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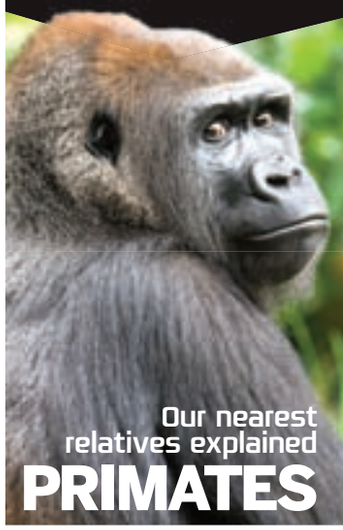
THE MAGAZINE THAT FEEDS MINDS

HOW IT WORKS

SCIENCE ENVIRONMENT TECHNOLOGY TRANSPORT HISTORY SPACE

INSIDE



Our nearest relatives explained

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The natural chemical that takes us to extremes

HANGOVERS

Why alcohol turns the morning after into a nightmare

AIRCRAFT CARRIERS

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ip IMAGINE PUBLISHING

HOW IT WORKS

WELCOME

The magazine that feeds minds! ISSUE TEN

Get in touch

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

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"FEED YOUR MIND!"

Meet the experts

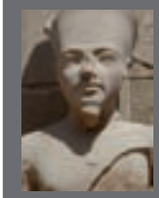
"Written by experts to be enjoyed by everyone" is how we like to roll, so meet the people that work so hard to bring you each issue...

Luis Villazon
Primates

Luis – or King Luis as he's known this issue – is definitely a jungle VIP with a PhD in Zoology that made him well qualified to write the feature on primates this issue.

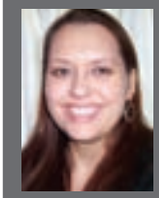
Aneel Bhangu
Circulatory system

Aneel is our resident surgeon in training and when he's not studying how to save people from cancer and trauma, he's been writing an excellent article on the human circulation system.



Dr Bridget McDermott
Duelling

An expert in military history was what we needed to turn in an article on duelling, and that's what we got in Doctor Bridget. She's been writing a book on duelling etiquette which was handy too.



Shanna Freeman
Mars 500

Shanna was called in from the States to contribute most of the space section this month. She got to grips with the feature on the Mars 500 mission and the look at Saturn's moon, Titan.

Richard Aucock
High-tech cars

We've borrowed Richard from one of our sister mags, Total 911. He's taken a break from writing about all things Porsche to contribute the high-tech cars article. Turn to page 26 to see what he produced.

With thanks to

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

sciencemuseum REUTERS Mercedes-Benz Audi DK NASA BMW 2010

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

This month it's aircraft carriers. We've got a fantastic cutaway illustration of the USS Abraham Lincoln on page 16-17 that shows just how amazing these ships are. Like a floating airbase-cum-communications station-cum-power station in one huge vessel.

What you're saying about How It Works

I realised that this wasn't just 'some' magazine – in fact it was absolutely amazing. I have subscribed and all the family have flicked through it and they have all equally loved it. Well done! – **AndrewGear111**

Nine issues on and I'm still loving it. Please keep up the good work . **Edna Franks**

Can I ask that there is less iPhone/Pad/Mac/Pod-related articles please? – **SouthernDave**

I love Apple. The California-based company has come in for a lot of criticism from some quarters so far in 2010, with accusations of monopolising and antitrust among other debates raging on internet chat rooms and forums the world over. Some of these criticisms are very well grounded but they won't stop me from loving the folks at Cupertino. Why? Because they never fail to give me interesting things to write about. Halfway through 2010 and they have already helped me with cover features across the whole portfolio of technology magazines that I run as Editor in Chief, and the stir caused by groundbreaking devices like the iPad stimulate an interest that converts directly into sales.

Love them or hate them, people enjoy reading about Apple devices as much as we enjoy writing about them, and it's not just the magazine industry that benefits. A whole host of companies have enjoyed success based around Apple devices, from accessory manufacturers making cases, speaker systems and in-car docks to the bedroom coders striking it rich by developing applications. In the struggling computer market, Apple's innovation stimulates a growth even in a time of worldwide recession.

After covering the iPad in issue 7, only three issue later another Apple product graces a How It Works cover; it seems only right that a bright new science and technology magazine should cover the brightest new technology, and if it keeps coming from the same company then so be it.

Dave Harfield
Editor in Chief

HOW IT WORKS

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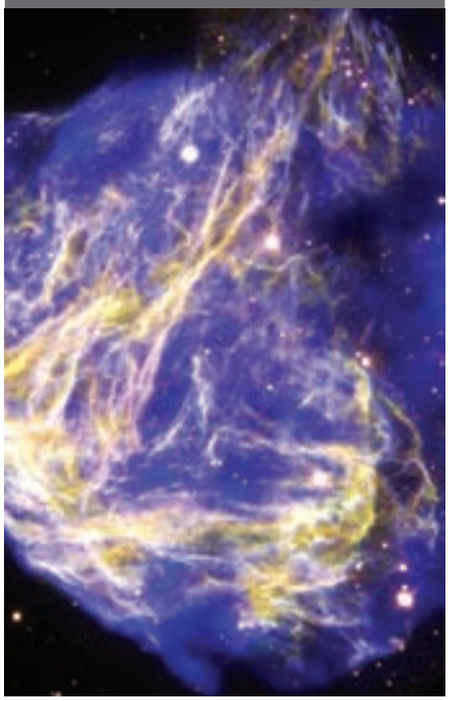

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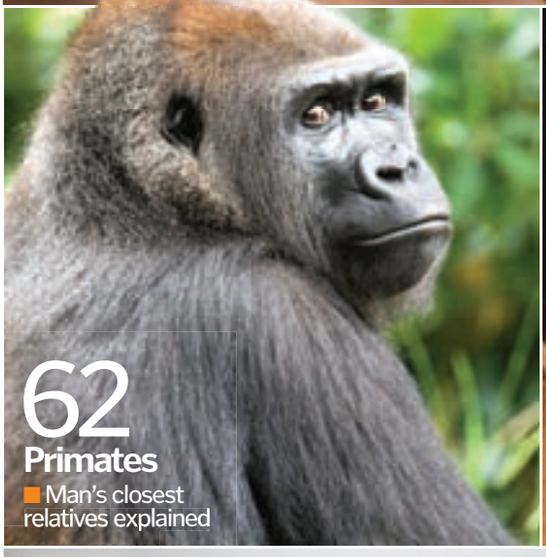

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BE NOW!

Dr Robert Bloomfield
Director IYB-UK

With a PhD in Genetics, Bob leads the panel of experts from the International Year of Biodiversity.

Josh Moore
Science Museum Explainer

Josh spends his time helping visitors get to grips with the science behind the exhibits at the Science Museum.

Alison Boyle
Curator of Astronomy and Modern Physics

Alison Boyle is Curator of Astronomy and Modern Physics at the Science Museum.

GLOBAL EYE NEWS

A fresh look at the world

© ESO/H.H.Heyer

Astronomers have detected violent, high-speed winds ravaging the surface of a planet in the Pegasus constellation

Superstom rages on exoplanet

© NASA

Orbiting a yellow dwarf-class sun in the distant Pegasus constellation, the planet HD 209458b has been discovered by scientists to hold one of the fiercest atmospheres yet discovered in our galaxy.

The planet – which circles its sun at one-eighth the distance of what Mercury orbits around ours – is reported by the team to have longitudinal winds of roughly 2km/s (7,000km/h) in the atmosphere of a 'hot Jupiter'. And when the team say hot, they mean scorching hot. The sun side of the planet – due to its orbit one side is always facing the sun – is on average 1,000 degrees Celsius at surface level and the atmosphere is largely a swirling mass of poisonous carbon monoxide gas.

In order to achieve these results, the research team used the European Southern Observatory's Very Large Telescope (VLT) and its powerful CRIRES spectrograph to detect and analyse the tiny fraction of starlight that filtered through the planet's atmosphere as it passed in front of its star. By doing this, the astronomers were able to use the Doppler Effect – the change in the wavelength of a planet's light spectrum caused by its motion towards or away from Earth – to obtain direct measurement of the exoplanet's mass and, consequently, a number of its characteristics.

It is hoped that this type of observation will one day prove useful in order to study the atmospheres of other, more Earth-like planets throughout the solar system, in order to derive if there is even the slightest possibility of life on them.

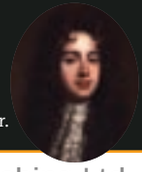
This day in history

15 July: **How It Works** issue 10 goes on sale, but what else happened on this day in history?

1099 At the climax of the First Crusade, Christian soldiers take the Church of the Holy Sepulchre in Jerusalem after an epic siege.

1381 John Ball, a leader in the Peasants' Revolt, is hung, drawn and quartered in the presence of Richard II of England.

1685 James Scott, 1st Duke of Monmouth, is executed at Tower Hill, England, after his defeat at the Battle of Sedgemoor.



1741 Alexei Chirikov sights land in Southeast Alaska. He sends men ashore, becoming the first Europeans to visit Alaska.

1799 The Rosetta Stone is found in the Egyptian village of Rosetta by French Captain Pierre-François Bouchard.

AR.Drone takes off

After a large-scale demonstration at the Electronic Entertainment Expo, the AR.Drone gets Europe and US release date

All images © Parrot

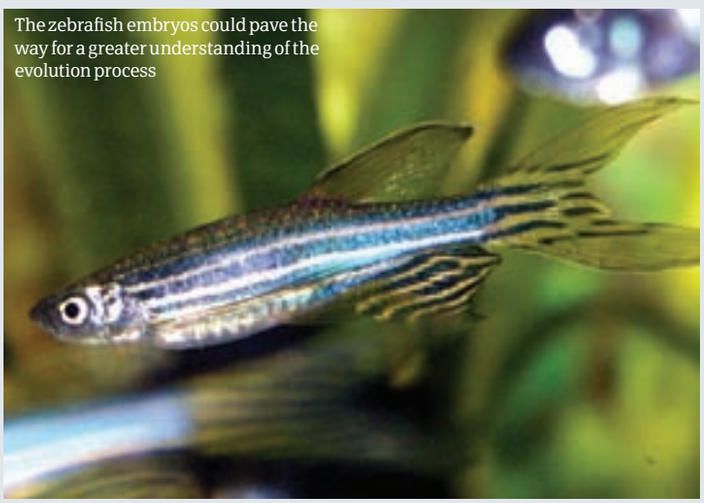
After a much-hyped build-up, the AR.Drone from Parrot has been given a launch date and price point for Europe and the US. The AR.Drone – a Wi-Fi controlled, high-tech quadricopter controlled by iPhone – is set to be released on 18 August in Europe and will retail for £299 in the UK from HMV. The Drone will go on sale in the US in September and will retail for $299. It has been confirmed that additional parts and spares will be available from the Parrot.com online store.

Excitingly, though, Parrot has released details on the selection of gaming apps that will be available to run with the AR.Drone, including AR.Flying Ace – a dogfighting program that allows two AR.Drones to fight it out over a Wi-Fi network, scoring hits by detecting and positioning themselves in relation to the other – and AR.Drone Gate, a program that allows you to fight virtual aliens with the quadricopter that are hiding in your very own living room. See http://ardrone.parrot.com for more info.

Who needs friends when you have the AR.Drone?

Fin to limb clue found by scientists

Study highlights an 'important step' in the evolution of animal limbs



The zebrafish embryos could pave the way for a greater understanding of the evolution process

A team of Canadian scientists have published a study in which they say they have attained evidence of a key genetic step in the evolution of animals' limbs from the fins of fish.

Dr Marie-Andree Akimenko and her team attained the results after studying the development of zebrafish embryos, discovering two genes that were important in the structure of embryonic fins were absent from those of mice's embryonic limbs.

"We found there were no [equivalent genes] in limbs, so this suggested these may have been lost in evolution," explained Dr Akimenko. "When we compared fin development and limb development, the early steps are very similar, but at one point there is a divergence, and that correlates with the beginning of the expression of these genes."

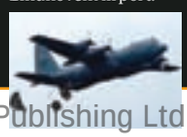
1815 Napoléon Bonaparte surrenders to Captain Frederick Maitland aboard HMS Bellerophon.

1888 The stratovolcano Mount Bandai, Japan, erupts killing approximately 500.

1918 In the last year of World War I, the Second Battle of the Marne begins in France with a German-led assault on allied forces.

1954 The first flight of the Boeing 367-80 is undertaken, a prototype aircraft for both the Boeing 707 and C-135 series.

1996 A Belgian Air Force C-130 Hercules carrying the Royal Netherlands Army marching band crashes on landing at Eindhoven Airport.



2003 The Mozilla Foundation, the non-profit organisation behind the popular web browser Mozilla Firefox, is formed.

MONTH IN FACTS

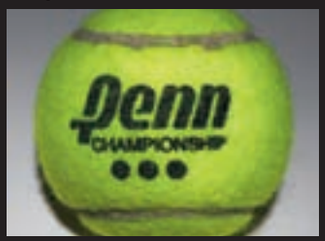
Short, concentrated bursts of facts and figures from the last month in news

£599

■ The cost of a new 32GB iPhone 4, which was released on 24 June.

11

■ The amount of hours it took for John Isner and Nicolas Mahut to complete their tennis match at this year's Wimbledon.



14 years

■ The amount of years since BP last had its share price as low as it is now, following the continued catastrophe in the Gulf of Mexico.

350

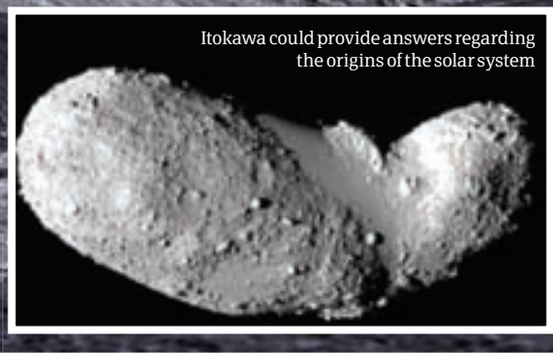
■ The amount of years the Royal Society – Britain's longest running scientific institute – has been operational for.

$1bn

■ The amount of money sought after by Viacom in a failed lawsuit against Google for allowing copyrighted material on YouTube.

Space capsule crash-lands

After a seven-year expedition to a distant asteroid, the Hayabusa space probe has returned to Earth


Itokawa could provide answers regarding the origins of the solar system

Returning from a seven-year trip to the Itokawa asteroid, the Hayabusa capsule and accompanying probe have re-entered the Earth's atmosphere and crash-landed in the Woomera Prohibited Area, Australia. The spacecraft – whose mission involved travelling to the asteroid, photographing it, landing and returning with a soil and rock sample – is hoped by its operator, the Japanese Aerospace Exploration Agency (JAXA), to still be in-tact and contain a full payload.

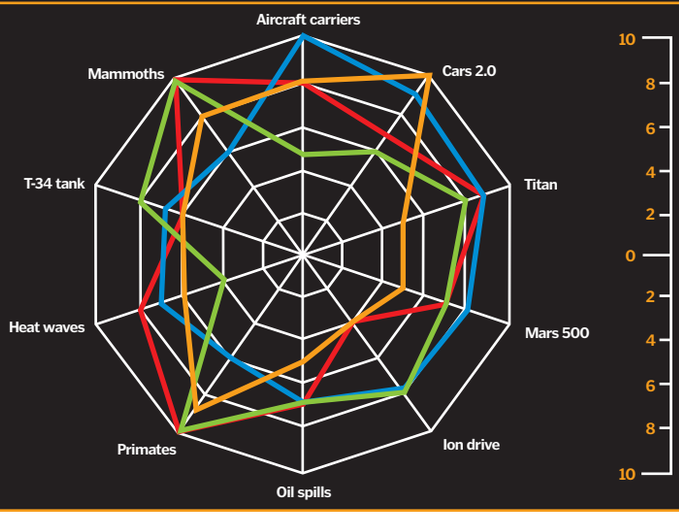
The re-entry itself was spectacular, producing a large fireball that tore across the Australian sky as the spacecraft shattered under the immense pressure and heat exerted on it by the Earth's atmosphere. Exploding in a glorious shower of light, shards of molten metal rained down in showers before dissipating and leaving nothing but the capsule's carbon shell, a protective shield guarding the payload.

Currently, there is a large amount of uncertainty as to whether the capsule actually contains any specimens from Itokawa, and if so, how many. Previous missions similar to Hayabusa – such as NASA's Stardust excursion – have contained samples but only on a nano-gram scale. Yoshiyuki Hasegawa, the associate executive director of JAXA, stated: "We will package the capsule and then send it back by aircraft – it's a special aircraft – from the Woomera range to Tokyo International Airport, to go to our facility, our laboratory, where we will analyse the samples."

Scientists are hoping that the samples possibly contained within the Hayabusa capsule will allow them great scope and unparalleled insight into the early history of the solar system and the formation of planets over 4.5 billion years ago. Speaking post-landing, Professor Trevor Ireland of the Australian National University, said: "If we look at any [sample] on Earth it has been thoroughly through the wringer; it's been messed up by plate-tectonic processes and geochemical processes. So if we want to look at what our Earth was made of, we have to leave Earth. That's the importance of Hayabusa and going to Itokawa."

THE EXCITE-O-METER!

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



Dave
Ed in Chief
Aircraft carriers float my boat this issue. They're amazing vessels and the cutaway illustration we have on page 16 is one of the best we have featured. Second on my list is the high-tech cars. I don't know much about cars but I love that tech.

Helen
Deputy Editor
If you like monkeying around and going ape like me, it will come as no surprise that my favourite feature this issue is the one on primates that appears on page 62. Almost as exciting is the massive woolly mammoth that can be found in the history section.

Rob
Staff Writer
Mammoths and primates score high for me this month, as well as the WW2 T-34 Russian medium tank. I like how by being a jack-of-all-trades, this vehicle outlasted the far superior German Tiger and Panther tanks, helping to win the war on the Eastern front.

Jon
Senior Sub Editor
Topping some of the features we had last month was always going to be tough, but I must admit that two of the in-depth pieces we have are top-notch. High-tech cars was always going to be high on my list of top reads, and the primates feature is really impressive.

AND THE VERDICT IS...

Rob's excitement remains super high for a second month in a row. Jon is the least excited of the team, dipping massively from last month. Dave is the most excited however, racking up a whopping 78 points of pure excitedness.

Solar night flight

Solar-powered torches are much derided so let's hope the first night-flight in a solar-powered plane fares better

By the time you read this we'll have found out whether the idea of solar-powered planes flying at night is a good one.

The Solar Impulse has graced our pages before and is a project that aims to take off and fly autonomously, day and night, propelled by solar energy, right round the world without fuel or pollution.

The first night flight will take place on 1 July, when the prototype will take off at around eight in the morning before climbing, during the whole day, to 8,500 metres. During this climb, the plane will store as much energy as possible in its batteries. Once the Sun's rays are less intense, the HB-SIA will commence a descent to 1,500 metres. It will then fly, with the energy stored in its batteries, until the next sunrise. The big question will be whether the pilot will be able to save enough energy to be able to stay airborne through the entire night.

By the time of publishing we'll know whether they succeeded or not so check the **How It Works** website at **www.howitworksdaily.co.uk** for any news.

Geneticist creates synthetic life

The notable Dr Craig Venter and his team of geneticists claim to have successfully created the first self-replicating, synthetic, bacterial cell

Researchers at the J Craig Venter Institute (JCVI) have published results indicating the successful construction of the first self-replicating, synthetic bacterial cell.

To achieve such a feat the team had to synthesise the 1.08 million base pair chromosome of a modified Mycoplasma mycoides genome. The synthetic cell has been called Mycoplasma mycoides JCVI-syn1.0 and it appears to demonstrate that genomes can be designed in the computer, chemically made in the laboratory and transplanted into a recipient cell to produce a new self-replicating cell controlled only by the synthetic genome.

Dr J Craig Venter said: "We look forward to continued review and dialogue about the important applications of this work to ensure that it is used for the benefit of all."

www.howitworksdaily.com

HOW IT WORKS TV

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

Fastest animals on Earth

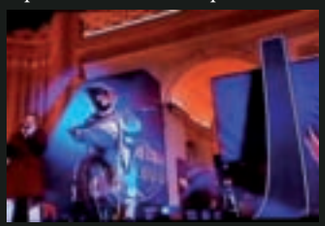
■ Watch the fastest animals on Earth through cutting-edge video cameras capable of slowing footage to 1/80th normal speed.

