spider. You can kick off with the fascinating lives of elephants right here.



18 Rain

© Sergio

19 Box jellyfish

20 The atmosphere

Elephants are the largest land animals in the world, with African males averaging five tons. They have evolved to this huge size to protect themselves from predators but almost everything that makes an elephant unique is a consequence of this bulk. Large mammals don't have enough skin surface area to shed excess body heat so elephants have large flapping ears to act as radiators. A heavy head precludes a long neck so elephants have evolved a trunk, both to stretch up into branches and to be able to reach down to the ground to drink.

Most mammals stand with their leg joints half bent, which makes it easier to accelerate from a standstill. Elephants can only support their body weight by keeping the bones all in a line, like a pillar. Humans are the only other animal that does this. Elephants do not have fused ankle joints, as some people think, but it is true that they do not jump. The impact stresses would risk serious injury if they tried. This is the same reason that elephants don't gallop. Instead, they have a curious half-jogging gait where the front legs run and the hind legs walk fast.

Elephants used to be classified as pachyderms and lumped with the rhino and hippopotamus. Scientists now place them in their own order, the proboscidea, along with the extinct mammoths. There are three species of elephant living today: the African Bush elephant, African Forest elephant and the Asian elephant. All elephant species are protected but poaching is a very serious problem and current population numbers are unknown.

5 TOP FACTS ELEPHANTS

No stick in the mud

1 Elephant feet spread out under their weight but shrink again when lifted. This lets elephants break the suction when they are walking through deep mud.

Bendy knees

2 Elephants are the only animal to have four forward-facing knees. All other four-legged animals have at least one pair of legs with knees that face backwards.

Thirsty work

3 Hanging around the savannah is thirsty work and the average elephant drinks more than 200 litres of water per day. That's two very deep bath-fulls!

The daily grind

4 Elephants replace their teeth six times in their life, with new teeth moving forward from the back of the mouth. When the last set wears down, the elephant dies of starvation.

Don't try to outrun one

5 They may not look fast and although elephants take a long time to accelerate during a charge they can, in fact, reach 40km/h (25mph). Quite a speed for its size!

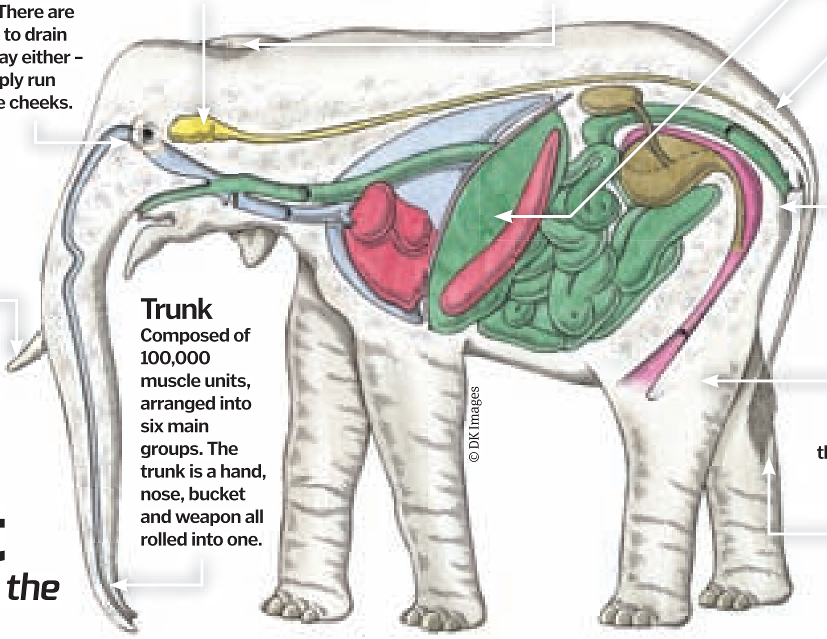
DID YOU KNOW? *Elephants are either right- or left-tusked. The 'master tusk' wears down quicker from extra use*

elephants

Cool it! An elephant's ears are used for cooling and communication

Anatomy of an elephant

The physical attributes of the world's largest mammal



© DK Images

Eyes
Elephants don't see well at distances of more than 20 metres. There are no ducts to drain tears away either – they simply run down the cheeks.

Brain
At 5kg, their brain is the largest of any land animal. Like humans and dolphins, elephant brains have a highly convoluted neocortex, thought to be a sign of complex intelligence.

Ears
The large flapping ears are used for cooling and signalling. African elephants have ears up to three times larger than those of the Asian elephants.

Stomach
Elephants have an inefficient metabolism that doesn't properly digest cellulose. Consequently they have to eat 100-200kg of plant matter every day.

Hair
Although they look smooth-skinned, elephants actually have sparse hair all over their body, particularly on the head and back. Hair on the tail can be 1m long.

Skin
Elephant skin is 2.5cm thick on the back legs and trunk, but it's surprisingly delicate and elephants frequently coat themselves in mud to escape the sun.

Tusks
Although they are useful for digging in the ground, stripping bark from trees and fighting, the ivory in the tusks is also the main reason that elephants are endangered.

Trunk
Composed of 100,000 muscle units, arranged into six main groups. The trunk is a hand, nose, bucket and weapon all rolled into one.

Legs
The leg bones are very thick and a wide foot spreads the load. Even so the pressure under an elephant's foot is 3.5 times greater than a human's.

Tail
Elephants can produce 75kg of dung per day so an efficient swat to keep the flies away is essential. The tail looks small but it's over 1m long.

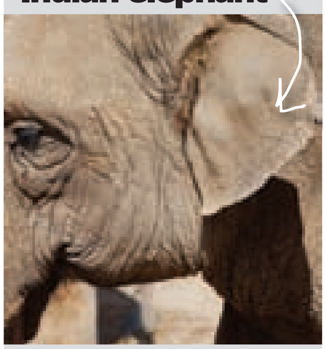
“The skin covering the ears is paper-thin and richly supplied with blood vessels”

Ears looking at you, kid

African elephants have enormous ears – 1.5 metres across for an adult. But those huge flaps aren’t there to improve their hearing; they are air conditioning units. The skin covering the ears is paper-thin and richly supplied with blood vessels. By waving them back and forth, the elephant can dump body heat. Elephants have also evolved a secondary use for their ears; as a threat display. With his ears outstretched, an elephant appears even bigger, which might discourage attacks. Asian elephants have smaller ears because they generally live in cooler habitats.

Elephants hear over a much lower range of sound frequencies than we do, but this is mainly a function of their much larger size. Their sense of hearing is very acute but it isn’t limited to their ears. Elephants also hear through the soles of their feet and the sides of the trunk.

Indian elephant



African elephant

Safety in numbers

Elephants have a highly matriarchal society. The herd is an extended family group of mothers, daughters, sisters and aunts with the oldest female in charge. Males leave the herd at an early age and wander alone or in temporary all-male groups, joining a herd only to compete for, and mate with, females during their oestrus cycle.

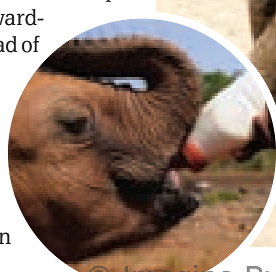
Herd members are all very aware of the various family relationships and will often renew contact with other related herds that have split away in the past. Non-breeding females will often act as nursemaids to young calves and at night the adults will surround the calves to protect them.

The longest pregnancy

Female elephants are fertile for just two days out of every four months. When the female oestrus cycle begins, she calls to advertise the fact and the males begin competing for dominance. The winner will mate with the female up to five times a day while she is fertile. Elephant testicles are kept inside the body, near the kidneys. The elephant’s penis is almost as long as his trunk and equally manoeuvrable but despite this, the normal mounting position only just allows the penis to reach the flap covering the downward-facing vagina. Instead of penetrating her, the male sprays about half a pint of semen at the entrance.

Elephants gestate for 22 months – longer than any other animal. When the calf is born it weighs around 115kg. It will be suckled by the mother for another 22 months after that. Most females only reproduce once every four to nine years.

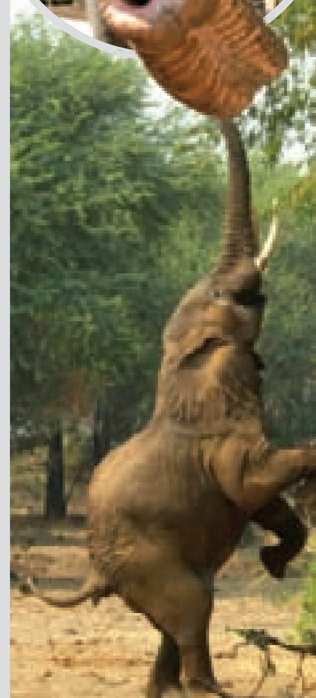
Junior here was nearly two years in the making



Packing a trunk

The elephant’s trunk has evolved from a fused nose and upper lip. There are two nostrils that remain separate all the way up the trunk. The African elephants have two finger-like projections on the end of the trunk, which can pick berries from a tree. The Asian elephant only has one projection and is limited to using it as a scoop.

Elephants have an excellent sense of smell and will often be seen pointing their trunks around to identify the source of a scent. But at the same time, the trunk is tough enough to be used for hoovering up mud and dust to squirt over the elephant’s body as a protection from the Sun. Elephants also suck up water through their trunk but it’s more a syringe than a straw because they always squirt the water into their mouth before swallowing.



A case of ‘trunk and disorderly?’

Head to Head LARGEST MAMMALS

1. Blue whale
Not only the biggest mammal but the biggest ever to have existed. In fact, whales could occupy all three spaces here.

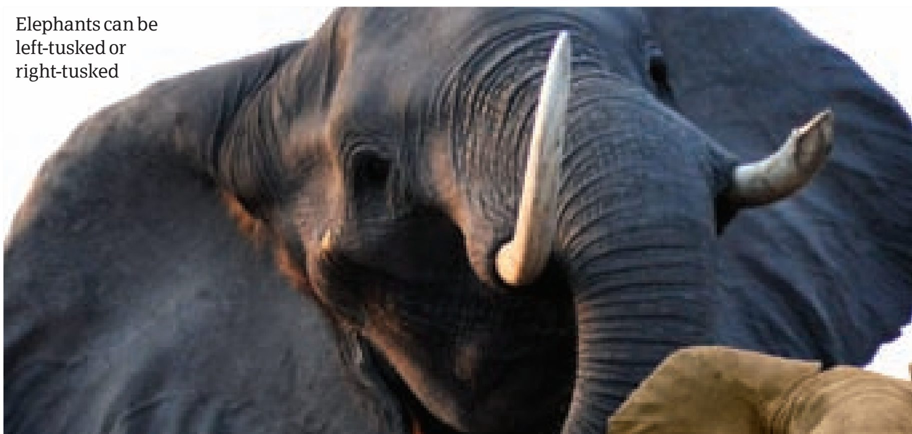
2. Elephant
The largest land mammal, elephants would occupy second and third place if we counted African and Indian as separate.

3. Rhino
The horny rhino comes in as the second largest land mammal with the hippo coming in a very close third. Rhinos are native to Africa and Asia.

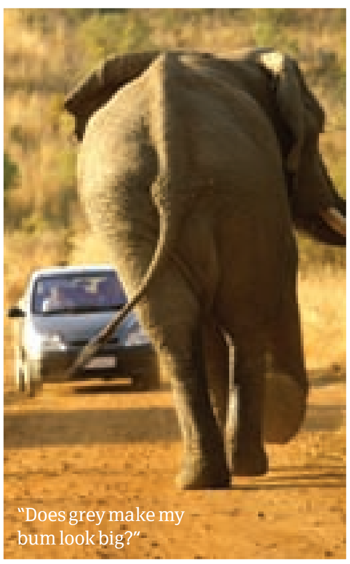
DID YOU KNOW? A prehistoric elephant species that lived in Crete 2 million years ago was only the size of a pig

Tusks

In most mammals, the largest teeth are the canines but elephant tusks are formed from the second upper incisors. Both male and female African elephants have tusks but female Asian elephants do not. The tusks grow throughout the elephant's life at a rate of about 18cm per year. The largest African elephant tusks can reach 3m long. One third of the tusk is embedded in the skull. This root is full of blood vessels and nerves that supply the growing tusk. The outer two-thirds is bony dentine covered in a layer of a mineral called apatite, which is mainly calcium phosphate. This layer is the ivory. African elephants use their tusks to dig for water and roots whereas Asian elephants use the tusks mainly for dominance displays between males.

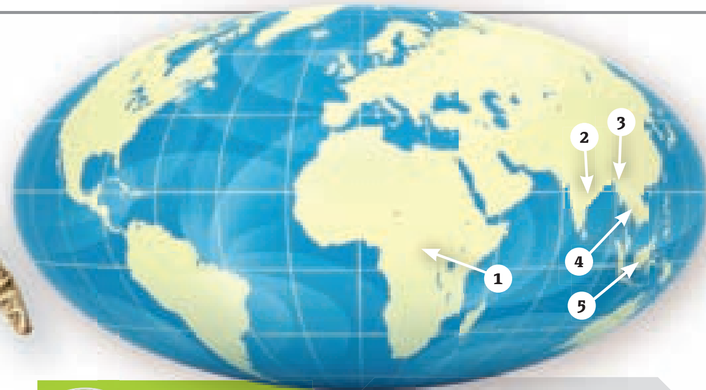


Elephants can be left-tusked or right-tusked



"Does grey make my bum look big?"

He looks ready to take someone to tusk



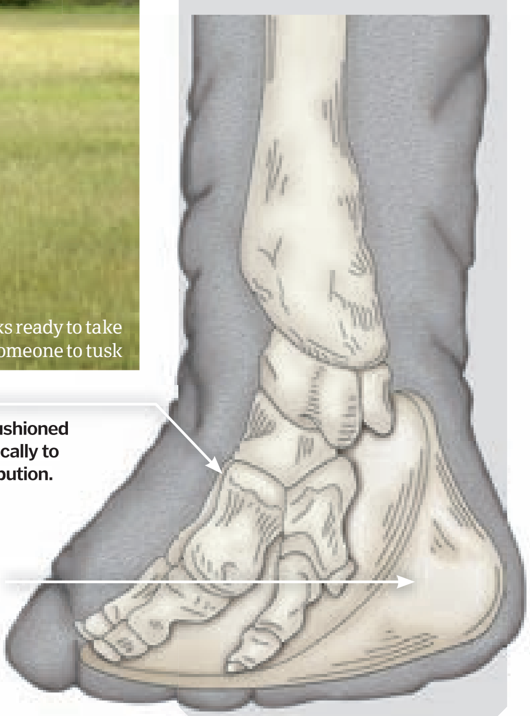
ON THE MAP

Where do elephants live?

African elephants are found in scattered populations across all of sub-Saharan African (1) countries, apart from Somalia and Madagascar. The Asian elephant is found mainly in India (2), with smaller populations extending through Burma (3), Thailand (4) and Borneo (5).

Dainty steps

An elephant is essentially walking in high-heeled shoes, because the heel bones are raised right up inside the foot and rest on a thick pad of fatty cartilage. This cushions the bones and aligns them more vertically so that the vast weight of the elephant rests directly over the pillar-like legs. African elephants have four toenails at the front and three on the hind legs. Asian elephants have five at the front and four at the back. But these 'toenails' are actually just hardened skin patches that aren't attached to the toe bones at all. Buried inside, elephants have five toes on each foot.



Lined up
The bones are cushioned and aligned vertically to aid weight distribution.

High heels
The heel bones are raised right up inside the foot.

Safe from harm?

One of the main reasons elephants have evolved to be so large is to protect themselves from predators. Lions and occasionally hyenas may successfully kill a young elephant, if it can be separated from the herd, but an adult elephant is virtually invulnerable.

Tusks, however, are their greatest vulnerability. The ivory in the tusks of a large African male can be worth more than £5,000 to poachers and an estimated 20,000 elephants a year are illegally killed for their ivory. Periodic legal culls and one-off sales of old ivory have made it much harder to police the illegal ivory trade. The evolutionary pressure from poaching is such that a once-rare genetic mutation, which results in tuskless elephants, is spreading rapidly. As many as ten per cent of Asian elephants in China may now be tuskless.

Forest fires

Understanding the nature of these deadly phenomena

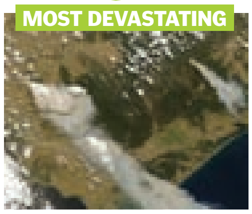
Forest fires burn over 4 million acres of land per year, with an average of 106,400 fires taking place. These can move up to speeds of 14 miles per hour, but what factor permits these fires to occur? Well, four out of five are man made. However, without the intervention of nature this devastation would not occur.

Dry weather conditions and drought prompt green vegetation to convert into bone-dry, flammable fuel – including trees, grass and bush. Strong winds and air currents are also a major factor, supplying the oxygen that sustains combustion. Both man made and natural heat sources such as lightning, cigarettes and even the Sun ignite the spark to light this phenomenon, referred to as the 'fire triangle'.

Fires spread in the direction of the most abundant supply of the three elements that make up this triangle, whereas rate of combustion is limited by one of the three. Fires are presented in three types – ground, surface and crown fires. The latter is the most hazardous, as it spreads the fastest and is the most destructive – jumping from tree crown to tree crown. Man-made fires may constitute the greatest percentage, but natural fires present the greatest total area burned, destroying everything in their path.

Head to Head WILDFIRES

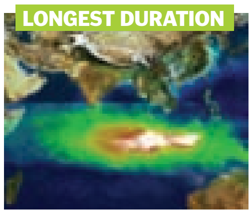
MOST DEVASTATING



1. Black Saturday bushfires, 2009

Location: Victoria, Australia
Duration: Over one month
Extent/coverage: 1.1 million acres of damage
Death toll: 173 fatalities

LONGEST DURATION



2. Indonesian forest fires, 1997

Location: South East Asia
Duration: Over one year
Extent/coverage: Spread to neighbouring countries Malaysia and Singapore
Death toll: More than 250 fatalities due to aircraft and maritime accidents

LARGEST

3. Great Idaho fire, 1910

Location: Idaho, USA
Duration: Two days
Extent/coverage: 3 million acres
Death toll: 86 fatalities

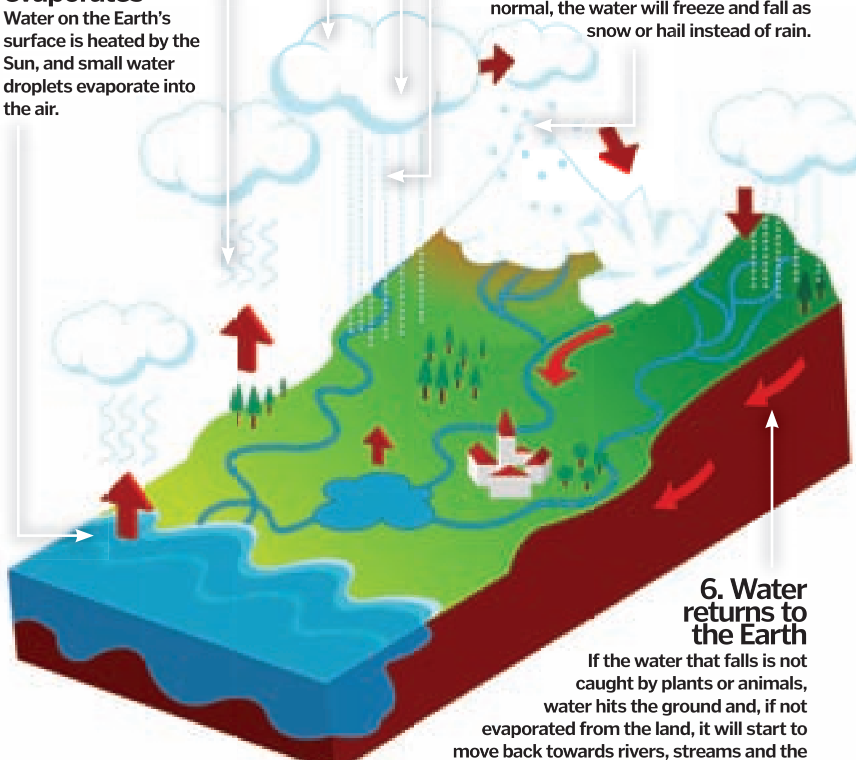
3. Clouds form
When the water vapour droplets reach a certain level, condensation starts to occur, forming clouds. This is due either to an increase in humidity or a drop in temperature in the atmosphere.

4. Rain forms
As more water vapour droplets gather within the cloud, they start to merge and become larger. Eventually they will become too heavy to be held in the atmosphere and gravity will start to pull them back towards Earth.

2. Water vapour travels
The heat from the Sun pulls these water vapour droplets upwards into the atmosphere.

1. Water evaporates
Water on the Earth's surface is heated by the Sun, and small water droplets evaporate into the air.

5. Rain falls
This water falling back to Earth is called rain. Sometimes it will not make it back to Earth, due to the air not being humid enough, and in this case, water evaporates back into the atmosphere. If the temperature of the air is lower than normal, the water will freeze and fall as snow or hail instead of rain.



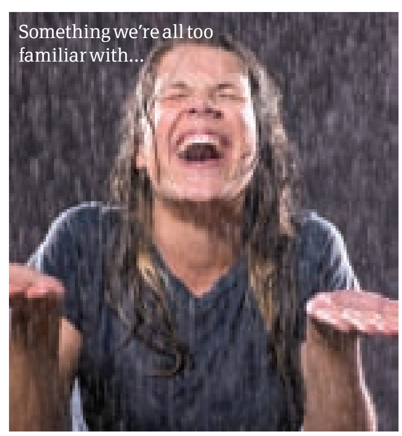
6. Water returns to the Earth
If the water that falls is not caught by plants or animals, water hits the ground and, if not evaporated from the land, it will start to move back towards rivers, streams and the sea – where the process begins again.

Why, and how, does it rain?

In England, rain is a more common occurrence than most of us would like, but it is very important for the maintenance of our ecosystem

Rain is defined as liquid precipitation. It is formed high above the ground in clouds by water vapour coming together into large droplets that become too heavy for the air to support. Gatherings of condensed water vapour are called clouds, and this is where rain comes from. Although a large amount of water is held in each cloud, rain does not fall all at once from the cloud because the water droplets grow at different speeds, with the fastest growing droplets becoming heavier quicker and falling first, the slower growing ones falling after.

Although scientists are not sure if there is water on other planets, the phenomenon of rain has occasionally been recorded. This rain involves other liquids, such as methane which falls on Titan, Saturn's moon, and sulphuric acid which falls on Venus.



Something we're all too familiar with...

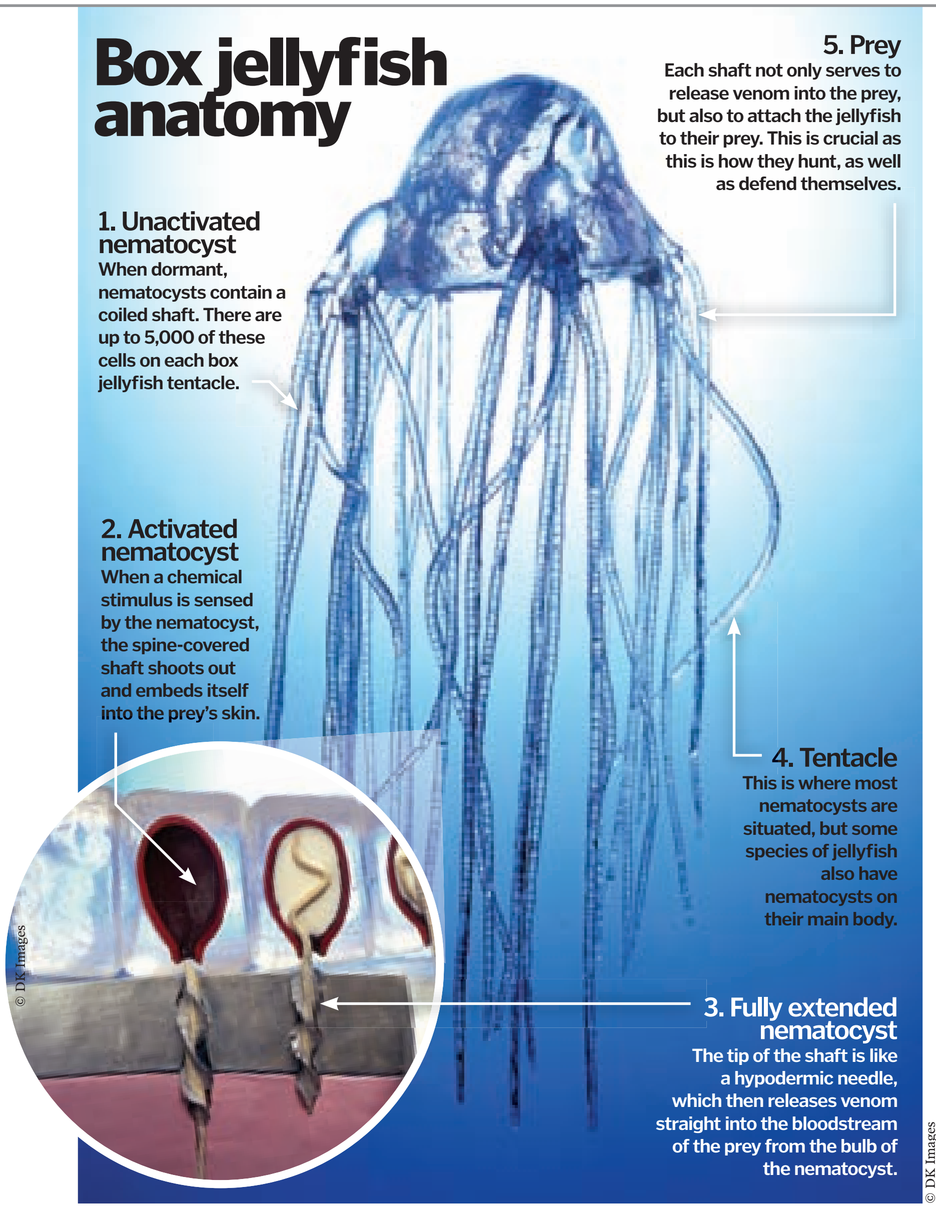
1. Brazilian wandering spider
Its venom is the most toxic found in spiders. It affects the neural system and muscle control can be lost.

2. Stonefish
The stonefish's venom causes intense pain in humans and can be fatal due to the venom potentially causing paralysis and shock.

3. Inland Taipan
The Inland Taipan has the most toxic venom of all snakes, but the King Cobra is often seen as the most deadly due to the quantity of venom in one bite.

DID YOU KNOW? The box jellyfish has six eyes on each of its sides. However, it does not have a central nervous system

Box jellyfish anatomy



The most venomous creature on Earth

Over 5,500 deaths have been recorded due to box jellyfish stings since 1954, but why is it so deadly to humans?

The box jellyfish is so named due to its box or bell like shape. It has four distinct sides and can have up to 15 tentacles, each one of these stretching up to three metres long with thousands of stinging cells, called nematocysts, on each one. The primary purpose for these nematocysts is to stun and paralyse their prey, ensuring that damage is not sustained to the creature's delicate tentacles. When the venom enters the bloodstream of the stung animal, it quickly targets the nervous system and heart, paralysing them. In humans, cardiac arrest often occurs and the individual will die before they receive aid. Even if they do survive the stings, massive scarring is left where nematocysts have attached due to the toxins attacking skin cells.

Very few creatures, such as sea turtles – which actually consume box jellyfish – are seemingly immune to the venom, but most creatures react in the same way as humans.

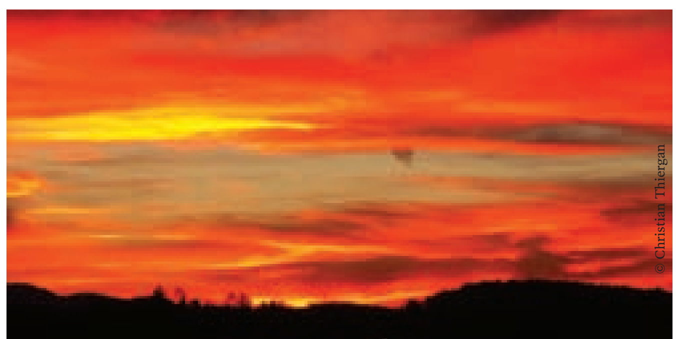
Stinging nettles

A plague for ramblers, how do these common leaves sting?

Each stinging nettle has very hairy leaves, with some of these hairs able to sting, while some are harmless. The stinging hairs lose their tips when they come into contact with the skin, and transform into a needle structure through which chemicals are released.

The chemicals which cause the stinging reaction are acetylcholine and serotonin, and these work alongside a histamine which causes the skin to itch. This irritation will normally reduce after a few hours, but some stings can cause irritation for much longer periods. Often, individuals will rub dock leaves over the area that the stinging nettle has come into contact with to try and reduce the pain, but there is no proof that this actually has any benefit. Indeed, many people assume that this myth has come into being because dock leaves grow close to nettles and parents look to try and appease children that have been stung with a placebo.

It's the stinging hairs and their chemicals that do the damage



Why do we get red sky at night?

Just how true is the famous phrase, and what causes the sky to turn red?

A red glow can often appear in the sky at dawn or dusk. The reason behind this red tint is a simple one, related to how light travels from the Sun up into the sky at this time. The low position of the Sun, coupled with the thick layer of atmosphere the light must travel through, cause short wavelengths to scatter. Only the longest wavelengths make it through, explaining why we only see a red colour displayed.

'Red sky at night, sailor's delight' came into use before scientific weather forecasting was developed. It is based on the assumption that weather systems generally move from west to east, a red glow at night, indicating a clear sky in the west, therefore suggesting that bad weather systems have passed through.

The Earth's atmosphere

It's all around us, but how much do we know about our atmosphere?

Our atmosphere (made up of 78 per cent nitrogen and 21 per cent oxygen, with other gases making up the last per cent) is held in place by gravity and consists of a number of different layers that work together to protect us from solar radiation and to keep consistent temperatures. The atmosphere gets thinner with altitude, with 80 per cent of its mass in the first layer closest to the Earth's surface. There are five main layers that make up the atmosphere. The troposphere is the first layer (and is where our weather occurs), followed by the stratosphere, mesosphere, thermosphere and exosphere. There is no definite boundary between where the atmosphere ends and outer space begins, though the Kàrmàn line at 100km above sea level is often regarded as a the boundary.

There are other layers that exist alongside the five main layers. The lowest of these is the 'planetary boundary', which is within the troposphere and closest to the Earth's surface and its depth can vary widely between 100m to 3,000m as it is directly affected by conditions on the surface. The ozone layer is the one that most of us will be familiar with and this is contained within the stratosphere, in its lower portion. Around 90 per cent of the ozone in the atmosphere lies here. The ionosphere is what causes auroras, such as the northern lights, as it is ionised by solar radiation and stretches from 50 to 1,000km, overlapping the exosphere and thermosphere.

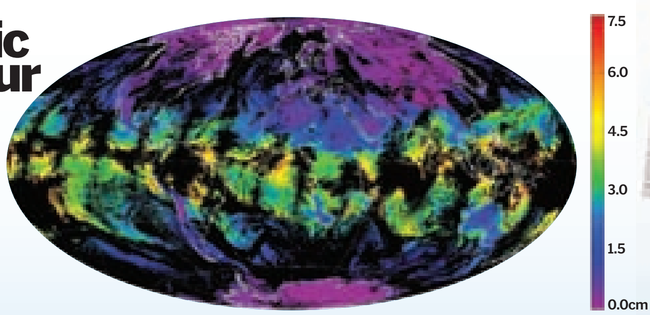
Finally, the homosphere and the heterosphere run from the Earth's surface to around 80km and from 80km upwards respectively. They are so-named because of the way the gases within them are mixed. The heterosphere has a chemical composition that changes with height, whereas the homosphere's make-up remains more constant. The five main layers are based on the thermal structure of the atmosphere, whereas the additional layers mentioned here are classified according to composition.

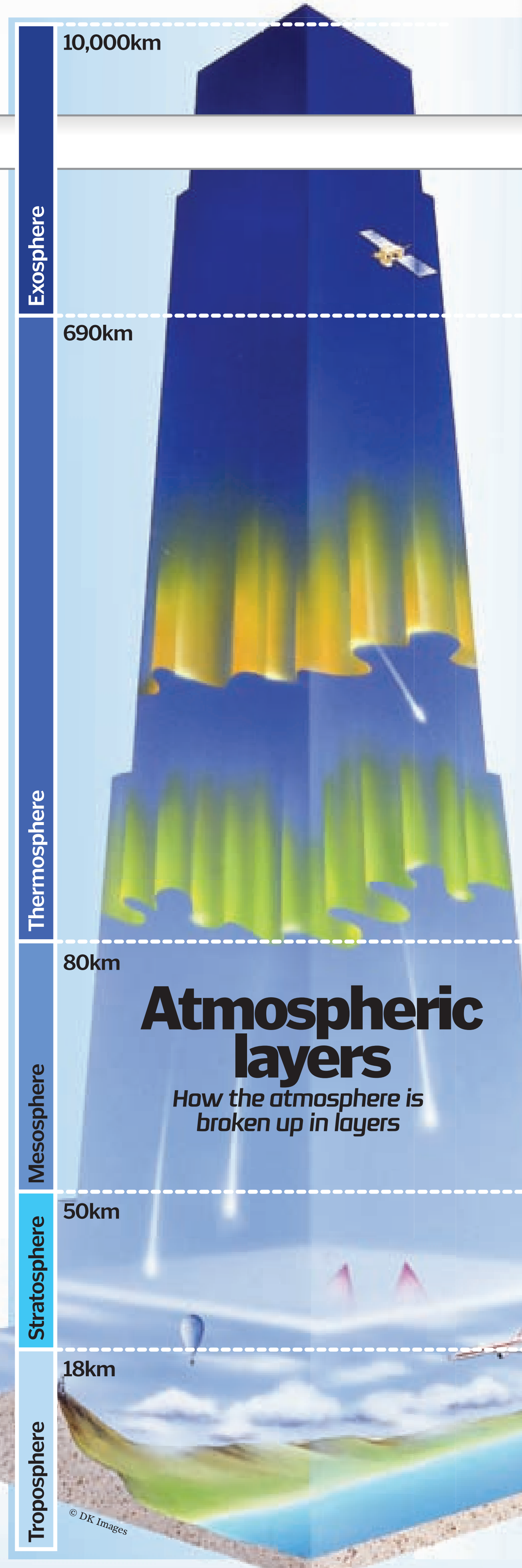

The northern lights are caused partly by the atmosphere

Atmospheric water vapour

Moisture in the air

The gaseous water vapour in our atmosphere is responsible for our rain, snow, hail, fog, and clouds. If the vapour was to fall evenly over the planet as precipitation, each year 25mm of water will have fallen.





Head to Head
OTHER PLANETS' ATMOSPHERES

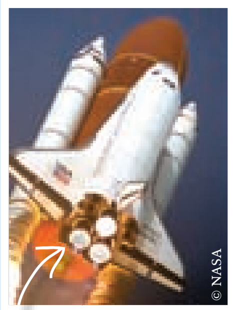
1. Mars
Mars has a thin atmosphere, less than one per cent as dense as that of Earth. CO_2 makes up 95 per cent of the atmosphere and doesn't sufficiently transfer heat.

2. Mercury
There are traces of an atmosphere, containing elements including hydrogen, helium, oxygen and sodium, but it's difficult to calculate its pressure.

3. Venus
Venus has a hot, dense atmosphere, which leads to an absence of liquid water. It has a high percentage of CO_2 and a mean temperature of 460°C.

DID YOU KNOW? The atmosphere reaches out to a whopping 10,000km above the Earth's surface

5. Exosphere
The final layer where particles are widely spaced and can travel hundreds of kilometres before colliding with another particle. The makeup of this layer is mainly hydrogen and helium.


© NASA

4. Thermosphere
Temperatures start to increase with height. This is also the layer in which the International Space Station orbits, between 320 and 380km, and shuttles fly into. It extends up to the base of the exosphere, called the exobase.


This rock made it through the mesosphere

3. Mesosphere
Extends from the stratopause (again, the layer boundary) to a height of 80-85km and is notably the layer in which meteors burn up when entering the atmosphere. Temperatures decrease with height, and in the mesopause is the coldest place on Earth (around -100°C).

2. Stratosphere
Starts from the tropopause (the boundary between the first two layers) up to around 51km, with temperatures increasing with height. This is where you'll find things like weather balloons.

1. Troposphere
The first layer of atmosphere, starting at the Earth's surface and extending to between 7km and 17km. It is heated by a transfer of energy from the Earth's surface, so it gets cooler as it goes higher.

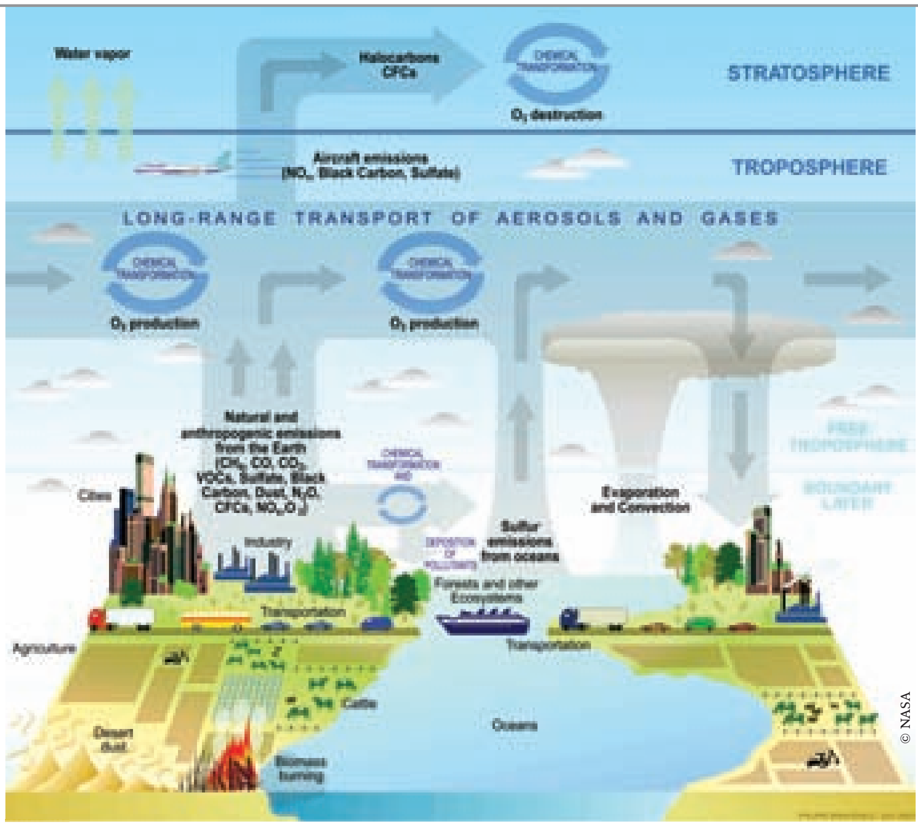
Pollution in the air

The effects of pollution include smog, acid rain, the greenhouse effect, and holes in the ozone layer. Each problem has implications for both our health and the environment.

The carbon dioxide gas produced when fuel is burned may contribute to the greenhouse effect. Plants can convert CO_2 back to oxygen, but the human production of Co_2 currently exceeds the amount the plants can convert back.

Rife in cities, smog is the result of smoke, fog, and chemical fumes caused when different pollutants combine.

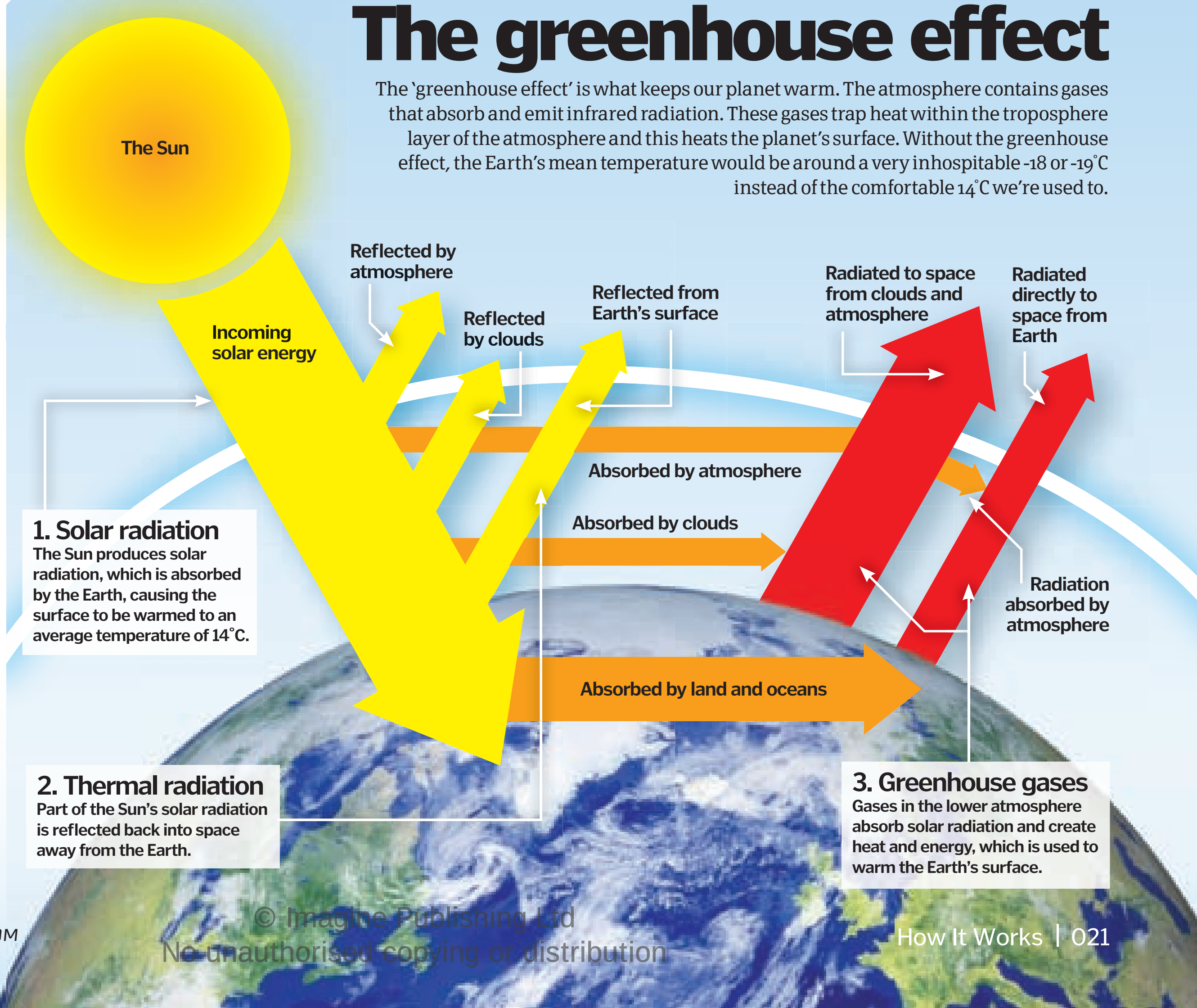
Acid rain occurs when a pollutant, such as sulfuric acid combines with droplets of water in the precipitation and becomes acidified.



© NASA

The greenhouse effect

The 'greenhouse effect' is what keeps our planet warm. The atmosphere contains gases that absorb and emit infrared radiation. These gases trap heat within the troposphere layer of the atmosphere and this heats the planet's surface. Without the greenhouse effect, the Earth's mean temperature would be around a very inhospitable -18 or -19°C instead of the comfortable 14°C we're used to.



1. Solar radiation
The Sun produces solar radiation, which is absorbed by the Earth, causing the surface to be warmed to an average temperature of 14°C.

2. Thermal radiation
Part of the Sun's solar radiation is reflected back into space away from the Earth.

3. Greenhouse gases
Gases in the lower atmosphere absorb solar radiation and create heat and energy, which is used to warm the Earth's surface.

"If a deadly venomous spider does bite you, your chance of dying as a result of it is less than ten per cent"

Anatomy of a spider

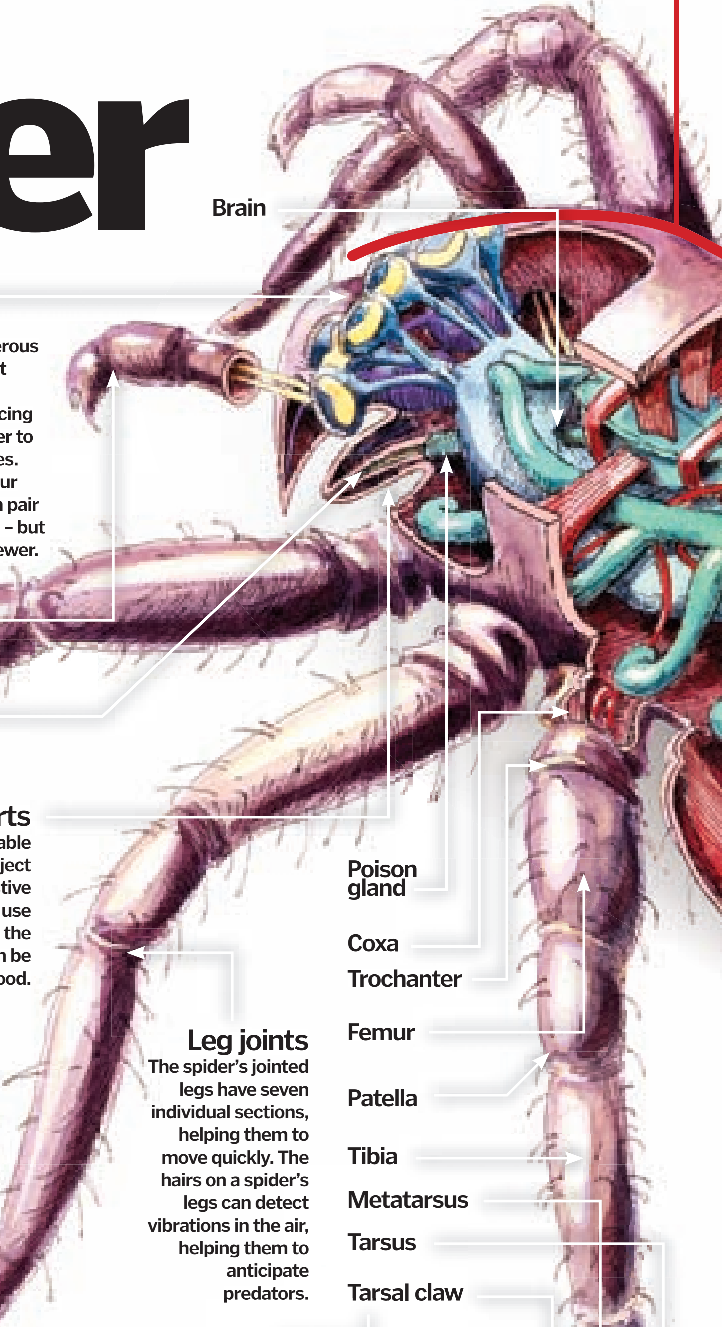
Inside the animal behind the most common phobia in Britain

Part of the arachnid class of animals – which actually includes scorpions, ticks and mites – spiders are eight-legged arthropods with two body sections. With its ability to inject venom into its prey, immobilising them for ease of eating, the spider has become both feared and revered.

© Opoterser

Forward-facing eyes

Despite having numerous eyes, the spider is not known for its good eyesight. Forward-facing eyes enable the spider to better judge distances. Most spiders have four pairs of eyes – a main pair and three small pairs – but some species have fewer.



