NEW

THE MAGAZINE THAT FEEDS MINDS

HOW IT WORKS™

SCIENCE | ENVIRONMENT | TECHNOLOGY | TRANSPORT | HISTORY | SPACE

INSIDE

INTERVIEW

PROFESSOR BRIAN COX

HYDROGEN CARS

How the cars of the future will emit harmless water

EMERGENCY VEHICLES

Under the hood of the cars and vans that save lives

VOCAL CORDS

Discover how we speak and sing

INSIDE THE iPAD

THE REVOLUTIONARY NEW GADGET CRACKED OPEN!

941 FACTS AND ANSWERS INSIDE

CORAL REEFS

The world's largest living organism explained

+ LEARN ABOUT

- QUICKSAND
- AIRSHIPS
- SOLAR AIRCRAFT
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- PETROL PUMPS
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WELCOME

The magazine that feeds minds! ISSUE SEVEN

Get in touch

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

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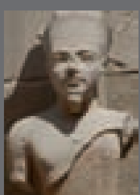
Imagine Publishing, 33 Richmond Hill
Bournemouth, Dorset, BH2 6EZ

"FEED YOUR MIND!"

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…



Dr Bridget McDermott
Hieroglyphics

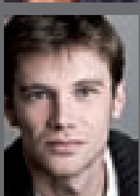
Dr Bridget McDermott is an expert in the field of ancient military technology. She has had a long career in Egypt and has worked with museum collections around the world.

HydroKev
Hydrogen cars

A hydrogen car advocate and publisher who lives in one of the hotbeds of research and development, southern California. He publishes several alternative fuel websites.

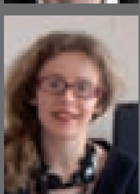
Luis Villazon
Coral reefs

Luis Villazon studied Zoology at Oxford University before becoming a science writer. He also served as a coastguard for nine years on the rugged cliffs of north Devon.



Ian Farrell
Dialysis

Ian Farrell is a journalist currently living in Cambridge, UK. He studied chemistry at York University and gained a PhD in chemical physics from Queen Mary, University of London.



Vivienne Raper
Quick sand, Grand Canyon

After gaining a PhD using radar and lasers to study the polar ice fields, she became a journalist and, since then, has written for the *Financial Times*, *Science Careers* and many more.

The sections explained

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

ENVIRONMENT
The natural world explained

HISTORY
Questions answered on how things worked in the past

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

TECHNOLOGY
The wonders of modern gadgetry and engineering explained

SCIENCE
Explaining the applications of science in the contemporary world

SPACE
From exploration to the solar system to deep space

Editor's pick

I've already enthused over the iPad so the next best thing in this issue, in my opinion, is the hydrogen cars. Why worry about rising oil prices when there is already a working, clean solution at hand.

With thanks to

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

sciencemuseum DK NASA REUTERS

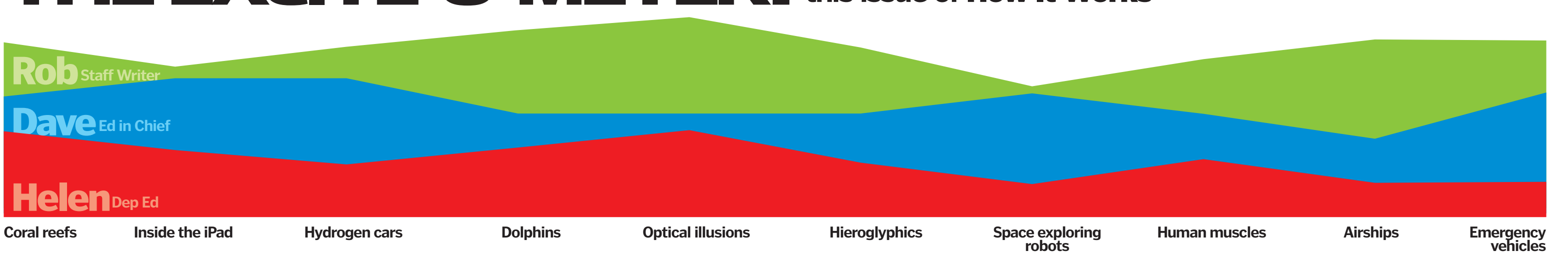
The Apple iPad is finally here! I've been editing technology magazines for a decade now so you could be forgiven for thinking that I'm jaded about the release of new technology. You'd also be wrong. I think the Apple iPad is one of the most exciting gadgets to come out since I first opened MS Word and typed a scathing review of Windows ME back in 2000.

Despite the lack of a forward-facing camera, no multi-tasking, no proper GPS and not much change to the operating system, the potential for this device is huge and may well represent a huge shift in the way we browse the web and read magazines. I can't wait to make products for this device and the possibility of blending audio, video and text on an ergonomic and portable device is huge. We've already got the great digital versions of How It Works available for iPhone from the iTunes store and these will look fantastic on this new device. We're not content with offering you a tame review of this revolutionary device, so we've teamed up with **iFixit.com** to offer you a unique view of what lies inside it.

Dave Harfield
Editor in Chief

THE EXCITE-O-METER!

What's been getting us excited in this issue of How It Works



AND THE VERDICT IS…

Once again staff writer Rob's excitement levels are the lowest but Dave's love of the iPad and interest in hydrogen cars have pushed levels artificially high this issue. That said he only just pipped Helen to the post by two points.

HOW IT WORKS

CONTENTS

The magazine that feeds minds!

ISSUE SEVEN

06 Global Eye

Experience some amazing sights from the worlds of science, technology, nature, space and transport

Sections

Transport

14 **Emergency vehicles** Get under the hood and into the driving seat of fire engines, police cars and ambulances

20 Superchargers

21 **Petrol pumps** Ever wondered how you can fill your car up so easily? We'll show you…

22 Solar Impulse

24 **Hydrogen cars** The latest in gas powered, lean-green driving-machines

Environment

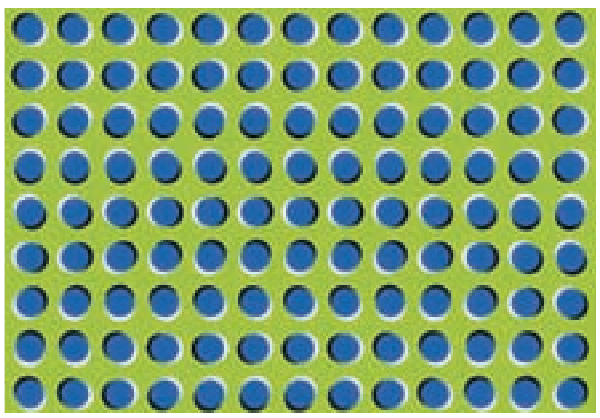
28 **Dolphins** A nose-to-tail explanation of the friendly sea-bound mammals

30 Flocking

31 Measuring wind speed

31 Sea level

50 **Inside the Apple iPad**
Under the skin of the latest gadget from Apple

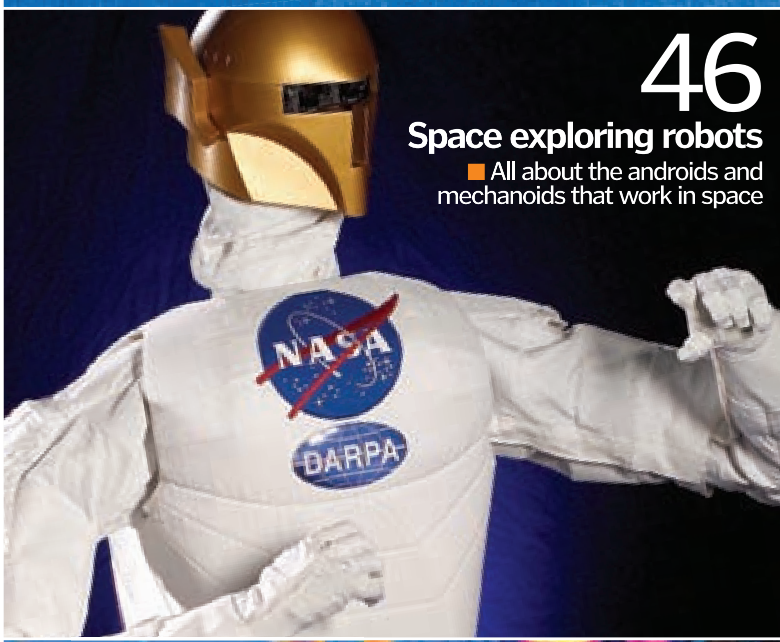


68 **Optical illusions**
Why do certain images fool the brain?

28 **Dolphins**
The playful and intelligent sea-bound mammals explained

14 **Emergency vehicles**
Inside the vehicles that save lives

24
Hydrogen cars
The next generation of green motors that produce nothing but water



46
Space exploring robots
All about the androids and mechanoids that work in space

36
Coral reefs
Fascinating facts about the largest living organisms on Earth

E NOW!

32 Slugs and snails
32 Pistol shrimps
33 Erosion and the Grand Canyon
35 Quicksand

36 **Coral reefs**
An in-depth look at the largest living organisms on Earth that lie beneath the ocean waves

Space

40 **Neptune**
All about the eighth planet from the Sun in our solar system

42 Where is the Kuiper Belt?
42 What are brown dwarfs?
43 The Spitzer Space telescope

44 **How do orbits work?**
A closer look at how and why planets circle around the Sun

45 The Lunar Recon Orbiter
45 The Perseids shower

46 **Space exploring robots**
Learn about the androids and robots that work hundreds of miles above the surface of the earth

Technology

50 **Inside the iPad**
Lifting the lid on the latest revolutionary gadget from Apple

54 Smoke alarms
54 Nanotechnology

56 **Inside a coal mine**
Ever thought about a change in career? It's a dirty job, but someone's got to do it

58 Ballpoint pens
58 Harmony remote control

59 **Gambling machines**
Inside a slot machine

55 Rebreathers

Science

62 **Human muscles**
The secret of human strength and movement revealed

64 Fermentation
64 Newton's Cradle
65 Dialysis machines
66 Carbon dating
67 Vocal chords

68 **Optical illusions**
Those bizarre images that fool our brains get explained

History

74 **Airships**
Understand how these magnificent machines stayed in the air

76 Roman toilets
76 Medieval sextants

77 **Armour**
How knights protected themselves

78 Hieroglyphics

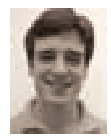
Regulars

12 **How It Works interview**
Scientist of the moment Brian Cox talks LHC

BRAIN DUMP
Because enquiring minds want to know...

82 **Expert answers**
Experts from the Science Museum answer your questions

Sam Furniss
Science Museum Explainer
Sam is an aspiring stand-up comedian and science fanatic

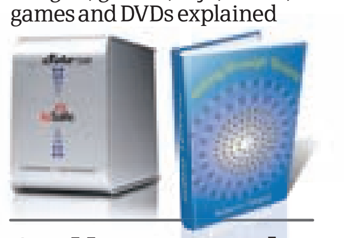


Rik Sargent
Science Museum Explainer
Veteran panel member Rik returns to supply answers once more

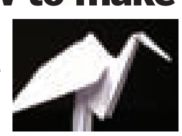
Chi Wing Man
Science Museum Explainer
Chi's background is in biochemistry and he also loves kebabs!

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

86 **The latest reviews**
Gadgets, gizmos, toys, books, games and DVDs explained



94 **How to make**
Another lesson from our in-house origami expert



96 **How It Works – Inbox**
Have your say on How It Works

GLOBAL EYE NEWS

A fresh look at the world

Image courtesy of STFC

Aerial view of Harwell Science and Innovation Campus

© BIS

Introducing the new UK Space Agency

Britain's long-term contribution to the space industry goes from strength to strength as the UK Space Agency sets up camp at the ESA's Harwell facility

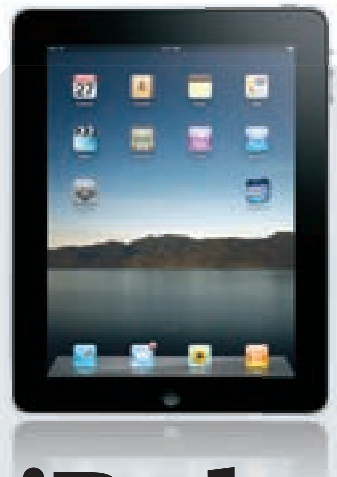
UK SPACE AGENCY

© BIS

On 23 March UK Minister of State for Science and Innovation Lord Drayson and Business Secretary Lord Mandelson announced the launch of the International Space Innovation Centre (ISIC). This £40m centre, funded by both public and industrial investment, is the new home of the first UK Space Agency (UKSA). ISIC is located at the European Space Agency's Harwell Science and Innovation Campus, which opened last July.

UKSA's current main areas of interest include analysing data collected by Earth's observation satellites, monitoring climate, and making recommendations on the security and resilience of space systems and services. Lord Drayson has high hopes for the agency and its potential to boost the economy as well as prove the UK's position in the space sector. He claims: "The action we're taking today shows that we are really serious about space. The UK Space Agency will give the sector the muscle it needs to fulfil its ambition. Britain's space industry has defied the recession. It can grow to £40bn a year and create 100,000 jobs in 20 years. The government's commitments on space will help the sector go from strength to strength."

The government-backed UKSA launched on 1 April and will represent Britain on all civil space-related issues. The UK finally has a means of drawing on its expertise in space science and technology under one coherent management system. Overall this is a giant leap for the UK space industry, and hopefully one that will bear fruit over the coming years.



iPad sells 300K

… and that's just in the first 24 hours

Despite its reception by critics being distinctly mixed post-launch, the Apple iPad sold more than 300,000 units in its first 24 hours on sale after its US launch on 3 April.

This feat is even more impressive when you take into account that Apple has yet to release its full range of iPads, with the 3G-enabled variety not due out till later this month.

In addition to hardware sales seeing unprecedented numbers, Apple also revealed that it has sold over 250,000 eBooks since the iPad's launch, with Steve Jobs enthusing, "It feels great to have the iPad launched into the world – it's going to be a game-changer. iPad users, on average, download more than three apps and close to one book within hours of unpacking their new iPad."

In fact, the launch was so exciting for the Apple CEO that he even ventured out to his local Apple Store in order to talk to customers about their brand-new purchase.

This day in history

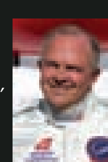
22 April: How It Works issue 7 goes on sale, but what else happened on this day in history?

1500 Pedro Alvares Cabral, an explorer from Portugal, became the first European to ever set eyes on Brazil.

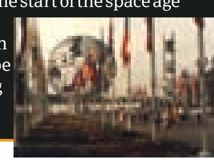
1889 The date of the Oklahoma Land Run of 1889, during which 2 million acres of public land became open for settlement.

1933 On this day in 1933 Sir Frederick Henry Royce died. The OBE holder founded British car firm Rolls-Royce.

1944 Steve Fossett, the first man to fly non-stop around the world in a balloon, is born.



1964 New York plays host to 1964's World's Fair. The Unisphere commissioned for this event is a stainless steel representation of Earth designed to commemorate the start of the space age and "man's achievements on a shrinking globe in an expanding universe".



© NASA

Hubble turns 20

This month the Hubble Space Telescope celebrates two decades of service

The world's most recognisable space telescope reaches a landmark birthday, 20 years after its launch on 24 April 1990. Despite a shaky start due to a problem with the primary mirror, which was rectified after a servicing mission in 1993, the Hubble Space Telescope has produced some of the greatest images of the cosmos ever seen.

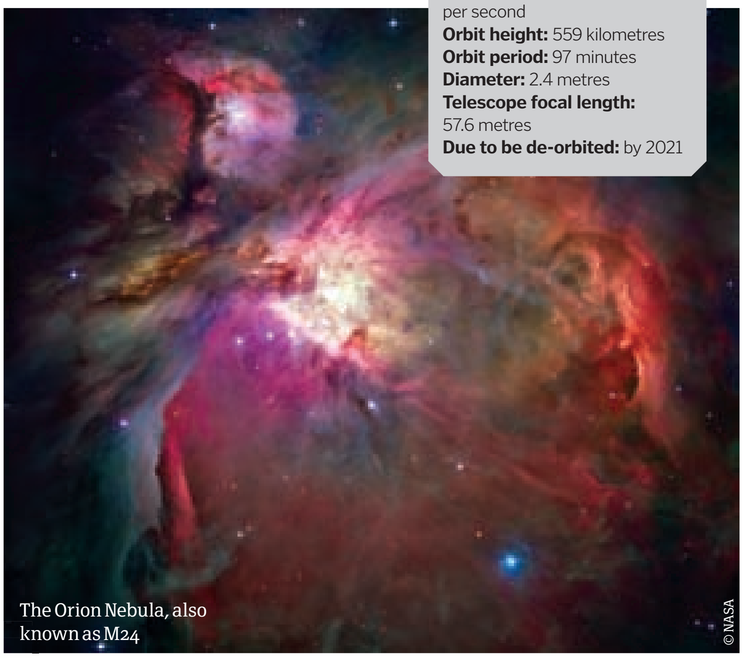
Hubble's last MOT took place in May 2009 and should see the telescope through to 2014 when its successor, the James Webb Telescope, is due to launch. Hubble is now in great shape since a new infrared camera was installed, enabling the device to observe the most distant galaxies ever recorded.

And don't forget, this spring the Science Museum is showing *Hubble 3D*, an IMAX experience narrated by Leonardo DiCaprio that documents the never-before-seen footage of the recent Hubble service mission. You can find details of the movie in this month's Brain Dump on pages 82-85.

The Statistics

Hubble Space Telescope

Service: 20 years
Mass: 11,110kg
Orbital velocity: 7,500 metres per second
Orbit height: 559 kilometres
Orbit period: 97 minutes
Diameter: 2.4 metres
Telescope focal length: 57.6 metres
Due to be de-orbited: by 2021



The Orion Nebula, also known as M24

© NASA

Take 3D gaming along in your pocket

Nintendo announces 3D DS

A new handheld claims to achieve 3D effects without the need for special glasses

Videogame giant Nintendo has announced a 3D successor to its DS handheld gaming platform. By this time next year, claims Nintendo head honcho Satoru Iwata, gamers will be enjoying 3D effects on the 3DS (a working title) without the need for special glasses.

A familiar sight on train and bus journeys, the DS has gone through several incarnations with each model varying in size from the original chunky DS to the slimline DS Lite and the larger-screened DSi XL. The last time the company ventured into three-dimensional territory, however, was with the Virtual Boy, which used an effect called parallax to create the illusion of depth. This much-hyped format ultimately died a death as only a few games were ever developed for the platform and the device was far from convenient to use.

The games industry expects to get its first glimpse of the exciting 3DS at this year's annual E3 expo held in Los Angeles in June.

1969
Englishman Sir Robin Knox-Johnston CBE completes the first ever non-stop solo circumnavigation of the globe, arriving in Falmouth, Cornwall, from where he set sail back on 14 June the previous year.

1970
The first year that Earth Day was celebrated. This date was dreamed up by an American senator to address global issues.

1993
The first global web browser, Mosaic Version 1.0, is released.

2000
In response to the massive growth of telecommunications, the UK undergoes a major change of dialling codes, which increased the number of available telephone numbers.

2008
Lockheed's F-117 Nighthawk stealth aircraft is officially retired by the US Air Force.

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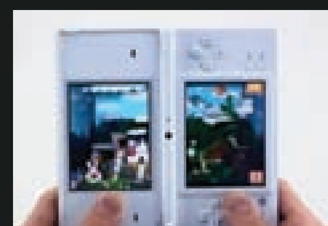
HOW IT WORKS TV

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

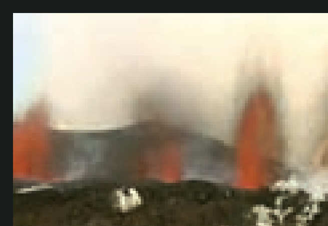
How the 3DS might look

This clip of a DSiWare game that uses head-tracking technology to create 3D effects could reveal how the 3DS screen may look.



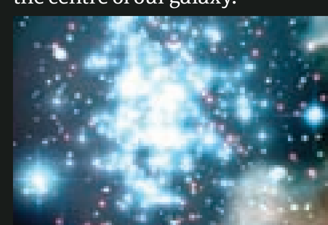
Stunning volcano in Iceland

Near the Eyjafjallajokull glacier in southern Iceland, this volcano erupted sending lava hundreds of metres into the air.



Sagittarius A*

A video that reveals how difficult it is to observe Sagittarius A*, the supermassive black hole at the centre of our galaxy.



How the Colosseum worked

This re-enactment reveals how Rome's mighty Colosseum was built, operated and fought in.

GLOBAL EYE INTERVIEW

A fresh look at the world

Professor Brian Cox

CERN's Large Hadron Collider, the world's most powerful particle experiment, is a pretty complicated subject to grasp, but Professor Brian Cox's welcoming take on the topic made him an overnight 'rock star' scientist. We caught up with one of the world's most engaging scientists to find out about his latest projects…

How It Works: Please tell us a little about your latest series for BBC 2, *Wonders Of The Solar System*, and what you hope it will offer viewers.

Brian Cox: "*Wonders*" is a documentary about astronomy and physics. Since the BBC last made a documentary series about the solar system a decade ago, we have lived through what I believe is something of a golden age of exploration. We've confirmed that there was once water on Mars, and have seen evidence that there may still be liquid water beneath the Martian surface today. We are now virtually certain that Jupiter's moon Europa has a liquid water ocean beneath its icy crust that is perhaps 100km deep, and therefore contains more water than all the Oceans of Earth. We've seen fountains of ice erupting from Saturn's tiny moon Enceladus, and parachuted to the surface of the giant moon Titan, on which we have discovered lakes of liquid methane, methane snow and methane rain.

I strongly believe that the exploration of nature is critical to our progress and survival as a civilisation. I know that many, indeed most people I meet, share this view, and are very open to being inspired to support science, engineering and exploration. I wanted to create a science series with an agenda as well as being entertaining and informative. My agenda is to celebrate and promote exploration, and I hope I make the case for this in the shows.

HIW: What, for you, is the most remarkable parallel between Earth and the numerous other bodies that exist within the solar system?

BC: I think by far the greatest discovery has been the existence of liquid water beneath the surfaces of several of Jupiter's moons. I mentioned Europa above, but we now think that Callisto and Ganymede may also have sub-surface oceans. On Earth, wherever we find water, we find life. Many biologists are now speaking in optimistic terms about the possibility of alien life existing on these moons. The discovery of life beyond Earth, especially if it has a radically different biochemistry and therefore evolved separately, would be in my view the greatest scientific discovery of this or perhaps any age.

HIW: You have a gift for making sense of the most impenetrable-sounding subject matters, inspiring a new generation to learn. Who in your life has influenced your zest for knowledge?

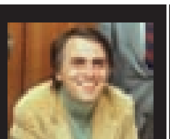
BC: Without doubt the greatest science communicator in history was Carl Sagan. This was not only because he brought the wonders of the universe into my life as an excited 12-year-old watching the *Cosmos* TV series, but also because he genuinely had a wider agenda. He passionately believed that science is the way to make the world a better place. Science is an inherently modest, careful and tremendously successful way of understanding nature and making progress. I would argue that it is the best way we have. Science communication should therefore be about more than just relating facts or entertaining the audience. It should be slightly polemical, and Sagan was absolutely that!

HIW: You embarked on a rather incredible voyage that gave you a peerless view of the Thin Blue Line that envelops our atmosphere. What was that experience like?

BC: The journey to the edge of our atmosphere was remarkable for many reasons. Of course, as shown in the programme, seeing our fragile

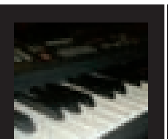
CAREER

1968 English particle physicist Brian Cox hails from Oldham, Lancashire, where he developed a fondness for science watching American physicist Carl Sagan's (right) *Cosmos* TV series.



1991 In the Eighties he embarked on a music career with rock and roll band Dare before, in 1991, enrolling at Manchester University where he later earned a PhD in high-energy particle physics.

1997 During his university years Brian became the keyboardist in the band D:Ream, who had a number one in 1994 with *Things Can Only Get Better*. The song gained a new lease of life when it became the anthem for the New Labour party in 1997.



2002 He has received several prestigious awards for his work in science and was elected as an International Fellow of the Explorers Club in 2002. Then, in 2006, he gained a very well-deserved British Association Lord Kelvin award for his efforts to instil a love of science in the public.

atmosphere is a moving experience. What we didn't use in the programme, however, was my reaction to flying in the beautiful English Electric Lightning. This is a machine that was built to go fast and high, and be as safe as possible given that. I found this exhilarating, because I take quite a dim view of our health and safety obsessed age. I think, for example, that the Apollo programme might never have happened if we'd asked the questions we do today about safety and risk. I got a little glimpse of *The Right Stuff* flying in that plane, and it was exciting and inspiring. Engineering on the edge!

HIW: Please explain – in true Professor Cox style – the basics of the ATLAS experiment at CERN?

BC: The LHC recreates the conditions that were present less than a billionth of a second after the big bang in a tiny area of space the size of a single proton. It can do this up to 600 million times every second. ATLAS, and the three other large detectors at the LHC, photograph these collisions and store the data for analysis. The reason we do particle physics is that we've discovered that as you go back in time towards the big bang, as the universe gets hotter and hotter, it becomes simpler. One way to think of it is that the underlying simplicity of the laws of nature are obscured by the complexity of the universe today. But this complexity is a property of our old, cold universe. In a sense it has crystallised out as the universe expanded and cooled. If we want to reveal the underlying simplicity to better understand the fundamental laws that govern our universe, we have to journey back in time. This is what the LHC, together with its detectors, does.

HIW: You worked in a science-consulting capacity on the 2007 film *Sunshine*, how conceivable were the events that took place, and were you happy with the final film?

BC: *Sunshine* is science fiction. The events depicted in it are entirely fictional, as it always says at the end of films! So the Sun isn't going to die soon, and even if it did we wouldn't be able to do anything about it! The film is not about this, however. It's about humanity's relationship with the power and sheer magnificent scale of the universe. How are we to react to the knowledge that we are in some ways utterly insignificant and helpless observers in a vast, violent and in a sense meaningless universe? The beauty of the film is in its subtle message that the way forward is not fundamentalist awe and reverence, as personified by Captain Pinbacker, but in the more modest but ultimately more profound and relevant reaction to nature shown by the physicist Capa. I particularly love the end of the film when Capa raises his hand to the surface of the Sun. I spoke about that moment at some length with Cillian Murphy, the actor who plays Capa. I think he brilliantly conveys what we spoke about in his expression in this scene. I don't need to tell you what we spoke about – just watch and you'll get it!

HIW: Are you a gadget man and is there one particular gadget or piece of kit that you wouldn't like to live without?

BC: I like quality engineering. My favourite 'gadget', although I would be more inclined to call it a work of art, is my Naim hi-fi. Superb British craftsmanship that magically conveys the emotion of musical performance though engineering!

HIW: In an illustrious career, what has been your favourite project so far?

BC: Scientifically, my favourite achievement was publishing my first paper based on experimental data from the H1 experiment in Hamburg, based on my PhD work in the late Nineties. There is nothing like analysing data.

In my media career, I am very proud of certain moments in *Wonders*. Particularly the last ten minutes or so of the last episode, when I was able to really speak about my view of our universe, the importance of exploration and how I see our place within it.

HIW: And finally, what is next on your to-do list?

BC: Next, I have a paper to write on measuring the coupling of the Higgs particle to gluons! Then after that I'm off to film my next BBC series called *Universal*. It will be about the origins, evolution and fate of our universe, the laws of nature and crucially our origins and evolution as complex structures in this complex and beautiful universe.

HIW: Actually, this is the "and finally" question, will we ever see Professor Brian Cox perform *Things Can Only Get Better* on a stage again? **Crosses fingers**

BC: No.

"I take quite a dim view of our health and safety obsessed age… the Apollo programme might never have happened if we'd asked the questions we do today about safety and risk"

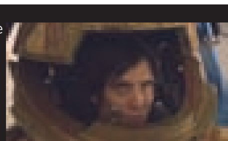
Brian's latest series, *Wonders Of The Solar System*, is now available on BBC DVD.

Brian ventures close to a lava lake

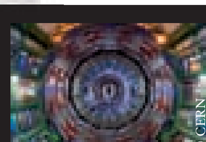
One man more interested in solar eclipses than most

All Images © BBC

2007 Brian took a science consultant role on Danny Boyle's sci-fi flick *Sunshine*, starring Cillian Murphy and Chris Evans.



2008 Since inadvertently becoming the face of the Large Hadron Collider, Brian has starred in many exciting TV and radio shows to further ignite people's interest in science and the world around us.



© CERN

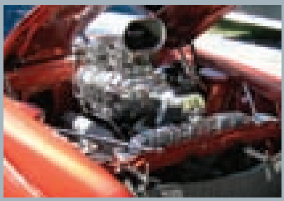
2009 Brian becomes Professor of Particle Physics at the University of Manchester.

2010 > PRESENT Brian's involvement with the ATLAS experiment at CERN's Large Hadron Collider in Geneva is ongoing and his presenting career continues to thrive.

© CERN

This month in **Transport**

Issue seven sees one of the largest Transport sections ever. The team were heaving under the weight of so many cool ideas that they just had to unburden themselves and here's the result. If you always chose to be the boys in blue when playing cops and robbers as a kid, the feature to your right will have you making siren noises in delight. However, if you prefer green to blue, take a look at our explanation of the latest hydrogen powered cars over on page 24.



20 Superchargers

22 The Solar Impulse

24 Hydrogen cars

TRANSPORT
14 Emergency vehicles
20 Superchargers
21 Petrol pumps
22 The Solar Impulse
24 Hydrogen cars

Emergency vehicles

Emergency vehicles are an integral part of any society. We look at some of the vehicles that are saving lives…

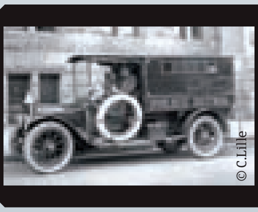
Police cars

An integral part of modern policing, the police car is built for protection and speed

There are many different types of police car, each tailored to maximise the operating efficiency in the role it is designated with, ranging from traffic cars to response cars, to dog units and SUVs among others. The most common of these, however, is the patrol car, a multi-role vehicle that is used primarily to convey officers about their patrol or business with maximum efficiency. These vehicles are always marked with police colours and have audio and visual warnings in the form of sirens and flashing lights.

Due to the demanding levels of operational usage necessary by these 24/7 vehicles, their design and technology tends to differ from standard civilian models. Durability is often central to their outfitting, with heavy-duty suspension and brakes installed as well as long life tyres, robust gearbox (transmission) and extensive engine cooling systems. Due to the long periods of idling the vehicle has to maintain, engines are often upgraded to larger

The evolution of the police car



© C.Lillie

1920s

Early police cars were more akin to wagons or the riot vans of today, with low speed, acceleration, zero safety features and a penchant for breaking down in bad weather.

© Mo...

1950s

More stylish, with a much-needed boost to their top speed and acceleration, the police cars of the Fifties integrated two-way radios, vastly increasing ease of communication between officers.

Head to Head POLICE CARS

MOST FAMOUS


© Cliff

1. USA
Easily winning the best-police-car-on-film award, the standard American cop car's shape and styling has been made iconic by its use in Hollywood films.

BRIGHTEST

2. Britain
Chunkier and less stylish than their American counterparts, the standard British car comes adorned with garish primary colours and a fat back end.

MOST STYLISH

3. Japan
The most futuristic-looking of all police cars, this Japanese variant is based on the Honda NSX and is therefore rather fast and also an excellent drifter.

DID YOU KNOW? *The first police car was an electrically driven wagon that operated in Akron, Ohio in 1899*

Inside a police car

The essential equipment of the modern police car

© Alex Pang

2. Two-way radio
Absolutely central to the car's operating efficiency, the two-way radio allows officers to stay in touch with the police switchboard and other officers at all times.

3. Mobile data terminal
The mobile data terminal allows officers to call up a vehicle's details, driver's licence information, incident logs and criminal records on the fly.

4. Siren/lights
An important part in communicating with the general public, the car's siren and lights can alert drivers to the officer's presence, as well as indicating to other vehicles their positioning.

7. Equipment
Non-electrical equipment in patrol cars can include among others: firearms, firearm enclosure, traffic cones, signs, a first aid kit and fire extinguisher.

8. Markings
The markings that adorn police cars vary depending on their vehicle type and role.

1. Chassis
Either marked or unmarked depending on the vehicle's role, patrol cars sport streamlined, durable chassis designed to be as resistant as possible for their weight.

5. Wheel base
Upgraded over the standard civilian model, the wheelbase, tyres, engine and alternator are comparably more durable and robust to deal with 24/7 running.

6. Suspect transport enclosure
The rear compartment of all patrol cars has remote locking as well as bars or bulletproof glass to separate the passenger from the officers and prevent them escaping.


© Bob

The modern police car has plenty of gadgets

variants with greater power and a higher maintenance threshold. The alternator (a device that charges the car's battery when running) gets the same treatment also, as due to the extra electrical equipment installed in the vehicle – such as the two-way radio – there is a greater demand for electricity and therefore juice from the battery.

Inside the patrol car the officer in command has a variety of equipment in which to enable their role as a peacekeeper. A two-way radio provides a direct link back to the switchboard, station as well other officers on patrol, while the integrated mobile data terminal allows officers to search for information such as licence details, incident logs and criminal records. Vehicle tracking and CCTV systems are also installed in most patrol cars, allowing the police to track any stolen vehicles in the area that have been bugged. It also allows them to gather evidence against any criminal who performs an illegal act in the vicinity of the car and also automatically recognise cars by the licence plate, easily allowing them to follow vehicles with a notorious past. Other non-electrical equipment at officers' disposal includes: firearms (in certain countries), a first aid kit, fire extinguisher and traffic cones.


© FORD

The police car of the future

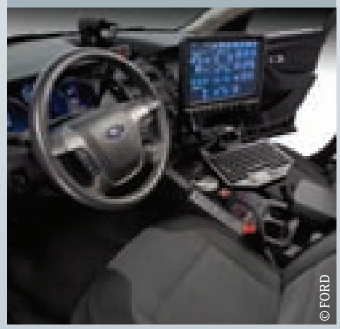
The face of mobile policing is set to change in 2011 as Ford is to introduce its brand new, high-tech Police Interceptor. Based on the Ford Taurus, but with 90 per cent of its interior redesigned for law enforcement needs, this car will boast many new features. These include seats with anti-stab plates, lower front seats to accommodate officers' utility belts, a host of electronic tracking and data management technology, a fuel-efficient engine capable of running on 85 per cent ethanol-blend fuel, side curtain airbags, an automatic blindspot warning and a rear-view CCTV camera.

With a focus on being as pursuit-ready as possible, the Taurus Police Interceptor will be resilient, economical and super fast thanks to its light weight and advanced safety technology.

The Statistics

Police Interceptor

Chassis: Ford Taurus
Engine: 3.5-litre V6
Power: 365bhp
Torque: 350lb-ft
Fuel: Petrol/E85 ethanol-blend fuel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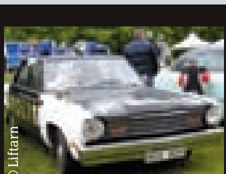

© Liftarn

1970s

Incorporating advances in construction, electronics and safety features, the cars of the Seventies were quicker and more effective than their predecessors. Video cameras started to be incorporated also.

2000s

Modern-day police cars have unparalleled levels of surveillance, safety and build quality. Now electronic systems ensure that officers have the best tools to maintain law and order safely and effectively.

"The pump in any fire engine works by pressurising the water from the water tank through a series of mechanisms"


© BrwDdw

A huge array of hoses and equipment is kept inside these cabinets


Engines have internal tanks and can also be connected to fire hydrants

Emergency vehicles: Fire engines

Natural and man-made fires would rage out of control without these fire-fighting machines, but how do they work?

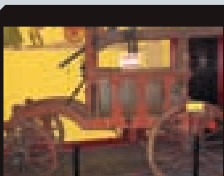
Fire engines work by transporting firefighters, water, a mobile pump and a plethora of fire-fighting and life-saving equipment to the scene of any fire. These heavy-duty fire-fighting vehicles are often built from large-scale truck or mobile crane platforms and are powered by massive diesel engines necessary to respond quickly to an incident. The fire engine itself is separated into two distinct areas, the cabin/control room at the front and the water tank/ utility area at the rear.

The cabin and control room operates as both seating area for the unit's commander, driver and crew while en route to an emergency, and also as the communications and operations centre during the mission. The crew are separated from the commander and driver within the cabin – with the crew positioned behind in specially designed 'jumpseats' – but connected via radio link so that briefings can be delivered during the journey. Once at the scene of the blaze, the cabin then becomes the control room with pump control, valve control and communications all being managed and maintained from within.

The pump in any fire engine works by pressurising the water from the water tank through a series of mechanisms which are powered by the vehicle's own diesel engine. To achieve this, many engines employ an impeller (a rotor encased within a tube or conduit) mechanism, which uses centrifugal force in order to pressurise the water. Once pressurised the water can then be released at will through the engine's numerous valves, operated through the valve control panel. During particularly fierce fires where the engine's internal supplies of water run dry, firefighters can access nearby fire hydrants whose position is supplied by the engine's on-board terminal and data link to headquarters.

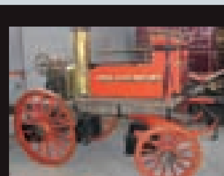
Once stationary the engine's range of hoses and equipment can then be utilised by the firefighters. Running down either side of the rear tanker section of the fire engine lie a series of lockers, cabinets and drawers that contain the engine's complete array of hoses, each designed with a specific role in mind. Its safety and rescue equipment can also be found in the side compartments. Tractor drawn aerial engines, which are used whenever fire has broken out in high, hard-to-reach areas, are also fitted on top of their tank with a telescoping hydraulic platform from which firefighters project hose streams from an elevated position.

Evolution of the fire engine



1732

The earliest fire engines were mere wooden carts with barrels of water stored in the back. These were drawn by men and then later horses and relied on a manual pumping mechanism operated by the fire officers to pump water out of the containers and onto any fire.



1906

Despite the emergence of motor vehicles, most fire engines were still drawn by horse in the early 20th Century, as demonstrated by this 1906 steam-powered variant. The water was pumped onto the fire by a double-acting on-board steam engine, which was raised to working pressure from cold water in ten minutes on route to the blaze.

Turntable
1 The turntable ladders that are fitted to most fire engines nowadays are powered by hydraulics and tend to extend telescopically, allowing the firemen to reach great heights.

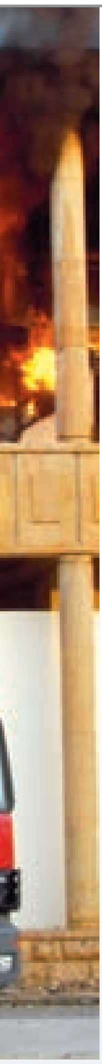
Steamy
2 The first iterations of modern fire engines, which were built in the late 19th Century, were drawn by horses and powered by steam. See the boxout below for more…

Hello kitty
3 Despite the act of cat rescue being associated with the fire service, in reality very few cats are retrieved by fire engines… they normally make their own way down.

New York, New York
4 The New York City Fire Department employs over 11,000 fire fighters and operates more than 190 fire engines, housed across multiple stations.

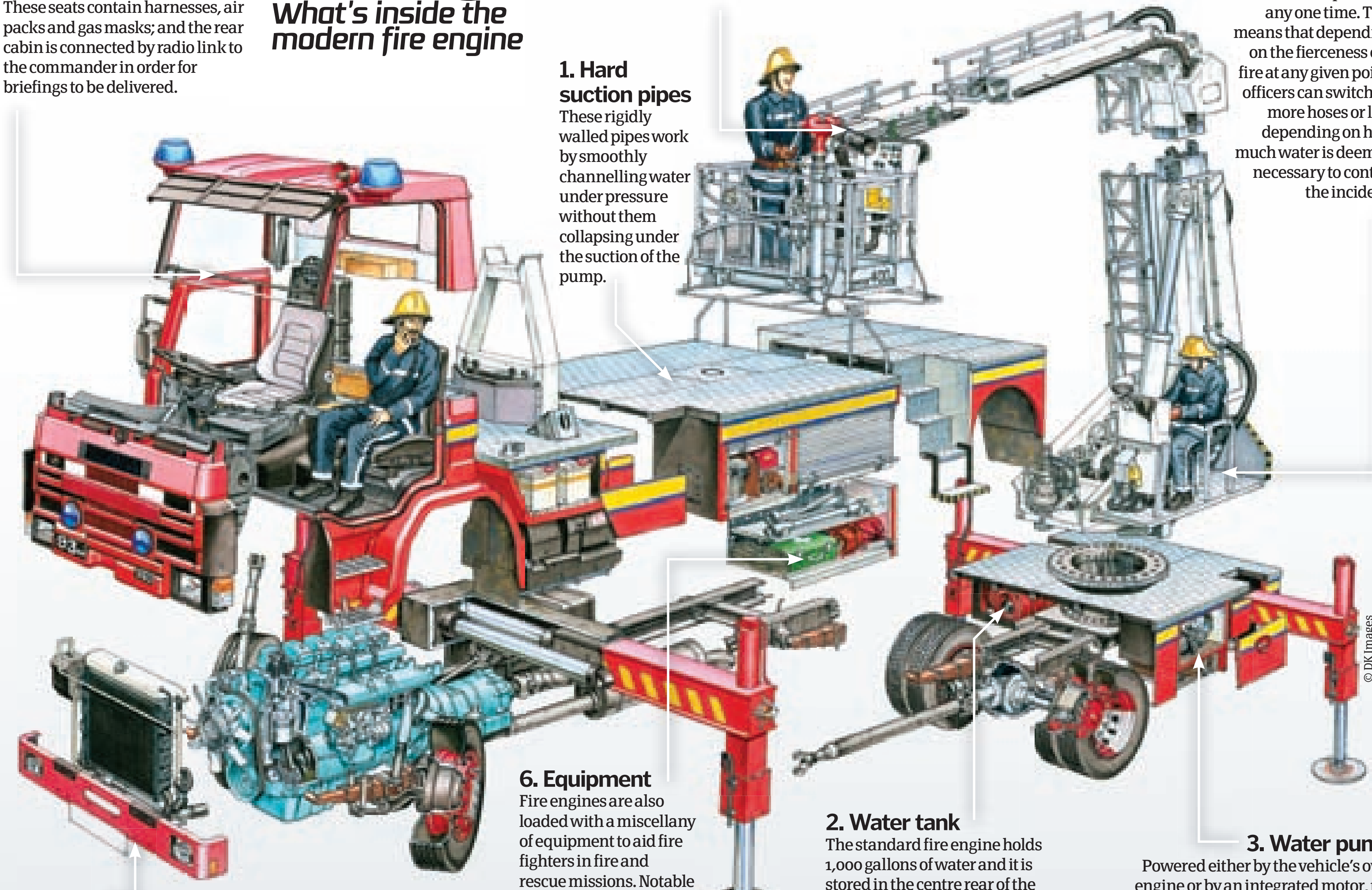
Jaws
5 One vital piece of equipment carried in fire engines are the Jaws of Life, a mechanical device designed to help prise civilians out of crushed cars and collapsed buildings.

DID YOU KNOW? *The minimum size for a US fire engine's tanker truck is 1,000 US gallons (8,330lbs)*



Inside a fire engine

What's inside the modern fire engine



7. Cabin
The cabin includes seats for both the driver and commander of the unit, as well as a series of 'jumpseats' for the firefighters. These seats contain harnesses, air packs and gas masks; and the rear cabin is connected by radio link to the commander in order for briefings to be delivered.

5. Hoses
There are many different types of hoses on modern fire engines, ranging from the small booster line, to the pre-connected crosslay hoses, right up to the colossal deluge cannon.

4. Pump control
The pump control allows fire fighters to specify how many valves are opened at any one time. This means that depending on the fierceness of a fire at any given point, officers can switch on more hoses or less depending on how much water is deemed necessary to control the incident.

1. Hard suction pipes
These rigidly walled pipes work by smoothly channelling water under pressure without them collapsing under the suction of the pump.

8. Bumper
Certain fire trucks may be fitted with a battering-ram styled bumper. This is utilised when the fire engine needs to progress through a congested area, and to move vehicles which are illegally blocking fire hydrants.

6. Equipment
Fire engines are also loaded with a miscellany of equipment to aid fire fighters in fire and rescue missions. Notable items include: the Jaws of Life, crowbars, a sheet rock puller, pike poles, spanner wrenches and nozzle adapters.

2. Water tank
The standard fire engine holds 1,000 gallons of water and it is stored in the centre rear of the vehicle. However, the limit may be exponentially increased depending on the severity of the fire and many vehicles hold upward of 5,000 gallons.

3. Water pump
Powered either by the vehicle's own engine or by an integrated motor, the water pump generates the pressure to project the water out through the engine's hoses. This pressure is often generated by mechanisms creating centrifugal force.

© DK Images

Steam punk

Before diesel engines, steam was the way forward

Unlike the sleek high-powered fire engines we have today, originally the vehicle designed to carry and pump water was a machine powered by steam. Constructed in the heart of the industrial revolution these engines looked more akin to trains than trucks and relied on cisterns as a source of their water, pumping it through rudimentary pipes by steam-driven pressure.

In addition, these fire engines provided no safety features for their operators and until technology advanced enough, they had to be pulled by men or horses. Indeed, it was not until 1841 that a self-propelled fire engine was invented, and it was not until well into the 20th Century that this became standard across Europe and America.

© Privatend

1950

After two world wars, the motorcar had gained a strong foothold in society and all fire engines were now motorised. Due to the severity of the fires faced during wartime bombing raids, fire engines had also become far more resilient, with ramming bumpers, toughened metal chassis and larger tanks.

2000

Throughout the late 20th Century fire engines continued to evolve, adding larger cabin compartments, multiple pumps, differing hose adapters, hydraulic lifting platforms, bigger water tanks, ground stabilising struts and a miscellany of safety equipment such as the Jaws of Life, seat harnesses and radio intercoms.

"The ambulance works by marrying a robust, high-speed vehicle with a mobile hospital"

Emergency vehicles: Ambulances

Crucial for transporting sick and injured people to hospital, ambulances are highly technical vehicles fitted with cutting-edge technology

The role of modern ambulances is to transport paramedics, doctors, medical equipment and pharmaceuticals to an incident in order to aid ill or injured civilians, before returning them to hospital for further treatment or care. To achieve this, ambulances are physically constructed to context-sensitive designs, allowing them to operate with maximum efficiency, as well as being fitted with state-of-the-art technology. While the common ambulance is a motorised van, they range in size and form massively, with bikes, cars, trucks, boats and planes used extensively.

Focusing on the common van variant of vehicle, the ambulance works by marrying a robust, high-speed vehicle, with an air-conditioned, interior, high-tech mobile hospital, which can be utilised by on-board paramedics and doctors. Each ambulance carries a stretcher with accompanying trolley and hydraulically powered tail lift, electronic equipment – such as a defibrillator, oxygen pump, ventilator and heart monitor – a wide selection of drugs, medical equipment and a selection of passenger seats. The purpose of this mobile treatment room is not to completely cure the patient, but to stabilise and transfer them to the larger and better-equipped hospital, where emergency surgery can take place if deemed necessary.

Like all emergency vehicles the ambulance is equipped with both visual and audible warnings in the form of a siren, flashing lights and primary coloured markings. They are also fitted with a two-way radio for contacting the hospital to alert them to an impending arrival and a mobile data terminal to log time spent getting to the patient, treating the patient and returning them back to hospital. They also have CCTV cameras to gather evidence which can be used in malpractice lawsuits, and data recorders to log the speed, braking patterns, activation of emergency warning lights and sirens of the vehicle.


© RAMA

All the essential equipment to keep people alive

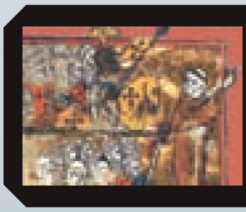
3. Equipment cabinets
A cavalcade of equipment such as syringes, neck braces and sterilisers are kept in these ready for quick access.

2. Trolley
Important for carrying patients to and from the ambulance, the trolley allows a mobile stretcher to be raised, lowered and tilted as necessary.

Not a machine you want a flat line on


© Ernstl

The evolution of the ambulance



1050
During the Crusades of the 11th Century, the religious order the Knights of St John set up mobile hospitals to treat pilgrims wounded in battle, transporting basic medicines hundreds of miles.

1890
Horse drawn carts had been the standard for mobile ambulances for hundreds of years, however it was during the 19th Century that the first hospital-based ambulances began to be operated.

5 TOP FACTS AMBULANCE

Queeny
1 The first record of ambulances being used in a life-saving capacity is from Spain in 1487, where Queen Isabella ordered mobile hospitals to collect and treat soldiers after battle.

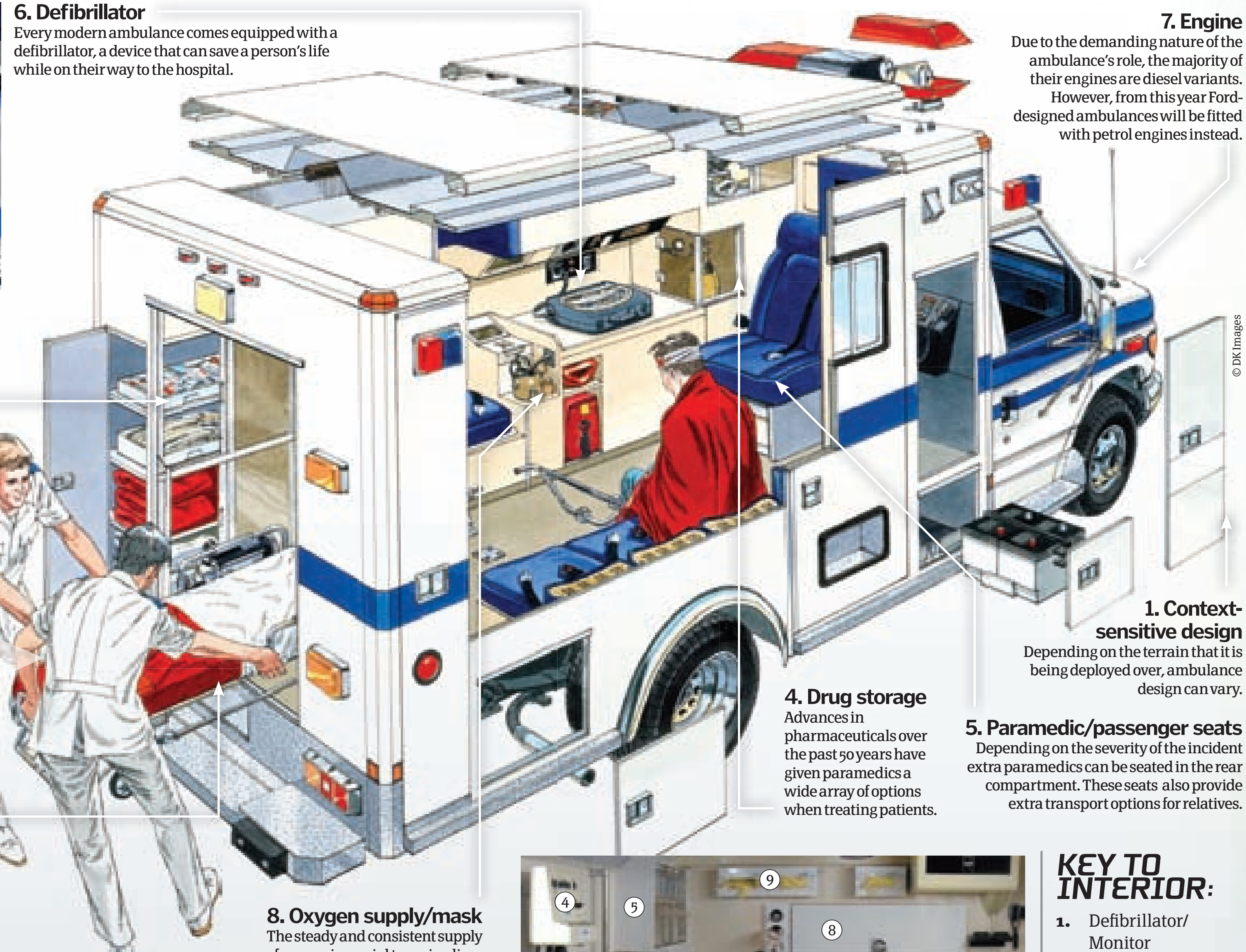
War machine
2 The H-13 Sioux helicopter, a model used as an air ambulance by the US during the Korean War, transported over 18,000 wounded soldiers during the conflict.

Roughing it
3 The first ambulance station in Queensland, Australia, operated out of the Brisbane Newspaper Company and during night shifts staff slept on the floor.

Tramtastic
4 In the North American city of St Louis, during the late 19th Century due to the extensive nature of its tram network, a tram-based ambulance was introduced.

Congested
5 Due to the severe congestion suffered in large city centres, many paramedics are now trained to ride motorbikes as their smaller size allows them to reach patients quicker.

DID YOU KNOW? Not all ambulances come in van form, with many vehicles ranging from mopeds up to full-blown ships



© DK Images

6. Defibrillator
Every modern ambulance comes equipped with a defibrillator, a device that can save a person's life while on their way to the hospital.