Hayabusa spacecraft burns up on re-entry

■ Watch the Hayabusa spacecraft explode and shatter into a shower of light as it re-enters the Earth's lower atmosphere.

Bike jump off Arc de Triomphe

■ Watch as BMX legend Robbie Maddison launches himself off the top of the Arc de Triomphe.



The Parthenon explored

■ Watch a mini-documentary on the construction, history and secrets of the Parthenon in Athens, Greece.

Kate Bellingham

Having joined some of the UK's finest names in science on *Tomorrow's World,* Kate Bellingham disappeared from our screens to pursue family life, a successful teaching career, and even gained a Masters in electronics. But now she's back, throwing herself into her work, spreading her passion for learning by dressing up like Lady Gaga and promoting science careers through STEM

How It Works: Describe going behind the scenes at the Natural History Museum for the BBC's *Museum Of Life*.

Kate Bellingham: It was really exciting and it also felt like a great privilege because there's a so much that goes on that people aren't aware of. I knew it had a .ac.uk website, which means it does academic work, but I didn't realise so many of the people working there are the world's top experts in their fields. [...] I felt I was in the company of natural history gods. They were so keen to share their knowledge and to explain things and even if I was asking the dumbest question they were delighted to explain why something mattered or what the significance was. It's nice to see that it's very much about people – yes it's about the specimens and an incredible collection that is valued throughout the world, but it's also about people and how people can advance our knowledge and how we can use that in the modern world in terms of the environmental challenges we have.

At one point they asked if was prepared to go in the water, I literally ran down the beach to buy a wetsuit. Whether it's creating a new archaeopteryx mould or jumping into the sea, this is what I like doing. The audience see me fall over in the sea and I feel like the girl next door instead of the person pontificating on the subject of science. Yep that's fine.

HIW: What was it like to be involved with a British institution like *Tomorrow's World*?

KB: It was a great honour to be part of *Tomorrow's World*. I remember when I got the job thinking 'I don't believe this; they're letting *me* do it'. And because it was already an institution it also felt like quite a responsibility. There we were with all these people watching with high expectations and we had this responsibility to come up with the goods to produce both an entertaining, informative and accurate programme. [...] It was the first live television I'd done; I'd barely done any before so they took quite a chance with me. And the day after I did my first show I remember someone saying 'we did quite well yesterday; we got seven' and I said seven what? And they said '7 million viewers!' And I suddenly thought 'oh my goodness me, there were 7 million people watching me do that'. I think that's what really hit home: this was an opportunity to share my love of science and technology with just *so* many people.

HIW: Do you have any humorous *Tomorrow's World* anecdotes?

KB: I remember being driven in a concept car by Richard Noble – who at the time was the world land speed record holder – and this concept car was the basis of ThrustSSC that Andy Green was going to break the world land speed record in. It was a Mini that had been adapted with some kind of rear-wheel steering to demonstrate the principle of something, and I came away from it thinking, 'I've just been in a car, driven by the fastest man in the world!'

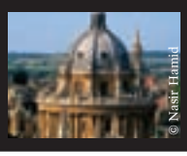
HIW: What do you think of modern science programming, such as *Wonders Of The Solar System* and *Bang Goes The Theory* for younger viewers?

KB: Oh, *Wonders Of The Solar System*! What an amazing programme – my family were glued... The great thing now is the number of channels and not just the stuff you see on television but also the stuff available through the internet. Because there are so many more things out there, in a way, that makes it more challenging for us as providers of the programmes because the audience expect different things. I'm delighted there's such a wealth of stuff out

CAREER

1963 Born and raised in East Yorkshire, Kate – who always loved science and maths – attended a school in Pocklington and the Mount School in York.

1980-1984 Kate took A-Levels in maths, further maths and physics. You might not know that she also studied music and gained grade eight in piano and oboe. Kate went on to achieve a Physics BA(Hons) at Oxford University in 1984.



1984-1987 Kate did work experience at BBC Radio Humberside, but her very first job was as a computer programmer.

1987-1990 Kate joined BBC Radio in London where she took part in an engineering training course for people who don't have a degree in the subject. In 1988 Kate presented a show called 'Sound & Vision' along with four other young engineers. It was during this time she met her husband Martin.

there: *Richard Hammond's Engineering Connections* is on terrestrial television so it's there for everyone; and the specialist stuff on the Discovery Channel is super [...] I think *Bang Goes The Theory* has done a really good job of family viewing and could bring more people back in.

I'd also love to see more programmes about bringing maths to life – helping demonstrate that maths isn't something to be scared of, but something that's absolutely current everywhere in our lives. [...] There's been some super stuff on *The One Show* by Carol Vorderman. People will watch Carol doing maths because it's not going to hurt – it's going to be okay – and I'd love more of that. I'd love to be involved in anything like that. But then I have a day job too; telly is a bit of a sideline for me at the moment.

HIW: Why did you return to study?
KB: One of my proudest moments was getting my distinction in my Masters in electronics. Some people take a career break when they have children; I took a Masters in electronics. I really enjoyed that. I wanted to keep up with things and while you can keep up by reading journals, I knew it wasn't the right motivation for me. So going and doing the Masters course part-time meant I could get back into the thick of it. As part of it I did a major project with original research. And the sense that I'd contributed to global human knowledge on a particular subject was great.

HIW: Tell us more about your work with the STEM Careers project.
KB: [The Government] felt that things in schools weren't going quite right in terms of science and maths –particularly engineering and technology. One area they picked up on was careers – not just deciding what job you want to do, but also helping young people realise that the subjects they're studying are things real people do out in the world. So bringing it to life and providing context encourages people to progress and understand why it's so good to continue with maths after 16 – the further you take maths the further it takes you. There has been a sense that if you do these subjects you're specialising whereas actually you're not – more employers will value a science and maths qualification probably than any other individual qualification, so by doing these you're keeping your options open.

HIW: How do you promote engineering and science as a subject for women to get more active in?

"I remember someone saying 'we did quite well yesterday; we got seven' and I said seven what? And they said '7 million viewers!'"


Kate's passion for science and engineering has continued throughout her career


Museum Of Life thrust Kate back into the national spotlight

KB: I'm a patron of the WISE Campaign (Women Into Science, Engineering and Construction), and we feel that it's not just a case of painting it pink for the girls, or getting girls into the room and shouting it louder. It's about recognising that individuals can have a different approach to science and technology, particularly the physical sciences and engineering. And if we allow people to approach it from what their personal interest is – and whether that's going into technical textiles with a starting point of fashion, or whether it's going into Bloodhound SSC with a starting point of the physiology of what it feels like to drive the car – well, that's great, let's bring people in that way.

HIW: Explain your involvement with the Bloodhound project...
KB: There are lots of ways of reaching out to share both the importance and excitement of what we're now calling STEM – science, technology, engineering and maths – and [Bloodhound] appeals to the people who'd like us to keep the world land speed record. It also appeals to the people who are interested in how fast we can get a vehicle to go, but the prime reason for doing this is to have a high-profile project that incorporates British engineering and technology for educational purposes.
They're encouraging people to look at it in different ways. So to people interested in design we're saying okay, you could design what a car looks like, or you could use maths – with computational fluid dynamics – to come up with ways of making the car not only elegant but also have the right aerodynamic shape to make it go faster, so people can come into it that way.

HIW: What's next on your to-do list?
KB: Well, I'm involved with something that's kind of serious, kind of jokey. I try to promote engineering as new and vibrant and while we value the work of Brunel et al, there's a lot of new stuff going on. One area is smart materials and technical textiles. I had a chat with the people from the design and technology teachers' organisation and suggested getting some school pupils to design an outfit that includes technical textiles for me to wear at a high-profile event – the British Engineering Excellence Awards in October. Now, what springs to mind is Lady Gaga or Blackpool Illuminations. There's no going back, I can't turn up in an M&S frock now. It has to be the 'Engineering Excellence design and technology technical textiles frock'. Watch this space.

The BBC's *Museum Of Life* DVD is available now priced £24.99.

Learn more

For great resources regarding where studying science at school can take you, Kate recommends **www.futuremorph.org**, **www.mathscareers.org.uk** and **www.stemnet.org.uk**.

All Images © BBC

1990-1994 In 1990, Kate replaced Maggie Philbin on the BBC's *Tomorrow's World*, broadcast live each week. Kate worked to promote science and engineering in schools and took up the role of President of Young Engineers.

1994-1999 During this time, Kate was involved with many projects designed to educate and instil a passion for learning in young audiences. In 1997, Staffordshire University awarded Kate an Honorary Doctorate.

1999-2003 After beginning a young family, Kate went back to school to earn her Masters in electronic communication systems at the University of Hertfordshire.

2003-2009 After gaining Qualified Teacher status, Kate put her love of maths to great use, teaching at Hemel Hempstead School, Hertfordshire. Kate became the National STEM Careers Co-ordinator for the DCSF.

PRESENT Kate was asked to co-present *Museum Of Life*, the BBC's recent series about the Natural History Museum.

This month in **Transport**

It's another sea-faring section this month, but one that's a far cry from our mega yachts feature from issue 8. While those craft were indeed high-tech, they can't hope to measure up to the level of sophisticated technology present in the state-of-the-art aircraft carriers that are the subject of this month's feature. Turn the page to see an amazing cutaway of an American Nimitz-class carrier.

24 Air bags

25 In-flight refuelling

26 High-tech cars

TRANSPORT

The Statistics
F/A-18C/D Hornet

All-weather multi-role (air and ground) attack and strike fighter aircraft.

Unit cost: $29 million
Max speed: Mach 1.7+
Propulsion: 2x F404-GE-402 turbofan engines (17,700lb static thrust each)
Ceiling: 50,000+ft
Combat range: 1,089Nm (1,253mi, 2,000km)

The Statistics
E-2 Hawkeye

Provides tactical early warning information via advanced radar system.

Unit cost: $80 million
Max speed: 300kts+ (345mph, 552km/h)
Propulsion: 2x Allison T-56-A427 turboprop engines
Ceiling: 30,000ft (9,100m)
Crew: 5

Aircraft carriers

Living on an aircraft carrier can be a stimulating, equally exhausting experience. Learn why, despite its name, there can be no room for passengers…

Aircraft carriers of the world don't come much larger than the US Navy's nuclear-powered Nimitz-class. At 4.5 acres and stretching 1,092 feet, the flight deck of USS Abraham Lincoln dwarfs the Chrysler Building. Despite its awesome profile, however, its role is more than symbolic. The carrier can balance and mobilise a seagoing airbase of multiple strike and combat support aircraft, with a ship's company of over 5,000 souls. It can deploy anywhere within international waters while retaining the sovereign territory of its home place of berth. Therefore, unlike an airbase stationed on foreign soil, no permission for landing or overflight rights is required.

Despite its loner appearance, however, the aircraft carrier is not without friends; it is often flanked by a more nimble carrier 'battle' group that can offer added protection, tactical options and extra supplies to the fleet.

"When word of crisis breaks out in Washington, it's no accident the first question that comes to everyone's lips is 'where is the nearest carrier?'"

Former President Bill Clinton

DID YOU KNOW? The Nimitz-class of supercarrier was named after significant WWII Pacific fleet commander Chester Nimitz

Nuclear-powered Nimitz

America's Nimitz-class aircraft carriers are powered by two small on-board pressurised water reactors (PWR), which drive the ship's four steam turbines that not only power four five-bladed propellers, but also generate electricity to power everything on the ship. The nuclear reactions taking place in the PWRs can generate enough power to reach a top speed of 30 knots. Inside the reactor cores a huge amount of energy is given off due to fission – the splitting of large atoms (uranium) into smaller ones and releasing kinetic energy in the process.

There are two separate loops inside each aircraft carrier's nuclear power station. The primary loop contains superheated water, or coolant (in liquid form). This coolant is pumped through the uranium-fuelled reactor – where it reaches up to 900°F – under high pressure so it doesn't boil inside the core. This superhot water is then passed through a steam generator. The heated water in the primary loop doesn't get converted to steam itself (because it's under high pressure), rather the intense heat of it is used to convert the cooler water in the separate secondary loop into turbine-driving steam to power the generator. And because the loops are separate and the water never mixes, the radioactivity is safely contained in the reactor of the primary loop. The steam from the turbine is then cooled and condensed, converting it back into liquid water ready to run the cycle again.

The reactors rarely require refuelling – maybe once every 25 years – offering carriers practically unlimited range. Refuelling involves removing the used core and replacing it with a shiny new one replenished with enriched uranium nuclear fuel.

The Statistics

EA-6B Prowler

Electronically jams enemy radar and electronic data links.

Unit cost: $52 million
Max speed: 500kts+ (575mph, 920km/h)
Propulsion: 2x Pratt & Whitney J52-P408 engines (10,400lb thrust each)
Ceiling: 37,600ft
Combat range: 1,000+Nmi (1,150mi, 1,840km)

The Statistics

F/A-18E/F Super Hornet

Multi-role attack and fighter. Has air superiority as a fighter escort and recon aircraft.

Unit cost: $57 million
Max speed: Mach 1.8+
Propulsion: 2x F414-GE-400 turbofan engines (22,000lb static thrust each)
Ceiling: 50,000+ft
Combat range: 1,275Nmi (1,467mi, 2,346km)

The Statistics

SH-60 and MH-60 Seahawk helicopter

Twin-engine, medium lift, utility or assault helicopter.

Unit cost: $5.9 million to $10.2 million
Max speed: 180kts (207mph, 333km/h)
Propulsion: 2x T700-GE-700 or T700-GE-701C engines
Crew: 3-4
Range: 380Nmi (437mi, 600km) air refuelling makes range ultimately unlimited

The aircraft

There are around 85 aircraft on board a Nimitz-class, including dozens of different types capable of taking out enemy aircraft and ground targets, performing electronics warfare to mess with enemy radars, providing early warning signals for tactical operations, and attacking submarine enemies.

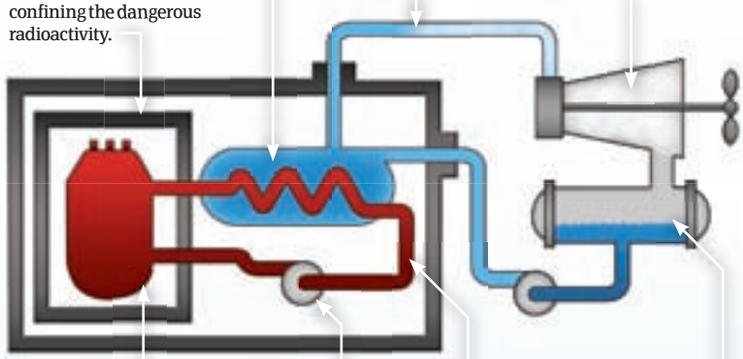
Although the flight deck is big, all 85 aircraft cannot be parked up top so most are stowed in the carrier's garage, or hangar bay. Over 60 aircraft and spare jets can be kept two decks down in a three-deck high area that extends more than two thirds of the length of the carrier.

5. Steam generator
The steam generator uses heat from the coolant in the primary loop to turn the water in the secondary loop to steam ready to turn the turbine. Once the coolant's heat is released at the steam generator, the colder coolant returns to the reactor to go round again.

6. Steam
The steam created in the secondary loop turns the turbine, driving a generator that produces electricity.

8. Turbine
Steam turns the turbine shaft, driving the generator and producing electricity. A Nimitz's two PWRs generate enough electrical power to supply a population of 100,000.

4. Radiation shield
Concrete surrounds the radioactive materials, confining the dangerous radioactivity.



3. Reactor
Nuclear fission of uranium fuel takes place inside the tightly sealed reactor, releasing huge amounts of heat (between 500°F and 900°F), which is transferred to the coolant.

1. Primary coolant pump
Circulates coolant around the reactor and through the steam generator.

2. Pressurised water (coolant)
Natural water is superheated but doesn't boil because it is kept under high pressure.

7. Condenser
This device turns the steam into liquid by cooling it. The condensed water is then piped back into the steam generator to be reheated again.

"The Nimitz-class must carry enough supplies to satisfy a three-month stretch at sea"

No hanging about below deck

Hangars serve as dual-purpose maintenance and storage facilities for half the carrier's aircraft contingent at any one time, with the remainder in flight or housed on the flight deck.

Typically each bay is separated by a steel dividing door; a throwback to Kamikaze raids of WWII to confine and limit the incendiary threat of fire. The hangar and flight deck are connected by lifts. With its increased capacity, the Nimitz-class carriers like the USS Abraham Lincoln operate four deck edge high-speed elevators, each capable of lifting two F/A-18 jets; in so doing it can relocate eight aircraft simultaneously from hangar to flight deck in a matter of seconds.

The USS Abraham Lincoln, see the cutaway below for more detail

Hitting the deck

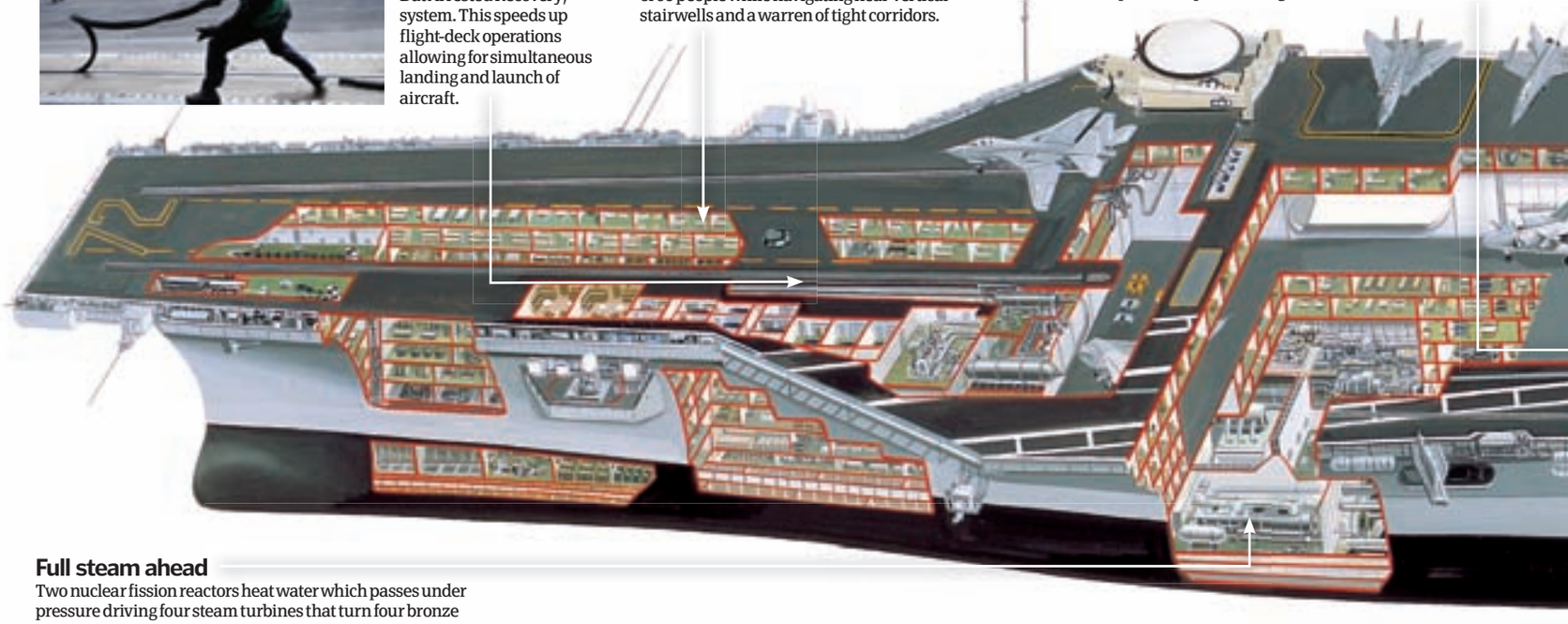
Two angled flight-decks support the CATOBAR (Catapult Assisted Take Off But Arrested Recovery) system. This speeds up flight-deck operations allowing for simultaneous landing and launch of aircraft.