Cephalothorax

The cephalothorax is the fusion of head and thorax that distinguishes spiders from insects, which have three separate head, thorax and abdomen sections. This large section of the spider's body carries four pairs of legs and two pairs of mouthparts.

Brain

Pedipalps

This pair of small feelers are ideal for controlling and tearing up food.

Chelicerae

These fangs are small but deadly projections that inject poison into the spider's prey.

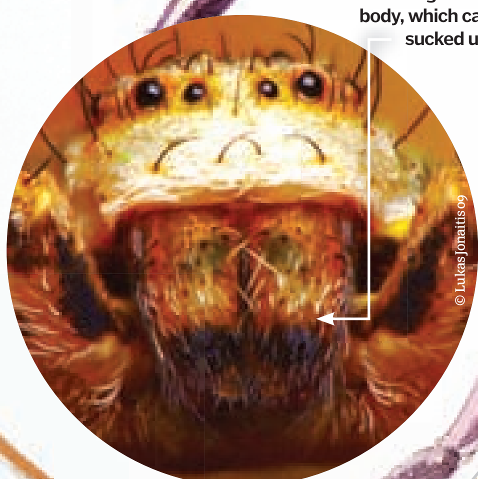
Mouthparts

The mouthparts enable the spider to inject victims with digestive enzymes and then use their fangs to liquefy the body, which can then be sucked up as food.

Leg joints

The spider's jointed legs have seven individual sections, helping them to move quickly. The hairs on a spider's legs can detect vibrations in the air, helping them to anticipate predators.

Poison gland
Coxa
Trochanter
Femur
Patella
Tibia
Metatarsus
Tarsus
Tarsal claw



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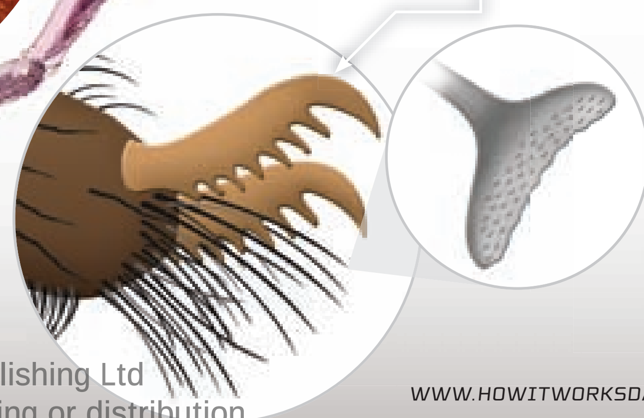


Feet

A spider's foot is covered in hairs, each of which is covered in microscopic feet. These mini feet allow the spider to grip on to any surface.

Fancy a bite?

The poison gland connected to a venomous spider's fangs contains dangerous chemicals that are released into a victim by digging the fangs into the victim's body. Unless the spider feels threatened, these fangs will remain tucked away. Some spider poisons have horrible side effects, including tissue degeneration, cell death, and sickness, and yet even if a deadly venomous spider does bite you, your chance of dying as a result of it is less than ten per cent. Male funnel-web venom contains robustoxin, which affects the nervous systems of humans and monkeys, but not of other mammals.

While most species have trachea and book lung respiratory systems, some just have one or the other

5 TOP FACTS SPIDERS

Good vibrations
1 Spiders do have eyes but they aren't very effective. Instead, spiders use vibrations. The tiny bristles all over a spider's body surface are sensitive to touch, vibration and airflow.

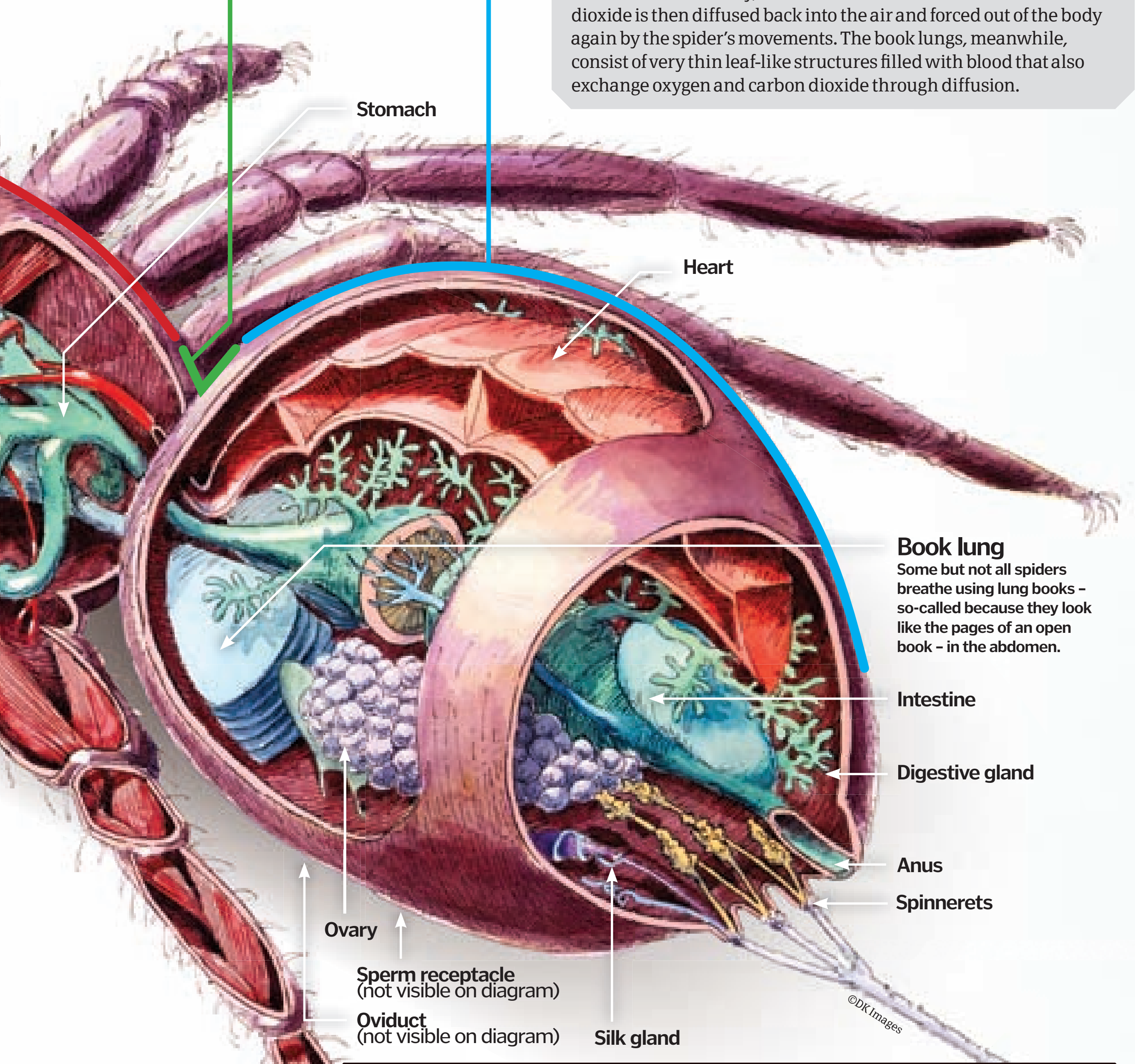
Spiders' digest
2 Spiders digest food outside their body. They cover the insects in digestive enzymes which break down the body, and allows the spider to suck up the liquid prey.

Arthropods
3 Spiders are arthropods, so the skeletal system of their body is the outermost layer. The hard exoskeleton helps the spider maintain moisture and not dry out.

Special silk
4 Spider silk has other uses than spinning webs. Black widow silk was at one time used in military gun sights because of its strength and uniform thickness.

Flying spiders
5 Young spiders, or spiderlings, can travel great distances by doing something called 'ballooning' – the process of floating on the breeze using a strand of silk.

DID YOU KNOW? *If a train was to hit a sheet of spider's silk the thickness of a pencil it would stop the vehicle in its tracks*



How do spiders breathe?

There are two kinds of respiratory system inherent to the spider – trachea and book lungs. The trachea system consists of tubes running the length of the body. The natural movements of the spider forces air into the body, where it diffuses into the blood. Carbon dioxide is then diffused back into the air and forced out of the body again by the spider's movements. The book lungs, meanwhile, consist of very thin leaf-like structures filled with blood that also exchange oxygen and carbon dioxide through diffusion.

MOST WANTED

Some of the most notorious spiders on the planet

1 Brown recluse

The brown recluse can be distinguished by the dark violin-shaped marking on its back. It uses stealth – not a web – to catch its prey by sneaking up and sinking its venomous fangs into the victim. Most bites to humans are accidental and painless, until three to eight hours later when the site becomes red and painful. In bad cases the wound becomes necrotic causing the cells and tissue to die, which can leave severe scarring.

2 Black widow

Identified by their vivid red-on-black markings, black widows are found in the more temperate regions of the globe. Though the venom can bring about nasty symptoms in adults, a bite from the black widow doesn't actually sound the death knell for its victims. Children and the elderly, however, are more at risk.

3 Mexican redknee tarantula

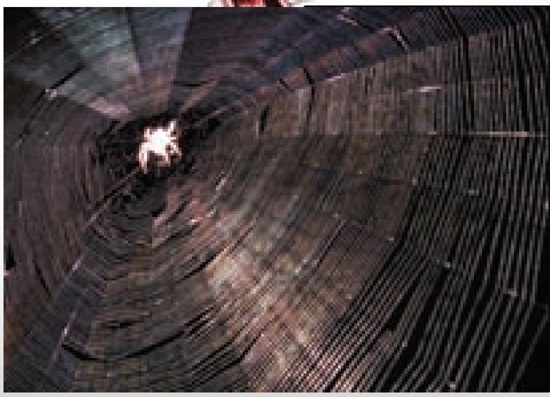
The Mexican redknee is most wanted not because it's a deadly creature but because it makes for a popular pet. Found in the mountains of Mexico and often employed for its impressive appearance as a Hollywood prop in the likes of the *Indiana Jones* and *James Bond* films, this spider is actually very docile and moves very slowly.

4 Wolf spider

Mottled brown in colour – and therefore often confused with the brown recluse (above) – the wolf spider is so-named because it was once thought to have hunted in packs. Though wolf spiders are hairy, they are not closely related to the tarantula. Wolf spiders are not poisonous unless you're allergic, and they can be found throughout Europe and in Britain.

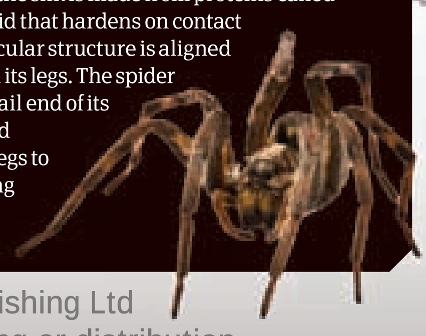
5 Funnel-web spider

A native to the coastal and mountain regions of eastern Australia, the funnel-web is a small but deadly part of the family. Its glossy, almost hairless body gives it a menacing appearance and some species can serve a highly toxic, fast-acting venom. The female funnel-web will spend most of her life inside her burrow, which is lined with white silk.



Nature's strongest fibre

Weight for weight, spider silk is stronger than steel. Produced in the silk gland in the abdomen, the silk is made from proteins called fibroin. It's exuded as a liquid that hardens on contact with the air when the molecular structure is aligned by the spider pulling it with its legs. The spider squeezes the silk from the tail end of its body using structures called spinnerets. It then uses its legs to stretch the material into long threads for weaving into webs to catch prey.



This month in **Technology**

The TV is often attacked as the enemy of education. We disagree. Think of all the amazing science and nature programmes available. So, lay off the TV, and if you're interested you can find out how all these great shows get to your home right here.

28 Bowling alleys

29 Gas masks

30 Speed cameras

The future of TV

Explore the next generation of TV technology and discover the newest technology driving the future of home entertainment

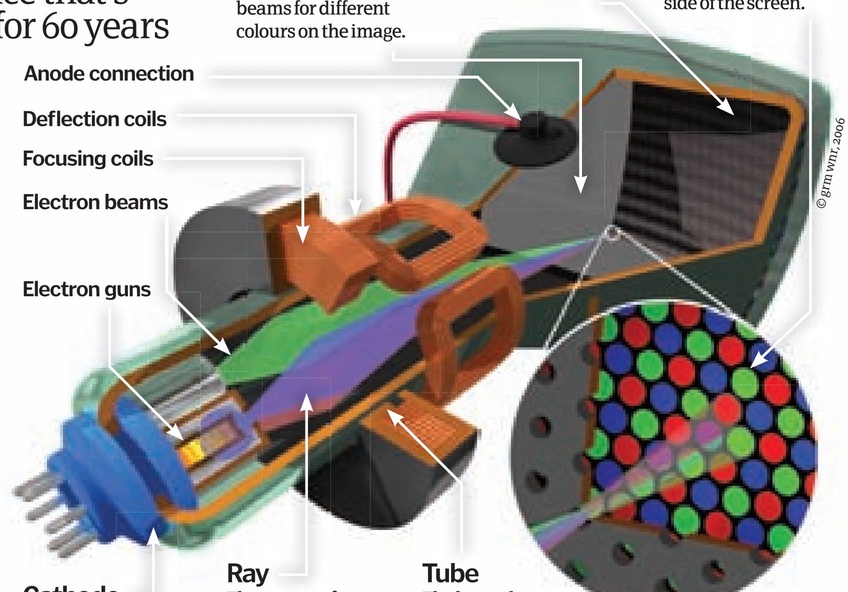
From analogue to digital and now plasma and 3D, the telly has long been our window on the wider world of entertainment and news. The technology behind this vital element of broadcast communications has developed massively over the decades and here we will show you exactly what goes on inside this magic box of tricks. So read on to discover the many different technologies used to achieve these moving pictures.

CRT televisions

Before we greet the modern age of TV tech, let's look at the science that's been bringing us images for 60 years

Before the advent of today's much thinner, less bulky LCD, plasma and OLED screens, traditional televisions electronically displayed images using a cathode ray tube (CRT). Sounding like weapons from a bad B-movie, a cathode ray tube and ray guns were essential to the last generation of televisions. The CRT in a colour television consists of a viewing screen covered in a layer of phosphor, a glass tube, and electron guns – one for each colour signal (red, green and blue).

The electron guns fire negatively charged electrons emitted from a cathode, which is like the heated filament in a light bulb. These electrons pass through a positively charged metal anode, turning the flow of electrons into a beam that can be focused or deflected before hitting a phosphorescent screen. The phosphor glows in response to the electrical current, producing images on the screen.



5 TOP FACTS TELEVISION

Scottish roots
1 In 1926 Scotsman John Logie Baird was the first person to demonstrate the first working television system for members of the Royal Institution.

First remote
2 The first wireless TV remote control – capable of changing the channels and switching the unit on and off – was the Flash-matic from Zenith, produced in 1955.

First plasma
3 The plasma display was invented in 1964 by Donald Bitzer, originally to help students working in front of computers for long periods of time.

Aunty Beeb
4 Public service broadcaster, the British Broadcasting Corporation (affectionately known as the BBC or Beeb) is the largest broadcasting corporation in the world.

How many?
5 The number of television sets in the average American home is 2.24 according to A.C. Nielsen Co – so it's bad luck if you're in the room with the 0.24 of a TV!

DID YOU KNOW? Panasonic currently makes the largest TV screen at 152 inches

© Sony

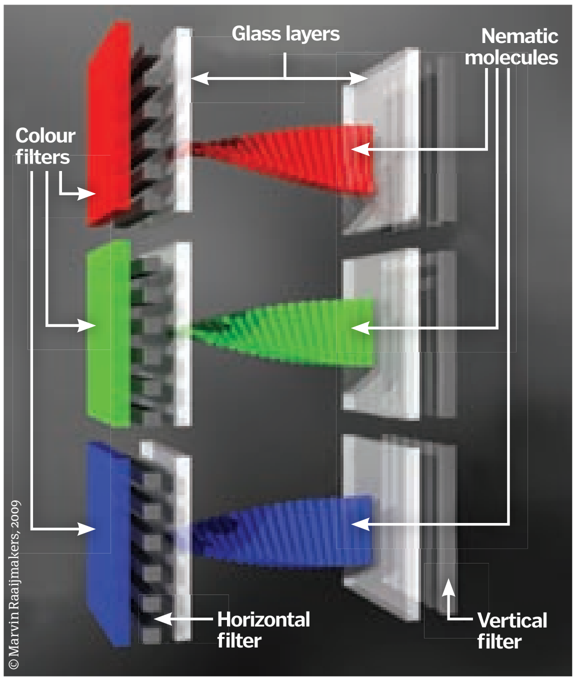
LCD TVs

Although they're more delicate than CRT TV screens, liquid crystal display panels are much higher quality

We've been using liquid crystal displays (LCD) since the Seventies in simple devices such as calculators, but these days we're using LCDs in TVs. LCD screens create images using thousands of tiny filters (red, green and blue). Between the two polarised transparent panels in an LCD TV, are pixels filled with a liquid crystal solution. Liquid crystals have a symmetrical molecular structure, but in response to an electrical current the arrangement of these molecules can be changed to act like a shutter either blocking light out or letting it pass through and strike a colour filter. A light source shining through the display from behind cannot pass through when the crystals are aligned, but when they are twisted, light can pass through. It is these patterns of clear and dark crystals that form the image.

Unlike CRT TVs, which have a layer of phosphor, LCDs use colour filters so the display can never be damaged by image burn-in, a problem with many plasma televisions. LCD TV manufacturers have been working to speed up pixel response times in order to reduce lag.

© Panasonic



© Marvin Raaijmakers, 2009

© Sony

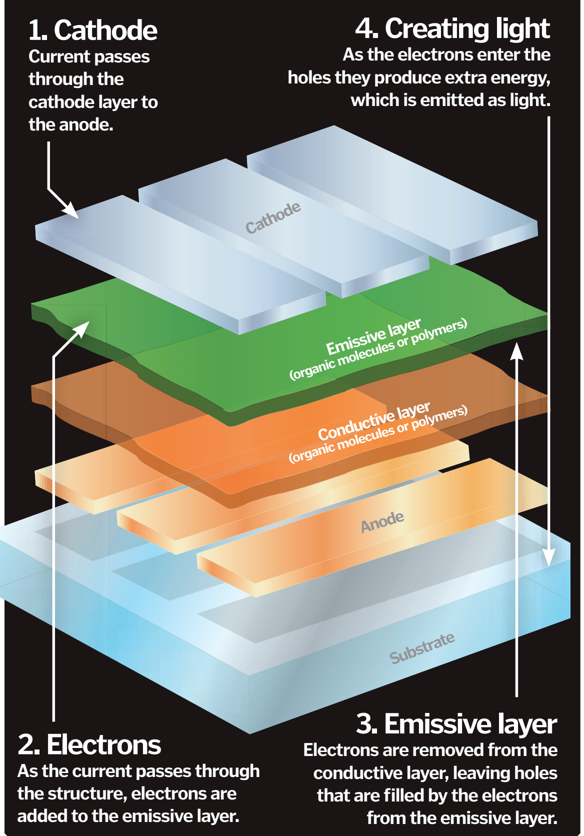
OLED TVs

Organic technology is the future of television

Like other televisions, organic light-emitting diode (OLED) TVs colour their pixels by mixing different intensities of blue, green and red light. OLED screens, however, can achieve much better pictures as they use thin films of organic molecules that create this light in response to an electrical current.

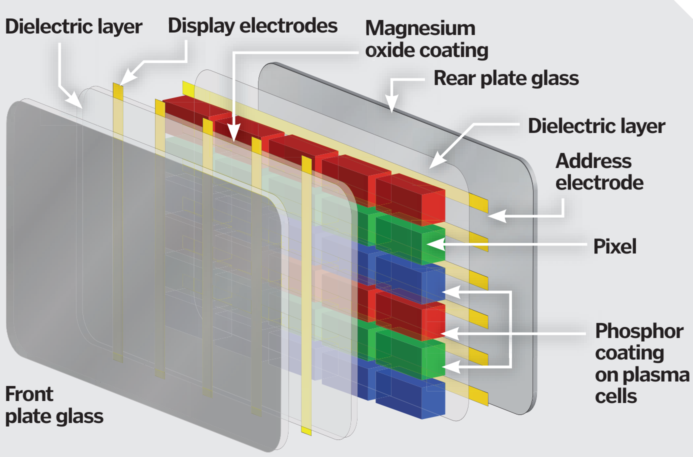
OLEDs are also much more energy efficient than the traditional light-emitting diodes (LEDs) used in LCD screens, because the organic pixels create light without the need for a backlight. This also means OLED screens can be much thinner than LCDs. Larger screens use active matrix organic light-emitting diodes (AMOLEDs), which allow the individual control of every pixel on the screen.

The main tangible advantage for consumers is that the pixels in an OLED screen can be totally turned off when creating black colours, improving the contrast between light and dark. Whereas traditional LCD screens can only turn blacks into dark greys, OLEDs can achieve super-impressive blacks. The maximum contrast of an OLED is 1,000,000:1 compared to that of an LCD, which is only about 10,000:1.



PDP TVs (plasma)

Using gas to create the perfect picture in plasma screens



Essentially ionised gas, a plasma is an electrically conductive state of matter containing positively charged ions and negatively charged electrons, allowing the gas to conduct electricity.

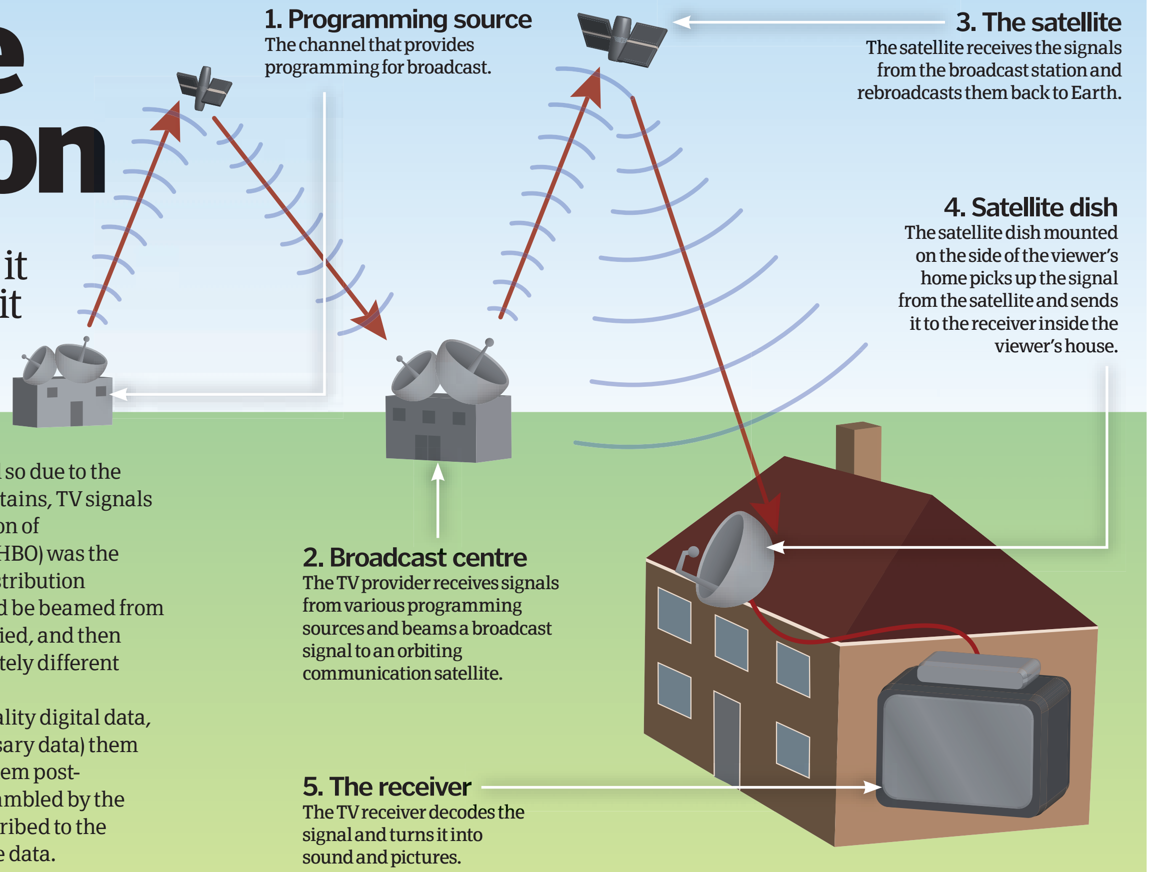
A plasma display panel (PDP) consists of thousands of tiny cells filled with a mixture of xenon and neon gas sandwiched between two large glass panels. Between the rear panel and this layer of cells is a layer of long electrode strips called the address electrodes. Between the front panel (the viewing side) and the layer of cells, meanwhile, is another layer of electrodes called transparent display electrodes.

In response to electrically charging the electrodes, the gas inside the cells becomes plasma, emitting photons and creating invisible ultraviolet light. The cells are coated with red, green or blue phosphor chemicals that turn the invisible light into light that we can see. The plasma cells that make up the pixels in a PDP TV switch on and off much faster than those in an LCD, producing clearer pictures.

"TV signals couldn't travel very far before the introduction of communication satellites"

Satellite television

Can't go over it, can't go round it, so let's bounce it up into space and hope it comes back down…



Television signals travel in straight lines and so due to the curvature of the Earth, not to mention mountains, TV signals couldn't travel very far before the introduction of communication satellites. Home Box Office (HBO) was the first programming service to use satellite distribution satellites, which meant that the signals could be beamed from Earth to a satellite in stationary orbit, amplified, and then bounced back down to receivers in a completely different location on the ground.

Because satellite signals contain high-quality digital data, it's necessary to compress (remove unnecessary data) them before transmission and then reconstruct them post-transmission. All satellite TV signals are scrambled by the provider so that only people who have subscribed to the channels in question can receive the useable data.

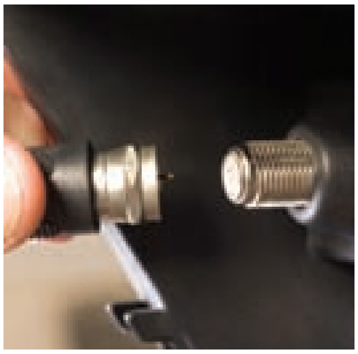
Cable TV

Providing a service for viewers in remote regions

The development of cable and satellite television distribution saw the boom of multiple, subscription-based channels. The cable service grew in response to the fact that consumers in remote areas could not receive over-the-air radio wave TV signals with their antennas. In the late-Forties, however, it was discovered that a TV signal could be received by a main receiver and then transported to these remote locations using coaxial antenna wires. Picture quality could be further improved with the use of amplifiers to maintain signal strength.

By the late-Fifties cable operators had begun using microwave technology to pick up broadcast signals from stations great distances away, and so the cable TV industry grew from just providing TV to rural areas to offering wider programming choices. Today the central location from where the cable channels are distributed is called the headend. With the transmission of different channels at different radio frequencies many channels can be distributed through one cable – without the need for separate wires – and tuned by the viewer. And digital signal compression technology provides more channels over the same bandwidth.

The most significant development in the cable industry, however, has been the advances of satellite TV, and today almost all cable broadcasting is distributed by satellite. Nowadays, advanced cable services such as pay-per-view are changing the way people use their televisions.



Digital TV

Move over analogue TV, digital is the future…

In 2012 all analogue TV signals will be switched off in favour of digital. All television customers will therefore require digital equipment, such as a set-top box, to receive and understand the signal, or a digital TV, which is capable of receiving a digital signal.

While analogue sound and picture data is transmitted through cables as radio waves, the data in a digital signal is transmitted in binary form as a series of zeros and ones (essentially representing either the on or off position of a switch) through cables or satellites. Once the signal reaches the receiver, this data is decoded either by a digital-enabled TV decoder or a set-top box capable of deciphering the information in older TVs.

The picture and sound received are a better quality from digital signals as more information can be sent – and quicker – meaning you can receive more channels.

Some digital TVs contain hard-drive memories likes those in a computer, which enables the user to pause, store, record and play back live TV.

Head to Head TVs

LARGEST


© Panasonic

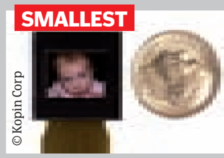
1. 152-inch Full HD 3D PDP
Developer: Panasonic
Size: 152 inches
Fact: Panasonic unveiled the largest 3D PDP in the world at this year's CES 2010.

THINNEST


© LG

2. LG 42SL9500
Developer: LG
Size: 2.6mm
Facts: Little thicker than a coin, LG's 2.6mm thick 42-inch screen is among the thinnest in the world.

SMALLEST

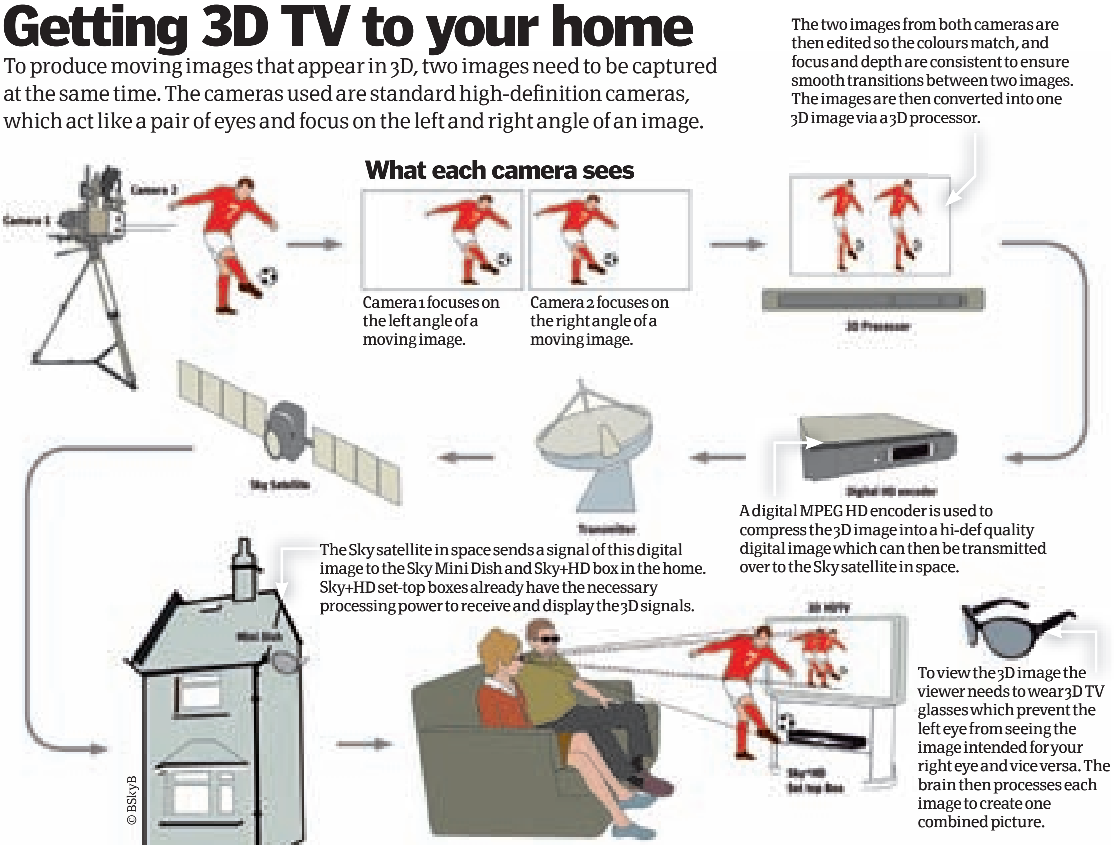

© Kopin Corp

3. SVGA LVS CyberDisplay
Developer: Kopin Corp
Size: 0.44 inches diagonal
Facts: These hi-res LCDs display images equivalent to a 50-inch TV seven feet away.

DID YOU KNOW? Sky's first 3D football broadcast was Man Utd v Arsenal on 31 Jan 2010

Getting 3D TV to your home

To produce moving images that appear in 3D, two images need to be captured at the same time. The cameras used are standard high-definition cameras, which act like a pair of eyes and focus on the left and right angle of an image.



Full HD 3D TV

3D TV is revolutionising home entertainment and altering the way we view television. Join us as we ascend to the next level of home entertainment

Since 3D extravaganza *Avatar* has become the highest grossing film of all time, 3D films and 3D broadcasting is set to become the norm. More channels are starting to consider offering this three-dimensional service. Capturing three-dimensional images for broadcast involves the use of special HD cameras that capture two separate images at once – just as your real-world eyes do – and then editing the two images together using a 3D processor. The 3D image is then compressed as a digital image and transmitted via satellite into the homes of special 3D spectacle-wearing viewers.

Telly expert Panasonic is also helping to bring futuristic three-dimensional quality to the medium with its new line in Full HD 3D plasma TVs that work together with high-tech active shutter glasses. The technology inside the glasses projects full HD images to both the left and right eyes by precisely controlling the shutters with the left- and right-eye images. Frame by frame Panasonic's new plasma TV displays can output individual high-definition images that alternate for each eye at 60 frames per second, creating full HD images by precisely controlling the opening and closing of the shutters on the glasses.

3D or 2D, *X-Factor* will still be garbage!

The Panasonic 3D camera, yours for $21,000!

© Panasonic


© Panasonic

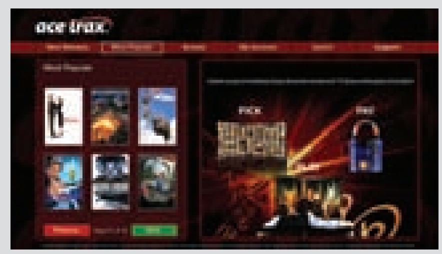
Pay-per-view

Select, buy and view one-off premium programmes

Viewing live one-off sporting events like football matches, or gaining access to single-view movies is a growing trend called pay-per-view (PPV) whereby cable operators charge customers a fee for viewing a programme. So how do the operators keep the programmes available only to those who have paid the fee? Well, the signal sent out from PPV channels is scrambled until the subscriber decides they'd like to view the programme of their choice by contacting the operator. Once the order is received, the cable operator descrambles the signal for the duration of the programme, using a device called an addressable converter near the customer's home.

Video-on-demand

Subscribe to video on-demand services and take control of the TV schedule

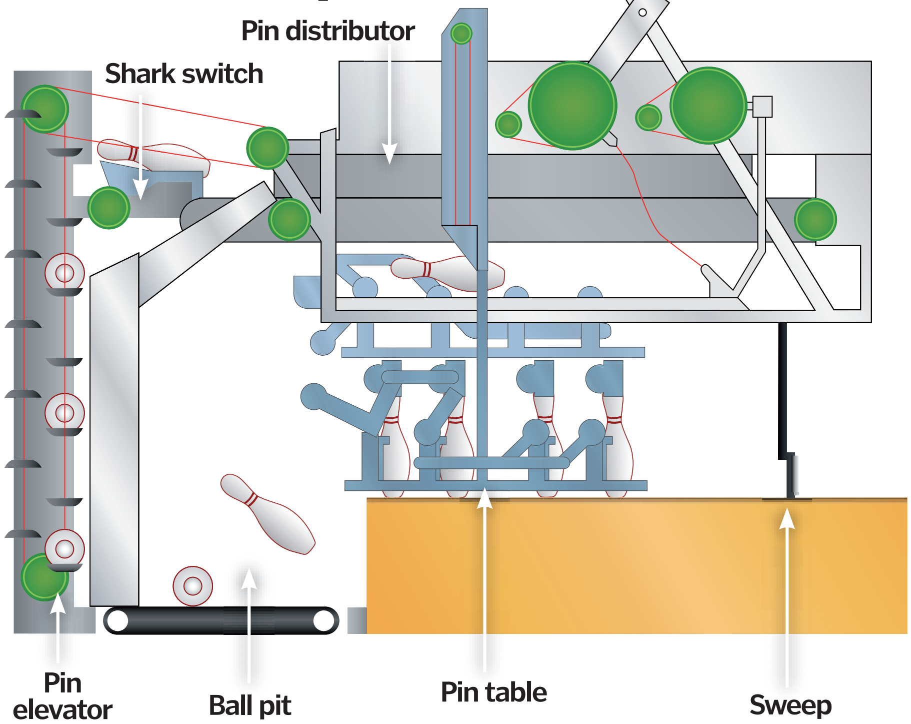


The next technological leap from PPV is video-on-demand, a new and popular interactive phenomenon that enables subscribers to select and view the programme of their choice whenever it suits them. The cable provider digitally stores programmes to be distributed when ordered. The customer can then watch their favourite shows whenever they want.

The difference between VOD and ordinary digital distribution is that the signals for VOD are held at a local headend, which is the location from where the signals are distributed, rather than a central headend. Your digital box will select a video stream personal to your chosen programme, but even if your local headend is supplying 1,000 subscribers, you each have your own stream because the data is sent using fibre-optic cables until the last few hundred metres when it is transferred to copper coaxial cable.

> "The glossy, 60-foot lane is normally constructed out of 39 strips of sugar maple wood"

Side view of a pinsetter



How a bowling alley works

The workings of a ten-pin bowling alley

Any bowling alley works through a combination of a wooden or synthetic lane flanked by semicylindrical gutter channels, an automated pinsetter machine and ball sorter, and a return ball gully and stacker. The glossy, 60-foot lane is normally constructed out of 39 strips of sugar maple wood, which itself is coated with varying layers of oil down its length. This coating is often heavy towards the bowler end, before dissipating down the alley, allowing any spinning ball more purchase in the final quarter of its journey allowing pro-bowlers to hit the pins at varying angles. At the pin end of the alley, starting at the termination of the lane, lays the pin-deck. This deck is where the pins are set-up and knocked down, and thanks to this constant activity, it is coated with a durable impact-resistant material.

Behind the deck lies the first part of the mechanical pinsetter machine. The pit and shaker collects both the fallen ball and pins before shuffling them to its rear and into mechanical lifts that raise them to above the alley. Once there, the ball is then funnelled onto a metal track which then descends back under the lane to the conveyer belt gully and back to the bowler. The pins on the other hand get dropped from this elevated position into the pinsetter's turret, where their bottom-heavy weight ensures that they drop base first. Once filled, the turret then waits for the sweep – a mechanical bar that literally 'sweeps' any still-standing pins backwards into the pit – to operate before dispensing a freshly ordered set of pins into the spotting table. This table then lowers the pins gently back onto the pin deck ready for the process to begin again.

In addition, returned balls are automatically slowed and filtered by spinning rubberised pads as they reach the docking station and ball stacker at the bowler end of the lane, as well as scores being automatically logged and recorded by the lane's in-built computer system and displayed on a screen.

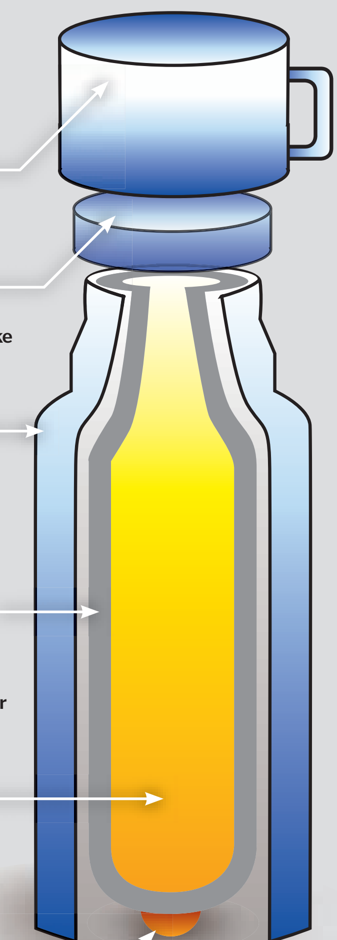
What's inside a vacuum flask?

How to keep hot things hot and cold things cold

Vacuum flasks use thermodynamic principles to keep the hot or cold contents of a vessel warmer or cooler than the temperature outside. A glass of cold water left on a table will eventually warm up till it's room temperature, and likewise a hot cup of coffee will cool down until it's the same temperature as the room. Creating a vacuum between the contents in a sealed vacuum flask and the outside environment provides thermal insulation, preventing heat transfer and therefore temperature change.

Because there are so few atoms inside a vacuum, heat transfer via conduction and convection is limited, meaning the temperature within the flask remains the same for longer. The heat will eventually become the same temperature as that of the outside environment but only really through the weaknesses of the seal at the top of the vessel and the cap.

Inside a vacuum flask



5. Cup
A handy cup is usually screwed on the top of the flask.

1. Cap
The only place where heat transfer can potentially take place is through the limitations of the seal.

2. Outer casing
The outer materials are made of either metal or plastic and serve to protect the fragile inner glass.

3. Vacuum layer
A double-walled glass envelope contains a vacuum that forms a barrier separating the inner content from the temperature outside.

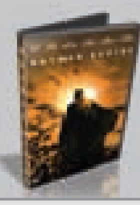
4. Contents
The hot or cold contents will maintain the same temperature for far longer inside a vacuum flask.

Insulated support

Head to Head
CHEMICALS IN THE MOVIES

VX NERVE GAS
1. The Rock
Set in the prison at Alcatraz, *The Rock* sees Sean Connery and Nicolas Cage attempt to save the planet from deadly nerve gas.

RADIOACTIVE
2. Right At Your Door
A dirty (radiological) bomb goes off in LA, forcing a man to seal himself in his house while his wife is outside.



FEAR GAS
3. Batman Begins
This fictional toxin was used by The Scarecrow to induce irrational fear in the minds of his victims, driving them mad.

DID YOU KNOW? The use of a gas mask is no longer isolated to conflicts. They are also used in industries and laboratories

1. Visor
Shatter-proof, fog-resistant polycarbonate plastic lenses or full-face lenses allows the wearer to operate and manoeuvre.

2. The skirt
Face covering piece, known as the 'skirt', holds other components in place, making sure no contaminants get in at any cost.

4. Voice amplifier
Certain gas mask types include an attachable electrical voice amplifier. This makes the voice of the wearer much louder than the built-in voice emitter diaphragm.

5. Respirator
Respirators are likely to use a filter. This serves to purify the air breathed in by the user, neutralising pollutants.

3. Straps
A series of elasticised silicone rubber straps allow the user to tighten the hood sufficiently, so in no event should this device fall off.

Gas masks

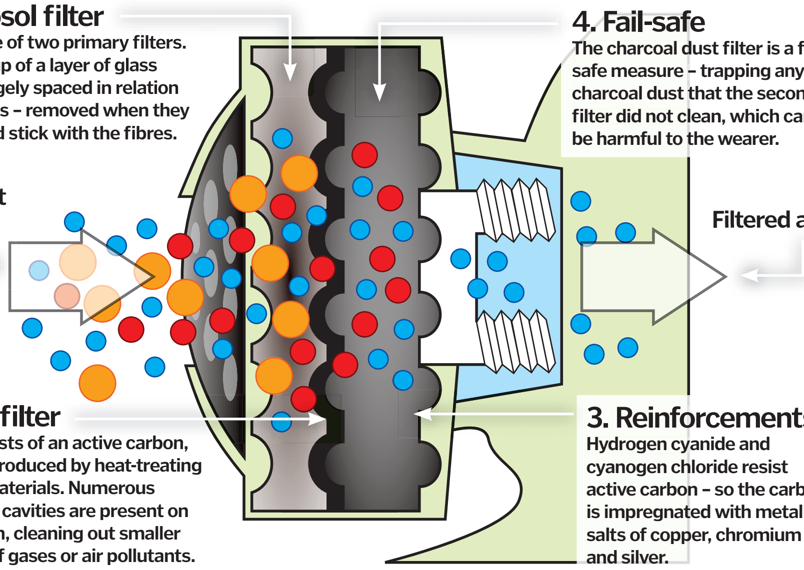
The ins and outs of this respiratory device

Since American inventor Garrett Morgan's release of the patented Morgan safety hood and smoke protector, 1914 – cited to be the basis of early US Army gas masks used during World War One – the device and its design has since developed by mirroring the chemical agents used in warfare.

The gas mask equipment operates by protecting the wearer from fatal noxious gases, through to toxic industrial fumes. This device is made up from several key components that protect the wearer, including polycarbonate plastic lenses and flexible face covering pieces. Most importantly would be the filter cartridge, which utilises activated charcoal to combat pollutants. This carbon is extremely absorbent with its high surface area, producing decomposition catalysts that neutralise the harmful effects. Modern carbon filters are merged with a mixture of molybdenum and triethylenediamine. Alkali-treated carbon is used to soak up sewage and chlorine-based fumes. However, these filters are not inexhaustible and cease to remove pollutants once saturated.

1. Aerosol filter
This is one of two primary filters. It is built up of a layer of glass fibres, largely spaced in relation to particles – removed when they collide and stick with the fibres.

4. Fail-safe
The charcoal dust filter is a fail-safe measure – trapping any charcoal dust that the second filter did not clean, which can be harmful to the wearer.



2. Gas filter
This consists of an active carbon, which is produced by heat-treating organic materials. Numerous pores and cavities are present on the carbon, cleaning out smaller microns of gases or air pollutants.

3. Reinforcements
Hydrogen cyanide and cyanogen chloride resist active carbon – so the carbon is impregnated with metallic salts of copper, chromium and silver.

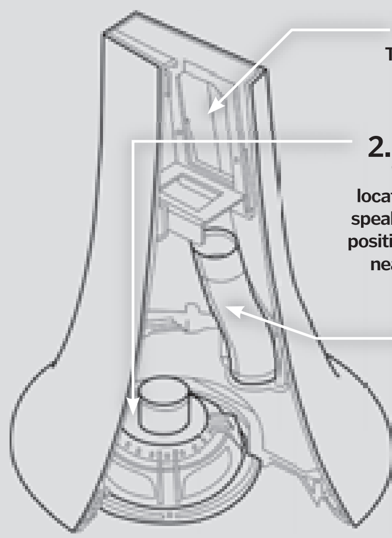
Flat panel speakers

Flat is the new black, as flat panel speakers follow flatscreen TVs

The Starck Parrot is built around a genuinely unique type of speaker system. Instead of the usual cone, a honeycomb membrane is placed on each side of the speaker and is vibrated by sets of exciters located at specific points around it to produce the sound.

Using this method means the speaker's emitting surface is far wider than the traditional cone which, in turn, means the reflections of the sound from nearby walls are more spread out. This diffusion leads to the reflections building on the sound instead of crashing over it as they often do with normal speakers.

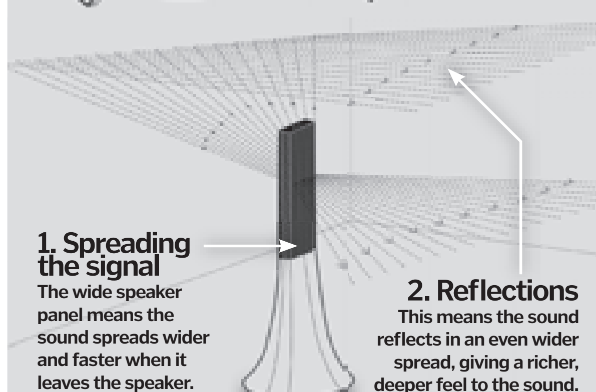
Finally, the bass speaker is mounted beneath the panels and close to the floor, meaning the floor itself is used to amplify the bass signal.



1. Flat panels
The honeycomb grids at the top of the unit project the sound.

2. Bass speaker
The powerful woofer located in the base of the speaker is in the downfire position. Keeping the bass near the floor amplifies the signal.