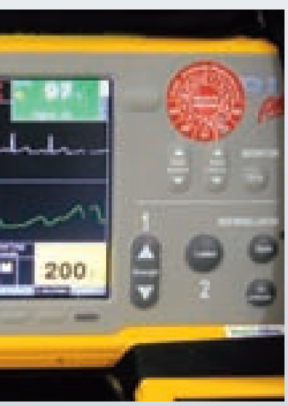
7. Engine
Due to the demanding nature of the ambulance's role, the majority of their engines are diesel variants. However, from this year Ford-designed ambulances will be fitted with petrol engines instead.

1. Context-sensitive design
Depending on the terrain that it is being deployed over, ambulance design can vary.

4. Drug storage
Advances in pharmaceuticals over the past 50 years have given paramedics a wide array of options when treating patients.

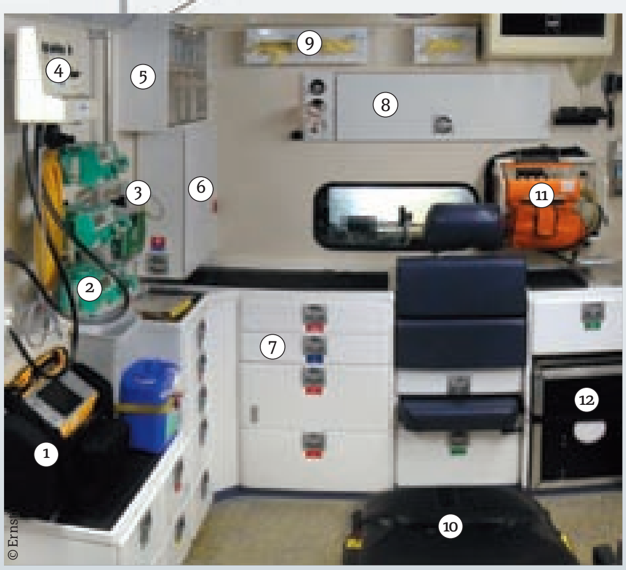
5. Paramedic/passenger seats
Depending on the severity of the incident extra paramedics can be seated in the rear compartment. These seats also provide extra transport options for relatives.

8. Oxygen supply/mask
The steady and consistent supply of oxygen is crucial to saving lives and every ambulance comes equipped with a pump station and oxygen mask.



Inside an ambulance

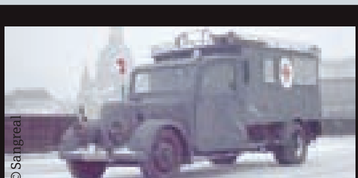
Within every ambulance is a host of life-saving equipment and technology



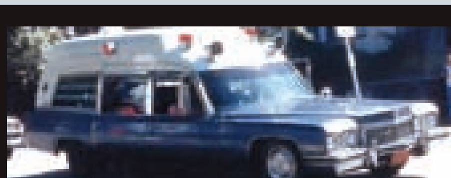
© Ernst

KEY TO INTERIOR:

1. Defibrillator/ Monitor
2. Syringe driver
3. Suction unit
4. High Flow CPAP (oxygen supply)
5. Syringes and needles
6. Drugs
7. Intubation equipment
8. CPAP-Helmet/ Immobilisation equipment
9. Medical gloves
10. Stretcher
11. Ventilator
12. Emergency suitcase

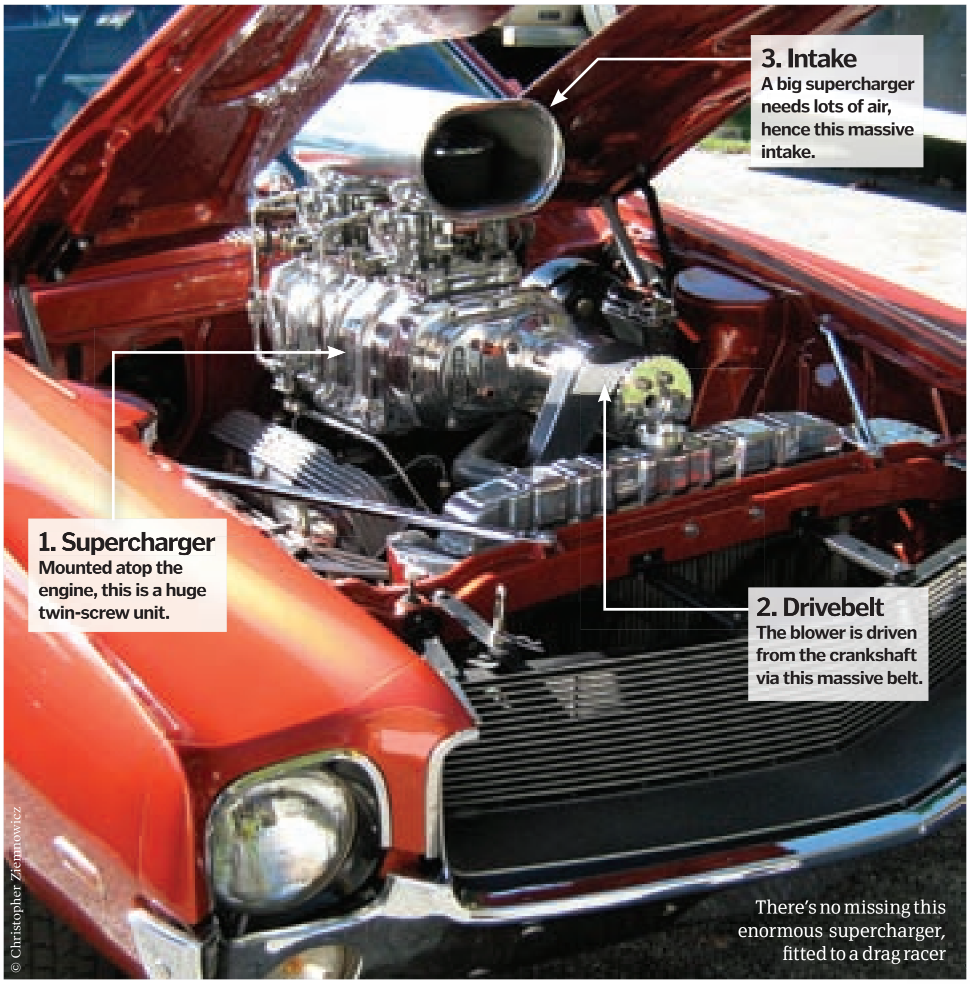

© Sangreal

1940
The mass-production of the automobile at the beginning of the 20th Century heralded a new age of faster, motorised, car and truck-based ambulances. These vehicles originated in a military capacity.



1970
During the late Sixties and Seventies the emphasis on ambulances saving lives on the move, instead of just transporting civilians to hospital, was forwarded through numerous technological and scientific breakthroughs.

"A supercharger compressor can be driven directly or via chains or belts by the engine crankshaft"



There's no missing this enormous supercharger, fitted to a drag racer

Superchargers, how do they work?

Bolt a supercharger to your engine for an instant power boost!

Supercharger – it's an evocative word and for good reason. A supercharger has long been a relatively simple way to increase an engine's power. Normally, an engine relies on the pumping action of the pistons to suck air and fuel into the cylinders. A supercharger, however, is a compressor that forces air into the engine, therefore allowing more fuel to be burned and increasing the power by up to 50 per cent.

A supercharger compressor can be driven directly or via chains or belts by the engine crankshaft, or by the exhaust gases. However, systems using the latter method are commonly called turbochargers (although, strictly speaking, turbochargers are simply a form of supercharger). The compressor is geared so it spins at a very high speed – around 50,000rpm.

Most engine-driven superchargers use a positive displacement pump. This delivers the same volume of air per revolution at all engine speeds, which ensures that the fuel/air mix remains constant.

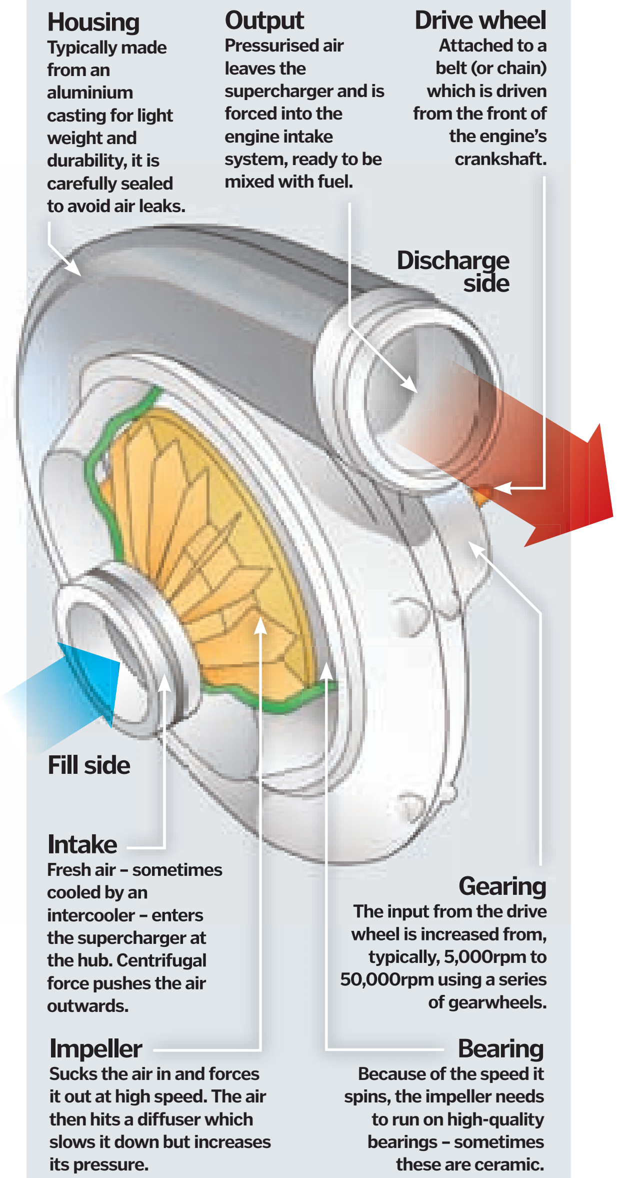
A problem with supercharging is that compressed air gets hot, which is less efficient for combustion. Therefore, some supercharged engines have an intercooler that is effectively a radiator in reverse, cooling the intake air that passes through it.

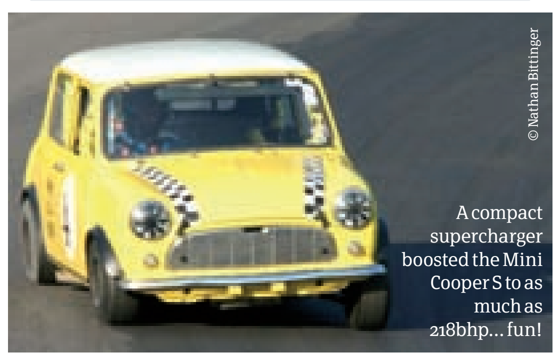
DID YOU KNOW?

Superchargers are often used in aeroplanes, because at high altitude the air is thinner so compressing it helps maintain efficiency.

Air flow explained

How air is forced into the engine intake





A compact supercharger boosted the Mini Cooper S to as much as 218bhp… fun!

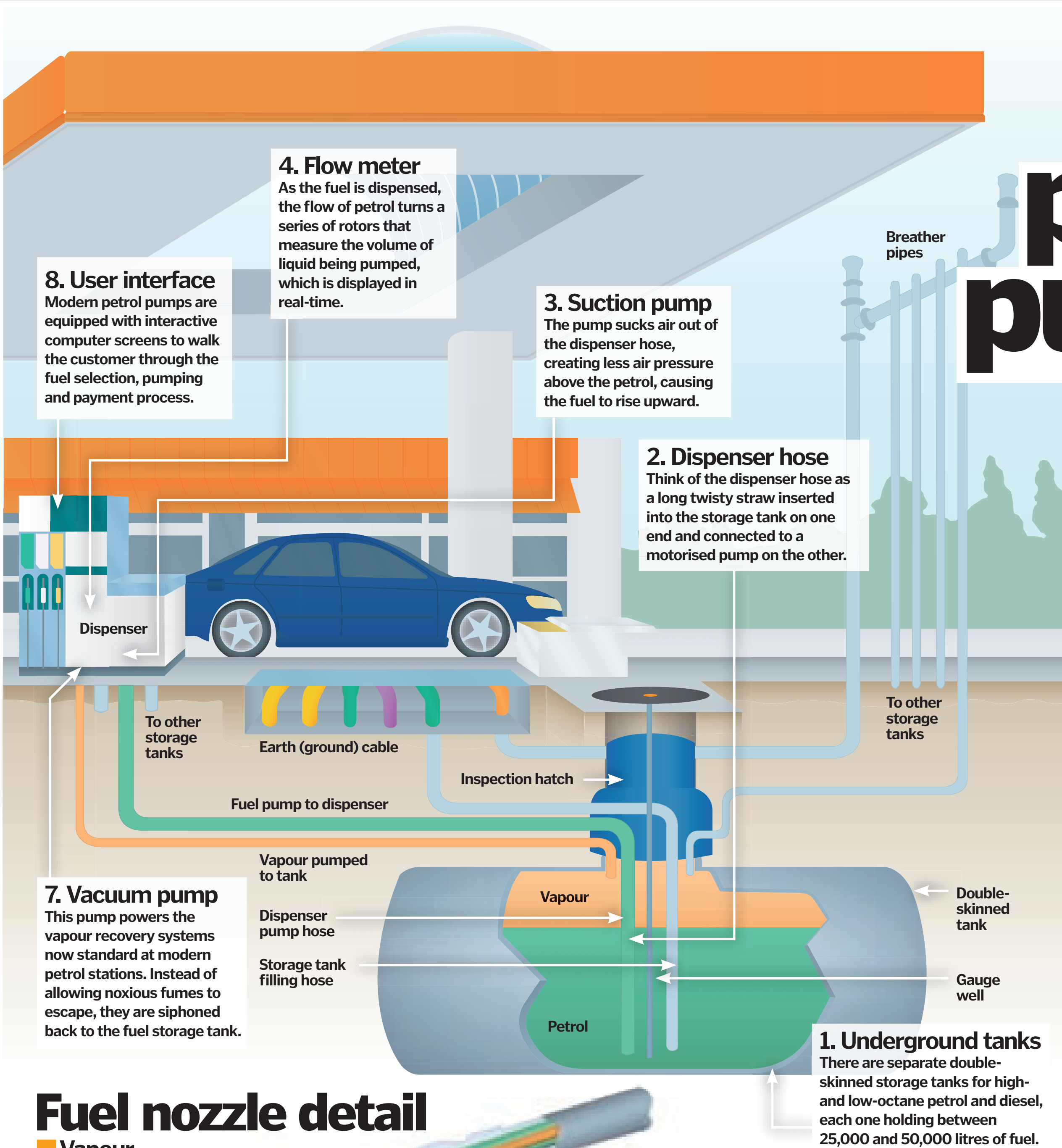
Head to Head TYPES OF PETROL

1. Unleaded petrol
The higher the octane rating, the more compression it can take before igniting. High-octane petrol is a must for high-performance engines.

2. Diesel
Diesel packs more energy into the same amount of fuel. A litre of diesel contains 130,500 Btu/gallon compared to petrol's 115,000 Btu/gallon.

3. Biodiesel
Derived from the fatty oils of plants instead of fossil fuels, biodiesel is more fuel-efficient than petrol and burns far cleaner than diesel or regular unleaded.

DID YOU KNOW? New 'clean diesel' engines have fuel efficiency and emission levels rivalling hybrids



How petrol pumps work

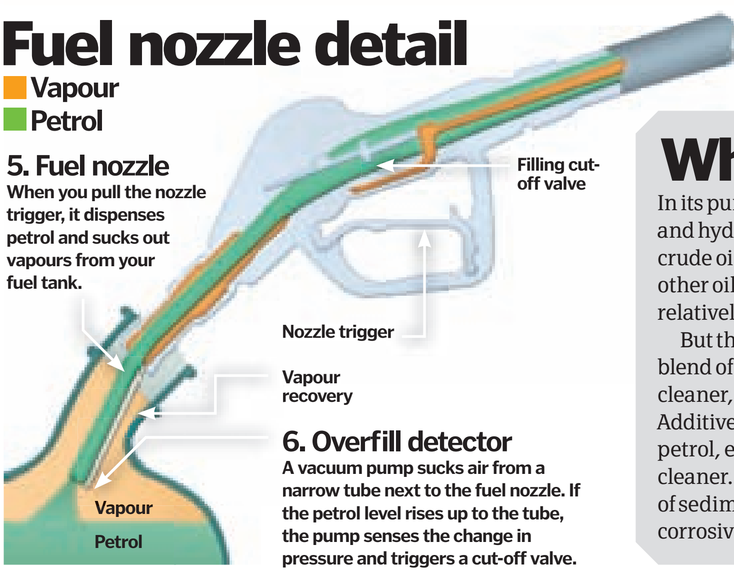
Peek inside the fuel-pumping petrol dispenser

Next time you're lost in boredom at the petrol pump, pretend you have a pair of x-ray specs on. If you stare straight down, several metres below you are three massive storage tanks. Two of them contain regular unleaded petrol – one with the highest-octane grade of fuel, the other with the lowest – and the third holds diesel.

When you select your fuel grade and pull the trigger, suction pumps inside the petrol dispenser draw up fuel from both the high- and low-octane tanks and blend them to the precise octane level. A spinning 'fuel-o-meter' inside the pump records how much petrol flows past, keeping track of your purchase. Since petrol expands and contracts with hot and cold weather, a temperature probe compensates for fluctuating volume, ensuring you get what you pay for.

In the old days, caustic petrol vapours seeped out of the tank during a fill-up. Modern petrol stations are equipped with vacuum pumps that siphon out the offending fumes and store them below ground in the fuel tanks. Aim those x-ray glasses at the fuel nozzle itself and you'll see that the dispenser line is held open by air pressure from within the tank. When the fuel level reaches the tip of the nozzle, the air pressure is choked off and the dispenser switches off automatically.

Fuel nozzle detail



What's in your tank?

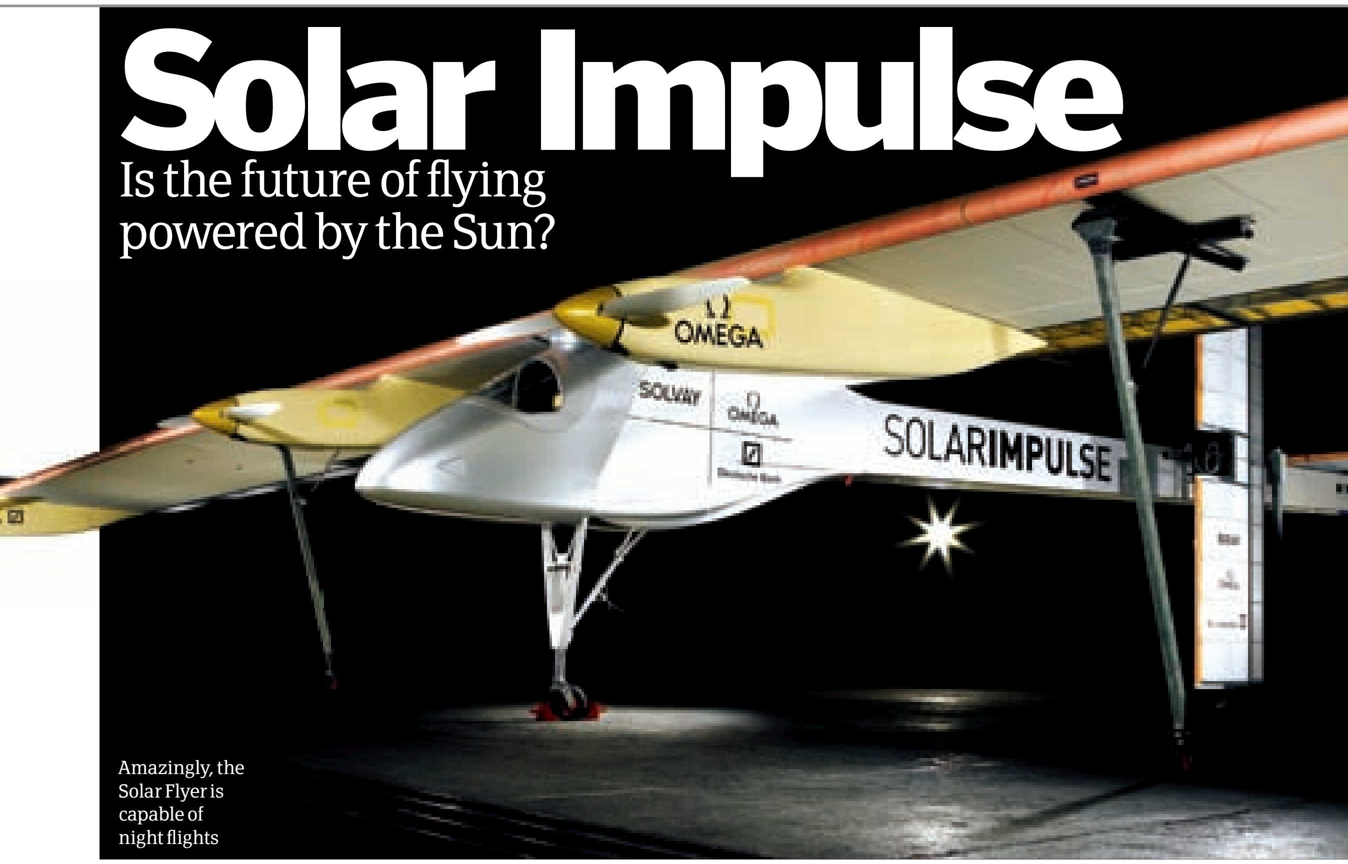
In its purest form, petrol is nothing but a string of carbon and hydrogen atoms. It is distilled and separated from crude oil (petroleum) through the refining process. Unlike other oil-based fuels like butane or propane, petrol has a relatively high boiling point, making it more stable.

But the gas at the pump isn't pure petrol. It contains a blend of additives and stabilisers that help the fuel burn cleaner, store longer and make your engine run efficiently. Additives called oxygenates increase the oxygen content of petrol, enhancing its octane level and helping it burn cleaner. Antioxidants are added to decrease the formation of sediments in tanks. Finally, detergents and anti-corrosive agents are added to keep engines running clean.

"While still in its prototype stage the Solar Impulse has already completed numerous tests successfully"

Solar Impulse

Is the future of flying powered by the Sun?



Amazingly, the Solar Flyer is capable of night flights

Harnessing the power of the Sun, the Solar Impulse project aims to fulfil a very grand ambition, to produce the first aircraft capable of perpetual flight. It would be the first aircraft to fly round the world without ever needing to refuel, propelled through solar power.

The Solar Impulse works by sporting a wingspan the size of an Airbus A340 (63.40 metres) layered with state-of-the-art solar monocrystalline silicon cells, each 150 microns thick and chosen for their lightness, flexibility and efficiency. This massive wingspan is partnered by a super lightweight fuselage (1,600kg) built round a carbon fibre-honeycomb composite using a sandwich structure of a series of 120 carbon fibre ribs. Attached to the wings are four gondolas each containing a 10hp motor, a lithium polymer battery set and a management system controlling charge/discharge and temperature. Surrounding these is a raft of thermal insulation used to conserve the heat radiated from the batteries and keep them functioning at 8,500 metres, where the temperature can drop to -40°C. Its cockpit, where every piece of instrumentation has been specially developed and redesigned to save energy, is also cutting-edge.

In order to conserve energy – critical to the night flight portion of this planned 36-hour world tour – each of the Solar Impulse's twin-bladed propellers, which are capable of operating in a 200-4,000rpm range, are limited by a reducer to ensure energy is not wasted when solar energy is in abundance. Indeed, the statistics point to this being one of the most important challenges faced by the Solar Impulse. At midday each metre-square piece of Earth receives the equivalent of 1,000 watts of solar power, a figure that over a 24 hour period averages out at just $250W/m_2$, or in other terms, enough power for each of the engines to produce only 8hp. This means as little energy as possible needs to be wasted during the more prolific day, as it needs to be stored for the night time where the battery reserves are all that stands in the way of the Impulse losing total power.

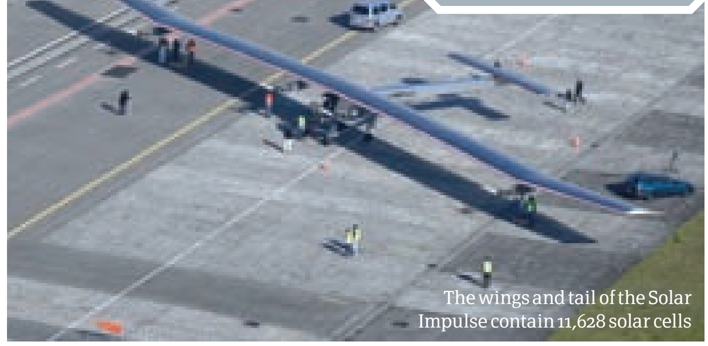
While still in its prototype stage the Solar Impulse has already completed numerous tests successfully and if it can stick to its ambitious schedule, a second, fully operational variant should be built and ready for the challenge in 2012.

DID YOU KNOW? The 8hp produced by the Solar Impulse's engines is the same amount of power the Wright brothers had available to them in their 1903 flight.

The Statistics

Solar Impulse

Wingspan: 63.40m
Length: 21.85m
Height: 6.40m
Motor power: 4 x 10hp electric engine
Solar cells: 11,628
Average speed: 70km/h
Maximum altitude: 27,900ft (8,500m)
Weight: 1,600kg
Take-off speed: 35km/h



The wings and tail of the Solar Impulse contain 11,628 solar cells

The cockpit is high-tech but only carries a maximum of two pilots

All images courtesy of © Solar Impulse

"Once the driver starts the vehicle, the compressed hydrogen along with oxygen from the air will flow into the fuel cell"

Hydrogen-p

Discover how future hydrogen cars produce zero emissions and less dependence upon foreign fossil fuels

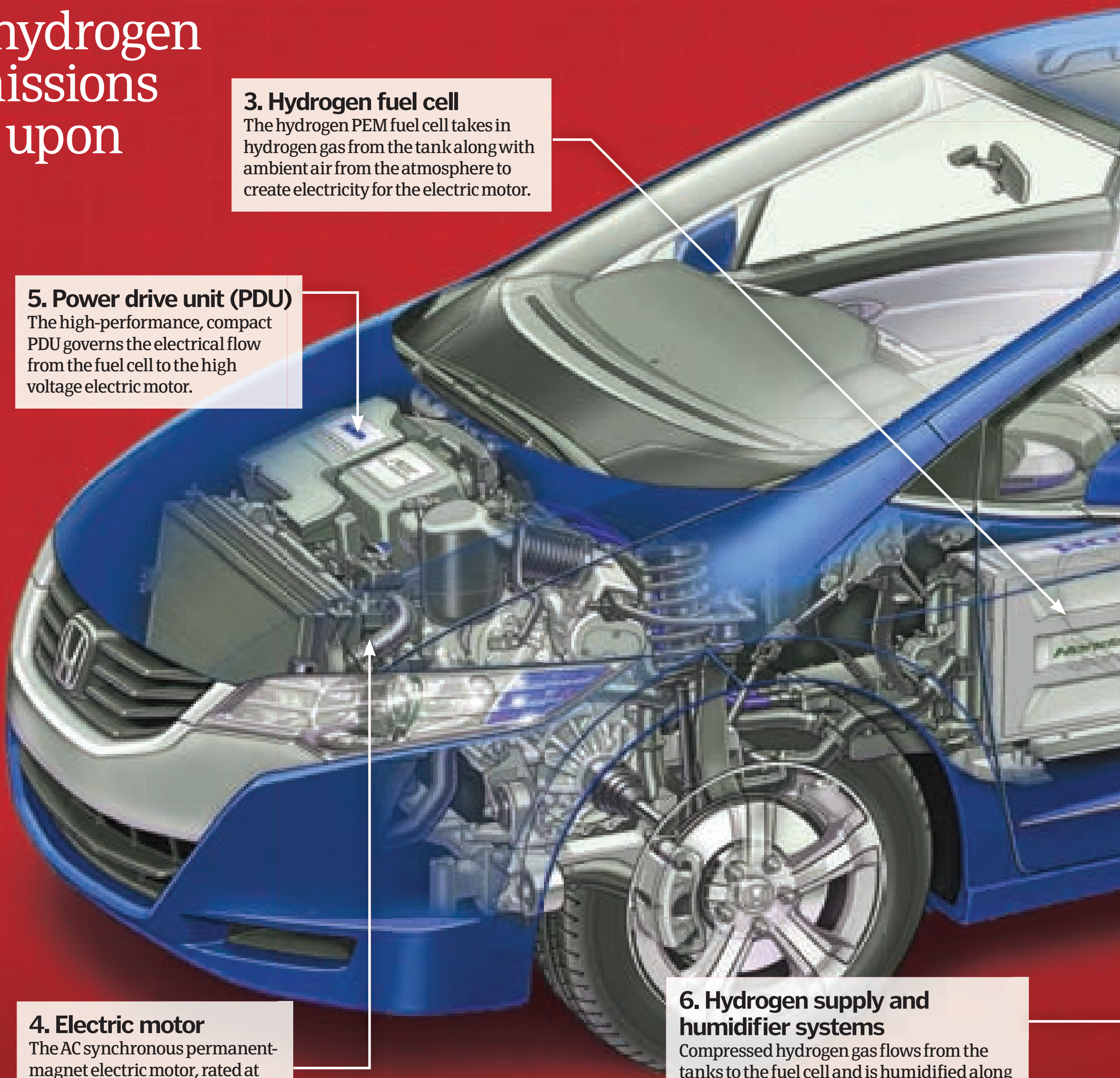
There are two basic types of hydrogen cars, including those that run on PEM (proton exchange membrane) fuel cells and those which burn hydrogen (H_2) inside an internal combustion engine (ICE). All major car manufacturers have developed one or both of these types of vehicles.

The most popular of these two varieties are those that run on hydrogen fuel cells. This is because these are seen as zero-emission vehicles that will not contribute to greenhouse gases but will help towards breaking the dependence upon foreign fossil fuels.

The fuel cell car works as follows. Drivers at a refuelling station will pump compressed hydrogen gas into the car's tank. Once the driver starts the vehicle, the compressed hydrogen along with oxygen from the air will flow into the fuel cell.

The positive and negative ions of hydrogen molecules will split around the fuel cell creating an electrical charge. On the backside of the fuel cell, the hydrogen ions join with the oxygen to form water vapour which flows out the tailpipe of the vehicle. The electrical current created by the fuel cell flows to an electric motor, which powers the wheels of the car.

The hydrogen ICE vehicle is a bit more simplistic in that it uses either compressed or liquid hydrogen and burns it inside the cylinders of the engine. Near zero tailpipe emissions are created when burning hydrogen in this fashion. ICE vehicles are currently cheaper to build or retrofit than fuel cell vehicles.



Hydrogen cars Important moments in hydrogen car development

1807
Francois Isaac de Rivaz of Switzerland built the very first automobile to burn hydrogen inside an internal combustion engine.

1860
Etienne Lenoir of France built the Hippomobile, which was later fuelled by electrolysing water and using the hydrogen in a one-cylinder engine.

1941
During World War II, Boris Shelishch had converted a GAZ-AA truck to run off hydrogen after Nazi's had cut off Russian oil supplies.

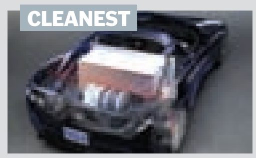
CLEAN

1. Bio-fuel car
These vehicles use an internal combustion engine and may run on ethanol, biodiesel or other available non-fossil based fuels.

CLEANER

2. Plug-in hybrid
The plug-in hybrid (PHEV) combines the zero emissions of an electric car with a small engine as a mileage range extender.

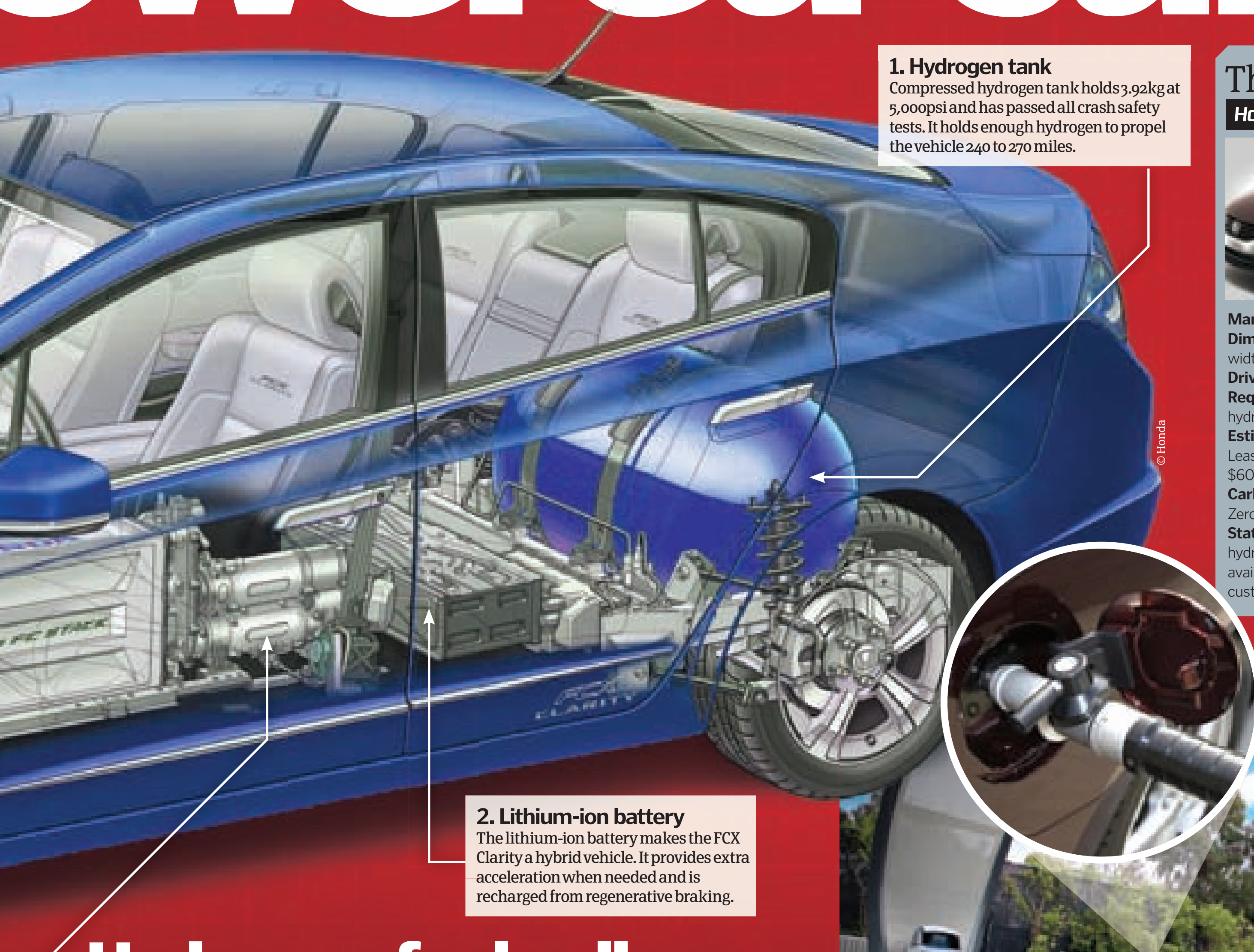
CLEANEST



3. Electric car
EVs (electric vehicles) are zero emissions vehicles that the owner can recharge at home. These vehicles are mainly useful for making short trips.

DID YOU KNOW? *The estimated cost of producing a Honda Clarity is $300,000 per car*

owered cars



© Honda

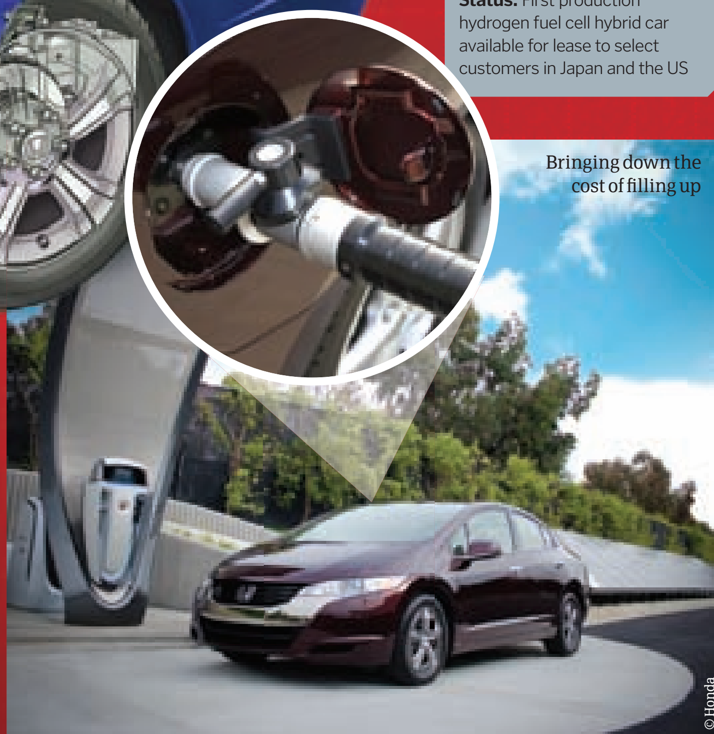
1. Hydrogen tank
Compressed hydrogen tank holds 3.92kg at 5,000psi and has passed all crash safety tests. It holds enough hydrogen to propel the vehicle 240 to 270 miles.

2. Lithium-ion battery
The lithium-ion battery makes the FCX Clarity a hybrid vehicle. It provides extra acceleration when needed and is recharged from regenerative braking.

The Statistics
Honda FCX Clarity

© Honda

Manufacturer: Honda
Dimensions: Length: 190.3in, width: 72.7in, height: 57.8 inches
Driving range: 240-270 miles
Required fuel: Compressed hydrogen gas at 5,000psi
Estimated price: Leasing to select customers at $600/month
Carb emissions rating: Zero emission
Status: First production hydrogen fuel cell hybrid car available for lease to select customers in Japan and the US



Bringing down the cost of filling up

© Honda

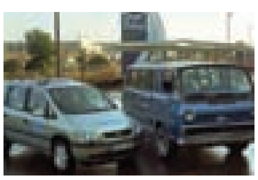
Hydrogen fuel cells

The hydrogen PEM fuel cell vehicle works by taking H2 from the compressed hydrogen tank and then running it along with oxygen from the air through a fuel cell. Hydrogen gas is channelled to the anode of the fuel cell while the oxygen is channelled to the cathode.

On the anode side, a catalyst (such as platinum) splits the hydrogen atom into protons (positively charged) and electrons (negatively charged). The PEM allows only the protons to pass through it to the cathode. The electrons must pass along an external circuit, which is how electricity is created.

1959
Harry Karl Ihrig created the first fuel cell vehicle (FCV), which as an Allis-Chalmers farm tractor which is now at the Smithsonian Institute.

1966
General Motors researchers created the Electrovan, which is the first hydrogen fuel cell car of record that resembles the FCVs of today.



1979
The BMW 520h prototype was built which had an internal combustion engine that could run on either hydrogen or gasoline.

1999
The Honda FCX-V1 prototype is created that used a Ballard fuel cell for power and a 49kw electric motor.

"A mixture of hydrogen gas and ambient air is drawn into the engine where a spark ignites the H2"

H2ICE

Under the hood of a hydrogen internal combustion engine

Hydrogen internal combustion engines (H2ICE) work in a similar fashion to gasoline engines. Mazda uses a Wankel rotary engine and BMW, Ford and others use a piston engine, but the concept is the same.

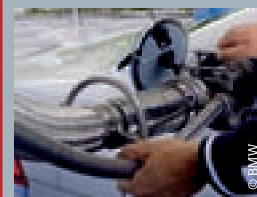
A mixture of hydrogen gas and ambient air is drawn into the engine where a spark ignites the H2. Hydrogen has a higher flame speed than gasoline, burning more quickly so timing adjustments need to be made. Also, since H2 is the smallest atom, it is prone to leaks, so couplings and fittings also need to be adjusted.


Specialist tanks are needed to transport the fuel

© BMW

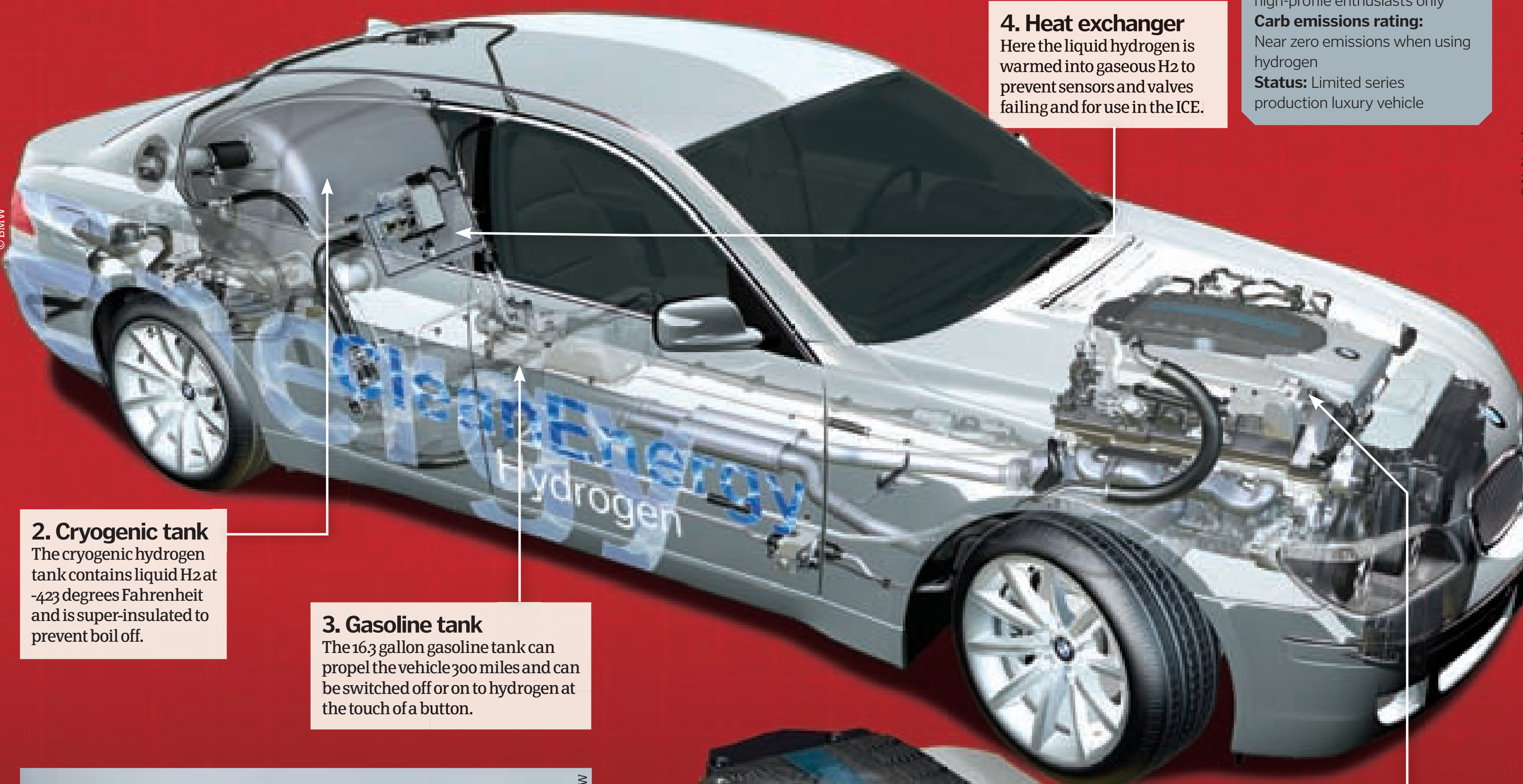
The Statistics

BMW Hydrogen 7


© BMW

Manufacturer: BMW
Dimensions: Length: 205in, width: 74.9in, height: 58.4 inches
Driving range: Driving range is 125 miles on hydrogen and an additional 300 miles on gasoline
Required fuel: Hydrogen or gasoline
Estimated price: No price as it is being loaned to high-profile enthusiasts only
Carb emissions rating: Near zero emissions when using hydrogen
Status: Limited series production luxury vehicle

© Air Liquide



© BMW

4. Heat exchanger
Here the liquid hydrogen is warmed into gaseous H2 to prevent sensors and valves failing and for use in the ICE.

2. Cryogenic tank
The cryogenic hydrogen tank contains liquid H2 at -423 degrees Fahrenheit and is super-insulated to prevent boil off.

3. Gasoline tank
The 16.3 gallon gasoline tank can propel the vehicle 300 miles and can be switched off or on to hydrogen at the touch of a button.

1. Hydrogen ICE
The BMW Hydrogen 7 runs on a dual-fuel hydrogen internal combustion engine using either hydrogen or gasoline for power.


Not a car you'll see on your local forecourt

© BMW

Mix it up
Gaseous hydrogen (green arrows) is flowing from the pressure control valve and mixing with ambient air (blue arrows) as both are drawn into the engine's cylinders for combustion with gasoline for power.

5 TOP FACTS USES OF HYDROGEN

Water
1 Hydrogen is the most abundant element in the universe and on planet Earth. Our oceans and drinking water are primarily hydrogen, so there's plenty of it available!

Refining gasoline
2 One of hydrogen's many practical uses includes using it to refine crude oil and remove sulphur to create the gasoline and diesel fuel we use in our cars.

Weather balloons
3 High altitude weather balloons are typically filled with hydrogen due to low cost and the ascent rate which can be easily controlled using the correct methods.

Making margarine
4 Hydrogen is used in the hydrogenation process to turn liquid corn oil or sunflower oil into margarine, perfect for spreading on your toast in the mornings!

Bleaching the body
5 Hydrogen peroxide has been used in current times to safely bleach a person's hair or teeth, and you can often spot when someone's had this done from a mile away!

DID YOU KNOW? California aims to have 46 hydrogen stations in place by 2014

Hydrogen refuelling stations

A vision of the petrol station forecourts of the future

Hydrogen refuelling stations may dispense compressed hydrogen gas, cryogenic liquid hydrogen or possibly even both. Those that dispense compressed H_2 do so at two different pressures including 5,000psi (360 bar) or 10,000psi (700 bar).

The advantage of dispensing hydrogen at 10,000psi is that the hydrogen cars can travel approximately twice the distance than at the lower pressure. Most hydrogen produced today for refuelling stations is made by high temperature steam reforming of natural gas.

Hydrogen molecules from both the steam and natural gas are separated from the other molecules including CO_2. In recent years, more renewable hydrogen is being created using wind or solar energy to electrolyse water (H_2O), producing hydrogen (H_2) and oxygen (O). Another type of H_2 refuelling station that is currently being developed is one for the home so that car owners can refuel in the privacy of their own garages.

© Air Liquide

Canadian hydrogen energy expert Air Liquide supplied fuel for the hydrogen fuel station that served a fleet of 20 zero-emission buses that carried visitors to and from the 2010 Winter Games.


© Air Liquide

The future of motoring?

We compare some of the hottest hydrogen cars from motoring's biggest names

The Statistics
RX-8 Hydrogen RE

Manufacturer: Mazda
Dimensions: Length: 174.6in, width: 69.7in, height: 52.8 inches
Driving range: In hydrogen mode, 62 miles. In gasoline mode, 341 miles
Required fuel: Compressed hydrogen (dual fuel car)
Estimated price: Not for sale
Carb emissions rating: In hydrogen mode, near zero emissions
Status: Limited production leasing as a fleet vehicle in Japan


© Mazda

© Mercedes-Benz

The Statistics
B-Class F-Cell

Manufacturer: Mercedes-Benz
Dimensions: Length: 168.2in, width: 70in, height: 63.1 inches
Driving range: 250 miles
Required fuel: Compressed hydrogen gas
Estimated price: Not for sale, but estimate price for a lease is $800/month
Carb emissions rating: Zero emissions
Status: Limited production as the plan is for 200 to be manufactured in 2010


© Toyota

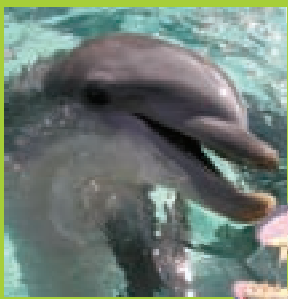
The Statistics
FCHV-adv

Manufacturer: Toyota
Dimensions: Length: 186.4in, width: 71.4in, height: 66.3 inches
Driving range: 450+ miles
Required fuel: Compressed hydrogen gas
Estimated price: Not for sale
Carb emissions rating: Zero emissions
Status: Currently a prototype, planned production in 2015


© GM

The Statistics
Chevy Equinox Fuel Cell

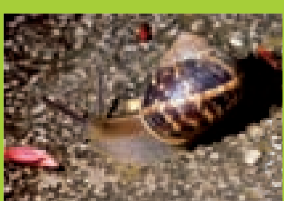
Manufacturer: General Motors
Dimensions: Length: 188.8in, width: 71.4in, height: 69.3 inches
Driving range: 200-250 miles
Required fuel: Compressed hydrogen gas
Estimated price: Not for sale, only on loan to members of Project Driveway
Carb emissions rating: Zero emissions
Status: Limited production SUV



This month in **Environment**

Welcome to the Environment section where we do our level best to explain the amazing phenomena from the natural world. A particularly well-rounded issue sees us cover just such subjects from the land, sea and sky. Flick on a few pages to discover how the Grand Canyon was eroded, how birds flock and how coral reefs are formed. Look out for the quicksand too...

30 Flocking



32 Slugs and snails

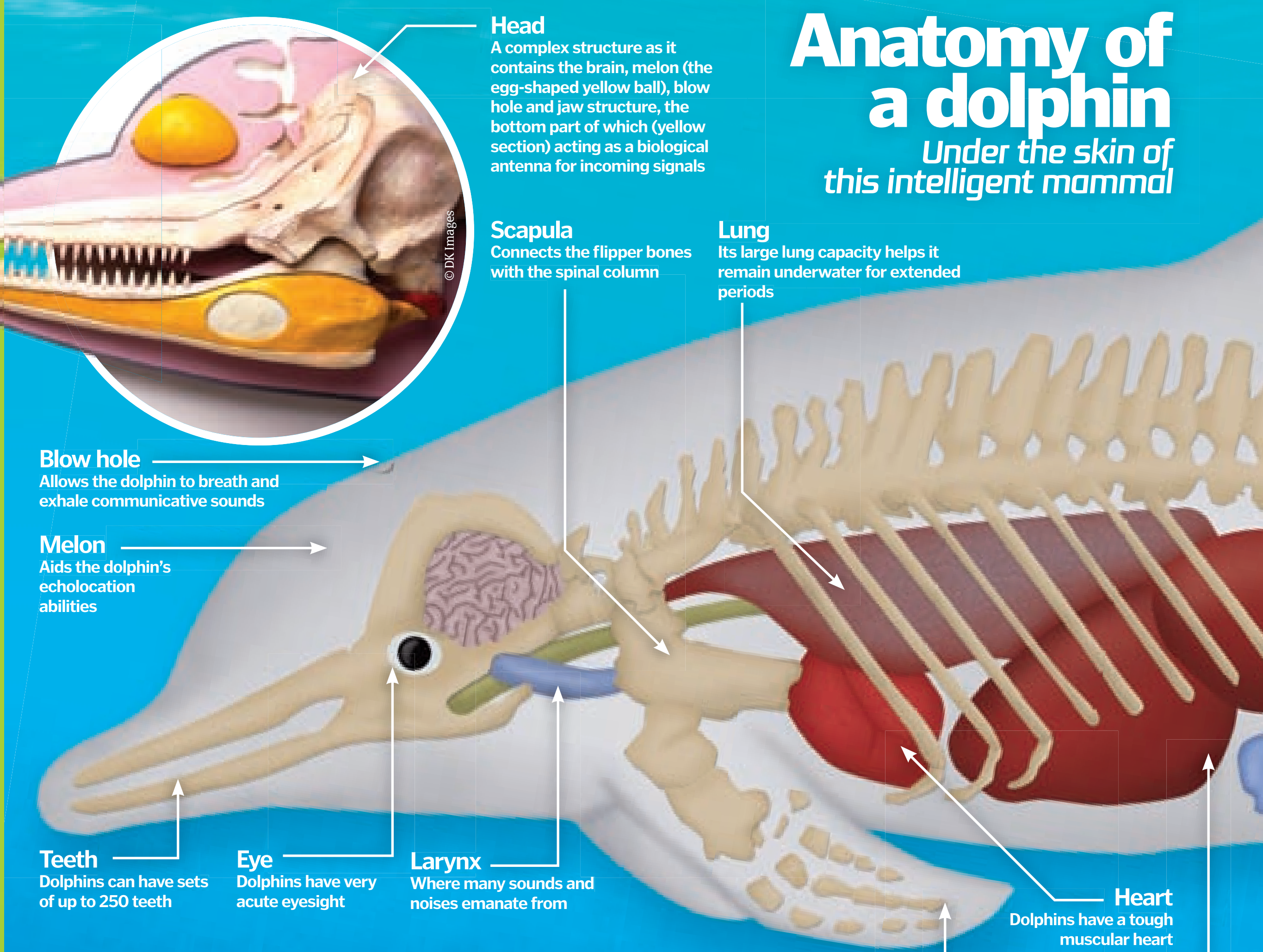
35 Quicksand

ENVIRONMENT

28 Dolphins
30 Flocking
31 Sea level
31 Wind speed
32 Slugs and snails
32 Pistol shrimps
33 Grand Canyon
35 Quicksand
36 Coral reefs

Anatomy of a dolphin

Under the skin of this intelligent mammal



Popular in human culture due to their intelligence and playfulness, dolphin species can be found all over the world, ranging in shape, size and character dramatically

Dolphins

There are many species of dolphin ranging from the modestly sized Maui dolphin, right up to the giant Orca killer whale. They are found all over the world, both in the ocean and also in rivers, and are considered to be the most intelligent of all marine mammals. All species are carnivorous, eating mostly foraged fish and squid, and numerous varieties hunt in packs, encircling schools of small fish to confuse them. Dolphins evolved from terrestrial mammals over 50 million years ago and are theorised by scientists to be descended from artiodactyls.