Cutting crew quarters

Crew typically endure cramped living quarters with triple-stacked bunks, often sharing compartments and toilet facilities with upwards of 60 people while navigating near-vertical stairwells and a warren of tight corridors.

Is there a doctor on board?

Yes. The medical department is located under the hangar deck to ease patient access, offer stability during surgical procedures and protection from damage under fire. On Nimitz-class carriers it operates a spacious surgical suite and intensive care unit.



Full steam ahead

Two nuclear fission reactors heat water which passes under pressure driving four steam turbines that turn four bronze propellers – each measuring 20ft and weighing 30 tons apiece – to achieve a maximum speed of 35 knots (equivalent to 40mph). The protruding bulbous bow adds buoyancy, reducing drag for enhanced handling and propulsion. It adds extra lift to the flight deck that aids in an aircraft's launch.

A carrier sails on its stomach...

While the 2,480-strong air wing busies itself with flying and maintaining the aircraft, the 3,200 ship's company crew provide the supporting carrier services ranging from nuclear reactor maintenance to culinary services and scrubbing the dishes.

The Nimitz-class must carry enough food and supplies to satisfy a three-month stretch at sea, with multiple kitchens and mess halls that satisfy the three-meal-a-day appetite of all those on board. To wash this down each ship boasts desalination units, converting an ocean of seawater into 400,000 gallons of freshwater to be used by the crew.

During downtime the cramped crew compartments that house 60 or so men each offer small commons room access with a TV reception. Catching up with home is made easy with banks of phones via satellite link-up, a ship's newspaper, post office and its own postcode! Other necessities and opportunities for work and distraction include a hospital, dental practice, general stores, laundry facilities, library and a barbershop.

5 TOP FACTS CARRIERS

Top guns
1 As if landing at 150mph on the open ocean wasn't hard enough, the extreme Gs associated with decelerating to zero within feet of touchdown puts great stress on the pilot.

Shooters
2 Steam-driven catapult officers must gauge the airflow speed and direction over the flight deck and balance this with varied settings for aircraft to attain sufficient speed and lift.

AGOs (Arrest Gear Operators)
3 Aside from clearing the pilot for landing, the AGO must set the arrest gear engines to apply the correct level of resistance to the arrest cables that capture the aircraft.

The well-oiled 'Grapes'
4 Purple jerseys signify aviation fuel handlers. These crew members manage highly flammable workloads at speed on the flight and hangar decks.

The fire-fighters
5 Red jerseys operate all mobile fire and crash-and-salvage equipment. They are responsible for the rescue of flight-deck personnel and deal with fuel spillages.

DID YOU KNOW? *While nuclear-powered carriers have unlimited range, non-nuclear ones make do with 17ft to the gallon*

The island
Approaching 50m tall the tower is one tenth as wide at the flight deck where space is at a premium. It bristles with radar and communication antenna that can sense the proximity of the fleet, target encroaching threats and receive TV/satellite reception.

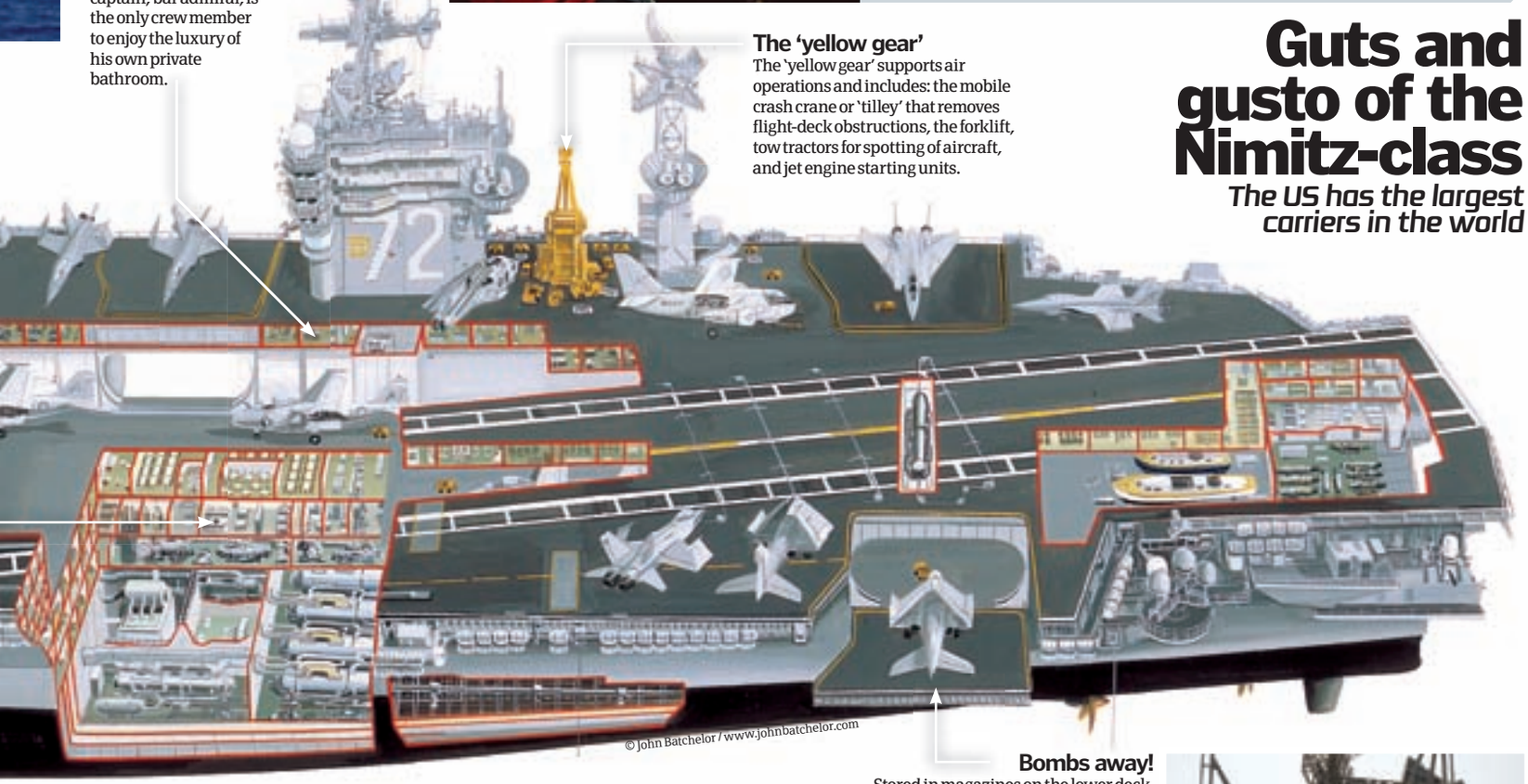
The captain's log
The captain's quarters double as office space and afford comparative luxury with a 30x30-foot living space. The captain, bar admiral, is the only crew member to enjoy the luxury of his own private bathroom.

No man is an 'island'
The primary flight control (or 'Pri-Fly') is home to the Air Boss. With a crow's nest view of proceedings and an array of GPS receivers and radar screens to hand, he choreographs the well-oiled ritual of take-off and landings, flight-deck manoeuvres and those in-flight aircraft in close proximity to the ship.

Below, the Bridge is home to the Officer of the Deck (OOD) – appointed on four-hourly rotations by the Commanding Officer (Captain). He stays at his station while 'under sail' and is responsible for all safety and operational decisions from navigation through to communications. With its computer-enhanced air detection systems, the nearby CDC (Combat Direction Centre) provides the Tactical Action Officer with real-time data to assist his role in supporting the CO in defensive/offensive operations.

The 'yellow gear'
The 'yellow gear' supports air operations and includes: the mobile crash crane or 'tilley' that removes flight-deck obstructions, the forklift, tow tractors for spotting of aircraft, and jet engine starting units.

Guts and gusto of the Nimitz-class
The US has the largest carriers in the world



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A vested interest
Coloured vests signify flight-deck function. The whites represent safety officer and crew; blue are the aircraft handling and chock crewmen; green is the catapult and arrest crews; yellow includes the catapult/flight-deck officers; and brown, the plane captains.

Bombs away!
Stored in magazines on the lower deck, weapons are transferred to below flight deck by bomb elevators; once assembled they are transferred to carts and the flight deck elevators where they can be manually fitted by flight deck crew.

Landing on a postage stamp
Despite its 4.5 acres, the carrier has limited space and planes require mechanised support to take off and land. Aircraft are spotted by tractors, readied with fuel pumped from tanks below deck and primed with missiles. During a take off the carrier speeds into the wind, causing air to flow over the deck. This acts in conjunction with powerful steam-driven 'Fat Cat' catapults that propel 30-ton jets with the necessary speed and lift to launch at a rate of up to four every minute.

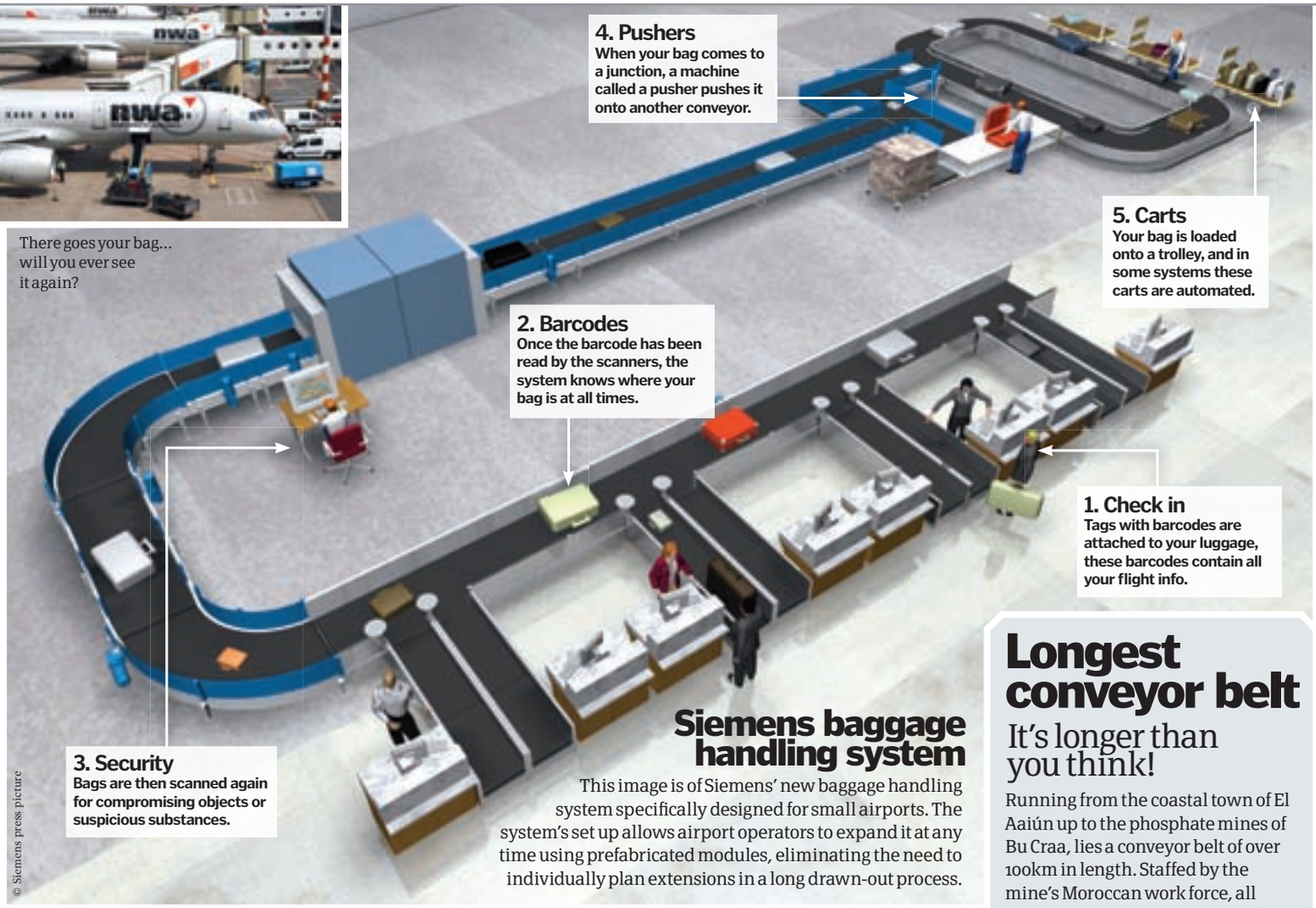
Hitting a 'postage stamp' on open water, aircraft rely on 1.375-inch-thick arrest cables, suspended five inches off the flight deck, separated at 35-40 foot intervals. These cables connect to hydraulic cylinders that act as giant shock absorbers. When the tail hook connects with a cable it pulls a piston within a fluid-filled chamber of the cylinder; as it's drawn down energy is absorbed, bringing aircraft to a halt.

Smaller carriers forgo the CATOBAR system for short take-off and vertical landing (STOVL). The RN developed a 'ski jump' ramp at the end of the deck to help launch aircraft that require little or no forward movement to take off or land.

"Once cleared by security the baggage is then loaded onto a DCV and carried through underground tunnels"

© Barcex

There goes your bag... will you ever see it again?



© Siemens press picture

Siemens baggage handling system
This image is of Siemens' new baggage handling system specifically designed for small airports. The system's set up allows airport operators to expand it at any time using prefabricated modules, eliminating the need to individually plan extensions in a long drawn-out process.

Baggage handling

How is your luggage transferred to and from an aircraft?

A baggage handling system consists of a series of automated conveyor belts, destination-coded vehicles (DCVs) – unmanned carts mounted on tracks and powered by linear induction motors – label scanners, sorting machines and security checkpoints that serve three main tasks. The first is to move bags from an airport's check-in area to the departure gate, to transfer luggage from one gate to another, and to move baggage from arrival gates back to the baggage claim area safely.

To understand how the system works, it is best to follow a single bag from check-in to an aircraft. From check-in a bag has a label attached to it that acts as a tag, containing all necessary information on its target destination and delivery time frame, before being carried off on a conveyor belt to an automated barcode scanner. Here its tag is read and loaded onto the system's computer database, allowing it to track the individual piece of luggage throughout the rest of its journey.

After this initial scan the luggage is then carried by further conveyor belts to a security checkpoint and x-ray machine, where it is scanned automatically again for compromising objects or suspicious substances. Once it has been cleared by security the baggage is then loaded onto a DCV and carried through underground tunnels (sometimes up to a mile away from the initial check-in desk) to its target destination gate. At the junction for the requested gate, the DCV then dumps the luggage onto a parallel-running conveyor that takes it to the gate's sorting station.

At this point the automation in the baggage handling system ends and human baggage handlers then sort and load the luggage into containers ready to be wheeled to the plane's hold. Luggage is separated depending on size, end destination (ie is the passenger going to be transferred at the next airport or is that their end destination) and type – skis and other odd-shaped objects for example.

Longest conveyor belt

It's longer than you think!

Running from the coastal town of El Aaiún up to the phosphate mines of Bu Craa, lies a conveyor belt of over 100km in length. Staffed by the mine's Moroccan work force, all resources excavated from the mine are transported along the conveyor belt to the coast in order that they may be directly loaded onto cargo ships. Recently, as part of the National Geographic Megaflyover project, the conveyor belt had a portion of it imaged in super high resolution, allowing its epic scale to be better appreciated. The belt dwarfs the longest airport system of conveyor belts yet built, a record currently held by Dubai International Airport with its amazing 92 kilometres of baggage handling machinery.

"It's the first to ship with integrated internet connectivity and a computer operating system"

Mavizen TTX02

The electric powered superbike

The Mavizen TTX02 isn't just an electrically powered superbike, it's the first to ship with integrated internet connectivity and a computer operating system, which means the rider can monitor every aspect of the bike's performance when racing. An operating system is the software that powers a computer, like Windows on your PC. This operating system – referred to as Linux – is "open source" which means that anyone is free to hack and customise it so that every aspect of the bike's performance can be studied and potentially modified. It's also the first bike to have USB ports, opening up the possibility of attaching any number of peripherals to it through that system to either improve or monitor the performance.

This modular approach is also found in the batteries, with Mavizen offering three different battery formats based on the needs of the rider. The bike is even designed on a road-legal chassis, although drivers will have to install the number plate, lights and mirrors themselves.

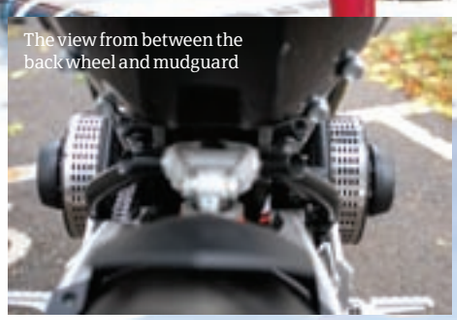
Frame
A powder-coated chromium-molybdenum trellis means the bike's body is both light and strong.

Rear brake
A single disc back brake is installed to aid in controlling the bike.

The Statistics

Mavizen TTX02

Cost: £26,000
Dimensions: Height: 810mm, wheelbase 1,430mm, handlebar width 720mm
Weight: 110kg (without batteries)
Top speed: 130 miles per hour
Power: Lithium polymer battery pack in one of three interchangeable sizes
Torque: 105Nm at 4,800rpm
Engine size: Two 96-volt DC Agni 95R electric motors
Tank range: Up to 10kWh
Fuel capacity: Sprint Package – 4kWh/Circuit Package – 7.5kWh /Endurance Package – 10kWh



The view from between the back wheel and mudguard

Batteries definitely included

The TTX02 is powered by two 96-volt direct current Agni 95R electric motors instead of a petrol engine. Mavizen offers three different battery packs for the engines which provide different energy outputs depending on the capacity of the batteries installed up to a maximum output of 400A for 20 seconds or 36kW per motor. Interestingly, all three battery packs can be installed in the same chassis, meaning that the bike is not only fast and light but also highly adaptable.

Head to Head ELECTRIC VEHICLES

1. Sinclair C5

A battery assisted tricycle invented by Sir Clive Sinclair and launched in 1985, it was derided as a joke at the time but has attained cult status.

2. Toyota RAV4 EV

An electric version of the popular SUV, the RAV4 EV reached a top speed of 78mph when it was launched in 1997.

3. Tesla Roadster

The Tesla Roadster is one of the first battery powered sports cars and can go from 0-60mph in 3.7 seconds.

DID YOU KNOW? *The TTX02 competed in the inaugural Time Trial Xtreme GP in 2009*

Main fuse (not shown)

A vital part of the safety procedures for any electrical vehicle.

Twist throttle

The throttle doesn't work traditionally, but instead sends electrical pulses to the motor controller.

The bike's lightweight frame aids performance

The TTX02 can reach speeds of up to 130mph

Front brake

A double disc front brake is installed, allowing the bike to slow quickly if needed.

Make sure you don't forget your charger...

Learn more

Some of the best resources available are the websites of bike manufacturers with both Mavizen (**http://www.mavizen.com/**) and EMB (**http://www.electricmotorbike.org/**), the makers of the Lectra motorbike, good places to start. *50 Ways To Greener Travel* by Sian Berry, published by Kyle Cathie, is also worth a look.

Interview

How It Works spoke to CEO Azhar Hussain

Mavizen CEO Azhar Hussain with the TTX02

How It Works: How was the bike originally conceptualised?
Azhar Hussain: Mavizen was conceptualised as a way to prove that eSuperbike technology is here and viable. Launched in 2008 to support the world's first fully sanctioned, zero carbon race in 2009, it acts as the technology, advisory and consulting arm of the TTXGP helping to support the grid and drive technological innovations forward. Mavizen first built the TTX01 to prove that electric race bikes were viable and the technology was ready. We then built on this with the TTX02, taking design inspiration from and improving on the Agni X01, the bike that won the first ever electric superbike race, the 2009 TTXGP.

HIW: What can buyers expect?
AH: Buyers can expect a race-ready eSuperbike, designed to facilitate easy access to electric racing and a fantastic base on which to develop new custom software solutions. The TTX02 has been incredibly well received by all those who have ridden it, partly because of the KTM RC8 chassis which offers excellent handling and reliability and in part because it is incredibly easy to ride with much improved throttle control over many older electric bikes. It is also possible to use the TTX02 on the road.