3. Angled ports
The angled port directs bass sound out of the unit without letting moisture in.



1. Spreading the signal
The wide speaker panel means the sound spreads wider and faster when it leaves the speaker.

2. Reflections
This means the sound reflects in an even wider spread, giving a richer, deeper feel to the sound.

"Radar-based speed cameras work by projecting a continuous radar signal over a set stretch of road"

How speed cameras work

Recording your speed in a flash

Speed cameras come in a variety of flavours, however the most common is the radar-based variant. Radar-based speed cameras work by projecting a continuous radar signal over a set stretch of road, which as a vehicle passes by alters the returning signal's frequency, indicating the presence of the vehicle and its speed.

In addition to the continuous radar signal, the area of road which the camera is pointed at is often covered with either inductive loops or piezoelectric strips, which initiate once passed over by a moving vehicle and, due to their set distance apart, allow speed to be measured against distance travelled. Further, another central technology evident in radar-based speed cameras is its automatic number plate recognition (ANPR) system. This system uses a form of optical character recognition (OCR) – an electronic conversion and translation of image data to typewritten characters – to log and determine the plate number and subsequently the owner of the vehicle in question.

Most speed cameras (there are over 6,000 speed cameras in Great Britain) are distributed at the sides of roads and are largely rearward facing in order to prevent drivers being blinded by their flash. However, present developments have seen cameras positioned on overhead gantries, central reservation hubs and even custom-built docking stations. These fixed speed cameras are connected to a central system and storage database (where recorded images and data are processed ready for prosecution) and each installation costs between £20,000-£40,000 ($30,000-$60,000). When first installed, radar-based cameras used film in order to process the images they took, however, now film variants are sidelined in favour of digital processing procedures, as the film limit of 400 images is made obsolete by digital storage.

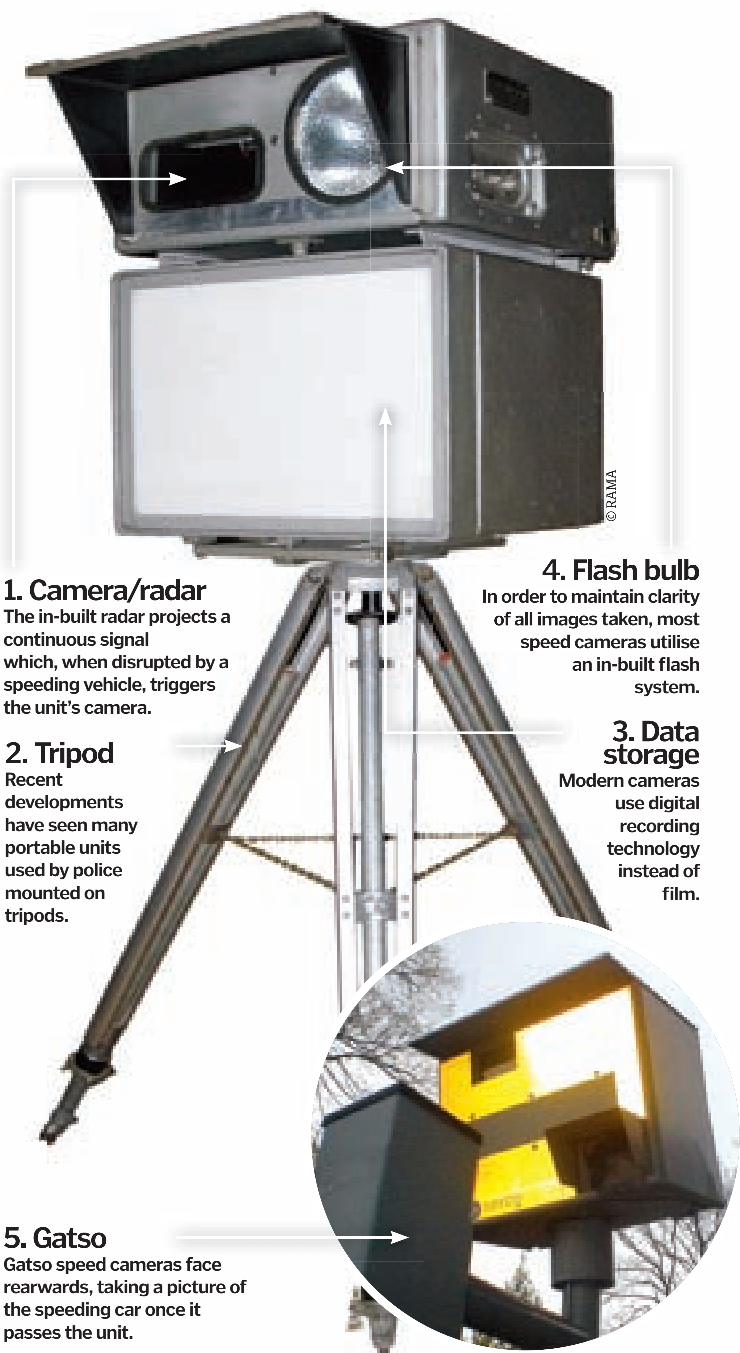
Despite their huge cost, the money required to install a speed camera is often quickly recouped through the fines that caught drivers are required to pay by law. In Great Britain the average penalty for speeding is £60 ($90) and three points on a licence, meaning that a single camera requires 300 to 600 speeding offences to recoup its cost.

Looks like someone's going to be getting a letter through the post...

DID YOU KNOW? A temporary speed camera placed on the M62 motorway in West Yorkshire, England, accrued more than £1 million in fines over an 18 month period

An image of a speeding car taken from a roadside speed camera

© Makemake



1. Camera/radar
The in-built radar projects a continuous signal which, when disrupted by a speeding vehicle, triggers the unit's camera.

2. Tripod
Recent developments have seen many portable units used by police mounted on tripods.

3. Data storage
Modern cameras use digital recording technology instead of film.

4. Flash bulb
In order to maintain clarity of all images taken, most speed cameras utilise an in-built flash system.

5. Gatso
Gatso speed cameras face rearwards, taking a picture of the speeding car once it passes the unit.

MOST MUSICAL

1. Thanko MP3 Player
One minute's winding gets you ten minutes of music from this 1GB MP3 player that can also be charged via USB.

MOST ILLUMINATING

2. Baylis Wind Up Bike Lamp
With 90 minutes' worth of charge off one minute of winding, these front and back bike lights will keep your path well lit.

MOST ESSENTIAL

3. Bayliss Wind Up Mobile Phone Charger
This superb item gives you three minutes on the phone for every 45 seconds spent winding, plus it's a torch.

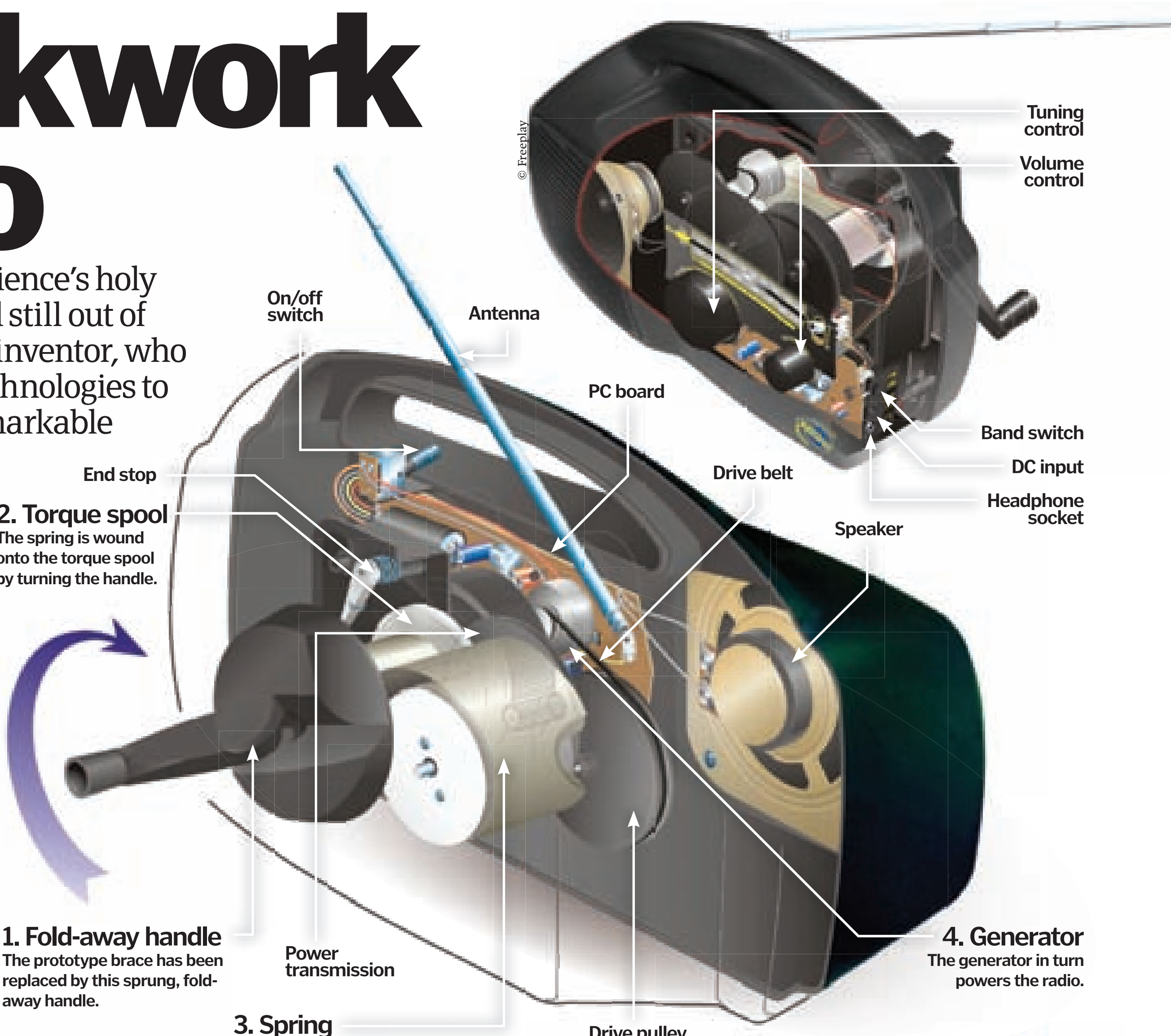
DID YOU KNOW? *Inventor Trevor Baylis once worked as an underwater escape artist in a Berlin circus*

Clockwork radio

Free energy, one of science's holy grails for decades and still out of reach. Except for one inventor, who combined two old technologies to create something remarkable

Trevor Baylis invented the clockwork radio in 1993 to help get information about AIDS to outlying regions of Africa that had no electricity. The device gets around this by having the user provide the electricity, turning a hand brace. The brace, a tool originally intended to help drill holes in wood, provided enough electricity to power an attached motor and radio for short periods.

His real breakthrough came, however, when he added a clockwork mechanism, the energy imparted by turning the brace being stored and then unwound by the clockwork spring at a set rate, meaning the radio could be powered for far longer. The prototype ran for 14 minutes on a two minute wind while later models would run for up to 50 minutes.



2. Torque spool
The spring is wound onto the torque spool by turning the handle.

1. Fold-away handle
The prototype brace has been replaced by this sprung, fold-away handle.

3. Spring
The key component, its gradual release of energy powering the generator.

4. Generator
The generator in turn powers the radio.

Cycle helmets

Keeping your head protected

Six thousandths of a second. A tiny fragment of time but in a bike crash it can mean the difference between life and death. Bike helmets contain a layer of crushable foam designed to collapse during a crash and not only cushion your head from the impact but slow it down by six thousandths of a second. That's enough to reduce the peak impact on your brain, the moment of force where your head hits the road or another hard surface. Without a helmet, that impact can lead to serious brain injury but with one, the impact is cushioned enough to stop your brain being pulled around by internal nerves and blood vessels being acted on by the forces of the crash.

3. Close fit
Padding at the front and rear of the helmet makes it more comfortable to wear and ensures it fits properly.

2. Protective matrix
The Kevlar matrix that runs through this helmet's structure may seem thin but it provides vital protection.

1. From bulletproof to crash proof
Kevlar isn't just an action hero's best friend any more. This helmet uses the substance to provide extra protection.

"Commercial OTEC plants of the near future will easily reach the 100-megawatt mark"


Great for surfing, and for creating electricity!
© Misty07

Power from the oceans

Ocean thermal energy is the latest in sustainable energy, here's how it works

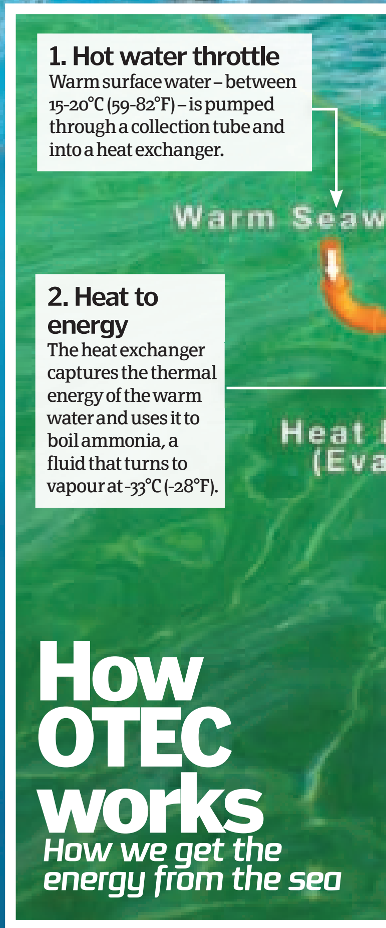
The world's oceans aren't separate bodies of water, but one vast sea connected by global currents. As warm tropical currents reach high latitudes, the cooling water sinks and turns southward. In certain tropical locations around the globe, the steamy surface currents and deep icy flows cross paths, creating tremendous temperature differentials between the shallows and 1,000 metres below.

Off the coast of Hawaii, where the temperature gap between shallow and deep waters is a constant 20°C (36°F), engineers are constructing the first large-scale 'energy island' that will convert the potential energy of the ocean into a clean, inexhaustible source of electricity.

The technology is called ocean thermal energy conversion (OTEC) and it's nothing short of revolutionary. The theory behind it sees warm surface water pumped through a heat exchanger, which pulls out the stored energy and uses it to boil an excitable fluid like ammonia. The forceful steam produced by the evaporating ammonia is funnelled into a generator, where it rotates a sequence of turbine blades, generating electricity.

But it doesn't stop there. A second heat exchanger pumps cold water from the depths to convert the ammonia vapour back to a fluid state, ready to be reused in the closed-cycle system. No fuel is burned and zero emissions are produced. The floating power plant can run 24 hours a day, 365 days a year exclusively on the heat differential of the ocean.

The pilot OTEC plant in Hawaii will generate a constant ten megawatts of electrical power, but commercial OTEC plants of the near future will easily reach the 100-megawatt mark, enough to power a small city.



5 TOP FACTS OTEC

Seas of energy
1 The belt of tropical waters circling the planet stores 1,000 times more heat than the Earth's atmosphere, a great potential source of energy.

Sun sponge
2 An incredible 80 per cent of the solar energy that reaches the Earth's surface is then absorbed by the vast oceans that cover every corner of the globe.

Limitless potential
3 If we could capture even one-tenth of one per cent of the energy stored in ocean waters, it will equal the daily electricity consumption of the United States, times 20.

Squeaky clean
4 A conventional coal-fired power plant for a small city coughs up millions of tons of CO_2 per year. An OTEC plant powering the same city would produce zero.

New hope
5 Potential locations for OTEC sites include nations like Australia, but also third-world countries like Haiti, where clean OTEC power could revitalise economies.

DID YOU KNOW? Every day, tropical waters absorb enough solar energy to equal heat generated by 250 billion barrels of oil

Fringe benefits of using OTEC

During 35 years of OTEC research, engineers and scientists have discovered several other important, energy-saving uses for OTEC technology. The offices of the National Energy Laboratory of Hawaii Authority (NELHA), for example, are cooled year-round by deep seawater. Instead of refrigerating fresh water to circulate through its air conditioning system, NELHA pumps in 6°C (43°F) seawater, saving $4,000 a month on its electric bill. A luxury eco-resort in Bora Bora does the same thing.

Fresh, desalinated drinking water is another valuable byproduct of OTEC technology. Instead of using ammonia as a propellant, an 'open-cycle' OTEC system vaporises warm surface water in a near vacuum to power the turbines. By condensing the water vapour with a blast of deep-sea air, you're left with pure H_2O.

The electricity and fresh water created by the open-cycle OTEC process can also be used to produce pure hydrogen, the essential component of zero-emission hydrogen fuel cells. Using a device called an electrolyzer, it's possible to split fresh water into hydrogen and oxygen. The precious hydrogen could then be shipped to shore or around the world.

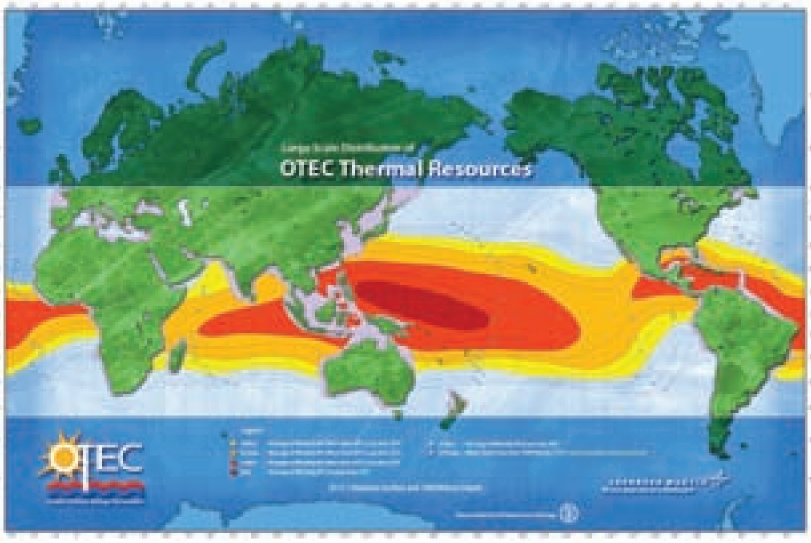
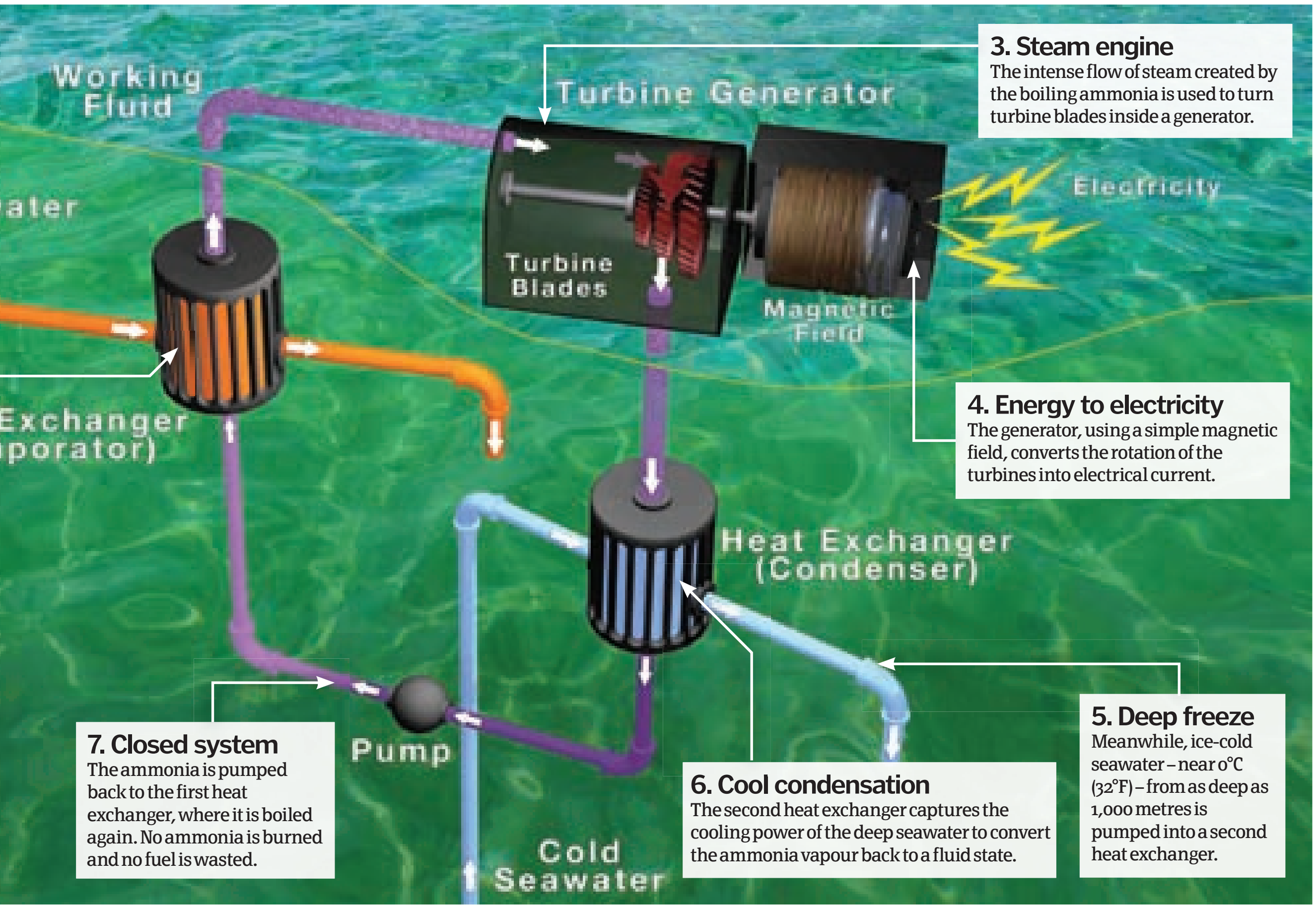


Image © Lockheed Martin



3. Steam engine
The intense flow of steam created by the boiling ammonia is used to turn turbine blades inside a generator.

4. Energy to electricity
The generator, using a simple magnetic field, converts the rotation of the turbines into electrical current.

5. Deep freeze
Meanwhile, ice-cold seawater – near 0°C (32°F) – from as deep as 1,000 metres is pumped into a second heat exchanger.

6. Cool condensation
The second heat exchanger captures the cooling power of the deep seawater to convert the ammonia vapour back to a fluid state.

7. Closed system
The ammonia is pumped back to the first heat exchanger, where it is boiled again. No ammonia is burned and no fuel is wasted.

Image © Lockheed Martin

Head to Head HYDROPOWER

DAMS

1. Tidal power
Hydroelectric power is commonly generated by building a dam (or barrage) across an estuary to store water in a reservoir. The ebb and flow of the tides can be used to turn a turbine to produce electricity. The difference in height between high tide and low tide can also be used to collect the store of water to be released.

WAVES

2. Wave power
The movement of waves over the surface of the ocean can be turned into electricity. Waves travel as crests and troughs, and an object floating on the surface will rise and fall accordingly. This motion can be converted into electricity in a chamber at a wave power station. The rising and falling water causes air to be forced in and out of a hole in the top of the chamber. This air can be used to power a turbine that can generate electricity.

CURRENTS

3. The power of the currents
The power of water can also be harnessed using the oceans' currents. Installing large underwater turbines with rotors capable of turning with the surging movement of ocean currents rushing past can be used to generate clean electricity to nearby coastal areas. The main problem with this form of energy is that the currents need to be strong and the seabed needs to be both shallow and near to the coast.

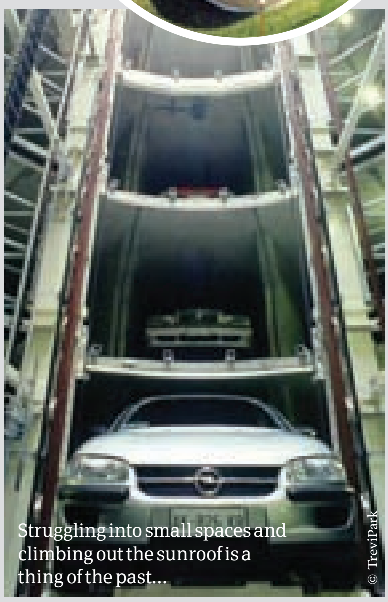
Image © Lockheed Martin

"The first stethoscope was invented in 1816"

Automated car parks

State-of-the-art and fully automated, the latest generation of car parks are highly technical

Automated car parks work by utilising honeycomb-type underground structures where cars can be automatically deposited and retrieved by a series of lifts and conveyer belts. An example of this new generation of car parks are Treviparks. Here, cars drive onto a platform on the surface, then their drivers exit the vehicle and, using a remote terminal, initiate the auto-parker. From here, cars are taken underground on the platform/lift before being slotted into one of the underground concrete bays and stored. When the driver returns to the terminal, the car is automatically conveyed out of the bay onto the central lift and transported to the surface.



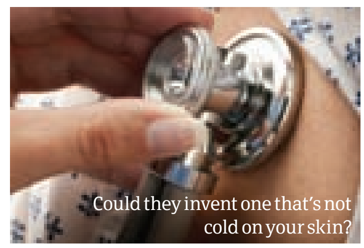
Struggling into small spaces and climbing out the sunroof is a thing of the past...

The acoustic stethoscope

Taken from Greek, 'stethoscope' equates to chest examination, but how does this acoustic device allow us to listen to the internal sounds of a body?

The first primitive design, invented in 1816 by Rene Laennec, resembled an ear trumpet and it wasn't until 1851 that the binaural form was adapted. Inaudibility at low frequencies inspired Rappaport and Sprague in 1940 to create the double-sided design that we use today.

The dual head chest piece features a diaphragm (disc) and a bell (cup), either of which can be placed against the patient's chest. Both detect vibrations which create acoustic waves that travel through the air-filled tubes to the listener's ears. The bell transmits lower frequency sounds ideal for listening to the lungs, where as the diaphragm detects higher frequencies making vibrations in the heart audible. A tuneable diaphragm was incorporated in the Seventies to amplify the volume of low frequencies.

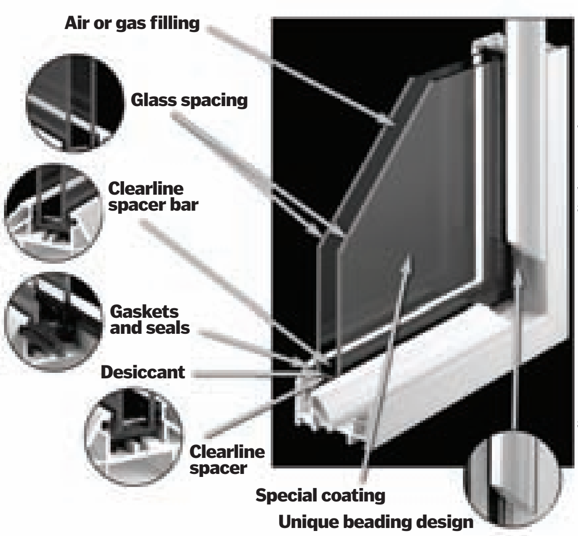


Could they invent one that's not cold on your skin?

Double glazing

How does double glazing keep your house warm and are there any other reasons why we use it?

Double glazing in essence is trapped air between two separate panes of glass. The air in-between the sheets acts as an insulating buffer zone that prevents heat loss and gain. Double glazing also serves as a sound barrier, reducing noise pollution. Double glazing is championed as a must-have of modern living over traditional single sheet windows, because it is less likely to suffer with condensation. Condensation occurs on single glass panels because the warm air inside the house is cooled on contact with the window by the cold outside air. With double glazing the insulation between the two acts as a barrier and prevents the transmission of air temperature therefore condensation is much less likely to occur.



How does a microphone work?

Understanding the technology that lets you belt out your favourite track when you're singing karaoke...

All microphones utilise a diaphragm, designed to vibrate when hit by sound waves. These vibrations travel into the microphone causing the contained components to move. This energy is converted into an electrical current which becomes an audio signal. There are five varieties of microphone, each utilising a different method for the conversion.

Carbon mics use carbon dust, so that when sound hits the diaphragm the dust compresses altering its resistance, by running a current through the carbon the changing resistance alters the amount of current that flows. Dynamic mics employ electromagnets that move when the diaphragm vibrates, therefore creating a current. Ribbon varieties utilise a thin piece of ribbon suspended by a magnetic field; sound waves flex the ribbon which changes the current flowing through it. Condenser mics are a form of a capacitor, storing and sharing an electrical charge. One of the internal plates moves in response to sound which alters the ability to hold the charge; these changes create a measurable signal. Crystal microphones feature a diaphragm with an attached crystal. Certain crystals change their electrical properties when hit by sound waves, these changes are amplified into an electrical charge.

DID YOU KNOW? The very first aerosol spray can patent was submitted in Oslo on 23 November 1927 by Erik Rotheim

How do aerosol sprays work?

Understanding how these cans work well under pressure…

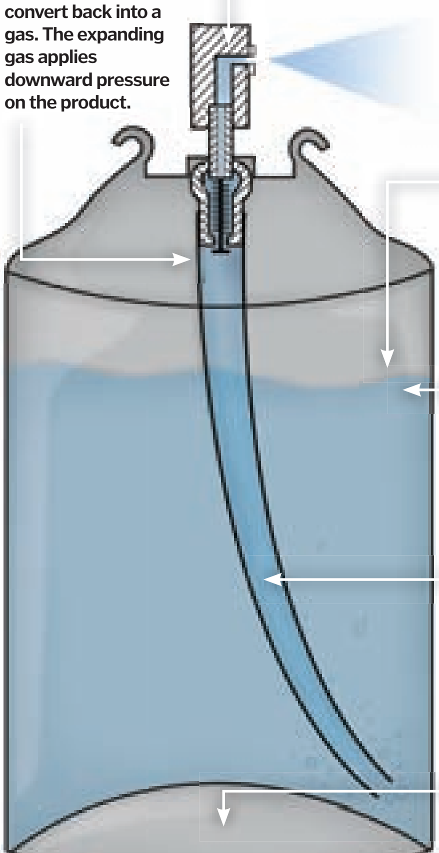
A tagger's ultimate weapon

© Bogdan

Inside an aerosol spray can are two fluids: propellant and product. The propellant is actually a gas under very high pressure, which squeezes it into a liquid state. This pressurised propellant is the engine inside an aerosol can.

To understand how this process works, start with an empty aluminium aerosol can. Pour in the product – hair spray, cooking oil, shaving cream etc – about two-thirds to the top of the can. Seal the can with a valve attached to a 'diptube', a straw that extends to the bottom of the can.

Now pump in the liquid gas under high pressure to fill the 'head space' of the can. When you press down on the valve, it reduces the pressure in the can, causing some of the propellant to 'boil' back into a gaseous state. As the gas expands, it forces the product up the diptube and out the 'actuator', a nozzle that atomises the product into tiny droplets.



3. Pressure release
Press the valve and the pressure in the can decreases, causing the liquid propellant to convert back into a gas. The expanding gas applies downward pressure on the product.

5. The actuator
Spray nozzles are designed to atomise the product and vaporise trace amounts of propellant. The use of different propellants can create foamy or bubbly sprays.

2. Propellant
The can is sealed and liquid gas is pumped through the valve at high pressure. Liquid gas takes up less volume than gas in a vapour state.

1. Product
The liquid product – sunscreen, paint etc – is poured into the empty aerosol can without any pressure, leaving head space for the propellant.

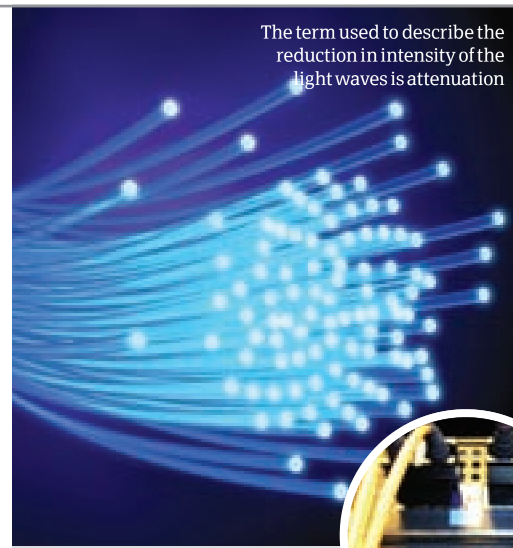
4. Going up
Every time the valve opens, more propellant converts to gas, forcing more product – mixed with small amounts of propellant – up the diptube.

6. Curved bottom
The arched bottom of an aerosol can gives it extra support against the pressurised contents.

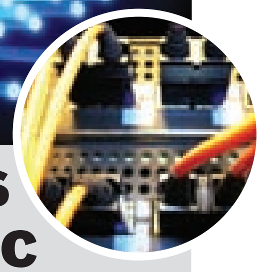
5a. Valve
The valve has a depressable head piece with a tiny opening that allows product to flow from the container to a nozzle at the top of the valve.

5b. Spring
Beneath the head a seal – kept closed by a spring – blocks the flow of product till the head piece is pressed down.

5c. Atomise
Once the head piece is depressed, the propellant forces the product out of the nozzle, which turns the liquid into tiny, mist-like droplets that spray out of the can.



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



How does fibre-optic internet work?

The next generation of communication will speed up download times

In today's culture of internet TV and streaming media there's a growing demand for extremely high transmission speeds. Although traditional copper wire has served internet users well until now, 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. Fibre-optics, meanwhile, have no such restrictions: as you'll remember from our article on fibre optics 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.

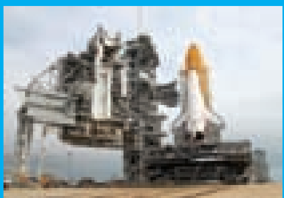
DID YOU KNOW?

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

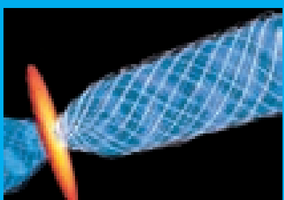
This month in Space

Ever wondered about the other planets that circle our Sun along with our beautiful blue ball? Ever wondered how far away they are? Or how big they are? Or even how long it would take to drive to them in a Mini Metro? (If you ticked the last one then congratulations, you're as weird as us!). If so, your luck's in as we answer all those questions in our cover feature this issue. We also take a look at the Space Shuttle orbiter and even attempt to explain the phenomena of black holes.

40 Viking lander

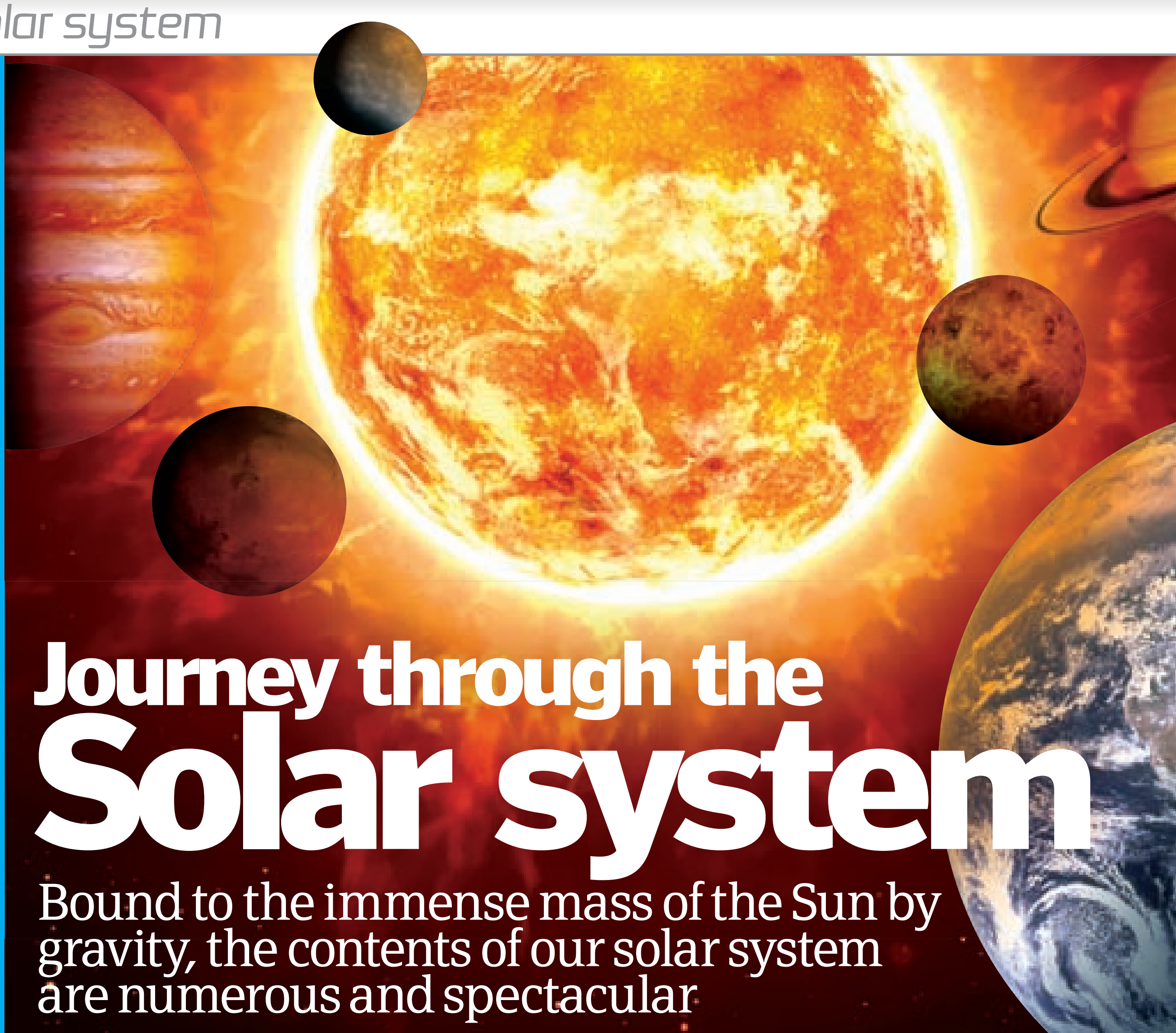


42 The Space Shuttle



44 Inside a black hole

SPACE



Journey through the Solar system

Bound to the immense mass of the Sun by gravity, the contents of our solar system are numerous and spectacular

The solar system formed about 4.6 billion years ago, when part of a giant molecular cloud experienced a gravitational collapse. The centre became the Sun, which comprises more than 99 per cent of the solar system's total mass. The rest of the cloud became a dense, flat rotating disk of gas from which planets formed, called a protoplanetary disk. In our solar system, most of that disk became the eight planets, each of which orbits the Sun.

There are two different categories of planets: gas giants and terrestrials. The gas giants are the four outer planets: Jupiter, Saturn, Uranus and Neptune. They are much bigger than the terrestrial planets and are mostly made of helium and hydrogen, although Uranus and Neptune also contain ice. All of the outer planets have ring systems made of cosmic dust. These planets comprise more than 90 per cent of the rest of the solar system's mass.

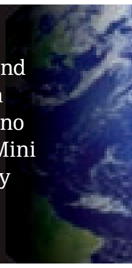
The four inner planets are very close to the Sun. To grant perspective, for example, the distance between Jupiter and Saturn is larger than the radius of all the inner planets put together. These terrestrials are made up from rocks and metals, have no ring systems and have a low number of satellites (moons). They include Mercury, Venus, Earth and Mars. Except for Mercury, the inner planets also have recognisable weather systems operating in their atmospheres.

In addition to the eight main planets, there are also dwarf planets such as Pluto. The five dwarf planets are Ceres, Pluto, Haumea, Makemake and Eris. In addition, the solar system is home to numerous small solar system bodies, which include all minor planets, asteroids and comets.

Earth to Saturn in a Mini Metro!

How long would it take to reach the planets in a moderately priced car?

Can't afford that ticket on the next spaceship out of town? Well, fear not, for if you are the patient type and hold an interplanetary driving licence then you can drive to that Earth colony orbiting Saturn in next to no time… well, relatively speaking. In our souped-up Mini Metro, travelling at an average speed of 120mph, any traveller can reach Saturn in only 842 years. Better stock up on travel sweets then…



Head to Head LARGEST PLANETS

BIG

1. Uranus
Diameter at equator: 25,559km
Average distance from Sun: 2.88 billion km (19 AU)
Orbital period: 84.02 years
Mass (Earth=1): 14.37 Earth masses
Number of moons: at least 27

BIGGER

2. Saturn
Diameter at equator: 60,260km
Average distance from Sun: 1.4 billion km (9.4 AU)
Orbital period: 29.5 years
Mass (Earth=1): 95 Earth masses
Number of moons: at least 62

BIGGEST

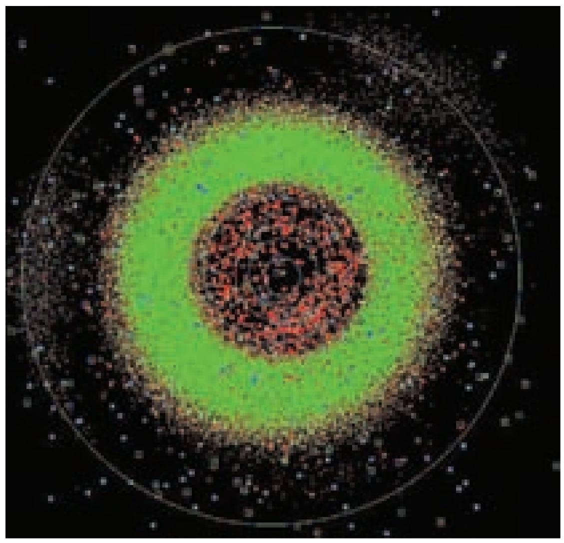
3. Jupiter
Diameter at equator: 142,985km
Average distance from Sun: 778 million km (5.2 AU)
Orbital period: 11.86 years
Mass (Earth=1): 318 Earth masses
Number of moons: at least 63

DID YOU KNOW? Astronomers estimate there may be billions of solar systems in our galaxy. About 70 have been discovered

What and where are the asteroid belts?

There are a few asteroid belts in our solar system, but none can compare to the main belt, a massive ring between the orbits of Mars and Jupiter. Here the dwarf planet Ceres, the large asteroids 2 Pallas, 10 Hygiea and 4 Vesta, and millions of small asteroids and dust particles orbit the Sun. Most of the larger asteroids have elliptical orbits and an orbital period of a few years. Some astronomers believe that the main belt's contents are left over from a planetary collision or from a planet that never formed due to the strong gravitational pull of Jupiter.

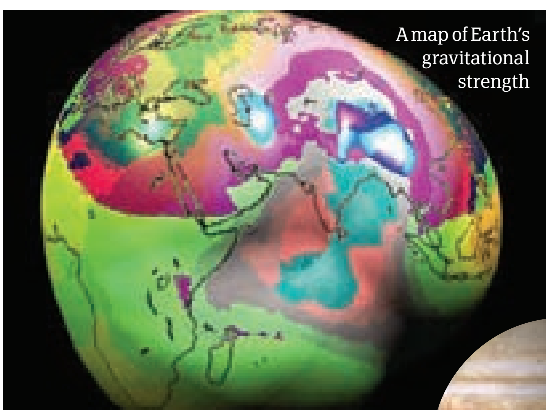
Below shows the placement of inner solar system objects on 20 July 2002. Light blue lines are planet orbits. Green dots show asteroids. Red dots are asteroids that come within 1.3AU of the Sun. Comets are dark blue squares, and dark blue points are Jupiter Trojans.



Bound together by gravity

When the International Astronomical Union (IAU) defined planets in 2006, part of that definition included the requirement that a planet has enough mass that its self-gravity causes it to reach hydrostatic equilibrium. The planet is able to resist compressive forces in space to hold together and stay rounded in shape.

Planets also "clear the neighbourhood" around their orbits. This means that there are no other bodies of the same size in its orbit. The Sun has a strong enough pull to keep the planets and other bodies orbiting around it.



A map of Earth's gravitational strength

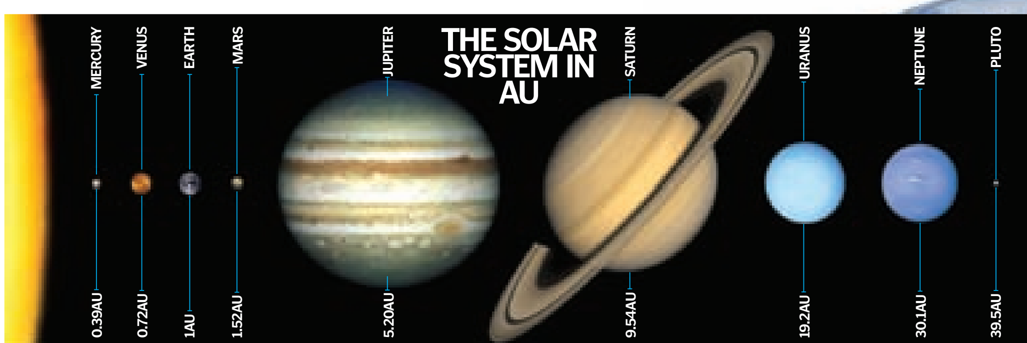
Measuring our solar system

Understanding the size of planets and where they are

Before the development of radar, astronomers measured the distance between planets through trigonometry, a process where distance to an object is derived from the measurements of angles and distances taken between two known positions. Today, radar is the predominant method of measuring distance and allows for more accurate measurements to be attained. This process works by astronomers timing how long it takes the radar beam, which is travelling at the speed of light, to travel the distance to an object and back. By multiplying the speed of light by time taken, then dividing that in two, scientists can derive the distance to the object.

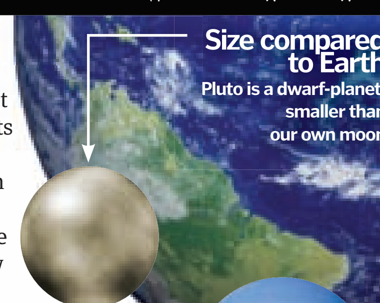
Once distance has been derived, the mass of the object can be ascertained by monitoring the orbital periods of circling satellites. To do this astronomers measure the angular separation between the satellite and the object and then use trigonometry to convert that angular separation into distance. Astronomers can then use Kepler's third law to determine total mass.

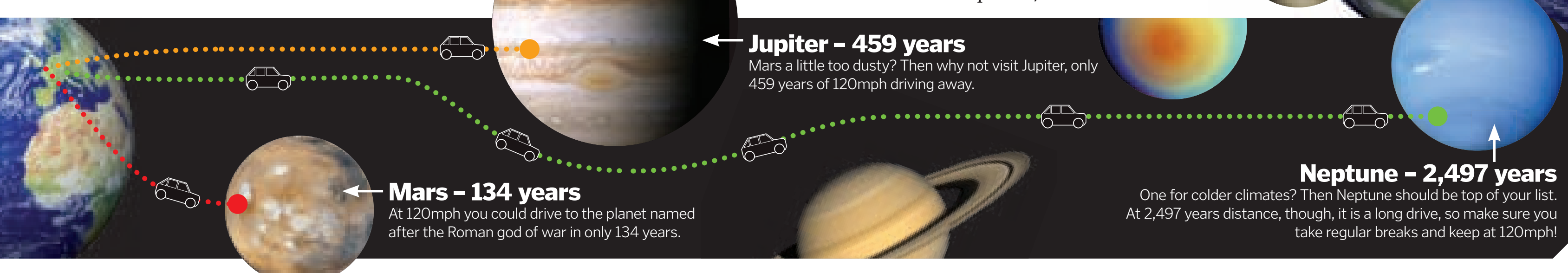
1 AU (astronomical unit) = 92,960,000 miles, the mean distance between the Sun and the Earth



Pluto the dwarf

Since its discovery in 1930, Pluto had been considered the ninth planet in our solar system. However, more recent discoveries of dwarf planets larger in size and mass than Pluto have made some astronomers question its status. In 2006, the International Astronomical Union (IAU) decided upon a conclusive definition of what constituted a planet. Pluto's low mass – not even a fifth the mass of the moon – excluded it from that definition. Now Pluto is considered a dwarf planet,





“Saturn is so light that if it could be hypothetically placed in a galactic-sized ocean of water it would float”

Our solar system

8. Neptune

Neptune was imaged for the first time in 1989, discovering an encircling set of rings and six of its 13 moons. Neptune's structure is very similar to that of Uranus, with no solid surface and central layers of water, methane and ammonia ices as well as a possible rock/ice-based core.