Dolphins have evolved to have a very streamlined fusiform (fat in the middle and tapered at both ends) body, ideally adapted for fast swimming and sudden, dynamic movements and changes in direction. This is aided by their tail fin (fluke) construction, which provides massive propulsion as well as acute directional control. Their prominent fin also aids mobility, providing stability at speed and through hairpin turns. At the front of their body lies their elongated head, jaw and beak structure, as well as a large area on the forehead called the melon. This is the part of the dolphin's body that deals with echolocation (biological sonar) and is a crucial tool for

Head to Head DOLPHINS

MOST FAMOUS

1. Bottlenose
One of the most famous of species, Bottlenoses tend to live in packs of 10-20 and hunt collectively. They are highly playful, often being utilised in aquarium shows.

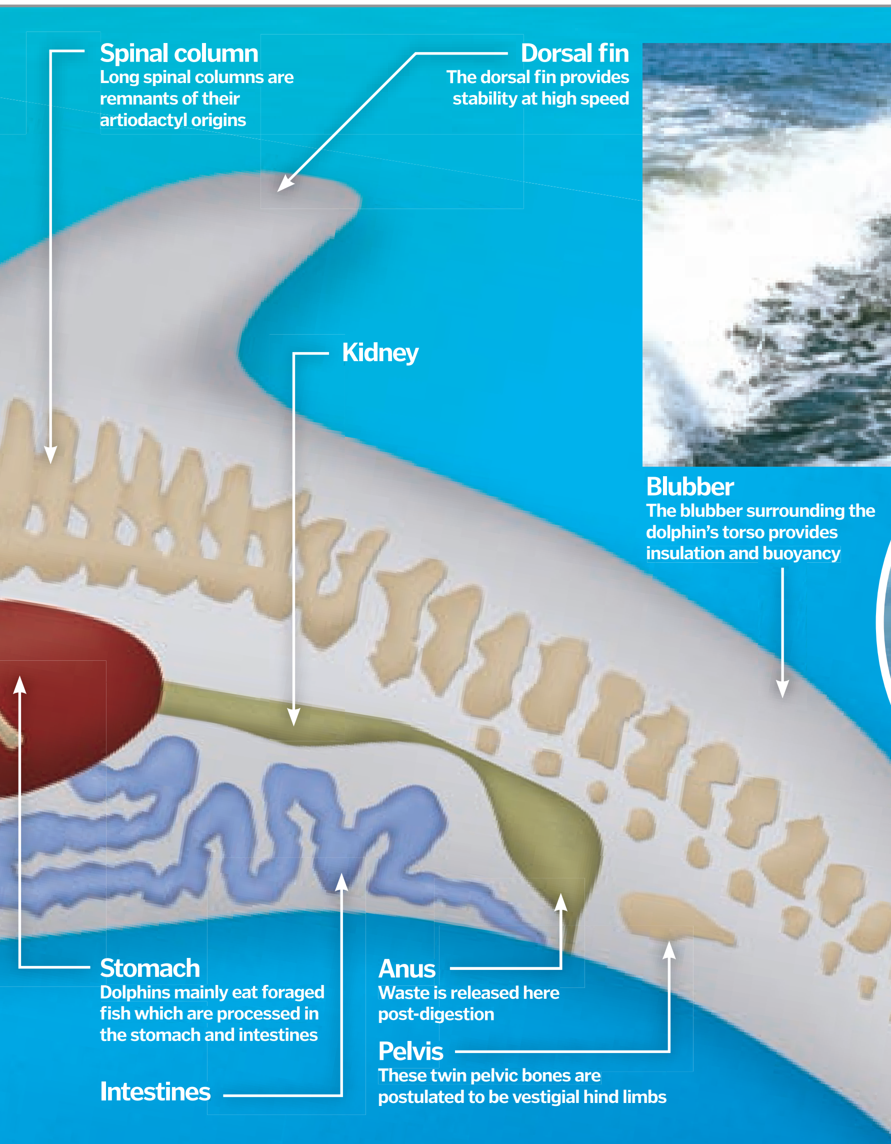
MOST STREAMLINED

2. Common
Characterised by their narrow nose and streamlined body, the Common dolphin is one of the fastest swimming cetaceans in the world.

MOST DECORATIVE

3. Spotted
Spotted dolphins are more exotic in their colouration than most other species. They are endemic to temperate and tropical oceans.

DID YOU KNOW? *For the ancient Greeks, spotting a dolphin while at sea was considered a good omen*



A Bottlenose dolphin breaching the bow wave of a boat

Dolphins are playful and are often seen jumping out of the water

Dolphin young

At an early stage of development the hind limb buds on a dolphin are visible at the base of the tail, as seen on this embryo of a Spotted dolphin in the fifth week of development. The needle here is 2.5cm long.

communication, positioning and environmental awareness.

Indeed, dolphins have a very complex sensory system, driven by their vivid eyesight and echolocation ability. Through their tiny ear structure they can discern and hear frequencies up to ten times the upper limit of adult human hearing and scientists postulate that their lengthy jaw with its numerous teeth (up to 250 in some species) acts like a biological antenna, receiving vibrations and sound waves and amplifying them within the skull. Processing this information is the dolphin's brain, which is not only one of the largest but also one of the most complex of all mammals, be they marine or terrestrial.

Despite having no sense of smell whatsoever, dolphins can make a series of noises to communicate or aid echolocation by manipulating a series of nasal air sacs located just below their blowhole. To communicate with each other they use a series of burst-pulse sounds and frequency modulated whistles, while to determine their positioning and the positioning of other animals or areas of interest (such as humans on boats), a series of clicks are adopted. These clicks tend to be continuous and increase in frequency the closer the dolphin is to the target.

Whaling problem

Despite the wide variety of dolphin species, many are dwindling in number or have been completely eradicated by natural and man-made causes. Indeed, in a 2006 survey the Yangtze river dolphin was officially labelled as extinct as no examples were recorded. One of the biggest human-caused reasons that dolphins are becoming extinct is whaling, which in some parts of the world is legal and bound in local tradition.

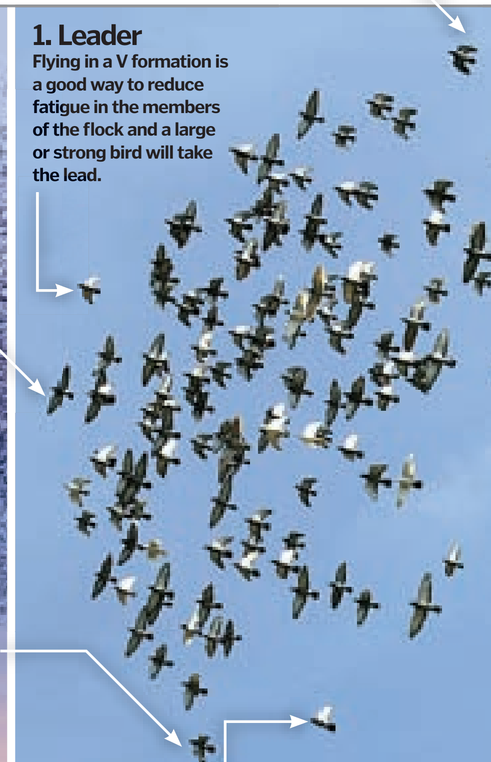
In Taiji, Japan and over the entirety of the Faroe Islands, dolphins are traditionally considered as food and are often killed en masse in harpoon or drive hunts, practices protected by law. This comes despite dolphin meat being high in mercury, causing health issues for humans if excessive quantities are consumed. Other contributory factors leading to the declining populations of dolphins include pesticides, heavy metals and plastics contaminating their habitat, as well as accidental deaths caused by fishing nets and motorboat propellers.

Learn more

There's a great documentary from the BBC called *Dolphins: Deep Thinkers*, narrated by Sir David Attenborough. You can watch it on YouTube if you go to **http://tinyurl.com/yevm6ll** where it's available in three parts. It attempts to find out how intelligent dolphins are through observing their behaviour.

A massive flock can be a truly awesome sight

© Science Photo Library



Flying in a flock

How and why do birds flock together, and why don't they bump into each other?

Watching as a massive collection of birds float across the sky like an unpredictable wave, it's difficult to comprehend how birds can fly in formation without the aid of the high-tech location equipment used by aerobatic teams like the Red Arrows. Such patterns may look like the result of extrasensory communication, but they're in fact the product of emergent animal group behaviour known as flocking. Every change of direction comes not as a result of an individual member of the flock, but rather of the snap decisions made by those individuals in response to the movements of their neighbours.

To comprehend how it works, in 1986 American computer programmer Craig Reynolds applied simple rules to bird behaviour to simulate flocking in his computer program Boids. The three rules he outlines include the fact that each bird steers itself to avoid crowding or bumping its neighbours (separation), each bird tries to match the average heading of its neighbours (alignment), and that each bird steers towards the average position of its neighbours, maintaining flock structure (cohesion).

The benefit of the flock

There are several benefits to flying as a flock. It improves a bird's chance of survival against predators because a large group of birds is stronger and better protected and with many eyes the flock is far more likely to spot a would-be marauder. Also, the predator will find it harder to concentrate on a single victim, increasing the individual member of the flock's chance of survival.

Flocking also enables birds to fly further using less energy because when the strong leader bird flaps its wings it creates uplift for the birds behind – each bird (except the leader) is flying in the up-wash from the wing of the bird in front. This enables the flock to use less energy and reduces fatigue.

Don't park you car under here!

© Science Photo Library

5 TOP FACTS FLOCKING

1 When to watch
The best time of year to witness flocking is winter as migratory birds prepare to head for warmer climes, and those that stick around for winter will be foraging and roosting together.

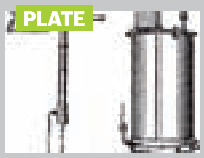
2 Honk honk
Sometimes geese at the back of their flock will make honking sounds to encourage the birds ahead to maintain their speed.

3 Sort Sol
Twice a year in Denmark massive flocks of starlings block out the sun during an event called Sort Sol or 'Black Sun'.

4 Movie sims
Craig Reynolds' Boids program inspired the film *Batman Begins* to simulate a swarm of bats. It was also the simulation behind the stampede of wildebeest in *The Lion King* animation.

5 Big flocks
There are more sub-Saharan red-billed Queleas in the world than any other species and their flocks can comprise tens of thousands – the flock can take hours to pass by.

1. Mechanical
Facts: These mechanically based anemometers are not the most precise and accurate way of measuring wind speeds, but they are the most commonly used due to their simplicity and ease of use.



2. Pressure
Facts: The earliest kinds of anemometers, they work by measuring the pressure wind can place on a set area, which in turn depresses a spring. However, they only work for high strength winds.

3. Sonic
Facts: Ultrasound anemometers work through transmitting sonic pulses between two receivers. The delay in receiving these pulses can be analysed in order to gauge wind resistance, therefore speed.

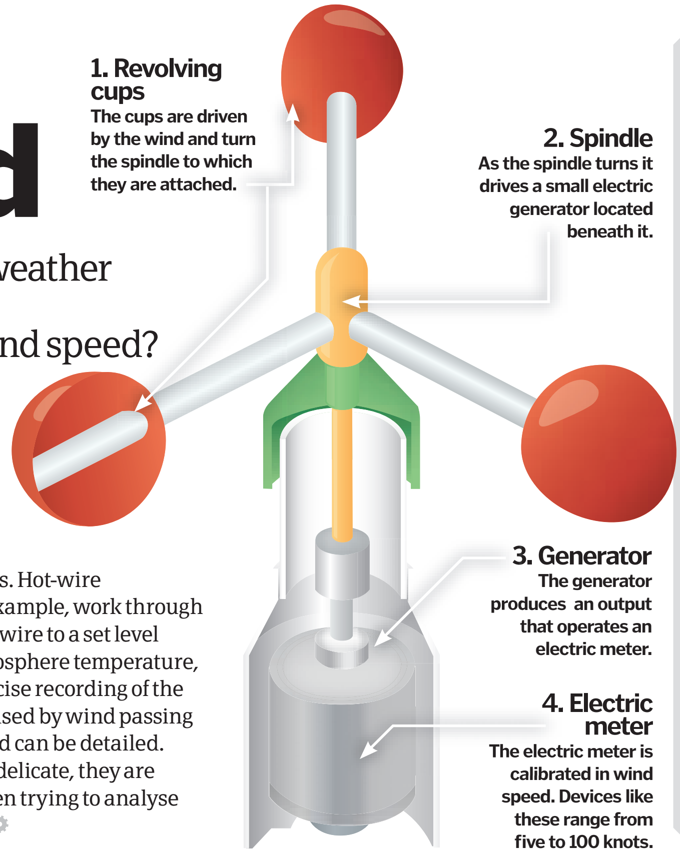
DID YOU KNOW? Tidal gauges in Amsterdam have been recording the sea level since 1700

Measuring wind speed

Anemometers can often be spotted in weather stations, but how do they actually give information to meteorologists about wind speed?

There are several types of anemometer employed to gauge wind speed, but the one we would most probably recognise is the cup anemometer. These have three cups spaced equal distances apart on arms horizontal to a central shaft. The cups catch the air as it drives past them, causing the shaft to spin. By counting the number of turns occurring in a second, you can then calculate the average wind speed. Some cup anemometers also have tiny electricity generators built into them that calculate wind speed by analysing how much energy the spinning anemometer is creating instead of counting the spins.

There are also many other types of anemometers, which work using lasers, ultrasound measurements, pressure sensors or temperature sensors. Hot-wire anemometers, for example, work through the heating of a fine wire to a set level above ambient atmosphere temperature, and then by the precise recording of the speed of cooling caused by wind passing the wire, wind speed can be detailed. Although these are delicate, they are extremely good when trying to analyse wind fluctuations.



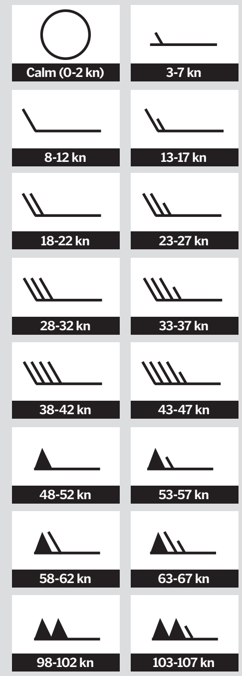
1. Revolving cups
The cups are driven by the wind and turn the spindle to which they are attached.

2. Spindle
As the spindle turns it drives a small electric generator located beneath it.

3. Generator
The generator produces an output that operates an electric meter.

4. Electric meter
The electric meter is calibrated in wind speed. Devices like these range from five to 100 knots.

Wind speed is measured in knots and wind barbs show the direction and speed of winds on weather maps. They point in the direction the wind is coming from.



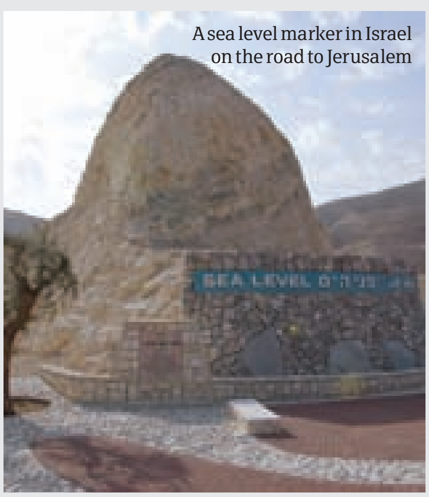
Sea level explained

What is the sea level and how is it measured?

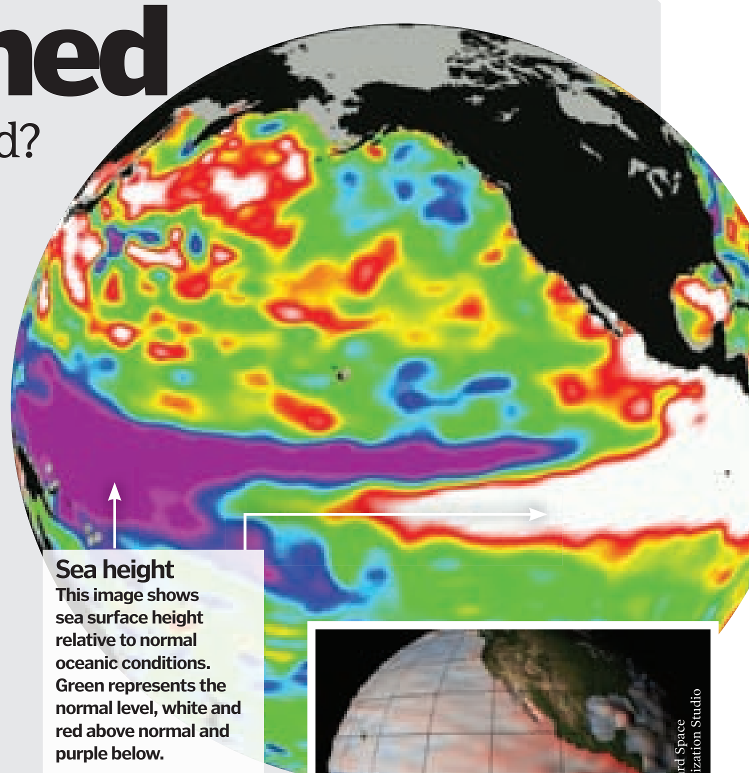
When scientists refer to sea level, they are talking about the mean average height of the surface of the ocean, a figure that is useful in determining the height of land and changes in environmental trends. This mean average is measured with great difficulty thanks to the altering forces exhibited on Earth by the solar system (gravity, radiation etc), which create waves and tides, as well as altering the ocean's temperature and therefore density and volume. Because of this the ocean is in a state of constant flux, rising and falling, heating up and cooling down. In order to measure it then, its average height needs to be taken from a fixed point over an extended period of time.

To achieve these measurements, scientists use tidal gauges (large cylindrical pipes with small holes in the bottom through which the ocean passes and is recorded by electronic sensors) which, through their simple yet ingenious design, allows water level to be measured while also minimising the effects of tides and waves. Despite the use of tidal gauges, the raw power and unpredictable nature of the ocean means that acquiring millimetre levels of measurements is extremely difficult and the use of satellite topology is now also widely used in conjunction.

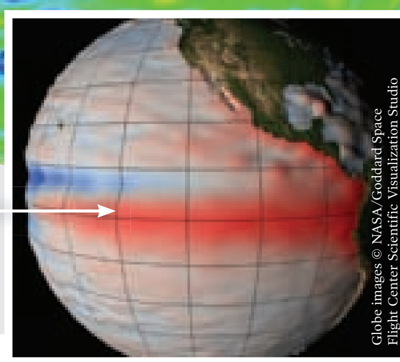
Current scientific consensus is agreed that, based on decades of mean average measurements, the ocean level is rising at two millimetres per year.



A sea level marker in Israel on the road to Jerusalem



Sea height
This image shows sea surface height relative to normal oceanic conditions. Green represents the normal level, white and red above normal and purple below.



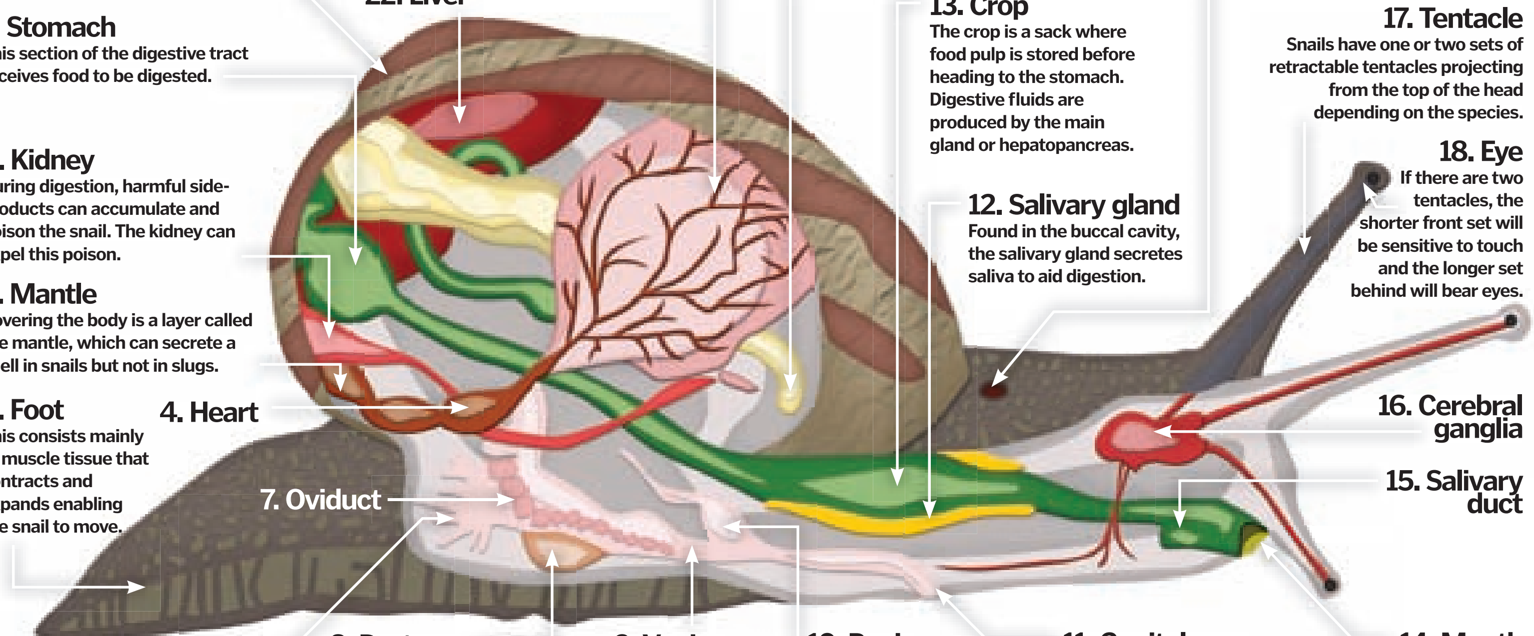
Relative sea level
Here, sea level is represented by colour (blue = low, red = high) and bumpiness.

Globe images © NASA/Goddard Space Flight Center Scientific Visualization Studio

"The snapping of the claw creates a shock wave"

Slugs and snails

The gardener's least favourite visitors, slugs and snails are quite incredible little slime balls



23. Shell
Made of calcium carbonate, a snail's strong shell will remain so if the animal's diet contains enough calcium.

21. Lung
Not all snails have lungs but those that do have a single cavity containing a network of blood vessels that functions like a lung.

20. Anus
The intestine opens outside near the anus. As the snail crawls away it leaves behind a dark trail of faeces.

19. Respiratory pore
Also called a pneumostome, this breathing pore is an opening through which air is breathed into the lung.

22. Liver

1. Stomach
This section of the digestive tract receives food to be digested.

13. Crop
The crop is a sack where food pulp is stored before heading to the stomach. Digestive fluids are produced by the main gland or hepatopancreas.

17. Tentacle
Snails have one or two sets of retractable tentacles projecting from the top of the head depending on the species.

2. Kidney
During digestion, harmful side-products can accumulate and poison the snail. The kidney can expel this poison.

18. Eye
If there are two tentacles, the shorter front set will be sensitive to touch and the longer set behind will bear eyes.

12. Salivary gland
Found in the buccal cavity, the salivary gland secretes saliva to aid digestion.

3. Mantle
Covering the body is a layer called the mantle, which can secrete a shell in snails but not in slugs.

5. Foot
This consists mainly of muscle tissue that contracts and expands enabling the snail to move.

4. Heart

16. Cerebral ganglia

7. Oviduct

15. Salivary duct

6. Mucous gland
The mucous gland in the foot secretes thick, sticky slime to help the snail traverse tricky ground without injury.

8. Dart sac
Some land snails shoot a mucus-covered 'dart' into mates, delivering a substance that improves sperm survival.

9. Vagina
Female reproductive organ located on the ventral surface of the foot.

10. Penis
Male reproductive organ is located internally when not in use and is found on the ventral face of the foot.

11. Genital pore
Found at the side of the head, this opening allows copulation and exchange of sperm.

14. Mouth
The mouth features a jaw and a rough ribbon-like tongue called the radula for grazing on plants.

Although they look very different, slugs, snails, octopuses, oysters and cuttlefish are all molluscs – Latin for 'thin shelled' – and either have a calcium-carbonate external shell, a small shell under the surface, or no shell at all. Slugs are shell-less while adult snails have coiled shells big enough to withdraw into.

Slugs and snails belong to the large group of molluscs called gastropods and make their home in a variety of locations from back gardens to oceans and everywhere in-between. They are the only molluscs that can live on dry land, and breathe using either lungs, gills or both.

Gastropods are hermaphroditic, which means they have both male and female reproductive organs, and can mate with themselves if no partner is available. During an elaborate mating ritual slugs entwine and stimulate each other until sperm is exchanged via their disproportionately large genitals. Another peculiar trait is apophallation, whereby one slug chews off the other's penis after mating. The apophallated slug may now only reproduce using its female genitalia.

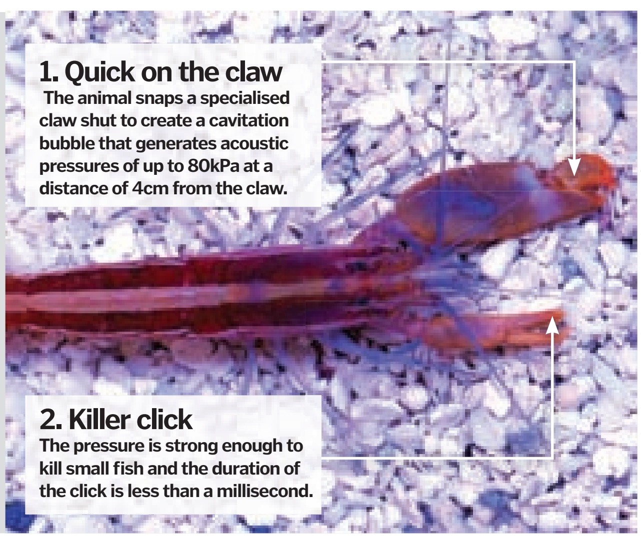
The pistol shrimp

This crustacean armed with its own gun is one of the most deadly residents of the world's oceans

The pistol shrimp apprehends its prey by snapping shut the larger of its two claws at lightning speed, creating a sonic wave that can stun or even kill small fish. The snapping of the claw creates a shock wave that emits a 60mph jet of water, behind which is a bubble of low pressure which then collapses.

It all takes place very quickly, but when the bubble implodes and the temperature inside rises dramatically, a very loud sound is produced, and a tiny spark of light is emitted. The sudden temperature rise – to 4,500°C, almost as hot as the Sun – is produced by the rapid drop in pressure at the point of collapse. The substance then rapidly vaporises within the bubble.

The bubble's collapse also causes a spark of light called sonoluminescence (light emitted from a bubble excited by ultrasound waves), but it's so brief it's not even visible to the naked eye.



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THE STATS GRAND CANYON

AVERAGE DEPTH **1 mile** LENGTH 277 river miles MIN WIDTH **600ft** MAX WIDTH 18 miles AGE **2 billion years** VISITORS PER YEAR 4.5 million

DID YOU KNOW? *Human artefacts dating back 12,000 years have been discovered at the Grand Canyon*

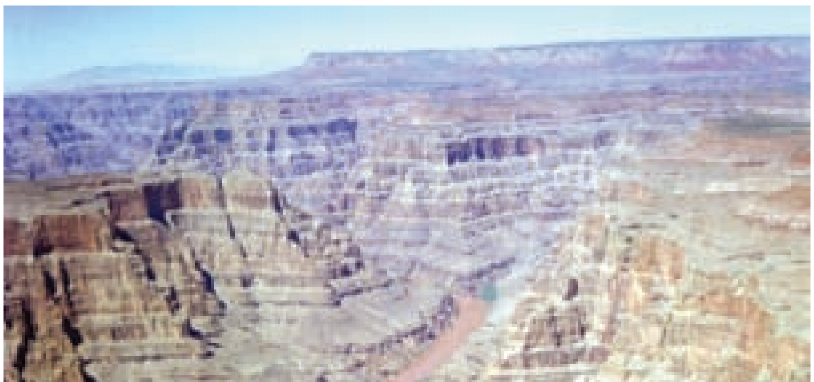
The Grand Canyon

One of the largest natural wonders of the world, this vast gorge was carved by water's erosive power

The exact processes that formed the Grand Canyon remain a compelling puzzle. But studies suggest this giant gorge was cut by flowing water just a few million years ago – a blink in geological time. The canyon's rocks have a much longer history – the oldest are around 2 billion years old.

Perhaps 30-70 million years ago, these rock layers were uplifted to form the high, flat Colorado Plateau. There are several theories explaining how and why this uplift happened. Around 5-6 million years ago, the Colorado River changed its course and began to carve down through the plateau.

The river uses sediment and rocks like chisels and sandpaper to chip away its channel. It has tremendous erosive power because it is fast flowing with a large volume, enabling it to carry a large amount of debris. Arizona's arid climate means rock is unprotected by vegetation, making it more susceptible to erosion.

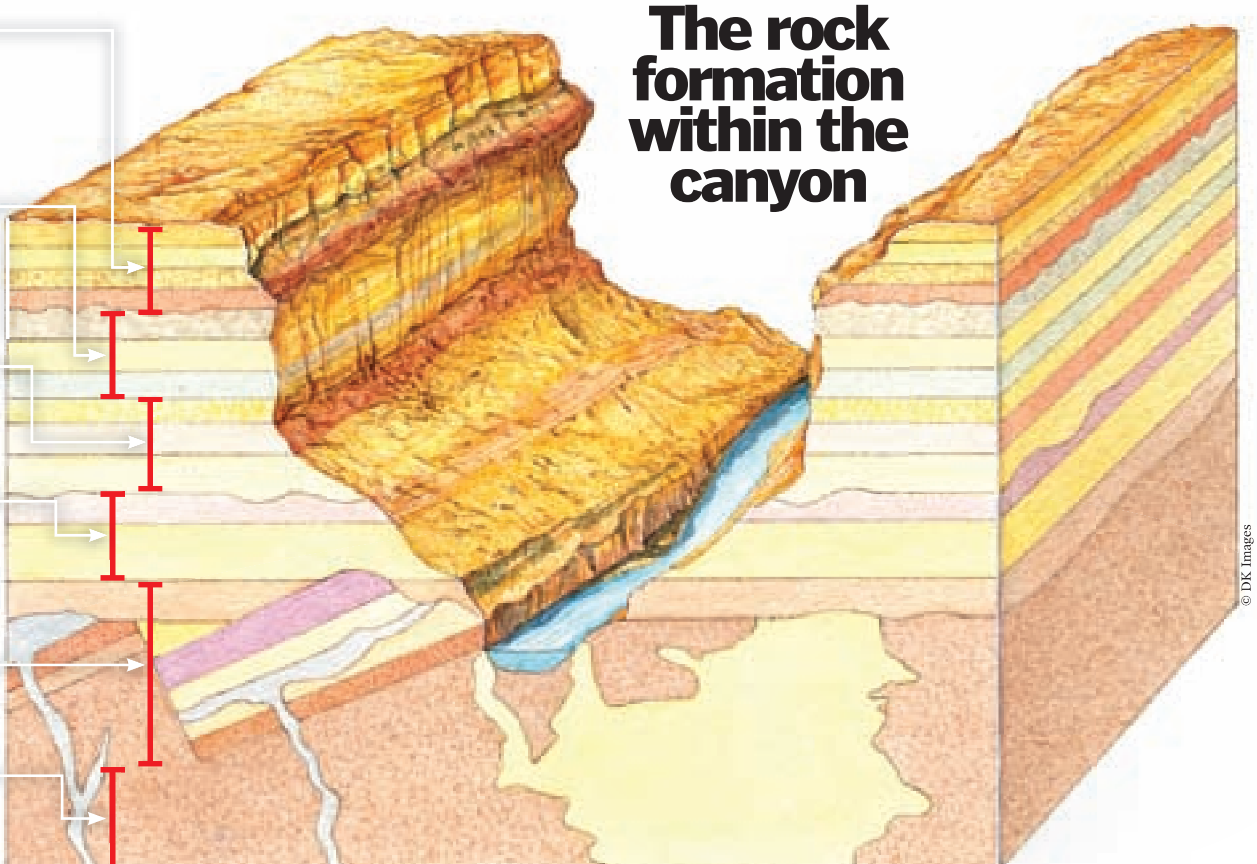


High-rise wildlife

Five of North America's seven life zones – areas with similar plants and animals – appear within the Grand Canyon's one-mile high walls. While desert scrub like cacti are found close to the river, a spruce-fir forest covers the North Rim above 2,500m.

More than 1,500 plant, 355 bird, 89 mammal, 56 reptile and amphibian, and 17 fish species are found around the canyon. Other wildlife species are rare or protected. For example, the Californian condor is among the world's rarest birds.

The rock formation within the canyon



6. Hermit, Coconino, Toroweap and Kaibab
Shales, siltstones, limestones and sandstones deposited 270-280 million years ago in environmental conditions ranging from desert to shallow seas.

5. Supao Group
Sandstones and siltstones deposited 285-315 million years ago along a coastal, low-lying plain. Coloured red by iron oxide.

4. Temple Butte, Redwall and Surprise Canyon
Fossil-containing rocks, such as limestones, formed from marine sediments deposited between 320 and 385 million years ago.

3. Tonto Group
Layers of sedimentary rocks like sandstone, limestone and shale deposited 505-525 million years ago in bays and lagoons.

2. Grand Canyon Supergroup
Rocks made of sediments laid down around 750-1,200 million years ago in a rift basin.

1. Vishnu Group
Formed around 2 billion years ago by heat and pressure as the North American continent and an island chain collided.

MOST WELL EXPLAINED

1. Kingdom Of The Crystal Skull

Referencing the often inaccurate depiction, Indy explains that what he and Marion are sinking into is not actually quicksand, but some sort of collapsing dry sandpit.

MOST UNLIKELY

2. The Princess Bride

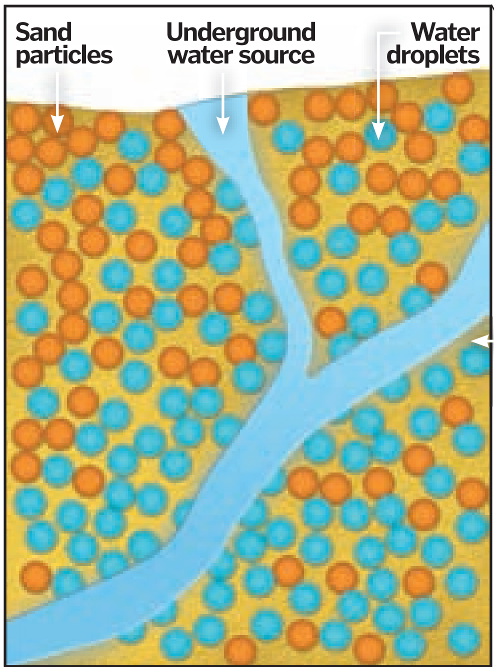
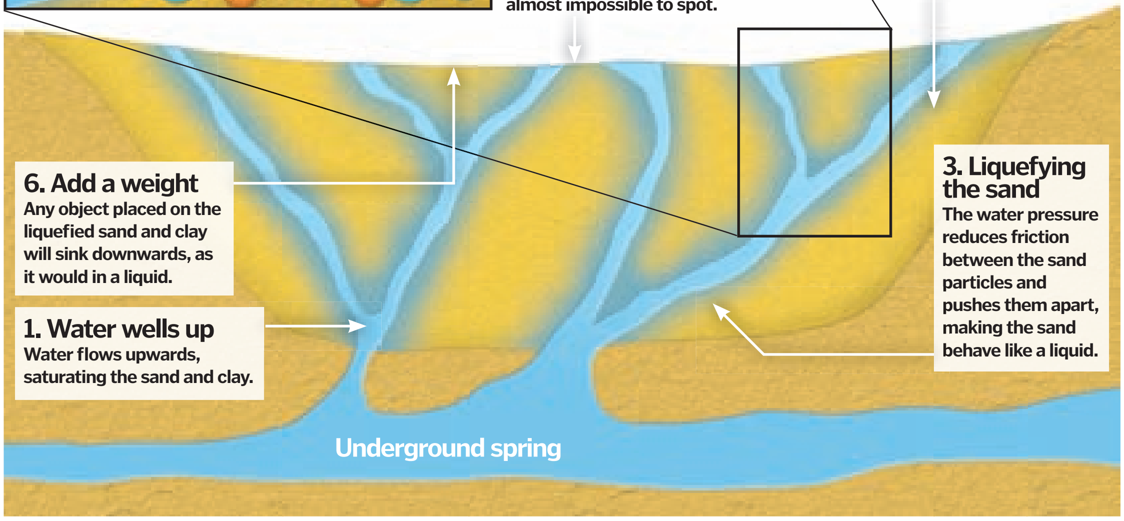
This fantasy favourite features a super-quicksand called 'lightning sand', which is dangerous because its grains are so small that you fall straight through it and perish below.

MOST POST-APOCALYPTIC

3. Beyond The Thunderdome

The third outing for Max the road warrior saw him very nearly lose his life in what looked very much like dry quicksand. Thankfully his mullet survived.

DID YOU KNOW? Morecambe Bay in Cumbria has deadly quicksand. Rescues are a race against time because of the tides

He's got that sinking feeling

Quite literally up to his neck in it

How deadly is quicksand?

Quicksand is a horror movie staple, but can it suck you under in seconds? And how can you escape?

Quicksand can kill, but seldom does. Its few victims don't get sucked in over their heads, but people trapped for long periods can die of exposure, thirst or drown in incoming tides.

Wet quicksand occurs when water wells up underneath sand and clay. The clay and water forms a gel that acts like yogurt. When undisturbed it's solid. However, like tilting a yogurt pot, it flows when shaken. A person walking on it can make it move, an earthquake shaking waterlogged sediments has a similar effect.

A person walking on quicksand sinks downwards, pushing the sand grains together. The sand eventually forms a solid bed, usually when the person is trapped to their waist. The densely packed sand grains hold their legs tightly, preventing them from escaping. To pull them out vertically would need the power of a car.

Dry quicksand is loosely packed sand that's been carried in the air or had air flowed through it. When someone steps on it, the sand grains pack closer together, causing the person to sink in.

How to escape from quicksand

1. Go back - Carefully retrace your steps if the sand under your feet feels like custard

2. Don't panic - If you get stuck, stay calm. The more you flounder, the deeper you'll sink

3. Strip off - Leave wellies in the quicksand and cut shoelaces. Big rucksacks can act as solid ground

4. Lie down - If you're sinking deeper, sit or lie in the quicksand to spread your weight

5. And roll - Try to roll out the quicksand, perhaps using a rucksack as an aid

Learn more

Morecambe Bay in the northwest of England is notorious for its mud and quicksand. Thankfully the Bay Search and Rescue team are on hand to save those who get into difficulty. Visit their website at **www.baysearchandrescue.org.uk** to learn more.

"Over geological timescales, coral reefs grow so as to regulate the depth of the water above them"

Coral re

Incredible biological richness in the most nutrient-poor waters in the world? How It Works explains the paradox of the coral reef

The secret to understanding how coral reefs work is that they flourish in tropical waters that contain hardly any food. They are often described as the rainforests of the ocean but it is more accurate to think of them as oases in a saltwater desert. Warm water doesn't dissolve nutrients very well so it doesn't support the soup of plankton that exists in colder waters. But this means that the water is also very clear, which makes it ideal for photosynthesis. By striking up a symbiotic allegiance with photosynthetic zooxanthella bacteria, the corals can harness the sunlight to provide them with most of their food, while at the same time retaining their animal ability to capture small prey and gather essential nitrogen.

The limestone skeleton that corals produce to protect themselves also dramatically affects the ocean environment. It absorbs and deflects wave energy, creating sheltered lagoons in its lee and provides innumerable crevices and attachment points for other animals. A reef is a complex ecosystem with each species contributing to the stability of the whole. Algae help cement the reef together, sea urchins keep the algae under control, molluscs stop the sea urchins from overgrazing, and so on.

Over geological timescales, coral reefs grow so as to regulate the depth of the water above them, even during times of rising sea level. This prevents the ecosystem from simply 'drowning' in the increasing gloom and makes coral reefs some of the most long-lived biological structures on the planet. Some coral atolls are 30 million years old.

Colourful soft corals, anthias. moray eel and other fish species

5 TOP FACTS REEF DWELLERS

Dwarf seahorse
1 The slowest fish in the world. Never straying far from the safety of its nest crevice, this fish swims at just five feet per hour, that's an incredibly slow 0.0004m/s.

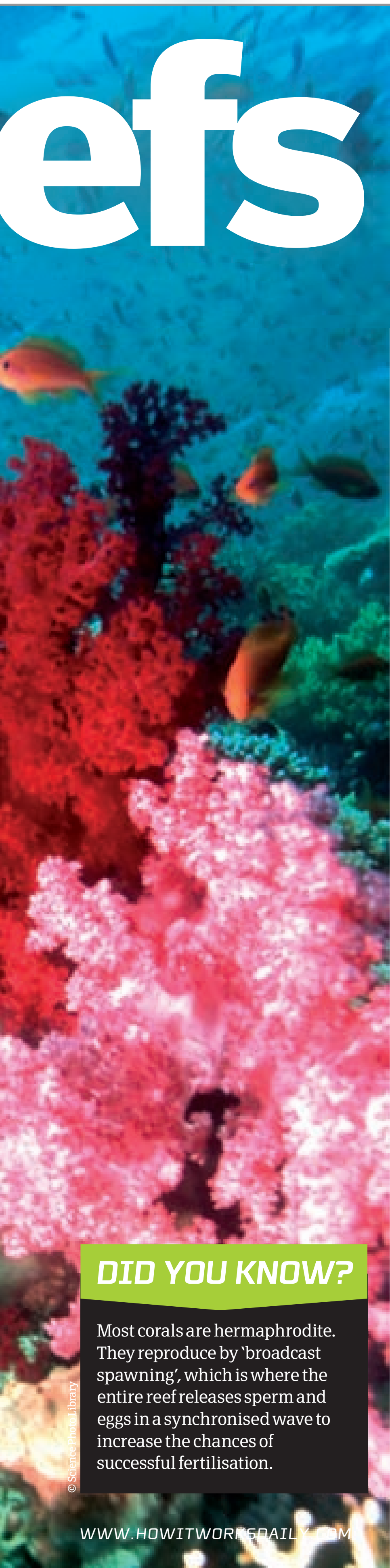
Seven-figure pygmy goby
2 The high risk of predation on the reef encourages this fish to live fast and die young. It is the shortest-lived vertebrate with a natural life span of just 59 days.

Yellowfin goatfish
3 At night, this bottom feeder trawls the sands for worms and crustaceans. But by day it changes colour and hides among shoals of bluestriped snapper.

Crown-of-thorns
4 This starfish grows up to 40cm across and each one can eat up to six square metres of living coral a year. It is the second largest sea star in the world.

Giant triton
5 A giant sea snail and one of the only predators of the crown-of-thorns. The triton is in decline because of overfishing for its huge 50 centimetre shell.

DID YOU KNOW? 60 per cent of the world's coral reefs are at risk of destruction. Ten per cent are already dead



Types of coral reef

Reefs form in shallow waters close to the shore. At the end of the last ice age, 10,000 years ago, the sea level began to rise. In order to keep close enough to the surface for photosynthesis, the coral reefs grew upward. They also grew outwards but because the sheltered conditions on the shoreward side of the reef are less favourable, they grew more slowly there. This, combined with the shrinking shoreline as the sea level rises, causes the reef to separate from the shore.

With enough time, erosion and rising seas may remove the central island altogether and all that is left is a coral atoll.

1. Volcano
An undersea volcanic eruption erupts enough lava to create an island that juts above the surface.

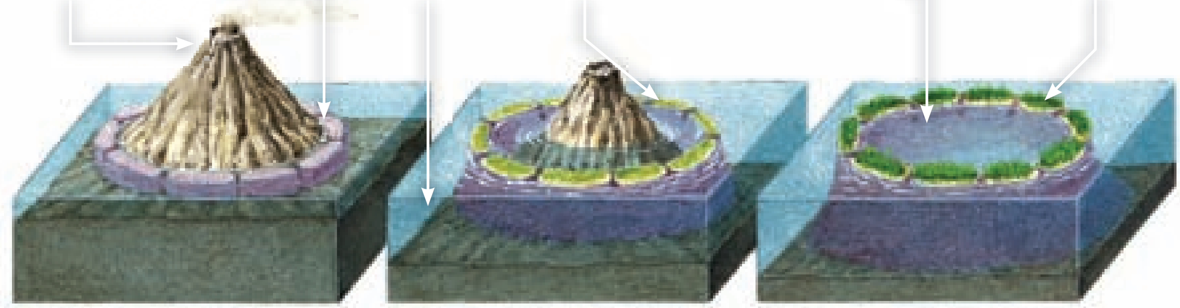
2. Fringing reef
The shallow seas near the shoreline and the turbulence from the wave action encourages the formation of a fringing reef.

3. Rising sea
Over time, the sea level rises, shrinking the portion of the extinct volcano that juts above the water.

4. Barrier reef
The coral grows upward, to stay close to the surface. A sheltered lagoon now forms between the coral and the shore.

5. Atoll
Eventually the volcano may become completely submerged, leaving a ring or partial ring of coral around a shallow lagoon.

6. Plant life
Broken coral and animal shells form sand that collects in the gaps between the coral. Plants take root, stabilising and raising the ground level.



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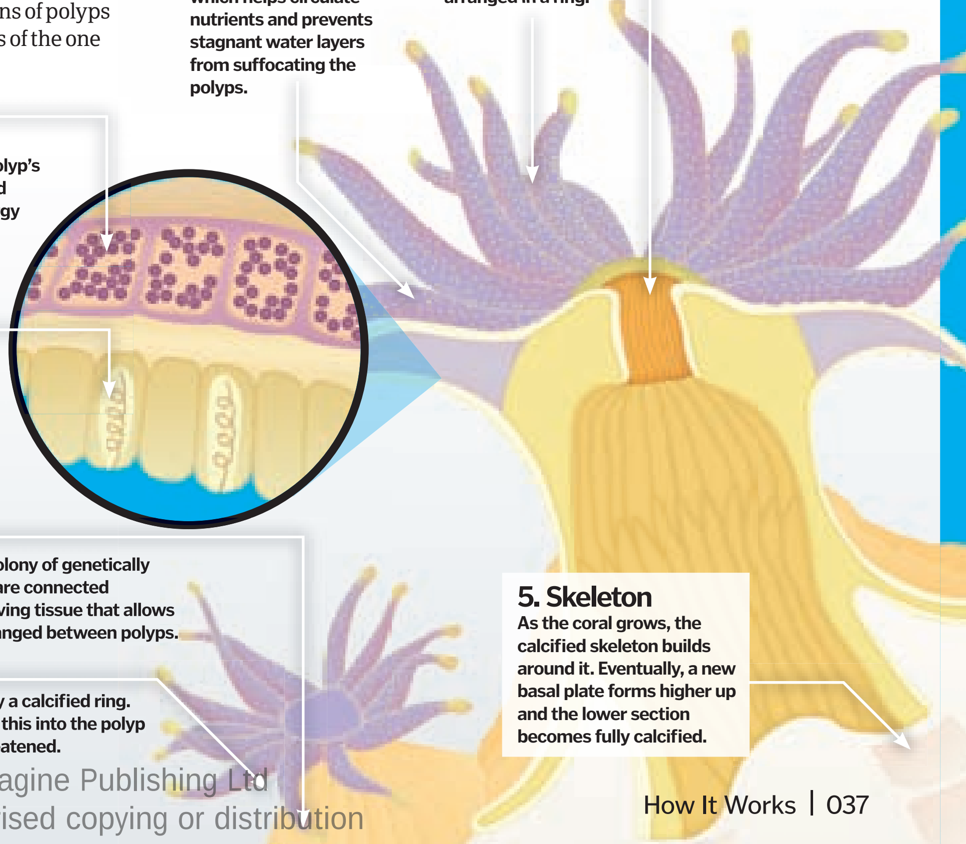
What's inside coral?

Coral looks and behaves rather like a plant but it is actually a colony of animals, related to sea anemones, called polyps. Each polyp anchors itself to the existing reef and builds a calcium carbonate skeleton to protect its body. Successive generations of polyps build on the dead skeletons of the one before as the reef grows.



8. Rough surface
Coral skeletons are deliberately rough to encourage turbulence, which helps circulate nutrients and prevents stagnant water layers from suffocating the polyps.

1. Tentacles
Reef building corals have tentacles in multiples of six arranged in a ring.

3. Mouth
Polyps only have one opening to their stomach cavity. This serves as both mouth and anus.

6. Zooxanthellae
Photosynthetic bacteria called zooxanthellae live within the polyp's tissues. These trap sunlight and provide 90 per cent of the energy requirements of the coral. In return, the polyp supplies nitrogen and carbon dioxide.

2. Nematocysts
Stinging cells in the tentacles, called nematocysts, are used to catch zooplankton that drift by. Each nematocyst can fire only once and then must be replaced.

7. Living tissue
A 'head' of coral consists of a colony of genetically identical cloned polyps. These are connected together by a surface layer of living tissue that allows metabolic products to be exchanged between polyps.

4. Basal plate
The polyp is glued to the reef by a calcified ring. Muscular ridges protrude from this into the polyp and can retract it quickly if threatened.

5. Skeleton
As the coral grows, the calcified skeleton builds around it. Eventually, a new basal plate forms higher up and the lower section becomes fully calcified.

DID YOU KNOW?

Most corals are hermaphrodite. They reproduce by 'broadcast spawning', which is where the entire reef releases sperm and eggs in a synchronised wave to increase the chances of successful fertilisation.

© Science Photo Library

> "The Great Barrier Reef is the largest structure in the world made by living organisms"

Easy come, easy goby. A common resident of the coral reef

Creatures of the coral reef

Coral reefs support an amazing array of animals and creatures

Coral reefs cover just one per cent of the ocean's surface area, but they account for 25 per cent of its biodiversity. Compared to the placid and largely empty deep waters around it, a coral reef boils with life. As well as 8,000 species of fish, coral reefs are home to sponges, crustaceans, starfish, turtles and sea snakes. Some, like the crown-of-thorns sea star, eat the coral directly but most reef creatures are active predators. This, coupled with such a tightly knit environment, leads to a frantic, cut-throat existence.

Reef fish, like the queen angelfish, are adapted to fit into tiny crevices and are often highly flattened, using their pectoral fins to paddle around in short spurts, rather than the energy-efficient cruising of open water fish like tuna. Because of the enclosed nature of a reef, swimming speed is less of a consideration than close range defences. Reef fish are often brightly coloured and this may be to camouflage themselves against the equally bright corals or to confuse predators with false eyespots, such as those of the foureye butterflyfish. Many fish have poisonous spines to make themselves less appetising. Gobies have eyes that can swivel independently, like a chameleon, to let them scan for predators.

A queen angelfish is perfectly adapted to reef living

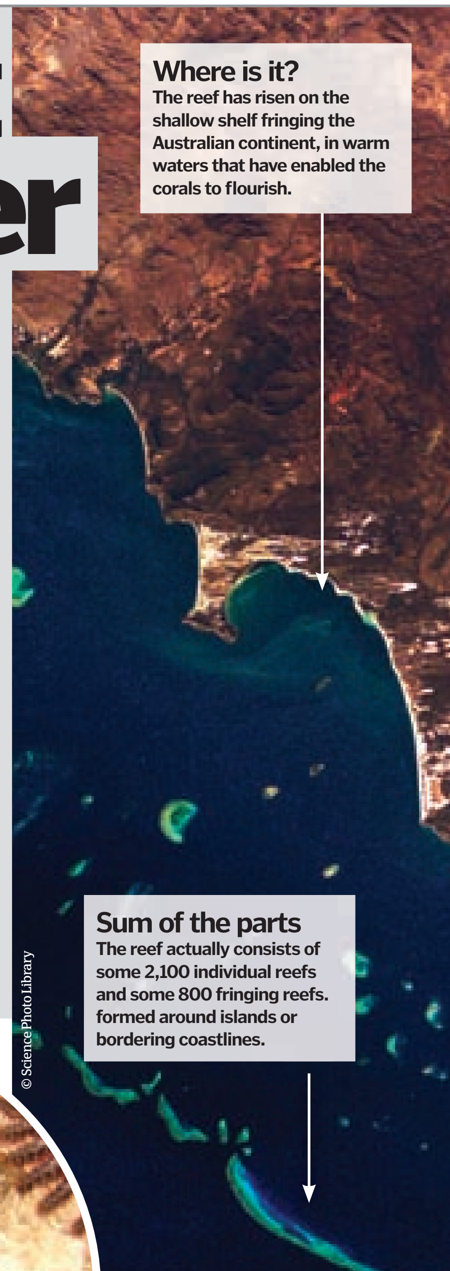
© Laszlo Ilyes, 2006

© Ron Lutz, 2007

Great Barrier Reef

It's a big one down under...