HIW: Are there any problems with the bike or the technology?
AH: With any new technology there is inevitably going to be problems and it is our challenge to meet these and improve performance. The greatest challenge is battery technology, it is improving at a dramatic rate but still has some way to go.

HIW: What's next for Mavizen?
AH: Mavizen will continue to supply customers with competitive bikes for the TTXGP and expand its presence in the road market. TTXGP has already gone from a single race in 2009 to three championships with 12 races and a grand finale in Albacete, Spain, with 35 teams expected to make the grid across all championships. TTXGP's future is bright.

"The system operates akin to a solid rocket booster"


Air bags post deployment from steering wheel and dashboard

© Janipewter

Air bags

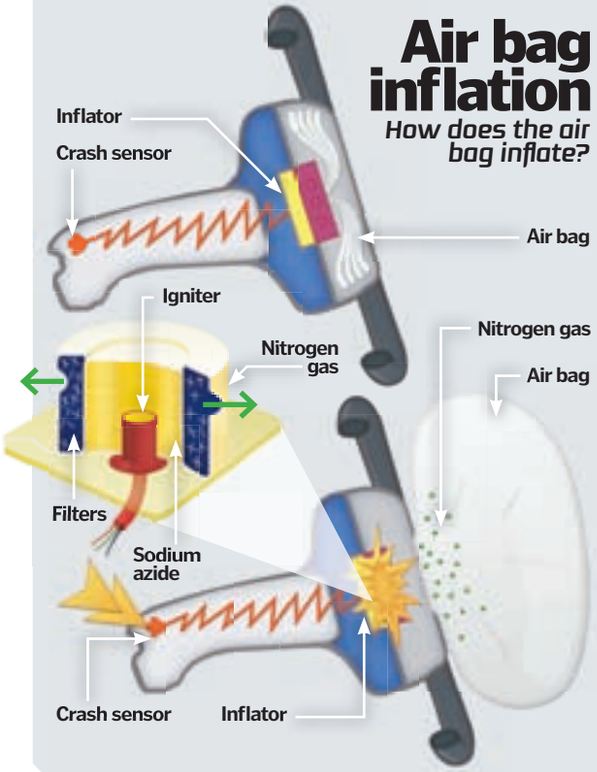
How do they inflate so quickly?

Air bags consist of three main parts: the bag itself, which is constructed from a thin, nylon-type fabric and folded into the steering wheel or dashboard of a vehicle; the air bag sensor, a device which tells the bag when to inflate; and the air bag's inflation system, a mechanism which produces and releases nitrogen gas quickly to cause bag inflation.

The inflation system is key to any air bag, as it must complete its process in a fraction of a second. The system operates akin to a solid rocket booster, igniting a solid propellant that burns extremely rapidly to create a large volume of gas. This gas inflates the bag at over 200mph in order to mitigate the forward momentum the human is experiencing during the crash. Once inflated, the bag then releases the gas slowly through small holes in order for the passenger to then exit the vehicle.

Air bag inflation

How does the air bag inflate?



© Segway

Segway

Exploring the technology that drives this personal transporter

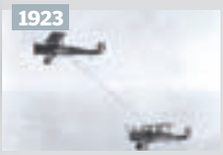
The Statistics

Segway i2

Weight: 47.7kg (105lbs)
Tyre size: 19" (48cm)
Max speed: 12.5mph (20kph)
Max range: 24 miles (38km)

Segways work by using a combination of gyroscopes, electric motors and a user-controlled vertical steering column to propel individuals around outdoor and indoor environments. Direction is dictated by the tilting of the vertical frame – left to turn left, right to turn right – and forward and backwards momentum is dictated by the positioning of the user's weight and posture while on the Segway. Lean forwards and the internal microchips instruct power to be delivered from the electric motors to rotate the wheels forwards, lean backwards and the reverse is delivered. Power is derived from an internal series of cell batteries that are recharged with electricity sourced from any standard power supply.

Head to Head REFUELLING EVOLUTION

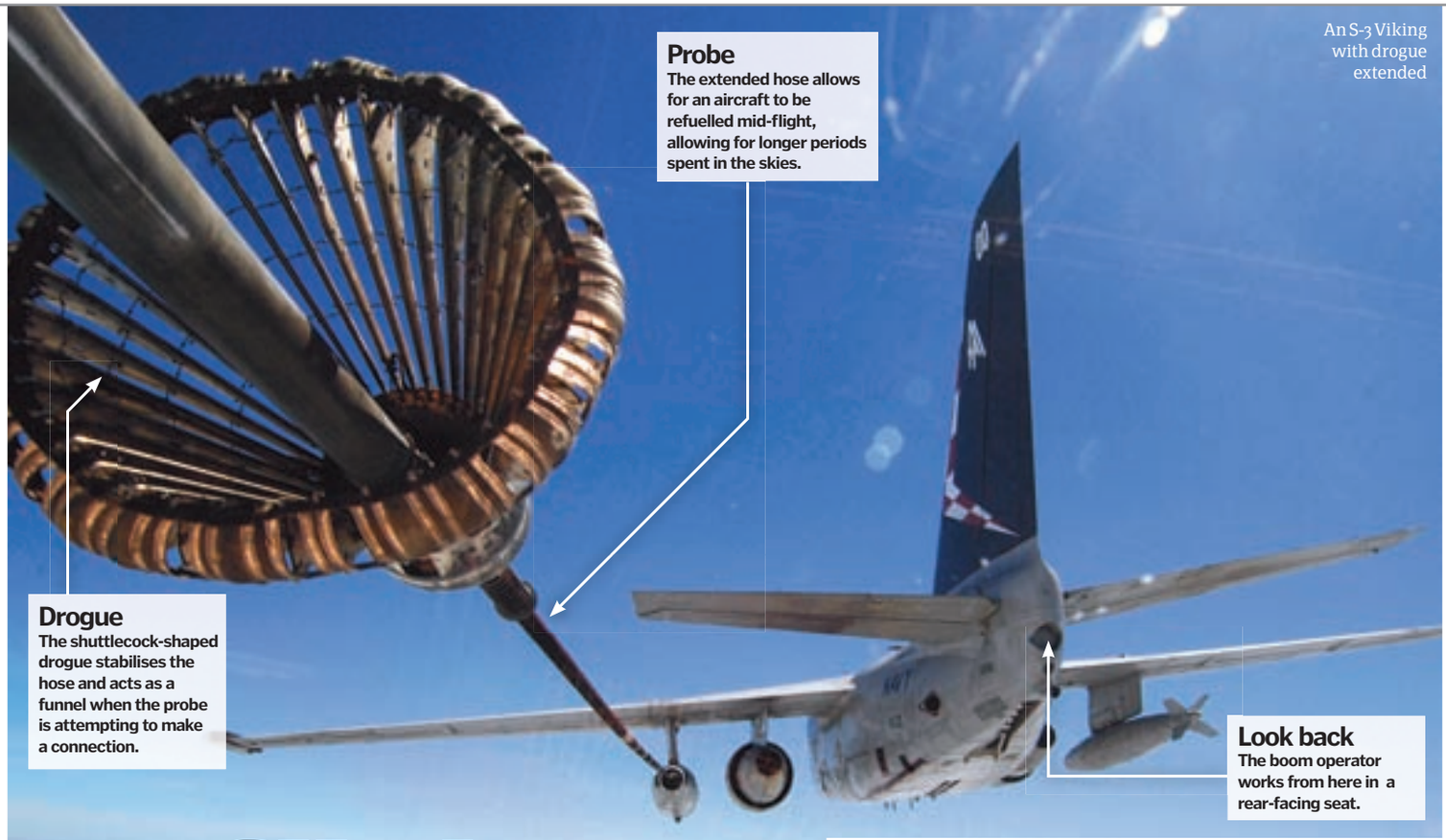


1. Basic
The first mid-air refuelling took place on 27 June 1923 between two US Army Air Service biplanes, allowing a DH-4B biplane to remain aloft for over 37 hours.

2. Standard
The introduction of jet planes and supertankers meant aircraft needed to, and more importantly could be, refuelled quicker and at higher speeds.

3. Advanced
High-speed supersonic aircraft, such as this F-18A, are refuelled by colossal flying tankers using boom and drogue automated systems.

DID YOU KNOW? *The world's first dedicated aerial fuel tanker was the Boeing KC-97 Stratotanker, built in 1950*



An S-3 Viking with drogue extended

Probe
The extended hose allows for an aircraft to be refuelled mid-flight, allowing for longer periods spent in the skies.

Drogue
The shuttlecock-shaped drogue stabilises the hose and acts as a funnel when the probe is attempting to make a connection.

Look back
The boom operator works from here in a rear-facing seat.

In-flight refuelling

Nozzle control
The "boomer" flies the nozzle into alignment with the receptacle by positioning the ruddervators with a control stick.

How It Works looks at the technology that is allowing military aircraft to stay in the air for extended periods of time

Aerial refuelling is the process of transferring fuel from one aircraft to another while in mid-flight in order to allow the receiving aircraft to continue operations for extended periods of time. This is a crucial factor for military aircraft while operating in war zones as it allows a round-the-clock instantaneous response time, meaning aircraft can support troops faster and more effectively. In-flight refuelling also allows aircraft to take-off with a greater armament payload to fuel reserve ratio, as it can receive more fuel while airborne.

Currently, there are two methods used in aerial refuelling procedures. The first option is a probe and drogue system, where fuel is transferred down a suspended, flexible hose to an aircraft's receptor probe. The other choice is a flying boom system where fuel is transferred down a static pipe extension and guided into the aircraft's fuel receptor by a human engineer. Hybrid systems, where both aforementioned systems are combined, also exist but they are rare, often being used to refuel helicopters instead of jet aircraft.

The boom and receptacle system – also called a 'flying boom' – allows for greater amounts of fuel to be transferred to the target aircraft faster than probe and drogue due to its rigid telescoping tube. The tube is stabilised when extended by twin wings, mounted on either side, which the operator – referred to as a 'boomer' – controls within the tanker-carrying aircraft to make adjustments to its positioning. The receiving aircraft's pilot then collaborates with the boomer – using radio communication and visual cues, such as flashing lights – to make a clean connection between boom and receptacle.

The probe and drogue system refuels aircraft differently, restricting the speed at which fuel can be transferred but allowing for greater flexibility and numbers of aircraft being refuelled at one time. The system employs a flexible hose (there can be multiple hoses) from the tanker aircraft that trails behind it, often from either of its wings. On the end of the hose lies the drogue, a shuttlecock shaped conical basket – this both stabilises the hose while trailed and also provides the receiving aircraft's probe a funnel aid when attempting to make a connection. Fuel flow is controlled from within the tanker aircraft, with a series of green and red lights indicating to the pilot of the receiving aircraft when fuel is flowing and when to disengage.

"Manufacturers work closely with scientists to steal a march on their rivals"

Cars 2.0 – the future is now

Cutting-edge car tech

Discover the cars of tomorrow you can buy today

Car makers have a process for introducing their latest technology. They debut it in their most exclusive, expensive motors before filtering it down to more mainstream versions as the tech becomes cheaper. This means that if you have the cash, you can buy a 'Tomorrow's World' car, right now.

This is becoming a key area for manufacturers. Cars are basically so good nowadays, the differences are increasingly going to be found in the technology that they carry. Brands have huge departments dedicated to developing features that will give them even the slightest edge in the marketplace; they also work very closely with scientists from suppliers, to steal a march over their rivals.

We will all benefit in time. BMW introduced satnav on the 7 Series in the Nineties – today, most cars can have it. Mercedes sold anti-lock brakes on the S-Class in the Seventies; nowadays, even city cars have anti-skid electronics that can pulse-brake individual wheels to stabilise the car and keep them on the straight and narrow.

So what can family hatchback buyers look forward to in the future? These three cars are among the most high-tech on sale, and showcase what tomorrow's Ford Focus may come with...

The Statistics

Nissan GT-R

Manufacturer: Nissan
Dimensions: Length: 4,655mm, width: 1,895mm, height: 1,370mm
Class: Supercar
Body style: Coupe
Engine: 3.8-litre twin-turbo V6, 485PS
Transmission: Six-speed paddle-shift dual-clutch
Price UK/US: £56,800/$85,060
Features: Multi-function display, carbon-fibre driveshaft, Bilstein electronic dampers, six-speed rear-transaxle gearbox, hand-built twin-turbo engine

5 TOP FACTS
BEST OF THE REST

Range Rover
1 Traditional dashboard dials are replaced by 'virtual' instruments. These are graphical representations of speedo, fuel gauges and other dials on a high-res screen.

Nissan
2 Scratch Shield paint self-repairs light scratches: an elastic resin forms a clearcoat over the paint, which has a 'memory' that restores scratched paint.

Volkswagen Phaeton
3 Windscreen wipers have a special park system that varies their resting position to reduce wear. They also sense weather conditions and can adjust for dealing with snow.

Jaguar XJ
4 Bowers & Wilkins 1200W stereo has 20 speakers, 15 channels and uses Dolby Pro Logic II technology. It can offer 7.1 surround sound – better than many home systems.

Fiat
5 eco:Drive efficiency computer monitors your driving style onboard. Drivers can plug a USB drive into the Blue&Me connector and analyses the efficiency of their driving.

DID YOU KNOW? *Car makers have had to develop new high-speed connectors such as FlexRay to handle data flows*

Supercar for the PlayStation generation

The Nissan GT-R is a car that is faster than a Porsche and is a cult car for computer game fans. This is because it is one of the world's highest tech cars – and a key interface is the colour multi-function display screen in the dashboard. This provides the computer-style link for fans of Sony's PlayStation.

It was developed by videogame maker Polyphony Digital, which is the company also responsible for the *Gran Turismo* series. Well, why not – after all, it was the videogame that fostered the cult of the GT-R. The collaboration with the software developers was natural.

It used the car's standard touch-screen satnav system, but developed bespoke software that interfaced with the car's engine ECU systems. It came up with an array of user-definable instrumentation, and added on functionality that normally is only seen in the racing car world. It means the road car can be analysed in the same infinite depth as a videogame racer: the perfect crossover from console to circuit!

© Nissan

Motorsport-inspired marvel

Nissan wanted to provide the ultimate driving interaction with the car, and it does so through its multi-function monitor

1. How smoothly do you steer?
The shape of the steering g-force graph can rate driving smoothness. Peaks and sudden inputs go against racing driver ideals.

2. Grip of your tyres, in numbers
The sideways g-force graph provides information about grip levels of tyres. Tyres can then be changed depending on use.

3. G-force recorded
Acceleration g-force graphs record data inputs from the last 20 seconds, providing a continually moving stream of information.

4. Any display you like
Two displays can be selected by the user – preset display screen or summary display screens.

5. Touch-screen tech
The touch screen uses resistive technology. This means the driver or passenger don't have to worry about fiddly buttons.

6. Advise on what you should see
Vehicle engineers provided a list of key data streams that performance drivers need to monitor.

7. A year in the virtual world
Software developers spent a year developing the multi-function display, using top-of-the-range virtual software.

8. Virtual becomes reality
Real-world development was conducted during design, at race tracks such as Laguna Seca in the US and Germany's Nurburgring.

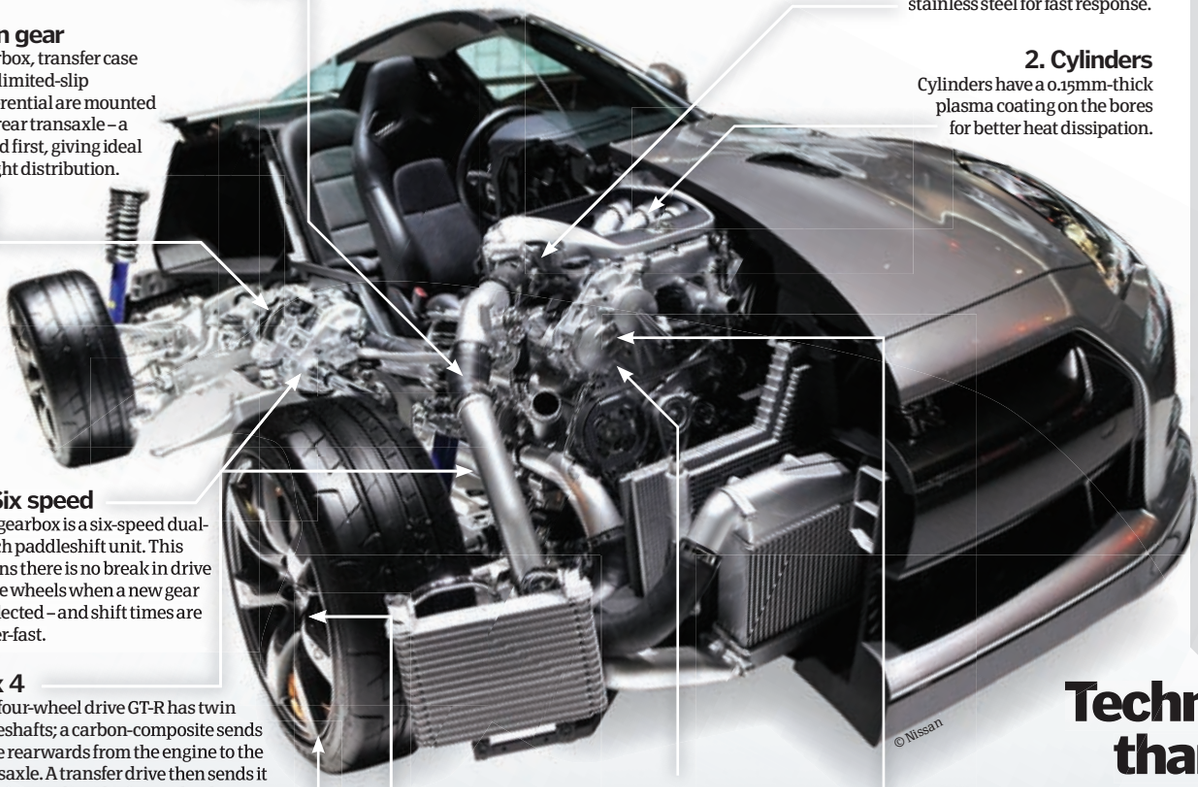
9. Gearshift guide
Gears can be selected fully automatically by the car's computer – but the driver can take control too.

8. Dampers
Electronic Bilstein dampers use 11 data feeds to constantly adjust stiffness in response to driving style and road conditions.

3. In gear
Gearbox, transfer case and limited-slip differential are mounted in a rear transaxle – a world first, giving ideal weight distribution.

7. Turbochargers
Twin IHI turbochargers each have their own air-to-air intercooler, providing colder and more dense air for a bigger bang. Internal turbines are lightweight stainless steel for fast response.

2. Cylinders
Cylinders have a 0.15mm-thick plasma coating on the bores for better heat dissipation.


© Nissan

5. Six speed
The gearbox is a six-speed dual-clutch paddleshift unit. This means there is no break in drive to the wheels when a new gear is selected – and shift times are super-fast.

4. x 4
The four-wheel drive GT-R has twin driveshafts; a carbon-composite sends drive rearwards from the engine to the transaxle. A transfer drive then sends it back forwards to the front wheels.

10. Gangster rims
Wheels are forged aluminium for the lightest weight possible. Dunlop tyres were developed especially for the GT-R and can safely run for 50 miles even when punctured.

9. Brakes
380mm Brembo brakes are fully ventilated and have six pot front monoblock callipers. They can slow the car from 62mph to rest in 36.9 metres.

6. Hand made
The entire engine is hand-assembled by a single technician. They work in a special sealed 'clean room' at Nissan's Yokohama plant.

1. Fast!
485bhp 3.8-litre twin-turbo V6 engine can accelerate from 0-62mph in 3.5 seconds. It can reach 194mph.

Technology: more than just virtual

Nissan did not just concentrate on electronic gadgets when developing the GT-R. The fundamentals of the car are also high-technology and use some of the world's most expensive engineering materials during production.