The Statistics

Neptune

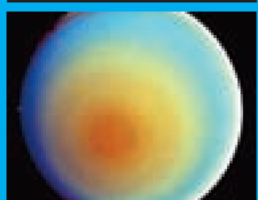
Type: Gas giant
Rotation (Equatorial): 60,179 days
Rotation (Polar): 16.11 hours
Volume: (Earth = 1) 57.74
Average distance from Sun: 2.8 billion miles
Number of moons: 13
Speed: 5.43km/s
Surface temp: -220°C

7. Uranus

The first planet to be discovered by telescope, Uranus appears to the eye as a pale blue, characterless disk, encircled by a thin system of 11 rings and 27 tiny moons. Its blue colour is a result of the absorption of the sunlight's red wavelengths by methane-ice clouds within the planet's cold atmosphere – a process which also renders its atmosphere calm and inert thanks to the creation of haze particles. In reality, however, Uranus's atmosphere is active and consistently changing with huge winds driving systems of ammonia and water over its surface.

The Statistics

Uranus



Type: Gas giant
Rotation (Equatorial): 30,799 days
Rotation (Polar): 17.24 hours
Volume: (Earth = 1) 63.1
Average distance from Sun: 1.78 billion miles
Number of moons: 27
Speed: 6.81km/s
Surface temp: -214°C

5. Jupiter

The largest and most massive of all planets in the solar system, Jupiter has almost 2.5 times the mass of the other eight planets combined and over 1,300 Earths could fit inside it. Jupiter is also the first of the gas giants and is largely not solid in composition, consisting of an outer layer of gaseous hydrogen and helium, an outer layer of liquid hydrogen and helium and an inner layer of metallic hydrogen. However, deep in its body (roughly 37,000 miles in) there is a solid core made up of rock, metal and hydrogen compounds.

6. Saturn

A massive ball of gas and liquid, Saturn is the least dense of all the planets in the solar system. Circled by a spectacular system of rings, which are composed of stellar dust, boulders and gases, Saturn has a hazy appearance and due to its rapid spin is a massive ten per cent larger at its equator than at its pole. Interestingly, Saturn is so light – thanks to its composition from the lightest elements – that if it could be hypothetically placed in a galactic-sized ocean of water it would float. As with Jupiter, Saturn is a gas giant with a tiny solid core composed of rock and ice.

The Statistics

Saturn

Type: Gas giant
Rotation (Equatorial): 10,759 days
Rotation (Polar): 10.66 hours
Volume: (Earth = 1) 763.59
Average distance from Sun: 888 million miles
Number of moons: 34
Speed: 9.69km/s
Surface temp: -140°C

Comets

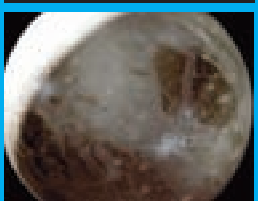
Comets are small, fragile, irregularly shaped bodies composed of a mixture of non-volatile grains and frozen gases

9. Pluto

Often mistaken as the last planet in our solar system, Pluto is actually not one but instead a dwarf planet. Dwarf planets are bodies that orbit the Sun and have enough mass and gravity to be spherical, but ones that have not cleared the region around its orbit. Pluto is such a dwarf planet and is one of the furthest circling bodies of our solar system. Pluto's atmosphere is 99.97 per cent nitrogen and it is astronomically cold, with an average temperature of -230 degrees Celsius.

The Statistics

Pluto



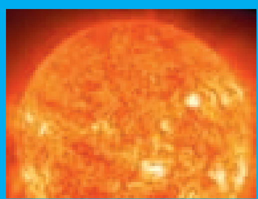
Type: Dwarf
Rotation (Equatorial): 90,613 days
Rotation (Polar): N/A
Volume: (Earth = 1) 0.0059
Average distance from Sun: 3.7 billion miles
Number of moons: 3
Speed: 4.666km/s
Surface temp: -230°C

The Sun

4.6 billions years old and currently in its main-sequence stage, our Sun is a huge sphere of exceedingly hot plasma containing 750 times the mass of all the solar system's planets put together. Deep in its core nuclear fusion of hydrogen produces massive energy that is gradually carried outwards through convection before escaping into space.

The Statistics

The Sun



Type: Star
Rotation (Equatorial): 25 days
Rotation (Polar): 34 days
Mass: (Earth= 1) 333,000
Surface temperature: 5,500°C
Core temperature: 15 million °C
Diameter (Equatorial): 864,900 miles

Main belt

Often referred to as the asteroid belt, the Main belt is an encircling ring of meteors, asteroids, dwarf planets and dust particles that sits between the terrestrial planets and the gas giants.

5 TOP FACTS SOLAR SYSTEM

Lightweight
1 Hypothetically speaking, Saturn is so light that if it were placed in a galactic sized swimming pool it would float. Hard experiment to carry out though!

Binary
2 Due to the size and short orbital distance between Pluto and its largest moon Charon, it is often treated as a binary system as its centre of mass lies with neither.

Dust bowl
3 Mars, often referred to as the 'red planet', is actually red thanks to its coating of iron dust, which prevails in its carbon dioxide-rich atmosphere.

Big boy
4 Jupiter is so large that over 1,300 Earths could fit inside it and it has a mass which is 2.5 times larger than the total of all other eight planets combined.

Tantastic
5 During the day on Mercury, the closest planet to our Sun in the solar system, the temperature reaches up to a positively scorching 430 degrees Celsius.

DID YOU KNOW? *Our solar system is nearly five billion years old and is made up of eight planets and 170 moons*

Map of the solar system

Discover the star, planets and space phenomena that make up our solar system

The Statistics
Jupiter

Type: Gas giant
Rotation (Equatorial): 4,331 days
Rotation (Polar): 9.93 hours
Volume: (Earth = 1) 1,321
Average distance from Sun: 483.6 million miles
Number of moons: 63
Speed: 13.07km/s
Surface temp: -110°C

The Statistics
Earth

Type: Terrestrial
Rotation (Equatorial): 365.26 days
Rotation (Polar): 23.93 hours
Mass: (Earth = 1) 1
Average distance from Sun: 93 million miles
Number of moons: 1
Speed: 29.783km/s
Surface temp: 15°C

3. Earth
While similar in internal composition to its neighbouring planets – composed of three distinct layers made up mainly of iron, magnesium and silicates respectively – Earth differs on its surface thanks to an abundance of liquid water and an oxygen-rich atmosphere. Due to Earth's rotation the planet bulges at its equator by 13 miles when compared to both its poles and its spin axis is tilted at an angle of 23.5 degrees, one of the factors that gives rise to its seasons.

4. Mars
Known as the red planet thanks to its rust-red colouring, and named after the Roman god of war, Mars is home to the highest volcanoes (albeit dry and inactive) of any planet in the solar system. Current research and evidence suggests that while Mars is an inert planet now, in the past it was very much active, with volcanic activity and water existing over large parts of it. Mars is the outermost of the four terrestrial 'rocky' planets and its internal structure is rich in sulphur, iron sulphide and silicate rock.

The Statistics
Mars

Type: Terrestrial
Rotation (Equatorial): 687 days
Rotation (Polar): 24.63 days
Mass: (Earth = 1) 0.15
Average distance from Sun: 141.6 million miles
Number of moons: 2
Speed: 24.007km/s
Surface temp: -125°C – 25°C

The Statistics
Mercury

Type: Terrestrial
Rotation (Equatorial): 88 days
Rotation (Polar): 59 days
Mass: (Earth = 1) 0.056
Average distance from Sun: 36 million miles
Number of moons: 0
Speed: 47.87km/s
Surface temp: -187°c – 427°C

1. Mercury
Iron-rich Mercury is the second smallest planet in the solar system and the closest to the Sun. There is almost no protective atmosphere surrounding Mercury and, because of this, temperatures on the planet fluctuate massively from 427 degrees Celsius during the day to -187 degrees Celsius during the night. Worryingly, if an observer were able to stand on the planet they would experience a period of 176 Earth days between one sunrise and the next. Better stock up on suntan lotion and woolly socks then...

2. Venus
The hottest of all planets, Venus – thanks to its permanent atmospheric blanket of dense gaseous clouds – has an average temperature of 464 degrees Celsius. The surface is dry, lifeless, scorching hot and littered with volcanoes and dust storms. Named after the Roman goddess of love and beauty due to its beautiful, sun-reflecting, cloud-based atmosphere, in reality Venus holds one of the most hostile environments of any planet. Interestingly, Venus spins in the opposite direction from most other planets.

The Statistics
Venus

Type: Terrestrial
Rotation (Equatorial): 224.7 days
Rotation (Polar): 243 days
Mass: (Earth = 1) 0.86
Average distance from Sun: 67.2 million miles
Number of moons: 0
Speed: 35.02km/s
Surface temp: 464°C

> "NASA's Viking programme was the first mission to return numerous images and data from Mars"

NASA's Viking programme

The Viking programme of the mid-Seventies was a triumph of space exploration

NASA's Viking programme was the first mission to return numerous images and data from Mars. It comprised two identical spacecraft, Viking 1 and Viking 2, each with an orbiter and a lander.

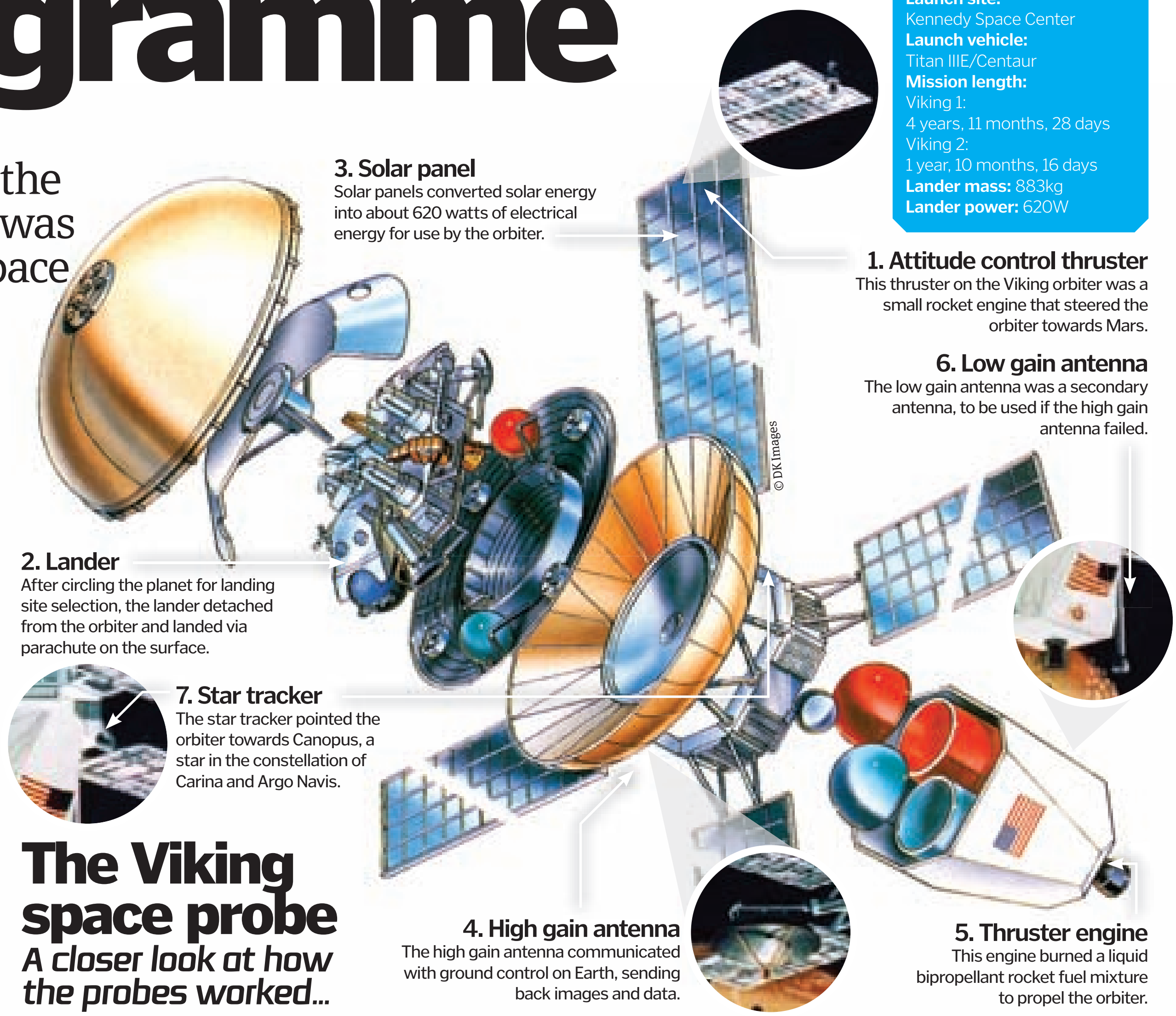
Both launched using a Titan IIIE/Centaur launch system. Viking 1 launched on 20 August 1975 and reached Mars after a ten-month journey. The orbiter took images and transmitted them back to NASA, who used them to choose a site for the lander. On 20 July, the lander separated from the orbiter and landed in an area called the Golden Plain. For more than six years, the lander took images and collected data from the surface. The orbiter's fuel ran out on 17 August 1980, while the lander shut down on 13 November 1982 when a mistake during a software update caused its antenna to go down.

Viking 2 launched on 9 September 1975, reaching Mars orbit on 7 August 1976. The lander touched down in the Nowhere Plain on 3 September. Viking 2's mission did not last as long as Viking 1; the orbiter shut down after a fuel leak about two years after arrival, while the lander had a battery failure after three and a half years. Together, Viking 1 and Viking 2 provided more than 50,000 photographs.

The Statistics
Viking landers

Launch date:
Viking 1: 20 August 1975
Viking 2: 9 September 1975
Launch site:
Kennedy Space Center
Launch vehicle:
Titan IIIE/Centaur
Mission length:
Viking 1:
4 years, 11 months, 28 days
Viking 2:
1 year, 10 months, 16 days
Lander mass: 883kg
Lander power: 620W

The Viking space probe
A closer look at how the probes worked...



The Viking landers' discoveries

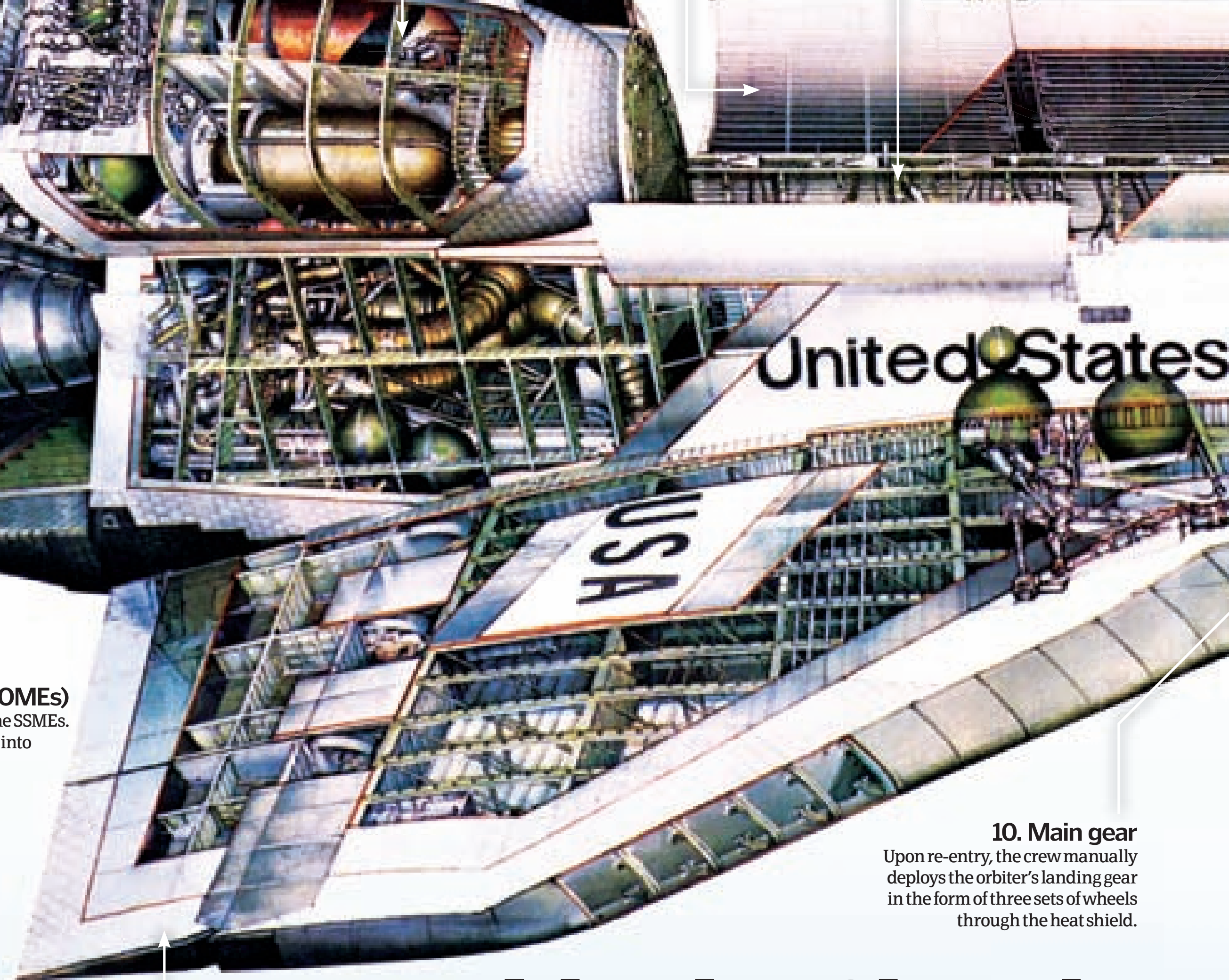
The Viking programme was the first truly successful mission to Mars, providing NASA with the first real data concerning the existence of water on the planet. Photographs showed large areas of erosion, channels and grooves in rocks, and river valleys. These were likely caused by massive amounts of water. Each Viking lander also carried four different types of experiments to test for signs of life on Mars, which included testing for carbon and gas concentrations in the soil. The results of three of the tests proved negative, while one was ultimately inconclusive.

This panoramic image was taken by Viking 1. It reveals large rocks and sand dunes on the surface of Mars, as well as a layer of clouds below the horizon

All unmarked images © NASA

"The first was the Columbia, launched on 12 April 1981, followed by the Challenger, Discovery, Atlantis and Endeavour orbiters"

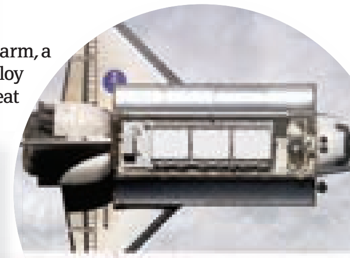
The Shuttle orbiter



14. Hydrazine and nitrogen tetroxide tanks

8. Vertical stabiliser
Much like on an aeroplane, the vertical stabiliser is designed to reduce side slip. It also holds a rudder and speed brake to assist with deceleration during re-entry.

5. Payload Bay
The payload bay contains the Canadarm, a robotic arm used to retrieve and deploy payloads. The bay's doors contain heat radiators and remain open when in orbit to help with thermal control.



11. Space radiators

6. Space Shuttle main engines (SSMEs)
These engines are fuelled by liquid hydrogen and liquid oxygen from the external fuel tank. They are used solely to propel the orbiter during its ascent.

7. Orbital manoeuvring engines (OMEs)
The OMEs are located in the aft fuselage near the SSMEs. These engines are used to help send the orbiter into orbit and adjust the orbit as necessary.


Endeavour after launch for mission STS-118

9. Elevons
The elevons are located on the edges of the wings. They are used for both roll control and pitch control during landing.

10. Main gear
Upon re-entry, the crew manually deploys the orbiter's landing gear in the form of three sets of wheels through the heat shield.

Inside the Shuttle

Under the skin of the Shuttle's surface

STS-7: Space Shuttle Challenger
1 Launched on 18 June 1983, this marked the first time that an American female astronaut entered space with the inclusion of Sally K. Ride.

STS-31: Space Shuttle Discovery
2 Launching on 24 April 1990, the crew of the Space Shuttle Discovery deployed the Hubble Space Telescope during STS-31.

STS-71: Space Shuttle Atlantis
3 On 27 June 1995, the Atlantis launched STS-71. This mission marked the first time that the Space Shuttle docked with the Russian space station Mir.

STS-88: Space Shuttle Endeavour
4 Launched on 4 December 1998, STS-88 was the first mission to the ISS. As its payload, it carried the first US node for the ISS, Unity.

STS-95: Space Shuttle Discovery
5 Discovery's 25th flight launched on 29 October 1998. It is also well-known as John Glenn's return to space at the age of 77.

DID YOU KNOW? Upon re-entry, the external Shuttle skin withstands temperatures as high as 1,648° Celsius

NASA's main spacecraft is scheduled to retire this year. Find out what goes on inside this craft

What we think of as the 'Space Shuttle', NASA calls the Space Shuttle transport orbital vehicle or orbiter (STS-OV, or just OV). It's a reusable winged plane-like spacecraft. In addition to its engines and thrusters, it also has a three-level crew cabin and a payload bay.

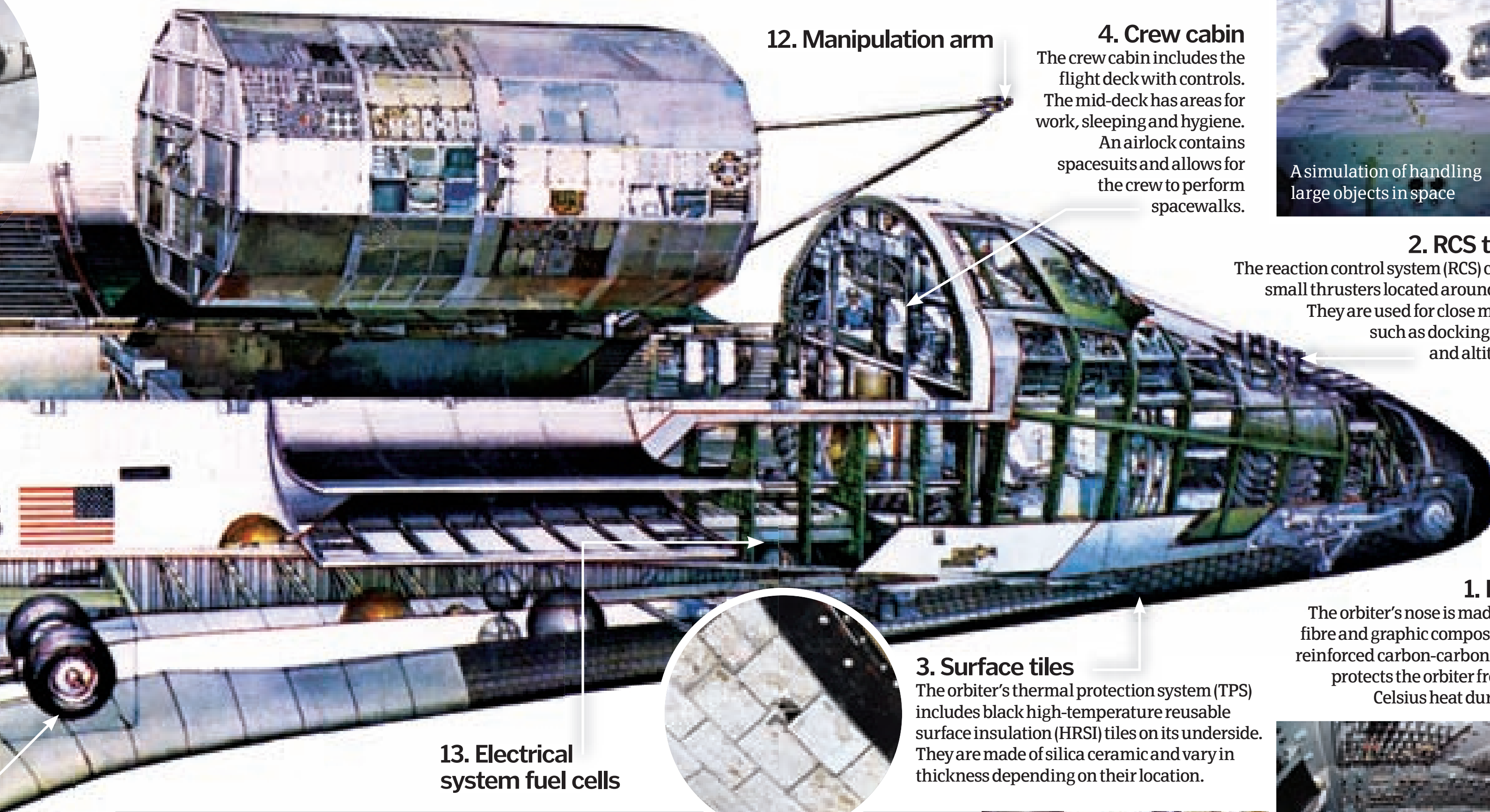
The orbiter fleet has had five different craft. The first was the Columbia, launched on 12 April 1981, followed by the Challenger, Discovery, Atlantis and Endeavour orbiters (the latter built to replace Challenger). Although all of the orbiters are similar, rotating maintenance means that each is somewhat unique. The Endeavour is the youngest orbiter, first launched on 7 May 1992.

Three of the orbiters – the Discovery, Atlantis, and Endeavour – are still in use. On 28 January 1986, the Challenger was destroyed a little more than a minute into its tenth mission. A seal on one of the SRBs failed, which caused it to leak flames onto the external fuel tank. The orbiter veered and was torn apart by as much as 20 Gs of aerodynamic force, which resulted in the death of its seven-member crew.

On 1 February 2003, the Columbia was destroyed upon re-entry into the atmosphere, killing its seven crew members. This occurred when gases entered one of the orbiter's wings through a hole made by a piece of foam during launch and caused a structural failure.


Discovery approaches the ISS for docking

A simulation of handling large objects in space



12. Manipulation arm

4. Crew cabin
The crew cabin includes the flight deck with controls. The mid-deck has areas for work, sleeping and hygiene. An airlock contains spacesuits and allows for the crew to perform spacewalks.

2. RCS thrusters
The reaction control system (RCS) comprises 44 small thrusters located around the orbiter. They are used for close manoeuvring such as docking, orientation and altitude control.

1. Nose cap
The orbiter's nose is made of a carbon fibre and graphic composite known as reinforced carbon-carbon (RCC), which protects the orbiter from the 1,650° Celsius heat during re-entry.

3. Surface tiles
The orbiter's thermal protection system (TPS) includes black high-temperature reusable surface insulation (HRSI) tiles on its underside. They are made of silica ceramic and vary in thickness depending on their location.

13. Electrical system fuel cells

Where the action is

Crew on the flight deck perform duties ranging from piloting the Shuttle to satellite launches

The orbiter's flight deck seats the mission's commander, pilot and two mission specialists. It looks much like the cockpit of an aeroplane, but with more controls – over 2,000 buttons, switches, dials and displays in total. In addition to forward controls in front of the commander and pilot, the flight deck also has displays and controls on its aft side. These are used to operate payloads.

The duties of the commander, pilot and specialists while on the flight deck depends on the details of the mission. In addition to firing the orbital manoeuvring engines (OMEs) to take the Shuttle in and out of orbit, the pilot also steers the Shuttle to rendezvous with the ISS or other crafts. Mission specialists may conduct experiments or retrieve and release satellites from the payload bay.

All Images © NASA

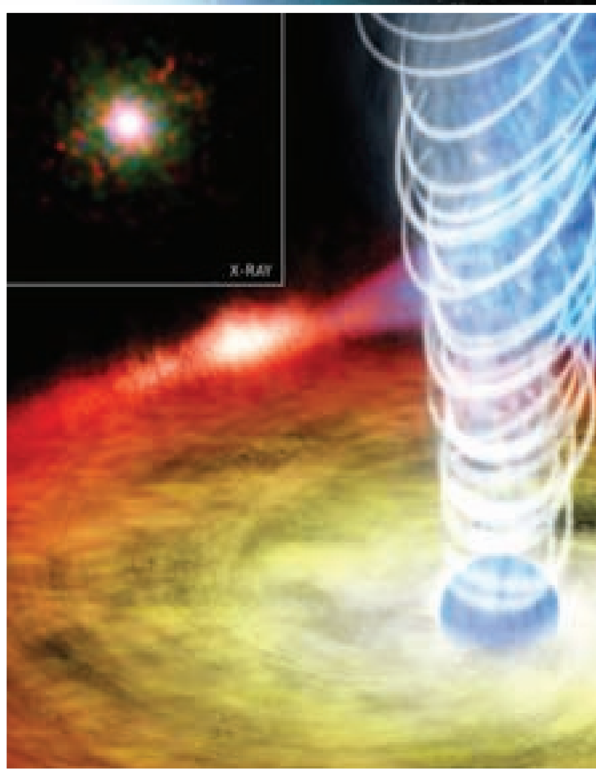
“At the heart of almost every galaxy lies a black hole, even our own the Milky Way”

Inside a black hole

Almost incomprehensible in size, black holes are hauntingly beautiful phenomena where the laws of space and time are rewritten. We take a look at the Sagittarius A* black hole at the centre of our galaxy

A black hole is a region of space containing, at its centre, matter compressed into a point of infinite density called a singularity (an area where spacetime curvature becomes infinite), which itself is surrounded by a sphere of space where the gravitational pull is so total that not even light can escape its pull – hence its name. The black hole is the result of the deformation and warping of spacetime (a mathematical model where space and time are combined into a single continuum) caused by the total collapse of individual stars or by the coalescence of binary neutron stars.

This collapse occurs at the culmination of a star's life span when, under the pressure of gravity, it is compressed perpetually – unable to resist due to the non-existence of nuclear fusion in its core – until it reaches critical mass. At this point, providing the star is over 1.4 to three solar masses (our Sun equals one solar mass) – a necessity for black hole formation instead of a white dwarf – the star will go into core-collapse supernova, expelling much of its remaining outer layers at one tenth the speed of light and leaving behind either a neutron star or, if the solar mass is high enough, a black hole.



Head to Head BLACK HOLES

LARGE

1. Stellar-mass black hole
Stellar-mass black holes have masses up to 15-20 solar masses. These mainly form from stars going into core-collapse supernova.

LARGER

2. Intermediate-mass black hole
These can contain thousands of solar masses. These variants mainly form from collisions of smaller black holes.

LARGEST

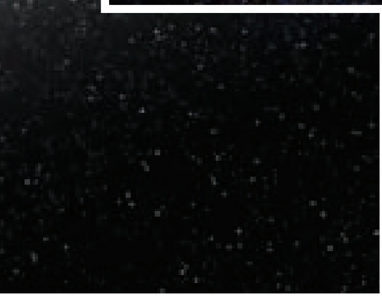
3. Supermassive black hole
The biggest black holes by far, supermassive variants can contain hundreds of thousands to billions of solar masses.

DID YOU KNOW? Sagittarius A* is a massive 26,000 light years from Earth

The Milky Way

The position of Sagittarius A in our galaxy*

Sagittarius A* lies at the heart of out galaxy the Milky Way. Unfortunately, from Earth Sagittarius A* is blocked from optical sight and presently scientists can only observe it through the actions of its surrounding stars.



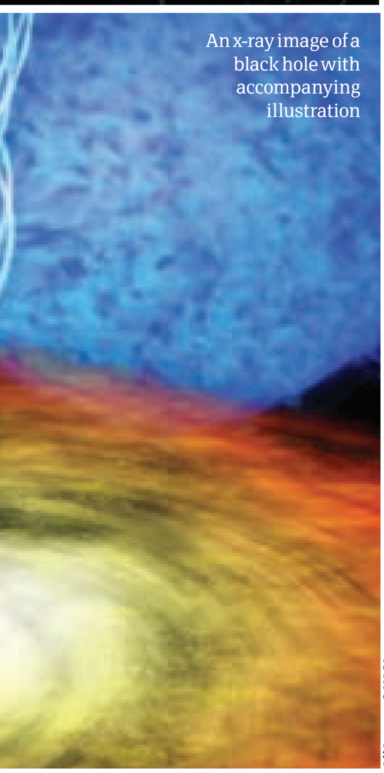
Sagittarius A*

Introducing the Milky Way's very own supermassive black hole

At the heart of almost every galaxy lies a black hole, even our own the Milky Way, which centres on a region of space called Sagittarius A* – at the middle of which lies a supermassive black hole. Black holes like these, however, do not form directly but from the coalescence of multiple smaller stellar-mass and intermediate mass black holes, which then form a supermassive black hole such as Sagittarius A*. Supermassive black holes also often form from the slow accretion of matter from neighbouring stars, the mass collapse of large stellar gas clouds into a relativistic star (a rotating neutron star), or directly from external pressure caused by the Big Bang.

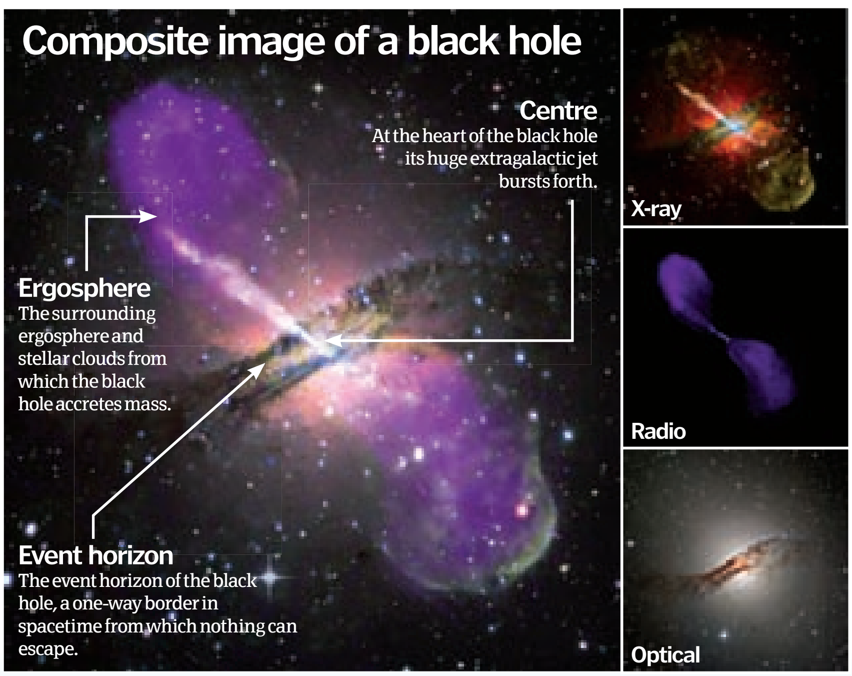
While unimaginable due to its very nature (it absorbs all light), its distance from Earth and the fact that the Sagittarius A* region is removed by 25 magnitudes of extinction from Earth (blocked from optical sight), our own supermassive black hole can only be observed by scientists through the actions of neighbouring cosmic phenomena. Indicating the presence of its existence most notably is the movement of star S2, which has been monitored by scientists following a slow elliptical orbit with a period of 15.2 years and a closest distance of less than 17 light hours from its orbit centre. From the slow motion of S2, scientists have extrapolated that the object which it is orbiting around has a solar mass of 4.1 million, which when taken with its relatively small diameter, strongly affirms that it is a black hole as no other known object can have such a large mass at such a small volume.

Sagittarius A* is a relatively small supermassive black hole when compared with others of its ilk, such as the black hole at the centre of the OJ 287 galaxy, which has a mass of 18 billion solar masses.



An x-ray image of a black hole with accompanying illustration

Composite image of a black hole



All Images © NASA

> "The simplest black holes have mass but neither charge nor angular momentum"

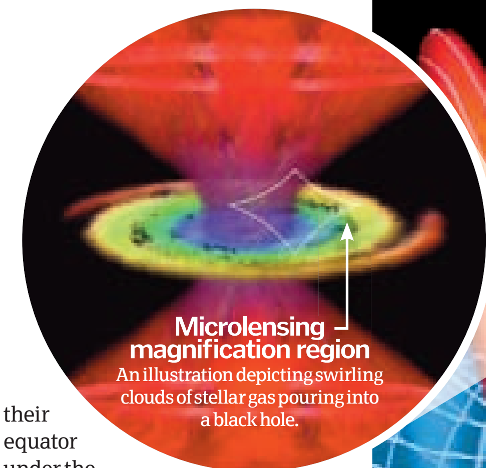
Inside our black hole

What are its properties and structure?

To understand our Sagittarius A* black hole it is important to understand how black holes in general work. After any black hole stabilises post formation, it has only three possible independent physical properties: charge, mass and angular momentum. Now, when an object is accreted (swallowed) by a black hole its own mass, charge and momentum is equalised with the black hole's own, distributing the matter evenly along its event horizon (a one-way spacetime boundary), which then oscillates like a stretchy membrane. The course that this pattern follows, however, depends on the individual black hole's properties and type.

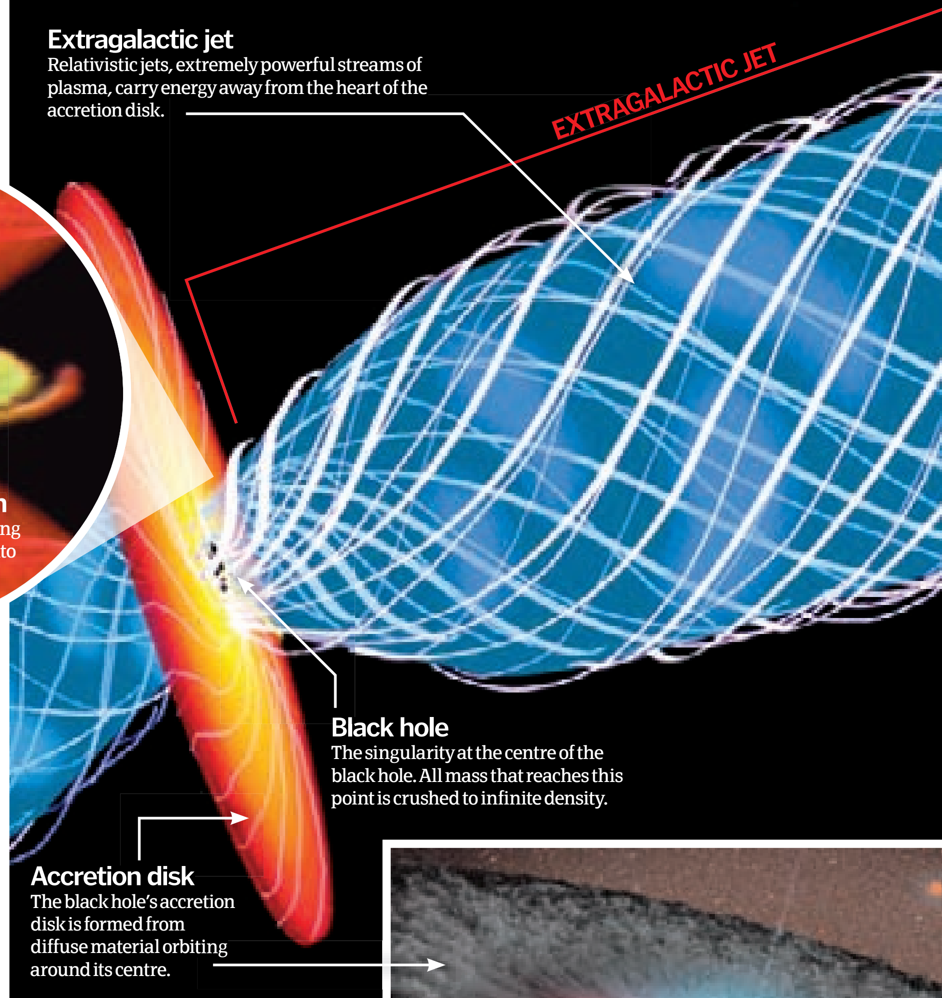
The simplest black holes have mass but neither charge nor angular momentum, accreting mass to a point-singularity centre, however most types of black hole formed from the core-collapse supernova of a star are thought to retain the nearly neutral charge it once possessed. Other, and theorised by scientists to be far more common, types of black holes – due to the spinning nature of stars – are rotating variants. These form from the collapse of stars or stellar gas with a total non-zero angular momentum and can be both charged and uncharged. These black holes, unlike the totally round, static variants, bulge near their equator under the phenomenal velocity of their spin (the quicker the rotation the more deformed the black hole will be) and instead of accreting matter to a point-singularity do so to a smeared disc singularity. Eventually all black holes, however dependent on their charge or rotation, revert to a non-rotating, uncharged variant.

Unfortunately, from the measurements taken from the stars surrounding our Sagittarius A* black hole, scientists have been left unsure about its physical properties. However, recent research from the University of California, Berkeley, suggests that A* rotates once every 11 minutes or at 30 per cent the speed of light. This information, when combined with the known close proximity of the surrounding stars (a spinning black hole drags space with it, allowing atoms to orbit closer to one that is static), would seem to suggest that not only is the gravitational pull of Sagittarius A* mitigated to a degree by its rotation but also that these measurements are accurate.



Microlensing magnification region
An illustration depicting swirling clouds of stellar gas pouring into a black hole.

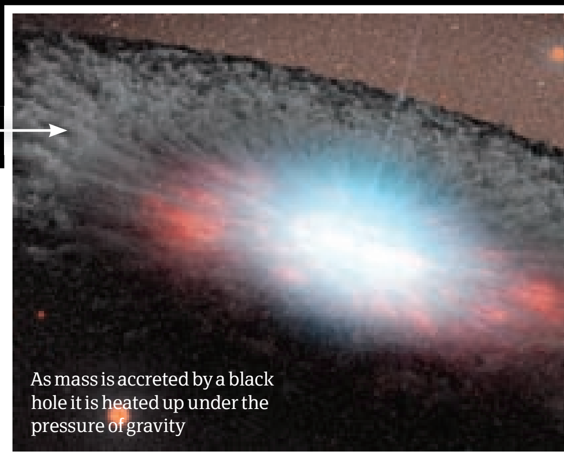
Formation of extragalactic jets from black hole accretion disk



Extragalactic jet
Relativistic jets, extremely powerful streams of plasma, carry energy away from the heart of the accretion disk.

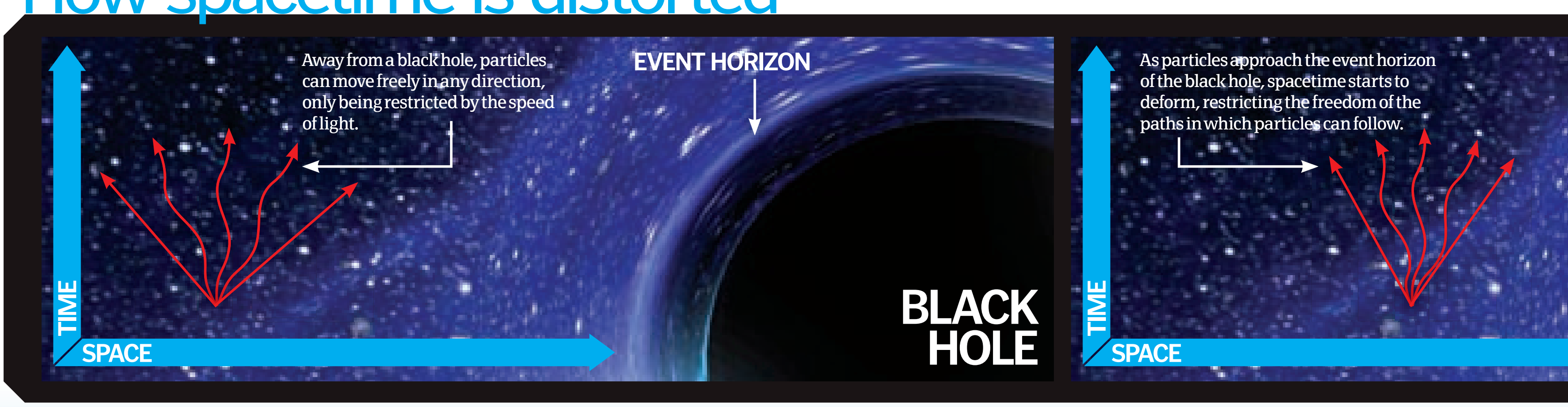
Black hole
The singularity at the centre of the black hole. All mass that reaches this point is crushed to infinite density.

Accretion disk
The black hole's accretion disk is formed from diffuse material orbiting around its centre.



As mass is accreted by a black hole it is heated up under the pressure of gravity

How spacetime is distorted



5 TOP FACTS BLACK HOLES

Do the worm
1 Certain theories postulate that rotating black holes could be avoided by entities and actually used as a wormhole shortcut through space and time.

Weakling
2 Despite their colossal size and perpetual accretion of matter, black holes can only suck in matter from a very small surrounding region as gravity is incredibly weak.

Primordial
3 In the current epoch of the universe only the collapse of stars carry the requisite density to form a black hole, however shortly after the big bang densities were greater.

Micro-management
4 Theoretically it is possible for micro-black holes to form through the high-speed collision of sub-atomic particles, although this is unlikely to ever happen.

Spaghetti
5 Any object that passes an event horizon will be stretched into long thin strands under the strong gravitational field of the black hole.

DID YOU KNOW? *The coinage of the phrase 'black hole' didn't occur until 1967*

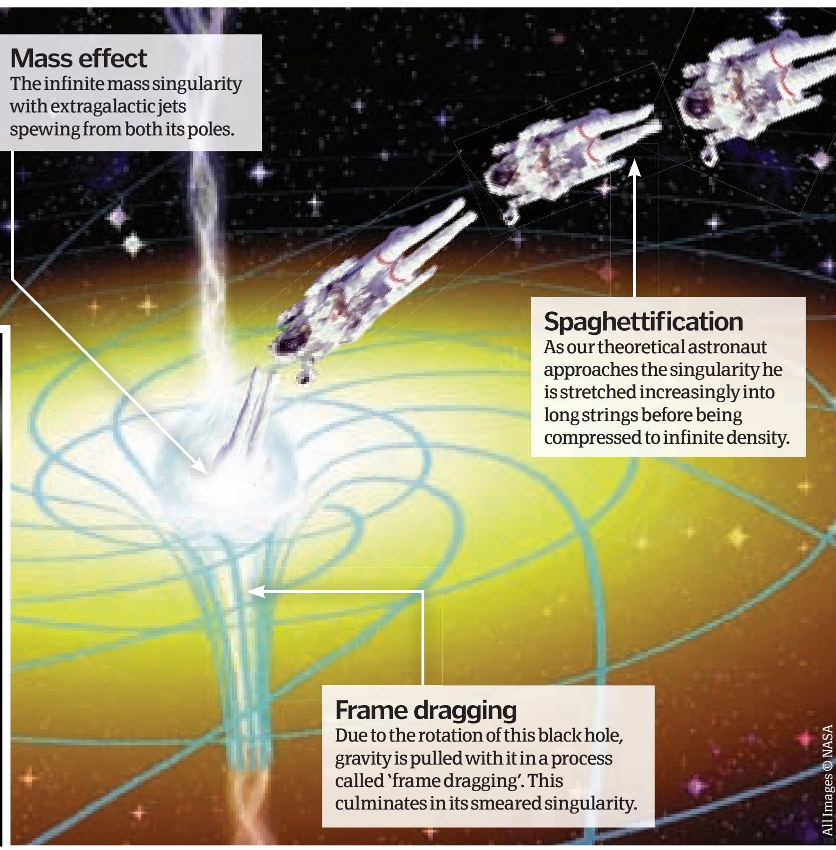
Let's do the time warp

The theoretical consequences of time and space distortion

The event horizon (a boundary in spacetime through which matter and light can only pass through inwardly) of a black hole is one of its central characteristics, and one that brings a host of issues for any object that passes through it. As predicted by general relativity (our geometric theory on gravitation) due to the colossal mass of the black hole – which by these rules is infinite at the heart of the black hole – spacetime is deformed, as mass has a direct bearing on it. Indeed, when the event horizon is passed, the mass's distortion becomes so great that particle paths are bent inwardly towards the singularity (centre) of the black hole, unable to alter their course. At this point both time and space begin to be warped.