The Great Barrier Reef is the largest structure in the world made by living organisms and covers 344,400 square kilometres. Coral reefs have existed off the north coast of Australia for at least 18 million years, but the formation of the modern reef began about 20,000 years ago. As sea levels rose by 120m over the next 14,000 years, the corals formed reefs around the flooded coastal hills, which became islands and eventually disappeared completely. The Great Barrier Reef is home to whales, dolphins, dugongs, sharks, turtles and giant clams. Fishing and tourism together account for around £1.2 billion each year.



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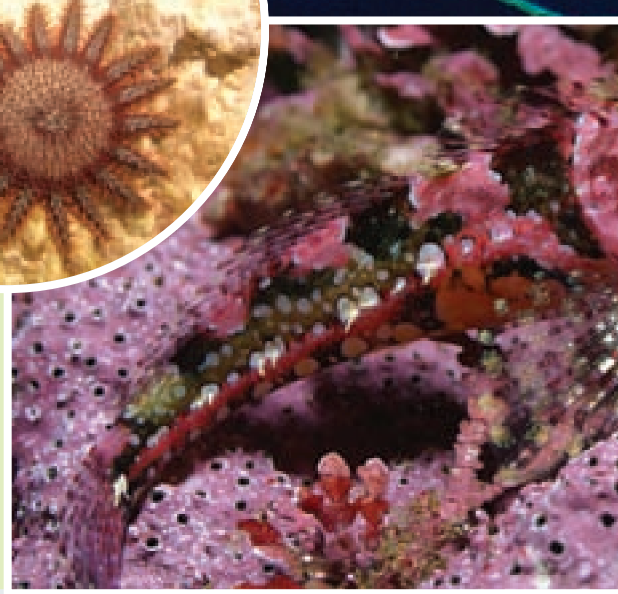
Plant life of the coral reef

There are three main kinds of coral plants. The familiar seaweeds (or macroalgae) are found in the shallowest waters, usually on the top of the reef. Turf algae are short filaments that form carpets usually less than one centimetre high. These are an important food source for reef herbivores because they grow very quickly.

The crustose coralline algae don't look like plants, they appear as red or pink splashes of paint, coating the surface of the coral. These thin sheets of plant life have cells reinforced with calcium carbonate, just like the corals. They favour the outer face of a reef, where the wave action is most aggressive and are important in cementing the reef together.



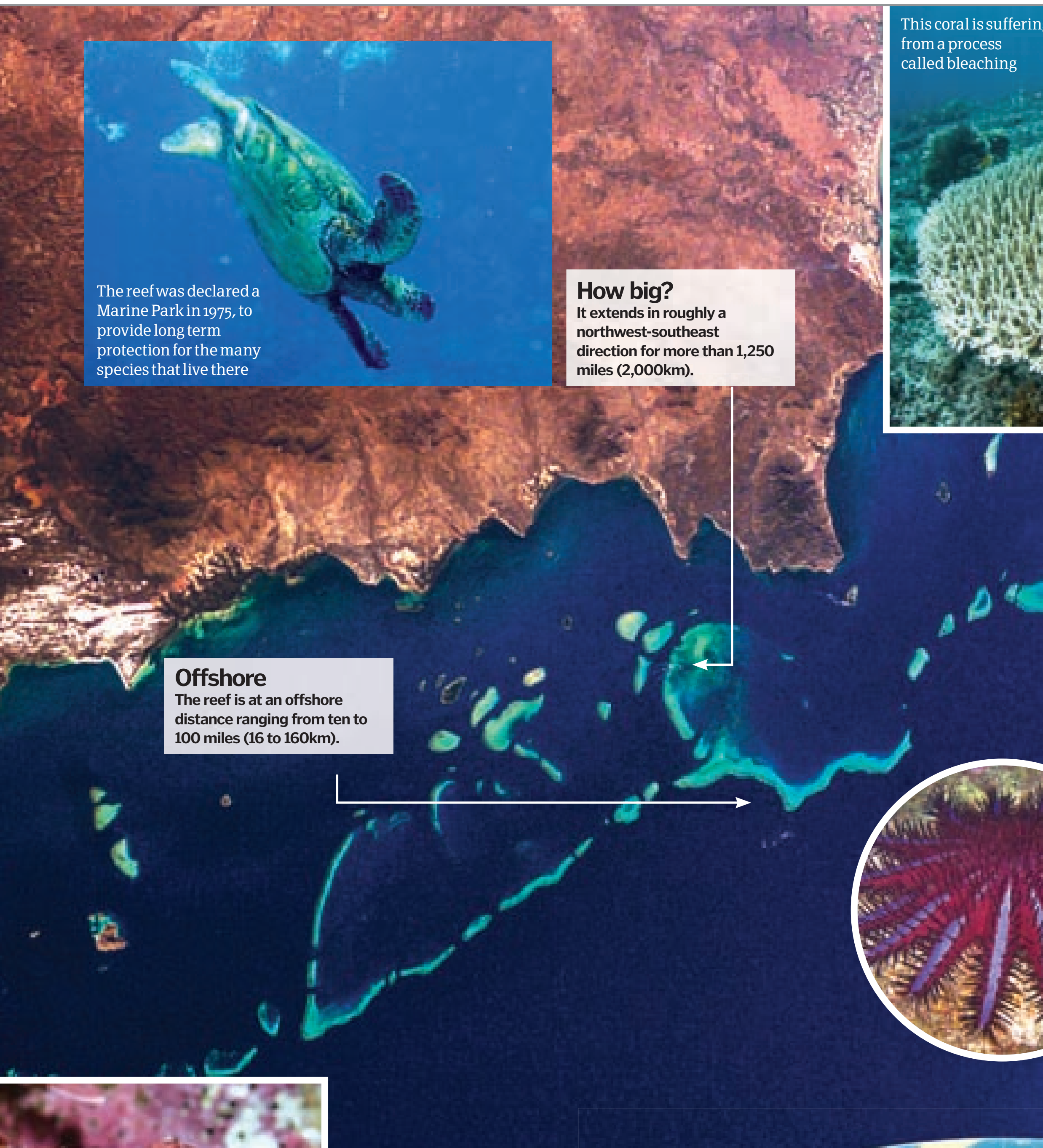
Head to Head
BIGGEST CORAL REEFS

1. East Rennell Island
At 86km by 15km, this is the largest raised coral atoll in the world. Its lagoon is also the largest in all the Pacific islands.

2. Belize Barrier Reef
The largest barrier reef in the northern hemisphere. The reef system includes hundreds of sand cays (low islands) and lagoons.

3. Great Barrier Reef
The largest reef in the world. It is 2,600km long, incorporates 940 islands and is visible from outer space.

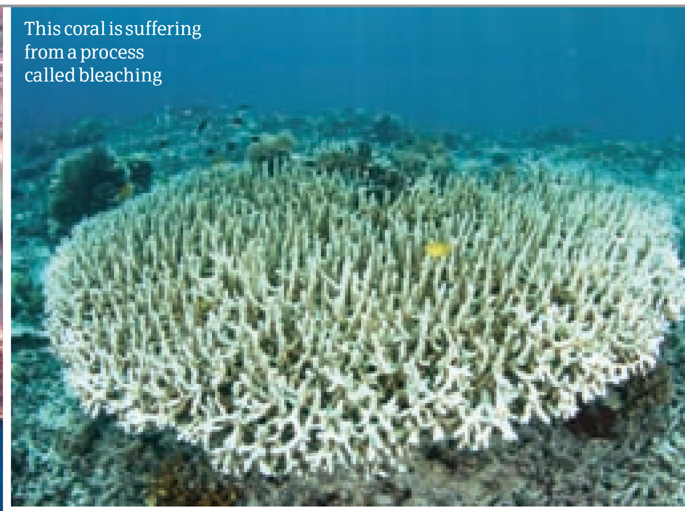
DID YOU KNOW? *Two-thirds of the global population of the Laysan Albatross (1.5 million birds) nest on the Midway Atoll*



The reef was declared a Marine Park in 1975, to provide long term protection for the many species that live there

How big?
It extends in roughly a northwest-southeast direction for more than 1,250 miles (2,000km).

Offshore
The reef is at an offshore distance ranging from ten to 100 miles (16 to 160km).

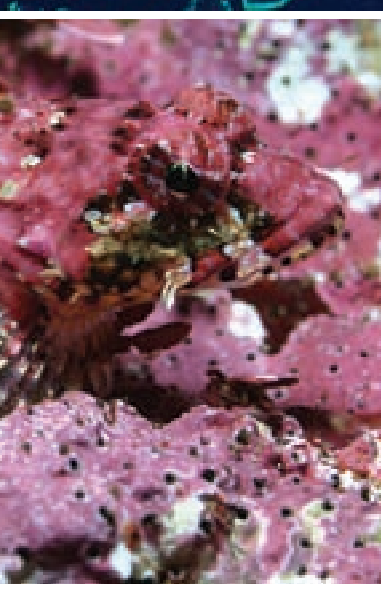


This coral is suffering from a process called bleaching

Threats to the coral reef

Corals are very sensitive to changes in sea temperature and water quality. When stressed, corals will eject their symbiotic zooxanthella bacteria in an attempt to conserve energy – a process known as coral bleaching. If the unfavourable conditions do not improve within a few months, the coral will not acquire new symbionts and will die. Global climate change is raising ocean temperatures; increasing the frequency of bleaching events. Rising carbon dioxide levels also make the seawater more acidic, which inhibits the formation of calcium carbonate skeletons. Corals are also threatened by fertiliser run-off from farms, and destructive fishing practices such as dynamiting.

© Jon Hanson, 2005



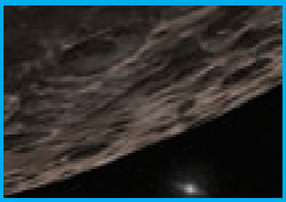
ON THE MAP

Where do coral reefs grow?
Looking for the largest organisms on Earth? Look here

1. Tubbataha Reef Marine Park
2. Great Barrier Reef
3. East Rennell Island
4. Brazilian Atlantic islands
5. Komodo National Park
6. Belize Barrier Reef
7. Greater St Lucia Wetland Park
8. Aldabra Atoll
9. Maldives

This month in Space

Two words. Space. Robots. That should be enough to get most readers interested in our main Space feature this issue, where we look at some marvellous machines that are designed to work hundreds of miles above Earth's surface. Amazing though they might be, we're confident they won't "go cylon" and start laying waste to the planet. Get started by reading about the surface of Neptune right here.



42 Kuiper asteroid belt

43 Spitzer telescope

46 Space robots

SPACE

40 Neptune
42 Kuiper belt
42 Brown dwarves
43 Spitzer space telescope
44 Orbits
45 Lunar Recon Orbiter
45 Meteor shower
46 Space robots

Neptune

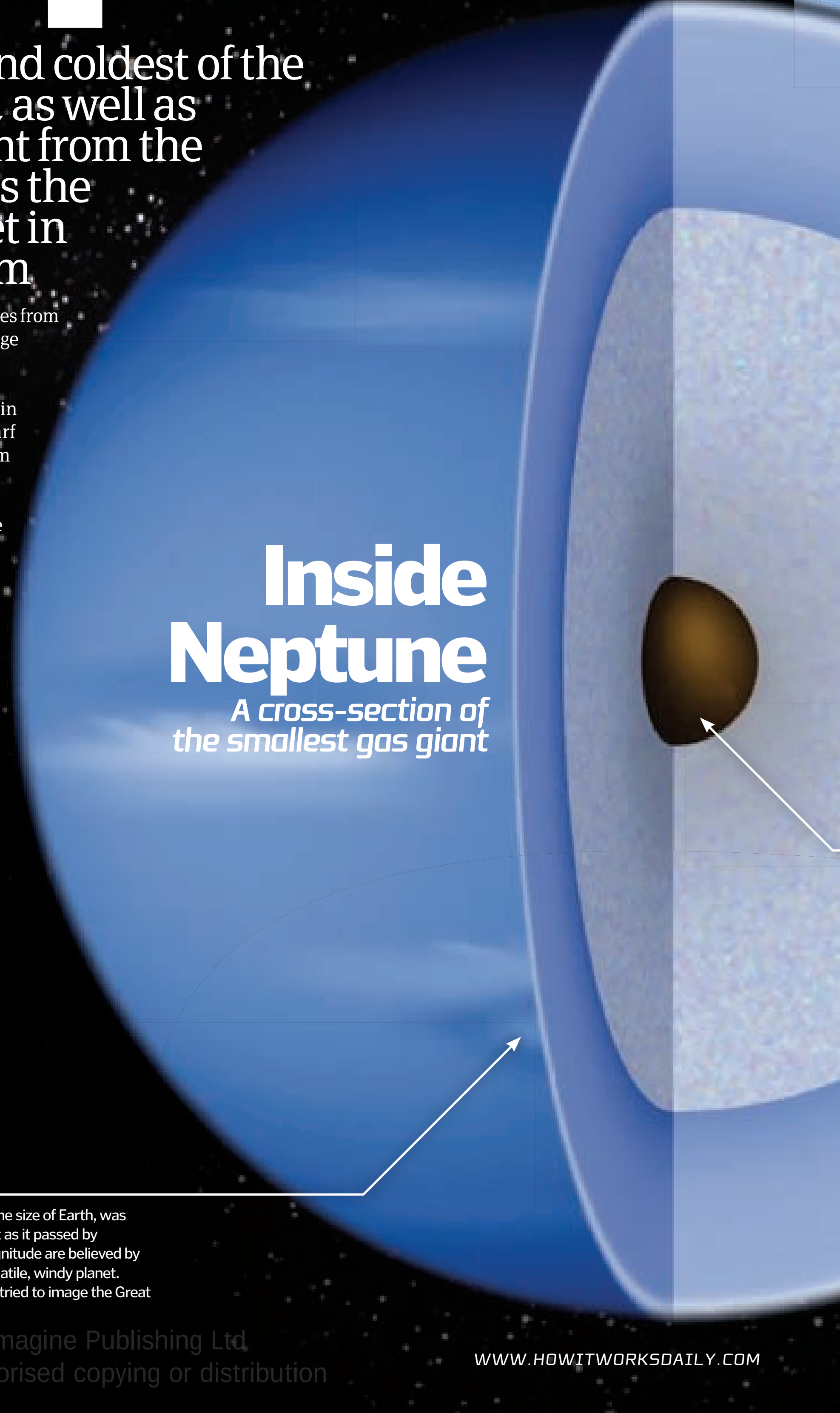
The smallest and coldest of the four gas giants, as well as the most distant from the Sun, Neptune is the windiest planet in our solar system

Over 4.5 billion kilometres from Earth and with an average temperature of -220°C, Neptune is the furthest planet from the Sun and the coldest in our solar system, excluding the dwarf planet Pluto. It is a massive (49,532km in diameter) sphere of hydrogen, helium and methane gas, formed around a small but mass-heavy core of rock and ice that, despite its similar size and structure to its inner neighbour Uranus, differs in appearance dramatically, presenting its turbulent, violently windy atmosphere on its surface. Find out what makes Neptune so unique and volatile right here.

A gigantic storm the size of Earth

5. Dark spot

The Great Dark Spot, a gigantic, dark storm the size of Earth, was captured on film by the Voyager 2 spacecraft as it passed by Neptune in 1989. Storms of this size and magnitude are believed by scientists to be relatively common on this volatile, windy planet. However, when the Hubble Space Telescope tried to image the Great Dark Spot in 1996 it had disappeared.



Inside Neptune

A cross-section of the smallest gas giant

5 TOP FACTS NEPTUNE

True blue
1 Neptune's eye-catching deep blue colouring is caused by the methane gas in its atmosphere, absorbing red light and reflecting blue.

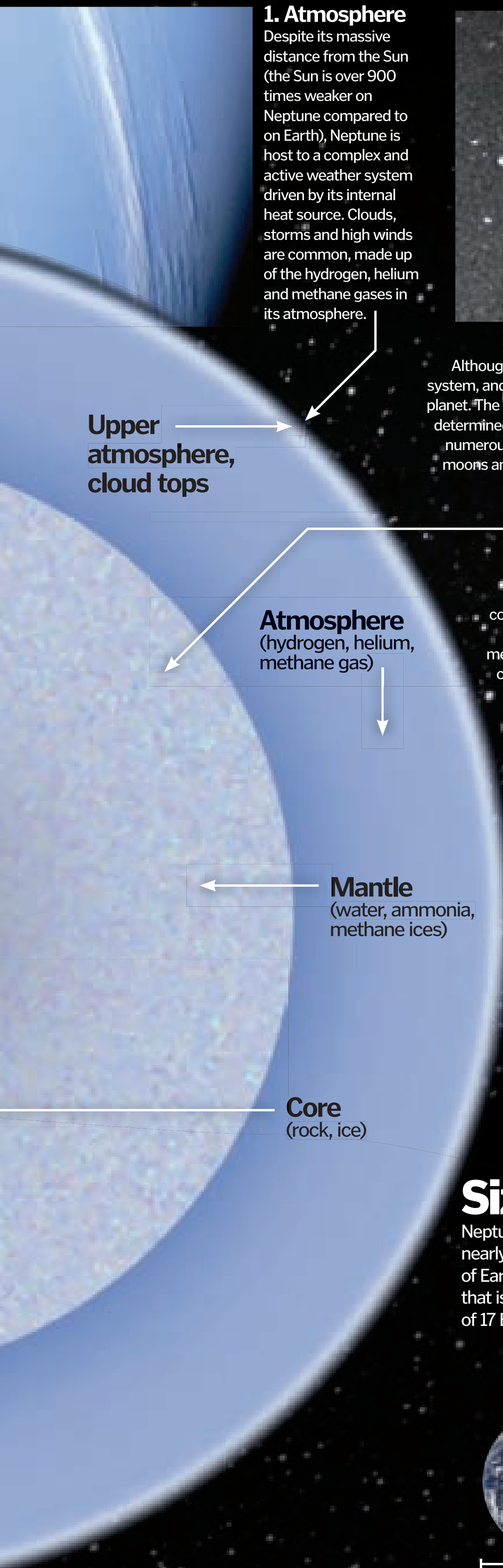
Gale force
2 Around its equatorial region Neptune is privy to winds in excess of 1,340 miles per hour as well as extremely violent storms.

Belt buster
3 Due to the fast nature of Neptune's spin around its axis, its equatorial region is 527 miles larger in diameter than at its poles.

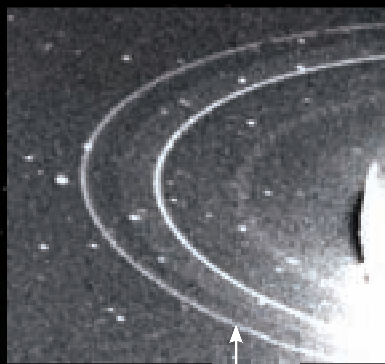
Son of god
4 Neptune's one major moon is actually named, funnily enough, after his Greek counterpart Poseidon's son, Triton.

The four seasons
5 Neptune undergoes seasons just like here on Earth. However, they last 40 years each instead of just the three months we're used to.

DID YOU KNOW? Neptune is not visible to the naked eye, with a small telescope necessary to discern it as a star-like point of light



1. Atmosphere
Despite its massive distance from the Sun (the Sun is over 900 times weaker on Neptune compared to on Earth), Neptune is host to a complex and active weather system driven by its internal heat source. Clouds, storms and high winds are common, made up of the hydrogen, helium and methane gases in its atmosphere.



2. Rings
Although not shown here, Neptune is actually a ring system, and is host to a series of six rings encircling the planet. The rings are made from tiny pieces of yet-to-be determined materials (probably rocks, stellar dust and numerous gases), which were gathered from nearby moons and phenomena and stretch a few kilometres across in width.

3. Structure
Neptune is very similar in size and composition to Uranus. Indeed, only 15 per cent of the planet's mass is hydrogen – contained within its shallow outer layer – with its main layer consisting of a mix of water, methane ice and ammonia, and its tiny central core postulated to be constructed purely out of rock. As with the other gas giants, the boundaries between layers are not clearly defined and change consistently.

4. Orbit
Neptune takes 164.8 Earth years to orbit the Sun and it is tilted to its orbital plane by 28.3 degrees, allowing its northern and southern poles to face the Sun in turn. The planet is also 30 times as far from the Sun than Earth is and it presents the second most circular orbit in the solar system, only beaten off by Venus in the parity between its aphelion and perihelion distances.

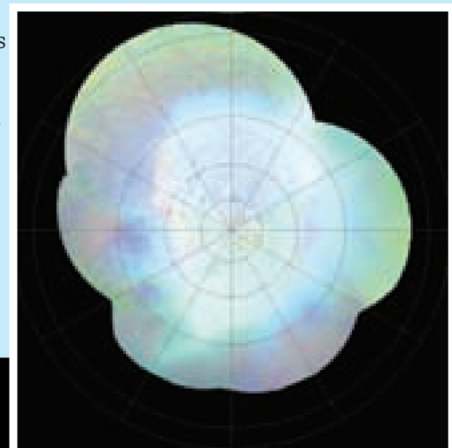
Dark carbonaceous dust litters Triton's south pole

Triton

Learning more about Neptune's massive moon

While Neptune has 13 moons in total (four in its ring system and nine out), it has only one major moon – Triton. Triton was the first of Neptune's moons to be discovered, just 17 days after the discovery of the planet was announced in 1846, and it is bigger than the dwarf planet Pluto. It follows a circular orbit around Neptune and exhibits a synchronous rotation, meaning that the same side always faces inwards. At both of its poles bands of nitrogen frost and snow are projected and redistributed by solar winds over its atmosphere and into space.

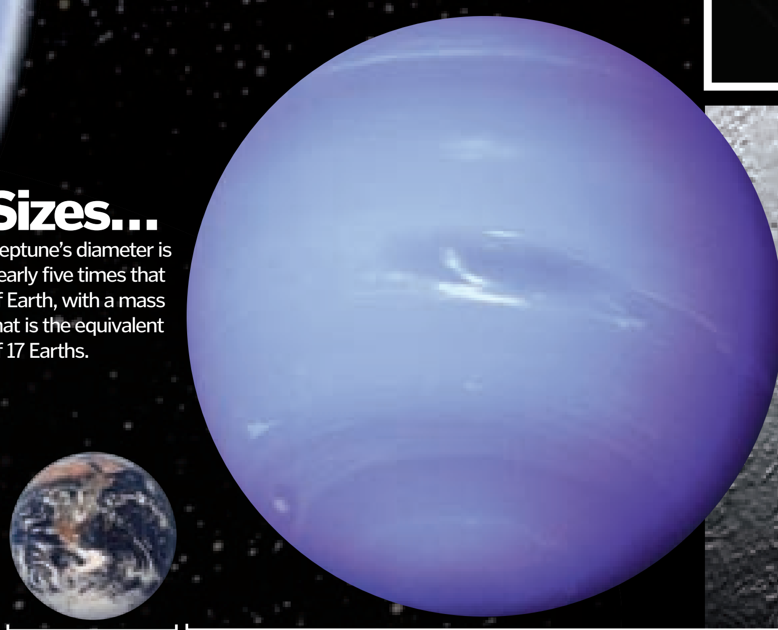
Triton is retrograde in motion, travelling in the opposite direction to Neptune's spin, and this scientists believe is evidence to its captured origin from elsewhere in the solar system, rather than formation in line with its planetary centre. Geologically young, Triton is two parts rock to one part ice and has a liquid mantle core and crusty, icy, craterous surface. At its southern pole lies a region of dark patches caused by the heating of sub-surface nitrogen ice into gas that erupts through surface vents in geyser-like plumes, depositing carbonaceous dust over its surface.



An image showing Triton's polar projection

Sizes...

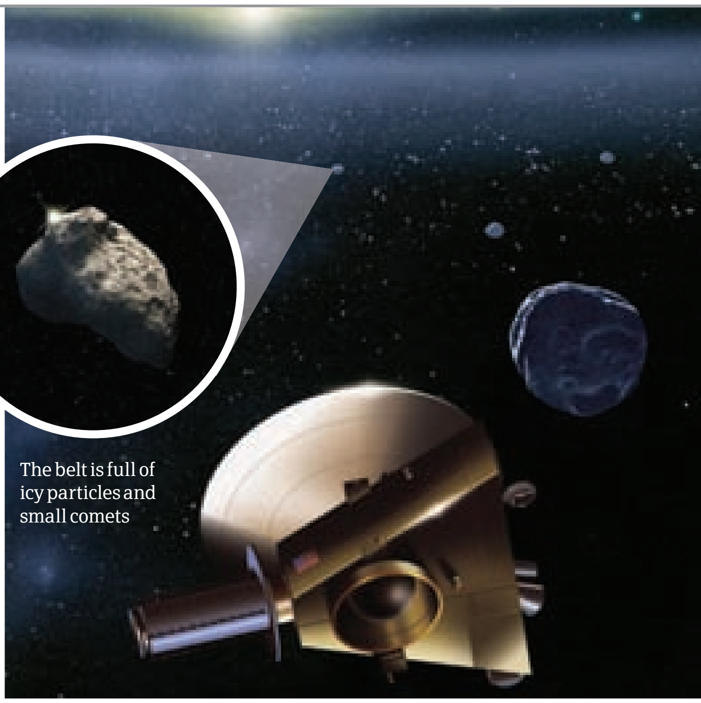
Neptune's diameter is nearly five times that of Earth, with a mass that is the equivalent of 17 Earths.



Triton's icy, scarred surface

Images courtesy of NASA

"Brown dwarfs are often considered to be the missing link between gas giant planets and red dwarf stars"



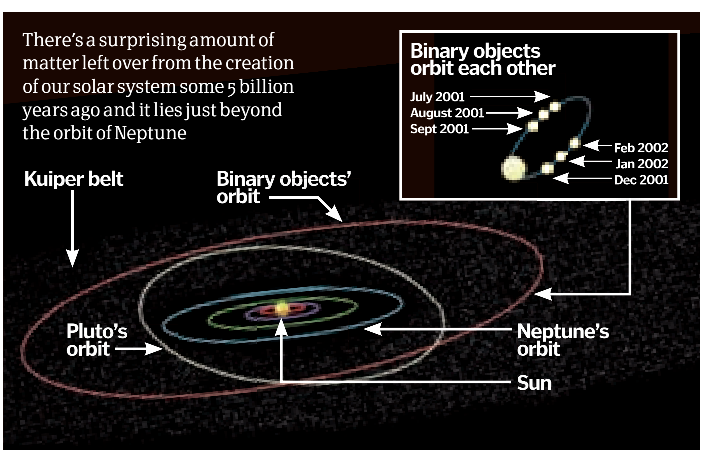
The belt is full of icy particles and small comets

Where is the Kuiper belt?

If you were looking for a gigantic asteroid field and a cloud of icy particles, where would you look?

If you were to scale down the Sun and planets so the Earth sat just 1cm away from the Sun, the furthest dwarf planet would sit some 30 centimetres away. Just beyond the orbit of Nepture, however, lies a wide belt of the remnants from the construction of our solar system. The Kuiper belt contains hundreds of thousands of icy particles thought to be up to 60 miles in diameter, along with up to a trillion smaller comets.

But the solar system doesn't end there – our entire solar system is entombed in an almost perfect sphere of ice, the Oort Cloud, that lies some half a kilometre further away on our previous scale (where the distance from the Earth to the Sun is just one centimetre). Lying on the boundaries of interstellar space, this shell is thought to contain up to 2 trillion icy bodies teetering on the very cusp of our Sun's gravitational grasp.

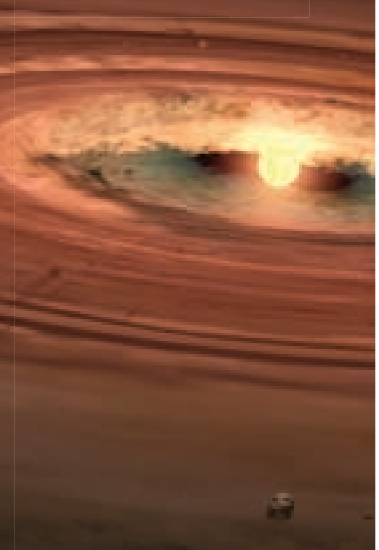


What is a brown dwarf?

These so-called 'sub-stellar' objects are barely bigger than planets, so what makes these failed stars stellar at all?

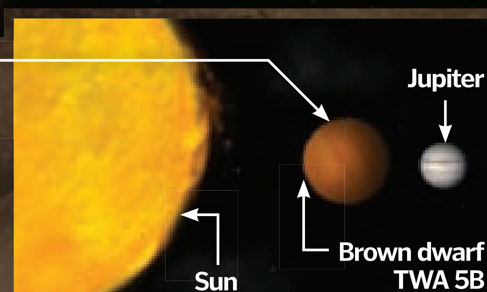
It's a conundrum that's racked the field of astronomy for the last 30 years – is a brown dwarf star really a star at all? Since they don't have the mass to initiate nuclear fusion like a normal star during its formation, they're often referred to as 'failed stars'. With masses that range from just a few times larger than our solar system's gas giant Jupiter, to around 75 times its size, brown dwarfs are often considered to be the missing link between gas giant planets and red dwarf stars – the smallest known 'true stars'.

Measuring or even discovering the presence of a brown dwarf star is notoriously difficult because they're so cool and small, so scientists use the presence of lithium as a determining factor. The presence of lithium is actually common in all young stars, but is usually burnt up in the first 100 million years of its life. Since the core of a brown dwarf isn't hot enough to get rid of the lithium it's a very useful indicator in labelling low-mass stellar objects 'brown dwarf stars'.



Size difference
Though an entirely hypothetical scenario, this artist's conception demonstrates the relative size difference between our own solar system and that of a particularly small brown dwarf system.

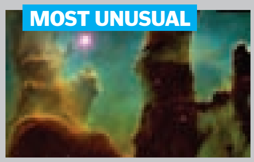
Not quite a star...
Brown dwarfs are also considered stars since they're born in exactly the same way – from the collapsing of a cloud of gas and dust. Sadly, the birth of a brown dwarf doesn't go to plan and the star doesn't gain enough mass for a hydrogen fusion engine in its core to ignite. In this respect, brown dwarfs are effectively stillborn stars.



All images © NASA

MOST IMPRESSIVE

1. The Story of Stellar Birth
This image shows young stars in a cosmic cloud in the Cepheus constellation, about 21,000 light years away from Earth.



MOST UNUSUAL

2. Towering Infernos
Stars are born in these 'mountains' of gas and dust, which are found in the Cassiopeia constellation 7,000 light years away.

MOST MYSTERIOUS

3. Mysterious Blob Galaxies Revealed
This red hydrogen blob is 11 billion light years away and contains three galaxies trillions of times brighter than our Sun.

DID YOU KNOW? The Spitzer was formerly known as the Space Infrared Telescope Facility (SITF)

Astronomers use Spitzer's orbit and parallaxing to determine the distance of dark planets and black holes

Spitzer Space Telescope

The last of NASA's four great observatories, the Spitzer Space Telescope was launched in 2003

Objects in space radiate heat in the form of infrared energy, but ground-based telescopes cannot detect it due to the Earth's atmosphere. Because the Spitzer Space Telescope orbits around the Sun, it can record this energy in the form of images. The telescope uses three highly sensitive instruments – a camera, a spectrograph and a photometer – that operate on different wavelengths and detect pixels to form pictures.

Infrared telescopes have to be kept very cold (-268°C) in order to function properly. The Spitzer was launched with a liquid helium supply to keep its instruments cold for a minimum of 2.5 years. It is far enough away from the Earth so that it does not pick up infrared energy from our planet, and was fitted with a solar shield to protect it from the Sun's heat. The liquid helium supply was used up on 15 May 2009, but the camera can still detect some infrared wavelengths.

© All images NASA

> "In essence, any orbit is maintained by the direction of its motion and acceleration, both of which alter constantly"

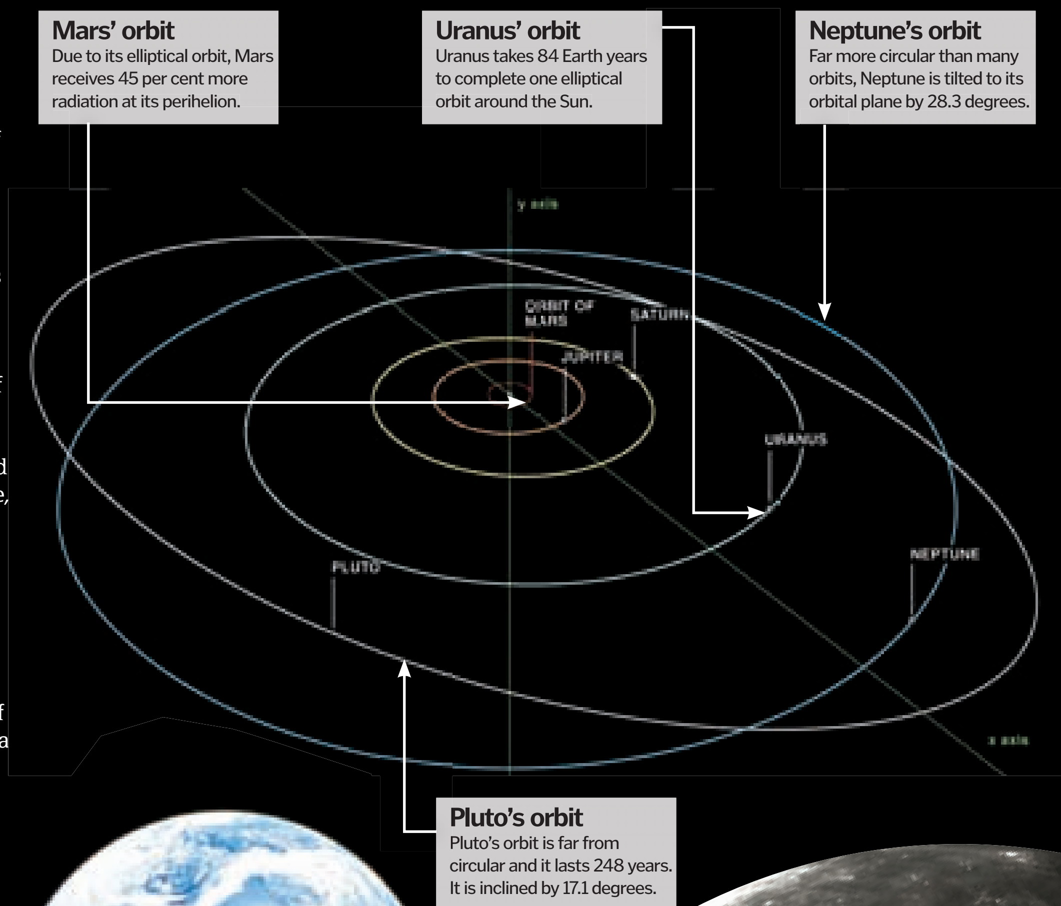
How orbits work

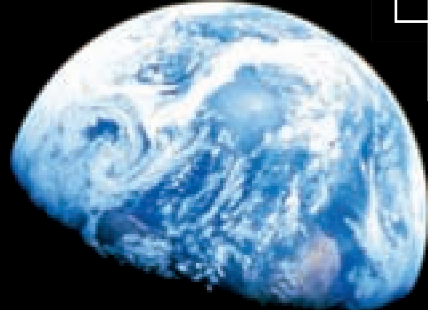
Why does the moon not crash into Earth?

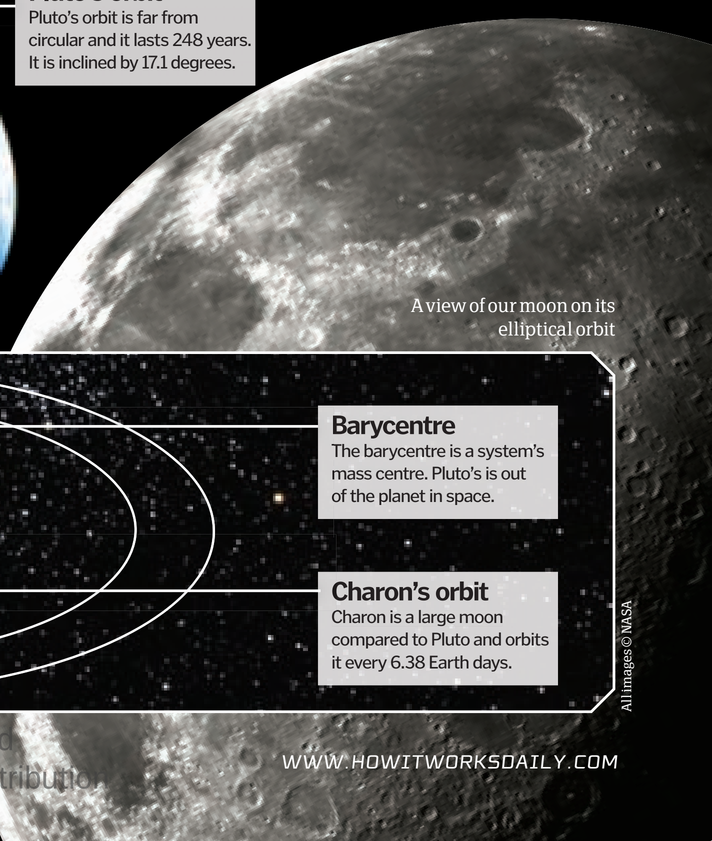
Orbits work because two bodies of mass are attracted to each other with force and that for every action there is an equal and opposite reaction, as explained in Newton's Third Law of Motion. In terms of orbits, this means that when one object rotates around another of a higher mass it experiences continuous free fall towards the larger body, undertaking a constant gravitational acceleration towards the greater object that deflects what would otherwise be its straight-line motion into a curved trajectory. In essence, any orbit is maintained by the direction of its motion and acceleration, both of which alter constantly, thereby producing its curved orbit.

All closed orbits are elliptical in shape, the degree of which varies from a perfect circle to a stretched egg form, and is referred to as an orbit's eccentricity. Many of our solar system's orbits – such as our moon's around Earth – are pretty circular with a low eccentricity. Here, both bodies rotate around the joint centre of mass – which in the Earth/moon relationship is deep inside the Earth – and the lesser body remains relatively circular throughout its orbit. Others, such as Pluto's orbit around the Sun, are highly elliptical and elongated, with a large gap between its perigee (its closest point of approach) and its apogee (the point where it is farthest from the orbit's focus). In the case of Pluto and its own moon Charon, while Charon follows a largely circular orbit due to its large size and close proximity (it is roughly half Pluto's size), the mass centre of the two objects is not within Pluto but out in space between the two.

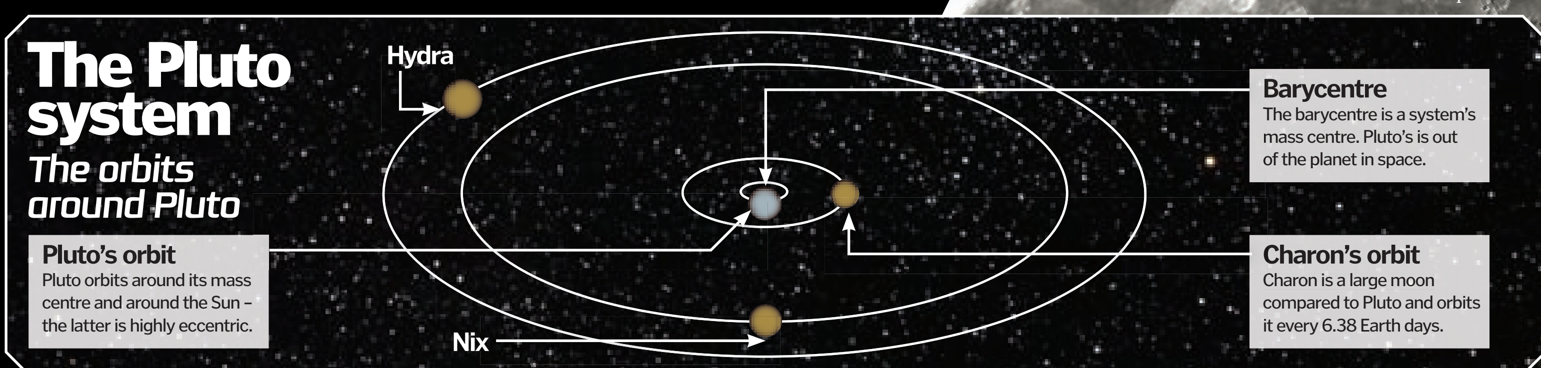
An easy way to understand orbits is to imagine a cannonball fired out of a cannon from the top of an impossibly high mountain – a visual image first used by Isaac Newton in the 18th Century. Once fired the cannonball moves sideways and falls towards the Earth (the central body), however it has so much tangential velocity that it misses the central object as it curves away beneath it due to its circular shape and continues to fall indefinitely, caught in an equilibrium sustained by its velocity and the pull of gravity.







A view of our moon on its elliptical orbit

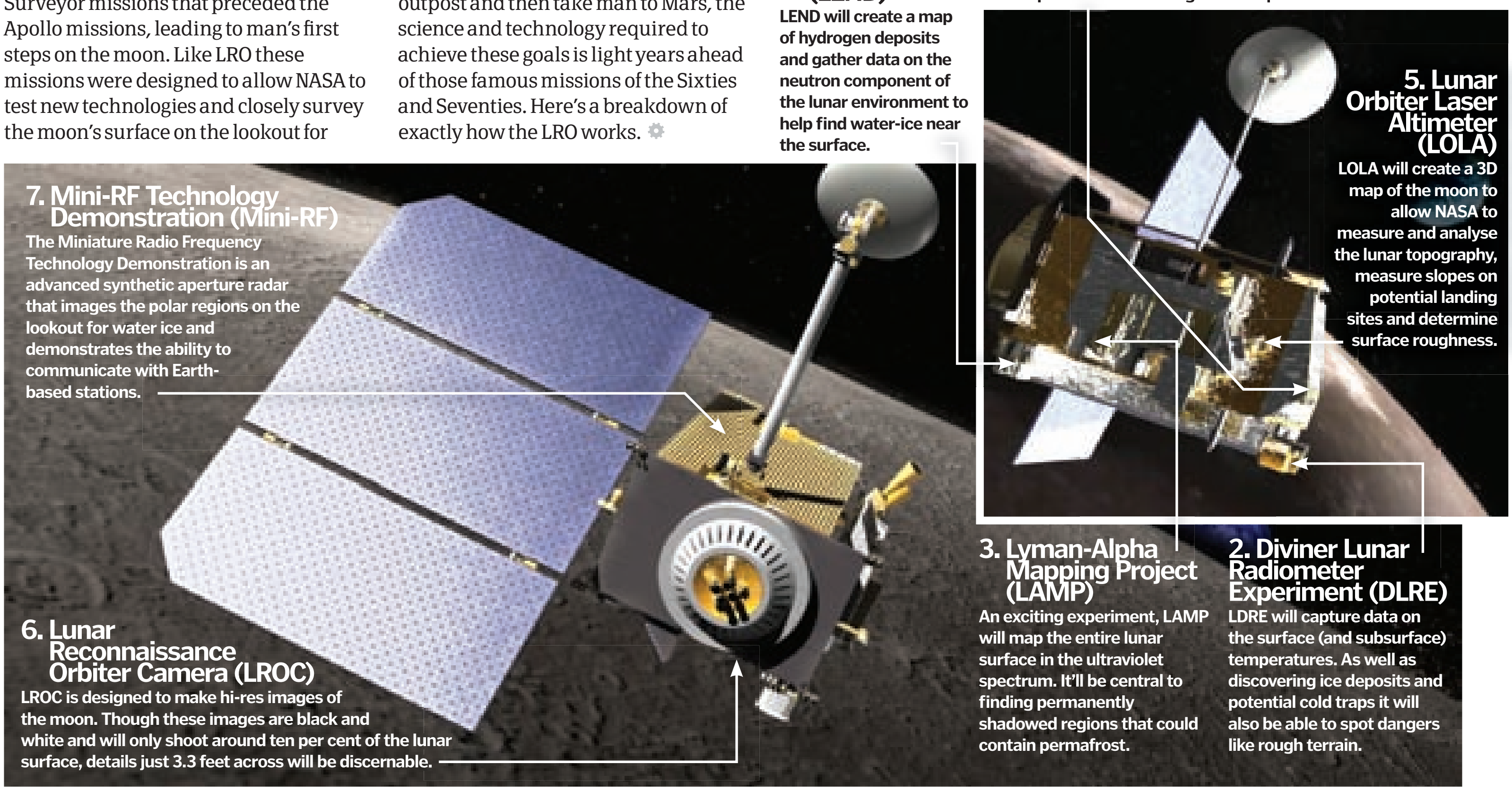


All images © NASA

The Lunar Reconnaissance Orbiter

The LRO is the first step in NASA's new programme to return to the moon and extend man's presence in the solar system

The Lunar Reconnaissance Orbiter (LRO) follows in the hallowed footsteps of the Ranger, Lunar Orbiter and Surveyor missions that preceded the Apollo missions, leading to man's first steps on the moon. Like LRO these missions were designed to allow NASA to test new technologies and closely survey the moon's surface on the lookout for suitable landing sites and areas of outstanding scientific interest. Since the LRO signals the start of a new stage in NASA's programme to create a lunar outpost and then take man to Mars, the science and technology required to achieve these goals is light years ahead of those famous missions of the Sixties and Seventies. Here's a breakdown of exactly how the LRO works.

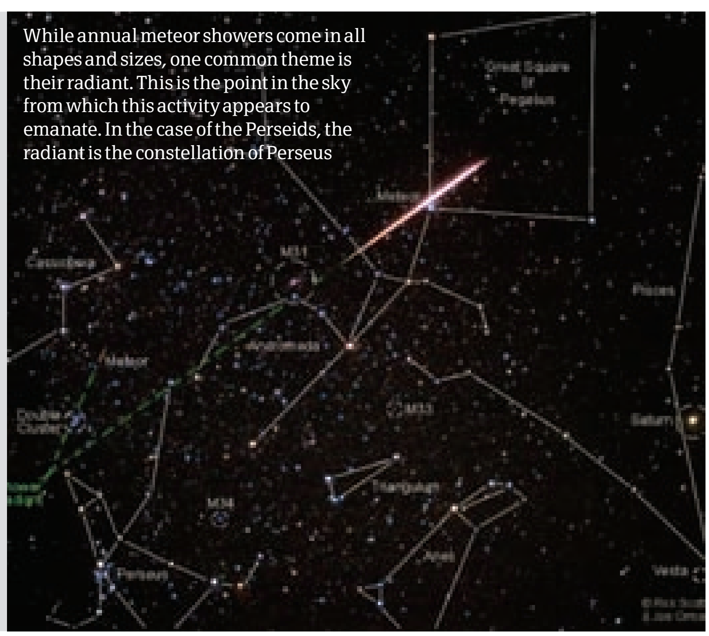


The Perseid meteor shower

Understanding hail from the heavens

The Perseids are one of amateur astronomy's most awe-inspiring events. Every summer, from the middle of July to the end of August, the Earth passes through the tail of comet Swift-Tuttle, causing minute particles of remnant dust to rain down on our atmosphere. Regardless of the fact that most of these particles are barely larger than a micron or two across, the speeds and forces involved cause these particles to burn up with such force the light show can be seen across much of the northern hemisphere leaving contrails miles long, or (if you're lucky) fireballs exploding like fireworks from space.

Perhaps it's nature's way of reminding us quite how delicate the balance of life is here on Earth, or an interstellar clue as to the origins of our solar system, but the activity of the Perseid shower is a sobering reminder that catastrophe is all a matter of timing.


While annual meteor showers come in all shapes and sizes, one common theme is their radiant. This is the point in the sky from which this activity appears to emanate. In the case of the Perseids, the radiant is the constellation of Perseus

"Robots have all but replaced man at the cutting edge of space exploration"

Space robots

Robots have moved from sci-fi to reality with alarming ease. But how is NASA's robotic technology helping us explore the universe?

Use of robotic technology in space goes back much further than Lunokhod 1, the first robot ever to land on a terrestrial body. Even the first unmanned spacecraft (Sputnik) had semi-robotic components on board, although their capabilities were rudimentary at best. However, since the cancellation of the Apollo programme, robots have all but replaced man at the cutting edge of space exploration.

There are several key reasons for this; with cost being top of the list, particularly in today's financial downturn. Robotic missions cost a fraction of their manned equivalents, involve less risk and produce far more useful, empirical information. Just in the last year, India's first unmanned lunar probe, Chandrayaan-1, was found to have detected the probability of ice-filled craters on the moon, something the 12 US astronauts who actually walked on its surface failed to deduce at a cost of tens of billion of dollars. Neil Armstrong's 'one small step for man' may have been symbolic, but the 'great leap for mankind' has since been accomplished by robots. Today, two Mars Exploration Rovers are already hard at work on the surface of a planet man is not expected to reach for at least another decade.

Robotic devices can be found operating in various forms; from satellites, orbiters, landers and rovers to orbiting stations such as Skylab, MIA and the current International Space Station. However, the most impressive of all are the rovers, first used during the Apollo 15 missions in 1971. Devices like rovers still rely on a combination of telemetry and programming to function. However, as the distance they are expected to travel grows, making it harder to receive instructions from Earth, the importance of artificial intelligence in making such devices more autonomous will only grow in future.

Mars Exploration Rovers

NASA's most ambitious strategy since Apollo continues apace with the Mars Exploration Rovers

The Statist

Sojourner

Dimensions: Length: 6
width: 48cm, height: 28
Mass: 10.6kg
Top speed: 0.07mph
Mission: Exploration an experimentation
Launch vehicle: Pathfi
Lander systems: Soft land and release
Current status: Abandoned on Mars

There have been three Mars Exploration Rovers (MER) so far. The first was Sojourner, carried by the groundbreaking Pathfinder, which landed in 1997 and continued to transmit data for 84 days. The second and third (Opportunity and Spirit) touched down three weeks apart in 2004 and are now six years into their missions. Spirit, after a productive start, is now permanently immobile although still functioning. Opportunity is moving steadily across the planet surface, using software to recognise the rocks it encounters, taking multiple images of those that conform to certain pre-programmed characteristics.

Head to Head ICONIC MOVIE ROBOTS

MOST DEADLY

1. Gort
When Gort used his death ray in 1951's *The Day The Earth Stood Still*, audiences were terrified. Gort received his comeuppance by losing star billing to Keanu Reeves in the remake.

MOST ICONIC

2. Robby
First seen in the movie *Forbidden Planet*, it was Robby's star turn on the show *Lost In Space* that made it TV's first robot icon.

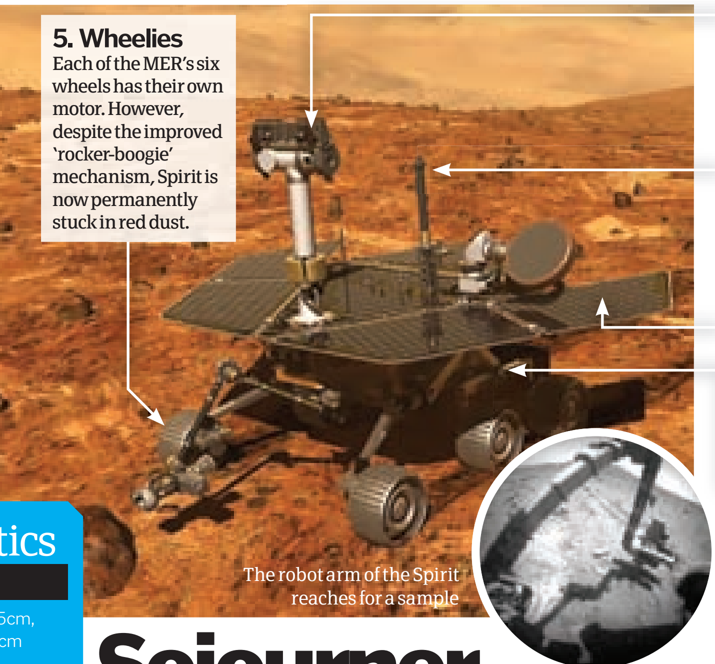
MOST ENDEARING

3. R2-D2
Perhaps Hollywood's most realistic robot in terms of ability, R2-D2 still managed to interface with anything and everything, from lifts to land-speeders.

DID YOU KNOW? The US was not first to land an object on Mars. The Russian Mars 2 crash-landed on the surface in 1971

Mars Exploration Rovers

Spirit and Opportunity are still transmitting from the surface of Mars despite some decidedly archaic components. Although reinforced against radiation, the 32-bit RAD 6000 CPU and 128RAM would sound meagre even in a laptop. However, other aspects are still state of the art, including the aerosol insulated compartment that keeps vital equipment working through the -100° Celsius Martian nights.



5. Wheelies
Each of the MER's six wheels has their own motor. However, despite the improved 'rocker-boogie' mechanism, Spirit is now permanently stuck in red dust.

The robot arm of the Spirit reaches for a sample

1. Click!
Both MERs boasts a panoramic camera (Pancam) capable of 1024x1024-pixel images that are compressed, stored and transmitted later.