"Night vision uses a front-mounted infrared camera to see in the dark"

Cars 2.0 – the future is now

S-Class

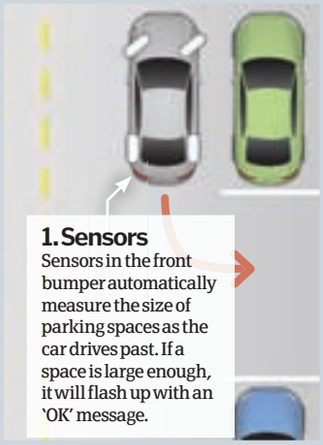
Mercedes has always sold the S-Class as a world-leader for technology, and the latest one is no exception. Here really is cutting-edge technology; it was the first car to have night vision, for example, which uses a front-mounted infrared camera to 'see in the dark' using a monitor in the dash panels. Mercedes has now enhanced it with new algorithms that can detect and warn about pedestrians.

It has two-in-one display screens, sensors that know if you're falling asleep way before even you do – it even parks itself at the touch of a button! And innovations on this today will certainly come to the mainstream models of tomorrow.


Cat-like vision with the S-Class dashboard

The car that (almost) parks itself

Mercedes has used feeds from the car's ultrasonic parking sensors to devise an 'auto park' algorithm. This can compute just how you need to turn the wheels as you go backwards in order to get into the space – and, of course, whether it's large enough in the first place!



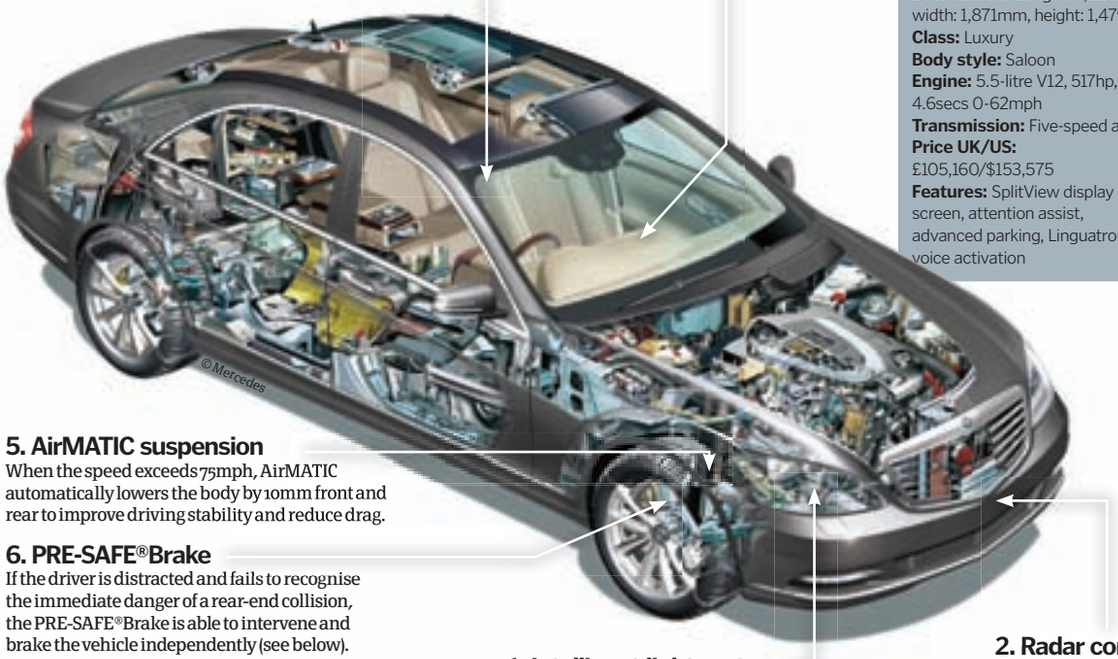
1. Sensors
Sensors in the front bumper automatically measure the size of parking spaces as the car drives past. If a space is large enough, it will flash up with an 'OK' message.

2. Activate
The system is activated only when the driver confirms their intentions by then selecting reverse gear.

3. Tight
Spaces can be just 1.3 metres longer than the car for parking to be allowed.

4. Rear seat entertainment package
Two eight-inch screens housed in the front headrests, separate DVD drive and two sets of headphones, as well as the Harman Kardon® Logic7® surround sound system.

3. Twin-screen tech
The central display screen has SplitView technology, for '2 in 1' viewing. The Bosch monitor is an active matrix TFT-LCD.



5. AirMATIC suspension
When the speed exceeds 75mph, AirMATIC automatically lowers the body by 10mm front and rear to improve driving stability and reduce drag.

6. PRE-SAFE®Brake
If the driver is distracted and fails to recognise the immediate danger of a rear-end collision, the PRE-SAFE®Brake is able to intervene and brake the vehicle independently (see below).

1. Intelligent light system
Bi-xenon headlamps follow the driver's steering movements and features five light functions designed specifically for typical driving situations or weather conditions.

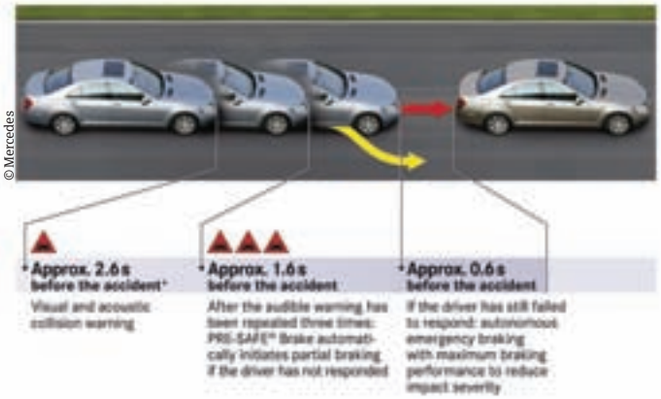
2. Radar control
The Distronic Plus system scans the road ahead and can automatically keep the car at a safe distance from the car in front.

The Statistics

Mercedes S-Class

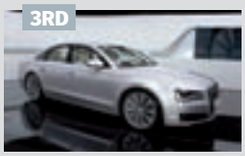
Manufacturer: Mercedes-Benz
Dimensions: Length: 5,226mm, width: 1,871mm, height: 1,479mm
Class: Luxury
Body style: Saloon
Engine: 5.5-litre V12, 517hp, 4.6secs 0-62mph
Transmission: Five-speed auto
Price UK/US: £105,160/$153,575
Features: SplitView display screen, attention assist, advanced parking, Linguatronic voice activation

Collision awareness



1. Mercedes S-Class
It has been a world-leader for car technology since it was launched – the current car shows no signs of letting up the gadgetry onslaught!

2. Nissan GT-R
Leading-edge technology is no-expense-spared, and even stretches into the computer gaming world for added kudos. Perfect for the PlayStation generation.



3. Audi A8
The road-reading A8 allows you to search for routes to your destination on your home computer then send them to your car... that's just the tip of the iceberg!

DID YOU KNOW? *Current 12v in-car power sources are almost at the limit for today's technology*

The most high-tech Audi on (Google) Earth

Audi has always sold itself on 'progress through technology' – Vorsprung durch Technik. As its range-topping luxury saloon, the exec A8 leads the brand. Even the way it's constructed is cutting-edge; unlike most cars it's made from lightweight aluminium, which cuts emissions and means it's readily recyclable.

Within the car is a mass of technology. Audi has worked hard on its in-car networking electronics for some time now, and the software it has developed is now very stable – which has meant it's been able to deeply integrate Google Maps into the car. Even better, this will soon move to Google Earth display, once the requisite high-capacity modem is installed.

It will give satnav detail and depth like never before, and allow for far more precise and useful location searches. The car itself will use this data, too: a profile of the road it's on is used by the gearbox, for example, to select the best gears for the corners coming up. It's yet another step closer to a fully networked road car system... how long before we get a car that can drive itself?

Google Maps
Launch A8s use a GPRS/EDGE modem. Audi has linked the satnav to Google Maps, which means owners can search for routes on their home computer and send it to the car.

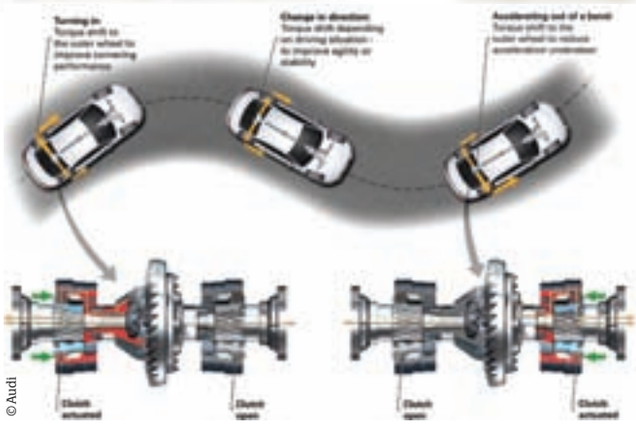
Car decides whether to push or pull
An active sport differential in the transmission electronically alters the road wheel driving torque split both front-to-rear and side-to-side.

Crash sensor
If it detects sudden braking, the car will switch on the hazard warning lights, close the side windows and sunroof, and pre-tension the seat belts.

Gearbox reads the road
The satnav system is linked to the gearbox; it 'reads' the road ahead and sets the ideal gearshift settings for upcoming corners.

Range-wide benefits
Like many car makers, Audi uses the same logic for its in-car computer systems throughout the range.

Car becomes Wi-Fi hotspot
Audi is installing a UMTS model into the A8. This will provide faster data transfer and allow full internet access – the car will also be able to function as a WLAN hotspot.



Quattro sports differential

Audi's unique sports differential distributes torque from the engine independently between the rear wheels. In the basic setting the torque-sensing centre differential delivers 40 per cent of torque to the front axle and 60 per cent to the rear. Should the system detect any loss of traction then part of this torque will be sent to the rear wheels in less than 100 milliseconds.

Drivers can choose from three operating modes; comfort mode focuses on stability, auto-mode provides a balance between stability and handling while the dynamic mode offers best handling at the price of a rougher ride.

The Statistics

Audi A8

Manufacturer: Audi
Dimensions: Length: 5,226mm, width: 1,871mm, height: 1,479mm
Class: Luxury
Body style: Saloon
Engine: 4.2-litre V8, 372hp, 5.7secs 0-62mph, 29.7mpg
Transmission: Eight-speed automatic
Price UK/US: £61,640/$75,375
Features: Google Maps, Google Earth, WLAN hotspot ability, safety pre-sensor, gearshift autoselect

Communicating the future

The road ahead for car tech

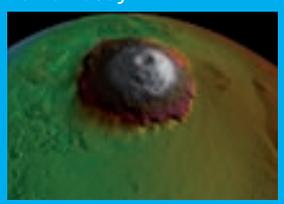
In-car technology is the big battleground of the future. Functions and features that are being seen in computer technology will fast come to cars too: expect augmented-reality parking, far more use of both on-board and satnav sensors, plus 'always on' communications for seamless interfacing with the outside world.

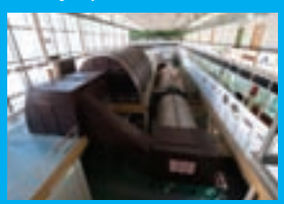
This will go a step further in years to come, too. A dream of car engineers is to have a networked road car system, where all cars are communicating with one another. There will also be dialogue with static items such as traffic lights, and analysis from traffic information centres.

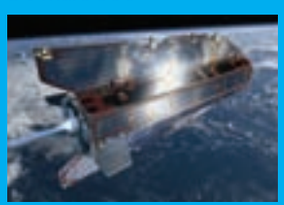
The technology behind cars like the BMW EfficientDynamics concept is set to trickle down to mainstream motoring

This month in **Space**

A manned mission to Mars is a complex undertaking, so it's a good idea to have a trial run first. Our main space feature takes a look at the Mars 500 mission currently under way in Russia. We like to think of it as *Big Brother* meets *Red Dwarf*, but the subjects currently in isolation are probably taking their work a little more seriously. And rightly so, the findings of this experiment will give experts a clearer idea on the psychological and physical effects of such a massive journey on the human body.







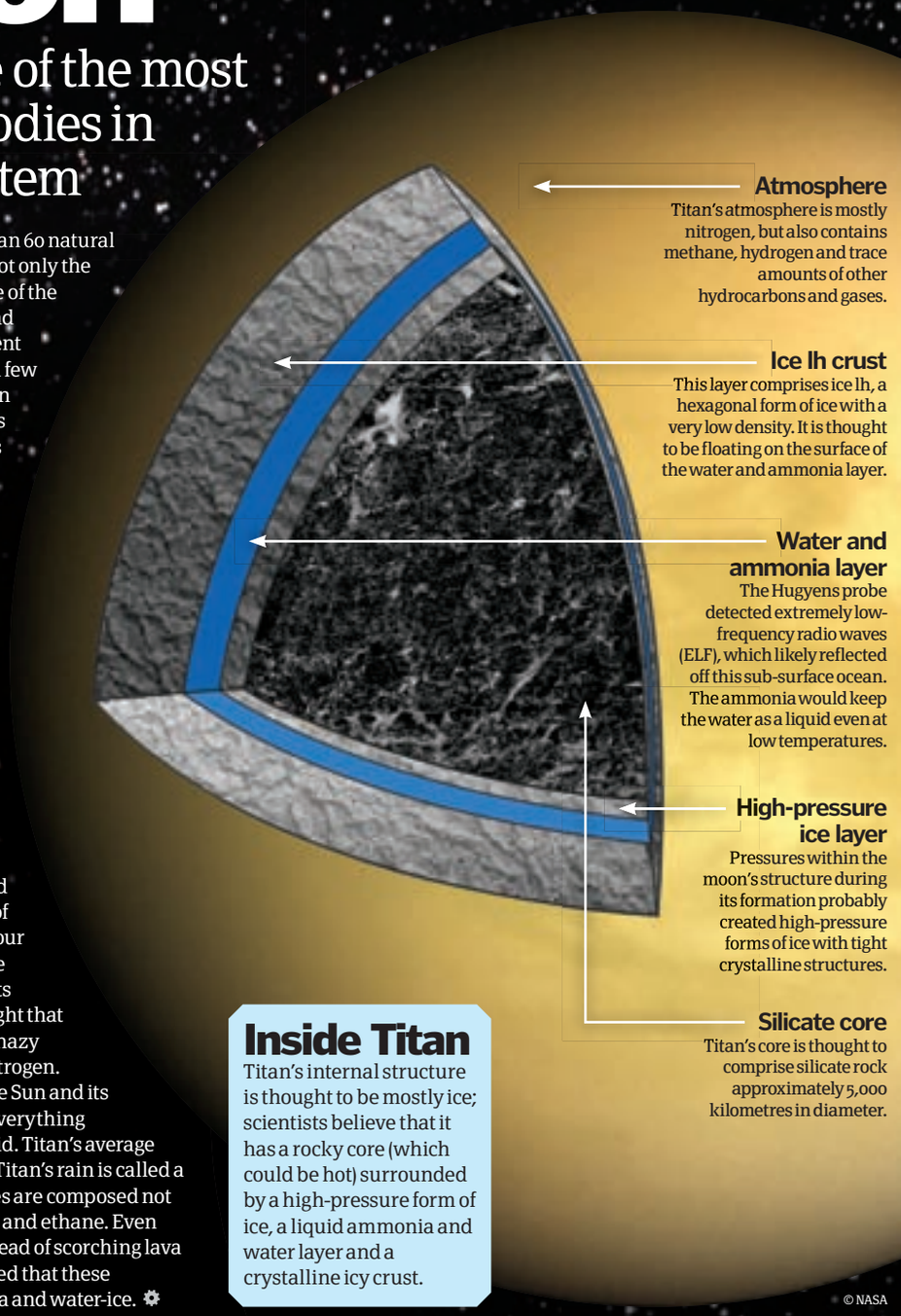
SPACE

Titan: Saturn's largest moon

Discover one of the most Earth-like bodies in our solar system

Of Saturn's more than 60 natural satellites, Titan is not only the largest, but also one of the most fascinating and mysterious. It is about 50 per cent larger than Earth's moon and a few hundred kilometres larger than the planet Mercury, but Titan is often compared to Earth. It has clouds in its atmosphere that produce rain, which has resulted in large lakes at the poles. Stable bodies of water like these do not exist anywhere else but Earth. Titan also has predictable wind patterns, as well as volcanoes and evidence of plate tectonics. These processes have given it a landscape dotted with mountain ranges, dunes, valleys and shorelines.

Scientists often call Titan 'early Earth' because they believe that its atmosphere and surface – which is mostly free of impact craters – are similar to our planet around the time that life began. However, Titan only gets about one per cent of the sunlight that Earth gets, thanks to its thick, hazy atmosphere mostly made of nitrogen. Because of its distance from the Sun and its thick atmosphere, just about everything related to the moon is very frigid. Titan's average surface temperature is –179°C. Titan's rain is called a "methane drizzle", and its lakes are composed not of water, but of liquid methane and ethane. Even Titan's volcanoes are cold; instead of scorching lava made of liquid rock, it is believed that these 'cryovolcanoes' spew ammonia and water-ice.



Atmosphere
Titan's atmosphere is mostly nitrogen, but also contains methane, hydrogen and trace amounts of other hydrocarbons and gases.

Ice Ih crust
This layer comprises ice Ih, a hexagonal form of ice with a very low density. It is thought to be floating on the surface of the water and ammonia layer.

Water and ammonia layer
The Hugyens probe detected extremely low-frequency radio waves (ELF), which likely reflected off this sub-surface ocean. The ammonia would keep the water as a liquid even at low temperatures.

High-pressure ice layer
Pressures within the moon's structure during its formation probably created high-pressure forms of ice with tight crystalline structures.

Silicate core
Titan's core is thought to comprise silicate rock approximately 5,000 kilometres in diameter.

Inside Titan

Titan's internal structure is thought to be mostly ice; scientists believe that it has a rocky core (which could be hot) surrounded by a high-pressure form of ice, a liquid ammonia and water layer and a crystalline icy crust.

5 TOP FACTS TITAN

Orbit and rotation
1 Titan both rotates and orbits Saturn once every 15 days and 22 hours. It is also synchronous with Saturn, meaning that the same side of the moon always faces the planet.

Life on the moon?
2 There is speculation that Titan could support life, based on a lack of the organic compound acetylene and lower levels of hydrogen than some have previously predicted.

Observing Titan
3 Titan can be very difficult to see from telescopes on Earth because it is so close to Saturn and its countless number of rings, which are extremely bright.

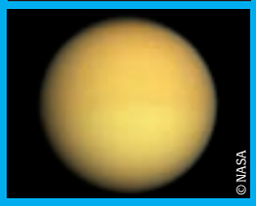
Titan as a colony
4 Titan has been considered as a candidate for colonisation. This is due to its high levels of hydrocarbons, which are far beyond all of the oil and natural gas reserves on Earth.

Flying on the moon
5 Scientists believe that people could theoretically fly on Titan with wings attached to their arms due to the low gravity and the thick atmospheric haze.

DID YOU KNOW? *Titan was discovered in 1655 by a Dutch astronomer named Christiaan Huygens, who called it Luna Saturni*

The Statistics

Titan



Diameter: 5,151 kilometres
Mass: 0.0225 Earths
Density: 1.88 grams per cubic centimetre
Average surface temperature: -178°C
Average distance from the Sun: 1,427,000,000 kilometres (9.54 AU)
Surface gravity: 0.14 g-force

Titan has a multi-layered atmosphere with very low temperatures and high pressure at its surface. Methane condenses, while surface activity such as volcanic eruptions and rain keep atmospheric gases circulating

Orange haze

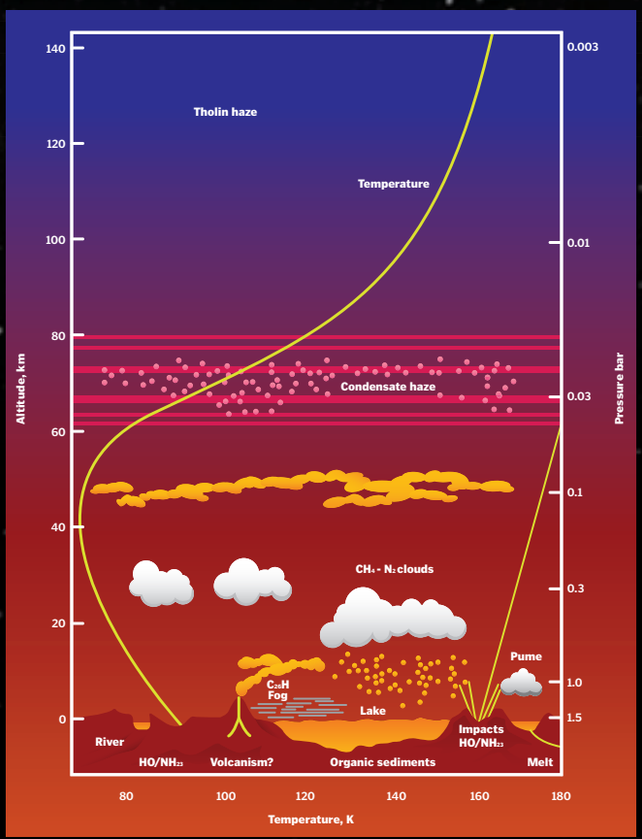
Other moons in our solar system have little-to-no atmosphere, but Titan is unique. Its atmosphere is quite dense – the atmospheric pressure is almost one and a half times that of Earth's. It is also very thick due to the moon's low gravity (lower even than our own moon's gravity), extending ten times further into space than Earth's atmosphere. Titan's atmosphere has multiple layers and is extremely complex, comprising about 98.5 per cent nitrogen, 1.3 per cent methane and 0.2 per cent hydrogen as well as traces of numerous other hydrocarbons and gases.