The consequences of this, while theoretical, are mind blowing. For example, theory states that if a hypothetical astronaut were about to cross the event horizon of a black hole, then apart from being stretched physically (spaghettification), they'd also be stretched in time. So, while the astronaut would pass the event horizon at a finite point in his own time, to a hypothetical distant observer, he'd appear to slow down, taking an infinite time to reach it. Further, if the astronaut were wearing a watch, it would tick more slowly as he approached the event horizon than a watch worn by the observer, an effect known as gravitational time dilation. Finally, when the astronaut reached the singularity, he'd be crushed to infinite density and over an infinite time (to the observer) before having his mass added to that of the black hole.

Magnetic field lines
The magnetic field lines emanating from the accretion disk collimates the relativistic jet outflow along the rotating axis of the black hole.



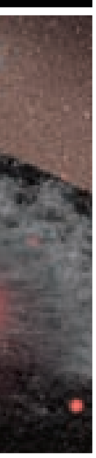
Travelling into a black hole…

Mass effect
The infinite mass singularity with extragalactic jets spewing from both its poles.

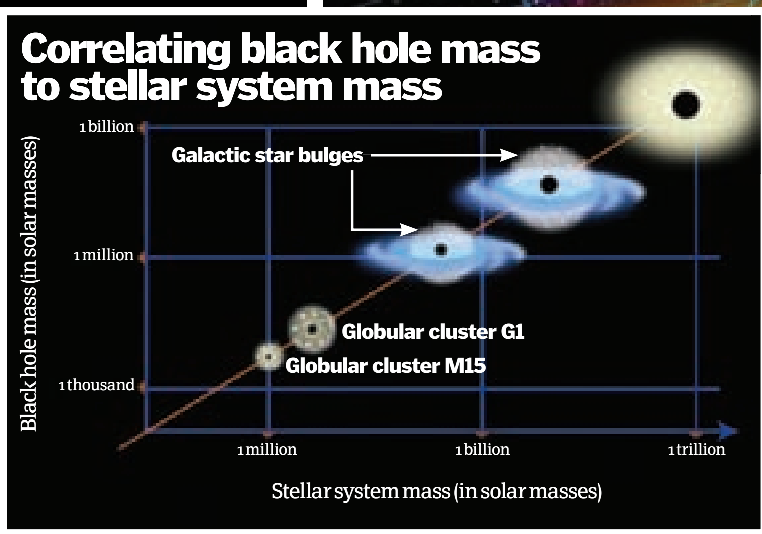
Spaghettification
As our theoretical astronaut approaches the singularity he is stretched increasingly into long strings before being compressed to infinite density.

Frame dragging
Due to the rotation of this black hole, gravity is pulled with it in a process called 'frame dragging'. This culminates in its smeared singularity.

All images © NASA

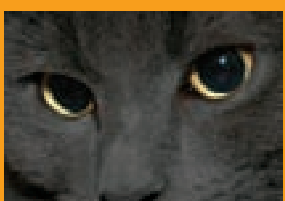


Correlating black hole mass to stellar system mass



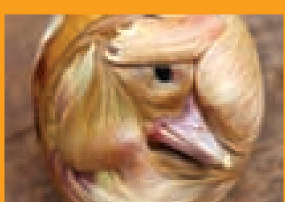
This month in Science

This issue's bumper section takes a broad view of scientific wonders. If you've ever wondered how the knee bone connects to the thigh bone, or about the physics behind your domestic electricity supply, then read on. We also take a look inside eggs and break down why coffee perks you up…



50 Cats' night vision

52 Caffeine



57 Eggs explained

SCIENCE

How the human skeleton works

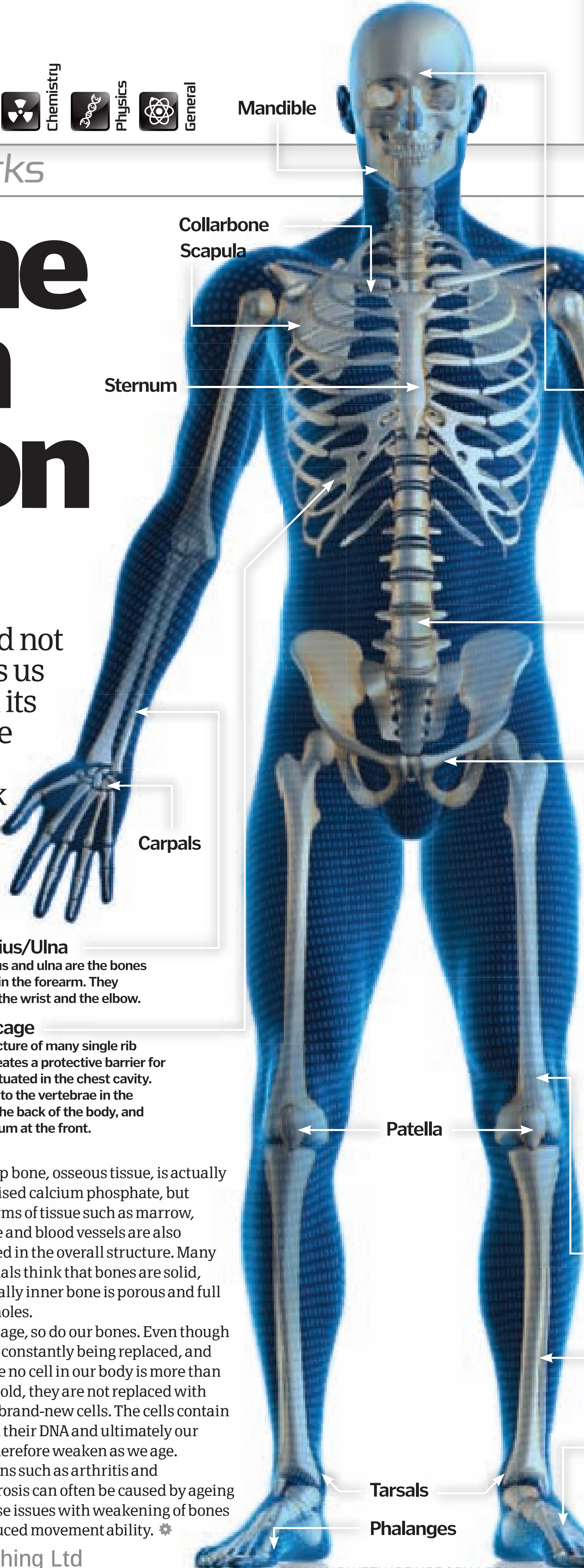
Without a skeleton, we would not be able to live. It is what gives us our shape and structure and its presence allows us to operate on a daily basis. It also is a fascinating evolutionary link to all other living and extinct vertebrates

The human skeleton is crucial for us to live. It keeps our shape and muscle attached to the skeleton allows us the ability to move around, while also protecting crucial organs that we need to survive. Bones also produce blood cells within bone marrow and store minerals we need released on a daily basis.

As a fully grown adult you will have around 206 bones, but you are born with over 270, which continue to grow, strengthen and fuse after birth until around 18 in females and 20 in males. Human skeletons actually do vary between sexes in structure also. One of the most obvious areas is the pelvis as a female must be able to give birth, and therefore hips are comparatively shallower and wider. The cranium also becomes more robust in males due to heavy muscle attachment and a male's chin is often more prominent. Female skeletons are generally more delicate overall. However, although there are several methods, sexing can be difficult because of the level of variation we see within the species.

Bones are made up of various different elements. In utero, the skeleton takes shape as cartilage, which then starts to calcify and develop during gestation and following birth. The primary element that makes up bone, osseous tissue, is actually mineralised calcium phosphate, but other forms of tissue such as marrow, cartilage and blood vessels are also contained in the overall structure. Many individuals think that bones are solid, but actually inner bone is porous and full of little holes.

As we age, so do our bones. Even though cells are constantly being replaced, and therefore no cell in our body is more than 20 years old, they are not replaced with perfect, brand-new cells. The cells contain errors in their DNA and ultimately our bones therefore weaken as we age. Conditions such as arthritis and osteoporosis can often be caused by ageing and cause issues with weakening of bones and reduced movement ability.



4. Radius/Ulna
The radius and ulna are the bones situated in the forearm. They connect the wrist and the elbow.

5. Rib cage
This structure of many single rib bones creates a protective barrier for organs situated in the chest cavity. They join to the vertebrae in the spine at the back of the body, and the sternum at the front.

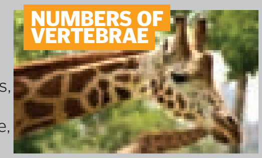
EXOSKELETONS

1. Snails
Exoskeletons are often seen in animals. These are bulky, tough outer layers that protect the individual, instead of the endoskeletons we have.

STRANGE SKELETONS

2. Snake
The skeleton of a snake is one of the strangest. Because of how it moves, it has more joints in the body, primarily vertebrae, and has no limbs.

NUMBERS OF VERTEBRAE



3. Giraffe
Considering the size of a giraffe's neck, you'd expect it to have more cervical vertebrae than a human, but it only has seven – the same as us!

DID YOU KNOW? *Around five per cent of all animals have backbones and are therefore classified as vertebrates*

Inside our skeleton

How the human skeleton works and keeps us upright

1. Cranium
The cranium, also known as the skull, is where the brain and the majority of the sensory organs are located.

2. Metacarpals
The long bones in the hands are called metacarpals, and are the equivalent of metatarsals in the foot. Phalanges located close to the metacarpals make up the fingers.

3. Vertebrae
There are three main kinds of vertebrae (excluding the sacrum and coccyx) – cervical, thoracic and lumbar. These vary in strength and structure as they carry different pressure within the spine.

6. Pelvis
This is the transitional joint between the trunk of the body and the legs. It is one of the key areas in which we can see the skeletal differences between the sexes.

7. Femur
This is the largest and longest single bone in the body. It connects to the pelvis with a ball and socket joint.

8. Fibula/Tibia
These two bones form the lower leg bone and connect to the knee joint and the foot.

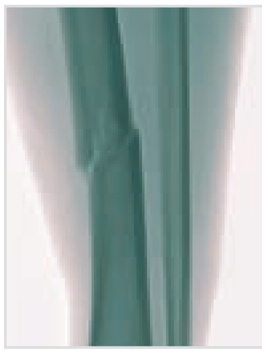
9. Metatarsals
These are the five long bones in the foot that aid balance and movement. Phalanges located close to the metatarsals are the bones which are present in toes.

Breaking bones

Whether it's a complete break or just a fracture, both can take time to heal properly

If you simply fracture the bone, you may just need to keep it straight and keep pressure off it until it heals. However, if you break it into more than one piece, you may need metal pins inserted into the bone to realign it or plates to cover the break in order for it to heal properly. The bone heals by producing new cells and tiny blood vessels where the fracture or break has occurred and these then rejoin up. For most breaks or fractures, a cast external to the body will be put on around the bone to take pressure off the bone to ensure that no more damage is done and the break can heal.

A typical cast for when someone has managed to break a bone. Unbelievably, a saw is the method of choice for removal!



Skull development

When we are born, many of our bones are still somewhat soft and are not yet fused – this process occurs later during our childhood

The primary reasons for the cranium in particular not to be fully fused at birth is to allow the skull to flex as the baby is born and also to allow the extreme rate of growth that occurs in the first few years of childhood following birth. The skull is actually in seven separate plates when we are born and over the first two years these pieces fuse together slowly and ossify. The plates start suturing together early on, but the anterior fontanel – commonly known as the soft spot – will take around 18 months to fully heal. Some other bones, such as the five bones located in the sacrum, don't fully fuse until late teens or early twenties, but the cranium becomes fully fused by around age two.

3 skulls © DK Images

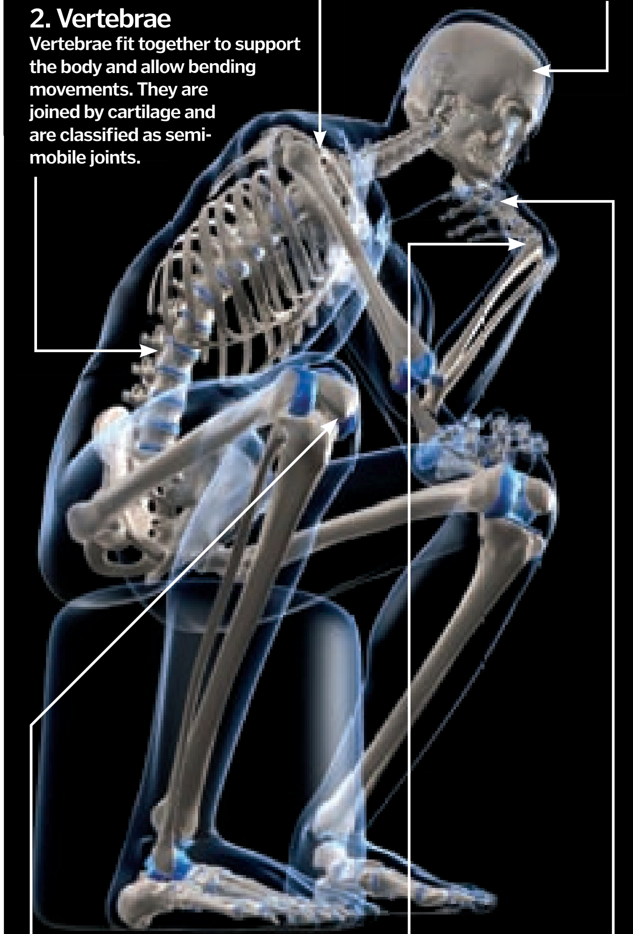
How our joints work

The types of joints in our body explained

1. Ball and socket joints
Both the hip and the shoulder joints are ball and socket joints. The femur and humerus have ball shaped endings, which turn in a cavity to allow movement.

2. Vertebrae
Vertebrae fit together to support the body and allow bending movements. They are joined by cartilage and are classified as semi-mobile joints.

3. Skull sutures
Although not generally thought of as a 'joint', all the cranial sutures present from where bones have fused in childhood are in fact immoveable joints.



4. Hinged joints
Both elbows and knees are hinged joints. These joints only allow limited movement in one direction. The bones fit together and are moved by muscles.

5. Gliding joints
Some movement can be allowed when flat bones 'glide' across each other. The wrist bones – the carpals – operate like this, moved by ligaments.

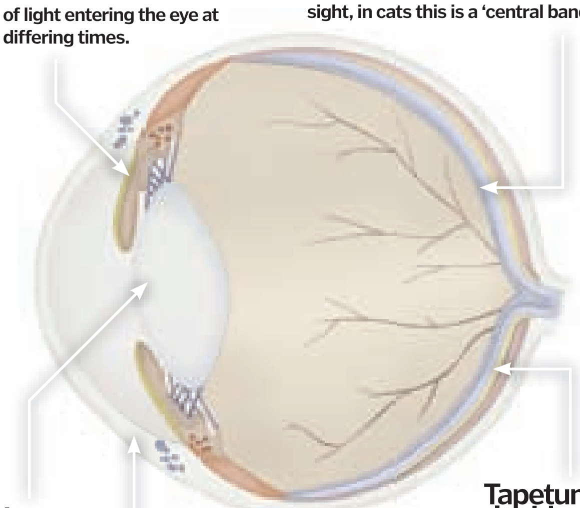
6. Saddle joints
The only place we see this joint in humans is the thumb. Movement is limited in rotation, but the thumb can move back, forward and to the sides.

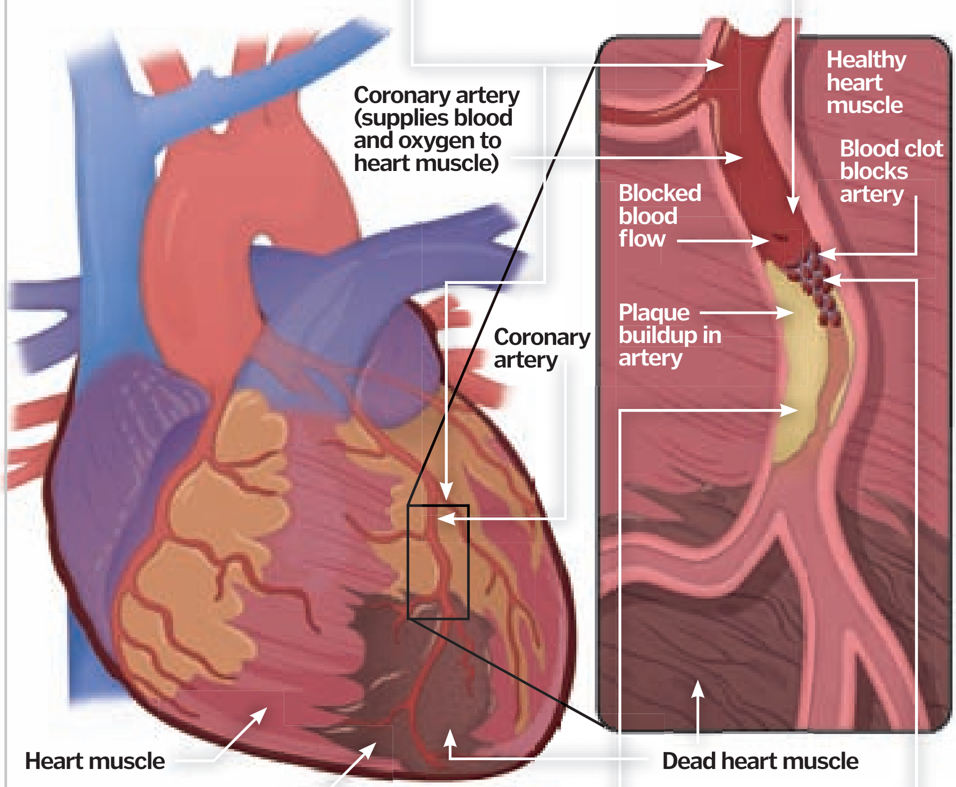
How do cats see at night?

Understanding the facts behind this feline phenomenon

Cats often hunt at night, and consequently they need superior night-time vision to primarily diurnal creatures. The way their eyes have adapted is by the introduction of an extra layer behind the retina, called the tapetum lucidum, which reflects light back through the retina to enhance perception in low-level light. This allows cats to see even when the level of light is seven times lower than a human needs to be able to see.

Many other animals that operate at night also have this layer and it is this that makes nocturnal animals' eyes seem to glow when you look at them at night. This concept has also been used to make 'cat's eyes' road markings. However, although this layer gives nocturnal creatures benefits at night, it can cause issues when there are high levels of light present as too much light travels through the eye. Many cats display a slit-like pupil to control amounts of light entering the eye.





Heart attacks

Heart attacks are one of the western world's biggest killers, but what causes them and how do they kill?

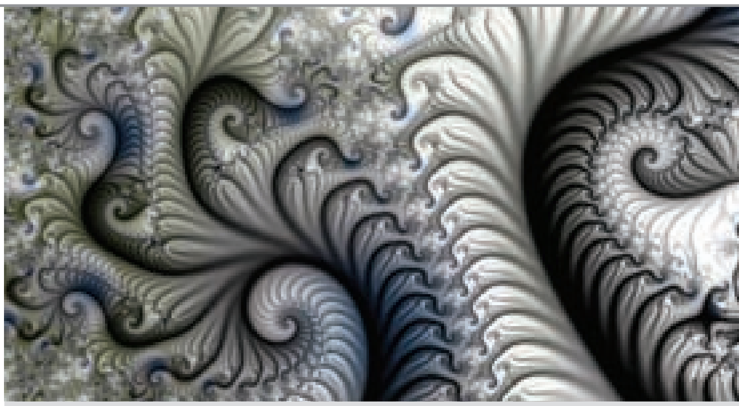
A heart attack, also known as a myocardial infarction, occurs when a blockage stops blood oxygenating the heart muscle. If this is not corrected quickly, the muscle tissue that is lacking oxygen can become damaged, or indeed die. The scale of impact on the individual's health after the attack is dependant on how long the blockage occurs for, what artery it affected and what treatment was received. Following the initial attack, heart failure or arrhythmias can occur, both of which may prove fatal. However, given the right treatment many sufferers go on to make good recoveries and can eventually return to their normal activities.

The most common reason for heart attacks is coronary artery disease (CAD). This is where arteries are constricted due to plaque build-ups and this layer then ruptures. Blood platelets make their way to the site of rupture and start to form blood clots. If these clots become too large, the narrowed artery will block and a heart attack occurs. Heart attacks can also be caused by coronary artery spasms, but these are rare.

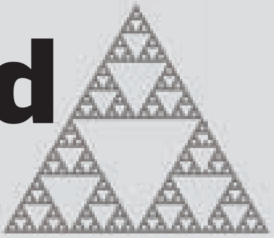
Although some people will be genetically predisposed to heart attacks, individuals can reduce risk by keeping their weight down, watching what they eat, not smoking and exercising regularly.


Chest pains are the first symptoms of an attack

> "The liver also releases sugar into the bloodstream for an instant energy boost"



Fractals explained

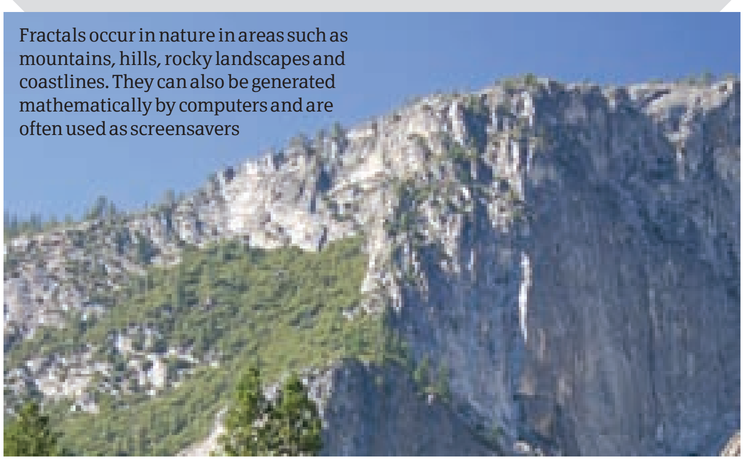


How self-similarity is all around us

A fractal (the Latin meaning for fractured) is any geometric shape that sports approximate self-similarity at all levels when broken down into smaller parts of its whole. In nature, finite fractals (an object that displays a self-similar structure over an extended but finite range) exist everywhere, with good examples being evident with clouds, snowflakes, crystals, cauliflower and even coastlines. Here, with these examples, when each object is broken up the resultant parts are similar in shape to the whole that they once were; they are not identical though – something which is achieved only in mathematical/symbol-based fractals – but they are self-similar in shape over an extended period and are therefore fractal in nature.

In mathematics fractals gain an extra dimension as they're then based on an equation that undergoes iteration, often infinitely creating a feedback based on recursion (a method of defining a function in which the function being defined is applied within its own definition). A good example of how fractals work can be seen in the Sierpiñski triangle (see image above), a self-similar, mathematically generated triangular pattern that can be reproduced at any magnification.

Depending on the totality of self-similarity that a fractal features, it is classified in one of three categories: exact self-similarity (identical at any scale), quasi self-similarity (distorted, degenerate replication) or statistical self-similarity (despite shape, maintains numerical or statistical measures of original).



Fractals occur in nature in areas such as mountains, hills, rocky landscapes and coastlines. They can also be generated mathematically by computers and are often used as screensavers

This guy looks like he needs a tranquiliser, not caffeine!

Understanding the power of caffeine

Can't start the day without a cup of coffee? Find out why you need it…

When we are awake the naturally occurring brain chemical adenosine is drawn to fast moving receptors in the brain. As adenosine attaches to the receptors it slows them down, which causes us to feel sleepy.

The receptor cells confuse caffeine for adenosine cells and as such willingly bond to it. The action doesn't slow down the receptor's movement as adenosine would and as the space is usurped they are unable to sense adenosine so the cells speed up, increasing neuron firing in the brain. The pituary gland interprets this as a fight or flight scenario so releases hormones to alert the adrenal glands to produce adrenaline. The combined reaction of these stages results in dilated pupils, a racing heart and an increase in blood pressure. The liver also releases sugar into the bloodstream for an instant energy boost.

Head to Head
CAFFEINATED DRINKS

SOME CAFFEINE

1. Tea
In a survey by the Food Standards Agency, the mean amount of caffeine found in tea was 40mg per cup.

MORE CAFFEINE

2. Instant coffee
The level of caffeine present in instant coffee was not much more with an average of 54mg of caffeine per serving.

MOST CAFFEINE

3. Ground coffee
Ground coffee, however, contains the most caffeine. The mean level was 105mg, in some cases ranging as high as 254mg per serving.

Bucket of blood
1 On average, adults have five to six litres: less than a bucket-full. If an adult's blood vessels were laid end to end they would stretch out over 100,000km (62,500 miles).

Pumping it
2 The heart pumps, on average, at a rate of 70 beats per minute. And on average, approximately ten tons of blood is moved around the body daily.

What's it made of?
3 Human blood consists of about 22 per cent solids and 78 per cent water. It consists of red blood cells, white blood cells, platelets, fat globules and gases.

How is it made?
4 Blood cells are made in the bone marrow, the soft, spongy material in the centre of the bones that produces about 95 per cent of the body's blood cells.

Clotting
5 Blood also contains important proteins called clotting factors, which are critical to the clotting process which kicks in when you get a cut or graze.

DID YOU KNOW? 44 per cent of the UK population have type O blood

Blood types

The ABO blood grouping system

In this blood group system, each individual has two inherited alleles – receiving one allele from each parent during conception. There are three different blood type alleles A, B and O, therefore possible genotypes are obviously AA, AB, AO, BB, BO, OO. AA and AO are expressed as phenotype A, BB and BO are expressed as phenotype B, AB is expressed as AB and OO is expressed as O. An individual will generally have the same blood group for life, unless they have bone marrow transplants, rare infections or certain autoimmune diseases.

Blood type is classified by the presence, or absence, of antigens on the surface of an individual's red blood cells. Dependant on blood type, differing antibodies will be produced and this is why knowing an individual's blood group can be very important. In blood transfusions for example, blood must either match or be of a type that will not be rejected by the existing blood type.

If you have blood type A, you will produce anti-B antibodies, which are formed early in life in response to food, bacteria and other environmental factors, and consequently, you must only receive O or A blood so that you do not kill off the newly introduced blood cells. Blood group O donors are so sought after as O group is universally accepted by other blood types, and giving someone the wrong blood type could ultimately prove life-threatening.

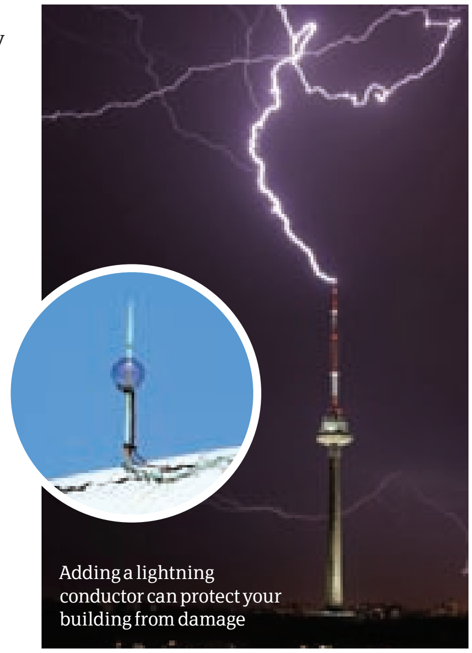
There are two primary blood groupings in humans, but the ABO system is generally recognised as the most important. Every individual displays one of four possible phenotypes

How do lightning conductors work?

Explaining the science behind those strange rods on top of buildings

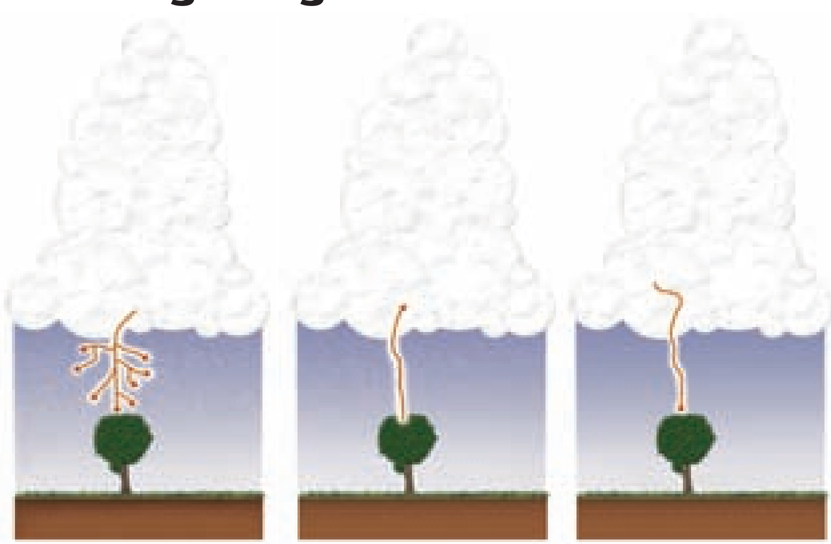
Lightning protection systems divert electricity given off by lightning by creating a link between the lightning flash and the ground. The part we see on top of the building is known as a lightning conductor (or lightning rod) and it is just one element of this system. A wire links the conductor, which can be either a strip of metal or a rod, down to the ground where electricity can then safely disperse.

To avoid electricity passing across into the building, there are often multiple wire routes and any materials that could conduct the electricity which are located close to the system must also be included within the system to avoid lightning leaping across. If this happens it is called a side flash and it can cause fires or damage to the building or adjacent ones.



Adding a lightning conductor can protect your building from damage

When lightning strikes…



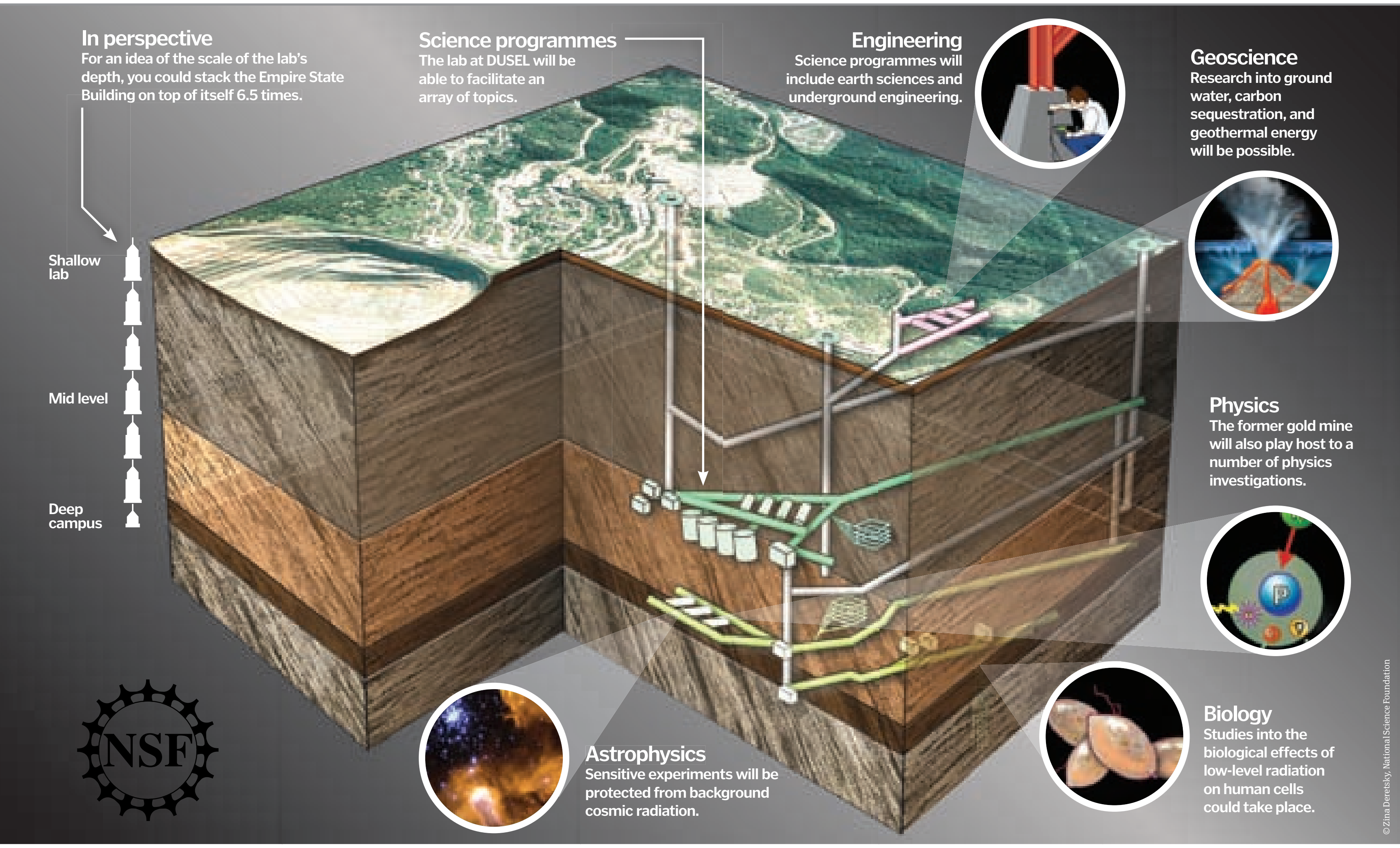
1. Charge moves down toward earth
As a cumulonimbus cloud passes over the ground, the ground beneath it becomes electrically charged to the same level – but with the opposite charge, a positive charge. As the cloud's electric current discharges, it is attracted to the closest items which display the opposite charge – buildings or trees.

2. Object reflects lightning back
When the discharge channel from the cloud, known as a 'leader', starts to get close to the ground, the electric field can increase in strength. If strong enough, it creates a 'conductive discharge' which can connect to the descending leader. If they do connect, current takes the path of least resistance – back to the cloud.

3. Electric current returns to the ground again
The electrical current will, however, still need to be discharged in some way, and because of this will return back to the ground for a second time. This process is called the return stroke and is what causes the bright white flashes that we see during lightning storms.

“Astroparticle physics – the science of explaining the very large with the very small”

The Deep Underground Science and Engineering Lab



World's deepest underground lab

The answers to our deepest scientific questions are even deeper than you think

So what is DUSEL? It's the Deep Underground Science and Engineering Lab which, as far as acronyms go, makes it pretty self-explanatory. The project is currently under consideration by the National Science Foundation and if successful will be housed at 2,500 metres (8,000 feet) down in an abandoned gold mine in South Dakota. The blueprints for DUSEL include deep labs for the study of geomicrobiology. Here, scientists will examine so-called 'Dark Life', massive microbial colonies that exist without sunlight at temperatures exceeding 100°C. These colonies, which contribute to half the Earth's biomass, may also be the earliest life on Earth.

DUSEL will also include facilities for geoscientists and engineers to work hands-on with deep subterranean rock formations under massive pressure. Their discoveries could lead to better earthquake prediction technology, safer sources of drinking water as well as effective techniques for carbon sequestration.

There are ten major deep-Earth laboratories around the globe, most of them devoted exclusively to astroparticle physics – that is the science of explaining the very large with the very small. Protected from cosmic interference by miles of rock, physicists smash atoms in search of elusive dark matter and dark energy, the unexplained substances that compose over 70 per cent of the universe's mass and energy.

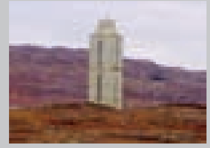
The main impetus for DUSEL is the study of extremely rare nuclear physics processes, like neutrino scattering, dark matter interactions, and neutrinoless double beta decay, which can only be studied in the absence of cosmic rays. Find out more about one of these experiments and why it needs to be conducted so far underground on the opposite page.

DEEPEST TRENCH

1. Mariana Trench
Depth: 11,034m (36,200ft)
Location: Pacific Ocean
Info: The deepest point in the Earth's oceans.

DEEPEST LAKE

2. Lake Baikal
Depth: 1,637m (5,369ft)
Location: Siberia, Russia
Info: This continental rift lake is over a mile straight down.



DEEPEST HOLE

3. Kola well
Depth: 12,261m (40,226ft)
Location: Kola Peninsula, Russia
Info: Drilling to learn about the Earth's crust since the Seventies.

DID YOU KNOW? *The work at DUSEL could help to create better earthquake prediction technology*

Physicists at Sanford could identify WIMPS using the LUX detector

LUX will be located in the Davis Cavern

The Sanford experiment: Hunting for WIMPs

The key to finding dark matter is underground

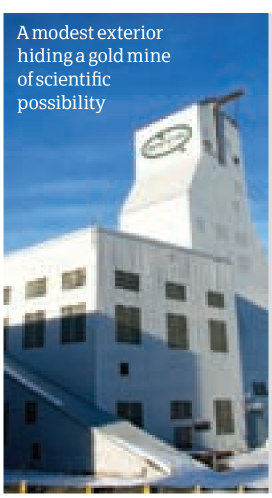
Astrophysicists believe that 25 to 30 per cent of the known universe is very much 'unknown'. It's composed of a mysterious cosmic glue called dark matter, an invisible, atom-less substance made of inexplicably massive particles. The race to explain dark matter is one of the greatest prizes in modern science.

The physicists at the Sanford Underground Laboratory are hot on the trail of one of the leading candidates for dark matter, theoretical specks called weakly interacting massive particles, or WIMPs. At 1,500 metres (5,000 feet) below the surface, Sanford scientists are building a Large Underground Xenon (LUX) detector to spot the first confirmed WIMP in the debris of an atomic collision.

The LUX detector, the most sensitive equipment of its kind, is a cylindrical tank filled with 65 kilograms of liquid xenon and armed with 122 photomultiplier tubes (PMTs) that can sense individual photons. If underground conditions are 'quiet' enough and the detector is sensitive enough, Sanford could usher in the dawn of a new scientific age.

My, that's a big drill

All photos South Dakota Science and Technology Authority (by Bill Harlan)



A modest exterior hiding a gold mine of scientific possibility

Deep science: why underground?

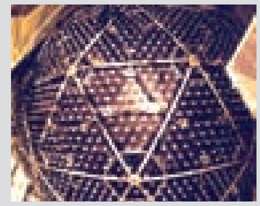
Every second, your body is bombarded with thousands of cosmic rays. These super-charged particles from distant solar systems – some as old as the big bang itself – rain down on the Earth in a continuous ionic storm.

For astroparticle physicists, who are searching for infinitesimally 'quiet' signal variations in very large experiments, the background noise of the cosmic storm can be deafening. The best way to shield their highly sensitive equipment from 'false positive' background signals is to conduct their experiments hundreds or thousands of metres below solid rock.

And it works. At a massive 2,000 metres (6,500 feet) underground, only one cosmic ray particle passes through a square metre of surface area every three days. The rate on the Earth's surface is 10,000 per second, or 50 million times higher.

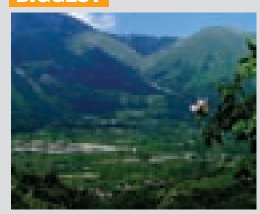
Deep labs

DEEPEST



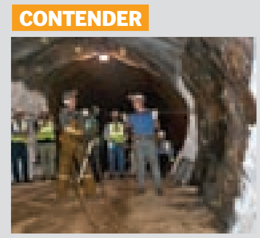
1. SNOLAB
Location: Canada
Facts: Buried 2km below the surface in a Canadian nickel mine, the deepest operational lab in the world is devoted to astroparticle physics experiments, specifically the search for dark matter. It famously solved the 'Solar Neutrino Problem' by proving that neutrinos could change 'flavour', proving the existence of a solar neutrino spectrum.

BIGGEST



2. Gran Sasso National Laboratory
Location: Italy
Facts: Protected by 1,400 metres of rock, Gran Sasso's three separate subterranean labs – totalling 180,000 cubic metres –specialise in neutrino physics, including those produced by supernova explosions. The facility, located under the town of L'Aquila, Italy, was undamaged in the region's 2009 earthquake.

CONTENDER



3. DUSEL
Location: USA
Facts: The proposed Deep Underground Science and Engineering Laboratory (DUSEL) at the Homestake Mine in South Dakota – 2.5 kilometres (8,000 feet) at its deepest shaft – would be a multidisciplinary lab studying dark matter physics, geomicrobiology ('dark life' microbes that live at great depths), geothermal processes and deep-Earth engineering.

BIGGEST EVER

1. Elephant bird
Elephant birds, native to Madagascar, have been extinct since the 17th Century. The eggs often measured over one metre in circumference.

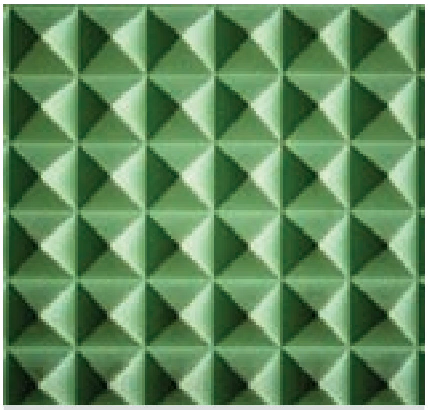
BIGGEST LIVING

2. Ostrich
Ostrich eggs are the largest of all eggs but the smallest relative to the size of the actual bird. On average they are 15cm long and 13cm wide.

SMALLEST

3. Hummingbird
The smallest bird egg is the bee hummingbird. You could put 4,700 of these inside one ostrich egg. It's the size of a pea and weighs .02 of an ounce.

DID YOU KNOW? In Britain the average person eats 172 eggs a year

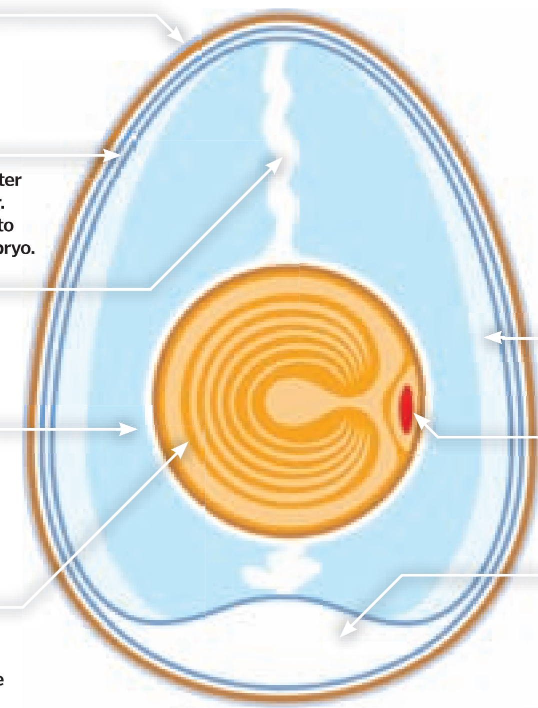


How do you soundproof a room?

With the increased noise of modern society, soundproofing is becoming more and more important for individuals living in urban environments

Soundproofing works by reducing the amount of external noise received in a set area through the absorption or blocking of incoming sound waves. The most common method utilised in order to achieve this is the installation of insulating panels – made mainly of foam – on the walls and ceiling of a room, which not only decrease the amount of sound waves transmitted through it, but also reduce echo, reverberation and the reflection of sound. This 'dampening' of sound waves also helps restrict their movement while in the room, preventing them from penetrating outwards or reflecting inwards.

Other ways in which a room can be soundproofed include the installation of a 'floating floor', a construction method that further reduces vibration and noise penetration by elevating the floor of a room on joists thereby trapping errant sound waves and reducing their reverberation. Double glazing can also aid soundproofing, as the vacuum created between the two panes of glass prevents sound waves from passing through. Finally, sound waves struggle to pass through liquids, so in certain circumstances the use of water tanks can reduce noise also.



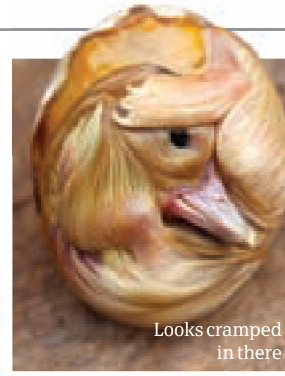
1. Eggshell
If hard, the outer layer is known as the eggshell, and will normally be a heavily mineralised protein structure.

2. Outer membrane
Some eggs only have a flexible outer layer and this is a membrane layer. This still serves a similar purpose to the eggshell in protecting the embryo.

3. Chalaza
These support the yolk in the egg, alongside the albumen. They ensure the yolk does not break and lose nutrients.

5. Albumen
The albumen, also known as the 'white' of the egg, provides support for the yolk and further nutrition for the embryo as it grows. This is the cytoplasm of the egg.

6. Yellow yolk
The yolk in particular is rich in fat, cholesterol and protein and will feed the embryo as it grows inside the egg.



Looks cramped in there

4. Inner membrane
This layer further defence against bacterial invasion.

7. Germinal disc
The nucleus of the egg when you consider the egg as a cell. It is also where sperm must enter to fertilise the egg.

8. Air cell
This bubble of air can contract and expand as necessary, serving as a kind of diaphragm to allow temperature change to occur.

What is an egg?

An egg is produced by many animals, but what exactly are they and how do they work?

Eggs are generally the fertilised ovum of an animal, although eggs produced by birds that we eat are actually unfertilised. All oviparous animals use the egg in order to reproduce, and generally this means little or no development of an embryo actually occurs inside the mother. However, eggs often have to be kept at a certain temperature in order for the embryo to grow inside the egg, and ultimately hatch successfully, so individuals involved in fertilising or producing the egg are often still needed after fertilisation.

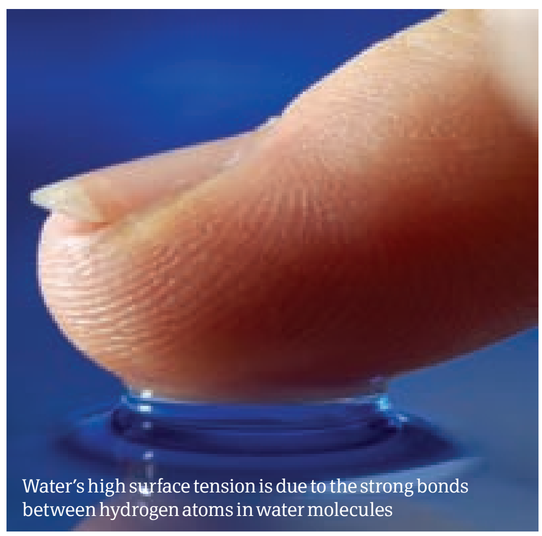
The main purpose of an egg is to contain all the elements that an embryo needs in order to develop in safety, most crucially an egg offers protection from external elements and also nutrients needed for growth and development before hatching.

Surface tension

How does surface tension work?