2. Antenna
Spirit and Opportunity use a low-gain antenna and a steerable high-gain antenna to communicate with Earth, the former also used to relay data to the orbiter.

3. Power me up
These MERs boast superior solar technology to Sojourner, with 140 watt solar panels now recharging the lithium-ion battery system for night-time operation.

4. Safeguarding science
A gold-plated Warm Electronics Box protects vital research equipment, including miniature thermal and x-ray spectrometers and a microscopic imager.

The Statistics

Spirit/Opportunity

Dimensions: Length: 1.6m, width: 2.3m, height: 1.5m
Mass: 167kg
Top speed: 0.11mph
Mission: Exploration and experimentation
Launch vehicle: Delta II
Lander systems: Guided and parachute
Current status: Active on Mars

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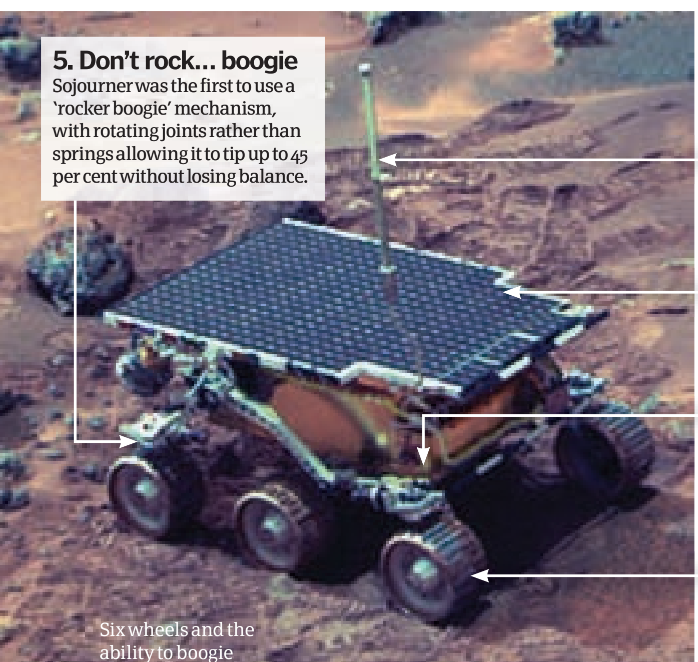
Sojourner

Sojourner was the first truly self-sufficient rover, largely restoring NASA's space exploration credentials when it touched down on Mars in July 1997. Although it only travelled 100 metres in its 84-day mission, this was 12 times longer than expected, producing a massive amount of data, including over 8.5 million atmospheric measurements and 550 images.



5. Don't rock... boogie
Sojourner was the first to use a 'rocker boogie' mechanism, with rotating joints rather than springs allowing it to tip up to 45 per cent without losing balance.

Six wheels and the ability to boogie

1. Telemetry
Sojourner relied on a single high gain antenna to receive instructions from the Pathfinder Lander for the manoeuvres it made.

2. Power up
Top-mounted solar cells provided the power. However, the non-rechargeable D-cell batteries led to the mission ending.

3. Payload
A heat-protected box surrounded the rover's key components, including the CPU and an Alpha Proton x-ray spectrometer to analyse the 16 tests performed.

4. Wheels in motion
Sojourner's revolutionary six-wheeled design took the rugged terrain in its stride.

NASA engineers work on the Spirit/Opportunity

A future landing method?

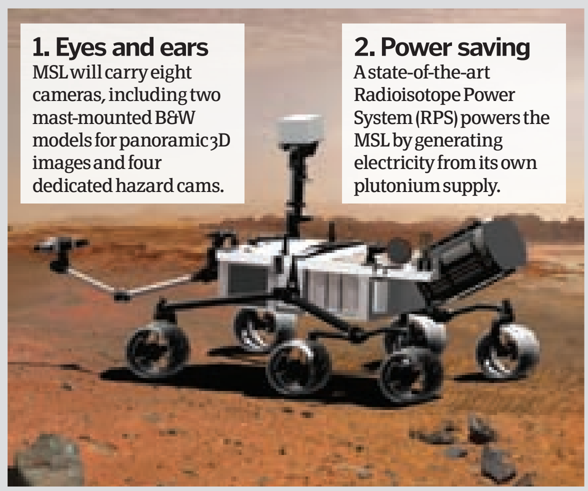
MSL: To Opportunity and beyond!

At a cost of $2.3 billion, the Mars Science Laboratory (MSL) is designed to go much further than the current Opportunity and Spirit MERs. Using four different landing systems it is expected to make a precision landing on Mars in the autumn of 2011. The six-wheeled craft will then spend a year determining whether Mars has ever supported life.

The Statistics

Mars Science Laboratory

Dimensions: Length: 2.7m, width: n/a, height: n/a
Mass: 820kg
Top speed: 0.05mph
Mission: Exploration and experimentation
Launch vehicle: Atlas V 541
Lander systems: Guided, powered, parachute and sky crane
Current status: Testing



1. Eyes and ears
MSL will carry eight cameras, including two mast-mounted B&W models for panoramic 3D images and four dedicated hazard cams.

2. Power saving
A state-of-the-art Radioisotope Power System (RPS) powers the MSL by generating electricity from its own plutonium supply.

3. Ever-increasing circles
Based on the same principle as previous MERs, MSL is far more agile, being able to swerve and turn through 360° on the spot.

4. Intel
MSL's Warm Electronics Box protects vital equipment like the CPU, communications interface and SAM (Sample Analysis at Mars) which literally sniffs the air for gasses.

5. Armed not dangerous
MSL's robotic three-jointed arm can wield five tools, including a spectrometer to measure elements in dust or rocks and a hand lens imager for magnifying samples.

All Images © NASA

"The lunar rover was first deployed in 1971 and only four were ever built"

Lunar rovers

Before the MER there was the lunar rover, for a time the most talked-about hand-held technology (not) on Earth

Although lunar rovers seem little more than sophisticated golf-carts compared to today's Mars Rovers, their impact was immense; allowing astronauts and equipment to travel much further than on foot and carry back rock samples that the Apollo 15-17 astronauts later returned to Earth.

The lunar rover was first deployed on Apollo 15 in 1971 and only four were ever built for a cost of $38 million (about $200 million in today's money). Powered by two 36-volt non-rechargeable batteries, the rovers had a top speed of eight miles per hour, although astronaut Gene Cernan still holds the lunar land speed record of an impressive 11.2mph. All three rovers remained on the lunar surface after their mission ended.

The Statistics
Lunokhod 2

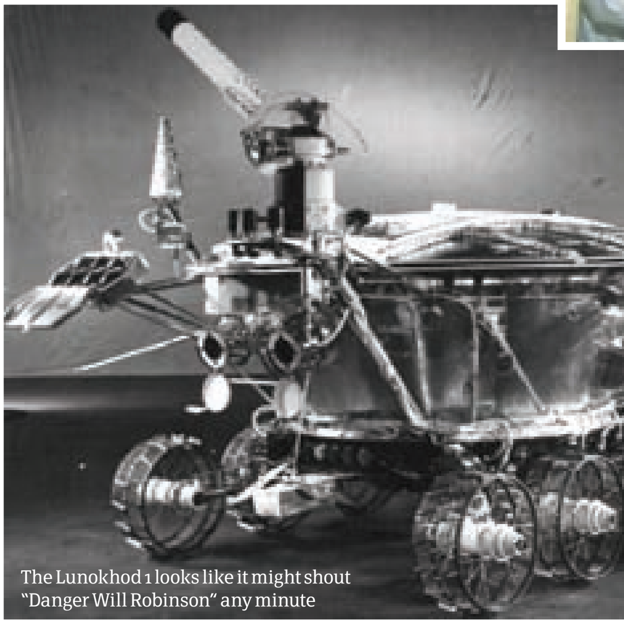
Dimensions: Length: 170cm, width: 160cm, height: 135cm
Mass: 840kg
Top speed: 1.2mph
Mission: Exploration and experimentation
Launch vehicle: Luna 17
Lander systems: n/a
Current status: Abandoned on moon

Lunokhod One and Two

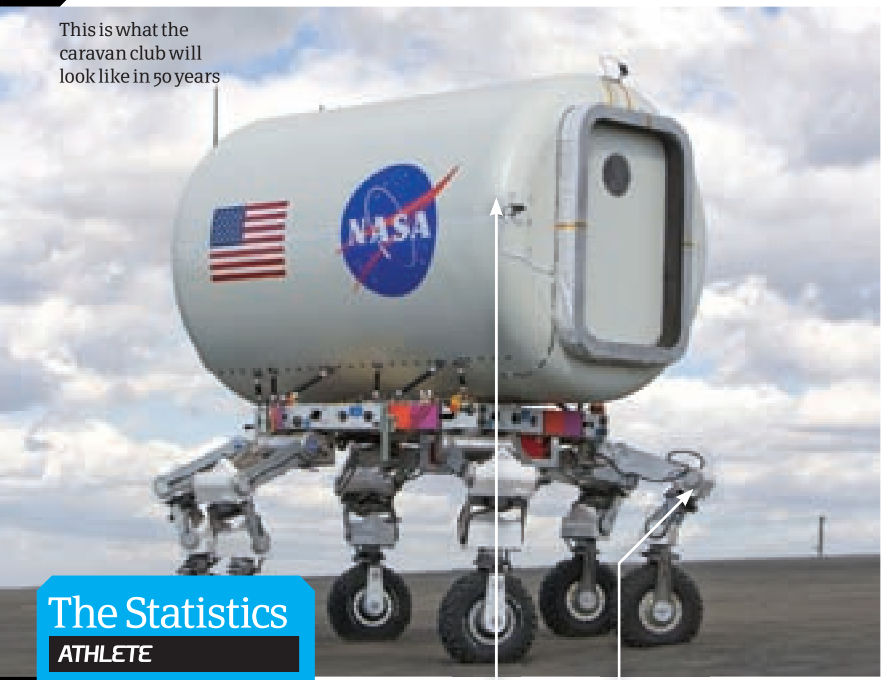
Apollo may have put Armstrong on the moon, but for robotics, Lunokhod was the benchmark

Lunokhod 1 was the first unmanned vehicle ever to land on a celestial body in 1970. The Russian designed and operated rover packed a lot into its 2.3 metre length, including four TV cameras, extendable probes for testing soil samples, an x-ray spectrometer, cosmic ray detector and even a simple laser device. It was powered by solar rechargeable batteries and equipped with a cone-shaped antenna to receive telemetry. It exceeded its mission time by lasting nearly 322 days, performing soil tests, travelling over 10.5 kilometres and returning over 20,000 images.

Lunokhod 2 followed in 1973, an eight-wheeled solar powered vehicle equipped with three TV cameras, a soil mechanics tester, solar x-ray experiment, an astrophotometer for measuring visible and ultraviolet light levels, a magnetometer, radiometer, and a laser photodetector. Its mission lasted only four months before Lunokhod 2 overheated, however in this time it covered 37km and sent back over 80,000 pictures.



The Lunokhod 1 looks like it might shout "Danger Will Robinson" any minute



This is what the caravan club will look like in 50 years

Payload
Large payload capacity of 450kg per vehicle, with much more for multiple ATHLETE vehicles docked together.

Legs
R6-DOF legs for generalised robotic manipulation base can climb slopes of 35° on rock and 25° on soft sand.

Walk
Capable of rolling over Apollo-like undulating terrain and 'walking' over extremely rough or steep terrain.

The Statistics
ATHLETE

Dimensions: Diameter: 4m
Mass: Unknown
Top speed: 6.5mph
Mission: Transport, exploration and experimentation
Launch vehicle: TBC
Lander systems: n/a
Current status: In development

Introducing the ATHLETE

The competition for future robots in space is fierce, with commercial companies developing contenders like ATHLETE

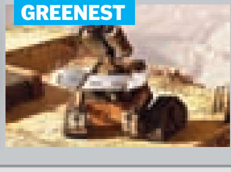
Currently under development by the Jet Propulsion Laboratory (JPL), the All-Terrain Hex-Legged Extra-Terrestrial Explorer (ATHLETE) is designed to be the next generation of MERs; bigger, faster and more versatile than the current models.

It's also the most striking to look at, about the same size as a small car with a spider-like design

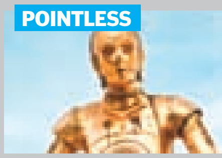
incorporating a central base and six extendable legs, mounted on wheels, allowing it to travel over a wide variety of terrains. Future plans include the addition of a voice or gesture interface for astronaut control and a grappling hook to haul it up vertical slopes. ATHLETE's modular design allows it to dock with other equipment, including refuelling stations and excavation implements. It also boasts a 450kg payload capability, making it a powerful workhorse.

The big cloud over ATHLETE is the current recession which is now placing the whole 'Human Lunar Return' strategy, for which it was designed, in jeopardy.

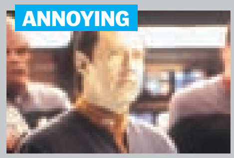
Head to Head
RUBBISH ROBOTS



GREENEST
1. Wall-E
Trust Pixar to make a robot that was both mechanical yet human-like. Wall-E's rubbish collecting function was also perfect for an age before climate change scandals.



POINTLESS
2. C-3PO
Why anyone would think droid 'campness' more important than AI is anyone's guess. However, C-3PO's uselessness saw him survive all six *Star Wars* movies.



ANNOYING
3. Data
The world's most advanced android; gifted with a positronic network and superhuman strength… and what does Data aspire to be? More human… come on!

DID YOU KNOW? In 1970, Lunokhod 1 became the first unmanned vehicle ever to land on a celestial body

SPAR Aerospace Ltd, a Canadian company, designed, developed, tested and built the Canadarm

The Canadarm Remote Manipulator System

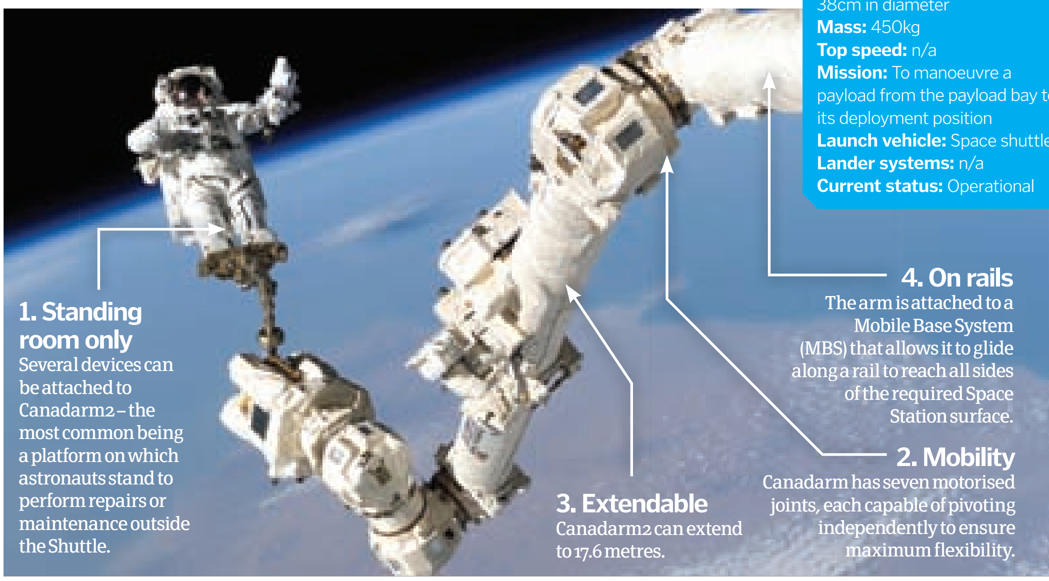
It will never win awards for its looks but the Canadarm has worked harder than any space robot before

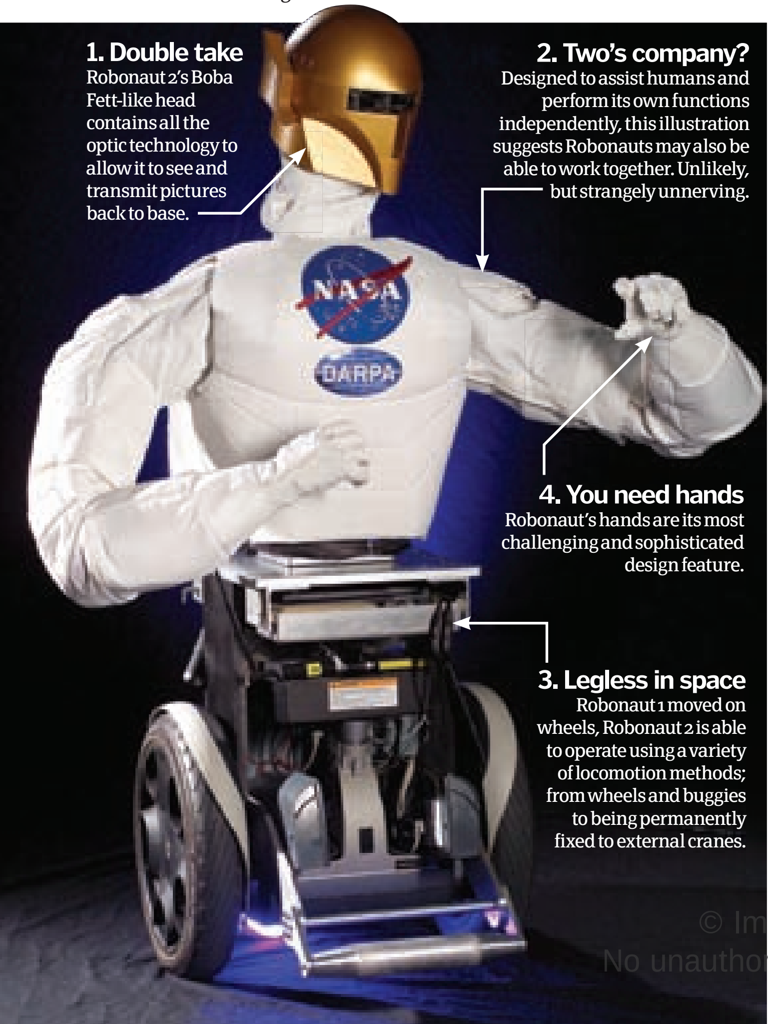
Remote manipulator systems (RMS) have been around since the Fifties, but it wasn't until 1975 that one achieved its own nickname. The Canadarm became both a symbol of national engineering pride for the country that designed and built it (Canada) and the most recognisable and multi-purpose tool on the Space Shuttle.

The Shuttle Remote Manipulator System (to give it its real name) is a 50-foot arm capable of lifting loads, manipulating them at small but precise speeds. It has been used extensively in Shuttle missions for a variety of purposes including ferrying supplies, dislodging ice from the fuselage and performing crucial repairs to the Hubble Space Telescope. Canadarm has never failed. Its successor, Canadarm2, is a key part of the ISS, used to move massive loads of up to 116,000kg. It is also useful in supporting astronauts on EVAs and servicing instruments.

The Statistics
Canadarm

Dimensions: 15.2m long and 38cm in diameter
Mass: 450kg
Top speed: n/a
Mission: To manoeuvre a payload from the payload bay to its deployment position
Launch vehicle: Space shuttle
Lander systems: n/a
Current status: Operational





Humanoid robots

Will we ever see a robot with real human abilities?

When the original Robonaut was unveiled at the Johnson Space Center (JSC) nearly a decade ago, one glance at its Davros-like design revealed the glaring weakness. How could something on a fixed-wheel chassis really help in the demanding EVAs for which it was required? The answer, currently under development by JSC and General Motors, is called Robonaut 2.

Robonaut 2 adds advanced sensor and vision technologies to do far more than basic lifting and moving, as currently performed by devices like the Canadarm. Whether helping with future repairs at the International Space Station, maintaining base stations for planetary landings, or doing hazardous jobs in the motor and aviation industries, Robonaut 2 is designed to literally work anywhere using bolt-on arm and leg appendages appropriate to the task at hand.

While not as dextrous as a real human hand, Robonaut 2's hands have 14 degrees of freedom and contain touch sensors at the fingertips

This month in **Technology**

As you can see, we got down and dirty with the biggest device in the news this month in our iPad teardown. As well as picking up a few domestic handheld goods, we also explore under ground in our in-depth feature on coal mining. On top of all that we ask how rebreathers help us to breathe under water, and if nanotechnology is a mystery to you, then look no further than page 54. You'll also be able to take a look inside a smoke alarm on the very same page…

54 Smoke alarms

56 Coal mines

61 Rebreathers

TECHNOLOGY

50 Inside iPad
54 Nanotechnology
54 Smoke alarms
56 Coal mines
58 Ballpoint pens
58 Harmony remote
59 Slot machines
61 Rebreathers

Inside the iPad

Will the iPad change the world?

iPad. A new breed of computer brought to us by Apple, the masters of must-have multimedia devices. Just as iPhone before it spawned a brand-new class of mobile phone, so too does iPad have its heart set on inciting the gadget-buying public to embrace this potentially genius fusion of laptop and smartphone.

The first-generation model launched on 3 April in the US has Wi-Fi but no 3G connectivity and yet it's cleared a colossal 300,000 units on day one. Apparently Apple's tablet has charmed a significant number of curious consumers all eager to adopt this convenient photo frame/eBook reader/laptop/app resource/tea tray. So why – if you haven't already done so – should you too look into splashing out (prices range from $499 to $829) on one of these stylish Apple devices?

Clearly the iPad's design oozes the smart, sophisticated architecture for which Apple has become synonymous, the signature Home button the only sign of life beneath a dead display. And yet there's much more going on under the skin of this super-slick tablet. Discover for yourself exactly what lurks beneath this unfeasibly polished plate as we delve inside the iPad.

The Statistics

Apple iPad

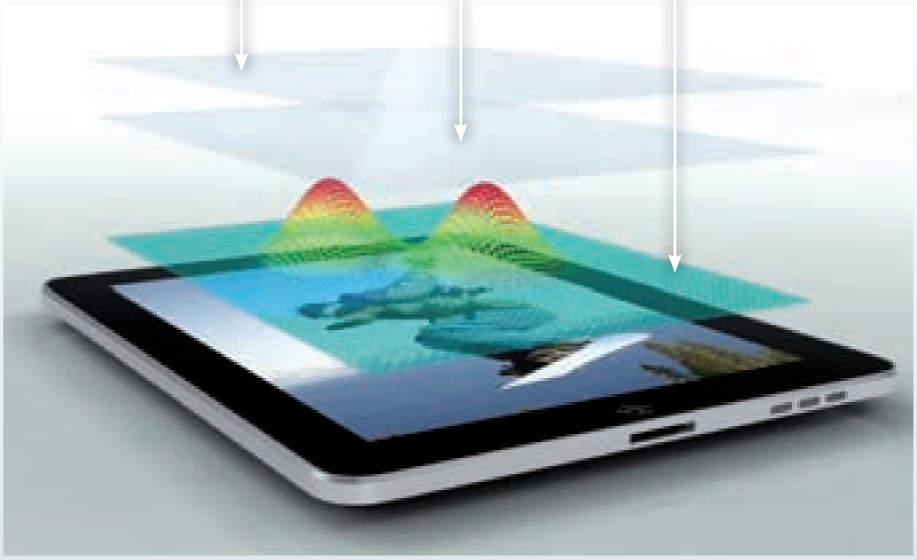
Height: 9.56 inches (242.8mm)
Width: 7.47 inches (189.7mm)
Depth: 0.5 inch (13.4mm)
Weight: 1.5 pounds (0.68kg) Wi-Fi model; 1.6 pounds (0.73kg) Wi-Fi + 3G model
Display: 9.7-inch (diagonal) LED-backlit Multi-Touch with IPS technology and fingerprint-resistant coating
Processor: 1GHz Apple A4 custom-designed,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

The glass
Apple's touch devices use optical grade glass, which is tough and scratch resistant. For iPad Apple has also added an oleophobic coating which prevents fingerprint marks appearing.

Full screen
With iPad it's all about the screen, and at 9.7 inches Apple's display practically takes up the whole front side.

Window on the world
At 1.18mm the glass panel is thicker than that of the iPhone (1.02mm).

In-plane switching
A technology more at home in LCD TVs, IPS improves the viewing angle by aligning the crystal molecules so their motion is parallel to the panel.



Screen

The 9.7-inch display is particularly interesting because it falls just short of full HD, but at the same time boasts some incredible technology which means that the iPad benefits from incredible viewing angles. The resolution is 1024 x 768 pixels at 132 pixels-per-inch (ppi) and it uses a system called IPS (in-plane switching) to get that great 178-degree viewing angle. The display also uses the same fingerprint-resistant oleophobic coating that resides on the iPhone.

5 TOP FACTS APPLE INNOVATIONS

iPod

1 This dynamic MP3 player has changed the face of music content delivery forever, and rekindled our love affair with Apple. iPod's integration with iTunes was pure genius.

Apple II

2 1977 saw the introduction of one of the world's earliest and most popular PCs. Apple II's pioneering software, unique hardware and affordable price tag was a milestone.

OS X

3 Launched in 2001, Mac OS X was Apple's tenth and finest incarnation of the company's operating system, bringing with it both an appealing appearance and ease of use.

iMac

4 Apple's products are renowned for their cool and clean designs and the iMac changed the appearance of people's workspaces with this stylish all-in-one Macintosh.

iPhone

5 Released in 2007, iPhone is one of Apple's most functional product innovations. An invaluable piece of kit, it reshaped smartphone consumer expectations.

DID YOU KNOW? iPad uses just 2.5 watts – just 1/5 of the power of a compact fluorescent bulb

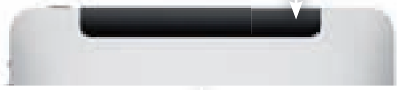
1. Bezel
A lot of discussion surrounds the inclusion of such a wide bezel. Design-minded people say it's ugly, but if its presence prevents unwanted or accidental touches on the screen, surely it's a price worth paying.

5. Software
iPad uses the same software that is used in the iPhone and iPod touch. While this does restrict the use of the iPad in that it's not a Mac, the App Store does mean that there will be plenty of apps you can run on it.

7. Screen lock
This prevents the screen from rotating between landscape and portrait.

6. Sleep/wake
The iPad also comes with the same sleep/wake button as the iPhone and iPod touch.

9. 3G plastic
The 3G version of the iPad comes with a plastic area, which allows for much better reception of a 3G signal.



12. Apple apps
Apple has repurposed a number of apps to suit the larger screen on the iPad. iTunes, the App Store, Calendar, Photos, YouTube and Contacts all get new interfaces and greater functionality. And not only that, but the iWork suite has been completely repurposed, making the iPad an ideal choice for business users wishing to travel light.

3. Display
The iPad display is a 9.7-inch (diagonal) LED-backlit glossy widescreen Multi-Touch display with IPS technology. The IPS technology allows for an incredibly wide viewing angle and makes the iPad great for sharing movies and pictures.

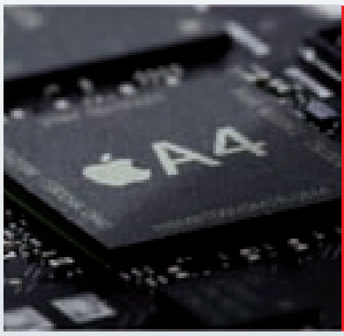
2. Apps
The iPad works in the same way as the iPhone and iPod touch, allowing you to download and organise your apps on a number of Home screens.

8. Volume up/down
There is also a hardware button to turn the volume up and down.

4. Dock
Unlike the iPhone and iPod touch, it's possible to fit six apps on the iPad's dock.

10. Unibody
The outer casing of the iPad utilises Apple's unibody construction method. This is where Apple takes a single piece of pressed aluminium and uses it as a single back cover.

11. Dock connector
The iPad uses the same connection that the iPhone and most iPods use. There are likely to be some interesting peripherals stemming from it. Apple itself has created a dock connected to a physical keyboard. The 802.11n Wi-Fi/Bluetooth card is integrated into the dock connector cable.



The processor

For the first time in its own device, Apple has made its own processor. In April 2008 Apple acquired chip-making company PA Semi – a sign that the company was looking to bring that side of computing in-house. This chip is based on an ARM design, which is the same chip inside the current iPhone. Apple describes the chip as a "1GHz Apple A4 custom-designed, high-performance, low-power system-on-a-chip".

The A4 is Package-on-Package (POP), with at least three layers of circuitry on top of each other. It's packaged just like the iPhone processors: microprocessor in one package and two memory modules in the other package – all sandwiched together in a thin POP.

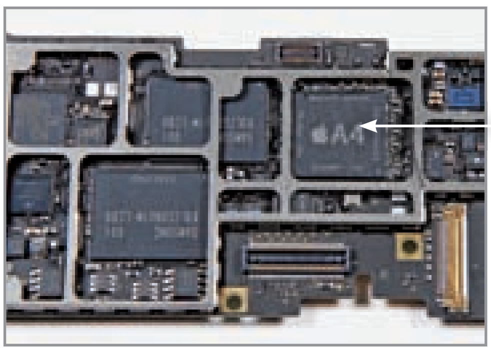
The iPad RAM is *inside* the A4 processor package – something that was confirmed by x-raying the processor. The x-ray showed two layers of RAM. As well as the ARM processor, the A4 package contains two stacked Samsung dies.

"There's an empty space where the 3G version's cellular communications board will live"

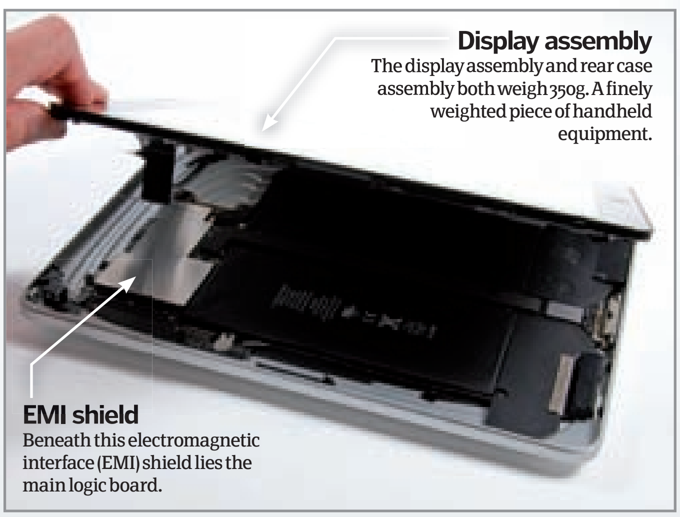
The iPad teardown

Cracking open the iPad to discover what's inside

It's a sad sight to see such a beautiful piece of kit in pieces on the table before you, but it also gives a fascinating insight into the technology inside. Although the 3G-enabled iPad won't be available in the US till late-April, there are telltale signs of future 3G integration, including an empty space where the cellular communications board will live.



Logic board
Decoding the A4's part number revealed 2GB of memory inside, which translates into 128MB of memory per die, for 256MB total (not 512MB, as previously reported).



Display assembly
The display assembly and rear case assembly both weigh 350g. A finely weighted piece of handheld equipment.

EMI shield
Beneath this electromagnetic interface (EMI) shield lies the main logic board.

Ambient light sensor
Where you might have been expecting to see a camera, instead sits an ambient light sensor to automatically adjust the display brightness.

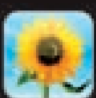
Audio-out jack

What comes as standard?

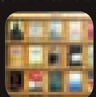
Out-of-the-box apps

The larger screen size of the iPad means Apple could redesign the standard apps that come on the iPhone to better suit the new tablet device. Here is a breakdown of what has changed so far...

Contacts
The new address book interface looks like an actual address book.



Photos
This has been redesigned so that albums can be explored using the pinch gesture.

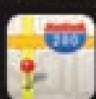


iBooks
iBooks is a brand new eBook reading app for the iPad that includes the iBookstore.

Calendar
The calendar has been reinvigorated – a great improvement.

Mail
Very smart and will reconfigure itself according to the orientation of the iPad.

YouTube
A revised interface has also been created for YouTube, but there's no video capability.



Maps
The same Google system, but with a much faster processor.

Safari
Apple touts the web-surfing skill of the iPad as a major selling point.

iPod
Browse artists and, with iTunes LP, look at excellent extra content.

Apps you wouldn't want to run:

Facebook ■ eBay ■ Amazon
These apps were created to make the functionality of the websites fit into a more appealing system on a smaller iPhone screen. With the iPad, this isn't necessary.

Battery life – lithium-polymer

The iPad features a built-in 3.75V, 24.8 watt-hour rechargeable battery that allows up to ten hours of use without a charge. With a much larger space available, the battery is much bigger than that of the iPhone or iPod touch, and therefore lasts longer even when in use.

Unibody

Apple has used its unibody production system to create the iPad, which means that the entire back panel is a single piece of aluminium. This makes the overall weight and depth of the iPad much thinner than rival makers can achieve with plastics, while maintaining a solid exterior.

EBOOK READER

1. Amazon Kindle
Considering the extensive support pledged to Apple's iBookstore, the Kindle should be shaking in its monochrome boots.

PURE GAMING

2. DS XL
With an excellent catalogue of brain-tickling titles, an intuitive control system and a new XL screen, Nintendo's handheld joy stands firm.

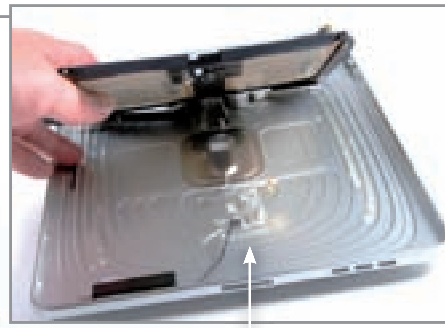
LOOKALIKE

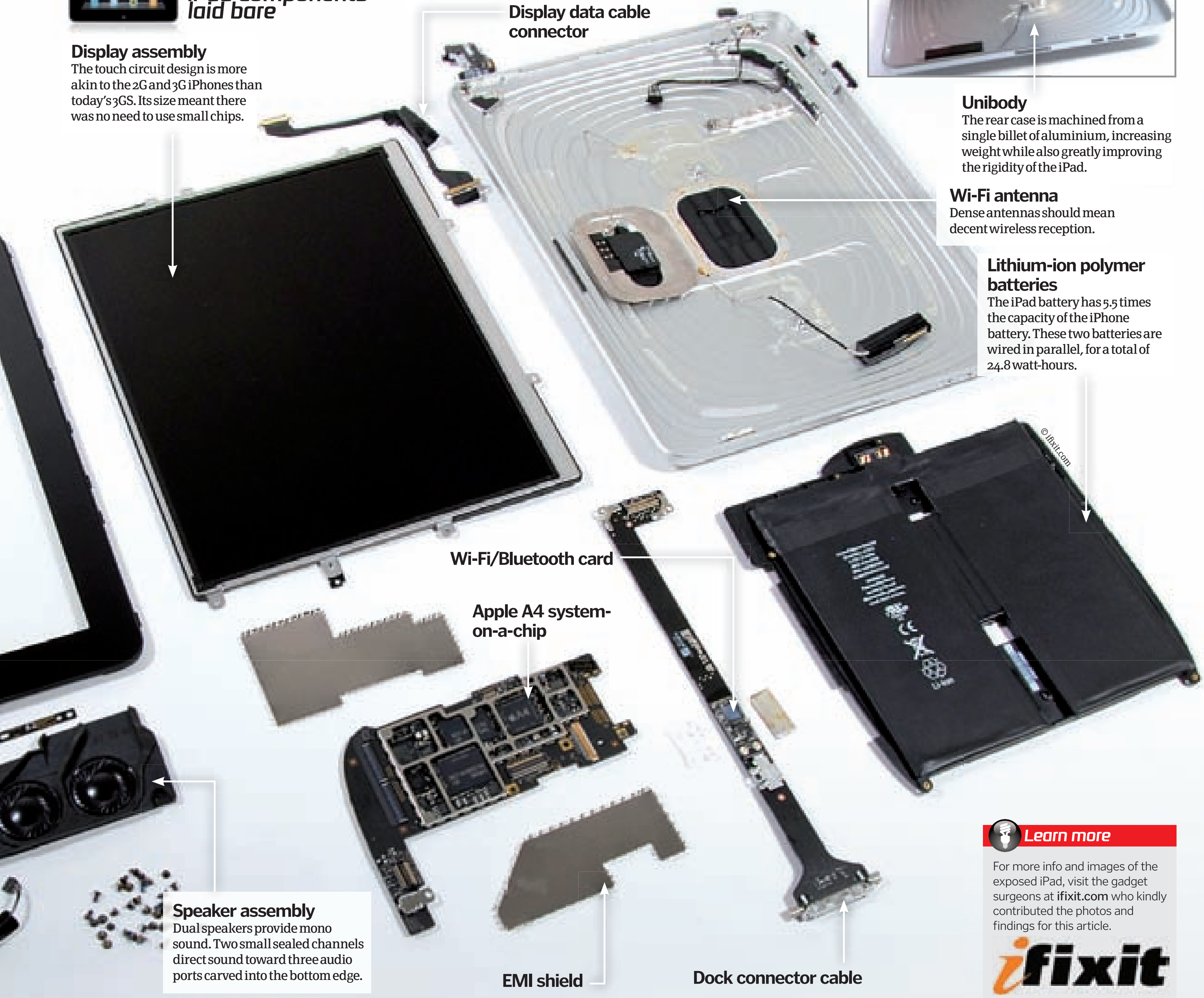
3. JooJoo
Although the Linux-operated JooJoo has a bigger screen size than iPad (12.1" to iPad's 9.7"), it doesn't have anywhere near the same app availability.

DID YOU KNOW? *There's space in the upper-right corner for the cellular communications board of the 3G iPad*

What's inside the iPad?

iPad components laid bare





Display assembly
The touch circuit design is more akin to the 2G and 3G iPhones than today's 3GS. Its size meant there was no need to use small chips.

Display data cable connector

Unibody
The rear case is machined from a single billet of aluminium, increasing weight while also greatly improving the rigidity of the iPad.

Wi-Fi antenna
Dense antennas should mean decent wireless reception.

Lithium-ion polymer batteries
The iPad battery has 5.5 times the capacity of the iPhone battery. These two batteries are wired in parallel, for a total of 24.8 watt-hours.

Wi-Fi/Bluetooth card

Apple A4 system-on-a-chip

Speaker assembly
Dual speakers provide mono sound. Two small sealed channels direct sound toward three audio ports carved into the bottom edge.

EMI shield

Dock connector cable

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

Speaker/microphone

The inclusion of a speaker and a microphone on the iPad, coupled with the recent SDK unlocking of the VOIP protocols, means that the iPad could easily be used as an internet phone. The omission of a camera on the device makes video chat less likely. More recent rumours that the iPad is ready to house a camera add even more weight to this argument.

"The smoke particles will disrupt this flow and the drop in electrical current activates the alarm"

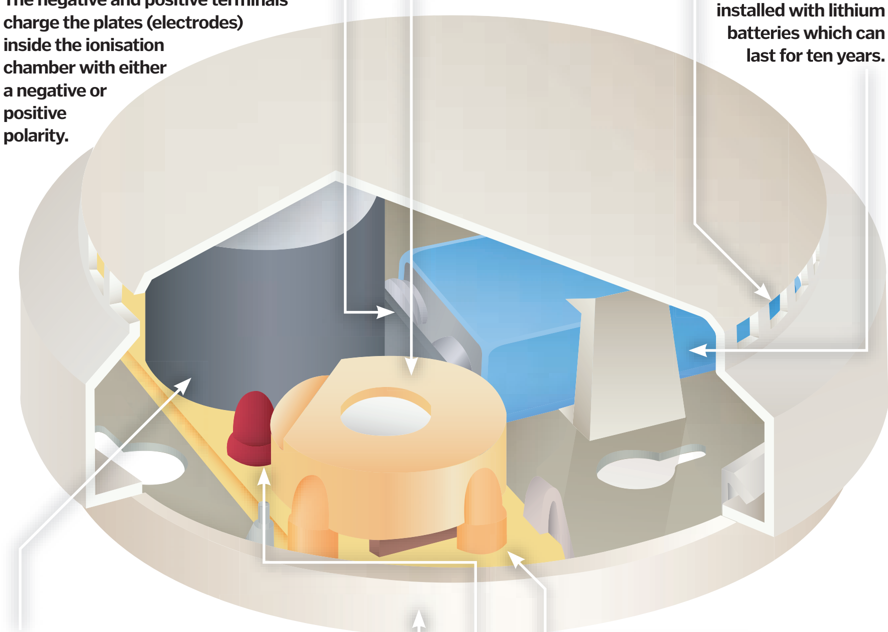
Smoke alarms

How a radioactive domestic device saves lives

Most homes have them installed, but how do smoke alarms detect smoke? The most common type of detector uses an ionisation chamber, which contains two plates (electrodes) separated by a small gap. Each electrode is connected to either the positive or negative battery terminal.

Between the electrodes is a tiny quantity of the radioactive element americium-241. This material emits particles called alpha particles which constantly smash into the chamber's air particles, splitting them into two – negatively charged electrons and positively charged ions. Polarity is always attracted to its opposite so, as the negative electrons and positive ions are attracted to the opposite electrodes, a small but steady electric current flows through the air, bridging the gap. The air effectively becomes a conductor.

If smoke enters the gap, the smoke particles will disrupt this flow and the drop in electrical current activates the alarm.



1. Battery terminals The negative and positive terminals charge the plates (electrodes) inside the ionisation chamber with either a negative or positive polarity.

2. Ionisation chamber Americium-241 ionises the air particles in the chamber. Air vents allow smoke particles to enter and neutralise the ions.

3. Mounting base Brackets located on the mounting base allow easy fixing to ceilings and walls with common DIY tools.

4. Test button The circuit board often features a test button, allowing the user to check the smoke alarm is functioning correctly.

5. Printed circuit board The circuit triggers the buzzer when the current drops below a certain level. It also activates a low power warning.

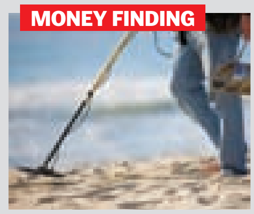
6. Air vents Many gaps allow the easy flow of clean air and smoke particles into the unit.

7. 9-volt disposable battery The battery is in constant use. Some smoke alarms are installed with lithium batteries which can last for ten years.

8. The buzzer The buzzer emits a high intensity sound when smoke is detected. An intermittent sound often indicates low battery power.

Head to Head
DETECTION DEVICES

MONEY FINDING



1. Metal detectors
Facts: Modern metal detectors can detect metal depth, size and even type. Specialist models can detect gold up to 15km away!

FISH FINDING

2. Fish detector
Facts: Using sonar waves, fish finders can detect the location of fish deep under water, increasing the chances of a successful catch.

LIFE SAVING

3. Personal lightning detector
Facts: A portable lightning detector can warn users of impending lightning strikes and calculate a storm's direction – very useful for golfers!

What is nanotechnology?

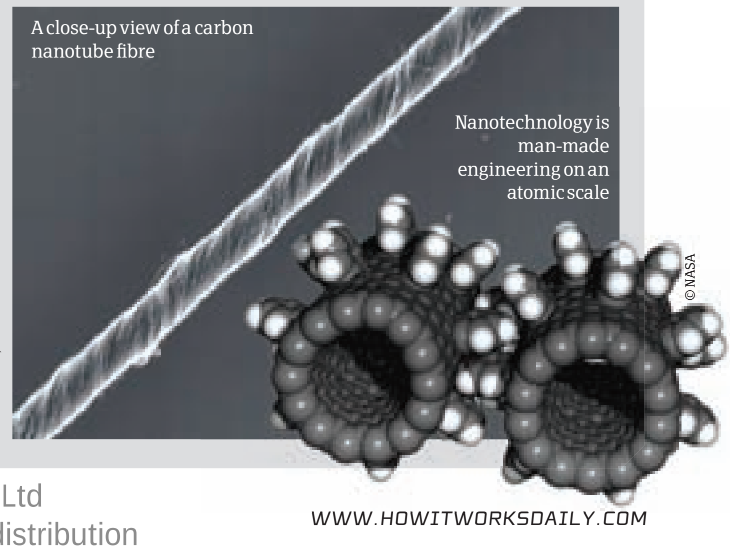
Nanotechnology sounds like a futuristic invention, but it's real and being used right now

Currently, nanotechnology can be loosely defined as the man-made engineering of functional systems on an atomic and molecular scale, with structures never exceeding the size of 100 nanometres (one billionth of a metre) in any dimension.

Presently there are two main approaches used in the formation of nanotechnology. The first is a 'bottom-up' approach where materials and devices are constructed from molecular components, and are assembled chemically through the principles of molecular recognition. The second is a top-down approach where nano-objects are constructed from larger entities without control on an atomic/molecular level.

Many things are currently made with nanomaterials, including flash memory (51 nanometre size) and super lightweight/strong carbon-fibre bicycles.

The future for nanomaterials is grander in scale, with 'active nanostructures', as well as 'molecular nanosystems' (molecular devices by design) predicted to emerge in the next 20-50 years.



A close-up view of a carbon nanotube fibre

Nanotechnology is man-made engineering on an atomic scale

© NASA

"Coal mining is the same dirty, dangerous job it's always been"

Coal mining

Coal miners literally move mountains to feed our insatiable appetite for cheap energy

There's something brutally simple about coal mining. Take away the monstrous new machinery and eco-friendly marketing jargon and it's the same dirty, dangerous job it's always been: find the black stuff and dig it up.

The two major schools of coal mining are surface mining and underground mining. To qualify for surface mining, the coal seam must lie within 60 metres of the surface. The miners' job is to remove all of the 'overburden' – the cubic tons of rock, soil and trees above the coal seam – and expose the coal layer for extraction. The main tools of the trade are dynamite and dragline excavators, 2,000-ton behemoths that can move 450 tons of material with one swoop of their massive buckets.

Perhaps the most dramatic and controversial surface mining technique is Mountaintop Removal (MTR), in which miners use explosives and heavy machinery to literally knock the top off a mountain – up to 200 metres below the peak – to get at the rich coal beds beneath.

Underground mining is decidedly more difficult and dangerous. In smaller mines, workers still use conventional methods, blasting and digging out large 'rooms' supported by thick 'pillars' of untouched coal. But that won't cut it for modern mining operations that regularly remove over 100Mt (1 Mt = 1 million tons) of raw coal each year.

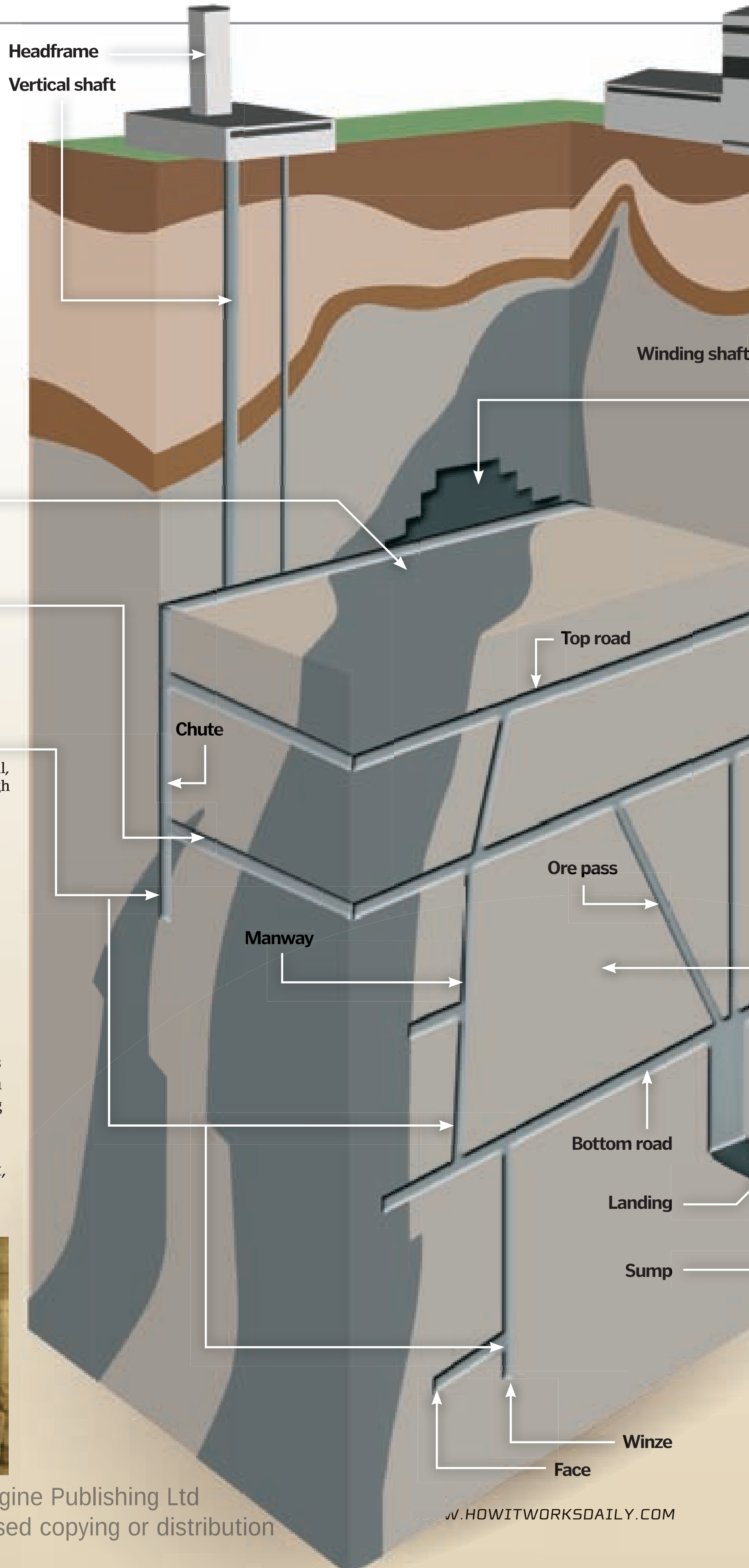
The go-to machine of the high-volume coal mine is a continuous miner. This long, low-slung machine rips through coal faces with a wide rotating drum armed with hundreds of drill bits. Each bit is sprayed with a fine mist of water, cooling the cutting surface and neutralising coal dust emissions. Using built-in conveyors, the machine rolls the coal off its back, where it's transported to the surface by haulers or conveyor belts.

Another day at the office for Short Round...

2. Coal seam
Mining companies go to great expense to reach these long horizontal fields of coal that range in thickness from a mere 50 centimetres to over four metres in height.

3. Cross cuts
Horizontal passageways are tunnelled through the ore bed to provide critical ventilation and to allow motorised access to coal seams via flat rail cars, commonly known as 'mantrips'.

7. Winzes, manways, chutes and drifts
A well-worked mine is a labyrinth of vertical, horizontal and sloped shafts carved through the coal by continuous mining machinery.



5 TOP FACTS COAL MINING

Worldwide production
1 Back in 2008, the world's coal mines produced 5,845Mt (1 Mt = 1 million tons) of black coal and 951Mt of brown coal. Makes you wonder how long it's going to last for, doesn't it?

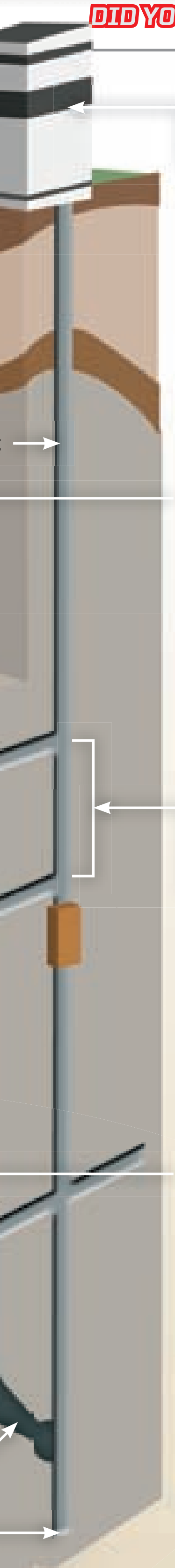
The coal king
2 China is by far the largest coal producer in the world with a staggering 18,557 mines. To compare, the United States has 1,458 mines and the UK has just 46.

Old friend steel
3 The steel industry is one of the heaviest consumers of coal. Worldwide steel plants burned 1,327Mt of coal – in its purified form called coke – in 2008.

Let there be light
4 Over 40 per cent of the world's electricity is provided by coal. China burns coal for 81 per cent of its electricity, while the US uses coal for 49 per cent of its electricity.

Super scrapers
5 A continuous mining machine can extract eight tons of coal per minute. Some quick maths will tell you that's 480 tons an hour, 11,520 tons a day and 4.2 million tons a year.

DID YOU KNOW? Coal provides over 23 per cent of the world's energy needs



1. Winding tower
Also called a headframe, the winding tower uses powerful drum hoists and thick steel cables to pull men, machines and coal from the deepest reaches of the main shaft.

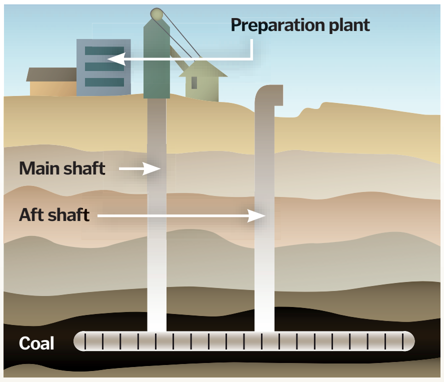
4. Room and pillar
In conventional coal extraction, miners use explosives to carve out large caverns in the coal seam, leaving a thick pillar of undisturbed coal for roof support.