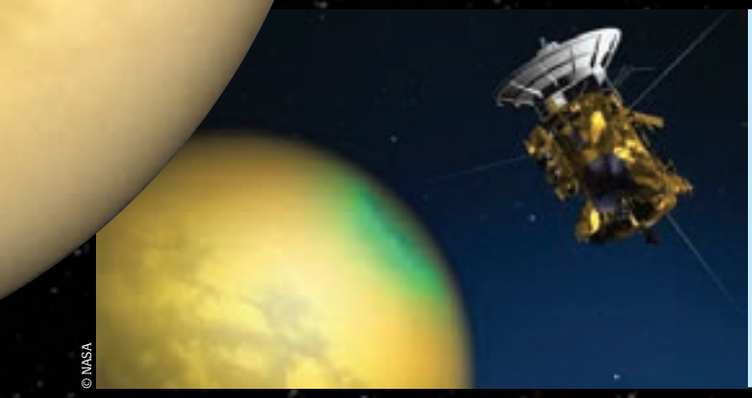
Both the atmosphere's orange-brown colour and thick haze are likely due to organic molecules such as tholins, which form when ultraviolet radiation from the Sun breaks apart the nitrogen and methane in the moon's upper atmosphere. The molecules that do not hang in the atmosphere fall down to the surface, contributing to the sand dunes that cover the planet.

Methane rain

Titan has rain like Earth, but it is made of methane instead of water. Scientists believe that the Sun should have converted all of Titan's atmospheric methane into tholins and other organic molecules millions of years ago. This means that there is a source of methane on the moon itself, and it is likely circulated back into the atmosphere through volcanic eruptions.

The thick, dense atmosphere and low gravity means that the methane rain falls very slowly and in drops twice as large as raindrops on Earth, mostly near the moon's poles. It doesn't rain very often on Titan – perhaps as little as once every few decades. When it does rain, however, there's a lot of it and it carves out ridges, dunes and valleys.





Missions to Titan

The Cassini-Huygens Mission was a joint project of NASA, the ESA and the Italian Space Agency. After several fly-bys of Titan, the Huygens probe landed on Titan's surface in 2005 and transmitted images and data back to the Cassini spacecraft. The probe provided the most in-depth look at Titan ever seen, including information about the moon's atmospheric make-up, weather and landscape. Its landing site showed a vast plain covered in water-ice rocks.

A joint NASA/ESA mission called the Titan Saturn System Mission (TSSM) has been proposed to launch as early as 2018. This mission would explore Saturn as well as Titan and another of Saturn's moons, Enceladus. It includes deploying two different types of probes on Titan: a montgolfière (or hot-air balloon) and a lander. The montgolfière would circulate in Titan's clouds and circumnavigate the moon, while the lander would splashdown in one of Titan's lakes.

"It's amazing that Pluto and Neptune can never collide"

Inset: Best-fit colour image of Pluto generated using Hubble and advanced computers

2 Pluto pics © NASA

Pluto's orbit explained

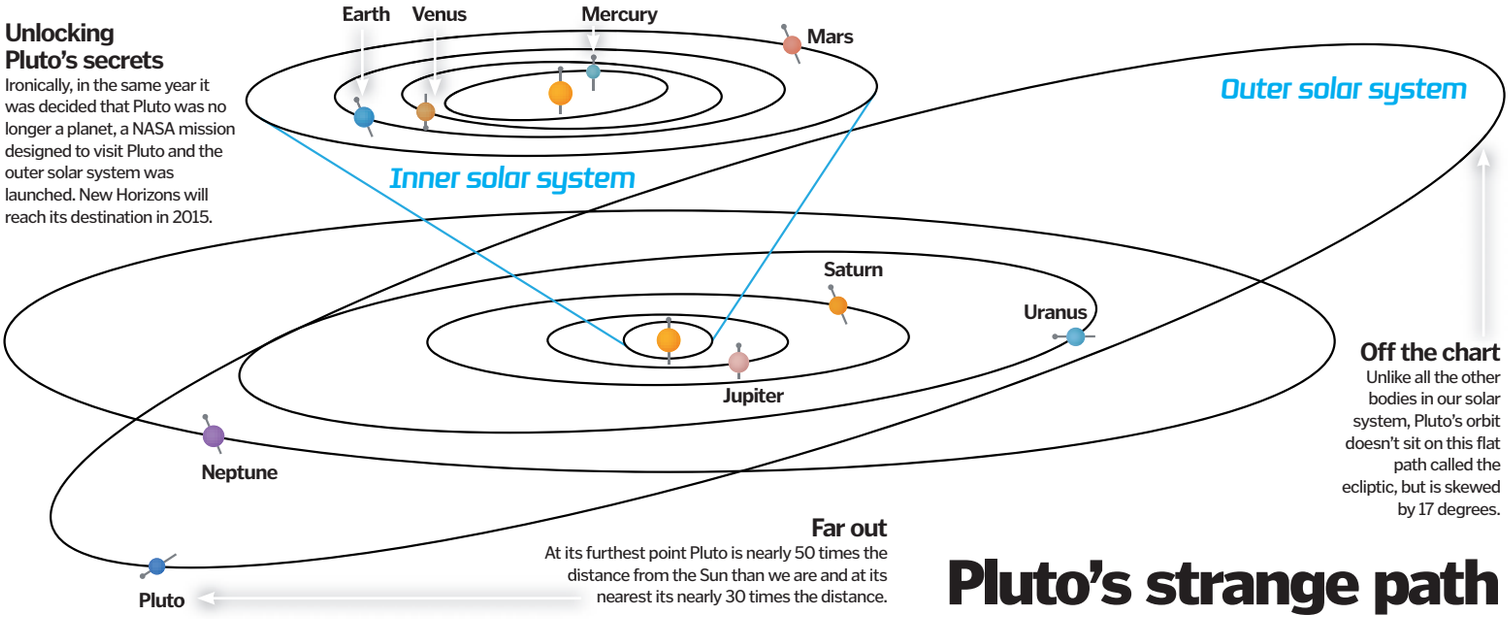
While Pluto itself is still shrouded in mystery, its orbit – odd as it is – is understood...

Pluto is the largest celestial body in the solar system yet to be probed by man. At the furthest point of its odd orbit, Pluto is nearly 50 times further from the Sun than the Earth (49 astronomical units, or AU). Unlike the Earth or its seven neighbours, the path Pluto takes around our Sun isn't circular, but elliptical. This means its 248 Earth-year orbit brings it within 29 AU at its nearest point and, remarkably, inside the orbit of Neptune. Moreover Pluto's orbit is also inclined by 17 degrees compared to the rest of the solar system, which otherwise sits along a very flat plane called the ecliptic.

Taking the chaotic path-crossing interactions with Neptune into account, it's amazing that Pluto and Neptune can never collide. This is thanks to its inclined orbit and the fact they're locked in a 3:2 orbital resonance, meaning Pluto's orbit takes 1.5 times longer than Neptune's.

Unlocking Pluto's secrets

Ironically, in the same year it was decided that Pluto was no longer a planet, a NASA mission designed to visit Pluto and the outer solar system was launched. New Horizons will reach its destination in 2015.



Off the chart

Unlike all the other bodies in our solar system, Pluto's orbit doesn't sit on this flat path called the ecliptic, but is skewed by 17 degrees.

Far out

At its furthest point Pluto is nearly 50 times the distance from the Sun than we are and at its nearest its nearly 30 times the distance.

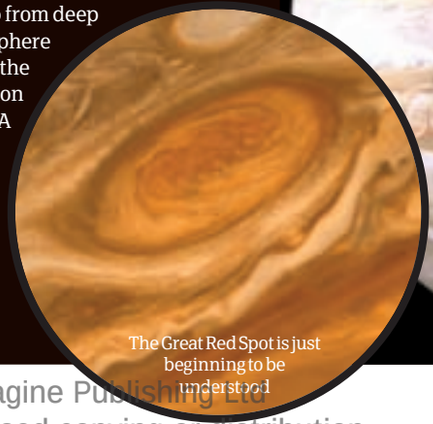
Pluto's strange path

Jupiter's Great Red Spot

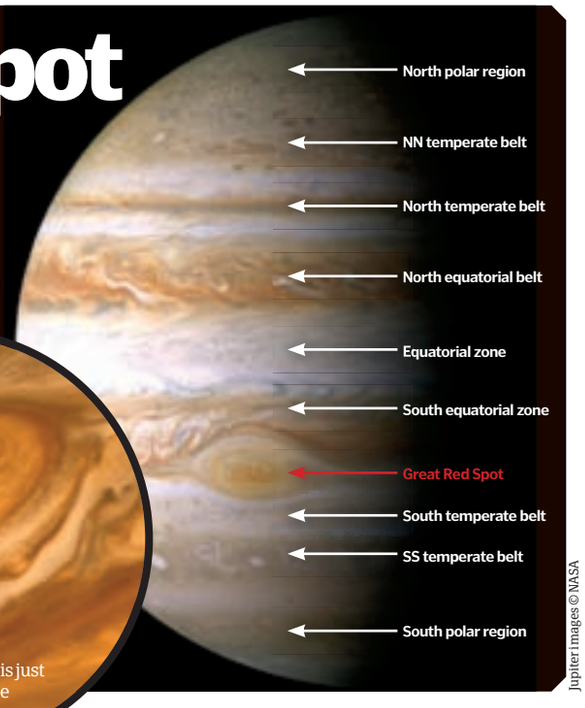
Understanding the biggest storm currently known to exist in the solar system

Jupiter's Great Red Spot has been one of astronomy's great mysteries since its discovery back in 1664 by scientist Robert Hooke. While no one knows quite how long its 350mph winds have been raging, we do know that its size, shape and intensity aren't constant. It's thought that in its formative years it was more akin to a cigar than a spot, and has been slowly shrinking – some 15 per cent in the last decade alone. However, it would still be possible to fit two Earths standing side-by-side inside the storm and have room left over for the moon.

The remarkable life span of the storm is largely accredited to the fact there are no landmasses on Jupiter, so unlike hurricanes here, there's nothing to slow its progress. While it's still yet to be proven, with the help of a smaller storm that's appeared over the last decade – Oval BA – NASA scientists are confident the red colour is a chemical reaction of material being dredged up from deep within the atmosphere being exposed to the ultraviolet radiation of the Sun. Oval BA has only recently taken on a red hue in its vortex, demonstrating that the storm is currently gaining in intensity.



The Great Red Spot is just beginning to be understood



Jupiter images © NASA

5 TOP FACTS
WONDERS OF THE SOLAR SYSTEM

Largest canyon
1 The largest known canyon in the solar system is also found on Mars. The Valles Marineris spans about 25 per cent of Mars's circumference at over 4,000 kilometres long.

Largest desert
2 The planet Venus is likely the solar system's largest desert, with a mean surface temperature of 460°C and less than 0.002 per cent water vapour in its atmosphere.

Largest crater
3 Mars has the largest impact crater of any planet in the entire solar system, the Borealis Basin, measuring in at approximately 8,500 kilometres wide.

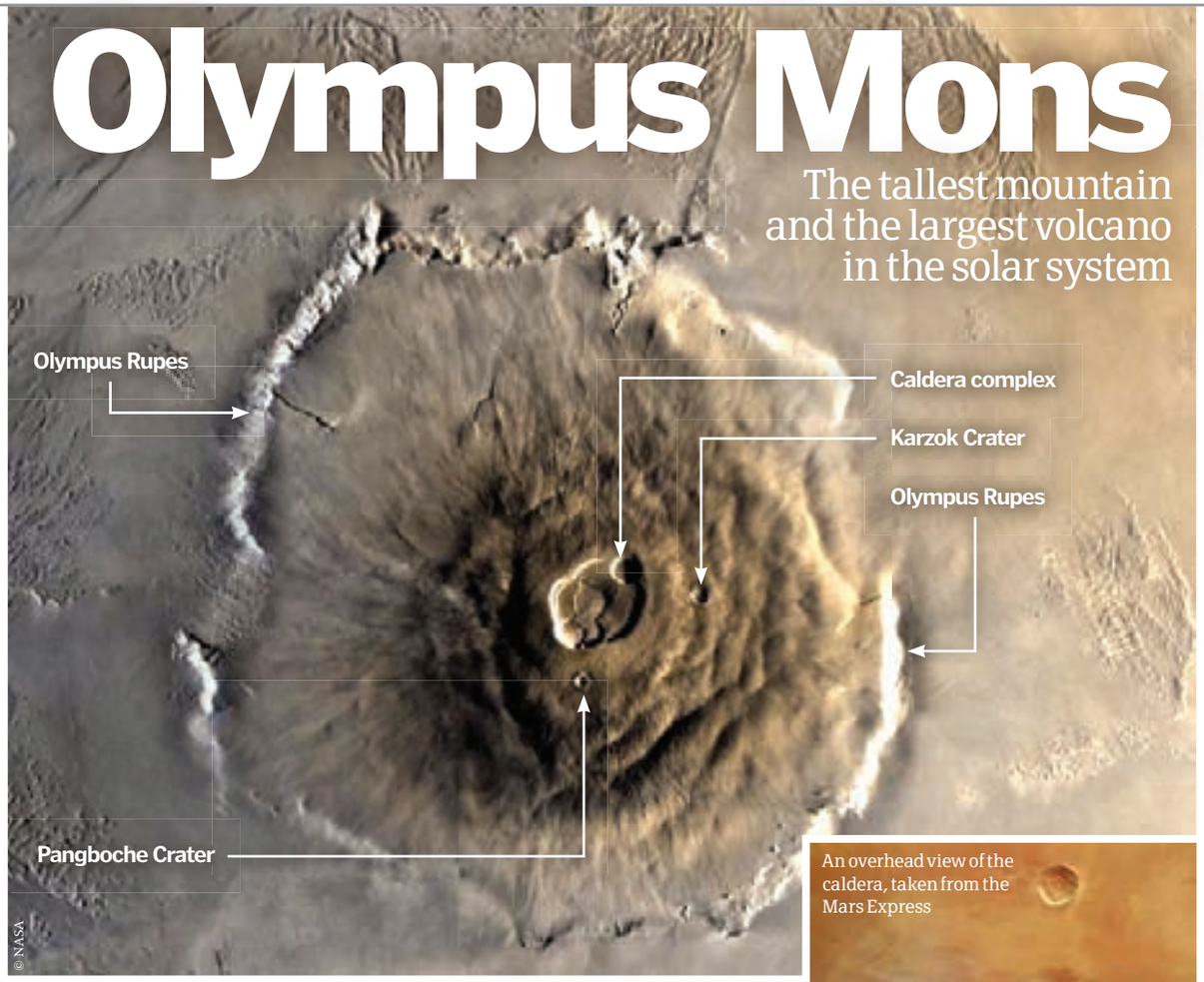
Largest lake (on Earth)
4 The largest lake (by surface area) is either the Caspian Sea – often referred to as a lake – with 371,000km² or Lake Michigan-Huron with a total of 117,600km².

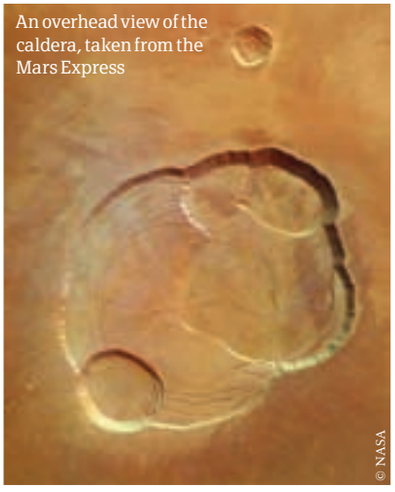
Largest Lake (not on Earth)
5 Titan, one of Saturn's moons, is believed to have several large methane lakes, including one that is approximately 100,000km² – not really ideal for a swim though...

DID YOU KNOW? *Before photos from Mariner 9 confirmed its mountain status, Olympus Mons was called Nix Olympica*

Olympus Mons

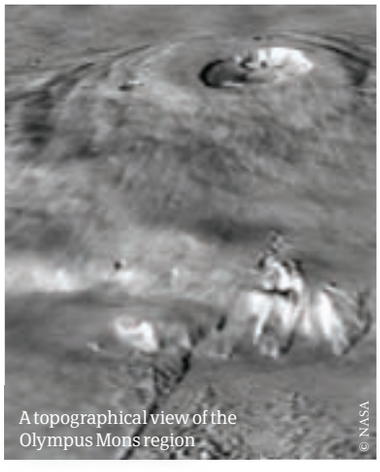
The tallest mountain and the largest volcano in the solar system



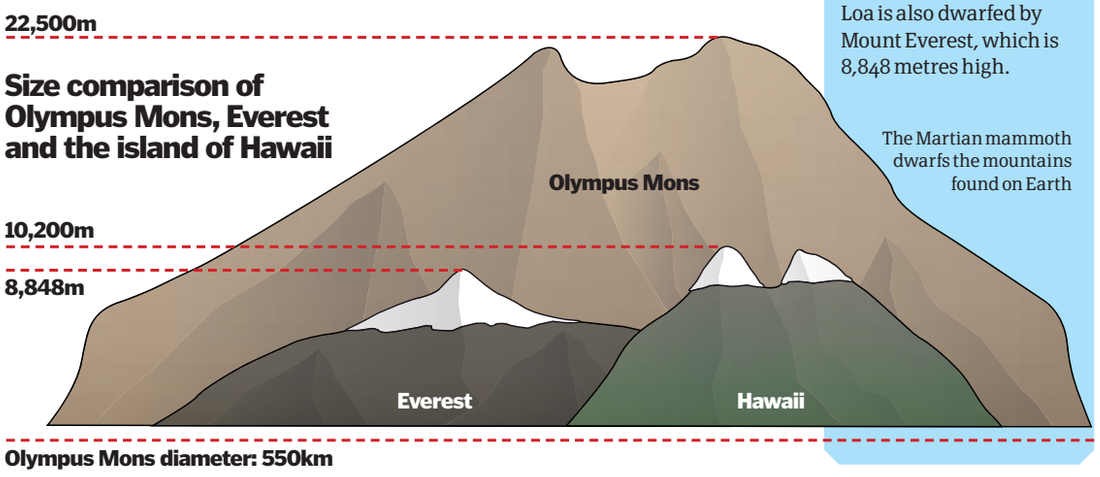

An overhead view of the caldera, taken from the Mars Express
© NASA

Mars has many interesting features, but none so striking as Olympus Mons. Astronomers believe the mountain formed fairly recently in the planet's geologic history, with the 'youngest' areas around 2 million years old. This shield volcano has a shallow slope and is wider than it is tall. It formed from very low viscosity lava that flowed over a long period of time. The peak of Olympus Mons contains a large caldera, a cavity that formed when the roof of the volcano's magma chamber collapsed and the ground above collapsed into it. More lava activity caused additional, smaller calderas that overlap the larger one, creating a caldera complex.

The volcano also has two named craters; the Karzok Crater is 15.6 kilometres wide and the Pangboche Crater is 10.4 kilometres wide. Olympus Mons lies in Tharsis, a bulging volcanic region on Mars. The area is also home to three smaller volcanoes known as the Tharsis Montes.