When you think of surface tension, that familiar tried-and-tested science experiment we all performed at school of balancing a paper clip on the surface of a cup of water, slowly filters back into our realm of consciousness – but why doesn't it sink?

Surface tension is caused by the attraction between the liquid's molecules by various intermolecular forces. In the liquid each molecule is pulled equally in all directions by neighbouring molecules, resulting in a net force of zero. At the surface of the liquid the molecules here are pulled inwards but this is balanced by the substance's resistance to compression, meaning there is no net inward force. But there is a driving force to diminish the surface area and as such the liquid squeezes itself together until it has the locally lowest surface area. So in the paper clip experiment the clip is prevented from submerging when the water level is at its maximum without spilling over the rim.



Water's high surface tension is due to the strong bonds between hydrogen atoms in water molecules

> "Materials like wood, glass, ceramics and cotton all have electrons"

Electricity explained

Learn some shocking facts behind the everyday energy we take for granted

Many people think of electricity as something you buy from the power companies, but as well as coming out of the wall socket, electricity is one of the many ingredients that make up the universe. Read on to find out why electricity occurs, how it behaves and how it reaches your home.

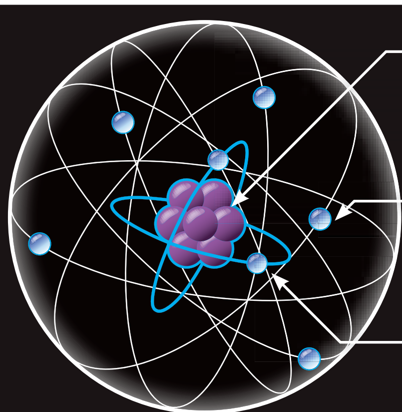
Everything in the universe is made of minuscule atoms and these atoms consist of a nucleus orbited by one or more electrons. These electrons carry a negative charge while the nucleus is positively charged.

We're all familiar with the effects of static electricity. We are not often aware of electricity around us as the positive and negative charges usually balance. When certain objects touch, however, electrons can jump between them. For instance, when you rub a balloon against your hair electrons will jump across to the balloon giving the balloon stationary negative charge or static electricity. Static electricity relies on electrons not being able to move around easily. Materials like wood, glass, ceramics and cotton all have electrons that like to stick with their atoms and because the electrons don't move the materials can't conduct electricity very well.

In most metals, electrons can move freely to form an electric current. When charges move, current electricity is formed and this is the power that drives much of the contemporary world. Current can be measured by the amount of charge passing a fixed point each second.

Inside an atom

Atoms are held together by electricity. The positive nucleus attracts the negative electron. The two cancel each other out so the atom has no electric charge



1. The nucleus The nucleus is at the centre of the atom and is positively charged

2. Negative charge Each electron is negatively charged

3. Electrons Electrons orbit the nucleus

A high voltage shock doesn't excuse that hair cut

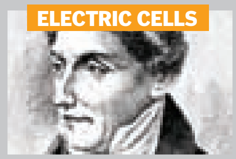
THE WORD

1. William Gilbert 1544-1603
Scientist and physician to Queen Elizabeth I, he invented the term and was the first to describe the earth's magnetic field.

THE LIGHTNING ROD

2. Benjamin Franklin 1706-1790
Flew a kite with a metal key attached into a thunderstorm to prove that lightning is a form of electricity.

ELECTRIC CELLS



3. Alessandro Volta 1745-1827
This Italian scientist's experiment using soaked paper in salt water, zinc and copper created the first electric cell.

DID YOU KNOW? *The word 'electricity' is derived from the Greek word for amber, elektron*

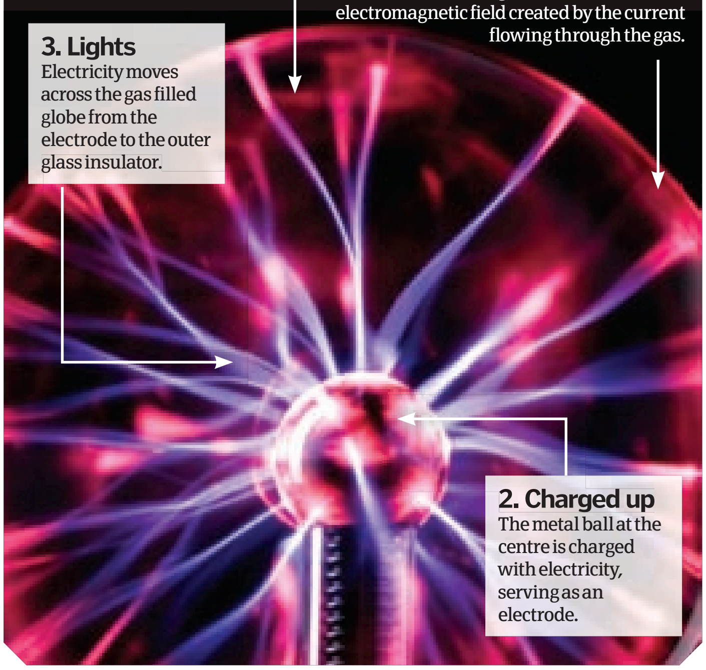
Plasma balls – static incarnate

They went out of fashion in the Eighties but still demonstrate electricity really well

1. Full of gas
The glass ball is filled with a mixture of gases, usually helium and neon, at low pressure.

4. Touch the power
Placing your hand on the glass alters the electric field and causes a single beam to migrate from the inner ball to the point of contact, the glass does not block the electromagnetic field created by the current flowing through the gas.

3. Lights
Electricity moves across the gas filled globe from the electrode to the outer glass insulator.



2. Charged up
The metal ball at the centre is charged with electricity, serving as an electrode.

Conductors

Very simply, a conductor is a material that allows electric charge to pass along it as a current. As stated, metals make good conductors as the electrons of their atoms are loosely bound and free to move through the material. For instance, in copper the electrons are essentially free and strongly repel each other. Any external influence that moves one of them will be replicated through the material.

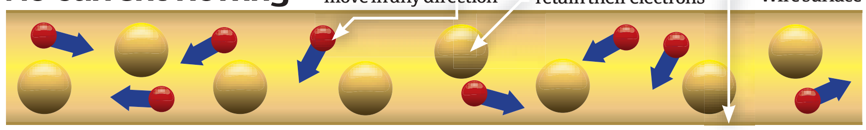
A superconductor is a material that has no resistance at all to the flow of current when kept below a certain temperature. For most superconducting materials, the critical temperature is below about 30K (30°C above absolute zero).

No current flowing

These free electrons can move in any direction

The copper atoms retain their electrons

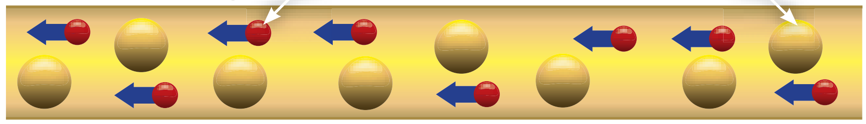
Wire surface



Current flowing

The free electrons move towards the positive terminal

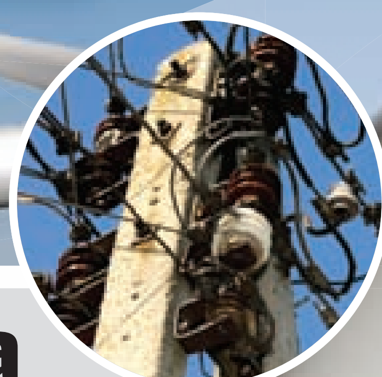
The copper atom remains in placc



Insulators

Insulators are materials that have the exact opposite effect on the flow of electrons. Their atoms have tightly bound electrons which are not free to roam around. That said, insulators can still play an important role in the flow of electricity by protecting us from the dangerous effects of a current flowing through conductors. If the voltage is high enough an electric current can be made to flow through a material that is not a good conductor, like the human body. The function of our hearts can be affected by an electric shock and the heat generated by the current can cause burns.

The ceramic insulators on this pylon are there to prevent this worker becoming toast

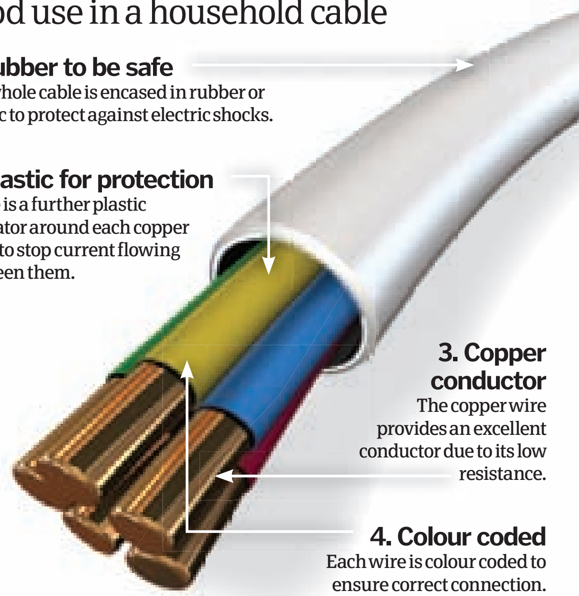


Conductors and insulators at work

Conductors and insulators are put to good use in a household cable

1. Rubber to be safe
The whole cable is encased in rubber or plastic to protect against electric shocks.

2. Plastic for protection
There is a further plastic insulator around each copper cable to stop current flowing between them.



3. Copper conductor
The copper wire provides an excellent conductor due to its low resistance.

4. Colour coded
Each wire is colour coded to ensure correct connection.

An electric current passes through a thin filament, heating it so that it produces light

Vive la resistance

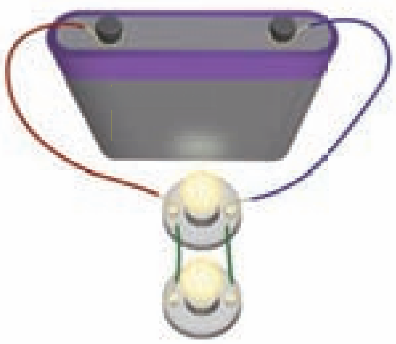
Resistance is a very important property, it's the factor behind many domestic appliances including old-school light bulbs, kettles, toasters, heaters and irons to name a few. All these rely on the creation of heat energy. Resistance is the ability of a substance to prevent or resist the flow of electrical current. Materials resist electric current because of a collision between electrons and atoms. This slows the electrons down and converts some of their energy to heat energy.

"Electricity can't do a lot of work without circuits as these provide a path for the electricity to flow around"

Circuits

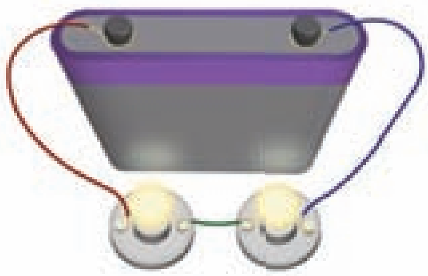
Putting electricity to work all over the world

Now that we've explained where electricity comes from it's time to look at some of the work it can do for us. Electricity can't do a lot of work without circuits as these provide a path for the electricity to flow around. Circuits include devices such as resistors, which control the flow of voltage, or difference in electrical charge, and capacitors, which store electrical charge and come in one of two types, series and parallel.



Parallel circuits

In a parallel circuit there is more than one pathway between its beginning and end. Since the electricity has more than one route to take, the circuit can still function should one component fail. This means that parallel circuits are much less prone to failure than the series variety. For this reason parallel circuits are the kind you will find in most everyday applications such as domestic appliances and household wiring.



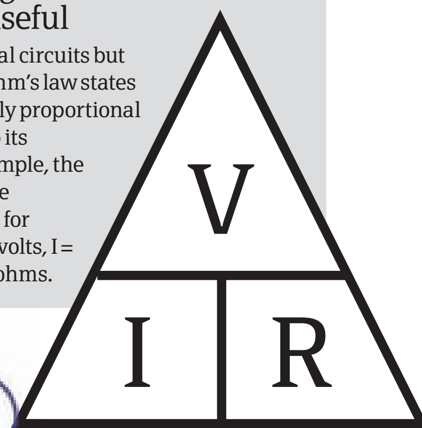
Series circuits

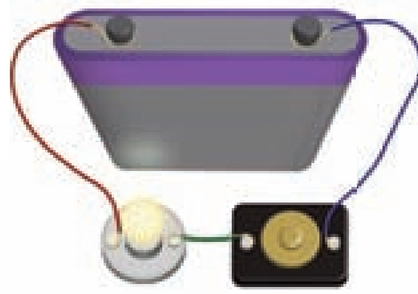
A series circuit has more than one resistor and only has one path for the charges to move along. A resistor is anything that uses electricity to do work (in this case, light bulbs) and the electric charge must move in series from one resistor to the next. If one of the components in the circuit is broken then no charge can move through it. An example of a series circuit is old-style Christmas lights, if one bulb breaks the whole string goes out.

Laws of circuits

Ohm's triangle; not as exciting as the Bermuda triangle but more useful

There are many laws that apply to electrical circuits but Ohm's law is one of the most important. Ohm's law states that an electrical circuit's current is directly proportional to its voltage and inversely proportional to its resistance. So, if voltage increases, for example, the current will also increase, and if resistance increases, current decreases. The formula for Ohm's law is $V = I \times R$, where V = voltage in volts, I = current in amperes, and R = resistance in ohms.





Circuit control

The simplest electrical control is a switch. This simply breaks the circuit to stop the current flowing and this is most notably seen in domestic light switches. They may seem simple, but the most complex computers are made from millions of electronically controlled switches.

CIRCUIT JARGON

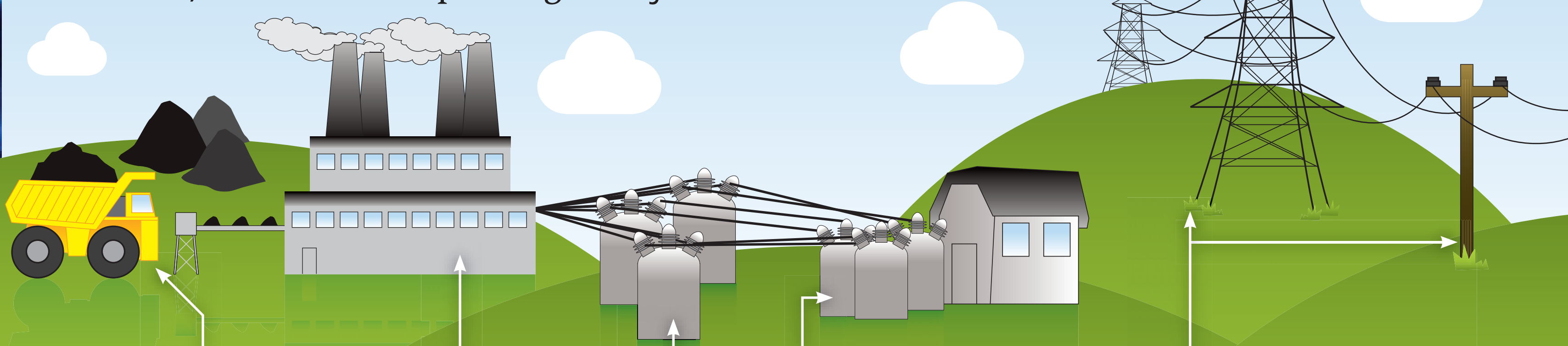
Current
The flow of an electric charge. Unit Volt, symbol V.

Voltage
Or electrical potential difference, the force that drives the current in one direction. Unit Ampere, symbol A.

Resistance
The opposition of an object to having current pass through it. Unit Ohm, symbol Ω.

How electricity reaches your home

It's taken for granted that the light will come on when you hit the switch, here's how the power gets to your house



1. Coal or nuclear
Coal is burnt at the electricity plant to generate steam. Nuclear power stations use a different method (see issue 3) so do hydroelectric plants (see issue 2).

2. Generation X
Be it nuclear, coal-fired or hydro a turbine spins a huge magnet inside a copper wire. Heat energy converts to mechanical energy which then converts to electrical energy in the generator.

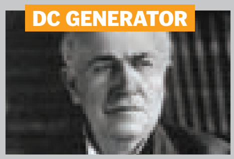
3. Danger! High voltage!
The electricity then flows though heavily insulated wires to a step-up transformer. This raises the pressure so it can travel long distances over the grid. It's raised as high as 756,000 volts.

4. Transform it
The electricity then runs along the power lines until it reaches a substation. This lowers the pressure to around 2,000-13,000 volts.

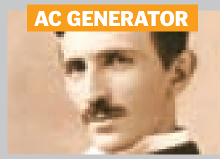
5. Pylon it up
The current continues along the lines to another transformer, either a pole transformer or an underground box, and pressure is lowered again to between 120 and 240 volts.

6. Service with a spark
The next stop is the service box at your home. Here your meter will measure how much power you use. Wires then take the electricity around your home powering your lights and everything else.

1. Michael Faraday 1791-1867
Faraday discovered that when a magnet is moved inside a coil of copper wire, a tiny electric current flows through the wire.



2. Thomas Edison 1847-1931
Edison built a DC (direct current) electric generator in America. He later provided all of New York's electricity.



3. Nikola Tesla 1856-1943
Developed an AC motor and a system of AC power generation. This became the established power supply in the USA.

DID YOU KNOW? Edison saw Tesla's system as a threat to his DC supply and spread stories that it wasn't safe

Electricity in your home

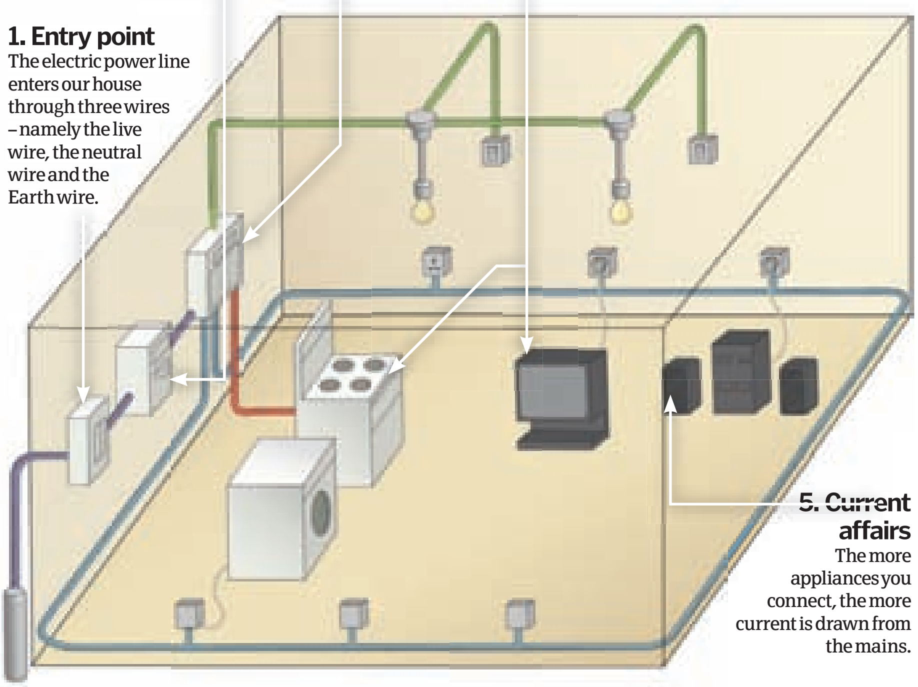
Once electricity reaches your home, how does it get around?

2. Electricity meter
Electricity meters are typically calibrated in billing units, the most common one being the kilowatt hour. Periodic readings of electric meters establishes billing cycles and energy used during a cycle.

3. Distribution box
This contains the main switch and fuses for each circuit.

4. Appliances of science
Domestic appliances are connected in parallel. In a parallel circuit even if there is a fault or short-circuiting in any one line, the corresponding fuse blows off, leaving the other circuits and appliances intact and prevents damage to the entire house.

1. Entry point
The electric power line enters our house through three wires – namely the live wire, the neutral wire and the Earth wire.



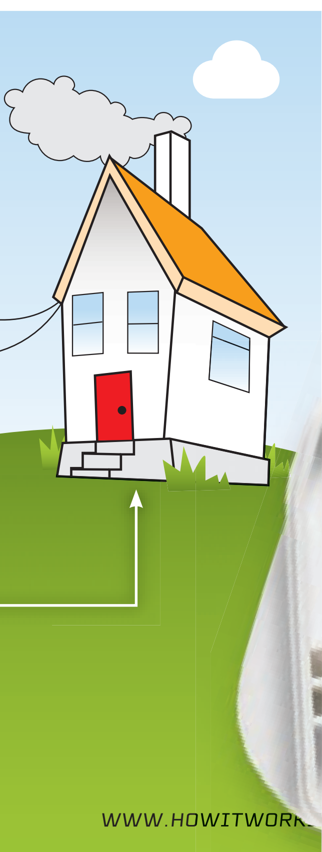
5. Current affairs
The more appliances you connect, the more current is drawn from the mains.

The only thing shocking about AC/DC these days is Angus Young's shorts!

© Weathermango

All about AC/DC

As we've seen, the word electricity is derived from the fact that current is electrons moving along a conductor that have been harnessed for energy. The difference between Alternating Current (AC) and Direct Current (DC) is related to the direction in which the electrons flow. In DC the electrons flow steadily in a single 'forward' direction. In AC electrons keep switching directions. The power supplied by electricity companies is AC because it's much easier to transport across long distances, it can easily be stepped up to a higher voltage with a transformer. It's also more efficient to send along power lines before being stepped down by another transformer at the customer's end.



Why are British plugs so big?

We owe our plugs to World War Two

Visitors to and natives of the British Isles get to use one of the weirdest plugs in the world; unlike many other plugs it has a fuse built in. After being bombed heavily by the Germans during WW2, much of the country had to be rebuilt. Building supplies were short so rather than wiring each socket to a fuseboard they were linked together on one wire and the fuses put in each plug, saving a great deal of copper in the process.

1. Ground to Earth
The Earth wire is there to prevent electric shock and is secured by a screw terminal.

2. Fused
The fuse is designed to blow and break the circuit if the appliance gets too much current.

Inside a British plug

Why do all countries have different plugs?

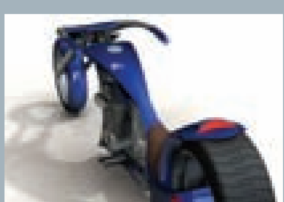
"Dammit, all I wanted was a %$**@* shave!"

Even more than baggage handling and passport control, one of the biggest problems faced by the frequent traveller is the fact that every country in the world has different plugs. In the US, shortly after the AC/DC battle had been resolved (AC won) a man named Harvey Hubbell invented the two pin plug "so that electrical power in buildings may be utilised by persons having no electrical knowledge or skill" (his words). This was later developed into a three pin plug by Philip Labre in 1928 with the third pin for grounding. At the same time developments like this were occurring all around the world with absolutely no global-standardisation. There was some effort made by the International Electrotechnical Commission shortly before the Second World War occurred and spoilt it all!

Two pin or three pin? It depends where you are!

This month in **Transport**

'What goes up must come down' goes the old maxim and the aircraft starring in our main feature this month can do both in a straight line. Vertical Take-Off and Landing aircraft are amazing vehicles and we thought them deserving of a closer look.



TRANSPORT

1. Wings
Through the Harrier's compact wings run a series of exhaust tubes that allow high-pressure air to be filtered from the engine to its tips, increasing stability during manoeuvres.

2. Nozzles
One of the Harrier's Pegasus engine vectoring nozzles. Through these four nozzles – which can be rotated through a 98.5-degree arc – the engine's thrust can be directed for vertical or short take-off.

VTOL aircraft

For the past 60 years, Vertical Take-Off and Landing (VTOL) aircraft have evolved massively as engineers have strived for what can be argued to be the Holy Grail of aeronautics

Harrier Jump Jet

The most famous of all VTOL aircraft, the Harrier fighter jet is utilised all over the world thanks to its advanced technology and aerodynamic versatility

For the past 40 years, since its introduction in 1969, the Harrier Jump Jet has epitomised the vertical take-off and landing concept. Born amid a fervent arms race to produce a light attack, multi-role fighter with VTOL capabilities, the Harrier proved that VTOL could work in reality, advancing the vastly expensive and solely academic efforts that had been designed previously. Indeed, to this day it is still in operation world wide, and praised for its versatility and reliability.

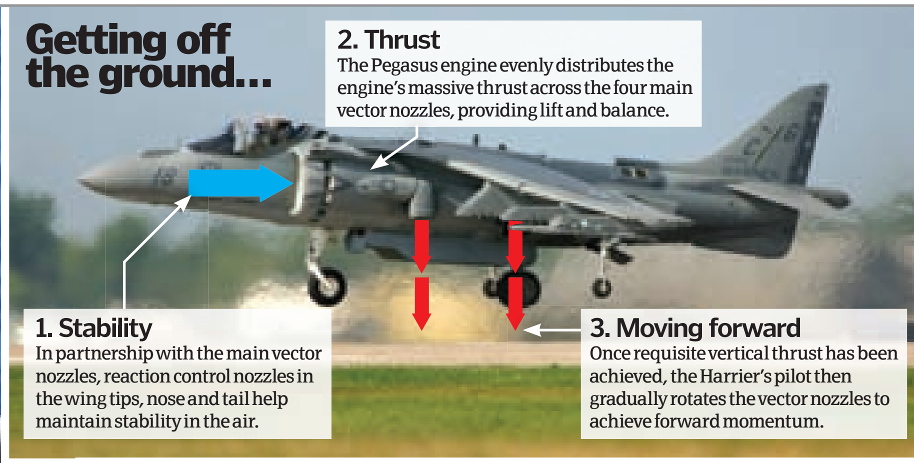
The Harrier's VTOL capabilities are made possible by its Rolls-Royce Pegasus engine, a low bypass-ratio turbofan that features four rotating nozzles through

THE STATS HARRIER JET

WEIGHT 13,968lbs LENGTH 14.5m

MAX SPEED 662mph THRUST 23,500lbf

Six Harriers were lost during the Falklands conflict, all from ground fire and accidents



One of the rotatable vector nozzles necessary to lift the Harrier vertically

© Wyrdlight

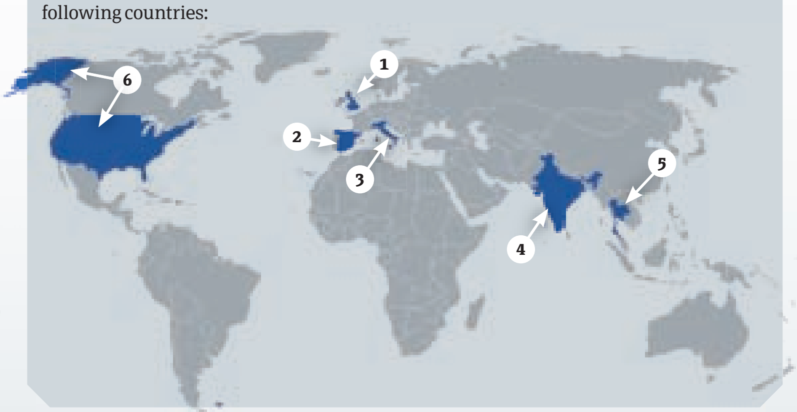
A shot of the Rolls-Royce Pegasus engine that powers the Harrier

ON THE MAP

Harrier deployment

The Harrier is operated worldwide by many military organisations in the following countries:

1 UK
2 Spain
3 Italy
4 India
5 Thailand
6 USA



which its fan and core airflows exhaust. These nozzles can be rotated by the pilot through a 98.5-degree arc, from the conventional aft (horizontal) positioning as standard on aircraft, to straight down, allowing it to take-off and land vertically as well as hover, to forward, allowing the Harrier to drift backwards. All nozzles are moved by a series of shafts and chain drives, which ensures that they operate in unison and the angle and thrust are determined in-cockpit by the pilot.

The control nozzle angle is determined by an additional lever positioned alongside the conventional throttle and includes fixed settings for vertical take-off (this setting ensures that true vertical positioning is maintained in relation to aircraft altitude), short-take off (useful on aircraft carriers) and various others, each tailored to aid the pilot's control of the Harrier in challenging conditions. Of course, the nozzle lever can be incrementally altered too by the pilot, as in order to fly the Harrier, fine control of the throttle in relation to the nozzle lever is central, adding an extra dimension to any potential pilot's training.

As well as the vectoring engine nozzles, the Harrier also requires additional reaction control nozzles in its nose (downward firing), wingtips (downward and upward firing) and tail (down and lateral firing) in order to remain stable once airborne. These nozzles are supplied with high-pressure air filtered from the engine and distributed through a system of pipes that run through the aircraft. Controlled through valves, this sourcing and utilisation of compressed air allows the pilot to adjust the Harrier's movement in pitch, roll or yaw. This system is energised once the main engine nozzles are partially vectored and the amount of compressed air filtered to the anterior nozzles is determined by airspeed and altitude.

> "The X-14 was one of the first VTOL aircraft to utilise the emerging concept of multi-directional engine thrust"

Other VTOL aircraft, old and new

Vertol VZ-2

One of the first fully functional VTOL aircraft, the Boeing Vertol VZ-2 paved the way for the gargantuan V-22 Osprey

Many VTOL aircraft have been designed in the past 50 years, however most fall into one of two categories; those based on vectoring engine nozzles, and those that adopt tilt-wing technology. The Vertol VZ-2 falls into the latter category and was a wildly experimental research aircraft built in 1957 to investigate the tiltwing approach to VTOL. Resembling a conventional helicopter, albeit with an extended plane-like T-tail, the VZ-2 had an uncovered tubular framework fuselage and a single-seater bubble canopy.

The VZ-2 sported twin rotors powered from a single 700hp turboshaft engine, which positioned on its rotatable wings, in partnership with a series of small ducted fans in the T-tail, provided thrust and lift. Due to its lightweight design, the maximum speed achieved was 210mph and it had a low operational service ceiling of 13,800ft as well as a minuscule range of 210km.

Despite these shortcomings, the Vertol proved a very successful and fruitful experiment as over its eight year life span it made 450 flights, including 34 with full vertical to horizontal transitions. The heritage of the VZ-2 can be seen today in the titanic tilt-rotor design and technology used on the V-22 Osprey.

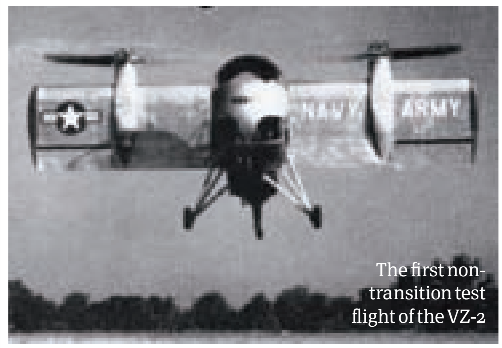
© George Chirnilevsky

> "The VZ-2 sported twin rotors powered from a single 700hp turboshaft engine"

The Statistics

Vertol VZ-2

Crew: 1
Length: 8.05m
Wingspan: 7.59m
Height: 4.57m
Weight: 3,700lb
Engine: 1x Avco Lycoming YT53-L Turboshaft



The first non-transition test flight of the VZ-2

Bell X-14

An experimental fixed-wing aircraft, the X-14 pushed back the boundaries of VTOL technology

Unlike the Vertol VZ-2, Bell's X-14 experimental VTOL aircraft was crafted and designed to be as close to existing aeroplanes as possible, with it even being constructed from parts of other existing aircraft. Not only were its wings fixed but its engine was in the standard horizontal position and, with a top speed of 180 miles per hour and operational service ceiling of 20,000 feet, the X-14's design appeared conventional. However, the X-14 was one of the first VTOL aircraft to utilise the emerging concept of multi-directional engine thrust, relying on a system of movable vanes to control the direction of its engine's power.

Interestingly, after a couple of years of successful flights, the aircraft was delivered to the NASA Ames Research Center as – in addition to providing a great deal of data on VTOL flight – its control system was similar to the one proposed for the lunar module and it was deemed a worthy test vehicle for space training. Indeed, Neil Armstrong, the first man to walk on the moon, flew the X-14 as a lunar-landing trainer and it was continually used by NASA until 1981 (seeing a total of 25 pilots climb in and out of its cockpit) when it was retired from service.

The Statistics

Bell X-14

Crew: 1
Length: 7.62m
Wingspan: 10.36m
Height: 2.40m
Weight: 3,100lb
Engine: 2x Armstrong Siddeley Viper 8 Turbojet

The X-14 being prepped on runway before a test flight

The Bell X-14 on a demonstration flight

Maximum lift
1 Neil Armstrong flew the X-14 VTOL aircraft as part of his space training, as its systems were similar to the lunar lander's he was to operate on the moon.

'Ow much!?
2 Despite its shocking performance, the average cost of a Yak-38 post retirement was $18.5 million, roughly half that of a newly bought AV-8B Harrier II.

Death toll
3 From 1991 to 2000 there have been a total of 30 fatalities caused by V-22s crashing during testing, the last being caused by a hydraulic leak and system failure.

Droning on
4 Many modern, unmanned machines have taken advantage of VTOL capabilities, often acting as surveillance drones or lightly armed missile launchers.

Flying bed
5 The first VTOL aircraft to be produced in 1953 was nicknamed 'The Flying Bedstead', as its skeletal frame resembled a wire frame bed.

DID YOU KNOW? *The Yak-38 used a hands-free landing system, utilising a telemetry/telecommand link to land*


A Yak-38 on the deck of a Soviet aircraft carrier

Yak-38

The Soviet Naval Aviation's first and only foray into VTOL multi-role combat aircraft, the Yakovlev Yak-38


A retired variant of the Yak-38 with one of its vector nozzles clearly visible

© George Chirnilevsky

The Statistics
Yak-38

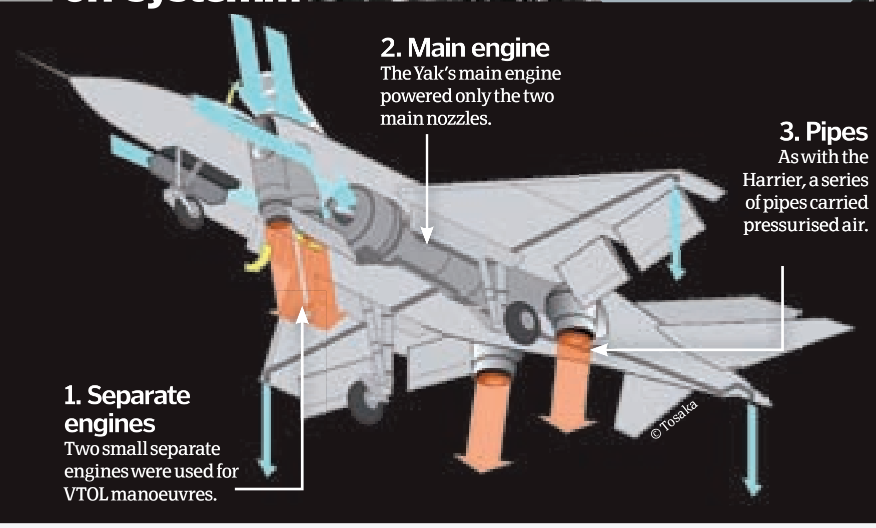
Crew: 1
Length: 16.37m
Wingspan: 7.32m
Height: 4.25m
Weight: 16,281lb
Engine: 1x Tumansky R-28 V-300 Turbojet

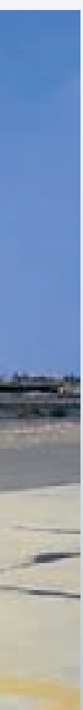
Influenced in design by the British Hawker P.1154 and Harrier Jump Jet, the Yak-38 VTOL aircraft looked similar to its contemporaries, but its radically different internal configuration and general poor quality build and systems turned out to be a costly mistake. Contrary to the Harrier's single Pegasus engine, where thrust was vectored through four nozzles from a single source, the Yak-38 featured only two nozzles from the main engine, relying on a pair of separate, less-powerful engines housed in the front portion of the aircraft to be used in conjunction for vertical take-off and landing.

Apart from being a less-refined and underdeveloped system, the Yak-38 was built en-masse; however, soon it encountered massive problems during sea trials. In hot weather the separate lift jets often failed to start (due to oxygen starvation), leaving it stranded on the flight deck and while it was initially deemed capable of carrying heavy payloads, the hot weather also reduced its operational range to such an extent that only extra fuel tanks could be carried. Further, the average engine life span of the aircraft was a minuscule 22 hours and many pilots encountered serious engine problems in every flight they undertook (over 20 Yak-38s crashed due to system/engine failure), with it quickly gaining a reputation as a killer. Finally, it was horrendously difficult to fly and could only be landed by remote telemetry/telecommand link, rendering it useless in land warfare.

Obviously, the Yak-38 did not live up to its conceptual ideal – a multi-mission 980km/h combat jet with VTOL capabilities, a service ceiling of 40,000ft and an operational range of 240km – and after a final deadly crash in June 1991 was retired out of service.

Yak-38 take-off system…





V-22 Osprey

The world's first tilt-rotor aircraft, the V-22 Osprey is at the cutting edge of VTOL technology

The pinnacle of tilt-rotor/wing VTOL aircraft, the V-22 has been in development for 30 years and offers the cargo carrying capabilities of a heavy lift helicopter, with the flight speed, altitude, endurance and range of a fixed-wing cargo plane.

This fantastic hybrid of two distinct forms of aircraft comes courtesy of its revolutionary tilt-rotor technology – twin-vectoring rotors that can be adjusted over 90 degrees by the pilot – which attached to foldable fixed-wings, allow for vertical take-off and then conventional flight. Both rotors are powered by Allison T406-AD400 tilt-rotor engines that – considering its massive size and carrying capacity (20,000 pounds internally) – develop 6,150hp each.

Interestingly, the V-22's design, despite being more accomplished at short take-off and landing (STOL) manoeuvres, loses out to tilt-wing VTOL aircraft – such as demonstrated in the Vertol VZ-2 – in VTOL manoeuvres by ten per cent in terms of vertical lift. However, due to the lengthy periods of time that the V-22 can maintain its rotors over 45 degrees, longevity of the aircraft is greatly improved.

Unfortunately, despite current safe and successful operation in the Iraq and Afghanistan conflicts, during testing numerous accidents occurred involving the V-22, resulting in over 30 deaths to crewmen and combat troops. For more info on the V-22 see issue three of How It Works.


The V-22 broke new ground for VTOL aircraft

The Statistics
V-22 Osprey

Crew: 4
Length: 17.5m
Wingspan: 14m
Height: 6.73m
Weight: 33,140lb
Engine: 2x Rolls-Royce Allison T406/AE 1107C-Liberty Turboshaft

"Skilful drivers can avoid wheelspin by careful use of the accelerator, especially on wet roads"

Traction control

A vital process that keeps you on the road

DID YOU KNOW? Most traction control systems don't work with ice. If two or more wheels can't gain traction and keep spinning, the system gets confused and can make things worse.

Spinning wheels may look cool in the movies but in reality they can be dangerous and reduce your car's ability to accelerate. That's because if the wheels are spinning, the tyres are not gripping the road.

Skilful drivers can avoid wheelspin by careful use of the accelerator, especially on wet roads. However, most of us benefit from traction control which senses impending wheelspin and steps in to take avoiding action.

Cars with traction control also have an antilock braking system (ABS) which stops the brakes from locking up and causing a skid. As part of ABS, each wheel has a sensor that measures the speed it's rotating and these are also used by the traction control system. If one wheel is suddenly sensed to be turning much faster than the others, the traction control assumes that it is spinning and applies the brake, in a rapid pumping action, to that wheel to slow it down. In fact, you could say it's ABS in reverse!

That is all a basic traction control does. However, some four-wheel drive cars have more sophisticated systems that actually control how much power is being fed to each of the four wheels. This can aid traction under heavy acceleration by transferring power from the rear to the front wheels when the rears begin to lose traction.

It is also possible to improve a four-wheel drive car's handling in the same way. When a car understeers, the front wheels push out of the bend (in other words, the car doesn't turn as much as required). By reducing the amount of power being fed to the front wheels (and even applying braking to the inside back wheel), the car can be brought back on track.

The opposite problem is oversteer, where the car turns too much and, in extreme cases, may spin out of control. Applying more power to the front wheels will help correct this tendency. It all combines to make modern cars safer and faster in all sorts of conditions.

Unleash your inner Stig!

5 TOP FACTS TRACTION CONTROL

1 Limited-slip differential
The predecessor of traction control was the limited-slip differential – still an integral part of the systems in modern sports cars.

2 First traction control
Buick was the first car manufacturer to offer a form of traction control, in 1971.

3 Anti-slip regulation
Traction control is also known as anti-slip regulation (ASR).

4 Formula One
From 2001, Formula One cars used traction control to avoid wheelspin, but it was banned in 2008.

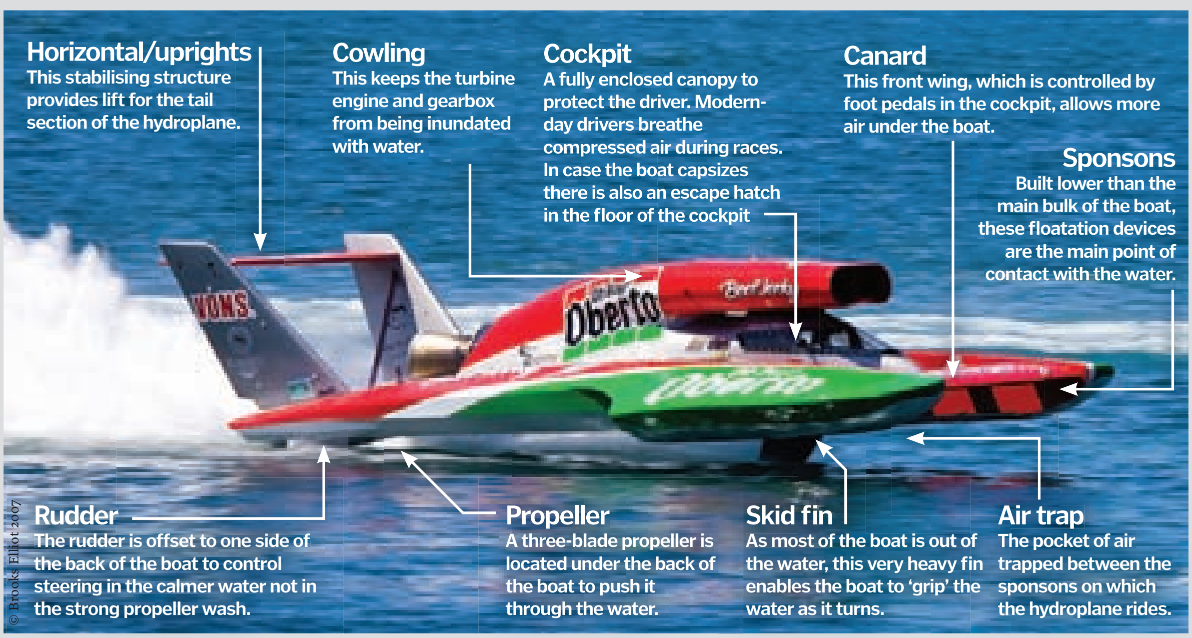
5 TCS v ESC
Although traction control and electronic stability control (ESC) are both similar, they have different goals.

Hydroplanes explained

The ultimate vessel for racing on water

Used for extreme racing, a hydroplane is a high-speed boat that experiences very little drag because it planes over the surface of the water at speed. Planing causes the boat to rise slightly out of the water, the boat is then supported not by its buoyancy but by the motion of passing water, forcing the hull up out of the water. Because the hydroplane is barely touching the water it can reach incredible speeds.

There are two main types of hydroplane – conventional and cabover (as in the cab is over the engine) – and their main differences are that the driver of a conventional hydroplane sits behind the engine and the vehicle has a large rounded shovel nose, while the cabover driver sits in front of the engine with what's known as a pickle fork front end (created by the shape of the two sponsons).



5 TOP FACTS
KIT FOR RUNNERS

Compression tights
1 Compression tights protect your muscles when running and can help them to recover quicker, as well as optimising temperature in hot and cold conditions.

Nike Plus
2 Keeping a running log improves performance and the Nike Plus keeps track of pace, distance and calories burned, as well as linking to an online community.

Running belt
3 Carrying a water bottle can change your running biomechanics, so strapping on a belt with a bottle holder frees up your hands and makes you run more naturally.

Socks
4 Many runners don't think about what they put on their feet, but the right pair will manage moisture, regulate temperature, add extra support and prevent blisters.

Running jacket
5 Jackets really cram in the technologies and can be expensive. The best will be lightweight and fit snugly, as well as protect you against the elements.

DID YOU KNOW? *Nike co-founder Bill Bowerman invented the waffle sole by pouring liquid urethane into the family's waffle iron*

Starting your car

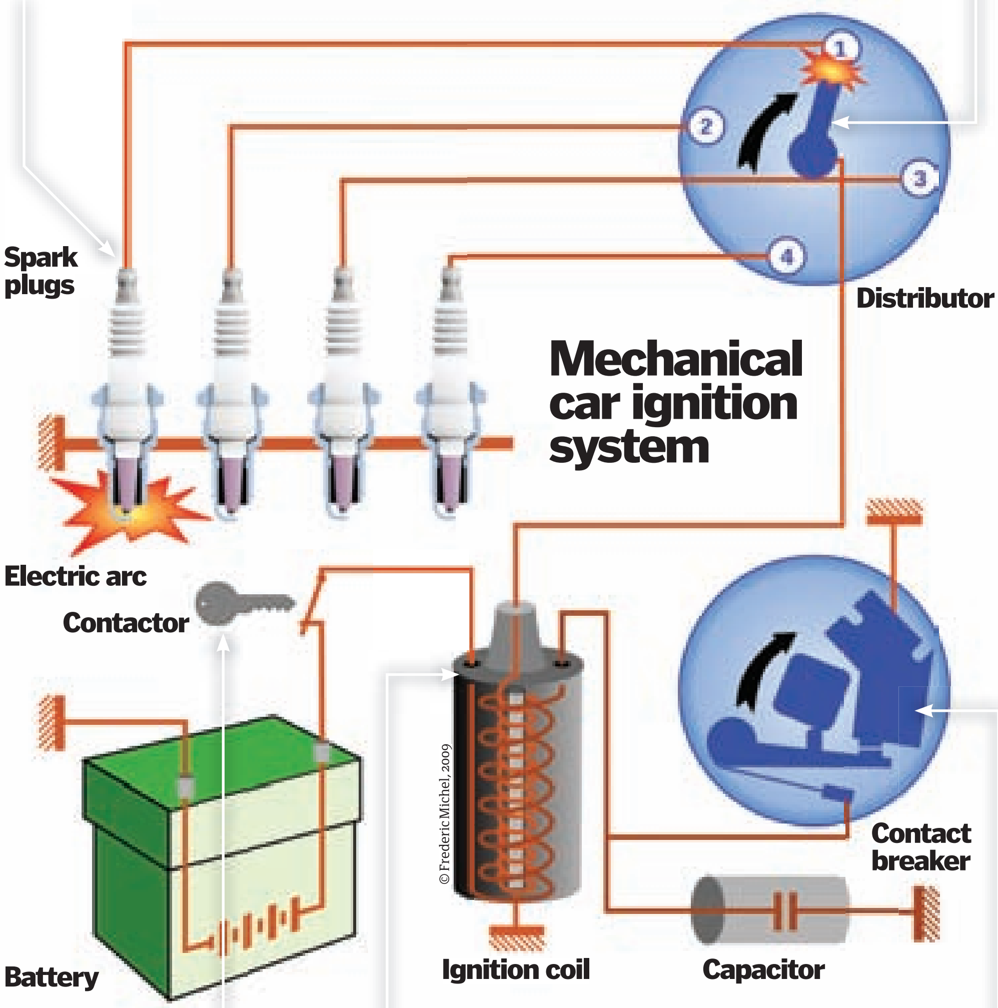
Understanding how mechanical car ignition systems work

A car's ignition system is like a large electrical circuit that delivers energy to run the car and it affects both performance and fuel efficiency.