6. Levels and decks
Extraction starts with the coal seam closest to the surface, then miners descend through a thick section of rock – or 'deck' – to reach the next workable level.

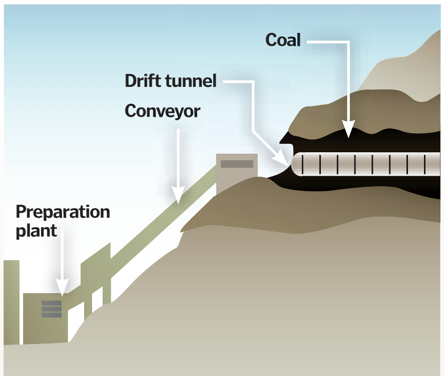
5. Panel
In longwall mining, miners carve four tunnels around a rectangular chunk of rock – called the 'panel' – hundreds of metres wide and thousands of metres long. The panel is then harvested from floor to ceiling with automated machinery called shearers.

Inside a coal mine
Take a trip into the claustrophobic depths of the mine

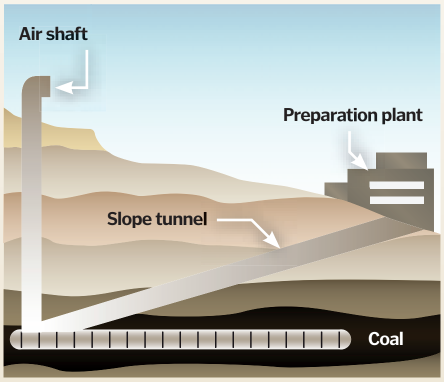
Types of coal mines
A closer look at the numerous different methods and mines that are often used to extract coal



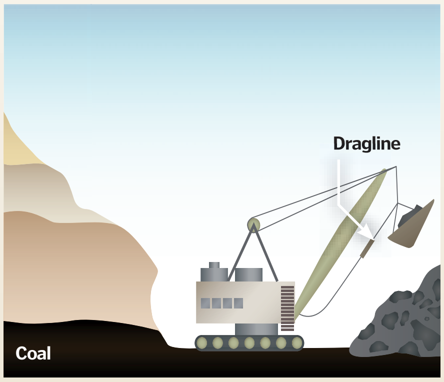
Shaft mine
Miners and equipment are transported down vertical shafts hundreds or thousands of metres deep to access fertile coal seams.



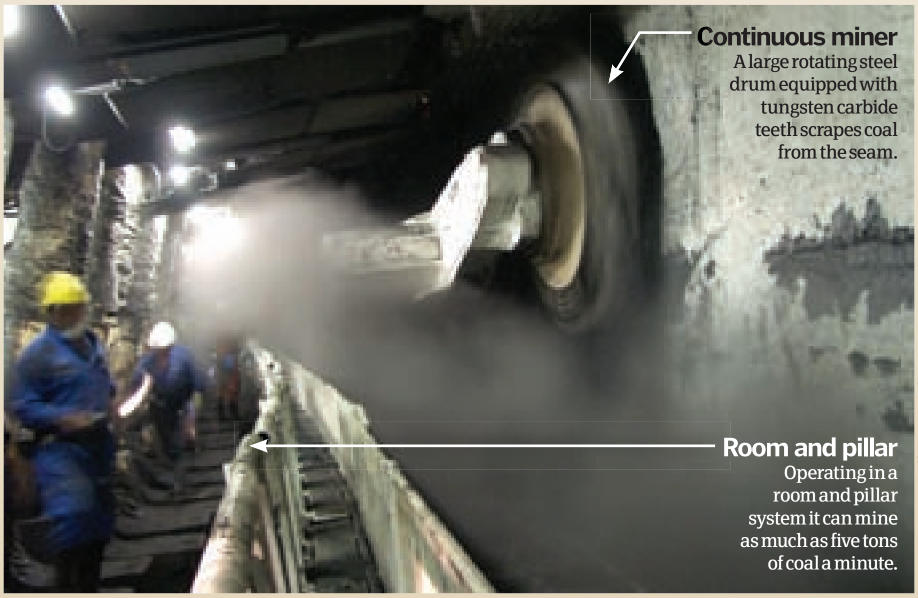
Drift mine
The simplest method of underground mining, the coal seam is accessed by digging horizontally into the side of a hill.



Slope mine
For a shallow underground coal seam, miners dig a slanted or 'sloped' shaft and remove the coal via long conveyor belts.



Surface mine
Also called a 'strip mine', miners remove a horizontal layer of soil and rock called the 'overburden' to expose a coal seam.



Continuous miner
A large rotating steel drum equipped with tungsten carbide teeth scrapes coal from the seam.

Room and pillar
Operating in a room and pillar system it can mine as much as five tons of coal a minute.

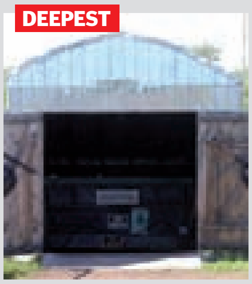
Image © Gebr. Eickhoff Maschinenfabrik und Eisengießerei

Head to Head
THE BIGGEST, DEEPEST AND MOST PRODUCTIVE COAL MINES ON EARTH

BIGGEST

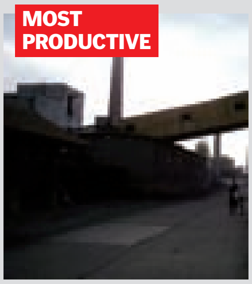
1. El Cerrejón
The largest surface mine in the world, this 69,000 hectare pit in Northern Columbia produces over 31Mt of bituminous coal per year, transporting it to the coast for export on its own 150km railroad.

DEEPEST



2. Cumberland Mine
Closed in 1958 after an earthquake-triggered collapse killed 74 miners, this Nova Scotia mine had sloped shafts over 4,200 metres deep, the deepest coal operation on record.

MOST PRODUCTIVE



3. Shandong Mine
The most productive mine in the world, this Chinese operation dug up 117.8Mt of raw coal in 2008. That's over ten per cent of the total annual coal production of the United States.

Learn more
For more information about coal mines head on over to **www.bbc.co.uk/nationonfilm/topics/coal-mining/** where you can take a trip through the coal mines of north-east England from the Thirties to the Nineties.

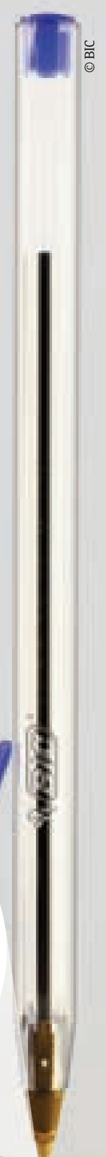
> "The Harmony remote works through its ability to learn and store multitudinous codes"

Inside a ballpoint pen

Why the writing is not on the wall for this essential instrument of everyday life

Even in a digital world, millions of ballpoint pens are sold daily due to the cheap, simple but effective technology inside. At the tip is a socket, which securely houses a tiny metal ball. A small part of its surface is exposed and it has just enough freedom to rotate in all directions. Above the socket is a chamber of ink that is not too thin (to prevent leaks) and not too thick (so it still responds to gravity).

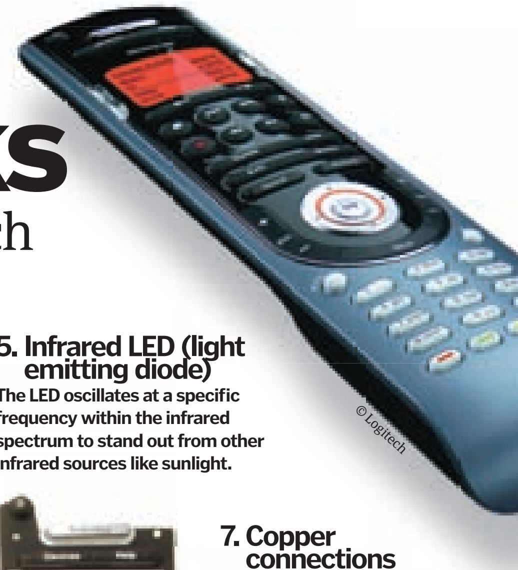
The ball and socket act as a seal, preventing the ink from drying up. During the writing motion, the ball rotates. Inside, gravity continually pulls ink down the chamber onto the ball's surface. The rotating motion transfers this ink to the surface where it instantly dries.



Great for writing but impossible not to chew…

How the Logitech Harmony TV remote works

The technology behind the couch potato's best friend exploded



6. Coloured LED
A coloured LED is a visual indicator of a button being pressed. It does not transmit any signals.

8. Microprocessor
The microprocessor stores a binary code for each contact point (button) and translates this into an LED pulsing sequence.

5. Infrared LED (light emitting diode)
The LED oscillates at a specific frequency within the infrared spectrum to stand out from other infrared sources like sunlight.

7. Copper connections
A gap separates each connection. When a key is pressed, a conductive material connects the points, creating an identifying signal.

1. Moulded cover
Each hole helps secure the keypad into place ensuring each button is positioned over its correct connection point.

2. Battery compartment
Remote controls' batteries last a long time. Power is only consumed during the short time the low energy LED flashes.

3. Printed circuit board
Copper circuits are 'printed' onto boards. A signal can only reach the microprocessor when a key is pressed.

4. Rubber keypad
When a rubber key is pressed down, a conductive material underneath connects two copper points and a signal can flow.

Most regular TV remotes use infrared (IR) to transmit instructions to a TV. When a button is pressed an electrical signal is sent to a microchip that identifies the selected command, which is itself associated with a unique binary code. The microchip in the remote then translates that code into a sequence of light pulses that are emitted from an infrared LED and picked up by the electrical equipment's IR receiver, translated back into binary code and then matched to a associated command.

The Harmony remote works through its ability to learn and store the multitudinous codes used by the various manufacturers, instead of being limited to a pre-programmed selection. Early varieties required the user to enter these codes into the remote to calibrate it, however recent developments have allowed remotes to find the requisite codes via the internet automatically.

5 TOP FACTS GAMBLING STATS

Big jackpot, big odds

1 The odds of winning the jackpot on a 'progressive' slot machine like Megabucks is one in 50 million, although if you are that one you're likely to become very rich.

'Easy' money

2 68 per cent of people who gamble at Las Vegas play the slot machines most often. And there's a large target market as nearly 90 per cent of visitors to Las Vegas gamble.

The house wins

3 In the United States, gaming was a $92 billion industry in 2007, double what it was a decade ago. And in the UK, there were 143 casinos as of 31 March 2009.

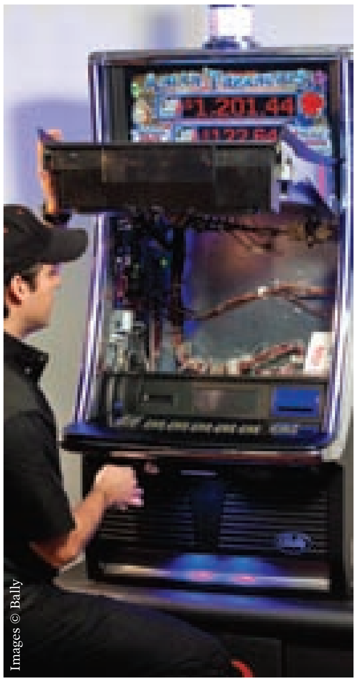
United States of Slots

4 Even though Nevada is widely considered the gambling state, there are 37 US states with some form of legalised electronic gaming device like slot machines or video poker.

Vegas' most wanted

5 The Nevada Gaming Commission maintains a list of 35 people who are not allowed in any casino or gambling establishment. Only one of them is a woman.

DID YOU KNOW? In 2003, a Californian man hit the $38.7 million Megabucks slot machine jackpot while in Las Vegas



How slot machines work

Beating the one-armed bandit is even harder than you think

Most amateur gamblers believe that if a slot machine hits the jackpot, then it immediately goes 'cold'. They also believe the opposite is true; if a machine runs cold for hours, then it's 'due' for a big payoff. But if you look inside modern slot machines, you learn the cold hard truth. Every single pull of the lever has equal odds of winning, and those odds are steep.

Since the earliest mechanical slot machines, gaming manufacturers have weighted the machines to tweak the odds. If you look closely at the reels of old machines, you'll find many more blanks and low-scoring symbols than pots of gold, especially on the third or final reel. This creates the famous 'near miss' effect.

Modern slots have replaced the gears, cranks and stoppers with precision step motors and random number generators (RNG). When you pull the crank on a modern slot, a built-in RNG selects three numbers between one and 64. Each number corresponds to one of 22 spots on the three reels. The trick is that half of the numbers between one and 64 correspond to blank spots and only one random number matches the jackpot symbol. The odds of nailing the jackpot are 1/64 x 1/64 x 1/64 or one in 262,144.

The lever is just for show. Three internal step motors spin each reel and stop them precisely at the positions chosen by the RNG. Still feeling lucky?

3. Reels
Three notched reels spin independently around a horizontal metal shaft. On old-fashioned machines, small pegs click into place to stop the spin on a 'random' symbol.

1. Coin slot
Modern slot machines not only take multiple coins, but accept paper money, credit cards and casino 'player' cards.

2. Lever
On mechanical slot machines, pulling the lever was necessary to trigger the spinning of the reels. Motors replaced that function decades ago, leaving the levers purely for show.

5. Payout trigger
These metal pins work in tandem with the reel plate to determine the payout amount. The better the combination, the longer the trigger is released. A jackpot dumps it all.

4. Reel plate
In the old mechanical slots, the reels operate like tumblers inside a combination lock. When the right combination hits, the tumblers align, triggering a set payout.

6. Winning line
Slot machines offer different payouts for different symbol combos. On modern slots, your payout increases with larger bets. The jackpot is usually reserved for the maximum bet.

Return vs payback

There is no such thing as a 'loose' or 'tight' slot machine. In modern casinos, slot machines are programmed to deliver a precise return percentage, somewhere around 95 per cent. That means 95 per cent of the money that goes into a slot machine is paid back out to the players and the casino keeps the rest.

But here's where things get tricky. The return percentage is not the same as the payback, which is the actual amount of money you win or lose during each gambling session at a slot machine. If you sat down at a slot machine for eternity and pulled the lever an infinite amount of times, your payback percentage would be exactly 95 per cent. Likewise, in a casino full of gamblers, the collective machines will pay back roughly 95 per cent of the total money gambled during the course of a day.

Unfortunately, you are only one person and you don't have infinite pulls. So your odds of winning are equally good or bad every pull. You could lose all day and that doesn't mean the machine is rigged. And it doesn't mean that the guy who wins the jackpot found the 'loose' machine. He just got very, very lucky.

Early scuba gear
1 In 1943 Jacques Cousteau and Emile Gagnan invented the aqualung, which allowed divers to explore underwater for several hours by breathing in air from a tank.

Did you hear that?
2 Beneath the surface of the water sound travels five times faster than it does in air and so scuba divers can have trouble quickly determining the direction of sound.

How deep can you dive?
3 A lot of people have lost their lives trying to set various records for the deepest dives and so the recommended recreational diving limit has been set at 130 feet (40m).

Lucky air supply
4 Diver Michael Proudfoot was exploring a shipwreck in 1991 when his breathing regulator was damaged. He found a bubble of air in the ship's galley, surviving for two days.

Longest recorded dive
5 American Richard Presley set the record for the longest deep dive in 1992 when he spent 69 days in a submersible module near Florida.

DID YOU KNOW? Objects tend to appear 25 per cent larger underwater

4. Check valves
A check valve on either side of the mouthpiece ensures that the gases only circulate in one direction so the diver doesn't simply inhale the same breath they just exhaled.

5. Shut-off valve
To prevent the loop from being flooded in case the mouthpiece is removed underwater, there is a shut-off valve.

1. Breathing gases
In semi-closed systems, divers breathe in a gas mixture like nitrox, which consists of oxygen and nitrogen. Fully closed systems use a diluent gas, such as trimix, which can be mixed with pure oxygen.

2. Pure O2
Closed-circuit rebreathers use pure oxygen combined with already mixed gases. Solid-state oxygen sensors in the tank containing pure oxygen carefully administer the correct amount of oxygen to the breathing loop.

3. Scrubber
To enable divers to 'rebreathe' already-exhaled air, the loop removes poisonous carbon dioxide using a scrubber, which turns CO_2 into solid calcium carbonate.

6. Counterlung
When the gas in the loop is not in the diver's lungs it is in this collapsible bag that maintains a constant volume of gas.

Images © Innerspace

Rebreathers explained

How does this underwater breathing apparatus recycle your breath so it's safe to inhale again

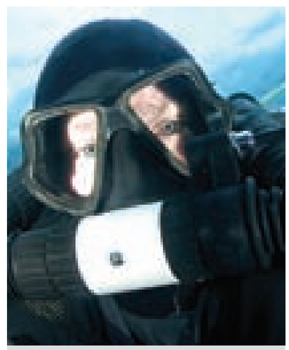
Traditional 'open' system scuba gear is inefficient because the diver's exhaled breath completely leaves the breathing system (or loop) as bubbles when it still contains plenty of useful oxygen. A closed or semi-closed rebreather circuit, however, can recycle some of the exhaled waste gas.

There are three kinds of rebreather: oxygen rebreather, semi-closed and fully closed. The source of breathing gas in an oxygen rebreather is pure oxygen, which cannot be used at decompression depths, limiting how far the diver can go. A semi-closed rebreather has a tank containing one type of breathing gas (such as nitrogen or helium) mixed with oxygen. Fully closed circuit rebreathers, meanwhile, are a cross between the other two and have two tanks – one that injects a highly controlled amount of pure oxygen and one that injects a mixture of oxygen and breathable gases.

The breathing loop consists of a mouthpiece through which the diver breathes, as well as a collapsable bag known as a counterlung, which inflates upon breathing out and deflates when you are breathing in (keeping the volume of gas the same throughout the loop). There is also a carbon dioxide scrubber that is filled with a chemical such as sodium hydroxide that absorbs the exhaled carbon dioxide as it is breathed out.

Advantages of rebreathers

Recycling reduces the volume of gas necessary in the system and can extend the amount of time divers can spend underwater, making rebreather tanks lighter and more compact than conventional scuba kits. And because the exhaled air isn't released from the system, little or no bubbles are expelled into the water. This all makes rebreathers very popular with the military who rely on stealth and an ability to remain underwater for long periods. We will add, however, that when the diver returns to the surface, gas is expelled to relieve pressure on the gas-tight breathing loop.



Pure oxygen

Although you don't use all the oxygen present in a single breath, if you continued to breathe the same air in and out over and over, you would eventually use it all up and begin to breathe only gases that are of no use to you. A controlled amount of pure oxygen is therefore added to the loop. Because pure oxygen contains reactive molecules called free radicals that are harmful, it is mixed with other breathable gases from a separate tank.

This month in Science

If it falls into the realms of physics, biology or chemistry then you can expect to find it explained in the science section which stretches before you for the next few pages. Things are not always as they seem and this is particularly true of optical illusions. If you've ever wondered why certain images have the ability to fool human perception, take a second glance at our main science feature this issue that attempts to answer that very question.

64 Newton's Cradle

65 Dialysis

67 Vocal cords

SCIENCE

62 Human muscles
64 Fermentation
64 Newton's Cradle
65 Dialysis
66 Carbon dating
67 Vocal cords
68 Optical illusions

How do muscles work?

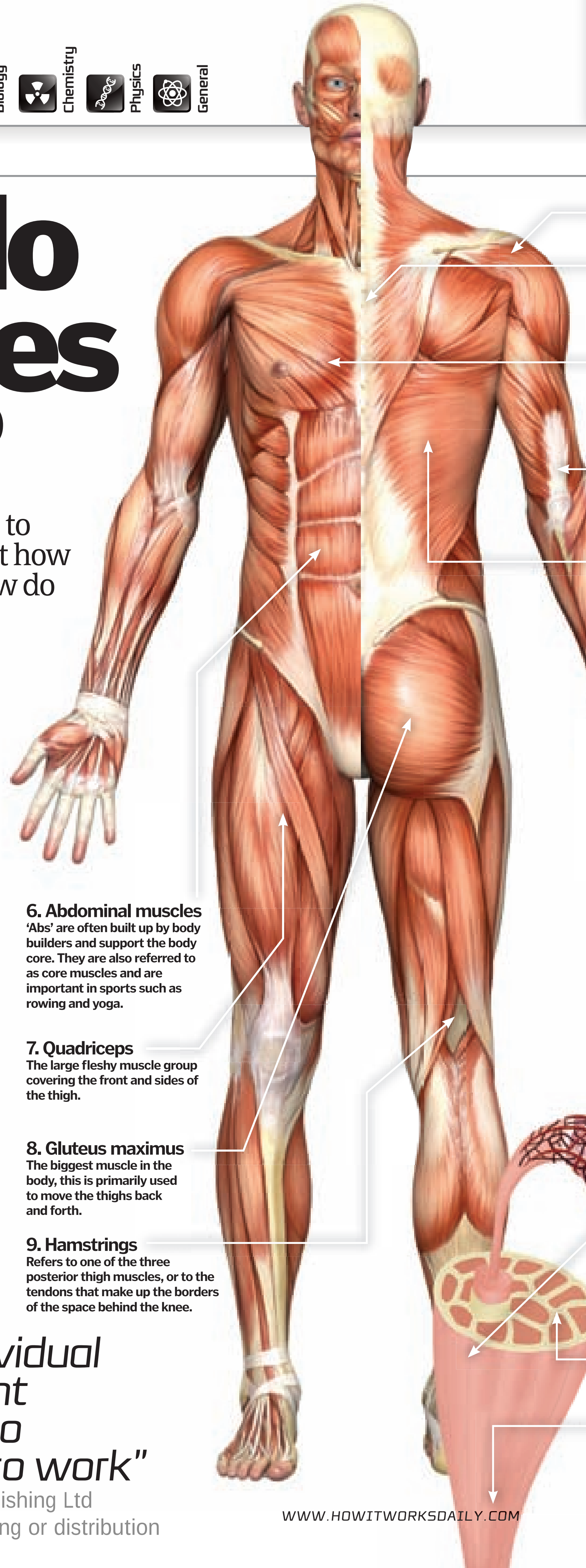
Muscles are essential for us to operate on a daily basis, but how are they structured and how do they keep us moving

A muscle is a group of tissue fibres that contract and release to control movements within the body. We have three different types of muscles in our bodies – smooth muscle, cardiac muscle and skeletal muscle. Skeletal muscle, also known as striated muscle, is what we would commonly perceive as muscle, this being external muscles that are attached to the skeleton, such as biceps and deltoids. These muscles are connected to the skeleton with tendons. Cardiac muscle concerns the heart, which is crucial as it pumps blood around the body, supplying oxygen and ultimately energy to muscles, which allows them to operate. Smooth muscle, which is normally sheet muscle, is primarily involved in muscle contractions such as bladder control and oesophagus movements. These are often referred to as involuntary as we have little or no control over these muscles' actions.

Muscles control most functions within our bodies; release of waste products, breathing, seeing, eating and movement to name but a few. Actual muscle structure is quite complex, and each muscle is made up of numerous fibres which work together to give the muscle strength. Muscles increase in effectiveness and strength through exercise and growth and the main way this occurs is through small damage caused by each repetition of a muscle movement, which the body then repairs and improves.

More than 640 muscles are actually present across your entire body to enable your limbs to work, control bodily functions and shape the body as a whole.

> "More than 300 individual muscles are present across your body to enable your limbs to work"



6. Abdominal muscles
'Abs' are often built up by body builders and support the body core. They are also referred to as core muscles and are important in sports such as rowing and yoga.

7. Quadriceps
The large fleshy muscle group covering the front and sides of the thigh.

8. Gluteus maximus
The biggest muscle in the body, this is primarily used to move the thighs back and forth.

9. Hamstrings
Refers to one of the three posterior thigh muscles, or to the tendons that make up the borders of the space behind the knee.

LARGEST MUSCLE

1. Gluteus maximus
The gluteus maximus, the buttock, is the largest muscle. It is a superficial muscle that helps control thigh movement.

SMALLEST MUSCLE

2. Stapedius
The smallest muscle in the body is the stapedius, which is situated in the middle ear and helps move the tiny bones which aide our hearing.

STRONGEST MUSCLE

3. Masseter muscle
This is very much dependant on how you define strength. The masseter (jaw) muscle can exert the highest direct force on an object.

DID YOU KNOW? Skeletal muscles account for around 40 per cent of your total body mass

1. Deltoids
These muscles stretch across the shoulders and aid lifting.

2. Trapezius
Large, superficial muscle at the back of the neck and the upper part of the thorax, or chest.

3. Pectoralis major
Commonly known as the 'pecs', this group of muscles stretch across the chest.

4. Biceps/triceps
These arm muscles work together to lift the arm up and down. Each one contracts, causing movement in the opposite direction to the other.

5. Latissmus dorsi
Also referred to as the 'lats', these muscles are again built up during weight training and are used to pull down objects from above.

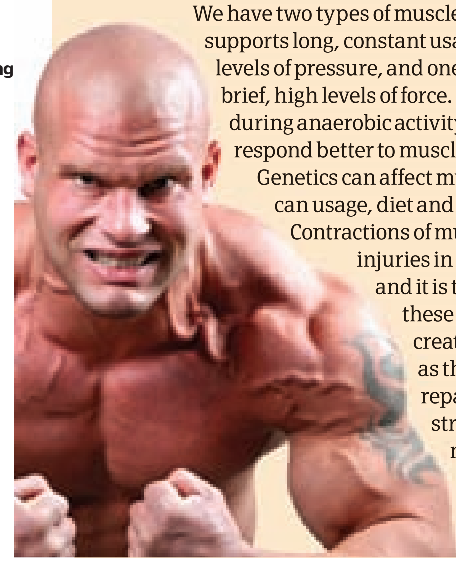
What affects our muscle strength?

How strong we are is a combination of nature and nurture

Muscle strength refers to the amount of force that a muscle can produce, while operating at maximum capacity, in one contraction. Size and structure of the muscle is important for muscle strength, with strength being measured in several ways. Consequently, it is hard to definitively state which muscle is actually strongest.

We have two types of muscle fibre – one that supports long, constant usage exerting low levels of pressure, and one that supports brief, high levels of force. The latter is used during anaerobic activity and these fibres respond better to muscle building.

Genetics can affect muscle strength, as can usage, diet and exercise regimes. Contractions of muscles cause injuries in the muscle fibres and it is the healing of these that actually create muscle strength as the injuries are repaired and overall strengthen the muscle.



Reckon this guy's been working out?

What are muscles made up of?

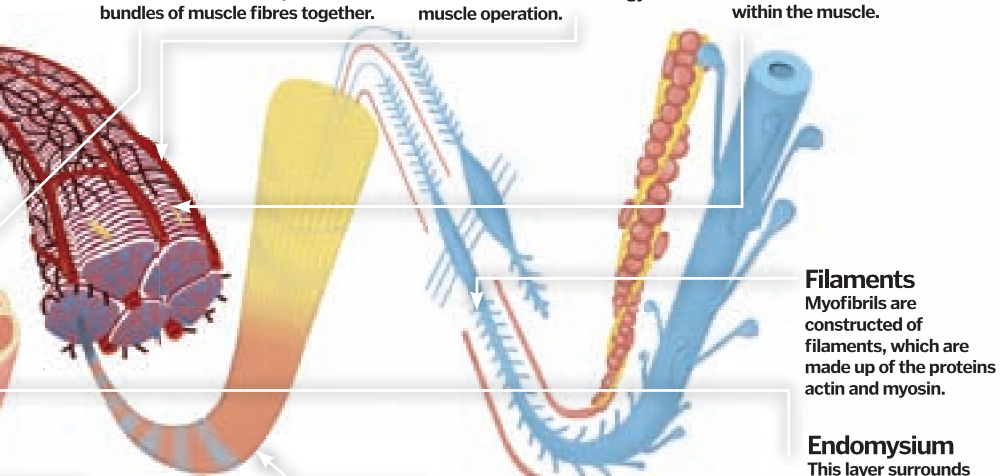
Muscles are made up of numerous cylindrical fibres, which work together to contract and control parts of the body. Muscle fibres are bound together by the perimysium into small bundles, which are then grouped together by the epimysium to form the actual muscle.

Blood vessels and nerves also run through the connective tissue to give energy to the muscle and allow feedback to be sent to the brain. Tendons attach muscles such as biceps and triceps to bones, allowing muscles to move elements of our body as we wish.

Epimysium
The external layer that covers the muscle overall and keeps the bundles of muscle fibres together.

Blood vessel
This provides oxygen and allows the muscle to access energy for muscle operation.

Perimysium
This layer groups together muscle fibres within the muscle.



Filaments
Myofibrils are constructed of filaments, which are made up of the proteins actin and myosin.

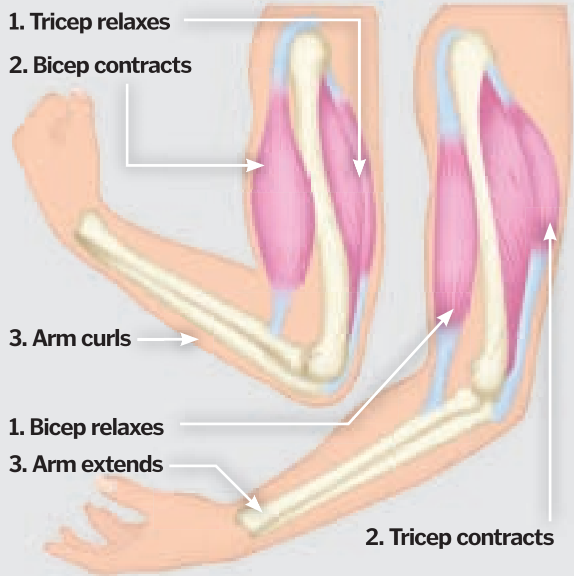
Endomysium
This layer surrounds each singular muscle fibre and keeps the myofibril filaments grouped together.

Tendon
These attach muscle to bones, which in turn enables the muscles to move parts of the body around (off image).

Myofibril
Located within the single muscle fibres, myofibrils are bundles of actomyosin filaments. They are crucial for contraction.

How does the arm flex?

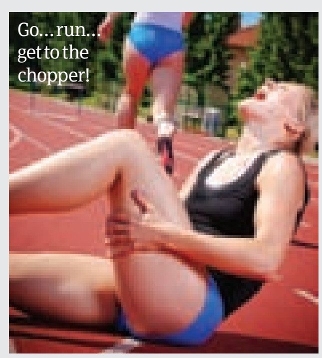
Biceps and triceps are a pair of muscles that work together to move the arm up and down. As the bicep contracts, the triceps will relax and stretch out and consequently the arm will move upwards. When the arm needs to move down, the opposite will occur – with the triceps contracting and the bicep relaxing and being forcibly stretched out by the triceps. The bicep is so named a flexor as it bends a joint, and triceps would be the extensor as it straightens the joint out. Neither of these muscles can push themselves straight, they depend on the other to oppose their movements and stretch them out. Many muscles therefore work in pairs, so-called antagonistic muscles.



What is a pulled muscle, and how does it happen?

They hurt like crazy so here's why it's important to warm up

A pulled muscle is basically a tear in muscle fibres. Sudden movements commonly cause pulled muscles, and often, when an individual has not warmed up appropriately before exercise or is unfit, a tear can occur as the muscle is not prepared for usage. The most common muscle to be pulled is the hamstring, which stretches from the buttock to the knee. A pulled muscle may result in swelling and pain can last for several days before the fibres repair themselves. To prevent pulling muscles, warming up is recommended before any kind of physical exertion.



Go…run… get to the chopper!

"Momentum and energy must be maintained in the system"

If this doesn't make you want a beer, nothing will…

The process of fermentation

Humans have used fermentation for centuries to produce alcohol and preserve many different types of food, but how does the process occur?

5 TOP FACTS FERMENTED PRODUCTS

1 Beer
Ales and lagers are produced through the fermentation of several various cereal grains. However, malted barley is most commonly used.

2 Vinegar
Vinegar's key ingredient is acetic acid, and this is formed through the fermentation of ethanol. Vinegar is an excellent preservative.

3 Cheese
Many cheeses, such as brie, camembert and blue cheese are produced through the process of fermentation.

4 Salami
Salami is actually dried, cured, fermented meat. This treatment stops meat ruining for extended periods of time, even when stored at room temperature.

5 Vodka
While most commonly made from fermented grain, vodka can also be made from rye, wheat or potatoes.

Fermentation is actually a means of deriving energy from organic compounds through oxidation of these materials. More specifically, the term fermentation often refers to the conversion of a carbohydrate into either an alcohol or an acid using enzymes that are released by micro-organisms.

Bacteria or yeast enzymes are used to break down the natural sugars present in carbohydrates into simpler acids or alcohols. Whether acid or alcohol is produced is dependant on whether oxygen is available or not, the type of agent used (bacteria or yeast) and also the type of carbohydrate fermenting. In aerobic environments, the process normally converts carbohydrates into alcohols and carbon dioxide, while in anaerobic environments organic acids, such as lactic acid, are often produced.

Newton's cradle

A popular desk toy, but just how does it work?

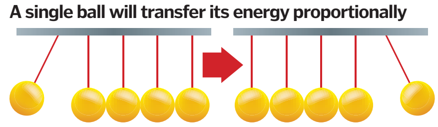
Invented in 1967 by actor Simon Prebble and named after the distinguished scientist and mathematician Sir Isaac Newton, Newton's cradle is a device that visually demonstrates the Laws of Conservation of Momentum and Energy, as well as the effects of friction and dampening.

The cradle is constructed from a series of odd-numbered metal balls (usually five or seven) each of which are suspended from a fixed rack by two wires or rods in order to keep them on a single plane. The device, when operated by lifting one of the outward end balls, acts akin to a simple pendulum. However, thanks to the inclusion of other balls in its swing arch, it transfers its kinetic energy through them to its polar opposite outward ball, swinging it up on the same plane and arch.

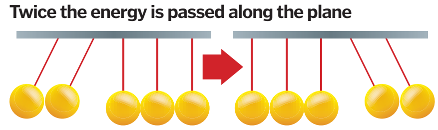
This effect is produced in accordance with Newton's aforementioned laws that state that the amount of momentum that an object has depends on its mass and velocity, and that the total momentum of any group of objects remains the same unless outside forces act upon them. This directly translates to the activity of the cradle as, considering the momentum and energy produced by releasing the outward ball must be maintained in the system, the opposite ball will have the same velocity and total mass as the instigator. Vis-à-vis, if two balls are initially released, two balls will replicate the arch on the other end of the cradle, as the total velocity and mass must be maintained.

Of course, while these laws would seem to indicate that the cradle's movement must therefore be perpetual, this is not the case, as friction caused between the balls' collisions as well as their natural elasticity and material dampening effects, means that the arch of any moving balls will decrease over time, eventually coming to a standstill. The longevity and conservation of momentum is therefore directly proportional to the material used in the balls, with metal often used thanks to its low elasticity.

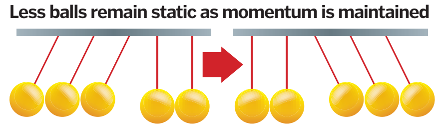
1 x ball
A single ball will transfer its energy proportionally



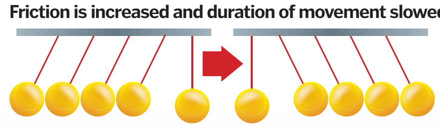
2 x ball
Twice the energy is passed along the plane



3 x ball
Less balls remain static as momentum is maintained



4 x ball
Friction is increased and duration of movement slowed



We never knew Newton had so many!

Small but powerful

1 Your kidneys are very small organs, weighing only 0.5 per cent of your total body mass. However, they also contain over 20 per cent of your body's blood.

How much!?

2 On average it costs £30,000 to keep a patient on dialysis for a whole year. Three per cent of the total NHS budget is actually spent on kidney failure services.

Cost effectiveness

3 The cost of a kidney transplant is £20,000 per patient, per transplant. Every transplant operation carried out saves the NHS £190,000 over nine years on dialysis.

The drugs do work

4 The efficiency of your kidneys is why you have to take repeat doses of drugs in order for them to work. Most of a dose is excreted from the body in your urine.

First transplant

5 The first ever kidney to be transplanted from a living donor to his identical twin brother took place on 23 December 1954 in Boston, Massachusetts USA.

DID YOU KNOW? *The kidneys also maintain the amount of water present in your body*

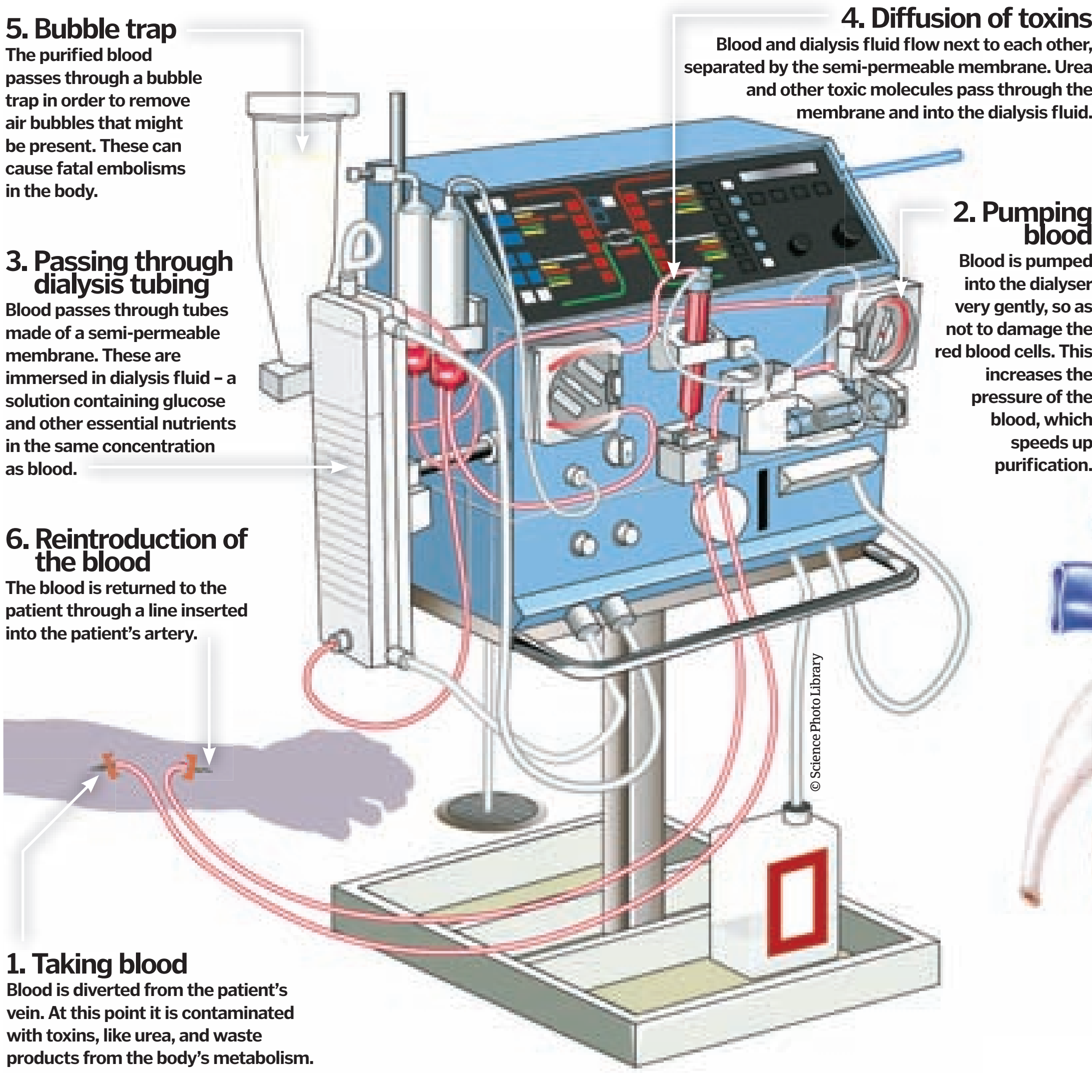
How kidney dialysis works

When your kidneys go wrong, it's the artificial process of dialysis that takes over and cleans the waste out of your body

They may not be the most glamorous organs in the body, but the kidneys play a vital role in human biology. They regulate the composition of bodily fluids and remove toxins and waste products. If your kidneys malfunction then these toxins quickly build up to life-threatening levels.

In the short term, kidney failure is treated by purifying blood outside the body – a process called dialysis. A patient's toxin-containing blood is taken from a vein in an arm or leg and pumped gently through a machine called a dialyser. Inside it flows through tubes made from a semi-permeable membrane (a porous material containing holes of a certain size) that are immersed in dialysis liquid – a solution close in composition to clean blood. The holes in the membrane are big enough to let out toxic molecules, such as urea, but not red blood cells, and other essential substances. Purified blood is then returned into a patient's artery.

Several hours of dialysis must be carried out at least twice a week for someone suffering from kidney failure. If the damage is permanent then a transplant is needed, though the wait for a compatible organ donor is often a long one. Dialysis is crucial in keeping such patients alive while a suitable match is found.

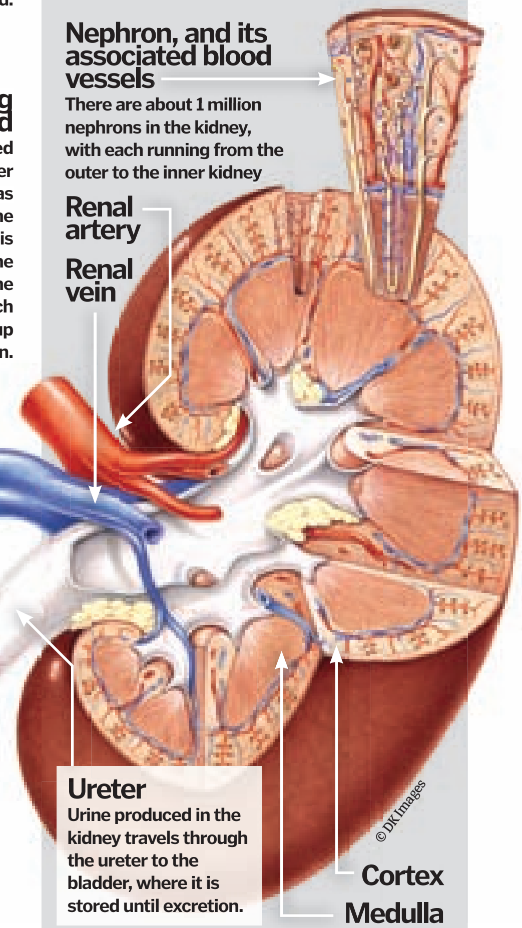


Functions of the kidneys

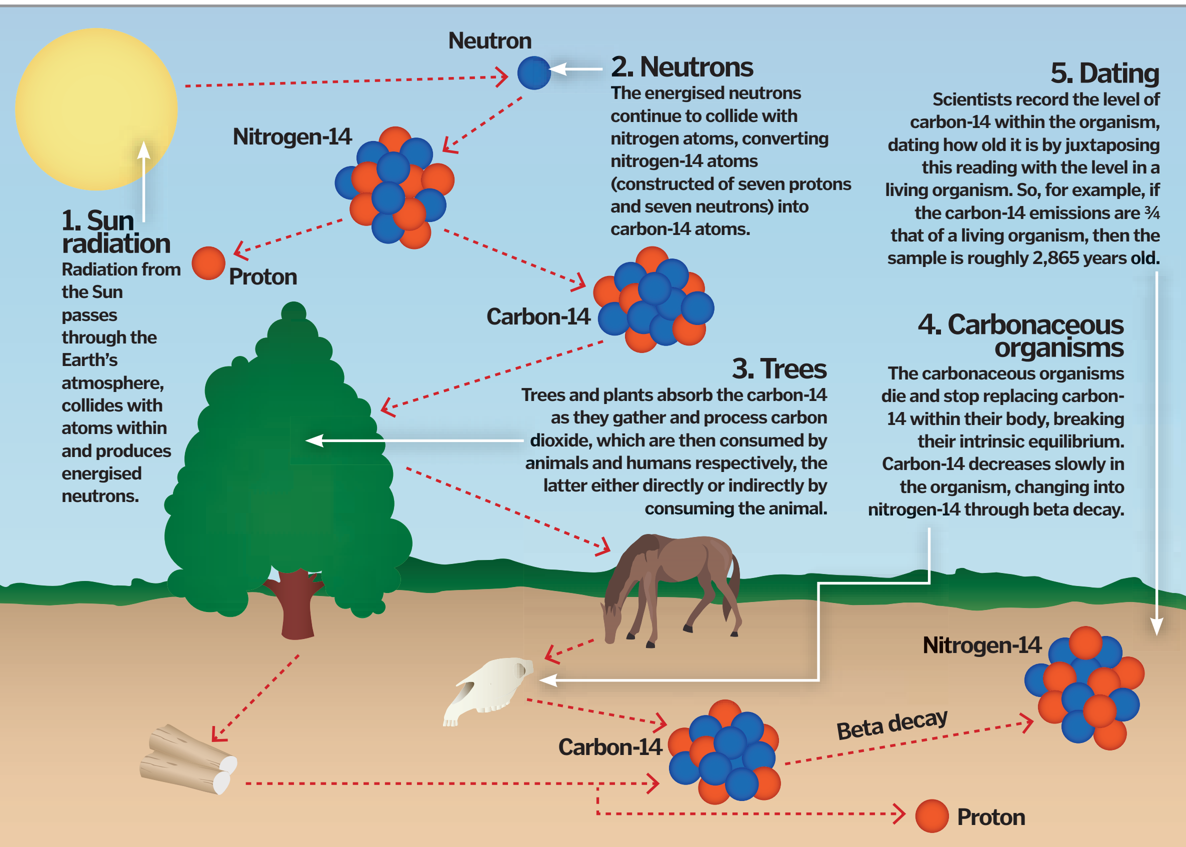
It's dirty work, but someone has to do it. The kidneys – two bean-shaped organs positioned midway down the back, either side of the spine – are nature's cleaners. They are responsible for cleaning up your bodily fluids, keeping the concentration of important ions constant, and maintaining the amount of water present in the body.

Your kidneys receive blood from the renal artery, process it and return it again through the renal vein. Waste products (urea, excess ions, drugs, metabolites, etc) are flushed out in your urine, which is stored in your bladder until you can find a convenient time and place to answer nature's call.

There are a number of known causes of renal failure, with the most common being diabetes, high blood pressure and a painless swelling of the kidneys known as glomerulonephritis. Other conditions include the (often inherited) development of cysts on the kidneys and repeated kidney infections in childhood.



"Find out how a radioactive isotope can tell us the age of things"



Carbon dating

How does it date things that are thousands of years old?

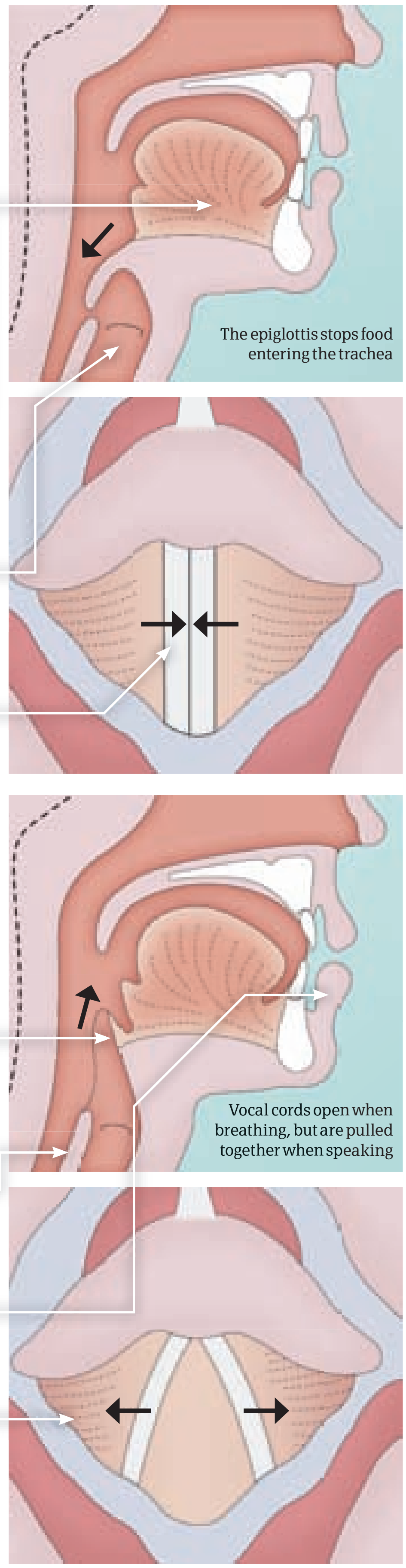
Carbon dating is a method of radioactive dating that uses the radioactive isotope carbon-14 to determine the time since it died (ie the time since it stopped replacing carbon-14). Carbon-14 naturally occurs in the Earth's atmosphere and is present in all living carbonaceous materials such as plants and animals. Scientists can use the measurement of carbon-14 to determine age as it is known that it has a half-life (the time in which it takes a decaying object to decrease by 50 per cent) of 5,730 years. This means that when an object (a deceased human for example) is unearthed, by recording the decayed levels of radioactive emissions emanating from it of carbon-14, precise dates of when carbon-14 levels stopped being constant can be determined and therefore its age predicted.

How do humans speak?

The vocal cords and larynx in particular have evolved over time to enable humans to produce a dramatic range of sounds in order to communicate – but how do they work?

Vocal cords, also known as vocal folds, are situated in the larynx, which is placed at the top of the trachea. They are layers of mucous membranes that stretch across the larynx and control how air is expelled from the lungs in order to make certain sounds. The primary usage of vocal cords within humans is to communicate and it is hypothesised that human vocal cords actually developed to the extent we see now to facilitate advanced levels of communication in response to the formation of social groupings during phases of primate, and specifically human, evolution.

As air is expelled from the lungs, the vocal folds vibrate and collide to produce a range of sounds. The type of sound emitted is effected by exactly how the folds collide, move and stretch as air passes over them. An individual 'fundamental frequency' (their standard pitch) is determined by the length, size and tension of their vocal cords. Movement of the vocal folds is controlled by the vagus nerve, and sound is then further fine-tuned to form words and sounds that we can recognise by the larynx, tongue and lips. Fundamental frequency in males averages at 125Hz, and at 210Hz in females. Children have a higher average pitch at around 300Hz.



Tongue
This muscle, situated in the mouth, can affect and change sound as it travels up from the vocal cords and out through the mouth.

Trachea
The vocal cords are situated at the top of the trachea, which is where air from the lungs travels up through.

Vocal cords
These layers of mucous membranes stretch across the larynx and they open, close and vibrate to produce different sounds.

Epiglottis
This is a flap of skin that shuts off the trachea when an individual is swallowing food. It stops food and liquids 'going down the wrong way'.

Oesophagus
This tube, situated behind the trachea, is where food and liquid travels down to the stomach.

Lips
Lips are essential for the production of specific sounds, like 'b' or 'p'.

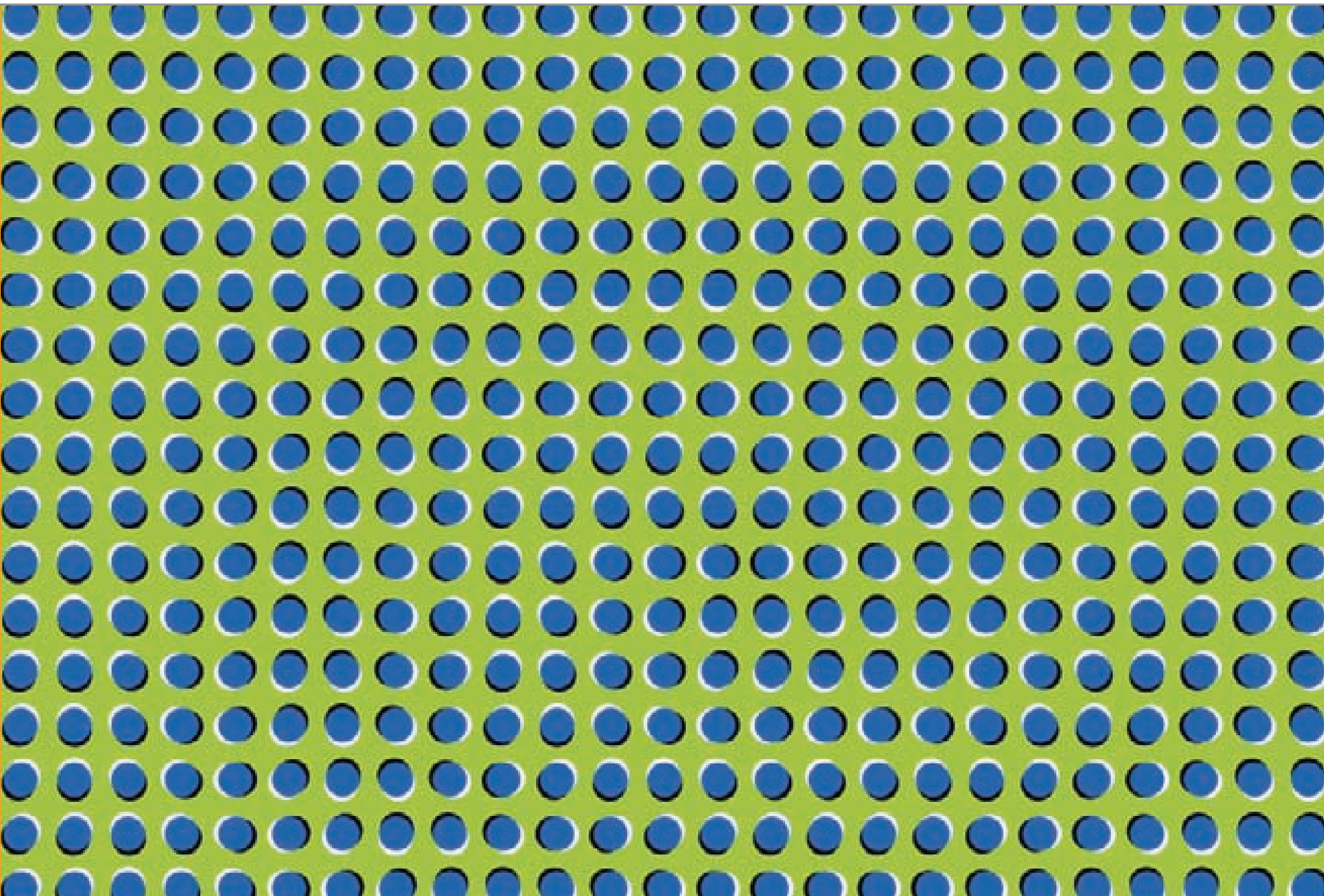
Larynx
Known as the voice box, this protects the trachea and is heavily involved in controlling pitch and volume. The vocal cords are situated within the larynx.