A topographical view of the Olympus Mons region
© NASA

Size comparison of Olympus Mons, Everest and the island of Hawaii



Olympic-sized mountain

Rising more than 27 kilometres above the surface, Olympus Mons is three times the height of Earth's tallest mountain, Mount Everest. It is about 550 kilometres wide, surrounded at its edges by escarpments called Olympus Rupes that are about six kilometres high. If a person were to stand on the surface of Mars, they would not be able to see the top of Olympus Mons due to its height, size and shallow slope. Olympus Mons likely grew to such an impressive height due to Mars's lack of plate tectonics. Without a shifting crust, lava piled up in one place. Mars's low surface gravity, only about 40 per cent that of Earth's, also accounts for the long lava flows that made Olympus Mons so wide.

Olympus Mons versus Mauna Loa

On Earth, the largest volcano is Mauna Loa, found in Hawaii. Another shield volcano, Mauna Loa stands just ten kilometres high above sea level and 75 kilometres wide. It's about 100 times smaller than Olympus Mons, and the entire chain of Hawaiian volcanoes could fit inside the Martian volcano. Mauna Loa is also dwarfed by Mount Everest, which is 8,848 metres high.

The Martian mammoth dwarfs the mountains found on Earth

"Mars 500 will simulate a manned flight to Mars using habitat modules"

Martian surface simulator
This module is designed to simulate the surface of Mars and has a volume of 1,200 cubic metres. An attached 'airlock' stores the Orlan spacesuits provided by the Russian Space Agency that three participants will use.

Habitation module
The habitation module is 3.6 metres by 20 metres. Each crew member has a compartment of about three square metres. The rest of the space contains a kitchen-dining room, toilet and communication/control room.

Mars landing module
Three of the men will live in this 6.3 metre by 6.17 metre module for the 30-day 'orbit' of Mars. It contains bunks, a toilet, workstations and all of the systems necessary for operations.

The Mars 500 mission

Find out how the six people isolated in this training facility for 520 days will help us get humans onto Mars

Although man has been sending spacecraft to explore Mars since the mid-Sixties, actually putting people on the Red Planet has remained elusive. While some of the challenges have to do with the logistics of getting to and from Mars, others centre on the effects that such a long-term mission would have on humans. Some of these questions, such as the effects of weightlessness, can best be answered via studies on the International Space Station. However, the best way to explore the social and psychological effects is to conduct a simulation on the ground. To this end, the European Space Agency, Russian Federal Space Agency and Russian Institute of Biomedical Problems (IMBP) have instituted a joint project called Mars 500.

Mars 500 will simulate a manned flight to Mars using habitat modules located at the IMBP's isolation facility in Moscow. The name comes from the 520 days that it would take to conduct an actual mission to Mars, allocating 250 days to reach the planet, 30 days to stay on its surface and 240 days to come back to Earth. To simulate this, all six participants will live and work together in four hermetically sealed interconnected modules during the first 250 days. Then a hatch will open and half of the team will move to an external module simulating a stay on Mars. For those 30 days the two groups will be separated from each other. At the end of the 'visit', the crew will be reunited for the 240-day return trip home. Mars 500 participants will otherwise be subjected to as realistic an environment as possible. Their living total space is just 550 cubic metres and they will be completely isolated from the outside world with limited communication.

Prior to the 520-day mission, there were two experimental runs at the IMBP, both with six crew members each. The first took place in November 2007 and was a 14-day simulation to test out procedures and the facility itself. Then from 31 March 2009 to 14 July 2009, the crew took part in an extended isolation study of 105 days and participated in several experiments. Both of these phases were a success and set the stage for the long-term mission.

The 520-day mission began on 3 June 2010, with a team of six males. While the 14-day study had a female

Head to Head MARS SPACESHIPS

1. Mariner 4

NASA's Mariner 4 space probe provided the first images of Mars's surface in 1964, forever changing the way that we think about the planet.

2. Mars 2

This orbiter/lander was launched in 1971 as part of the Soviet space program. However, communication was lost within 15 seconds of its landing.

3. Viking 1

The Viking 1 Lander touched down on the surface of Mars in 1976 and remained operational for six years, from July 1976 through to November 1982.

DID YOU KNOW? *A 1999 simulation at the IMBP didn't go well; incidents included a fight and a charge of sexual harassment*

Three crew members will spend 30 days in the Mars landing module, which contains three bunk beds, two workstations, a toilet and various systems

Waiting for a response could take as long as from a call centre...

Phoning home

Conversations could take a while

If the Mars 500 crew were truly on a mission to Mars, they would not be able to quickly communicate with the control centre or their family and friends due to the vast distance. For the first and last 30 days of the project, the crew members will have voice contact with the control centre (when they are 'closest' to Earth). The rest of the time, communication will be limited to email only, with an automatic built-in delay of up to 20 minutes.

All images © ESA

The modules...

Martian surface simulator

The team will use spacesuits to walk on this simulation of Mars's surface.

Medical module

Housing medical equipment and beds, this module is for diagnosing and treating anyone who falls ill.

Habitation module

This module houses crew member compartments, a kitchen-dining room, living room and communication room.

Storage module

This module stores food and other supplies as well as housing a gym and greenhouse.

Mars landing module

Half of the crew will spend 30 days in 'orbit' around Mars using this module.

Trying out spacesuits modified for use in Earth gravity while in the Mars surface simulator

© IBMP/Oleg Voloshin

crew member, it was decided that having an all-male crew for the long-term mission was the best way to go to avoid the possibility of sexual tension. Three crew members are Russian, including mission captain Alexei Sitev, an engineer-shipbuilder; Alexander Smoleevsky, a military physician and physiologist; and surgeon Sukhrob Kamolov. Wang Yue (a Chinese professional astronaut), Romain Charles (a French engineer), and Diego Urbina (an Italian-Columbian engineer) round out the crew. The entire team were required to speak either Russian or English and have a background in mechanical engineering, electronic engineering, life support systems engineering, biology or medicine. They also had to meet fitness, education and a number of other requirements. Each individual will earn approximately £68,000 for their work on the project.

Once the team was selected, they underwent more than six months of training, which included learning how to operate the equipment in their facility, how to conduct experiments and how to survive during emergencies. For example, if an astronaut on a real mission to Mars became sick or injured, his fellow colleagues would not be able to receive telemedical support for long portions of the trip. Although two of the Mars 500 crew members are doctors, all six needed to have some level of medical skill. They received advanced life support training using a life-sized mannequin called a Human Patient Simulator. During the mission they will each take refresher

"Each crew member also wears several different monitoring devices at different times during the mission"

courses and have their skills tested during simulated medical problems.

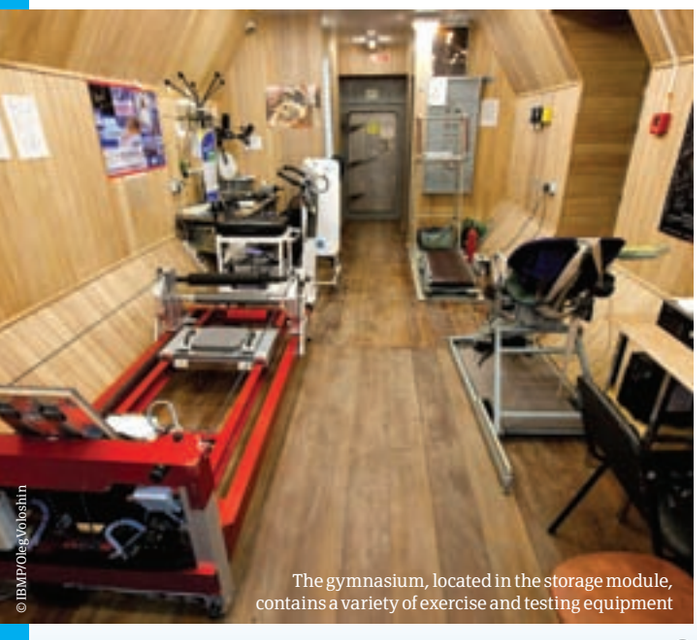
These six individuals are basically test subjects in experiments to determine how long-term isolation and confinement would affect astronauts on a mission to Mars. Data received during the project will be carefully analysed to help choose future crew members for long-term missions, as well as show how to avoid problems and solve those that do occur. On a real mission to Mars, just one small mistake by a member of the crew could prove fatal.

Just as on a real space mission, the team will follow a schedule of five eight-hour work days and two leisure days. During each working day, every single one of the men involved will perform responsibilities such as monitoring and maintaining various systems in the facility. Periodically they will be faced with simulated emergency situations and challenges. The crew will also conduct experiments, take daily exercise and eat from a limited supply of prepared foods. Participants were allowed to bring a small number of personal items, and the isolation facility contains books, videos and other forms of entertainment to use during leisure time.

Officially, the Mars 500 experiments are grouped into larger categories of protocols. Most of these protocols are focused on the physical and psychological well-being of the individuals involved, but some are designed to test out new equipment and software. Some of the experiments require crew members to use laptop computers to take questionnaires and tests as well as make voice recordings of their feelings and perceptions. Each team member also wears several different monitoring devices at different times during the mission. One device will measure his heart function via electrocardiogram. A sensor around his neck measures his light exposure as part of a study on a special type of blue-enriched light and its effect on sleep quality, waking alertness and performance. One device measures the frequency and proximity of his interactions with his colleagues, while another measures his sleep-wake activity.

This illustration of a potential Mars colony shows residents performing surface experiments outside of their home base

All images © ESA



© IBMP/Oleg Volobshin

The gymnasium, located in the storage module, contains a variety of exercise and testing equipment

How far off is the real thing?

When will we be going to Mars?

NASA has had the long-term goal of a manned mission to Mars since 2004, and the Constellation program intended to send a new spacecraft called the Orion to Mars by 2037. As of March 2010, however, the program was being dismantled. The ESA's Aurora Programme had the goal of putting a man on Mars by 2030 at its inception, but increasingly the ESA is looking at joining with NASA for any future Mars missions due to the cost. Other international agencies are no closer to a concrete plan. Members of an international non-profit organisation called the Mars Society have their own ideas as to how to best visit and colonise the planet, which they claim is cost-effective and would use existing technology. Overall, though, it appears that putting a man on Mars is still a long way off. It is hoped that the Mars 500 project will generate more interest in manned Mars missions.

Cyrille Fournier, a member in the 105-day isolation study, checks out the experimental greenhouse. The team can grow herbs and vegetables to supplement their meals

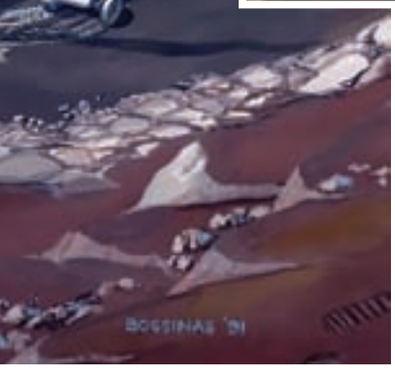
THE STATS MARS 500

HABITAT MODULE VOLUME 550m³ | BEDROOM SIZE 2.8-3.2m² | DURATION OF MISSION 520 days

MISSION APPLICANTS 6,000+ | TOTAL EXPERIMENTS 100 | LONGEST A HUMAN HAS BEEN IN SPACE 438 days

DID YOU KNOW? *The 520-day mission began on 3 June 2010*

Crew members of the 105-day isolation study work in the medical module, which contains beds and medical equipment



Crew members will periodically give exhaled breath, saliva, urine and blood samples. These will be used in several experiments, including a measure of the relationship between isolation and immune system response. Some of this exercise comes in the form of time spent on the Galileo 500, a machine designed to help prevent the loss in bone mass, muscle tone and cardiovascular fitness experienced by astronauts during long periods of weightlessness and inactivity. Although the participants of the Mars 500 will not experience weightlessness, they are still likely to lose fitness due to extended periods of inactivity. The individuals will also exercise on treadmills and have their brain activity monitored via electroencephalography (EEG). Cameras placed in the isolation facility will also record all of the team's activities.

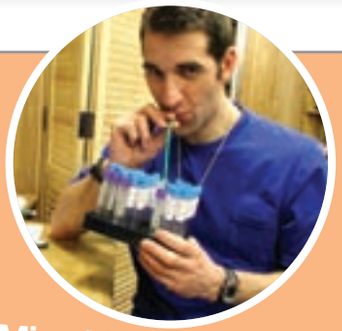
One of the protocols related to the testing and development of new software requires the men to play videogames. The Mission Execution Crew Assistant (MECA) is designed to study how electronic assistants can help astronauts during long-term missions. Once a week, two teams of three crew members each will play a co-operative multiplayer game called *Coloured Trails*, a single-player lunar lander simulation game and a collaborative trainer in which players take turns being the 'teacher' and the 'student' while learning how to use a range of technical equipment.

The Mars 500 project does have its limitations, as some critics point out. If any individual wants to leave the mission, he can let the control centre know and he will be released from the facility. There is also the lack of what ESA director Christer Fuglesang called "the scare factor", meaning that despite plans for simulated emergencies and equipment failures, the participants will never be in any real danger.

Oliver Knickel from the 105-day trial gets fitted with equipment to record his night-time brain activity

Stress and loneliness

One group of experiments during Mars 500 seeks to find out how the participants deal with stressful feelings such as loneliness, and how it affects their social and working relationships, productivity and motivation. The crew will provide feedback via questionnaires and tests on their computers.



Microbial ecology

Crew members will naturally bring micro-organisms with them to the facility, and a particular microbial population will develop during their stay. Samples will be taken from all areas of the habitat to determine the types of microbes that exist. The crew will also clean surfaces with experimental antimicrobial products and take beneficial microbial food supplements.

What they hope to learn

Mars 500 project experiments are called protocols, here are the top five things they hope to learn from the mission

Confinement and cardiac functioning

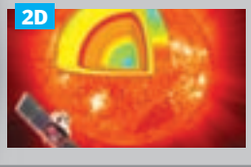
We already know that inactivity and weightlessness during long-term space missions contribute to a loss of cardiovascular health. ECG and blood pressure readings, along with other data, will be used to see whether there is also a relationship between this loss and the psychological stress of being in isolation.

Space-specific complex skills

Performing specialised tasks using hand controls, such as docking a spacecraft, are more difficult in weightless environments. If something happened to the pilot, other crew members would have to be up to the task. The men of Mars 500 will test software that will teach them how to perform these tasks.

Omega-3 fatty acids

Omega-3 fatty acids are known to improve nervous system functioning, while low levels are linked to hostility and depression. The omega-3 levels of Mars 500 participants will be periodically checked via blood samples to see how they change and determine if supplements would be beneficial during long-term confinement.



1. SOHO
Launched in 1995, SOHO is a Europe-led mission designed to study the Sun. Compared to both following missions, the visual fidelity of its findings were limited.

2. STEREO
NASA's next step was to take the study of the Sun into the third dimension. Utilising two spacecraft its mission was to study the nature of CMEs.

3. SDO
The SDO's visual capabilities dwarf both previous missions. Just three seconds of HD video revealed more detail about solar flares than many scientists ever knew.

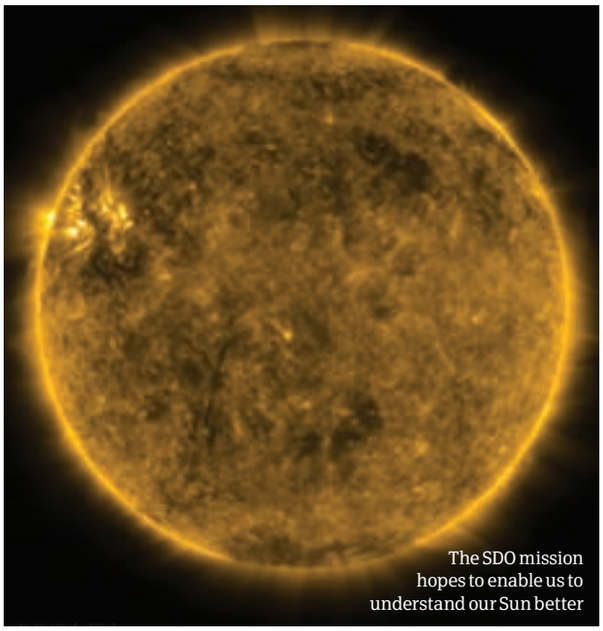
DID YOU KNOW? *The total mass of the SDO spacecraft at launch was 3,100kg, yet the SDO itself weighs just 290kg*

NASA's Solar Dynamics Observatory

If you think 1080p HD video is impressive, your tech-buds are in for a treat with the SDO...

The Solar Dynamics Observatory (SDO) is the crowning mission of a new NASA scientific endeavour designed to study our Sun. As the cornerstone of the Living With a Star program, the SDO is quite simply the most advanced spacecraft ever devised to help unlock the secrets of our Sun. Using the very latest technology the SDO can gather high quality data, process it with more advanced instruments and beam it back to Earth faster than any other scientific experiment undertaken by man.

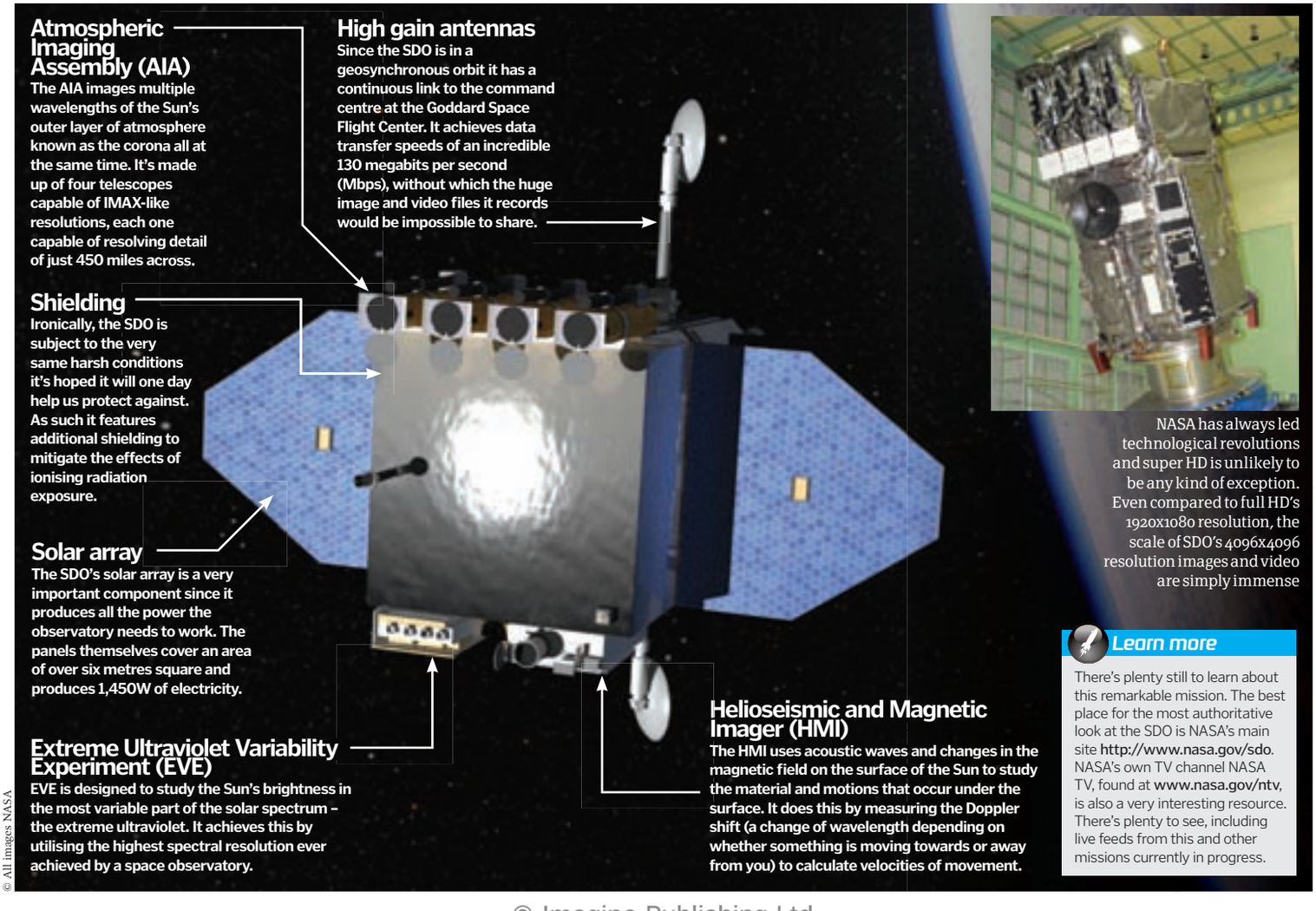
And an important mission it is too, since being able to understand and predict the processes of our Sun is becoming ever more important in this digital age. Launched in February of this year, the SDO will hopefully furnish us with the capability to better protect ourselves from 'space weather' side effects like power grid failures, long-haul flight radiation, not to mention satellite, telecommunications and GPS disruptions.