Today's mechanically timed car ignition systems ignite the fuel in an internal combustion engine, using an electrical spark. Engine fuel is transformed into gas when it is mixed with air and burned in a cylinder. When this happens the pressure built inside the cylinder forces a piston up, creating compression. Timing is everything and the fuel must be ignited at the optimal moment in the piston stroke in order to achieve the maximum power but minimum emissions. Igniting the compressed mixture with a spark at just the right time causes combustion, which thrusts the piston down in the engine block creating mechanical energy and transforming combustion into motive power.

5. Spark plugs
Fitted into each of the cylinder heads of a car's engine, spark plugs and their adjoining spark plug wires force high voltage electricity from the ignition coil into the engine, igniting the compressed air and fuel mixture in the engine.

3. Distributor
Consisting of a rotor and a cap, the distributor distributes electricity from the ignition coil to the spark plugs and engine cylinders in the correct order at the correct time. The rotor spinning inside the distributor enables the flowing electrical current to pass to the spark plugs via output contacts.



1. Ignition switch
Turning the key in the ignition releases low voltage electricity from the battery to the starter.

2. Ignition coil
Connected to the distributor, this electromagnet made of two coils of wire also functions as an inductor transforming the battery's low voltage into high voltage. When the circuit is broken the magnetic field of one coil collapses, engulfing the second coil with a powerful magnetic field which is fed to the distributor via high-voltage wire.

4. Contact breaker
Beneath the distributor is the contact breaker, which interrupts the current in the ignition coil at just the right time – a sensor tells the engine control unit the exact position of each piston. This induces a high voltage in the coil – strong enough for electricity to momentarily jump across the electrodes at the end of each spark plug.

Running shoes

The technology behind running shoes, for getting that personal best

Getting the right running shoe is key to improving speed without injury. Shoe technology has come on in leaps and bounds over the last decade with manufacturers investing in scientific experiments on the way we run, the difference between genders and so on.

Gel technology is used in both the rear and forefront of running shoes, which helps to reduce impact and also propel the foot forward. Midsoles have become more durable and a lot more flexible, meaning that they bounce back into position to support the foot throughout its full range.

Each company has its own inventions to make us better runners. Asics uses the Impact Guidance System (IGS), which is based on the philosophy of the human body to enable the foot to move through its natural heel-to-toe movement. Nike, however, has been responsible for a number of innovations over the years, but its Lunarlite range looked to astronauts in space to create a shoe with the lightest and most responsive cushioning ever created, which spreads across the whole foot and reduces impact, and therefore helping to prevent injuries.

1. Upper
A breathable and water-repellent structure for tying the laces.

2. Insole
To provide comfort and moisture management.

3. Gel cushions
A selection of gel cushions reduce impact.

4. Midsole
Lightweight and flexible, the midsole provides shock absorption.

5. Outsole
Made from carbon rubber this layer is hard-wearing and slip-resist.

"In this case, the kinetic energy is turned into heat and dissipated into the air"

There's no hiding from the science of breathalysers

Breath tests

How do breathalysers use the air in your lungs to find out how much you've had to drink?

Breathalysers use the way the body processes alcohol to analyse how much you've had to drink. As oxygen passes into your bloodstream when you breathe, alcohol passes into the air in your lungs and it's this alcohol that breathalysers measure using two different methods.

Roadside breathalysers use fuel cells to measure alcohol content by creating a chemical reaction that oxidises the alcohol and produces an electrical current that increases in strength depending on how much alcohol is present.

Larger breathalysers commonly used in police stations use spectrophotometers to achieve the same results. These identify molecules based on how they absorb infrared light, count how many ethanol molecules are present and use them to measure the alcohol content of the subject's blood.

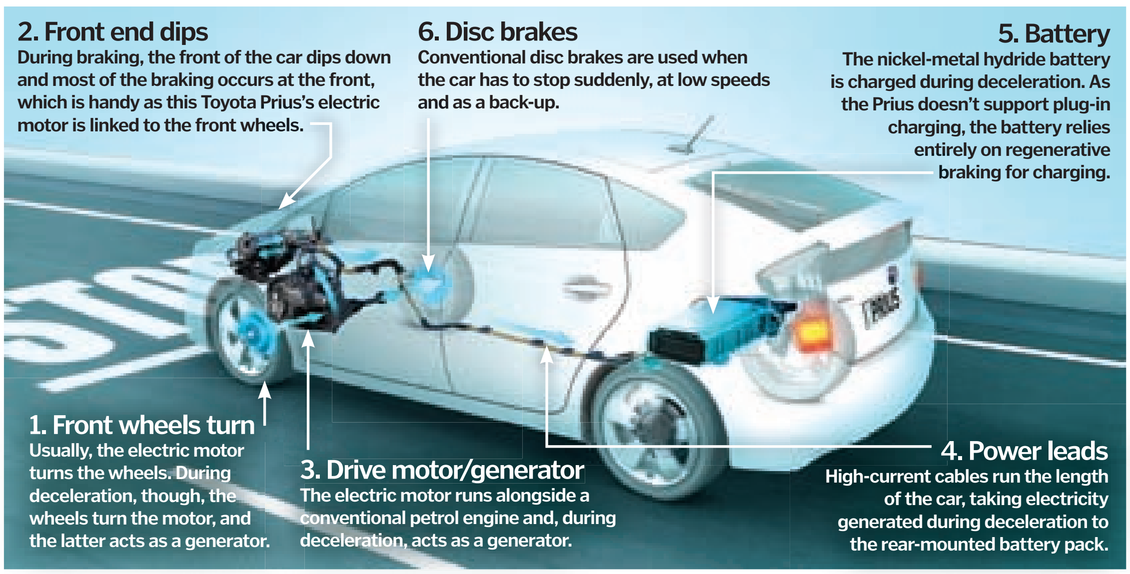
I'm a little teapot…

Regenerative braking

Instead of wasting the power generated during braking, a regenerative system pumps the energy back into the batteries

When a car's moving it's carrying a lot of kinetic energy and when the driver hits the brakes, something has to happen to this energy. Energy can't be destroyed, only transformed from one form to another and, in this case, the kinetic energy is turned into heat and dissipated into the air. With a petrol or diesel-engined car, there's nothing that can be done to avoid this wastefulness. However, hybrid and electric cars can capture the energy and feed it back into the car's battery.

These cars have an electric drive motor (or motors) and during deceleration this works as a generator, creating electricity that charges the batteries. This is possible because an electric motor and a generator are essentially the same thing – apply a current to the inputs and it spins as a motor; rotate the shaft externally and the unit produces electricity. The motor therefore helps to slow the car.



© Toyota

How do hubless wheels work?

The hubless-wheeled motorbike ridden by Captain Kirk in last year's Star Trek isn't just closer than you think, it's already been built…

While the wheels of hubless bikes look empty, there's a lot happening inside. The outer part of the wheel is still a tyre, but it's joined by a centre-free rim and a circular brake system, all of which rotate. The fixed part of the wheel sits within that and has the bike's steering directly attached to it which, in turn, is made much more precise by being in direct contact with the wheels. The bike's unsprung mass is also reduced, minimising wear and tear.

Hubless wheels also reduce vibration, are more comfortable to ride, brake far more precisely and, of course, look great. While they're not perfect, requiring precision manufacturing and exposing crucial components to the elements, they're a real step forward. So who knows, in a few years we may all be biking around looking as good as Captain Kirk, and who wouldn't want that?

Illustration © Mike Hansen

DID YOU KNOW? Riding-type lawn mowers are often modified and raced in special events, a sport invented in 1973


©Travelerroo

A hovering, rotor-based lawn mower with extended handle

©Daniel Barber

Lawn mowers

Explaining the mechanics behind these machines

Lawn mowers come in a variety of flavours, but most – notably those pushed by humans – are either rotor or cylinder variants. Cylinder mowers, which were the first to be designed in 1827 by inventor Edwin Budding, work by juxtaposing a fixed, horizontal cutting blade against a fast-spinning cylinder of blades rotating in helix form around a central axis, forcing grass against a cutting bar. These types of mowers were originally powered by the movement of their human operator, generating rotational motion by being pushed, however modern versions are now often powered by electric motor.

The rotor mower works in a similar manner, but instead of rotating a helix of blades around a horizontal axis, cutting grass against a static blade, it rotates scythe-type blades around a vertical axis, relying on the kinetic energy of the blades alone to cut grass. Rotor mowers can be powered in various ways, with some allowing cable-free operation thanks to internal combustion engines, others by electric motor, and the most common (as often found in private homes) corded electric versions.

Larger mowers exist mainly in commercial, industrial or agricultural spheres, where large areas of grass need to be cut regularly. Here, tractor, riding and robotic mowers are operated which are capable of cutting multiple acres of land without having to be emptied or refuelled.

Ski bindings

Keeping you upright while on the snow

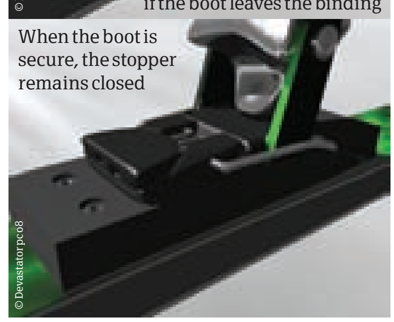
There are three types of binding for the various ski styles: alpine, cross-country and telemark. The alpine version secures the boot at the toe and heel, whereas cross country skis – considered to be less aggressive – only catch at the toe. Connecting via the toe and heel, telemark bindings need greater flexibility so employ a design that allows the heel to move back and forth.

To reduce injury in a fall, alpine bindings release the boot when a certain amount of torque is applied. This level differs for each skier, calculated on weight, height and boot size. This variety also includes a brake to stop the ski moving when no boot's attached; the brake pivots and aligns with the ski when downward pressure is applied.

The stoppers on alpine ski bindings


© Devastator pc08

The stopper comes down if the boot leaves the binding


© Devastator pc08

When the boot is secure, the stopper remains closed

"Think of it as an electronic equivalent of those kids' pictures that change as you move them from side to side"

The 2010 Range Rover dashboard

With virtual dials and a video screen that can display two images at once, the new Range Rover takes in-car entertainment to new heights

The Range Rover has come a long way from the original utilitarian off-roader of the Seventies. The latest model offers superb comfort and performance – both on and off road – and is packed with astonishing technology.

At first glance, the instrument panel looks conventional with its two dials, but look closer and you'll see they are, in fact, 'virtual' dials formed by a 12-inch wide thin-film transistor (TFT) display.

The space between the dials is used to display a range of information, from ambient temperature to the amount of space available for parking. And when the car is taken off-road the display can show specialised information such as steering angle, wheel articulation and suspension settings. Being able to customise the display in this way allows the driver to see just want he or she needs to at any one time, therefore reducing distractions and ensuring a clean, uncluttered dashboard.

The satnav display also helps reduce driver distraction. Like many luxury cars, the Range Rover can be ordered with a built-in DVD player but, while on other cars this has to be disabled while under way to ensure the driver's eyes aren't led astray, in the Range Rover the passenger can happily watch a movie which the driver can't see. However, on the same screen and at the same time, the driver will be able to view the satnav readout.

This world-first is made possible thanks to a dual-view touch screen. This uses a parallax barrier which sits over the LCD and allows vertical columns of pixels to be seen from one side but not the other side. Think of it as being an electronic equivalent of those kids' pictures that change as you move them from side to side.

It's amazing technology that we're sure will one day soon filter down into more affordable cars.

Head to Head
IN-CAR ENTERTAINMENT SYSTEMS

MOST EXPENSIVE

1. Naim for Bentley

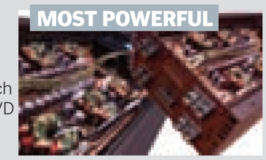
The Bentley Mulsanne has a bespoke sound system that can be yours for £220,000 with a car included!

MOST SOPHISTICATED

2. Pioneer AVIC-F10BT

As well as the usual audio outputs, this touch screen system has a DVD player, satnav and a hands-free phone kit.

MOST POWERFUL



3. Ground Zero GZPA 2.20000SPL

This amplifier has an output of up to 22,000 watts, along with Plutonium speakers.

DID YOU KNOW? *The parallax barrier technology was originally developed for 3D displays that could be viewed without glasses*

DRIVER'S VIEW

© Range Rover

Sitting on the right (in the UK, at least) means that the driver has a clear view of the satnav screen, allowing them to be guided safely to the destination.

CENTRAL VIEW

© Range Rover

Viewing the screen from the centre means you see a combination of both the left and right images. Thankfully, rear-seat passengers have their own DVD screens.

PASSENGER'S VIEW

© Range Rover

While the driver keeps an eye on the satnav, the passenger has a clear view of a DVD, no doubt improving their swimming technique in this instance.

1. Instrument panel
12-inch wide, super-clear TFT screen displays virtual dials plus a choice of other information, which the driver can select as required.

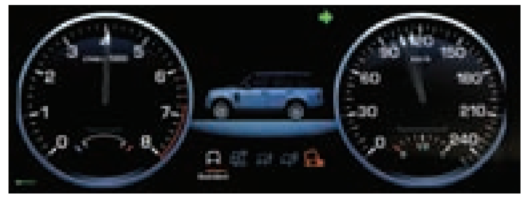
3. Steering wheel
Fingertip controls let the driver select TFT screen readouts, operate the radio, set the cruise control and make phone calls without taking his or her hands off the wheel.

7. Start button
Press here and the V8 petrol or diesel engine bursts into life. Top speed is as much as 140mph with the range-topping 5.0-litre supercharged petrol powerplant.

4. Climate control
Driver and passenger can set precisely the temperature they want to be comfortable.

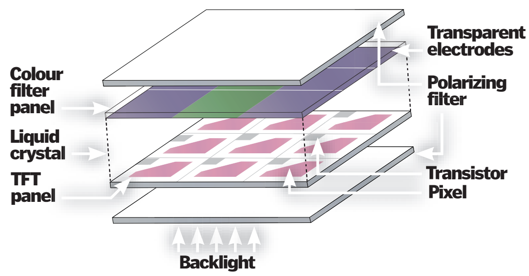
9. Speaker system
A 14- or 19-speaker system developed in conjunction with audio specialist Harmon Kardon brings concert hall quality into the Range Rover.

© Range Rover



Instrument panel

The 'virtual' dials are displayed on a TFT screen (an industry-best at 12" wide). It consists of semi-conductors that turn 'on' and 'off' to create an image of pixels. The advantage of TFT is that the info between the main dials can be altered to suit the driver's needs.



Entertainment on the move

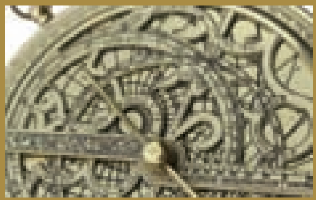
Ever since the first cars, people have wanted music on the move. In the early days, they had to take their wirelesses and gramophones out of the house and into their car. It wasn't until the Thirties that the first purpose-made car radios appeared, under the name Motorola.

In-car entertainment really took off in the Sixties with the invention of the Compact Cassette and the less successful eight-track cartridge. By the Eighties, people were starting to create custom installations, with powerful amplifiers and speakers. Then CDs began to displace cassettes and, in turn, these were displaced by the iPod.

In-car TVs appeared in the late Nineties, but reception problems meant their appeal is limited. DVD players, on the other hand, have proved very popular. The 21st Century then saw the rise of the in-car satellite navigation system. Expensive and bulky at first, you can now have one built into your car, or use a standalone unit or mobile phone.

This month in **History**

We're big fans of amazing machines from the past and the exploded view of a World War II Tiger tank takes pride of place in our history section this month. The war theme continues later with a look at the territories of Britain's ancient tribes and the techniques of medieval sword fighting. More peaceful articles include ancient navigation gadgets, the first telephone and a look at how the Eiffel Tower was built.



HISTORY

The Tiger tank

The German heavy tank of choice during World War II, the Tiger was a formidable adversary, bringing massive armour and firepower to the theatre of war

Tiger tanks were deployed throughout Europe as well as Africa during World War II

© Esselborn

Along with the Panzer, the Tiger is one of the most iconic German tanks of the Second World War. A monster conglomeration of metal and man, built to puncture holes in allied forces from the snowy plains of Russia, through the rolling countryside of France, to the dusty desert plains of North Africa, the Tiger was feared and rightly so, as it was an efficient and powerful killer. It was armed with a 8.8cm main gun, capable of firing rounds that not only tore through enemy armour but also carried highly explosive tips which literally ripped man and machine in two. On top of this it sported armour that was impregnable at wide firing angles and distances and was driven by commanders who had already proved themselves in warfare. It was due to these attributes that Tiger tanks accounted for thousands of allied kills.

Central to the Tiger's success was the radical change in its design philosophy. Switching from the traditional all-rounder designs of earlier German tanks, the Tiger was built with a focus on massive armour and firepower at the expense of manoeuvrability. This gave the Tiger the stopping power to pierce any armour the allied forces brought to the field of war, while also greatly minimising the probability of having its own armour broken. In fact, with 100mm (3.9") frontal hull armour, as well as the basically impregnable 120mm (4.7") frontal turret armour, attempting to take on a Tiger from the front was almost impossible. Indeed, historically in order to take out a Tiger allied forces were

GERMAN

1. Tiger

Twice as long in production than either the M26 or Iosif Stalin, the Tiger was one of the most technically advanced, and deadliest, tanks of the age.

AMERICAN

2. M26 Pershing

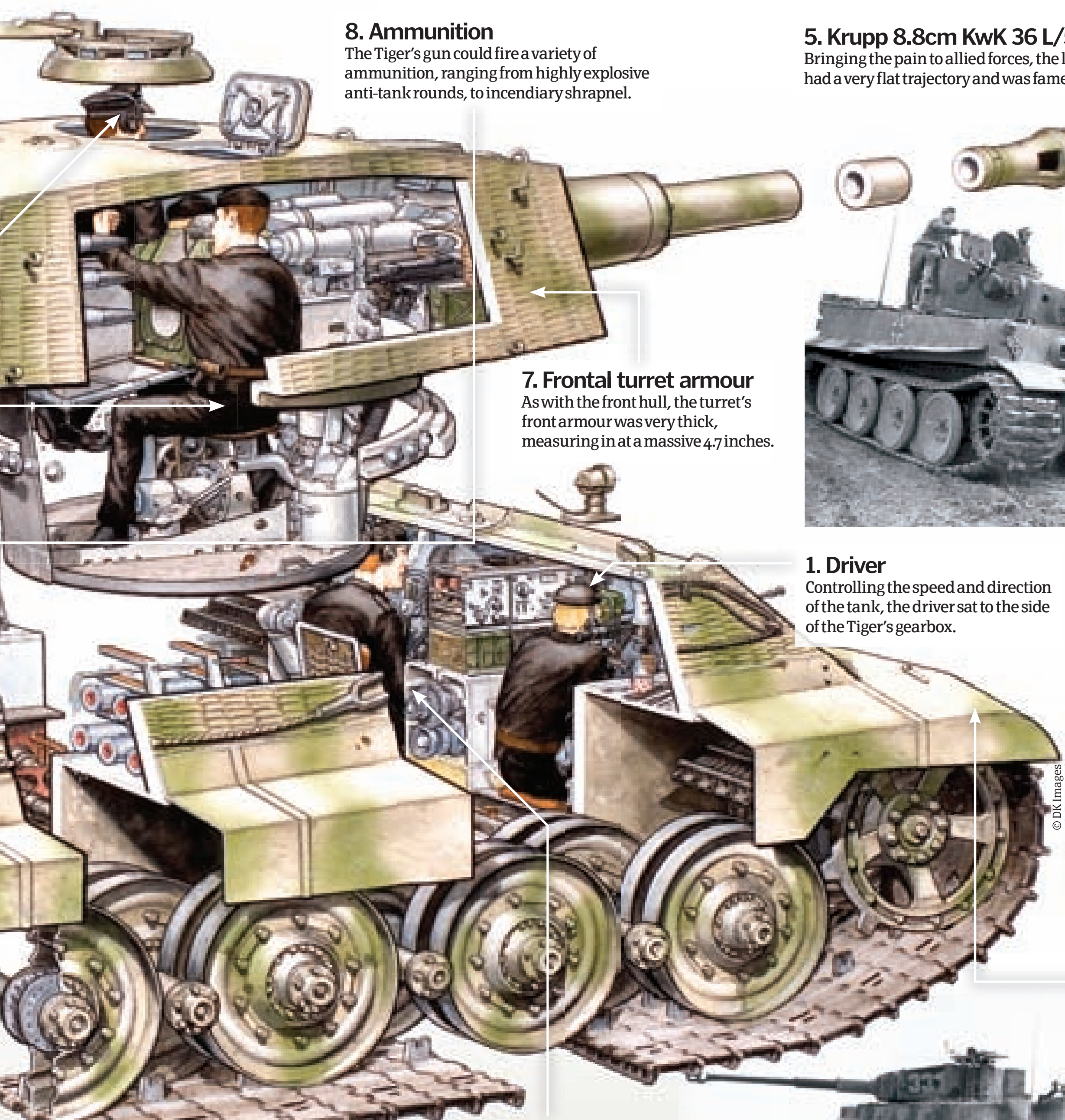
The American counterpart to the Tiger, the M26 Pershing was produced during WWII. It was lighter and quicker than the Tiger, with an impressive M3 90mm gun.

RUSSIAN

3. Iosif Stalin

The Russian equivalent of the Tiger, the Iosif Stalin evolved through numerous iterations throughout WWII. The tank sported a massive D25-T 122mm gun and was very light.

DID YOU KNOW? *According to documents, a number of Tiger tanks destroyed enemy tanks at ranges greater than one mile*



© DK Images

8. Ammunition

The Tiger's gun could fire a variety of ammunition, ranging from highly explosive anti-tank rounds, to incendiary shrapnel.

5. Krupp 8.8cm KwK 36 L/56 gun

Bringing the pain to allied forces, the large Krupp-made 8.8cm gun had a very flat trajectory and was famed for its accuracy and range.

7. Frontal turret armour

As with the front hull, the turret's front armour was very thick, measuring in at a massive 4.7 inches.

1. Driver

Controlling the speed and direction of the tank, the driver sat to the side of the Tiger's gearbox.

6. Frontal hull armour

The armour of the front hull was 3.9 inches thick, providing maximum protection from frontal assaults.

2. Radio operator

Crucial for communication and co-ordinating the attacks, the Tiger's radio operator was pivotal to its successful operation.

© Pirath, Helmuth

Certain terrains such as mud caused the tank's wheels to jam

© wassen

Most Tiger tanks are now decommissioned and reside in museums

© Scheck

often forced to flank it so they could target the weaker side and rear armour, as well as getting as close as possible to maximise the chance of piercing it.

The firepower that this new breed of tank gave the German forces on the other hand, did not need anywhere near that level of refinement in order to score a hit. The Krupp-made 8.8cm KwK 36 L/56 gun allowed German gunners to hit targets well over 1,100 metres away no bigger than 50cm². In fact, reports from the time indicate that Tigers took out numerous allied tanks at a range of over a mile (1,600 metres), thanks to their gun's flat trajectory and expulsion of rounds at high velocity. Ammunition types could be varied too, allowing the gunner to load the Tiger's main gun with rounds to suit most situations, be that highly explosive anti-tank shells, armour piercing rounds or anti-infantry incendiary shrapnel rounds.

Of course, as we know from the unfolding of history, the Tiger's dominance was short lived. This was due to multiple factors but mainly stemmed from its costly production – limiting the amount of units produced compared to its contemporaries – and also its poor mobility over certain terrain. Indeed, the Tiger was often too heavy for bridges and therefore had to drive through shallow rivers and gullies, a dangerous process considering the fragile nature of its multi-wheel, interlapped design, as in cold weather water, snow and mud often jammed them badly. Of course, the final nail in the coffin was at the close of the war, when much of Germany's armaments were destroyed post defeat.

The Statistics

Tiger tank

© Homu

Price: 250,000 Reichsmark
Speed: 38km/h (24mph)
Operational range: 110-195km (68-120 miles)
Weight: 56.9 tons
Crew: 5
Engine: Maybach HL230 P45 (V-12, 690.4hp)
Firepower: 8.8cm KwK 36 L/56 (92 rounds)

"Some tribes such as the Venicones buried their dead in stone casings, very much akin to a tomb or coffin"

What was Britain like before the Roman invasion

Britain's tribal territories

Before the Roman invasion in 55 BC, Britain was characterised by a large number of ancient tribes, each with its own culture

While the first modern humans populated the area we now call Britain at the end of the Ice Age (6,500 BC), very little is known about the intricacies of their culture and peoples until recorded history begins circa the Roman invasion of 55 BC. Indeed, if it were not for the Roman chroniclers of the time such as Tacitus and Ptolemy, who met the ancient tribes of Britain either in trade or in war, our sketchy picture of these peoples would be even more incomplete than it is today. However, centuries of historical records, stories and archaeological finds have at least given us a snapshot of their lives, leaders and customs.

Before the Roman invasion there were over 27 separate tribes living in Britain. These people had grown from the early hunter-gathers who had inhabited the area, and later the farmers who had developed agriculturally focused societies and who had built such sophisticated structures as Stonehenge. For the last 600 years BC though, influenced much by the arrival of the Celts from the continent, expansionist tribal kingdoms headed by dynastic and highly territorial rulers and chieftains arose, delivering cultures of fierce violence and sophisticated manufacture, artistry and trade.

While the Romans are often credited with bringing a unified currency, as well as structured towns and a host of amenities and technology, these features – at least in part – were already integrated into areas of British tribal society. Some tribes such as the Venicones buried their dead in stone casings, very much akin to a tomb or coffin. Others, like the Iceni, Catuvellauni and Atrebates, had already created and distributed currency throughout their territories.

Over 200 years, however, from 55 BC until well into the 2nd Century AD, the ancient tribes of Britain were either conquered or indoctrinated into the Roman empire, a process that largely converted the population's attitudes and cultures to those shared on the continent and saw a gradual climb in society towards standards of administration, architecture, sanitary systems and health care that resonate with today's society.


© Rhys Jones

The view of an encircling ditch around Danebury hill fort

Head to Head
ANCIENT BRITISH TRIBES

MOST REBELLIOUS


© PHGCOM

1. Iceni
Located: Norfolk
Facts: One of the most rich and powerful tribes in Britain, the Iceni revolted against the Romans after the death of their client-king Prasutagus and were lead until her death by Prasutagus' wife, the renowned Queen Boudicca.

MOST CIVILISED


© John Opie

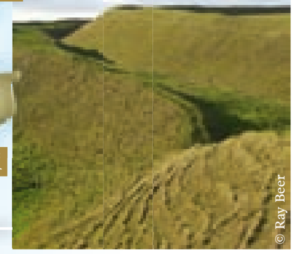
2. Catuvellauni
Located: South-east
Facts: One of the most pro-Roman tribes, the Catuvellauni quickly adopted Roman lifestyles and, as a result, were made very rich and powerful. One of the most famous British tribal kings, Cunobelinus, heralded from the Catuvellauni.

MOST DEFENSIVE


© Nigel Mykura

3. Durotriges
Located: Dorset
Facts: A southern tribe, the Durotriges differed from others by remaining largely in hill forts long after others had abandoned them. They were huge traders and, through numerous harbours, exchanged many goods with the Romans.

Maiden Castle, a great example of an Iron Age, multi-ditch hill fort


© Ray Beer

5 TOP FACTS TYPES OF SWORD

Longsword
1 A type of sword commonly used in medieval Europe, between 1250 and 1550. The sword itself could have reached as far as 1.2 metres and weighed up to 2.4kg.

The small sword
2 The small, dress or court sword is famed for the decorative hilts and highly effective curved handles. It gained popularity during the 17th and 18th Century.

Japanese sword
3 A Japanese sword or nihonto is one of the most recognisable weapons of Japanese culture. Most commonly known is the katana, used by samurai.

Jian
4 Jian are dual-edged Chinese straight swords (Dao are the single-edged variant), and have been used in the country for the past 2,500 years.

Flyssa
5 The flyssa is the traditional fighting sword used by the Kabyles tribe of Algeria and part of Morocco during the 19th Century. They varied in size from 12 to 38 inches.

DID YOU KNOW? The flyssa was famed for its ability to cut through chain mail armour

Look out! He also says "ni!"

Mastering techniques
German masters taught three basic attack techniques; hewing, slicing and stabbing. The latter two are more self explanatory but hewing, a stroke with one edge of the sword, came in three forms: over hew (strike from above), middle hew (from the attacker's side to the victim's side) and under hew (a strike from below).

Learning defence
Basic defences included 'from-roof' a position where the sword is held vertically or at 45 degrees above the right shoulder or head; 'ox' where the weapon is held either side of the head with the point directed at the opponent and the 'plough' where the sword is held either side of the body.

Medieval sword fights

How did medieval knights learn to fight and what techniques did they use?

Medieval sword fighting styles were brutal and far less elegant than those associated with the Renaissance. However, it was the first time in European history that a combat technique employed the art of self defence.

The fighting style was passed on from Italian and German training disciplines and encouraged blocking, increased attention to footwork, better shield and armour protection as well as mastering the practice of counter cutting. Counter cutting was the technique of matching both offensive and defensive strategies in tandem and was intended to refine the rash rapier-orientated moves traditionally necessary for the battlefield.

The longsword was one of the most commonly available weapons of the period, but only the aristocracy were permitted to own such a blade. It was often crafted to lengths of 1.2 metres and weighed as heavy as 2.4kg. Displaying a long cruciform hilt the longsword could be held with both hands and introduced the medieval fighting style known as 'half-swording' where the fighter places one hand on the hilt and one on the blade to better control the weapon.

Other areas of combat that were common included fighting with daggers and pole weapons, fencing with a single-handed sword and buckler (a type of shield) and armoured fighting.

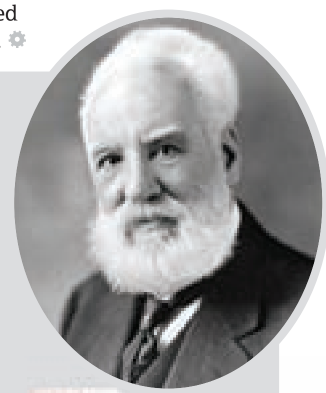
The first telephone

The telephone was a worldwide revolution and the start of instant long-distance communication

The first telephones to be manufactured featured three main parts: a speaker, a microphone and a hook switch, but the first telephone was much more basic.

Alexander Graham Bell, who is credited with the first patent for the telephone, created an instrument that featured a transmitter formed of a double electromagnet in front of which sat a membrane stretched around a ring holding a piece of iron in its middle. The mouthpiece was positioned before the diaphragm and when sounds were directed upon it, it vibrated and the iron moved.

This movement induced currents in the coils of the magnet which were passed along the electric current of the line to the receiver which consisted of a tubular electromagnet. One end of this was partially closed by a thin circular disk of soft iron and as the current was received the disk vibrated and acoustic sounds were emitted.

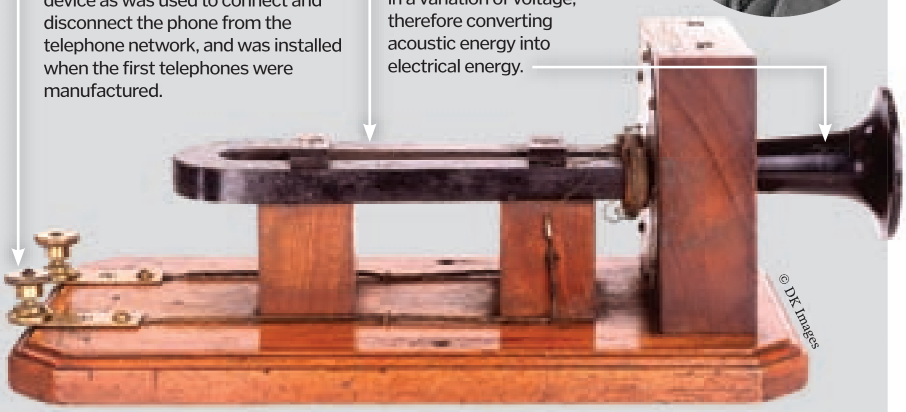


Alexander Graham Bell, the father of the telephone

1. Mouthpiece
When a person spoke into the mouthpiece the acoustic vibrations shook the iron held within a stretched membrane in the transmitter which resulted in a variation of voltage, therefore converting acoustic energy into electrical energy.

2. Receiver
The electric charges are pulsed through the line and then converted back into acoustic energy at the other end.

3. Hook
A hook switch was later added to the device as was used to connect and disconnect the phone from the telephone network, and was installed when the first telephones were manufactured.



© DK Images

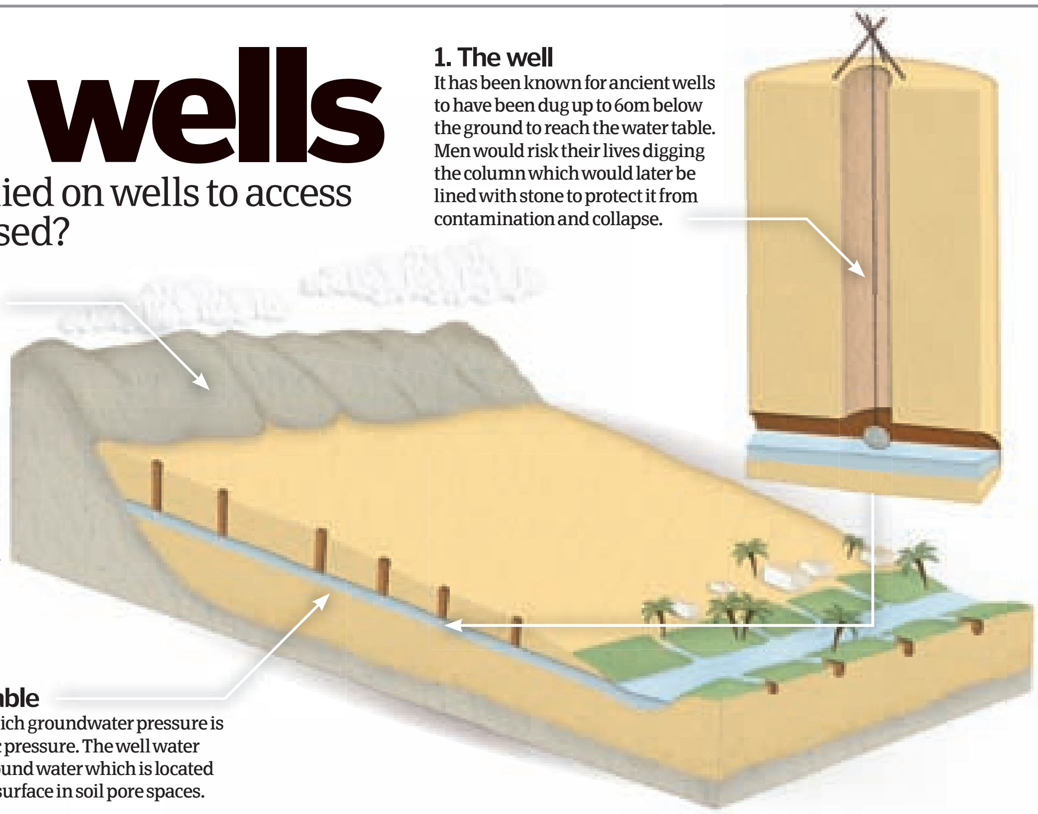
> "The well wall and outer rim were lined with stones to avoid contamination"

Ancient wells

Before running water, people relied on wells to access water but how was the water raised?

The first form of wells were hand drawn or dug wells, which were constructed through excavation of men digging down through the earth to below the water table. The well wall and outer rim were lined with stones to avoid contamination and reduce the risk of people or animals falling in.

Early wells were pumpless so a pot (pail) attached to a rope was fed to the bottom to collect water and retrieve it. The earliest known wells are from the Neolithic period, with the oldest dating back to 8100-7500 BC. Today wells are created with advanced drilling equipment and feature pumps to draw the water to the surface.



1. The well
It has been known for ancient wells to have been dug up to 6m below the ground to reach the water table. Men would risk their lives digging the column which would later be lined with stone to protect it from contamination and collapse.

3. Clean water
The water was free from contamination because it travelled down from natural springs in the mountain underground, becoming part of the area groundwater. Therefore when built on an incline the well would access running clean water.

2. The water table
This is the level at which groundwater pressure is equal to atmospheric pressure. The well water would come from ground water which is located beneath the ground surface in soil pore spaces.

What is an astrolabe?

Although thousands of years old the astrolabe still has its uses today in the fields of astrology and astronomy

Astrolabes were introduced to Europeans in the medieval era by Arabs as an astronomical instrument, but the device's origins have been cited as far back as 150 BC. When used correctly they can measure the height of the Sun or a star above the horizon.

Primarily intended for the purposes of astrology, geography, navigation and time keeping, the Europeans also used the device to form horoscopes. The tool itself consists of a disk (mater) which exhibits indented increments of time and/or degrees around the rim. This disk fits one or more plates (tympans) that are engraved with a circular projection of lines of equal azimuth and altitude to represent the celestial sphere above the horizon at that specific latitude. Above this then rests a rotating rete, a free moving framework showing the projection of the Sun's path. A complete rotation is equivalent to 24 hours.

5. Star pointer
The star pointer is placed at the position of their stereographic projection. By rotating the rete it is possible to decipher the position of the stars at their geographic location at that time of year.

4. Elliptical ring
This is used to chart the projection of the Sun's path. The interpreter can locate the Sun on that circle using a calendar to determine the Sun's longitude depending on what day of the year it is.

3. Rete
Placed on top of the plate is a rete, this is a freely rotating framework which is used to project the elliptical path.

6. Alidade
When held vertically the alidade can be rotated to chart the distance of a star along the line of sight.

2. Plate
The plates, or tymphans, are each intended for a specific latitude. The plate is engraved with a circular projection to represent the celestial sphere above the local horizon.

1. Mater
The mater is the main disk all the other parts rest upon. Around its rim are indented increments of time and/or degrees.

TOTAL WEIGHT	10,100 tons	COST	$1.5m	BASE AREA	2.54 acres
HEIGHT	324m	AGE	121 yrs	RIVETS	2.5m
STEPS TO THE TOP	1,665				

DID YOU KNOW? The Eiffel Tower was intended for Barcelona, but local officials refused the idea

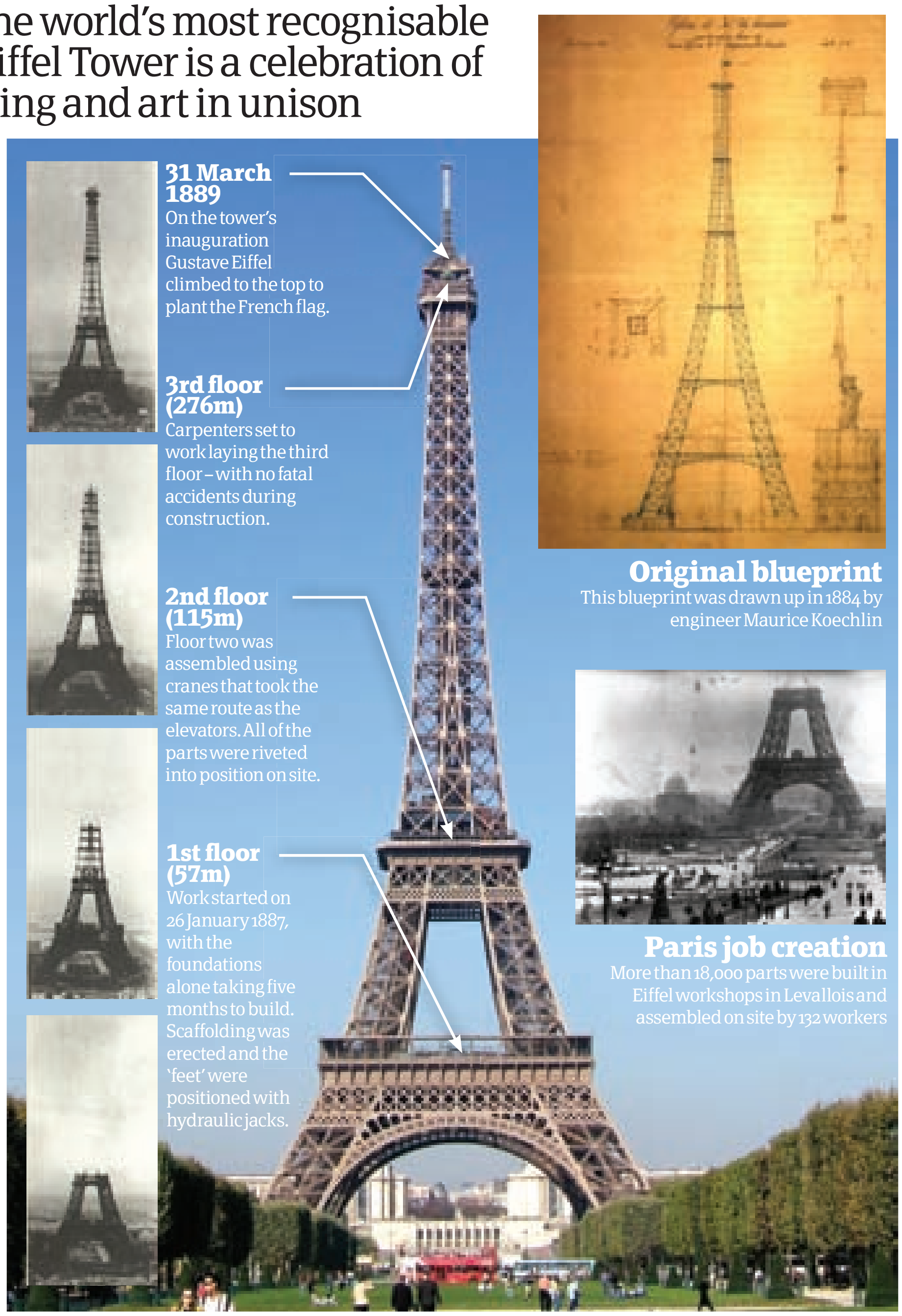
The Eiffel Tower

Arguably one of the world's most recognisable landmarks, the Eiffel Tower is a celebration of science, engineering and art in unison

The Eiffel Tower was the brainchild of French structural engineer Alexandre Gustave Eiffel, who proposed a 324m (986ft) tower for the capital's Champ de Mars, costing the city $1.5 million, for its World's Fair.

Work began in July 1887 and took just under two years to complete. To begin with the framework was pre-assembled in a factory and in total over 300 workers joined 18,000 pieces of puddle iron to produce parts of the frame. When the parts were ready they were transported to the Champ de Mars where welders secured each segment in place. As the tower grew, moveable platforms were propped into place on the intermediary levels, not only to enable the workforce to weld the latticework together but for their own safety. The tower features exposed latticework and consists of two main parts; a 2.54-acre base which compromises a platform sitting upon four individual legs known as pylons or bents, and a tower created as the pylons incline towards each other, rising upwards past a second platform which then merges into one long column.

The shape of the tower was engineered using a mathematical calculation involving wind resistance. Eiffel reasoned that the tower had to counterbalance the wind pressure applied on any point by spreading the tension between the construction elements at that point. Therefore the tower's curvature revealed two exponentials: a lower base section that delivers stronger resistance to wind forces, meaning the tower will only sway at a maximum of 6-7cm in the wind.



31 March 1889
On the tower's inauguration Gustave Eiffel climbed to the top to plant the French flag.

3rd floor (276m)
Carpenters set to work laying the third floor – with no fatal accidents during construction.

2nd floor (115m)
Floor two was assembled using cranes that took the same route as the elevators. All of the parts were riveted into position on site.

1st floor (57m)
Work started on 26 January 1887, with the foundations alone taking five months to build. Scaffolding was erected and the 'feet' were positioned with hydraulic jacks.

Original blueprint
This blueprint was drawn up in 1884 by engineer Maurice Koechlin

Paris job creation
More than 18,000 parts were built in Eiffel workshops in Levallois and assembled on site by 132 workers

History of the tower

The Eiffel Tower took just two years for 300 workers to complete and despite working on an open framework, and without the safety of intermediate floors, accidents were low and only one man died during construction. This is thought to have been due to the foresight of Eiffel who had insisted upon safety precautions in the form of moveable stagings, guard rails and screens.

In 1909, at the end of its 20 year lease the tower came under criticism as an eyesore, and was almost torn down. It was only saved because of its antenna, which was used for the city's communications.

Head to Head
FRENCH CONSTRUCTIONS

TALLEST VEHICULAR BRIDGE

© Vincent, 2006

1. The Millau Viaduct
Location: Spans the River Tarn near Millau, southern France
Years constructed: 2001-2004
Architect: Michel Virogeux and Norman Foster
Use: Four lane cable-stayed road bridge of the A75
Size: 343m high, 2,460m long
Fact: With one of the mast summits reaching a height of 343 metres, the Viaduct is taller than the Eiffel Tower.

MOST SYMBOLIC

2. Statue of Liberty
Location: Liberty Island, New York, USA
Years constructed: 1870-1886
Architect: Frederic Bartholdi
Use: An gift to celebrate the independence of America
Size: 305ft 6" tall and the base amasses 12 acres
Fact: Christened 'Liberty Enlightening the World', the statue was gifted by the French people to America for the centennial of the US Declaration of Independence.

OLDEST

3. The Pont du Gard
Location: Vers-Pont-du-Gard, south of France
Years constructed: 19BC
Architect: Marcus Vipsanius Agrippa
Use: Aquaduct constructed during the rule of the Roman Empire to carry water from the Fontaines d'Eure springs to the Roman city of Nimes.
Size: 49m high and 275m long
Fact: Today it is one of France's top five tourist attractions and was added to UNESCO's list of World Heritage Sites in 1985.

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

Proudly associated with sciencemuseum
www.sciencemuseum.org.uk

HOW IT WORKS EXPERTS

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

Alison Boyle
Curator of Astronomy and Modern Physics

Alison is responsible for a range of collections spanning most of the spacetime continuum. Since joining the Science Museum back in 2001 as part of the Antenna Science News team, Alison has worked on several astronomy and space exhibitions and is currently researching particle accelerators.

Mike Odd
Science Museum Explainer

Science Museum explainer Mike Odd loves revealing how things work – which is why he's on board for this month's Brain Dump – as well as performing science shows to large audiences. Mike's a dedicated cadet warrant officer in the Air Training Corps and it's his dream to one day obtain his pilot's licence.

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.

How does the speedometer in an aeroplane work?

David Carter

The official name for an aircraft speedometer is an Airspeed Indicator or ASI. Airspeed is a measurement of the plane's speed relative to the air around it. On the aircraft there is a tube called the pitot tube. The open end of the pitot tube is usually mounted on a wing and faces toward the flow of air. The airspeed indicator actually measures the difference between a static sensor inside the plane (not in the air stream) and a sensor (the pitot) in the air stream.

When the aircraft is standing still, the pressure in each tube is equal and the airspeed indicator shows zero. The rush of air in flight causes a pressure differential between the static tube and the pitot tube. The pressure differential makes the pointer on the airspeed indicator move. An increase of airspeed leads to the pressure at the end of the pitot tube raising.

In turn, the air pressure pushes against a diaphragm that moves a connected mechanical pointer on the face of the indicator (the gauge in the cockpit). The indicator is calibrated to compensate for winds in the air using electronic read-outs from the air and the ground. This system also compensates for altitude and air temperature to make the airspeed measurement accurate.