Differences between male and female vocal cords

Male voices are often much lower than female voices. This is primarily due to the different size of vocal folds present in each sex, with males having larger folds that create a lower pitched sound, and females having smaller folds that create a higher pitch sound. The average size for male vocal cords are between 17 and 25mm, and females are normally between 12.5 and 17.5mm. From the range in size, however, males can be seen to have quite high pitch voices, and females can have quite low pitch voices.

The other major biological difference that effects pitch is that males generally have a larger vocal tract, which can further lower the tone of their voice independent of vocal cord size. The pitch and tone of male voices has been studied in relation to sexual success, and individuals with lower voices have been seen to be more successful in reproduction. The reason proposed for this is that a lower tone voice may indicate a higher level of testosterone present in a male.

> "Stimuli have individual dedicated neural paths within the brain in the early stages of visual processing"



Optical illus

Deceiving the mind from objective reality, optical illusions highlight the holes in human perception and how the brain processes sensory data

There are three main categories of optical illusion. These are literal optical illusions (those which create images that are different from the objective reality), physiological illusions (caused by excessive stimulation of a certain type, such as brightness or colour), and cognitive illusions (where the eye and brain makes inaccurate unconscious inferences).

Literal optical illusions are easy to identify and describe, as they are illusions that create images that are different from the objects that make them. A good example of a literal illusion is The Café Wall illusion (see page 71) . Here, due to the composition of the wall's tiles and their brightness and contrast, its straight horizontal lines appear uneven, distorting the object truth and displaying an image which the mind perceives as accurate yet, on closer inspection, is false and misleading. There are two processes involved in how this works – the first is the local asymmetries of contrast between half-tiles integrating along the rows, the second is their extrapolation, forming the asymmetry of the long wedges. This is a neural signal distortion, which depends lawfully on the brightness contrasts.

Physiological illusions, as accurately represented in the Herman Grid illusion (page 70) ,

Café Wall

1 The Café Wall illusion was first described by neurophysiologist Richard Gregory in 1973, after a member of his laboratory saw the pattern displayed on a nearby café wall.

Escher

2 MC Escher, famous for his surreal landscapes and impossible objects, utilised explorations of infinity, architecture and tessellations to create illusionary effects.

Helmholtz

3 Herman von Helmholtz, one of the fathers of neurophysiology, described visual perceptions as unconscious inferences from sensory data and knowledge derived from the past.

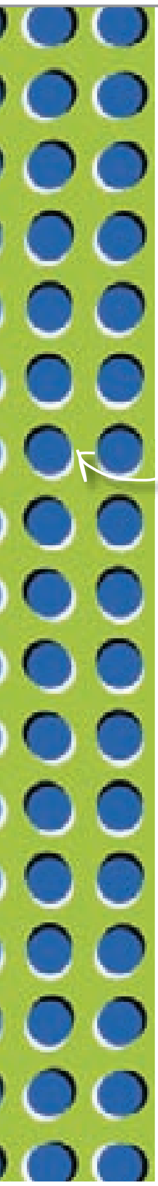
A moment in time

4 It takes roughly 1/10th of a second for the brain to process sensory data, leading to the process of unconscious inference and the prediction of future events by it.

Everyday use

5 Optical illusions are not just flights of fancy, but are actively used and formed everyday in the real world, be they in advertising or indeed military camouflage.

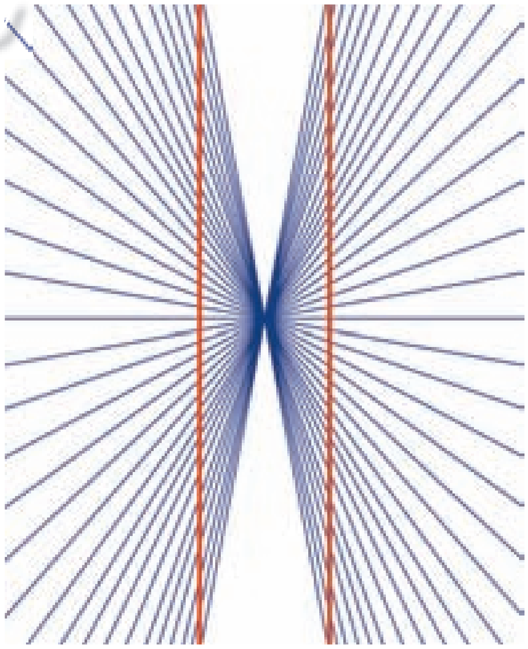
DID YOU KNOW? There are three different types of illusion: literal, physiological and cognitive



Moving illusions

A trick of the mind?

Images that appear to move are good examples of physiological illusions. Here, excessive exposure to stimuli of a specific type causes a physiological imbalance, as each has only one or a few individual neural paths within the brain. In this image the brain struggles to interpret the interacting colour contrasts and shape positions, with the brain receiving competing signals to base its interpretation on.



© JFibonacci

The Hering illusion tricks the mind into thinking it is moving forward, bending the two straight vertical lines outwards – this shows how the brain compensates for neural delays, filling in information before it is received and processed.

sions

work by exposing senses to excessive stimuli of a specific type, be that brightness, colour, movement or tilt. In doing this, the illusion exploits the fact that stimuli have individual dedicated neural paths within the brain in the early stages of visual processing, and that repetitions of such stimuli of only one or a few channels causes a physiological imbalance that alters perception and distorts reality. Note how in the Herman Grid illusion, grey dots appear at the intersections – this is because when the light and dark receptors of the receptive field of the retina compete with one another to become active and process the image, they create lateral inhibition as a result of the dark surround.

Arguably the most complex and yet-to-be understood illusions are those of a cognitive variety. Cognitive illusions are

Holbein's Ambassadors

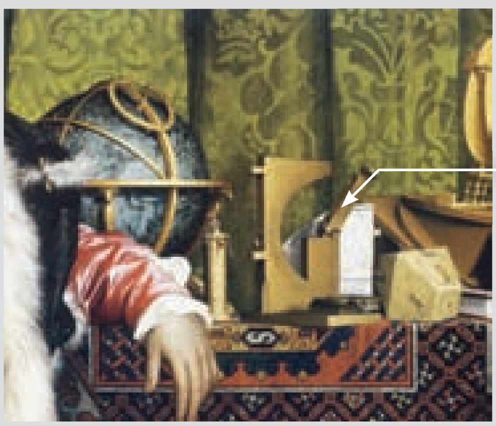
Distortion can hold powerful illusionary qualities in both art and architecture

One of the most famous and disturbing examples of the illusionary qualities of distortion used in art can be seen in Holbein's The Ambassadors. Here, a massive smeared object is rendered in anamorphic perspective in the centre of the colourful and complex image, appearing to a viewer from a front-on perspective as a vague shape of indiscernible prominence and interest, only then to morph when the image is viewed at a set angle, into a very noticeable and creepy human skull.

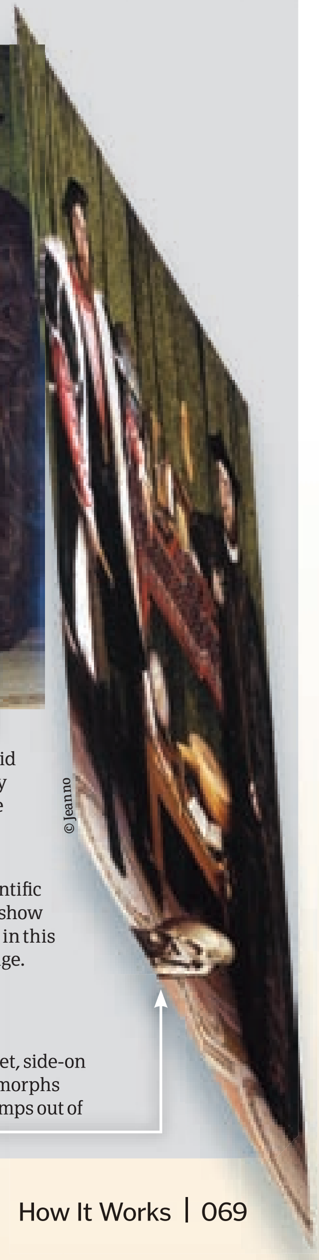
This is a good example of a cognitive, distortion illusion, where the large skull is hidden from the viewer thanks to alterations in its size, length and curvature, preventing an accurate interpretation by the brain of the signals its is receiving and therefore having objective truth hidden. Unlike the Duck-Rabbit illusion however (page 70), this is not a flipping illusion and once the viewer sees the skull from the necessary angle, the skull remains in the picture at all times and all angles after that.

On a lesser note, yet still of interest in terms of the picture's illusionary qualities, is Holbein's inclusion of various precise scientific instruments and devices to measure time and space on the shelf between the two ambassadors. Here an astronomical globe, a cylindrical calendar, two quadrants, a sun clock and a torquetum all, paradoxically, show imprecise times instead. These types of paradoxical games and illusions were highly popular in the Renaissance and were developed upon right through the 20th Century by the notable artists such as MC Escher and Salvador Dali.

Holbein's The Ambassadors. Did you immediately spot the massive skull?



The various scientific instruments all show imprecise times in this paradoxical image.



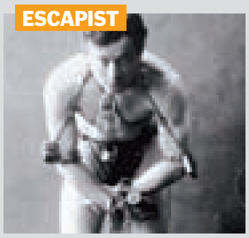
© Jeanno

Notice how at a set, side-on angle, the skull morphs suddenly and jumps out of the picture.

> "The brain adjusts what we perceive to what it thinks we should perceive in the future"

Head to Head ILLUSIONISTS

ESCAPIST



1. Harry Houdini
Facts: One of the most famous magicians to ever live, Houdini made a name for himself by escaping from seemingly in-escapable situations.

SPOON-BENDING

© Dmitry Rozhkov

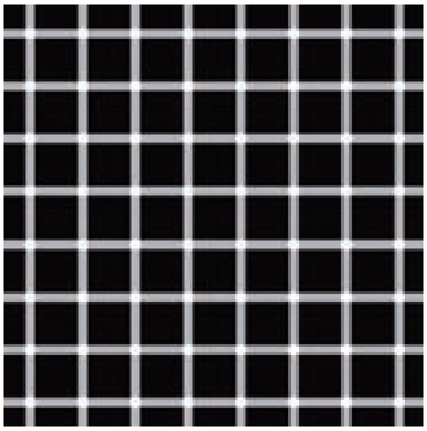
2. Uri Geller
Facts: Geller made a name for himself by being able to apparently bend cutlery into odd shapes purely with the power of his mind.

MIND GAMES

3. Derren Brown
Facts: One of a current generation of TV illusionists, Brown openly admits his illusionary skills and is known for his apparent ability to read minds.

postulated to arise through assumptions about the world that lead to 'unconscious inferences', or in other words, the brain determining objective truth unconsciously, from both past experience and immediate sensory data. Cognitive illusions exploit this automated response from the brain, tricking it to perceive falsities. One of the best examples of a cognitive illusion is the Hering illusion (page 69). Here, two vertical lines are made to appear bowed outwards by a series of spokes that are used to recreate the idea of movement. This works as when the mind receives the sensory information of the spokes, it is tricked into thinking that the viewer is moving forward and unconsciously adjusts its perception of the positioning of the straight lines in accordance with where it thinks they should be in the future.

Indeed, this is an interesting theory, as taken on face value it purports that the brain adjusts what we perceive to what it thinks we should perceive in the future, albeit at only 1/10th of a second. Of course, in most circumstances, these unconscious inferences are accurate, however as demonstrated in the Hering illusion, this gap in perception and the brain's short cut automated mechanism can be exploited.



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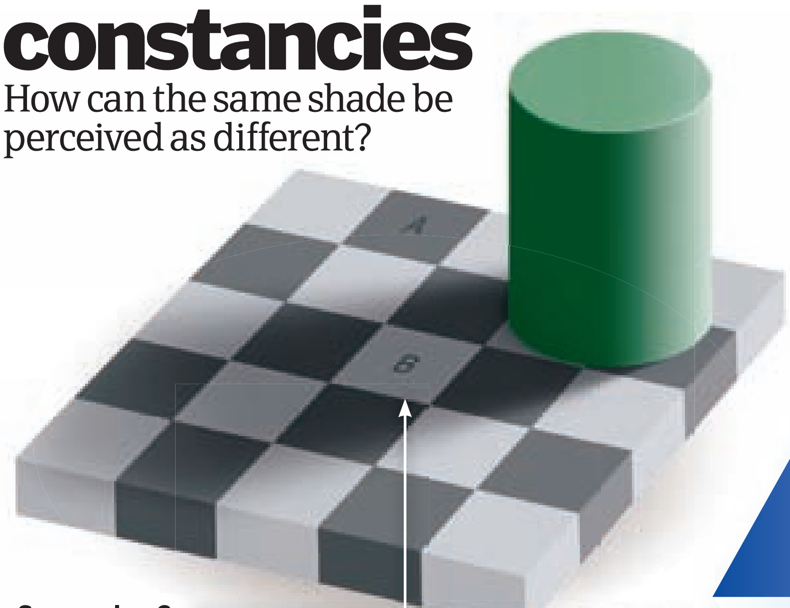
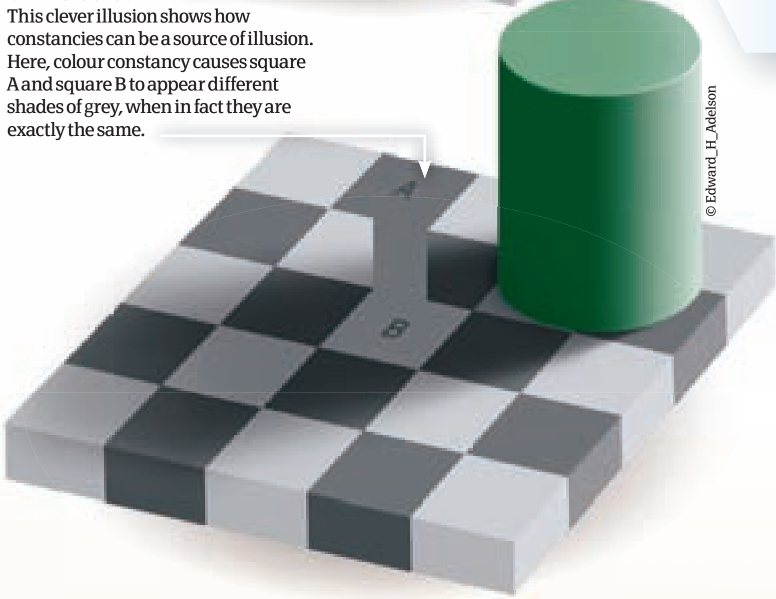
The Herman Grid illusion where shape, position, colour and 3D contrast converge to produce the illusion of black dots at the intersections.

Colour constancies

How can the same shade be perceived as different?



Same colour?
This clever illusion shows how constancies can be a source of illusion. Here, colour constancy causes square A and square B to appear different shades of grey, when in fact they are exactly the same.



© Edward_H_Adelson

When is a duck not a duck?

When it's a rabbit!

Perceptual organisation is believed by Gestalt psychologists to centre on the brain's perception of sensory data in terms of constructing a meaningful whole – so perceiving an object in full in order to perceive its parts and overall meaning. This sort of Gestalt thinking can be used to explain many illusions such as the Duck-Rabbit illusion. Here, the image as a whole flicks back and forth between being a duck and then being a rabbit, constantly altering how the mind perceives it.

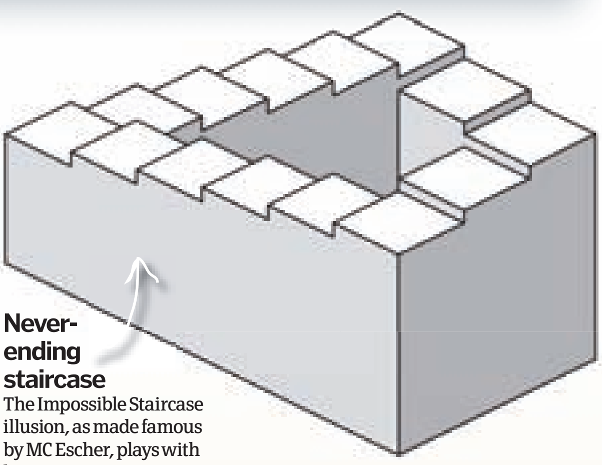
The Duck-Rabbit illusion, a good example of Gestalt organisation

DID YOU KNOW? Optical illusions can cause our brain to predict the future, although just 1/10th of a second ahead

Penrose triangle

Impossible geometry

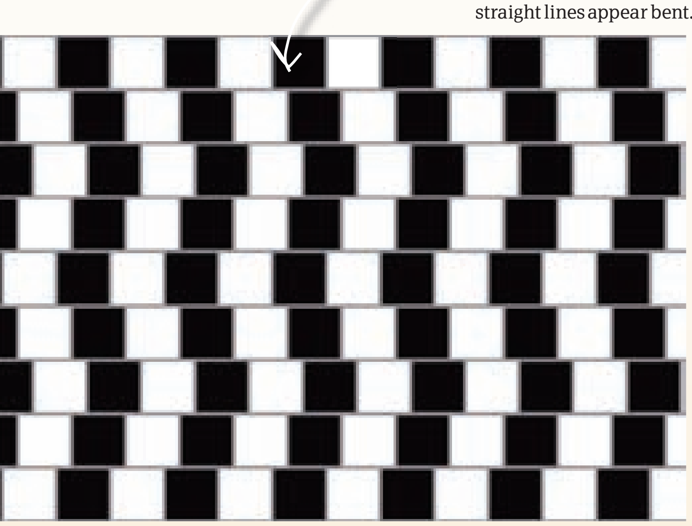
One of the most famous of the impossible object illusions, the Penrose triangle demonstrates how geometry can be warped to trick the mind.



Never-ending staircase

The Impossible Staircase illusion, as made famous by MC Escher, plays with basic geometry.

Described by Richard Gregory in 1973, the Café Wall illusion makes parallel straight lines appear bent.



Richard Gregory

Emeritus Professor of Neuropsychology at the University of Bristol

How It Works: Illusions vary in type and trick us in a variety of ways, be that through optical excess in certain stimuli (colour, contrast, perspective, distortion, etc) or through conscious or unconscious exploitation of assumptions made by the brain about the natural world. Why has the brain evolved to rely on such mechanisms?

Richard Gregory: The brain has a strictly impossible task seeing objects from images, which is why artificial intelligence is so difficult. There are always an infinite number of possible objects that might produce a given image. Perception works from probabilities based on previous experience and stored knowledge. The most probable is not always the correct answer, and in atypical conditions is usually wrong. What is surprising is how well human and animal perception normally works.

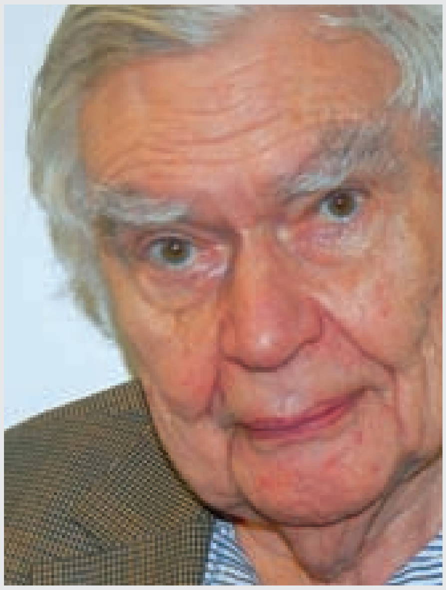
HIW: Interpretation seems central to making sense of the world and the contrast between illusion and non-illusion is an important distinction to make by the brain in achieving this. To what extent does the brain guess or create a hypothesis in representing objects? Would it be fair to say the brain predicts what it is about to see based on empirical evidence and inherited genetic code?

RG: Yes, perception has evolved to be essentially predictive as danger and reward lie in the (near or more distant) future. More generally, perceptions are predictive hypotheses, and are richer than the evidence. Science has surely developed from the brain's ability to create perceptual hypotheses, and has developed explicit strategies that give it extra power and reliability – though science is slow and needs human co-operation and instrumentation.

HIW: Illusions seem to originate, as you note in *Seeing Through Illusions*, either from bottom-up signals from the senses or from top-down knowledge represented in the brain. Is it important to differentiate these and if so, why? Further, how do illusions of reception differ from those of perception?

RG: By 'reception' I mean the first stages such as stimulation of the eye by patterns of light. Reception is relatively simple, giving reflexes and tropisms, while perceptions involve knowledge of objects and how they behave in various situations. Perception is cognitive while reception is more simply physiological. The distinction between bottom-up signals from the world of objects and top-down knowledge from past experience is fundamental for thinking about perception and its likely evolutionary origins. The brain predicts mainly from inductive generalisations and cognitive models or hypotheses of what is out there and what is going on. Perceptual prediction allows intelligent organisms to keep up and even behave ahead of events, and it works remarkably fast.

HIW: If we see phenomena as we understand them (or should that be misunderstand them in the case of illusions?) to what degree are flawed interpretations based on prior judgements? Does this inadequacy in human perception stem from evolutionary priorities?



RG: These are complicated issues. Understanding can be very different from perceptions. There should be far more studies of errors in the history of science and what causes them. We learn a great deal from errors and it seems odd that science does not use its own mistakes and blind alleys more effectively. Evolutionary priorities initiated perception, but through human curiosity and science the scene has changed fundamentally so its dreams can become realities, for example landing on the moon.

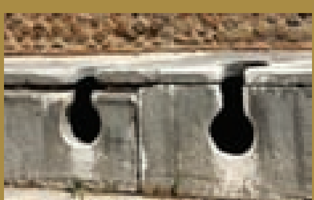
HIW: One of the most notable literal optical illusions is that of the Café Wall, which you described and wrote on back in 1973. Could you explain how this illusion works and what it teaches us about human cognition?

RG: The Café Wall illusion is interesting if only because it shows how lawful the early stages of perception are (especially reception). Varying the brightnesses or the separations of the lines affects the distortion lawfully and simply, as we would expect from physics rather than psychology. It seems to work from a process that normally corrects discrepancies at edges or borders, but in some circumstances produces distortions by pulling contrasting regions together across neutral regions, though they are really separate. Many illusions are due to generally useful processes producing errors in atypical situations. The Café Wall is a good example, from what we call 'border locking'. A more general and more theoretically important illusion is the Hollow Face –the back of a mask appearing convex simply because a hollow face is so unlikely. This is a cognitive illusion, where the physiological processes for seeing it are unimportant for understanding why it is an illusion and what it can tell us about normal perception.

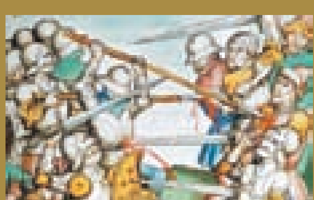
Read the review of Richard Gregory's book, **Seeing Through Illusions** on page 86

This month in **History**

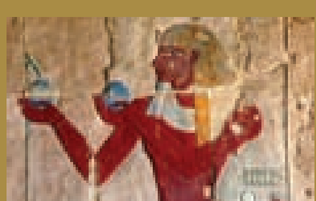
The History section is where we explain how it worked rather than how it works and here you'll find explanations of the machines, buildings, devices, inventions and even people from the past. If you've ever looked at images from the Hindenburg disaster and wondered just why these flying machines were attached to huge bags of flammable gas, then cast your eyes to the right to find out. Alternatively you can find out how Romans went to the toilet or how medieval knights protected themselves.



76 Roman toilets



77 Medieval armour



78 Hieroglyphics

HISTORY
74 Airships
76 Roman toilets
76 Medieval sextant
77 Armour
78 Hieroglyphics

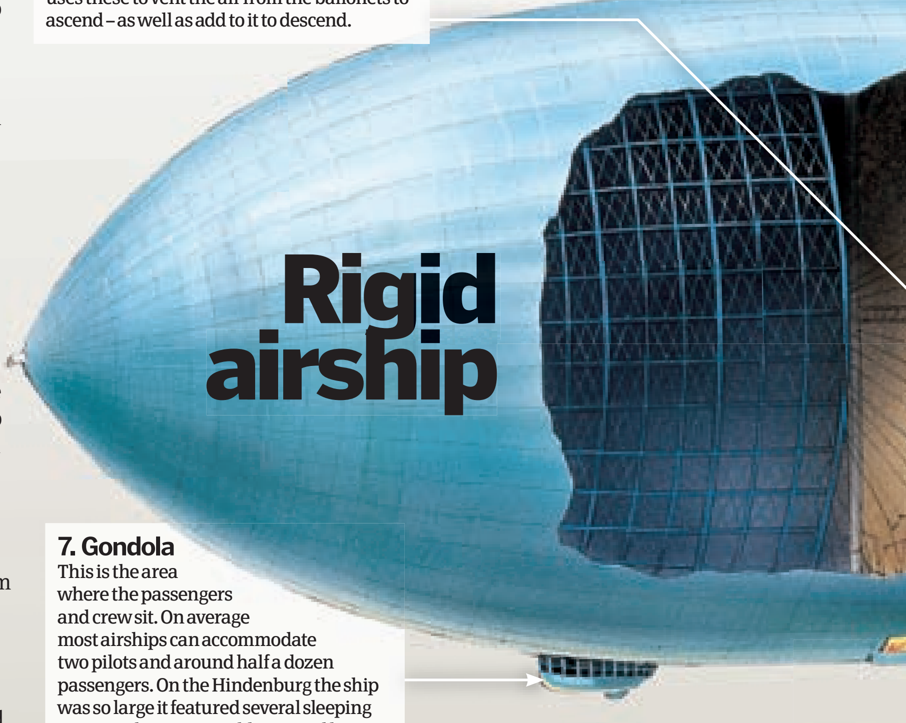
Airships

Combining both methods of a ship and a hot air balloon, we investigate how an airship flies

Airships use a combination of different gases in order to get off the ground, fly and descend. Today mostly helium gas is used to fly the lighter-than-air (LTA) craft, which although more expensive than hydrogen, was adopted as the non-flammable alternative after the infamous Hindenburg accident.

The helium-filled ship holds several 'tanks' of air known as ballonets. Because air is heavier than helium, all the pilot needs to do is open the air valves to release it and create positive buoyancy so the airship elevates. Once in the open skies the pilot controls the airship in flight much like a submarine under water, using a rudder to steer, adjusting the elevators to ascend and descend and throttling the engine (which provides forward and reverse thrust) to angle it into the wind.

At higher altitudes the air pressure outside the LTA decreases and so the helium in the envelope expands, to maintain pressure the pilot pumps air into the ballonets. This technique is also employed to descend, as filling the ship with more 'heavy' air makes it negatively buoyant and therefore sinks lower in the sky, or bring it in to land.



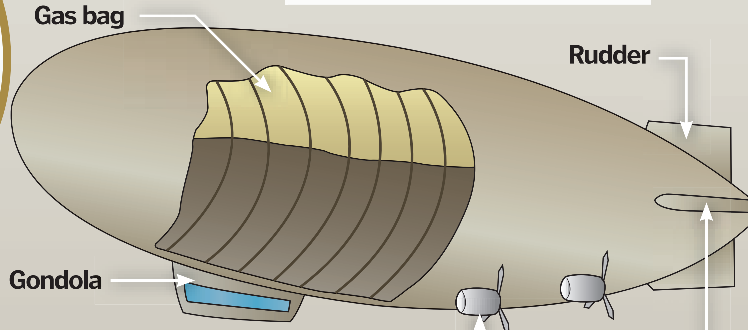
3. Air valves (inside envelopes)
Four air valves adorn an airship, and the pilot uses these to vent the air from the ballonets to ascend – as well as add to it to descend.

7. Gondola
This is the area where the passengers and crew sit. On average most airships can accommodate two pilots and around half a dozen passengers. On the Hindenburg the ship was so large it featured several sleeping rooms, a dining room, library and lounge.

6. Air scoops
The air scoops channel air from the propellers into the ballonets when needed. This is used to descend the aircraft. When the engines are turned off, electric fans move air into the ballonets instead.

The first airship

While the first hot air balloon was invented in 1783 by two French brothers – Jacques-Etienne and Joseph-Michel Montgolfier – the first powered airship was not constructed until many decades later in 1852. Henri Giffard built the first, which consisted of a 143-foot cigar-shaped gas bag with a propeller. It was powered by a three-horsepower steam engine. Just under half a century later in 1900 Count Ferdinand von Zeppelin of Germany invented the first rigid airship and therefore his name and work lives on.



DID YOU KNOW?

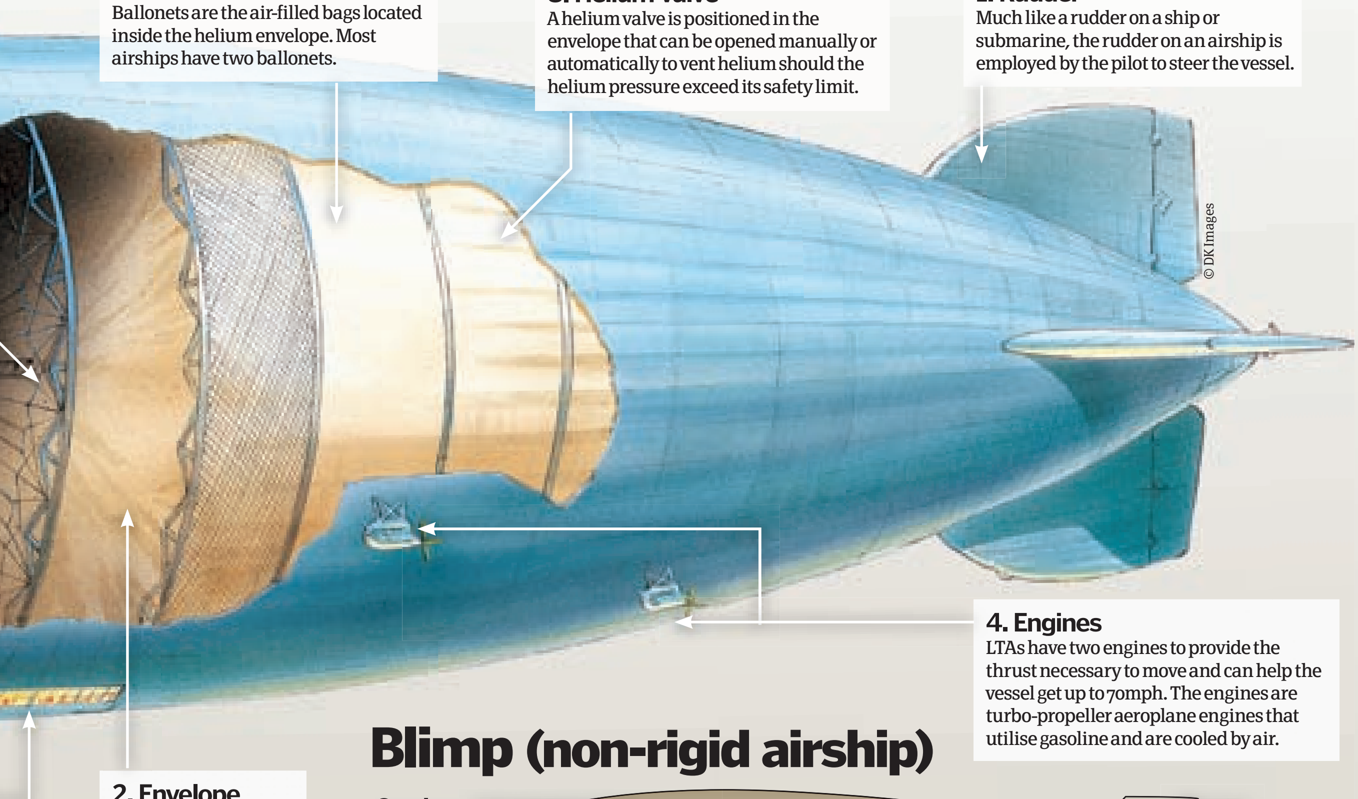
Multi-talented machines

Airships can stay elevated from a matter of hours to a stretch of several days, making them ideal for research or for watching sports events and so on. In recent times scientists have been adopting the method of transport to study whales, thanks to their less disturbing nature than helicopters, boats and planes.

Hindenburg

The German Hindenburg airship took off from Frankfurt in May 1937, taking just two and half days to reach New Jersey. The ship measured over 800 feet in length and weighed 242 tons. Accommodating a rigid design, it was filled with hydrogen – a much cheaper gas than the helium used today. On arrival it hovered tentatively over its landing area as 200 ground crew attempted to retrieve it with its landing lines. A small burst of flames was spotted on the upper fin and in just 34 seconds – reacting with the highly combustible gas – the ship was transformed into a huge fire ball. Some of the people on board jumped to safety and landed on the sand below, but 13 passengers, 22 crew and one ground man were killed in the accident.

An infamous image of a catastrophic disaster



5. Ballonets
Ballonets are the air-filled bags located inside the helium envelope. Most airships have two ballonets.

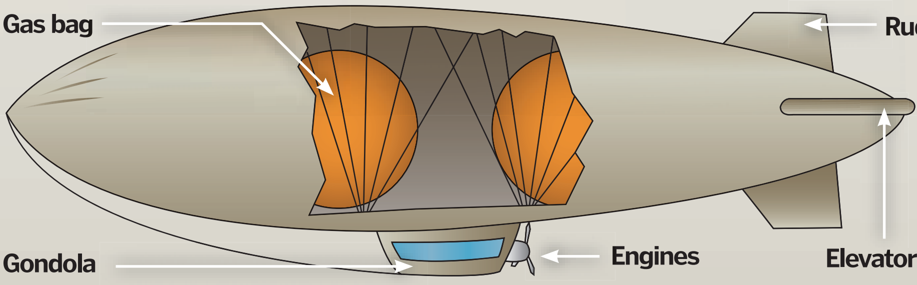
8. Helium valve
A helium valve is positioned in the envelope that can be opened manually or automatically to vent helium should the helium pressure exceed its safety limit.

1. Rudder
Much like a rudder on a ship or submarine, the rudder on an airship is employed by the pilot to steer the vessel.

4. Engines
LTAs have two engines to provide the thrust necessary to move and can help the vessel get up to 70mph. The engines are turbo-propeller aeroplane engines that utilise gasoline and are cooled by air.

2. Envelope
This refers to a large bag filled with helium gas. Made of an airtight, lightweight fabric, the envelope holds between 67,000 to 250,000 cubic feet of helium depending on the size of the airship.

Blimp (non-rigid airship)



Steering

If you'll imagine a submarine gaining positive and negative buoyancy to move up and down in the water by taking on and losing air, the same principle applies to airships but in reverse. To elevate the ship the pilot releases air so it becomes lighter, and to descend in the air the pilot releases air from the ballonets into the envelope to make it sink. A rudder is used to steer the direction of the ship but the pilot can manipulate the engine to move forwards and backwards, or to angle it into the wind.

Head to Head
TYPES OF AIRSHIP

RIGID

1. Hindenburg
Facts: Rigid airships are typically long to an excess of 360ft (120m) and are traditionally cigar shaped in appearance. They feature an internal metal frame and gas-filled bags.

SEMI-RIGID

2. Norge
Facts: A semi-rigid airship features a pressurised gas balloon (known as the envelope) that is attached to a lower metal keel.

NON-RIGID

3. MetLife, Fuji or Goodyear blimp
Facts: Perhaps one of the most common styles of airship seen today, the non-rigid airship – or blimp – features a large gas-filled envelope.

Learn more

For more information about airships and zeppelins you can visit **www.airships.net** for pictures, articles and a history of the Hindenburg and Graf Zeppelin crafts.

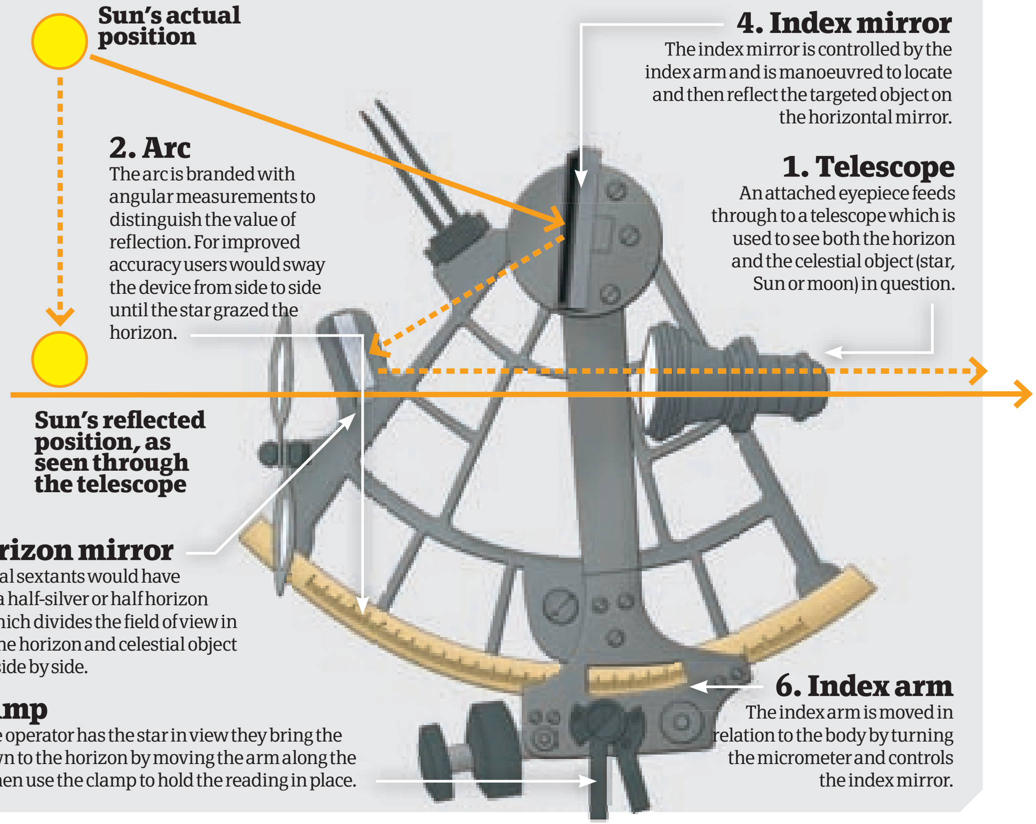
"The 'flushing toilet' was intended to rid the city of Rome of human waste and maintain good sanitation"

The medieval sextant

Although not the most precise of tools, a sextant is a medieval instrument used for calculating the angle of a celestial object with the horizon

To measure the angle between the horizon and a star, the Sun, the moon or a planet, the user has to peer through the telescope and locate the horizon.

The tool features two mirrors that are parallel but are offset from one another; a horizon mirror and an index mirror. The telescope must be fixed to look at the horizon and the radial arm is moved along the arc scaled in degrees. The arm is moved to manoeuvre the mirrors into position so that the reflection of the targeted star, for example, comes into view – first reflected in the index mirror and then off the horizon mirror down through the telescope until it lines perfectly with the horizon in a dual-like view. Practitioners claim the angle between the first and last direction of the ray of light is twice the angle between the mirrors – which is measured on the arc to decipher the angle of the star.



4. Index mirror
The index mirror is controlled by the index arm and is manoeuvred to locate and then reflect the targeted object on the horizontal mirror.

2. Arc
The arc is branded with angular measurements to distinguish the value of reflection. For improved accuracy users would sway the device from side to side until the star grazed the horizon.

1. Telescope
An attached eyepiece feeds through to a telescope which is used to see both the horizon and the celestial object (star, Sun or moon) in question.

3. Horizon mirror
Traditional sextants would have featured a half-silver or half horizon mirror which divides the field of view in two – so the horizon and celestial object are seen side by side.

5. Clamp
When the operator has the star in view they bring the body down to the horizon by moving the arm along the arc and then use the clamp to hold the reading in place.

6. Index arm
The index arm is moved in relation to the body by turning the micrometer and controls the index mirror.

Roman toilets

A flushing toilet can be found in every home, but it hasn't always been this way

Originally installed in the homes of the rich as a status symbol, and in army barracks to prevent diseases spreading, the 'flushing toilet' was intended to rid the city of Rome of human waste and maintain good sanitation. By AD 315 the capital had 144 public toilets, predominantly housed within the confines of the public baths.

The toilets were communal and typically featured a marble bench with a succession of holes. The bench was built over a channel of flowing water which would 'flush' the human waste away. Seven rivers were forced to run through the city's man-made sewers which served as a way of flushing the sewage out of Rome.

A shallower, narrower channel of water ran in front of the seats and was created as an off-shot from the main source. Placed within this stream were sticks holding a sponge, ready for the Roman to wipe themselves clean after using the facilities.

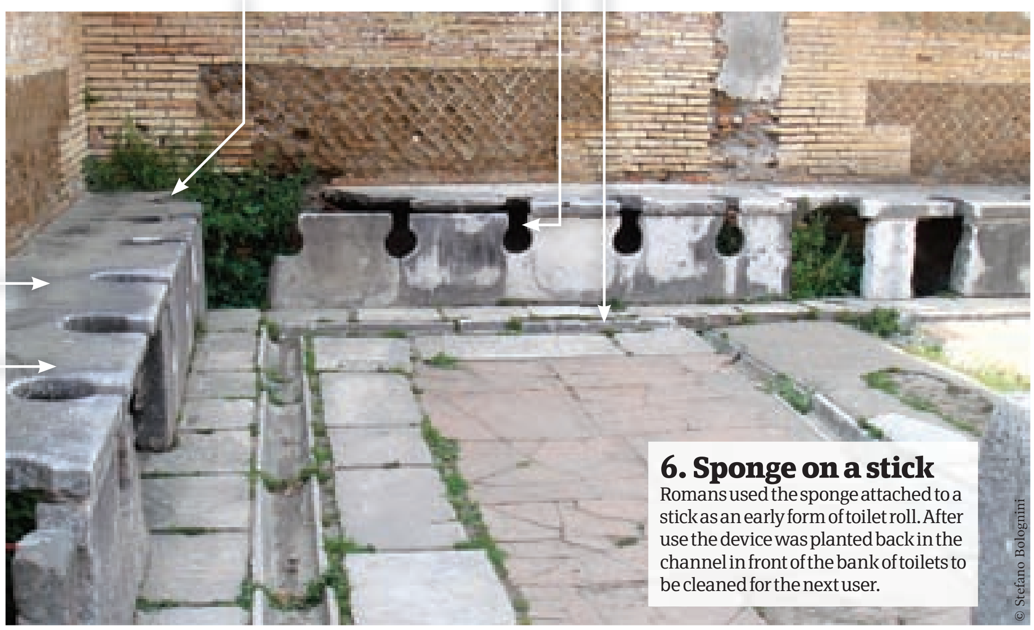
3. Sewer
Underneath the bench of toilets was the sewer. The Romans forced seven rivers through the city to offer a constant flow of running water.

4. Flush
The constant running water meant that anything deposited into this channel was clearly swept away out of the baths or private residences and out of the city.

1. Material
In public baths and private homes the toilet seat itself was fashioned predominately from marble.

2. Holes
The holes were made at the same size and equal distance apart to allow the user room to deposit.

5. Sponge stream
A narrow stream flowed past the feet of the seated Romans. This was to clean the sponges on sticks used to wipe themselves clean.



6. Sponge on a stick
Romans used the sponge attached to a stick as an early form of toilet roll. After use the device was planted back in the channel in front of the bank of toilets to be cleaned for the next user.

© Stefano Bolognini

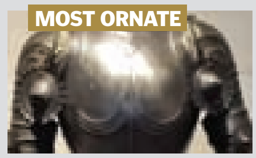
HEAVIEST

1. German
The German style was called 'Gothic' and had brutal lines and pointed tips. Germany was a centre of armour production in the medieval period.

MOST DECORATIVE

2. Italian
Lighter and known as the 'Milanese' style, Italian armour was highly decorative and among the most expensive in the world.

MOST ORNATE



3. Spanish
The most ornate suits of armour created in the medieval period came from Spain. Some were made from Toledo steel, seen to be the best in the world.

DID YOU KNOW? Until the early 15th Century, knights would wear cloth surcoats over their chain mail and plate armour

The famous picture by Dürer of a knight dressed in high-gothic armour

Medieval armour

An iconic image of the middle ages, crafting, donning and utilising medieval armour were complex skills, requiring great expertise

Medieval armour worked by protecting its wearer in battle through a series of fashioned steel plates and chain mail links. To achieve this, armour was designed to absorb impacts from blunt weapons such as maces and flails and deflect slashing or piercing weapons that, despite the strength of the fashioned steel, could still pierce it at weak points with enough force. Despite their apparent appearance of massive weight, these suits of plate mail were actually rather light (on average around 25kg/55lb) and were individually crafted to fit their owner as well as possible, maximising movement and dynamism while also taking into account the fighting style of its wearer.

There were two centres of armour production during the middle ages, the south of Germany and the north of Italy. German sets of armour, such as the one featured here, were referred to as 'Gothic' in style and featured brutal, jagged lines and pointed tips. The Italian style was referred to as 'Milanese' – due to the armour smiths' proximity to Milan – and was more decorative and lighter than their German counterparts. Kings, princes, dignitaries and successful knights often commissioned armour personally, and these suits were often inlaid with personalised etchings or engravings. This trend became much more common after the style of wearing a cloth surcoat over suits of armour phased out at the end of the 14th Century, allowing knights to show-off their power and prowess in the form of ornate decoration.

Encased within plate armour such as this, a knight was only vulnerable to powerful steel crossbows and, due to the rapid increase in gunpowder technology during the 16th Century, handguns and muskets. In fact, as guns became more and more widespread, the plate mail armour was increasingly phased-out due to its inability to stop fired rounds, ending up by the 17th Century reduced to purely ceremonial roles and historical re-enactments.

Parts of a suit of armour

1. Helmet
Crucial for taking and deflecting critical blows to the head, helmets often only left a thin slit for the knight to see through. Protective visors were also common.

2. Vambrace
These tubular parts of the suit of armour were lightweight and provided much-needed arm defence.

3. Breastplate
Ornate with elaborate designs common throughout the 15th Century, the breastplate was fashioned out of hardened steel to deflect blows.

4. Besagew
To aid mobility in combat, full suits of armour left gaps around joints. To protect these around the armpit a knight would wear a pair of these mini shields.

5. Gauntlet
This was the armour to defend the hand, which evolved out of a chain mail mitten. However, by the 15th Century multi-plate gauntlets were being produced that allowed individual finger movement.

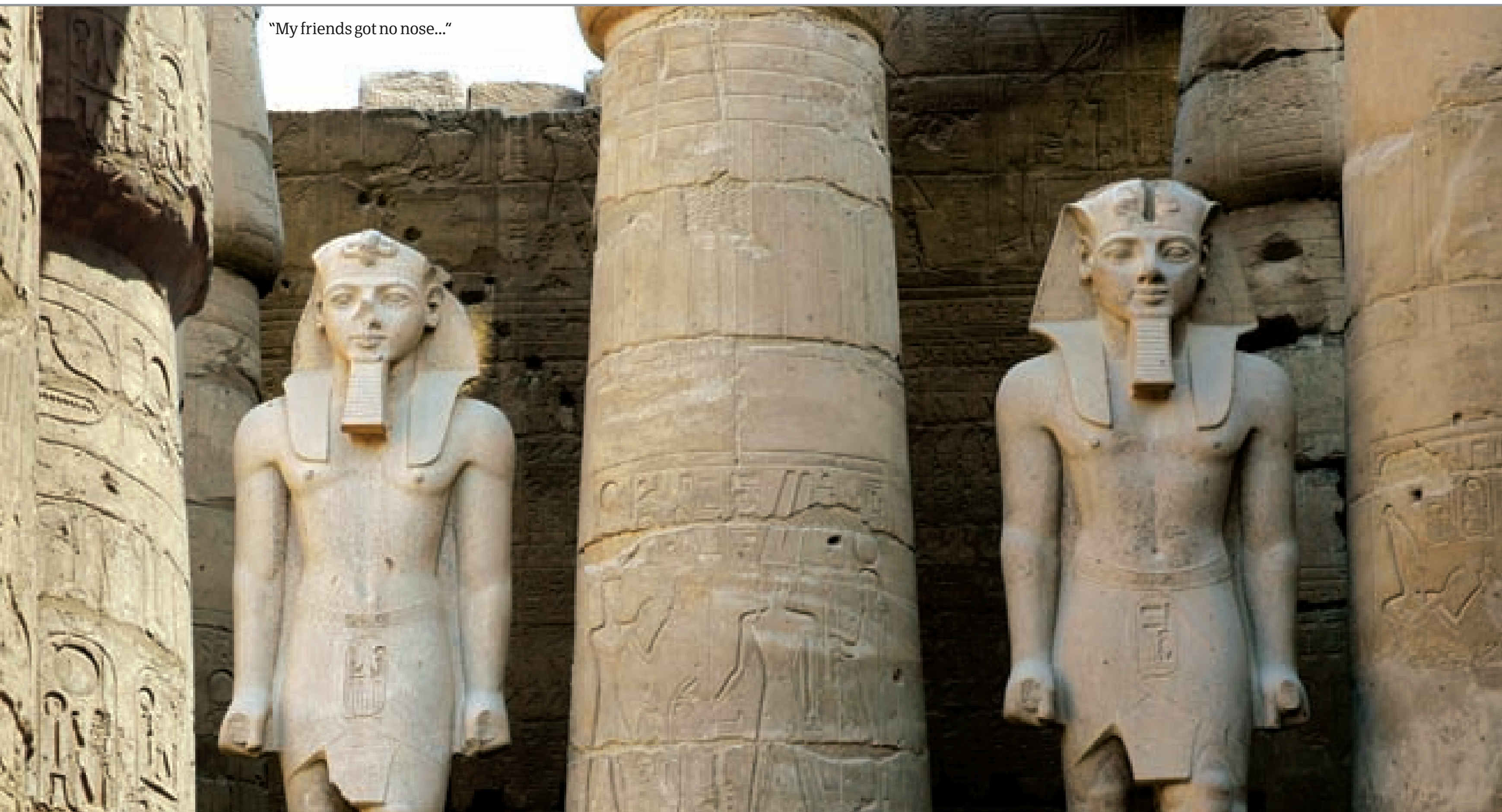
6. Cuisse
Protecting the thigh of the knight, the tubular cuisse was connected to the greave through a knee plate and series of leather straps.

7. Greave
Similar in construction to the cuisse, the greave provided protection for the shin and lower leg.

8. Sabaton
Sabatons were made from numerous articulated steel plates ending in a solid toecap.

9. Chain mail
Underneath the plate mail knights would wear a body suit of chain mail in order to protect exposed areas between individual plates.

"The language could be written left to right, or right to left, and executed both vertically or horizontally"



"My friends got no nose..."

Hieroglyphs

Understanding the language of the gods

In order to learn the Egyptian script (known in ancient times as medu netcher or `words of the gods`), it is best to start with the alphabet, which is published here in full. As you start to recognise the words and names in the Egyptian script you begin to understand the excitement and adrenaline that historians must feel when deciphering an ancient text – by doing so, you gain a unique insight into this incredible and mysterious civilisation.

The language is elaborate but also very accessible; it employs a series of grammatical structures that include verbs, nouns, negatives and particles; the Egyptians also used onomatopoeic words, for example `cat` is written `meow.` The language also contains a series of pictograms and phonograms, and is interspersed by determinatives. These are placed at the end of words in order to clarify their meaning.

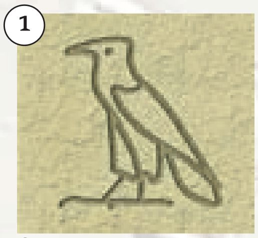
The script has an abundance of symbols that reflect the natural world; birds, mammals and trees often provide clues to the true meaning of the text. The language could be written left to right, or right to left, and executed vertically or horizontally. The script is continuous and you can learn to separate the words by identifying the determinative or the strokes at the ends of each section.

DID YOU KNOW?

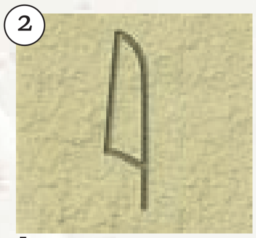
Ancient scribes

Most Egyptians were illiterate. They employed scribes who would write their letters on rolls of papyrus using reed pens and black ink.

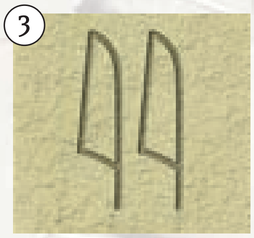
DID YOU KNOW? The Egyptians wrote poetry, curses, hate mail and fairy tales. They believed words had magical powers

1


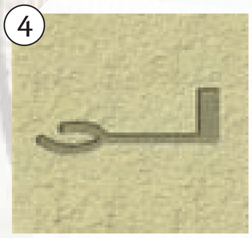
ꜣ (`ahhh`)
Egyptian vulture. This ominous bird is associated with both battlefields and graveyards.

2


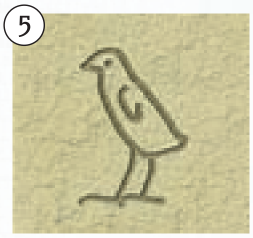
i
A flowering reed. The reed was used to make arrows and writing tools.

3


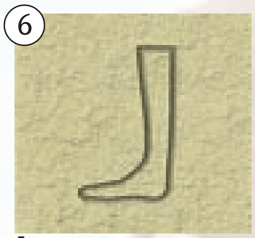
y (`eee`)
Two flowering reeds or strokes that may have represented the sound of the wind on rushes.

4


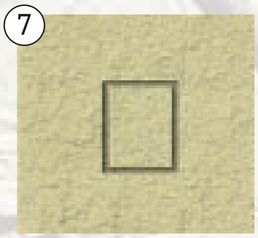
ꜥ (e)
The arm is often used in the Egyptian language to represent might or power.

5


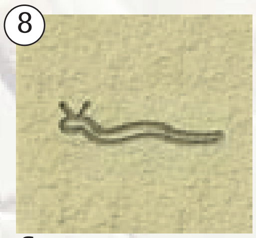
w (`ooo`)
The quail chick adds a pleasant sound. It is often employed among signs that represent time.

6


b
The foot and leg. Egyptians became familiar with human anatomy through mummification.

7


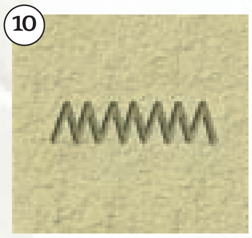
p
A seat, stool or throne. A sign in ancient Egyptian used frequently in royal titles.

8


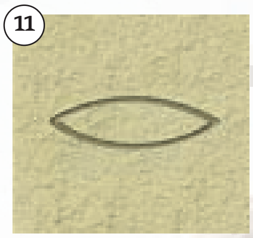
f
The horned viper is one of many snakes used in ancient Egyptian, it is often attached to a verb.

9

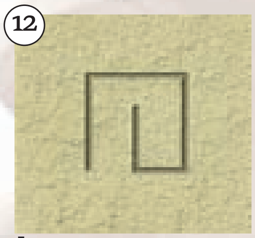

m
The owl is a common letter. It is rare to see the full face of any creature in imagery.

10


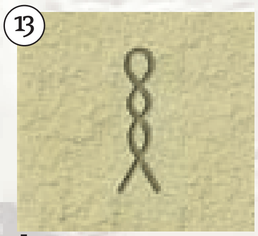
n
A water ripple is used to note transience, the words `to` and `towards` often contain this.

11


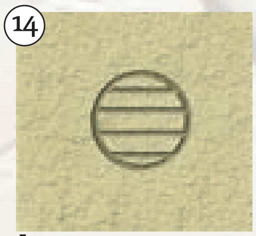
r
R is shown as a mouth. The letter is used in the words `recitation`, `to eat` or `to speak'.

12


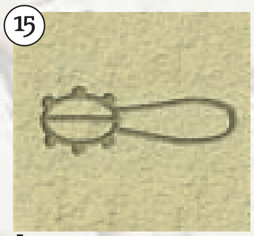
h
There are various `h` sounds in the alphabet. This sign shows a rural shelter or a house.

13


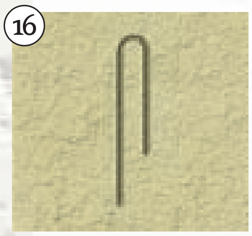
h (emphatic `h`)
A twisted piece of flax. Flax was a common material in ancient Egypt.

14


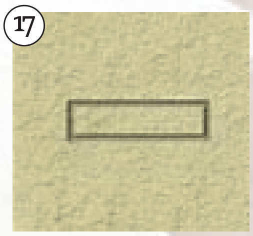
h (as in hock or lock)
The placenta can be found in many words including those that deal with fortune and smell.

15


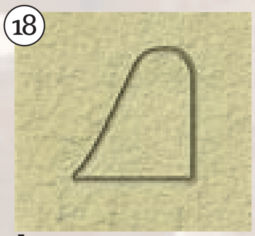
h (`ich`)
The belly of an animal; this letter is used in words that denote the physical form.

16


s - 2 symbols
A door bolt and a folded sheet of cloth. It sounds like the English `s`. It has several different variations.

17


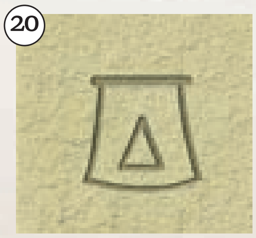
s (`sh`)
Water features were a symbol of affluence and upper class villas were designed with pools.

18


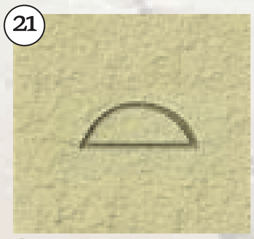
k (like `qu` in quaint)
The hill sign is used in the words `tall,` `high` and `exalted` as well as `high ground` or `summit'.

19

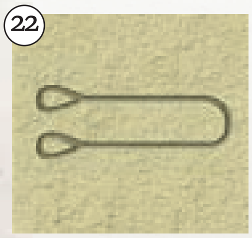

k
A reed basket with a handle. This can be used in many contexts and is employed as the pronoun `you.`

20


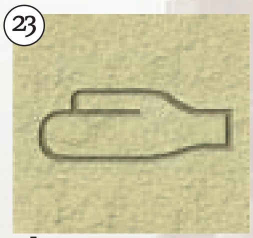
g
The Egyptians were fond of wine. The sign of this jar stand is transliterated with a hard `g'.

21


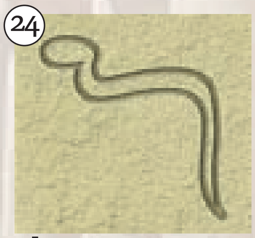
t
Bread was the most basic food in Egypt, here we see a small loaf of oven-baked bread.

22


t (`tsh`)
Tethering rope. The Egyptians had 38 signs for ropes and baskets. `t` is also a pronoun.

23


d
Human hand. There are 63 signs for the human body. This sign was used for words of action.

24


d (dj)
Snakes were feared creatures. This letter is often used in words of declaration or recitation.

The Rosetta Stone

The ultimate code-breaker

The Rosetta Stone is viewed as one of the most remarkable finds of the ancient world. It was discovered in Egypt in 1799. The top and middle sections of the stone are carved with hieroglyphs and demotic – a variation of the Egyptian text.

The lower section is decorated with the Greek script which ultimately acted as a code breaker for the upper sections. A series of scholars were involved in the race to decipher the hieroglyphic code but the breakthrough is credited to Jean-Francois Champollion (1790-1832). Champollion used the Greek portion of the text to reveal the secret language of the pharaohs.

The missing link
The Greek text helped decipher the hieroglyphs

Learn more

For more information about ancient Egypt and the use of hieroglyphs, point your browser to **www.bbc.co.uk/history/ancient/egyptians/** where you can learn more about this long-forgotten culture and get an insight into the daily life of an Egyptian civilian.

BRAIN DUMP

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HOW IT WORKS EXPERTS

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

Sam Furniss
Science Museum Explainer

Sam has a background in drama and uses this to excite and inspire visitors about science. An aspiring stand-up comedian, Sam's favourite part of the Explainer role is interacting with the visitors in Launchpad – the Science Museum's main interactive area. This is Sam's first time on our panel and he's provided the answer to questions on snow and the Indian summer.

Chi Wing Man
Science Museum Explainer

Chi Wing Man is a recent addition to the Explainer team and is another first-time member of the panel. His background is in biochemistry and teaching and Chi loves to make science engaging and fun, and he can also make an excellent doner kebab. Turn over the page for Chi's explanation of why carbon monoxide is so deadly.

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 giant bubbles he trains the Explainer team in the principles of science.

Why is snow white?

Katy Kruick

■ To answer this question there are two things which need to be considered – colour theory and refraction.

Refraction is the change in direction of light as it goes from one material to another. It is due to a slight change in speed of the light and it explains why straws look bent in water. When light enters snow, it refracts. This is because snow is made from lots of ice crystals tightly packed together, the important fact here being that these crystals are translucent (light can pass through but not in a direct path – it changes direction).

Additive colour mixing tells us that if we combine all of the frequencies of colours we get white light. When light falls on snow it is composed of a mixture of different frequencies which all refract slightly differently as they enter the ice crystals. Eventually due to refraction, the light leaves the surface of the snow in all directions and hits our eyes. This light is composed of a mixture of frequencies which our eyes detect as white light.

Sam Furniss

How does a Galileo thermometer work?

Sarah Cook

■ The Galileo thermometer consists of a vertical glass tube, typically filled with water, and sealed glass bubbles containing coloured water or alcohol. Each bubble is also attached to a specific mass (labelled with the temperature it represents) to calibrate its density (the amount of mass in a given volume). The temperature can be read by interpreting the distribution of these bubbles. The principle of buoyancy states that if an object is less dense than a liquid, it floats; and if the object is denser than the liquid, it sinks.

When the temperature of the liquid in the glass tube begins to warm up, it expands; hence lowering the density of the liquid, as its mass now occupies a larger volume. The opposite occurs when the temperature cools (ie density of the liquid increases). Therefore, if a bubble becomes denser compared with the liquid, it sinks; and if less dense, it floats.

Chi Wing Man

© Science Photo Library

The convoluted tale of the contrail, explained

Why do those long, white clouds form behind jets?

Craig Wilson

■ These long white clouds you are referring to are called condensation trails or contrails. Jet fuel is made of carbon and hydrogen which burns in the presence of oxygen. In this reaction some of the carbon joins with the oxygen to make CO2 (carbon dioxide) and some of the hydrogen joins with the oxygen to make H2O (water). The water which comes out of the engine is invisible water vapour but as soon as it is exposed to the colder temperatures of the upper atmosphere, it condenses into little drops of liquid water which become suspended in the air which is what we see as contrails.

This is a similar effect which you notice on a cold day when you breathe out; the water vapour in your breath condenses as it meets the cold air and you can see the breath.

Rik Sargent

What is an Indian summer?

Nigel Peterson

■ The definition of an Indian summer is a period of mild sunny weather that is out of season. The term is commonly used to describe a sunny spell which can occur after the first frost. The first recorded usage of the term was in 1778, from a Frenchman who lived in America called John de Crevecoeur who mentioned it in a letter. The term had spread to Britain by the 19th Century.

Indian summers are caused by stalled high pressure, this high pressure pushes air towards areas of low pressure which makes wind. Due to the rotation of the Earth these winds rotate counter-clockwise about the northern hemisphere and can sometimes curve south picking up warmer air and bringing it further north making it unseasonably warm.

Sam Furniss

sciencemuseum

What's on at the Science Museum?

New! Hubble 3D at the IMAX 3D Cinema

■ From 19 March ■ Prices: £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 and important tasks in NASA's history, and experience 3D flights through amazing imagery. Narrated by Leonardo DiCaprio.

1001 Inventions

■ Till 30 June ■ Free

Tracing the forgotten story of 1,000 years of science from the Muslim world, from the 7th Century onwards. Featuring interactive exhibits, displays and dramatisation, the exhibition explores the shared scientific heritage of diverse cultures and also looks at how a large number of modern inventions can actually trace their roots back to Muslim civilisation.

Force Field – the ultimate multi-sensory experience

■ Permanently open ■ £5.00 adults and £4.00 children/concessions, family tickets 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.

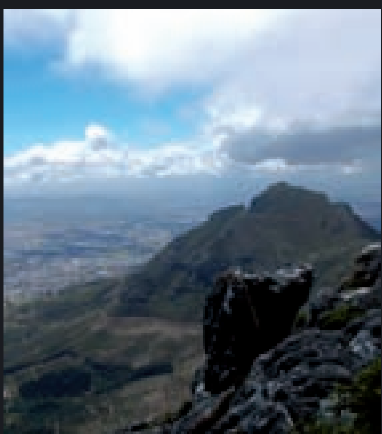
Who am I?

■ Coming soon – opening June 2010 ■ Free

To mark the end of its centenary year, the Science Museum will open an upgraded version of the 'Who am I?' gallery in June. Who am I? presents the latest in brain science and genetics through a mixture of exciting interactive exhibits for everyone to enjoy.

FROM THE FORUM

Every month we'll feature a reader's question from our fantastic forum at ***www.howitworksdaily.com/forum***



Why is it colder at the top of a mountain than it is at sea level?

Daniel Owen

■ The lowering of temperature as you reach higher altitudes is due to the change in atmospheric pressure. You may be aware that the air around us is constantly exerting pressure on us due to there being lots of air above us weighing down on us. It sounds a bit strange to say that air weighs something but it does, we just don't feel it because it is what we're used to, just like gravity is constantly pulling us down.

There is a direct relationship between temperature and pressure. If you increase the pressure of a system then the temperature will get higher. This is why bicycle pumps can get hot after use. Decrease the pressure and the temperature goes down as can be experienced letting the air out of a balloon very quickly, the balloon gets cold.

As you go higher up, the pressure gets less and less due to there being less air above you weighing down on you, therefore the temperature goes down too.

Rik Sargent

How do the streetlights turn on automatically at night?

Steve Betts

■ The most commonly used component in streetlights is called a cadmium sulphide photoresistor, or a CdS cell for short. The CdS cell changes the resistance of a circuit depending on the amount of light shining on it. When lots of light falls on a CdS cell, then the resistance is very low, which means it conducts electricity well. When there is not much light, the photo-resistor has a high resistance which means not much current can flow.

This change in current can then be used to control a relay. A relay is basically an electromagnetic switch; when the electromagnet has a high current (lots of light falling on the photo-resistor – daytime) then it pushes the switch open so no current can flow to the streetlight. When it gets dark, then not much current can flow to the electromagnet so the switch closes and allows electricity to flow to the streetlight, turning it on.

Rik Sargent

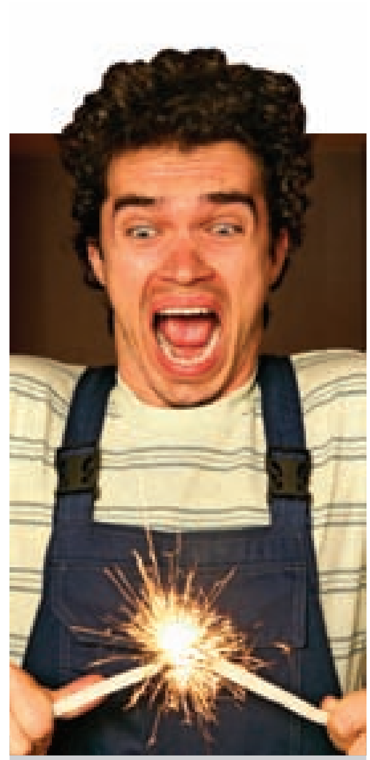
How do fans make you feel cooler?

Sarah Dobson

■ Switching on a fan and feeling a nice breeze can feel very refreshing on a hot day, but what is going on? Is the fan taking some of the heat energy away? In a small, perfectly insulated room, switching on a fan can increase the temperature in the room as fans usually have a motor which gives out heat.

The reason why fans make you feel cool is due to something called the wind-chill effect. Blowing air over your skin causes quicker evaporation of sweat which allows your heat energy to escape much quicker than normal, making you feel cooler. Let's hope we'll be needing them soon!

Rik Sargent



What are amps, watts, volts and ohms?

John O'Toole

■ Amps, watts, volts and ohms are units of measurement in a similar way that the metre is a unit for distance. The ampere (often shortened to amp) is the unit of electric current. The symbol for amps is A. Current is a measurement of how much charge is moving through a particular point in a unit of time. One amp is the current generated when 6.242×10^{18} electrons pass a particular point per second. That's 6,242 followed by 15 zeros – a lot of electrons!

Watts are a measurement of electrical power. The symbol for the watt is W and one watt = one joule per second (joule is the unit of energy). So a 60W light bulb converts 60 joules of electrical energy to heat and light energy every second!

Volts are the unit of measurement for voltage. Voltage is a measurement of electrical potential energy per unit charge and one volt is equivalent to one joule per coulomb (coulomb is the unit of charge).

When current flows through something, it'll experience resistance. This is measured in ohms. Some materials like wood have a high resistance which means little current can flow through. Other materials like copper have a low resistance and conduct electricity well.

Rik Sargent

Carbon monoxide is produced when carbon-based fuels like wood and oil are burnt

Why is carbon monoxide poisonous?

Paul Lawrence

■ Carbon monoxide (CO) is a poisonous, colourless, odourless and tasteless gas, which is formed when there is not enough oxygen present when carbon-based fuels such as wood and oil are burnt (ie incomplete combustion). Exposure to carbon monoxide can cause symptoms that include headaches, nausea and even death.

Carbon monoxide poisoning is mainly caused by your body's cells being deprived of oxygen, which is used to release energy from your food via aerobic respiration. Oxygen is usually carried through the circulatory system by haemoglobin found within red blood cells, with each haemoglobin protein being able to carry up to four oxygen molecules at a time. However, carbon monoxide reduces the amount of oxygen being delivered to cells in two ways. Firstly, the affinity (strength and likelihood of binding) of haemoglobin to carbon monoxide is over 200 times greater compared to that with oxygen. This means carbon monoxide is more successful while competing for the same binding site as oxygen on haemoglobin, therefore reducing the amount of oxygen that's carried. Secondly, if a carbon monoxide molecule binds with haemoglobin, subsequent oxygen molecules are bound more tightly, preventing the oxygen from being released.

Chi Wing Man

THE HOW IT WORKS KNOWLEDGE

...rs of kit and savants of stuff

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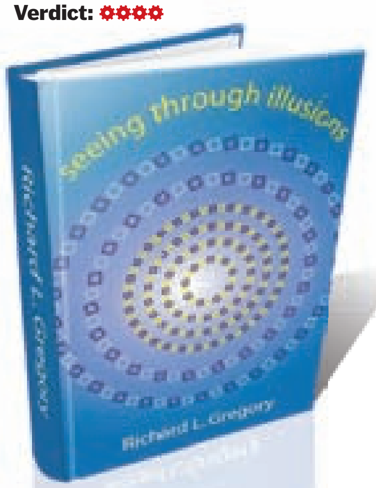
Weapon

Price: £20.00 / $30.00
ISBN: 978-1-4053-2918-7

Produced in association with the Royal Armouries Museum, *Weapon* is a definitive guide to weapons and armour throughout history, ranging from the ancient world of 3000 BC right up to the modern day. The level of photography is astounding and really makes you appreciate – albeit in a perverse sense – the care and craft that goes into constructing these tools of death.

Verdict: ★★★★



Seeing Through Illusions

Price: £16.99 / $34.95
ISBN: 978-0-19-280285-9

As ever with publications from the Oxford University Press, *Seeing Through Illusions* by notable neuropsychologist Richard Gregory is an authoritative and vivid exploration of illusion, perception and cognition. Through a variety of examples Gregory demonstrates how illusions provide important insights into how the brain perceives the world and how humans have evolved through time. Academic yet highly approachable.

Verdict: ★★★★

HOW IT WORKS EDITOR'S CHOICE AWARD

Four cylinders and 100 parts equal...

Internal combustion engine

Price: £29.99 / $45.99
Get it from: www.curiousminds.co.uk

ALMOST EVERYBODY DRIVES nowadays, yet despite there being record numbers of cars on the road, few owners understand how their engines work. With this set from Haynes, however, anyone of any age can build a working model (eight inches tall by 11 inches wide) of a four-stroke internal combustion engine. Don't worry, though, because this engine runs off two AA batteries – so you don't need to mess around with pumps and fuel to get it working.

The kit comprises of 100 parts and a detailed instructional manual that provides a step-by-step guide to assembling the moving pistons, camshaft, cooling fan, valve gear, timing belt, spark plugs and engine casing. The guide is excellent in other ways too as it also includes illustrated articles explaining how the engine and its individual components work, as well as fun 'did you know' type titbits and information.

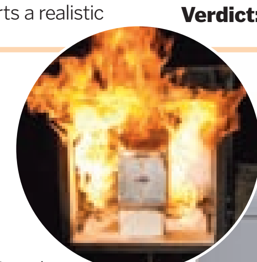
Along with the guide and components, the kit also includes an electric motor, screwdriver, screws, drive module, ignition pack and spark plug lights to set you on your way.

When fully built – a rewarding task in its own right – the engine can be turned on and off easily and sports a realistic ignition sound, illuminating spark plug lights and movable belt-driven fan, all the while having its pistons move accurately up and down as they would in a real engine. Obviously, because this is merely a model and not a realistic highly complex engine system, certain parts have been omitted from the build, such as the carburettor, dipstick and flywheel, however their exclusion helps keep the model clean and accessible to all.

Verdict: ★★★★★

ioSafe Solo

Like Superman, it's pretty much indestructible



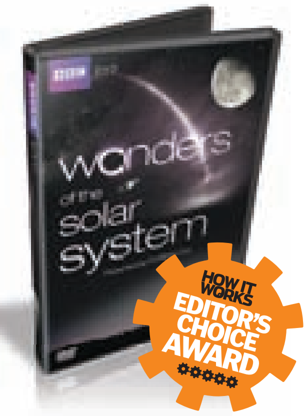
£199.99 / $249.99
Get it from: www.iosafe.com

DATA LOSS IS a major annoyance for anybody. Those times when that impressive collection of pictures, MP3s and videos goes up in smoke thanks to a drive burnout or you spilling your can of Sprite into the heart of your PC is just not very pleasant and can ruin the cheeriest of days. The good news, however, is that now you can safeguard against such eventualities with the ioSafe Solo, a heavy-duty external hard drive with an epic threshold for damage.

Coming in both SSD and standard disc forms, as well as in a variety of sizes, this external drive is wrapped up in a protective shell that is fire proof up to 1,550°F, waterproof for up to three days, and shock proof. In addition to these physical protections, the ioSafe Solo provides a high-grade Air Flow Cooling system, which ensures reliable 24/7 running no matter what the exterior temperature. Finally, the ioSafe can also be bolted down to any surface, safeguarding against potential theft.

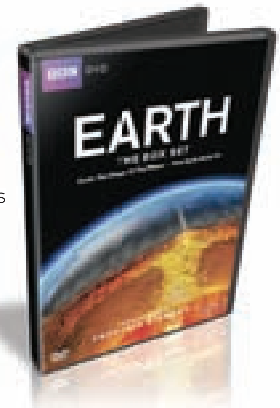
Verdict: ★★★★

Wonders Of The Solar System



■ **Price: £12.93 / $19.99**
■ **Get it from: www.bbcshop.com**
Presented by Professor Brian Cox, *Wonders Of The Solar System* is a passionate, enthused and accessible series on the phenomena of space. Using the very latest breathtaking images sent directly from space, as well as cutting-edge scientific statistics and knowledge from active space probes and lunar rovers, Professor Cox takes the viewer on a journey from the Sun to the far-out reaches of Neptune and beyond.
Verdict: ✪✪✪✪✪

Earth: The Box Set



■ **Price: £24.99 / $40.00**
■ **Get it from: www.bbcshop.com**
This handy box set combines BBC documentaries *Earth: Power Of The Planet* and *How Earth Made Us*, both presented by famous geologist Professor Iain Stewart. Interestingly, both series focus on the effects the Earth has had on humanity instead of the effects humans have had on the planet throughout history, highlighting how it works and what makes it so special. Visually it's very impressive and some of the locations provide a fascinating in-depth look at the history of our planet.
Verdict: ✪✪✪

Richard Hammond's Invisible World

■ **Price: £10.99 / $17.99**
■ **Get it from: www.bbcshop.com**
Forget the celebrity endorsement and *Richard Hammond's Invisible Worlds* is an interesting series where the invisible forces that shape our world are laid bare through cutting-edge imaging technology. From spectacular phenomena such as vast, super-fast lightning clusters, to the shrouded aerodynamics of bats, through to the microscopic world that lies beyond the vision of the human eye, *Invisible Worlds* is a great technical success and an entertaining watch.
Verdict: ✪✪✪

Stonehenge Decoded

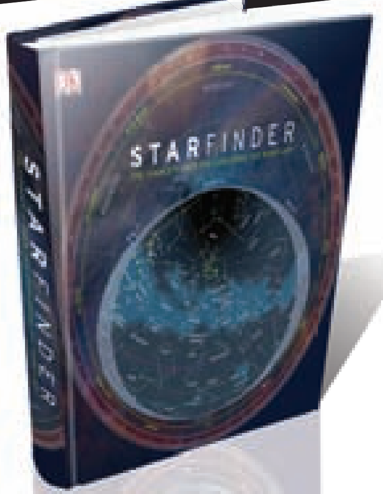
■ **Price: £15.53 / $17.99**
■ **Get it from: www.shop.nationalgeographic.com**
Presented by Hollywood actor Donald Sutherland, *Stonehenge Decoded* charts the discovery and excavation of a 4,500-year-old settlement less than two miles from the Stonehenge World Heritage Site. Believed by archaeologists to contain hundreds of houses, the settlement is the largest Stone Age settlement ever found in northern Europe and, as shown in the documentary, contains a mysterious wooden replica of Stonehenge at its centre. A detailed and accessible exploration of this ancient site.
Verdict: ✪✪✪✪

Polaroid 2

For those who hate delayed gratification

£179.99 / $267.99
Get it from: www.firebox.com
TIRED OF WAITING? Like photography? If the answer is yes to both of those questions then you will probably like this digital camera-cum-printer from Polaroid. The Polaroid 2 delivers a seven megapixel digital camera and a PoGo portable printer in one unit, allowing you to take a picture and then print it instantly, having the resultant two by three-inch picture in your hands within 40 seconds.

In addition, the Polaroid 2 also sports a three-inch LCD screen, anti red-eye system, movie mode, 4x digital zoom and timer. The camera also has a USB port to transfer pictures to computer for larger prints. On test the camera impressed only in certain situations, nevertheless, the ability to have the small wallet-sized photo (which can also have its back peeled off to form a sticker) in your hands in just over half a minute was mighty pleasing.
Verdict: ✪✪

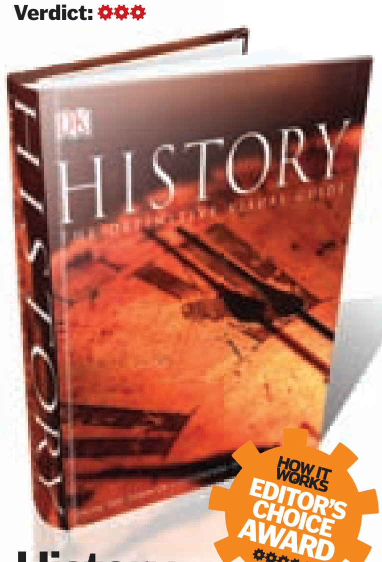


Starfinder

Price: £20.00 / $30.00
ISBN: 978-0756631208

Combining a practical guide to astronomy with card decks, sky maps, and a flashlight, *Starfinder* explains how to navigate around the night sky, shows you what you can expect to see, and provides all the tools you need to see the constellations for yourself. An easy-to-use and hardwearing companion for the young astronomer, yet slightly limited to those wishing for more depth and technical detail.

Verdict:



History

Price: £30.00 / $50.00
ISBN: 978-1-4053-1809-9

Exploring the human civilisations throughout all of recorded time, *History* looks at our development and progress from every angle, exploring key events, groundbreaking ideas, the political forces, the pivotal individuals and the technological discoveries that have shaped humanity. Edited by history scholar and television presenter Adam Hart-Davis, this title is just epic in its scale and research.

Verdict:

Star Theatre

Project the cosmos on your bedroom ceiling

Price: £119.99 / $178.99
Get it from: www.firebox.com

FORGET THOSE MOBILES for babies that project Henry the hippo and Ellie the Elephant above their cot; this is ceiling-based projection for adults and anyone with a fascination of space and stargazing. The Star Theatre projects a super-realistic simulation of the night sky on the wall or ceiling of your choice – all you then have to do is lie back and gaze away.

The system uses ultra-bright white LED technology to beam over 10,000 stars skywards and utilises special discs, which are loaded through a tray compartment, to display stars, delineated constellations and mimicked celestial movements in both the northern and southern hemispheres. The system can even be requested to randomly simulate passing shooting stars and uses a professional lens system common in most full-blown planetariums.

In addition, with the Star Theatre you have the added benefit of suffering from zero light pollution (providing of course you turn the lights off in your room!), a blight which hampers many astronomer who live anywhere remotely close to civilisation.

Verdict:

Magic IQ Box

Protect property with this puzzling piece of pine

Price: £8.99 / $13.00
Get it from: www.firebox.com

A SIMPLE AND innocuous-looking miniature wooden crate, the Magic IQ Box is actually a fiendish puzzle and small container. In fact, it is so difficult to open that once you have figured out how to open it in the first place, you suddenly realise that it is the ideal place to store rings, jewellery and other small items of wealth. Soon that solid silver dollar or wodge of bank notes is infuriatingly far away from your younger relative's green fingers, as while they may realise items of value are contained there within, they will be permanently separated from them by half a centimetre of wood. Don't forget how to open it however, or you too may be cursing and blinding at its ingenious protective qualities.

Verdict:

MiLi iPhone Projector

A stylish mobile projector for your iPhone, iPod or BlackBerry

Price: £239.99 / $357.99
Get it from: www.play.com

THE CURRENT GENERATION of smartphones boast pretty impressive screens, displaying videos clearly and crisply wherever you may be. However, they still don't quite match the viewing experience of watching films and television shows on the big screen, which can be a pain as immersion can be broken. To address this issue, the smartphone wizards over at MiLi have produced the MiLi iPhone Projector, a portable and futuristic-looking device that allows you to project any videos you may have on your iPhone, iPod or BlackBerry onto a 70-inch size area.

The system uses a brand new liquid crystal on silicon LED-driven micro-projector capable of displaying 640x480 VGA images as well as a built-in stereo speaker with AV slot. The unit is controlled through a brace of soft buttons on the device and also by an included separate remote, ideal for sofa/bed-based operation. Further, the attractive clamshell design incorporates a removable lithium-polymer battery that charges your plugged-in device while it plays, and allows the MiLi iPhone Projector to double up as a charging and docking station too.

At £239.99 however, this is a seriously expensive piece of kit and while we can't knock the build quality, functionality or desirability, unless you travel a lot where a large television is not possible or just have a lot of money to burn, we would wait a couple of months or so for an inevitable price drop.

Verdict:

Camera Obscura

Get back to camera basics

Price: £7.85 / $11.99
Get it from: www.mutr.co.uk

THE CAMERA OBSCURA was one of a few inventions that led to modern photography, providing a darkened box in which light from the outside world projected through a pin-sized hole upon a white screen to form an upside down image, allowing for traces to be taken and reproduced. This set, from Middlesex University Training Resources, allows you to recapture those low-tech days before film and digital photography with a wooden kit that you can assemble and use yourself. Once constructed the kit looks and feels authentic and accurately projects an image of what it is pointed at onto a screen inside the box.

Verdict:

Lego Radio Alarm Clock

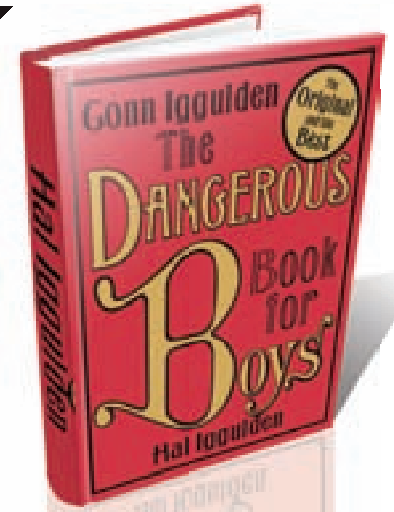
Like Lego? Well you'll love waking up to this

Price: £24.99 / $37.00
Get it from: www.firebox.com

EITHER MAINS OR battery powered, this Lego alarm clock provides a basic but easy-to-use radio alarm clock in the iconic shape of a Lego block. Both studs on the top twist to alter the sound level and frequency respectively and the front fascia contains buttons to activate features such as a backlight, time and alarm setters, snooze function and AM/FM switching. How you react to its styling, of course, will depend on how much you actually like Lego – with its bright red, chunky appearance running against the grain of modern post-iPod design.

In terms of functionality the Lego Radio Alarm Clock does what you would expect it to, and thanks to its minimalist appearance and large volume and tuner controls, it is easy to use first thing in the morning and late at night when all is not quite functioning at full whack. Further, the volume button on the top of the block can be pressed to activate its snooze function that saves both time and annoyance when you need just that extra bit of sleep after a late night the day before.

Verdict:

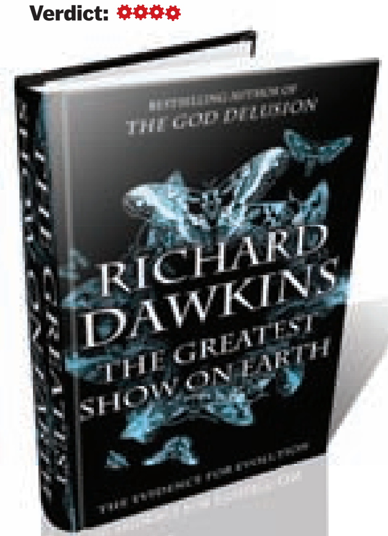


The Dangerous Book For Boys

Price: £11.99 / $17.79
ISBN: 978-0-00-723274-1

Throwing together a light-hearted compendium of fun knowledge, tricks, skills, games and instructional do it your self style constructions, *The Dangerous Book For Boys* aims to reclaim the days of yore where boys were boys and would spend their Sunday's fishing and building a tree house rather than tearing the head off another mythological beast in *God Of War III* on their PS3..

Verdict:



The Greatest Show On Earth

Price: £20.00 / $30.00
ISBN: 978-0593061732

Notable biologist and atheist Richard Dawkins continues his lucid support of Darwin's theory of evolution and takes the fight to creationists in his latest book, *The Greatest Show On Earth*. Sifting through fascinating layers of scientific facts and disciplines to build a cast iron case against the theory of intelligent design, Dawkins is vivid and persuasive in his writing style, and authoritative in his reasoning.

Verdict:

GROUP TEST
Microscopes

How It Works takes a closer look at some top scopes for home scientists

1

Celestron Digital Microscope

Price: £90.00 / $135.00
Get it from:
www.sciencemuseumshop.co.uk

The most expensive microscope in this month's group test is also the most advanced, with solid functionality and ease of use for those amateur scientists above the age of 14. Offering a magnification range of 40x to 600x, as well as 4x, 15x and 20x lenses and top-down and bottom-up electric illumination, this offering from Celestron doesn't disappoint and even allows you to save and transfer images to PC. Extras include three prepared slides, rock samples and a honeybee wing.

Verdict: ★★★★

HOW IT WORKS GROUP TEST WINNER

2

National Geographic Microscope Set

Price: £18.99 / $27.99
Get it from:
www.amazon.co.uk

Offering the best overall package and great value for money, although losing out to the Celestron in terms of optical quality. This set contains a solid microscope with 300x, 600x and 1,200x magnification as well as a sheer cavalcade of extras, including: three prepared slides, eight black slides, three specimen vials, a set of tweezers, petri dish, stirring rod, spatula, pipette, spare bulb, eight labels and individual test tube. A great kit for those looking to get into the world of microscopy.

Verdict: ★★★★★

3

Primary Microscope

Price: £35.00 / $52.00
Get it from:
www.sciencemuseumshop.co.uk

A microscope aimed squarely at younger scientists, the Primary Microscope provides a single basic lens with magnification power of 10x, 30x and 50x. There's also various colour viewing filters in a robust, bash-free casing, which is ideal for preserving its usability in those challenging environments. Powered simply by two AA batteries, the microscope on offer here provides both top and bottom light sources and comes bundled with some test slides and a curiosity box, perfect for the placement of bugs and creepy crawlies for a close inspection.

Verdict: ★★★

4

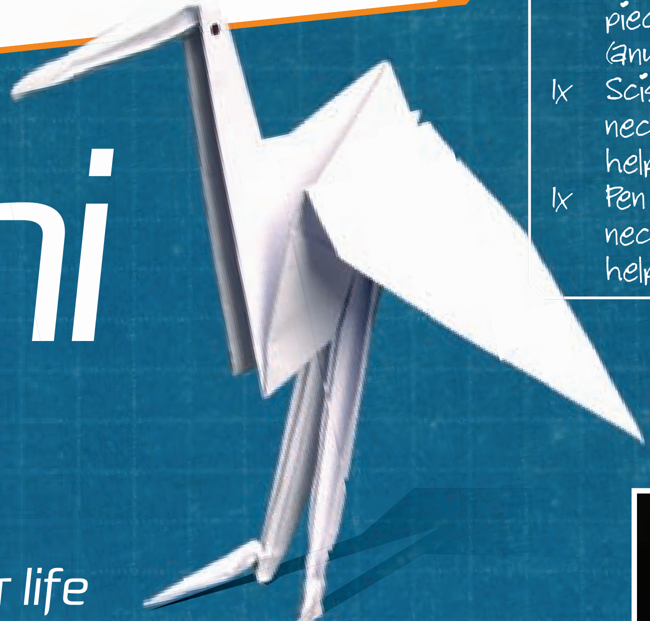
Natural History Museum Pocket Microscope

Price: £8.00 / $13.00
Get it from:
www.nhmshop.co.uk

The only truly portable microscope on test, this weighty and compact microscope allows close inspection of objects and specimens on the move. While the unit only provides 20x and 40x magnification, the clarity of the imaging is superb and the inclusion of a super-bright LED illuminator and focus wheel keeps things in vision and in detail at all times. Extras include a stand, lens cleaning cloth and rubberised grip.

Verdict: ★★★★

HOW TO MAKE
An origami crane



Origami crane

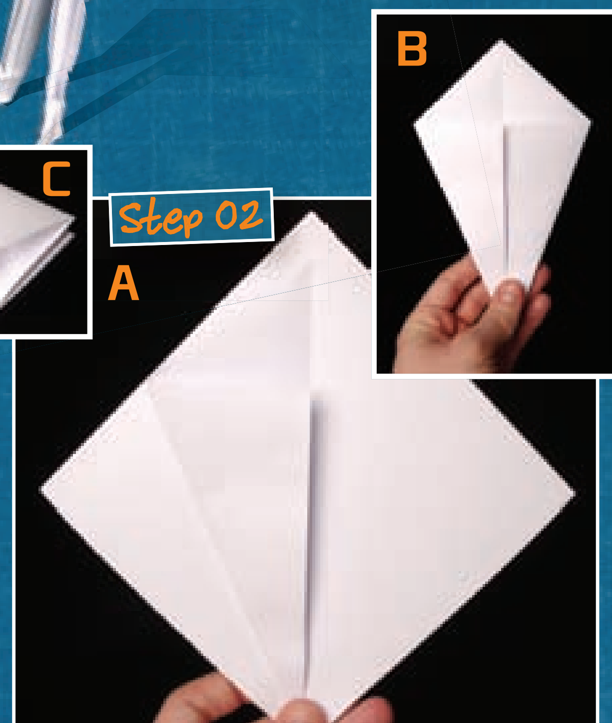
Bring some inner peace to your life with this crafty bird

Ah the crane; graceful and elegant, looming down on lesser birds like a… well, big loomy thing. Indeed, it is in meditation times such as this where the origami master lets his mind wonder to fairer pastures, where water bombs and paper projectiles are things of fancy and only tranquillity and peace resounds throughout the halls of the origami temple.

Of course, snaffling your very own crane is rather difficult to do nowadays and – after that unfortunate incident where the origami master attempted unsuccessfully to buy one in the local village with a bundle of hand-made paper sovereigns – they are also far too expensive to purchase.

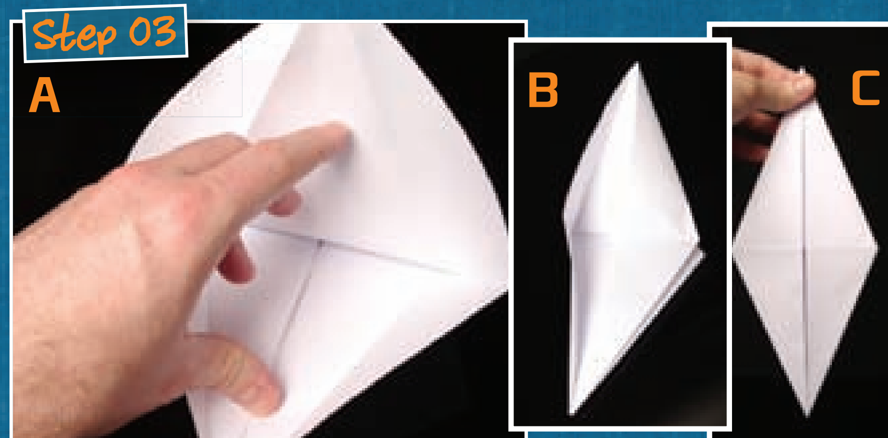
With that in mind therefore, all budding students of origami should follow these simple seven steps, for then they too can own their very own crane as well as advance their studies in the art of origami.

1. Fold your paper in half, open it up and fold it in half again the other way. Fold it over to form a triangle and then open it up and fold it over the other way to form another triangle. Open your paper – you should have these creases (A). Fold it in half (B) and then pinching at both east and west ends push together and fold down to form this double-layered construction (C).



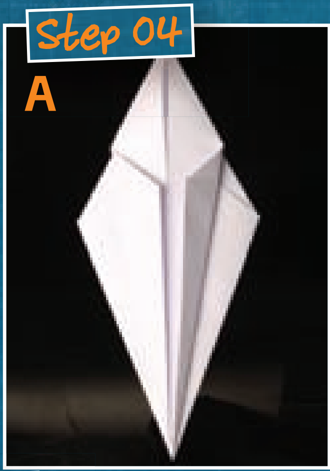
2. Making sure the vertical gap in the centre of the square of paper is at the bottom, fold the top layer's western tip across until it meets the centre crease. You should now have this (A). Now repeat the same process for the east tip, then flip the whole thing over and do the same with both lower east and west tips. You should now have this shape (B).

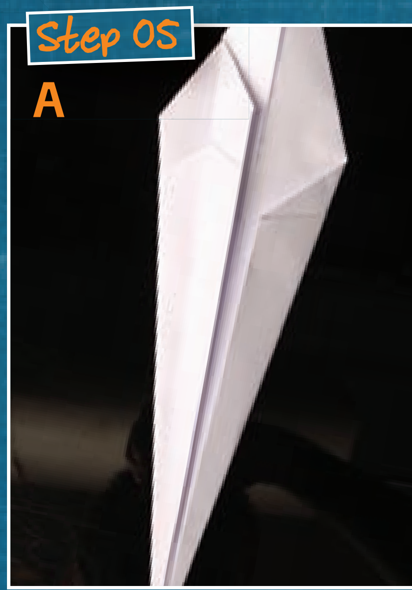
3. Okay, a tricky bit. Making sure that the gap in the centre of the paper is at the bottom, reopen the east and west folded-inwards tips and then select the top layer of paper at its southerly tip. Lift this up (A) and fold it over to the north, folding in the eastern and western sides as you do so (B). Once achieved, flip over and repeat with the bottom layer – you should now have this shape (C).



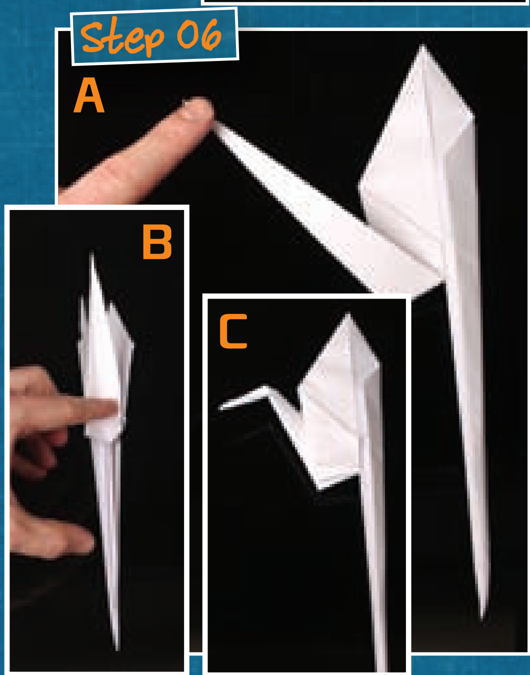
HOW IT WORKS

4. Fold the top layer's western and eastern tips into the centre (A) and crease, and then do the same for the bottom layer. You should have this (B).





5. Taking the top layer's western tip, once more fold it in two and into the centre (A), then flip the construction over and do the same on the opposite side (B).



6. Making sure the narrower leg is on the east side, fold the fatter western leg upwards on a diagonal before creasing (A). Now another tricky bit. Fold the leg back down, hold the paper side on and push the recently folded-up leg invertly into this pocket (B) then crease. Once achieved take the end of the exposed triangle (this is the crane's neck) and form a head on the end by folding downwards and inwards. At the end of this you should have this (C).

7. Finally, fold the northern top and bottom layer tips of the main paper body downwards and crease at 45 degrees (they will naturally want to fold here) to form the crane's wings. Then, once this is achieved, take your pair of scissors and cut right down the centre of the long southerly reaching triangular protrusion to form the crane's legs (you can tear neatly if you don't have scissors) before folding their bottom tips upward by a quarter of the leg length and then down and in again to form feet.

Completed!

Congratulations! You are now free to enjoy the calming influence of your very own origami crane.

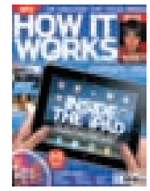
GET INVOLVED! Have you created a crane of epic proportions? Or maybe you've skilfully crafted some other clever inventions. Send your pictures to howitworks@imagine-publishing.co.uk

HOW IT WORKS

INBOX

Feed your mind. Speak your mind

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...

Keep your kids happy with **How It Works**

Letter Of The Month

The Mother's Day acid test

I was delighted to find the red cabbage litmus item in issue 4. I'm a childminder and it seemed a good idea to try with the children I look after – a good learning exercise and fun! We had a go and it worked really well so for Mother's Day we made cards with an underwater scene and stuck our home-made litmus paper fish on. We put a sachet of vinegar in each card and instructions to paint the fish with the vinegar then watch the magic. The children have been thrilled with the activity and the results and they can't wait to explain to their mums how they made the fish! Thanks for the idea.
Wendy Norfolk

HIW: How It Works deputy editor Helen is by no means the greatest chef in the land, but she did manage to boil up some red cabbage and create this particular How To Make. It's easy enough to do and the results are really striking. However, it never occurred to us to put the test to creative artistic use. Great idea, Wendy, and a double helping of science and art. Thanks for letting us know how your How To Make experience went – and don't forget, if anyone else has an ingenious experiment or crafty creation, do share it with us.

No time for complacency

Dear editorial team. Your magazine is brilliant. I am full of admiration, as is everyone I have shown it to. The presentation is first rate – paper, design, photography – and the articles are all extremely informative and to the point and, as far as I can tell, authoritative as well. I have at once signed up as a subscriber. But don't let this initial high quality slip; really go for making this magazine one of the world's finest as you say in your blurb. Don't let this be a flash in the plan, your magazine really has potential and if I was an investor I'd put my money into it.
Sebastian Hayes

HIW: Sebastian, we're almost hesitant to include your letter as it is extremely flattering – which makes us all blush… collectively – and people might think we've written it to ourselves. However, there is a cautionary word of advice in your letter, which we would like to address. While we're working very hard to keep the quality of the magazine improving all the time and to continue bringing you all the best information on the most fascinating topics all written by the most talented writers in their fields, we assure you we have no intention of putting our feet up any time soon.

Anyone want to sell their issue two?

Please help me. I was on holiday throughout December 2009 when issue 2 was released. Yes, I know I should have subscribed – and I have done so now. I'm truly distraught because I can't get hold of a back issue. The website is currently out of stock and for the last month I have been checking eBay every day, but still with no result.

I'm happy to pay another reader one crisp £20 note to sell me their pride and joy if you pass on my details. I really don't mind paying a premium, since I already paid €10 for issue 3 at Frankfurt Airport on my way back from Hong Kong as I was afraid of missing out on this one also.

Seriously, this is a great magazine and I would be very disappointed if I were to have a void in my collection. I regularly pick out articles to read and explain to my nine-year-old daughter who is truly mad about science.
Steven Lau

HIW: The exciting How It Works launch saw early editions sell out all over the place, and now those issues are highly sought after. In fact there are no spare copies of it in the office!

Still, all back issues are available through the Imagine eShop, a link to which you'll find on the website. However, as you've discovered, Steven, certain issues are now out of stock. We suggest you keep one eye on eBay and another on our forum, which has a thread under General Comments called Back Issues. If anyone wants to trade, head to the forum. We hope someone answers your plea. We've said it before and we'll probably say it again: the only way to avoid disappointment is to get yourself a subscription.

Keeping it clean

I'm old and grey but a science nut who's been buying (often with regret) scientific discovery publications over many years for my own interest as well as a teaching life tool for our five children. None of them come anywhere near the quality of your magazine in content, graphics or variety of subject matter. I must add, however, my family IS complaining as I make them wash their

Desperate times call for desperate measures!

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.

hands before touching it, don't bend the pages and return it promptly. Your magazine, How It Works, is that good. Really, well done.

Patricia Manis

HIW: Thanks, Patricia. You really take care of your prized possessions don't you? It's great to hear that your copies of the magazine are well cared for. We hope people will be able to use them as handy reference material for years to come so it's probably a clever idea to keep them in good nick.

Some like it swot

I love the human body/organ articles and animal ones the most, so please can we have some more of those? Also, I like the GCSE/A-level topics you cover much more than the stuff you don't learn at school – inside blackberries, for example – so more of this type of article with guides and diagrams would be good.

I love the history section more than the transport and technology pages, but it seems most of these articles – bar one or two – are really short. I also like general history, such as the Tudors and Stuarts, the Roman soldier, Colosseum, medieval castles and so on. I'd love it if you could feature more on that.

Loving issue 5 so far, it's looking like the best yet, with a great range of features I'm interested in (even the F1 was cool and I'm not a fan) so keep up the great work.

cjayp33

HIW: Good comments, cjayp33. We feel it's important to feature GCSE/A-level topics as well as the less academic topics not taught on the curriculum as we want to ensure a mixture of subjects for all tastes. History is a popular one and we've included a few larger double-page features on airships and hieroglyphs this issue. The beauty of the history section is that there are so many amazing things we could cover, it's difficult to pick between them all. Keep your ideas coming; we love hearing what you think.

Questions you've been asking… and that we'll answer soon

If you drink milk then orange juice does it curdle in your stomach? D Butt Why do we have moles? R Williams How does a recording studio work? P Mason How is the weather predicted? J Gilles **What's the fastest vehicle on Earth?** R Shanks How do MRI scanners work? S Greaves **Who invented the bicycle?** T Pitman How do heart pacemakers work? P MacMarn How do we blush? G Green

Send your questions to howitworks@imagine-publishing.co.uk

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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**
Assistant Designer **Jonathan Wells**
Senior Sub Editor **Jon White**
Head of Design **Ross Andrews**

Contributors
Mike Anderiesz, Russell Barnes, Ian Farrell, Natalie Johnson, HydroKevin, Bridget McDermott, Lynsey Kay Porter, Phil Raby, Vivienne Raper, Dave Roos, Luis Villazon

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Advertising
Digital or printed media packs are available on request.
Head of Sales James Hanslip
☎ 01202 586423
james.hanslip@imagine-publishing.co.uk
Account Manager Nathalie Stainer
☎ 01202 586431
nathalie.stainer@imagine-publishing.co.uk

International
How It Works is available for licensing. Contact the International department to discuss partnership opportunities.
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
☎ 0844 826 7322
Overseas +44 1795 414779
Email: howitworks@servicehelpline.co.uk
13 issue subscription (UK) – £41
13 issue subscription (Europe) – £50
13 issue subscription (USA) – £50
13 issue subscription (ROW) – £60

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

Printing & Distribution
Wyndeham Heron, The Bentall Complex, Colchester Road, Heybridge, Maldon, Essex, CM9 4NW

Distributed in the UK & Eire by : Seymour Distribution, 2 East Poultry Avenue, London, EC1A 9PT. ☎ 0207 429 4000

Distributed in Australia by : Gordon & Gotch, Equinox Centre, 18 Rodborough Road, Frenchs Forest, NSW 2086.
☎ + 61 2 9972 8800

Distributed in the Rest of the World by : Marketforce, Blue Fin Building, 110 Southwark Street, London, SE1 0SU.
☎ 0203 148 8105

ISSN 2041-7322