Mike Odd

Is it the weather or the sweets?

Why does mint taste 'cold'?

Anthony Miller

■ I'm sure we have all experienced the 'cool' sensation induced by eating a mint at some time or another, and the reason why this happens is due to the active ingredient called menthol.

When we perceive something to be hot or cold, this is due to electrical signals from the nerves which come into contact with the hot or cold 'thing'. Our brain then interprets these electrical signals as instructions such as – 'that is hot, don't touch!' or 'that is cold'

Mints usually contain an active ingredient called menthol. Menthol has the ability to affect the pores on our nerve cells which changes the electrical activity of the cell. This change in electrical activity corresponds to the same change that would take place if something cold came into contact with the cell. The cell interprets the change in activity due to menthol as a change in temperature and sends that information to the brain.

This accounts for the 'coldness' which we experience when eating a mint.

Rik Sargent

Why do we hiccup?

Steph McDowell

■ There are over 100 physiological reasons as to what sets hiccups off, the most common being expansion of the stomach and movement of stomach acid into the oesophagus. After this then it could be an irritation of the thorax or the phrenic nerve (the nerve to the diaphragm).

The mechanism of a hiccup usually involves a strong contraction of the diaphragm, the neck muscles and some other surrounding muscles. Just after the contraction begins we start to inhale at which point the glottis (a kind of fleshy trap door which separates the food and air tubes in your throat) shuts off the windpipe and this produces the 'hic' noise.

Scientists are still trying to find the actual purpose of hiccups. One theory is that they may have served useful for a common ancestor of ours. Standing on two legs gives us the advantage of using gravity to help digest our food, whereas four-legged creatures have to digest horizontally which means it's easier for food to get stuck in their throats.

Some scientists think the lodged food could have hit a nerve responsible for triggering the hiccup allowing the food to be swallowed. If this is the case then hiccups could have been highly useful rather than just making you look daft!

Mike Odd

Why do we sometimes remember our dreams, but sometimes not?

John Harrold

■ This is a very good question and I'm afraid it is one for which there is no satisfactory answer based on our current understanding of the brain. One thing studies have told us, though, is that dreams seem to happen more vividly and frequently during the REM (Rapid Eye Movement) stage of the sleep cycle, which tends to occur roughly four to five times in a normal night's sleep.

It has been reported by several studies that you are much more likely to remember the dream you were having if you are woken in the middle of this REM cycle. So if you would like to remember your dreams more frequently, you could try setting your alarm clock to go off in the middle of your REM sleep cycle (likely to be near the end of your night's sleep) and write down what you remember.

Rik Sargent

sciencemuseum

What's on at the Science Museum?

Rocket replica train

■ 31 March-18 April ■ Rides cost £5.00, including a goody bag.
This Easter, the Science Museum will be offering visitors the chance to enjoy an exciting steam ride on a replica of Stephenson's famous 1829 locomotive train Rocket. Visitors will be transported back in time on this 15-minute train journey, based in London's Hyde Park. Visitors can then venture inside the Science Museum to find the original Stephenson's Rocket in the Making the Modern World gallery. The ride opens on 31 March and runs until 18 April.

New! Hubble 3D at the IMAX 3D Cinema

■ From 19 March ■ £8.00 adults and £6.25 children/concessions.
Journey through distant galaxies and explore the mysteries of the universe on this mission to service the Hubble Space Telescope. Using 3D technology you can accompany space-walking astronauts as they attempt the most difficult tasks in NASA's history. Narrated by Leonardo DiCaprio.

1001 Inventions

■ Till 30 June (Please note: the exhibition will be closed between 25 Feb-12 Mar) ■ FREE
Tracing the forgotten story of 1,000 years of science from the Muslim world. Featuring interactive exhibits, displays and dramatisation, the exhibition explores the shared scientific heritage of diverse cultures and looks at how many modern inventions can trace their roots back to Muslim civilisation.

Force Field – the ultimate multi-sensory experience

■ Permanently open ■ £5.00 adults and £4.00 children/concessions available.
Using the latest simulation and effects technologies to place the audience in a truly experiential environment, Force Field lets visitors see, hear, feel and even smell what it would be like to venture into space.

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

Why use salt to melt ice on the roads?

James Hendy

■ Salt lowers the freezing/melting point of water/ice. The melting point of ice under normal conditions is zero degrees Celsius. Sea water, however, freezes/melts at -2.2 degrees Celsius due to its high salinity.

As to why salt lowers the melting/freezing point of water, this is a bit more difficult to explain without going into some complex chemistry. Basically water is made from H_2O, and anything else which gets in there, such as sodium in the case of salt, gets in the way and makes it harder for the H_2O to bond as ice.

Upon sprinkling salt onto ice, the salt first dissolves into the liquid water surrounding the ice causing the ice to melt. The salt can only lower the melting/freezing point of water up to around -16 degrees. If the temperature is below this point then salt is ineffective and it would be better to pour sand over the ice to help increase traction.

Rik Sargent

Can you calculate how far away lightning struck?

Natalie Jenson

■ We can calculate how far something travelled if we know its speed and the time it has been travelling using this equation: Distance = Speed x Time. The speed of light is very fast, at roughly 300,000,000 metres per second, so we see lightning almost instantaneously. In comparison, sound travels through air at around 330–350 metres per second, depending on temperature and humidity. You can work out how far away the lightning struck by measuring the time between seeing the lightning and hearing the thunder, then multiplying by the speed of sound. For example, if you count ten seconds before hearing the thunder, the lightning struck roughly 3,300 metres away.

Mike Odd

Arrr... just ten nautical miles to me favourite port...

What is a nautical mile?

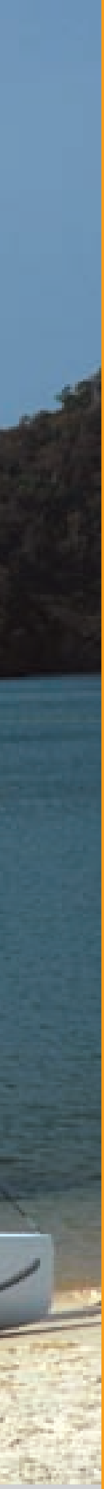
Hayley Horrocks

■ A nautical mile is based on the circumference of the Earth. If you cut the Earth in half at the equator, pick up one of the halves and look at the equator as a circle. Divide that circle into 360 degrees. Then divide a degree into 60 minutes. A minute of arc on the planet Earth is one nautical mile. Because this takes in to account the arc of the Earth, it is used in air and sea travel. A nautical mile is 1,852 metres, 1.852 kilometres, 1.1508 miles, or 6,076 feet.

The nautical mile is used by sea and air navigators because of its convenience when working with charts and maps. Most nautical charts are constructed on a scale that varies from the equator to 80° north or south latitude. This means it is difficult to show a single linear scale for use on charts (realistically on scales smaller than about 1/80,000). This isn't practical for more accurate navigation using lower scale charts.

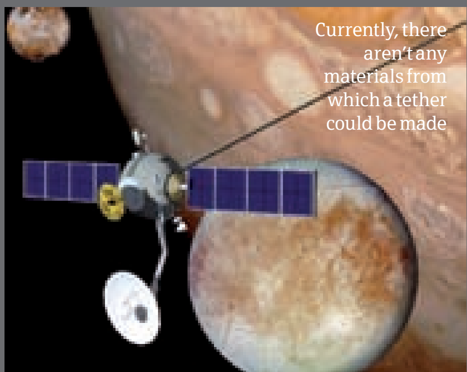
Since a nautical mile equals a minute of latitude, it is easy to measure a distance on a chart with dividers, using the latitude scale on the side of the chart directly to the east or west of the distance being measured. Being used to working with miles and kilometres means that this sounds complicated, but for the purpose of working with charts and maps it is far easier for the navigators to use.

Mike Odd



FROM THE FORUM

*Every month we'll feature a reader's question from our fantastic forum at **www. howitworksdaily.com/forum***



Currently, there aren't any materials from which a tether could be made

How would a space tether be built if they had the materials to build it?

Daedalus_51

■ There have been many different attempts by scientists and engineers to devise a way to build a space tether or 'elevator' and yes most of them involve constructing a really long cable of some kind – 38,000km or more to be exact!

The idea is that the cable would be in a geostationary orbit around Earth, one end of the cable would be attached to either a fixed or mobile platform on the Earth and the other end would connect with some kind of counterweight, high above the Earth's atmosphere.

The elevator would prove highly useful in being able to get things into space without the need for launching rockets, however such a project is not without its share of difficulties.

The main technical issue to overcome in building such a cable is to keep it from collapsing under its own weight. One idea is to vary the thickness of the cable to allow for the tension to stay constant throughout, as the gravitational force on the cable increases the closer it is to the Earth. It would need to be built out of a material which is incredibly strong, yet very light. In fact the strength required from such a material would need to be at least twice that of diamond!

Currently there are no such materials which could handle this strain, however there is a lot of exciting research happening at the moment in the field of carbon nanotubes which may prove useful. Carbon nanotubes are extremely strong carbon structures which have been synthesised in laboratories and it has been theorised that these nanotubes may have what it takes to withstand the strain while still being a relatively light material.

Rik Sargent

Star Wars: The Original Trilogy is available on DVD priced £29.99, courtesy of 20th Century Fox

© LucasArts

Could we travel faster than the speed of light?

Selwhort

■ The speed of light is roughly 300,000,000 metres per second which is fast enough to travel around our planet seven and a half times a second. Needless to say that is fast! In fact it's the fastest thing we know, but why is it so difficult to travel at this speed? Surely if we were far away from any other forces like gravity, we could just keep accelerating and eventually we would get there, wouldn't we?

Unfortunately no. One of the things which Einstein realised from his theories of relativity is that as any particle of mass increases in speed it also increases in mass. By the time the mass has finally reached the speed of light it would have infinite mass which would mean to get it to that stage would have required an infinite amount of energy and I don't know about you but there are a definite shortage of infinite energy sources in this universe!

Rik Sargent

Image: Akroti, 2006

How do cigarette filters work?

Sue Johnson

■ Filters were added to cigarettes in the Fifties when it was discovered that smoking causes lung cancer, leaving cigarette manufacturers under pressure to convince people that smoking was safe. The filters are made of a synthetic fibrous mass called cellulose acetate, which is a kind of fine plastic packed tightly so that it looks like cotton wool. The material is designed to accumulate the vapours and tar in the fibres before they reach the smoker's mouth. However, filters in no way lessen the unhealthy smoke being inhaled. In fact, chemicals are added to make cigarettes taste better and to increase the speed at which nicotine is delivered to the brain, thereby keeping users hooked.

HIW

sciencemuseum

What's on at the Science Museum?

Who am I?

■ Coming soon – opening June 2010 ■ Free

To mark the end of its centenary year, the Science Museum will open an upgraded 'Who am I?' gallery in June. Currently one of the most popular galleries in the Science Museum, Who am I? presents the latest in brain science and genetics through a mixture of interactive exhibits and object-rich displays.

Antenna

■ Coming soon – opening June 2010 ■ Free

'Antenna' hosts a series of events allowing visitors to get up close with new developments in science and breakthrough technologies. A new concept for Antenna will be unveiled in June 2010 providing an innovative new way for the public to engage with contemporary science.

Family events – The Eggs Factor

■ 2, 5-9, 12-16 April (12.00, 14.00) ■ Free

Have you got the Eggs Factor? Find out in this eggs-cellent workshop with eggs-citing eggs-periments all about eggs! The event takes place in the Flight gallery on the third floor. There is no booking process, 60 places are available on arrival. The show is 35 minutes long and suitable for children aged seven and above.

– Up, Up and Away

■ 2-18 April (11.30, 13.30, 15.30) ■ Free

Join us on this high flying adventure through the clouds in this fun interactive storytelling event about flight. The event is located in the Flight gallery on the third floor of the Museum. There is no booking process, 35 places are available on arrival. The show is 20 minutes long and suitable for children up to the age of seven.

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

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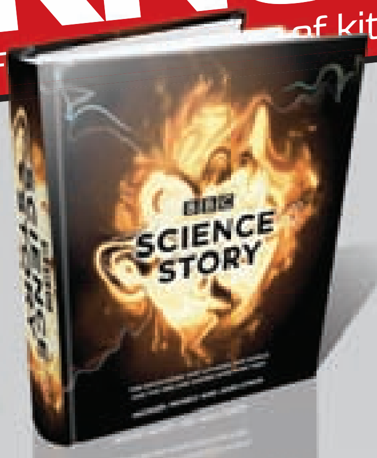


The Story Of Science

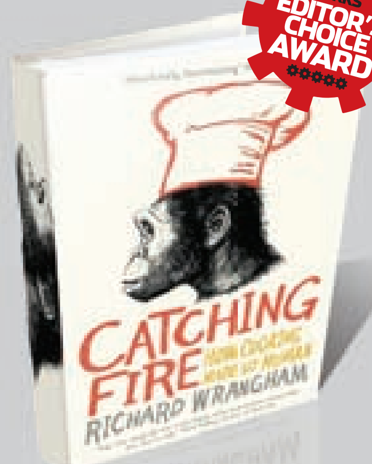
Price: £20.00 / $29.99

ISBN: 978-1-84533-547-2

A weighty compendium delivering the history of science in clear-cut, manageable chunks. *The Story Of Science* charts the people, experiments and research that have carried the movement forward from the ancient Greeks to the modern day. Overall, an insightful and entertaining read.

Verdict:

HOW IT WORKS EDITOR'S CHOICE AWARD



Catching Fire: How Cooking Made Us Human

Price: £15.00 / $26.95

ISBN: 978-1-84668-285-8

If you've ever thought that Darwin had a point but he never really gave you a specific enough argument, then be prepared to be wooed by Wrangham. His incredible argument suggests that the taming of fire and the cooking of food is what caused the advanced evolution of man. A very interesting read.

Verdict:

Make play time greener with this hydrogen-powered remote control car

Fuel Cell Hydrocar – RC

Price: £130.00 / $195.00

Get it from: www.sciencemuseumshop.co.uk

ENVIRONMENTALLY FRIENDLY MOTORING no longer has to be the privilege of Prius drivers and the super rich as, with this solar-powered, hydrogen-fuelled Hydrocar, even the youngest driver can enjoy and learn about the benefits of green driving. As part of the kit, would-be eco-drivers get a futuristic-looking remote control car, slim and minimal control pad, solar panel and water separating refuelling station. The refuelling station works by splitting water into hydrogen and oxygen by electrolysis (the use of an electric current to drive otherwise non-spontaneous chemical reactions), with the current being supplied by either the solar panel or by the included AC adaptor. The separated hydrogen is then collected in the station and stored ready for transfer to the car.

Transfer of the hydrogen is easily achieved by connecting the refuelling station's pipe – fitted with a one-way valve – to the car's fuel dock, and then pressing down on the station's pump mechanism. This pushes the hydrogen down the pipe and into the car – a process visible thanks to its clear plastic tank. From here the hydrogen is then released when driven over a miniature fuel cell which conducts a reversed chemical reaction to that of the refuelling station, powering the car's wheels and spewing out nothing but plain oxygen and water.

In terms of drivability the Fuel Cell Hydrocar isn't the quickest remote control vehicle we have had in the office – topping out a no more than 5mph – however, it is perfect for scooting about the house, and providing the Sun is out to some degree, then batteries can be well and truly banished and your home's electricity bill won't be compromised by Jeremy Clarkson-levels of motoring.

While not the fastest most or feature-packed remote control vehicle – something that may make some balk at the £130 price tag – the educational value that the Fuel Cell Hydrocar delivers is second to none, clearly and visually educating adults and children to the possibilities and processes of alternative energy sources. And that, taken in partnership with its largely zero-cost running, means that it is easy to recommend. Top draw!

Verdict:

Eee PC 1005P

Asus aims to please with this neat netbook

Price: £279 / $419.99

Get it from: www.pcworld.co.uk

THE NETBOOK MARKET is bulging with offerings from pretty much every established PC maker and Asus, with its Eee PC 1005P, is hoping to win you over with a combination of smooth curves, black and silver styling and host of pretty decent specs.

It's powered by a respectable Intel Atom N450, which clocks in at 1.66GHz, it has 1GB of memory and a 160GB hard drive. Other notable inclusions are an 11 hour battery, Windows 7 operating system, memory card reader, three USB ports, Intel GMA 3150 graphics

Apollo Saturn V

Recreate the moon landing in your own living room

Price: £70.00 / $90.00
Get it from: www.sciencemuseumshop.co.uk

ON THE 16 of July 1969 the largest ever rocket blasted off from the Kennedy Space Center bound for the moon with three lunar astronauts on board. This was a moment of incredible historic significance, and now you can recreate the vehicle that took those astronauts there in your very own living room.

This 1:96 scale, 1.14-metre tall model of the Apollo Saturn V rocket comes with everything you need to recreate this eponymous vehicle, delivering as part of the package: a launch platform, separate multi-part printed tubular components, engine cladding, the rocket second stage with five thrust nozzles, transition ring with fire wall, third stage rocket with helium balloon holders, an astronaut and plenty more.

The Saturn V comes from model virtuosos Revell, so you get a lot of quality and detail for your money, with a lot of neat touches such as a transparent section showing the rocket's innards and specialised brushes and paints for fine detail.

Verdict:

processor and a 10.1" screen. The result is a lightweight and very snappy machine.

It's always worth noting the keyboard on a netbook as the lack of space can translate to an awkward typing style and a good deal of frustration. Luckily the Eee PC has a very good sized keyboard given the space restraints. Another massive plus is the battery life, which will get you through your commute with no problems.

Verdict:

BioShock 2

- **Format: PC**
- **Price: £39.99 / £59.99**

This is a difficult second outing, no doubt, after the 2006 game of the year that was the original *BioShock*. *BioShock 2* assumes you've already played the original and thrusts you straight back into Andrew Ryan's subaquatic dystopia, this time in the form of a prototype Big Daddy in search of his Little Sister. It features the same strong narrative, distinct art deco style and mid-19th Century iconography of the original, but with diminishing returns from these, developer 2K Marin has played to the strength of its incredible new third-person combat mechanics. It's well worth dipping your toes in the water again.

Verdict:

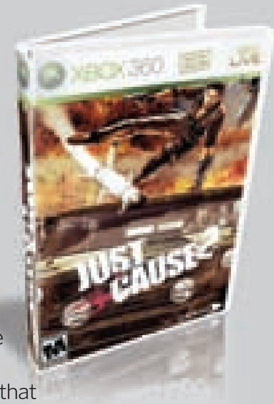
God Of War III

- **Format: PS3**
- **Price: £39.99 / $59.99**

Building on the visceral first and second titles, *God Of War III* sees the violent return of Kratos and the Titans for more god-slaying in one of the best titles to be released on PS3 so far. Armed with a host of new weapons, combos and abilities, as well as a renewed taste for chaos on a mass scale, *God Of War III* charts Kratos' mission to track down and slay Zeus, the king of the gods. Visuals in this third-person action title are top notch and really utilise the power of the PS3, with crisp visuals and slick frame rates maintained no matter how many enemies Kratos is pummelling at any one time. Gameplay is as rewarding and enjoyable, with plenty of variety to level design and enemy types also.

Verdict:

Just Cause 2



- **Format: 360**
- **Price: £39.99 / $59.99**

Rico Rodriguez is back in this third-person action-shooter and so is the fictional island of Panau, ideological extremists and all. Avalanche Studios has made good on its promise to fill this sandbox world up, so busy towns, military outposts and rival factions regularly punctuate the landscape on your way to usurp the evil dictator Baby Panay. The game is characterised by Rico's grappling hook and parachute, which he uses to perform insane stunts that would make Daniel Craig's Bond wet his pants. Coupled with an incredibly destructible environment, it's dumb but an awful lot of fun.

Verdict:

Alien Vs Predator

- **Format: PS3**
- **Price: £34.99 / $59.99**

Developer Rebellion's third *AvP* game was banned for "explicit decapitation and dismemberment" in Australia, but even if the violence is justifiable, the lack of quality isn't. Split into three campaigns covering a Marine, Alien and Predator experience in a human colony that has uncovered an ancient ruin, Rebellion has wrecked the heart-stopping experience of the original two games by overpowering the Marine and failing to provide an adequate AI challenge in the Predator and Alien campaigns. In broadening the experience for a mass market, Rebellion has diluted what was a triple-A title.

Verdict:

How Earth Made Us

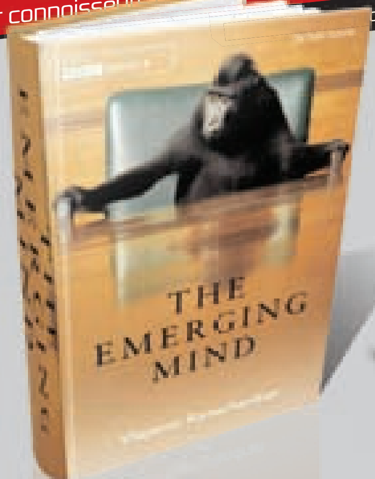
Fire, earth, wind, water… and heart?

Price: £24.99 / $34.99
Get it from: www.bbcshop.com

PROFESSOR IAIN STEWART was born a generation too early to properly appreciate *Captain Planet And The Planeteers*, but this BBC episodic quintuplet has a curious theme parallel with the early Nineties kids cartoon. *How Earth Made Us* documents the role that geological evolution has had upon the rise and fall of civilisation worldwide. It themes four episodes with the elements, and also human planet: a focus on the modern age as a burgeoning human population influences the moods of our planet.

You'd expect a geology professor to be enthusiastic about rocks, but professor Steward throws himself into the bowels of the Earth with the alacrity of a ravenous annelid. A 50-metre descent down an Iranian desert shaft in a bucket on a rope presents no challenge when you've scuba-dived miles of waterlogged tunnels, delved into a deep Mexican crystal cavern, cooked by a lake of molten lava and other activities unrestricted by an apparently limitless BBC budget. The series has a interesting point to make and some of the incredible journeys are definitely a sight to behold.

Verdict:

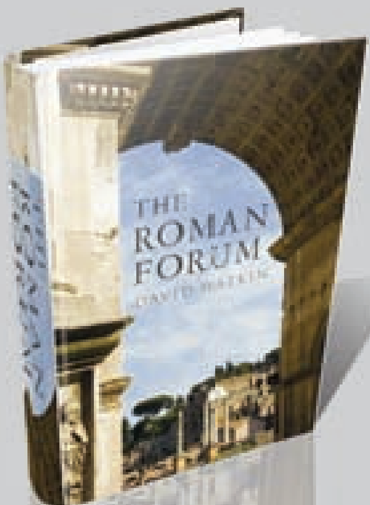


The Emerging Mind

Price: £7.99 / $12.00
ISBN: 978-1-86197-303-0

An intriguing journey into the depths of the human mind, Ramachandran pushes at the boundaries of neuroscience. Questions that have been the traditional remit of philosophy such as: what is art, what is free will, and what is the self, are explored and at least partially answered here through clear and methodical recounting of the results of studying the human mind.

Verdict:



The Roman Forum

Price: £15.99 / $19.95
ISBN: 978-1-86197-962-9

It's not quite the armchair read that we'd suggest, but there's no doubt that David Watkin's *The Roman Forum* provides a guide to this most famous of landmarks with a keenly unusual perspective. Watkin's dry tone is compensated for by a backdrop of several millennia of history that sheds new light on this European archeological treasure.

Verdict:

Freeloader

Because solar energy's there for the robbing

Price: £32.99 / $47.99
Get it from: www.solartechnology.co.uk

ON THE BACK of a wave of eco-friendly charging technology comes the Freeloader: a portable charging device that converts sunlight into a usable electric charge. The rechargeable lithium battery can be fully charged via the panels in anything from five to ten hours, or three to four using the USB/PC hookup, then deliver its entire charge to a device within an hour. And what devices does it cover? More or less anything, if the range of jacks and adapters supplied with the device are anything to go by, and it worked on everything we tried.

It's pocket-sized and wallet friendly, making it perfect for summer camping trips and festivals alike.

Verdict:

Addictaball

Try not to lose your marbles

Price: £11.99 / $19.99
Get it from: www.firebox.com

PERHAPS IT'S DUE to the rise of videogames that we've not seen the popular Marble Maze evolve beyond its two dimensions until now. Addictaball is a three dimensional ball-bearing maze that contains a labyrinth of plastic chutes, slides, holes and traps within a sphere.

It is, as the name suggests, quite addictive. More so than its two-dimensional predecessors in fact, and even includes some curious mechanics that remind us of the board game Mouse Trap. For the price and hours of fun, it's well worth the money.

Verdict:

Internet radio comes in a strange form

AirStream 10

Price: £222.25 / $330.00
Get it from: www.amazon.co.uk

IF YOU'RE NOT impressed by the offerings of regular radio and think that DAB is also lacking but you don't want to be tied to your computer for your listening pleasure, then the AirStream 10 is a possible option for your internet radio needs. Firstly, it's quite an odd piece of kit – it can be used upright or on its side. The aerial pulls out from the top, which if in use, means the AirStream 10 can't be used on its side, but we're guessing purchasers of this item won't be using analogue radio.

The control interface is extremely good. There is a touch panel to take you through modes, an iPod-esque click-wheel, which is incredibly easy to use and of course it has an ethernet connection to connect directly to the internet. Sadly, the internet connectivity, like the aerial placement, is a little unfortunate. With the device on its side the cable connecting to the internet is visible and makes the unit look clunky.

Sound-wise the AirStream is pretty competent, but it's by no means going to replace your home stereo although it does have a line-out so it can be linked to a bigger system. A nice effort, but a little confused and not worth a £200+ price tag.

Verdict: ✿✿✿

Pocket Cinema V10

Big screens come in small packages

Price: £189.99 / $299.99
Get it from: www.firebox.com

AS THE SPIEL on the website rightly points out, it's all very well having the latest multi-megapixel cameras and phones but when it comes showing off your drunken escapades, it makes no odds when you've only got a titchy screen a couple of inches wide to view it on.

Aiptek has come up with the Pocket Cinema, a small range of portable projectors that solves this most pressing of social problems. The pocket-sized V10 houses a rechargeable lithium-ion battery, can be charged via USB/PC connection or directly from mains and supports up to an 8GB SD card in its multi-media card reader port. It projects an image up to 50-inches wide from a distance of up to 180cm, and includes an integrated stereo speaker. The only niggles we have are with the one-hour battery life, which isn't enough to watch a full film, and the LED bulb, which isn't nearly bright enough in anything but a very dark room.

Verdict: ✿✿

Buckyballs

They're strangely attractive…

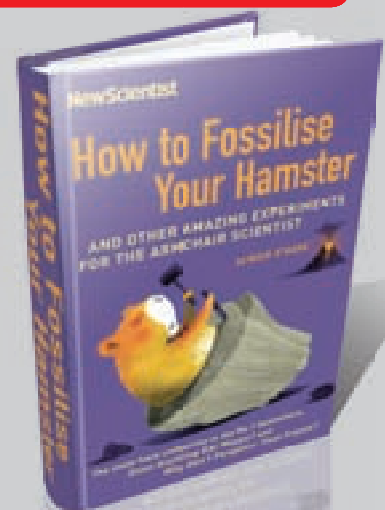
Price: £24.99 / $29.95
Get it from: www.pranksterhouse.com

RARE EARTH MAGNETS aren't rare and neither are the mineral ores they're made from, but scientists do have their reasons (which evade us) for calling them so and the name does help sex up the marketing campaign for Zoomdoggle's Buckyballs.

The name could only be coined by an American company as a British sense of humour would never have allowed this toy to have left the drawing board under such a title. But they do have their appeal however: Buckyballs are 216 strongly magnetised ball-bearings that will clump together if allowed, but can be teased apart to form a infinite variety of shapes. The balls are polarised, resulting in a single toy with unusual magnetic properties that can be pulled into strings, rings and far more sophisticated mathematical shapes.

It's being pushed as a toy, but the packaging does indicate that it is unsuitable for children. We think Buckyballs wouldn't be out of place on an executive's desk – it's far more interesting than Newton's cradle, after all.

Verdict: ✿✿✿✿

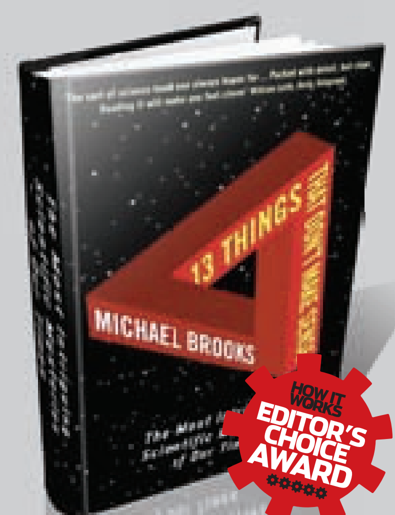


How to Fossilise Your Hamster

Price: £7.99 / $22.95
ISBN: 978-1-84668-044-1

A perfect gift for those you know with inquisitive minds and the predisposition to want to turn everything into an experiment. It covers all manner of topics, from the myth that a spoon left in a champagne bottle will retain its fizz to the physics of why spaghetti always breaks into three pieces when snapped.

Verdict: ✿✿✿✿



13 Things That Don't Make Sense

Price: £8.99 / $13.88
ISBN: 978-1-86197-647-5

Based on the most read article ever published by *New Scientist*, this book takes an in-depth look at some of the mysteries that still plague modern science. The book is engagingly written by Michael Brooks, a quantum physicist who is able to put complex theories into understandable English. If you are at all interested in modern science then this book will fascinate, and perplex, you.

Verdict: ✿✿✿✿✿

With the rain behind us and sunny days ahead, we try out the devices that put Michael Fish to shame

Weather stations

1
Technoline WS 6710
Price: £25.49
Get it from:
www.weathershop.co.uk

The cheapest personal weather station on test this month comes courtesy of Technoline, with the modest WS 6710 costing just over £25. For your money you get a small unit that provides a symbol weather forecast (sun, cloud, rain etc), indoor and outdoor temperature gauge, a MIN/MAX recording for indoor and outdoor temperatures, indoor humidity gauge, moon phase reading and quartz clock with display date. It is just a shame that while its cheap price doesn't compromise its functionality, it does so with its build, with the WS 6710 looking dated and aesthetically unappealing.

Verdict: ★★★

2
iROX HBR529
Price: £47.62
Get it from:
www.weathershop.co.uk

A couple of quid short of £50, the iROX HBR529 is almost twice as expensive of the previously reviewed WS 6710, and while you get a slightly more stylish unit with a couple of extras, it is hard to see where all the extra cash has gone. Despite this issue regarding its value for money, the HBR529 does deliver a symbol-based weather forecast, atmospheric pressure trend reading, indoor and outdoor temperature wireless sensor, air humidity gauge, radio controlled clock/alarm with snooze function, backlight and low battery indicator – so in terms of functionality it is sound. We just can't recommend it over the WS 6710, which has the majority of its features and at half the price.

Verdict: ★★

3
iROX HBR657
Price: £68.04
Get it from:
www.weathershop.co.uk

The most expensive and feature-packed unit on test, the HBR657 delivers a weather forecaster with seven symbols, an air pressure gauge, a wireless outdoor thermometer with heat alarm, indoor thermometer and heat index chart. There's also a pictorial 'comfort zone' reading, radio controlled clock with calendar, alarm system with snooze button, sunrise and sunset region timings for over 90 regions, moonphase diagram and powerful backlight. In terms of aesthetics, the HBR657 adopts a more robust appearance, our only issue (apart from the price) is that while the screen is the largest, the amount of numbers, readings and diagrams make reading it a bit of a chore.

Verdict: ★★★★

4
Oregon Scientific Weather Forecast Station
Price: £34.00
Get it from:
www.weathershop.co.uk

Out and out the most stylish unit on test, the Weather Forecast Station looks the part with a post-iPhone design sporting smooth curves and a large, well-lit display. It offers everything you would expect too from this type of unit, clearly displaying the outdoor and indoor temperature, humidity, a simple symbol-based 12-hour weather forecast, digital clock/alarm and Ice Alert LED. Simple to use and easy to set-up requiring only two AA batteries in the main unit and a single AA battery in its wireless thermometer, the Weather Forecast Station is an affordable piece of kit.

Verdict: ★★★★★

Origami water bomb

Soak your friends and enemies with this cheap but effective water bomb

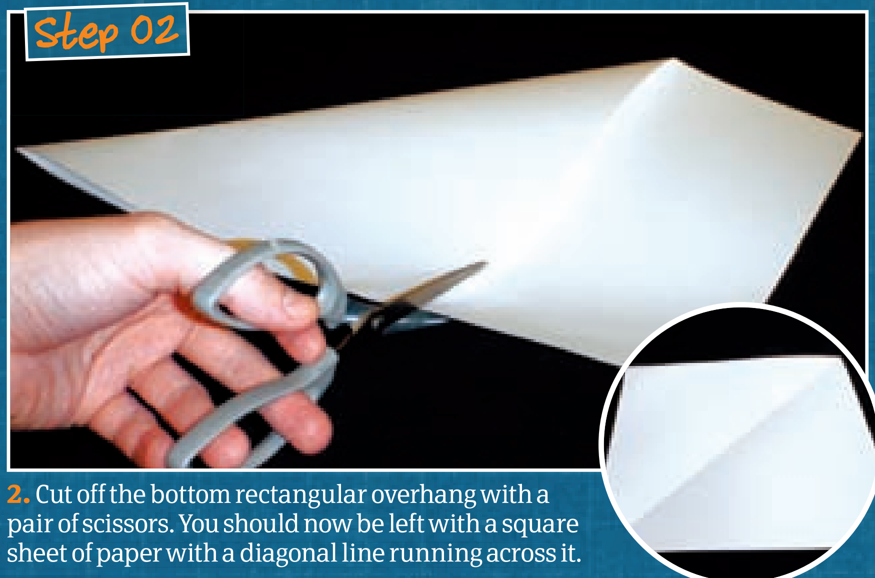
It is a fact that origami is a highly rewarding activity to partake in, building patience, hand-eye co-ordination, skill in geometry and general creativity, allowing a master to create a menagerie of paper beasties at whim. However, for the budding origami student who desires something practical as well as aesthetically Zen, options are few and far between.

Introducing, then, the origami water bomb, a beautiful but highly effective paper cube that not only allows your skills to be put to practical use, but also grants maximum return in the hilarity department as friends and foe tremble under your elemental control. By following these nine very simple steps, you too can become a watery warlord.

Step 01

1. Take your sheet of paper and fold the top right-hand corner diagonally across until it lines up with the left-hand side of the sheet, then make a crease.

Step 02



2. Cut off the bottom rectangular overhang with a pair of scissors. You should now be left with a square sheet of paper with a diagonal line running across it.

Step 03

3. Now take your piece of paper and fold it firstly along the uncreased diagonal (3A), and then across its centre in each direction. Your paper should now have four creases in it (3B).

Step 04

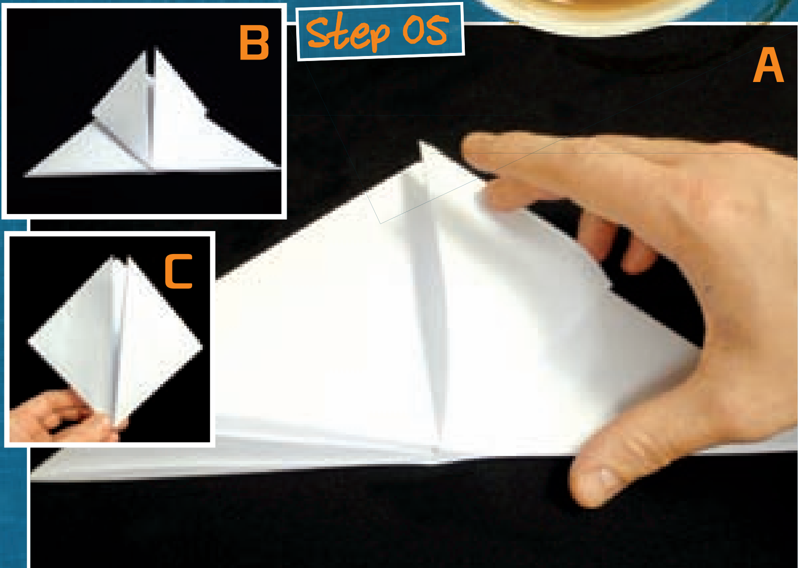
4. Now fold the paper in half so you have a rectangle then, taking the top right-hand corner of the folded paper, push inwards and down to create an overlapping triangle (4A). Once this is done, take the bottom left-hand tip of your new triangle and fold it in half (from west to east), then crease (4B). Finally, repeat this process with the left-hand side of the sheet; once achieved you should have a flappy double triangle (4C).

HOW IT WORKS

Construction materials:

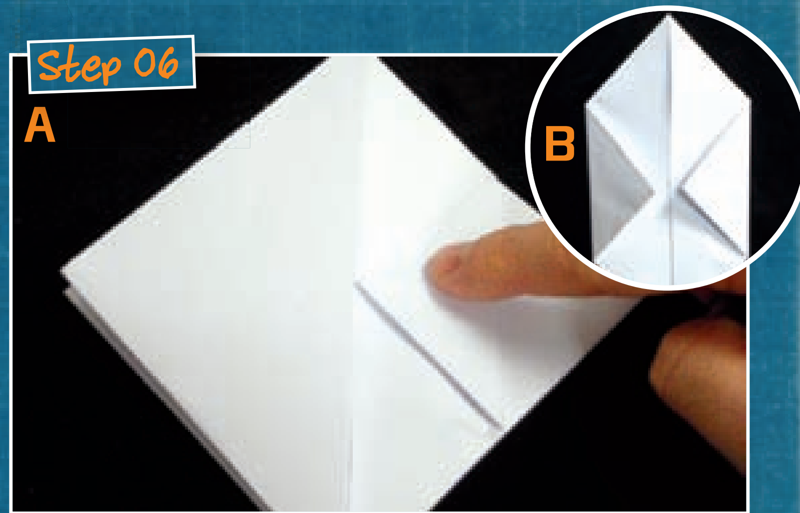
1x Sheet of A4 / A3 paper
1x Scissors

Step 05



5. Put your triangle down and take the bottom-right tip of the top triangle. Now fold it vertically till it meets the central tip (5A). Repeat this with the bottom-left tip of the top triangle (5B) then, turning the paper over, repeat again with both bottom tips. Your paper should now look like this (5C).

Step 06

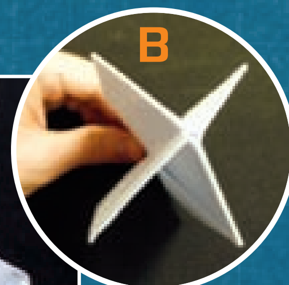


6. With the paper orientated so it is divided on each side from north to south, take the eastern tip and fold to the centre (6A). Do the same with the western tip before flipping over and repeating with both bottom tips (6B).

Step 07

7. Your paper should now resemble an irregular hexagon with four loose triangular tips at its top. Take the right-hand triangle and fold it in half downwards until its tip meets with the eastern and western triangle tips in the centre.

Step 08



8. Okay, this is the tricky bit. Squeeze the eastern triangle at its tip – this should open it up creating a pouch structure. Once the pouch is open fold the top-right triangle again from west to east into the pouch (8A). If correct, this triangle should marry up with the pouch structure and fit securely. Once achieved, do the same with each of the remaining top tips. Your paper should now look like this (8B).

Step 09

Completed!

9. Take your paper and, holding it lightly at two of its tips, blow into the small hole at its pinnacle. The paper structure should inflate rapidly creating a cube. Finally, fill the cube with water (poured through the same hole through which it was inflated).

Congratulations, you are now in the proud possession of the origami water bomb!

GET INVOLVED!

Have you caused mass watery-destruction with your own bomb? Then forget *You've Been Framed*, why not send the evidence to howitworks@imagine-publishing.co.uk

HOW IT WORKS

INBOX

Feed your mind. Speak your mind

The father of edutainment programmes?

Letter Of The Month

Bring back Johnny Ball

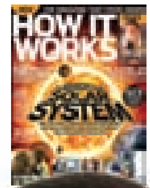
I was so pleased to see last issue's interview with the legend that is Johnny Ball. I'm an Eighties kid and it brought back so many great memories of watching him on *Johnny Ball Reveals All* and all his other shows when I was a kid – as I read the interview I could almost hear his voice.

He was such an excitable presenter and it's people like Johnny who inspire kids to learn about science and maths – proper subjects with real-life importance. It's vital that the TV bosses keep great icons such as him on the screen to ensure that kids don't just idolise idiotic non-celebrities like John & Edward and Katie Price. Bring back Ball.

John Leigh

HIW: We quite agree, John. If we're honest, we were a little starstruck to get to speak to the big man of edutainment. And you're right, it's essential that programmes like *Brainiac* aren't axed in favour of reality TV nonsense. We were so glad to get him in the magazine. Let us know which science personalities you'd like us to interview and we'll see what we can do.

Get in touch!



If you've enjoyed this issue of How It Works, or have any comments or ideas you'd like to see in a future edition, why not get involved and let us know what you think. There are several easy ways to get in touch...

Patience is a virtue

Hi guys. I just wanted to say how great the magazine is. I've been waiting for something like this for years. I've already subscribed. I only wish it came out more than once a month!

Is there any chance of making some How It Works files available to keep all the back issues in? I also have two recommendations to improve the magazine. First, a few explanations can occasionally seem a bit superficial. Second, I like the reviews section, especially the gadgets, but don't really think the computer game reviews fit in. Other than that, keep up the great work and I can't wait for issue six.

David Redfearn

HIW: If How It Works came out more than once a month I think the team here would more than likely have a breakdown, but thanks for your support. We will definitely suggest producing a binder to store your precious issues of How It Works to the HIW bosses, so thanks for that great idea, David.

The shorter, bite-sized articles are really there to give you a shot of information that's easy to digest and enjoy before moving on to the next tasty bite. We try to combine these shorter 'superficial' articles with the larger in-depth features throughout the magazine.

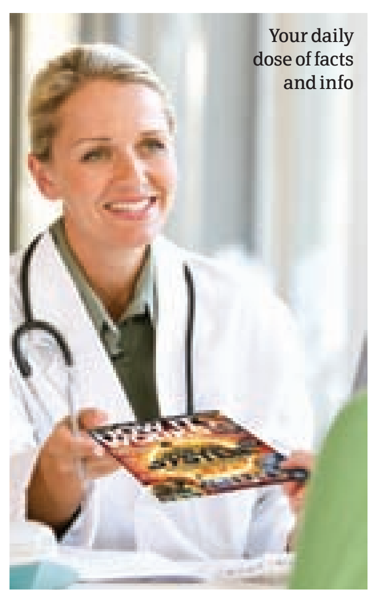
The Knowledge section is always crammed with the latest and greatest gadgets, books and techno toys that we think you'll all enjoy most. The section includes videogames because many of our readers have a console and love keeping up to date with the latest games on offer.

Sharing the knowledge

Thank you for such a broad series of articles featured in How It Works. As a pre-med college student, I found it useful to read about many real-world applications of information that I learned in class. I've shown the magazine to a few of my friends and they continue to thank me for showing them. It was also refreshing to see such a wide array of scientific topics compiled into a single magazine. While such a large extent of information can usually tend to be overwhelming, How It Works manages to help make science a universal language, providing clear and interesting articles that anyone can understand and enjoy! Thanks.

Joelle Gabet

HIW: If showing off our magazine to your friends gets you brownie points, then we're happy to help. We get lots of emails from students and professionals who, like you, are excited to see the topics they love covered in the magazine as well as learning about brand new subjects. That's the beauty of How It Works, whether it's something you're familiar with or that's completely new, we hope you'll find hours of informative entertainment here.



Your daily dose of facts and info

Forum

Those who like to spark debate and enjoy healthy discussions among like-minded individuals can visit www.howitworksdaily.com/forum and put their questions to the How It Works experts.

Email

If you'd like to contact us directly and perhaps even see your letter featured right here then get online and tell us what you think. Just email: howitworks@imagine-publishing.co.uk

Snail mail

Yes, we even welcome the good old postal method of communication, and you can send your letters to How It Works Magazine, Richmond House, 33 Richmond Hill, Bournemouth, Dorset BH2 6EZ.

Avoid the general public – subscribe!

I am really impressed with How It Works magazine and the fantastic website you've created. It's great to have a selection of top videos compiled for me – that way I don't have to trawl through the dross on YouTube to find the good stuff.

After trying out the first couple of issues and discovering that the quality of articles and diagrams inside can be maintained month after month, I went straight to the subscriptions bit on the website to sign up. I've never subscribed to a magazine before but I didn't hesitate with How It Works, and now I get my crisp copy every month without having to queue up with the general public. Keep up the good work. I'm really impressed.

Richard Lambert

HIW: We're so pleased to hear that you have subscribed; it's the only fail-safe way to ensure you never miss an issue. So many readers contact us saying they're disappointed to have missed an issue, and while back issues are available from our eShop, certain popular issues have already sold out completely and are very hard to come by on eBay.

As always, we're pleased you enjoy the magazine; it makes the late nights worthwhile! And we're pleased to hear that you're a fan of the various vids we post on the website – we try to put one up every day or at least every other day so it's worth checking back often so you don't miss out.

Teabreak time

I just want to say congratulations on a great magazine. I never miss an issue and as soon as the new one comes out I devour it with a cup of tea and a biscuit. And then I want to read the next straight away.

Kathryn Stacey

HIW: Drinking a cup of tea and eating a biscuit while reading How It Works… what better way to spend an afternoon? We spotted the magazine in among the papers and magazines on the counter in our local sandwich shop… it's the perfect magazine to browse through and then come back for more!

Questions you've been asking… and that we'll answer soon

How come a crocodile can't open its mouth as fast as it can snap it shut? D Cairns How do SATA II drives work? P Yourke What is the placebo effect? V Compton Why do stomachs rumble? F Gardner **Why do feet smell of cheese?** A Danks Why do we have body hair? T Morris **How are calories calculated?** G Faulkner Is time travel possible? P Newman How do ants breathe? T Rocca **How do computers work?** B Collins

Send your questions to howitworks@imagine-publishing.co.uk

HOW IT WORKS

Imagine Publishing Ltd
Richmond House, 33 Richmond Hill
Bournemouth, Dorset, BH2 6EZ
☎ +44 (0) 1202 586200
Web: www.imagine-publishing.co.uk
www.howitworksdaily.com

Magazine team

Editor in Chief Dave Harfield
dave.harfield@imagine-publishing.co.uk
☎ 01202 586229

Deputy Editor Helen Laidlaw
helen.laidlaw@imagine-publishing.co.uk
☎ 01202 586215

Staff Writer Rob Jones
Art Editor Duncan Crook
Senior Sub Editor Jon White
Head of Design Ross Andrews

Contributors
Julie Easton, Shanna Freeman, Natalie Johnson, Lynsey Kay Porter, Phil Raby, Dave Roos, Alasdair Stuart, Adam Smith, Luis Villazon, Jonathan Wells

Cover images
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Photography
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Head of Sales James Hanslip
☎ 01202 586423
james.hanslip@imagine-publishing.co.uk
Account Manager Nathalie Stainer
☎ 01202 586432
nathalie.stainer@imagine-publishing.co.uk

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International Manager Cathy Blackman
☎ +44 (0) 1202 586401
licensing@imagine-publishing.co.uk

Subscriptions
Subscriptions Manager Lucy Nash
subscriptions@imagine-publishing.co.uk
For all subscription enquiries
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Circulation
Circulation & Export Manager Darren Pearce
☎ 01202 586200

Production
Production Director Jane Hawkins
☎ 01202 586200

Founders
Managing Director Damian Butt
Finance Director Steven Boyd
Creative Director Mark Kendrick

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