The SDO mission hopes to enable us to understand our Sun better

Road to discovery

The SDO is designed around a five-year mission, though has enough resources to ensure a ten year life span. In that time scientists hope to gain in-depth information about how and why changes in the Sun produce its 11-year solar cycle brought on by changes in its magnetic field. As a major component of the Heliophysics System Observatory (essentially a whole fleet of solar, heliospheric and geospace spacecraft working together) it'll also help unlock the secrets of the complex processes at work in space in general.



NASA has always led technological revolutions and super HD is unlikely to be any kind of exception. Even compared to full HD's 1920x1080 resolution, the scale of SDO's 4096x4096 resolution images and video are simply immense

Learn more

There's plenty still to learn about this remarkable mission. The best place for the most authoritative look at the SDO is NASA's main site **http://www.nasa.gov/sdo**. NASA's own TV channel NASA TV, found at **www.nasa.gov/ntv**, is also a very interesting resource. There's plenty to see, including live feeds from this and other missions currently in progress.

"Ion drives are being used by NASA and the ESA to power a host of next-gen probes"

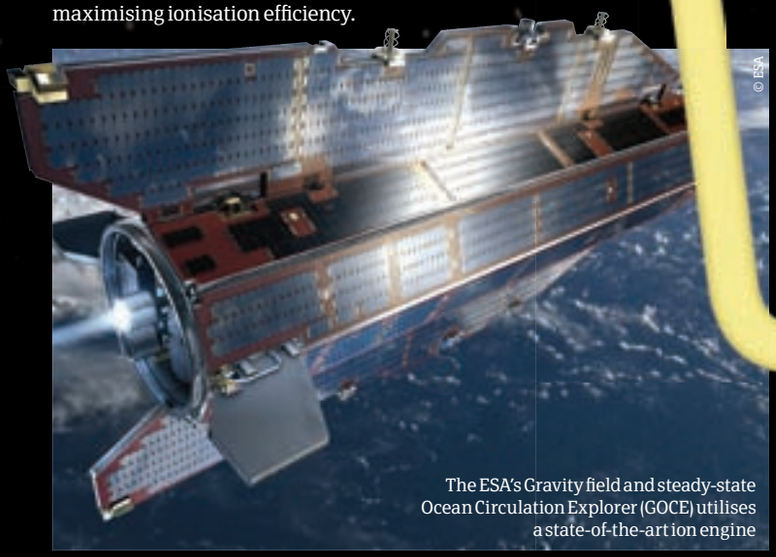
Ion engines

Positioned at the meeting point of science fiction and reality, ion drives are propelling humanity to the furthest outskirts of the universe

Ion engines generate thrust by forming and then accelerating ions at high speed. This is achieved in a two-stage process, firstly by electron bombardment – enforcing controlled collisions of negatively charged electrons with neutrally charged propellant atoms to form ions – and secondly by accelerating formed ions massively through a multi-aperture grid system out into space.

Ions are atoms or molecules that are electrically charged. Ionisation – the process all ion engines undertake – is the process of electrically charging an atom or molecule by adding or removing electrons. Ions themselves, therefore, can be positive or negative and any gas is considered ionised only when some or all of its atoms or molecules are converted into ions.

In a conventional ion engine – in the example detailed here, a gridded electrostatic ion thruster – propellant fuel (xenon, for example) is injected into the thruster's discharge chamber from its downstream end and then bombarded with electrons flowing from a hollow cathode at its upstream end. The electrons from the cathode are attracted to the discharge chamber's walls, which themselves are lined with high-strength magnets that are charged to a high positive potential by the engine's power supply. These positively charged magnets cause the electrons to be redirected back into the discharge chamber by a high magnetic field, forcing them to collide with the atoms of the propellent and maximising ionisation efficiency.


© ESA

The ESA's Gravity field and steady-state Ocean Circulation Explorer (GOCE) utilises a state-of-the-art ion engine

Xenon atoms

Propellant injection
Ion drives need lots of energy to operate and propellants must have a high mass to ionisation energy ratio. Currently, xenon gas is the propellant of choice for these drives due to its low ionisation energy, high atomic number, inert nature and low erosion threshold.

Electron

Magnet ring

Ba-Ca-Al – Heated by Sun, emits electrons

Cathode
Electrons are emitted through a hollow cathode before traversing the discharge and collected by the anode.

5 TOP FACTS ION DRIVES

Potential
1 The lowest energy state required to detach an electron from an atom is called its ionisation potential, and can also be known as its ionisation energy.

Thirsty
2 GOCE, the European Space Agency's Earth-orbiting satellite, will consume 40 kilograms of xenon over 20 months simply to power its ion drive.

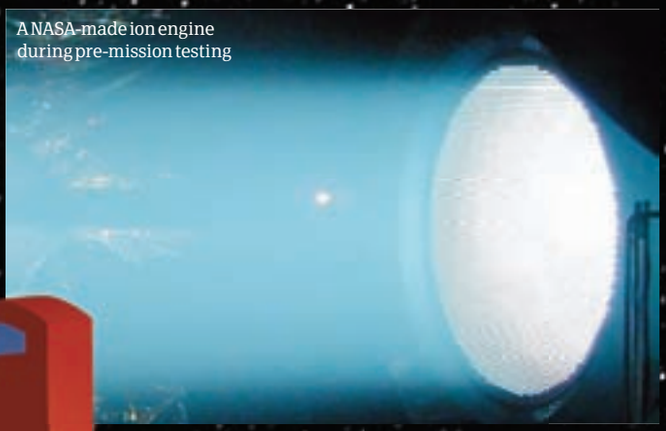
Pioneer
3 Dr Robert H Goddard, an American physicist and inventor, was the first person to postulate on the possibility of an ion drive all the way back in 1906.

Sci-fi
4 A large number of space crafts in science fiction are powered by ion drives, including the instantly recognisable SS Enterprise of *Star Trek* fame.

Noble
5 Xenon, the primary gas used to power current ion engines, is referred to as a 'noble gas' as it is odourless, colourless and has a very low chemical reactivity.

DID YOU KNOW? *An ion is simply an atom or molecule that is electrically charged*

Collision
Released high-energy electrons impact with propellant atoms causing a second electron to be released, yielding two negatively charged electrons and one positively charged ion.


A NASA-made ion engine during pre-mission testing

From this point, the newly formed ions are attracted to the drive's grid system, a series of electrodes positioned at the downstream end of the thruster. Each grid – in this case two – contains thousands of coaxial apertures that act very much like lenses, electrically focusing ions through the optics. This is because since the ions are generated in a region of high positivity and the accelerator grid's potential is negative, the ions are attracted toward the accelerator grid and are focused out of the discharge chamber through the apertures, creating thousands of ion jets. These jets, once neutralised, form the engine's ion beam and provide thrust for the spacecraft.

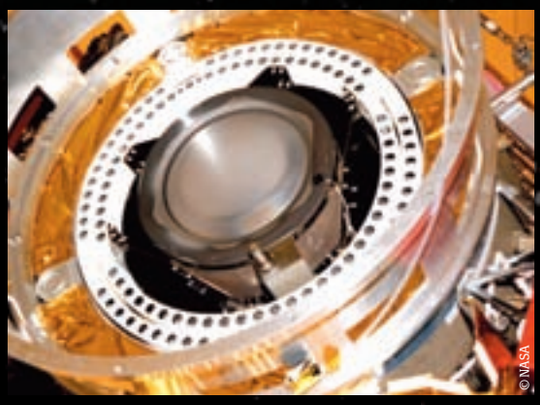
Currently, ion drives are being used by both NASA and the ESA to power a host of next-generation probes and satellites, including the latter's Gravity field and steady-state Ocean Circulation Explorer (GOCE).

Multi-aperture grids
Positively charged ions are extracted from the plasma sheath through a system of multi-aperture grids. Ion thrusters such as this one use a two-grid system, where the upstream grid (screen grid) is charged highly positive and the downstream grid (accelerator grid) is charged highly negative, attracting and propelling ions outwards to generate thrust.

Positive grid

Negative grid


Technicians at NASA work on a prototype ion drive
© NASA


© NASA

Magnetic field
Generated by a series of magnetic rings, a magnetic field is utilised to greatly enhance the engine's ionisation efficiency.

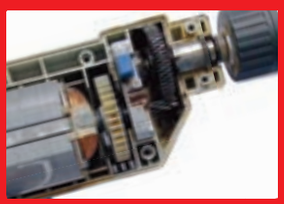
Neutraliser
Another hollow cathode outside of the main engine injects negatively charged electrons into the positively charged ion beam to ensure neutralisation of the beam, spacecraft and surrounding void.


The GOCE's ion drive ejects xenon ions at velocities exceeding 40,000m/s
© ESA

This month in **Technology**

Bigger and newer is always better and if you are in any doubt over that fact then just take a look at this month's technology section. It kicks off with a look at the outside and inside of the latest iPhone from Apple, which promises to be the most advanced smartphone available to mankind. Things don't come much bigger than the world's biggest buildings and we've also taken a look at the amazing engineering behind some of the most incredible constructions on Earth.

48 IMAX screen



49 Power drills

52 Megastructures

TECHNOLOGY

Antenna

Maybe the most technologically advanced component of the iPhone 4, the frame unifies all of the system's communications as one all-encompassing antenna.

Hi-res screen

It's got more pixels-per-inch than the human eye can even distinguish!

Folders

The new 'Folders' function enabled in iOS4 allows apps to be grouped in clusters for ease of access.

A4 chip

The A4 chip has seen a direct transition from iPad to iPhone 4 and provides unparalleled speed and power in comparable handheld devices.

5 TOP FACTS NEW FEATURES

FaceTime
1 The forward-facing 5MP camera enables the new and exciting FaceTime video calling feature, allowing high-quality face-to-face visual communication.

Glass
2 Both the front and back feature Apple's special optical grade glass, a chemically strengthened alkali-aluminosilicate that is 20-30 times harder than plastic.

Retina Display
3 The brand-new screen on the iPhone 4 – referred to as the Retina Display – has 326 pixels-per-inch, which exceeds what human eyes can actually detect.

A4 chip
4 The iPhone 4 features the custom built A4 chip debuted in the Apple iPad. It is a package-on-package system that is quicker than those of previous iPhone iterations.

Tapered design
5 The new design is not just for aesthetic purposes but also allows for far greater reception and service as it acts as an antenna for the phone's communications systems.

DID YOU KNOW? *Within hours of the iPhone 4's release, complaints surfaced over loss of reception when held in a certain way*

Inside the iPhone 4

How It Works cracks open Apple's latest and greatest iPhone to see what new features and technology it brings to the smartphone foray

Apple is a company that will never undersell anything. Its strict privacy, powerful marketing and lust for innovation pushes the company to incredible levels of enthusiasm with everything it does. Even, for instance, when it made the upgrade from iPhone 3G to iPhone 3GS. This drive is even more evident in the recently released iPhone 4, Apple's latest iteration of the iPhone that was embroiled in a leak/raid/court saga that is still on-going now, the consequences of a prototype model being lost, found and made public way before Apple's official unveiling. The furore that followed was unsurprising as, after all, this was the successor to the smartphone throne and offered a faster, more powerful system and radical aesthetic redesign of the most hyped phone on the planet. Now released into the cold light of day, **How It Works** decided to find out just what was so special about the iPhone 4.

Display

The iPhone 4's new screen has 326 pixels-per-inch – bearing in mind the human eye loses the ability to distinguish at 300ppi – and it also contains the new IPS technology which increases the viewing angle and is present on the iPad. The screen also contains 78 per cent of the number of pixels of the iPad but in a 3.5-inch screen. Apple calls this a Retina Display and is specially designed to make text as easy to read as traditional print. Covering the screen is a glass panel constructed of Corning Gorilla Glass, a chemically strengthened alkali-aluminosilicate that is 20-30 times harder than plastic.

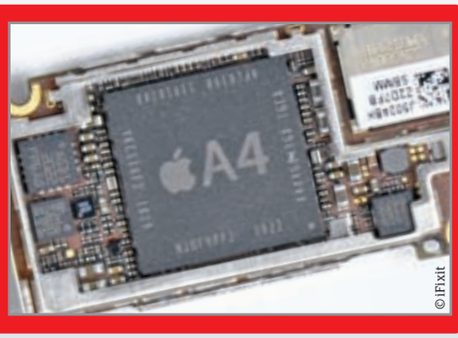
The display is covered by Apple's special optical grade glass

Tapered frame

Apple has integrated the UMTS, GSM, GPS, Wi-Fi, and Bluetooth antennas into the stainless steel inner frame. The dual-purpose stainless steel inner frame/antenna assembly addresses possibly the two biggest flaws concerning previous iterations of the iPhone: continuous dropped calls and lack of reception. Apple has gone a step further though and tuned the phone to utilise whichever network band is less congested or has the least interference for the best signal quality.

A4 chip

The iPhone 4 is powered by the same A4 chip as recently debuted in the Apple iPad, an ARM processor featuring package-on-package construction. The A4 is made from custom silicone and is a complete system on a chip, with 256MB of RAM on top of it in order to deliver enhanced performance over previous models. The chip will allow for the iPhone 4's new features such as the latest operating system (iOS4) and other new abilities like 'Folders' and 'Multitasking' to be taken advantage of greatly, delivering raw speed and huge processing power.



FaceTime

A step-by-step guide to making a video conference call with the iPhone 4's new FaceTime feature

1. Commerce
Well, both parties need an iPhone 4, so you and your friends will need to buy one before FaceTime can commence for anyone.

2. Box
FaceTime works right out of the box with no need to set up a special account or screen name, so just un-box the phone and go to your home screen.

3. Contacts
Next, find the entry in your contacts of the person you want to call and once brought up simply tap the FaceTime button. Or, if you are already in audio contact with the person, simply tap the FaceTime button.

4. Invitation
Either way, once the FaceTime button is pressed, the contact then receives an invitation via pop-up on their iPhone 4, which s/he can then accept or refuse (the latter is probable if you are known to steal their French fries).

5. Link
As soon as the person accepts the FaceTime invitation the direct video link begins, working seamlessly in both portrait and landscape modes.

"Here are the innards of Apple's latest device"

inside the iPhone 4

More than the sum of its parts... which are many and highly intricate

As ever, it is a sad sight to see one of Apple's beautiful products broken, laid out on a table post dissection. However, in a quest to understand just how the iPhone 4 works it is a necessary evil, one that gives a fascinating insight into the technology there within. Here, then, are the innards of Apple's latest device courtesy of gadget gods iFixit.com, who kindly contributed photos and findings for this article.

VGA camera
This is the front-facing VGA camera of the iPhone 4. While the five megapixel camera on the rear of the iPhone 4 is ideal for video recording, the smaller camera on the front optimises use of Apple's FaceTime for mobile-to-mobile video calls.

Vibrator
This is the iPhone 4's new vibrator motor, which... well... vibrates.

Frame
The iPhone 4's design is a dramatic departure from the aluminium and plastic found on previous iPhone models. The rugged stainless steel bezels around the iPhone 4's perimeter double as both structural supports and antennas to boost reception.

Rear casing
The rear panel of the iPhone 4 is detached by removing two small silver screws in the base of the unit. This will make replacing the back panel easy if it gets broken. This is doubtful, however, as it is made from toughened, scratch-resistant material.

iOS4

The iPhone 4 comes shipped with a pre-installed version of Apple's latest operating system, iOS4. This provides over 100 new features including, among others: Multitasking – allowing users to run favourite third-party apps and switch between them instantly without any slow down in performance or unnecessary draining of battery reserves; Folders – the ability to group and organise apps into folders with drag-and-drop simplicity; iBooks – made possible by the fidelity of the iPhone 4's new screen, eBooks can now be browsed, bought, downloaded and read 24 hours a day; Playlists – create and edit custom playlists plus sync and display nested playlist folders from iTunes. Importantly, while iOS4 is available on most other iPhone models, only on the iPhone 4 are all new functions and features accessible, with previous models' specifications unable to cope with some of the more complex processing demands.

Enough features to keep you busy!

The Statistics

Apple iPhone 4

Dimensions: 115.2 x 58.6 x 9.3mm
Weight: 137g
Display: 3.5-inch, 960 by 640-pixel resolution, 326ppi
Processor/speed: 1 GHz ARM Cortex A8 core
Camera: 5MP, 720p HD, LED flash
Memory: 512MB
Ports: 3.5mm stereo headphone minijack, 30-pin dock connector
Battery: 3.7V 1420 mAh li-polymer
Extras: Apple earphones with remote and mic, dock connector to USB, USB power adapter

THE STATS iPHONE 4

SCREEN PIXELS-PER-INCH 326 CAMERA **5MP 720p** BATTERY 3.7V 1420mAh
RAM **512MB** HDD 16-32GB CORE **1GHz ARM Cortex A8**

DID YOU KNOW? *The gyroscope in the iPhone 4 was manufactured by ST Micro for Apple and is not commercially available*

What's inside the iPhone 4?

iPhone 4 components laid bare

Camera
This is the phone's new wizzy 5MP camera, which is capable of recording 720p high-definition video at 30fps. This is a large upgrade over the 3.2MP camera found in the iPhone 3Gs.

Screen
The front glass panel is constructed of Corning Gorilla Glass, a chemically strengthened alkali-aluminosilicate thin sheet glass. Gorilla Glass holds many advantages for the iPhone 4's front panel, including its high resistance to wear and increased strength from an ion-exchange chemical strengthening process.

Home button
The only button again on the face of the iPhone, the iPhone 4's Home button is directly connected – unlike on previous models – to the home button's switch.

Battery
Considerably larger than those of iPhones of old, the new 3.7V 1420 mAh li-polymer battery dominated the inside of the new phone. This is unsurprising considering the next-gen circuit boards and processors it needs to power. The battery is not soldered to the logic board either, meaning replacing it will be easy.

Circuit board
The main circuit board of the iPhone 4 houses the new A4 S5PC100 ARM A8 600MHz processor, debuted on the iPad early in the year. In addition, the board houses the new three-axis gyroscope, Samsung-produced flash memory, Cirrus Logic audio codec, magnetic sensor, touch-screen controller, Wi-Fi chip and Broadcom GPS/Bluetooth receivers.

Sizes...
Compared to its predecessor, the iPhone 4 is slightly longer, narrower and much thinner.

Antenna/speaker enclosure
This improved audio chamber aids in clarifying sounds leaving the iPhone 4, including calls via speakerphone as well as music played through the speaker inside this housing.

Dock connector
The 30-pin dock connector is the same as on previous iPhone models and positioned as usual at the base of the device.

Long life
The iPhone 4 comes with a built-in rechargeable lithium-ion battery that can be charged by USB or power adapter. The new bigger battery provides up to seven hours talktime on 3G networks and up to 14 hours on 2G. The standby time is a goliath 300 hours. Internet usage longevity is also up from the iPhone 3Gs and stands at six hours on 3G and ten hours on Wi-Fi. Equally, the iPhone 4 is now capable of a splendid ten hours of video playback and 40 hours of audio playback before needing to be recharged.

Gyroscope
The current iPhone 3GS is not just fitted with a simple accelerometer – a type of sensor that can detect a device's linear acceleration along one of three x, y and z axes – but a combined accelerometer, compass and gyroscope, providing precise information about six-axis movement in space. The iPhone 4, however, adds an additional new electronic sensor for detecting three-axis angular acceleration to its gyroscope around the x, y and z axes, enabling precise calculation of pitch, yaw and roll.

Learn more
For more info and images of the exposed iPhone 4, visit the gadget surgeons at **ifixit.com** who kindly contributed the photos and findings for this article.

"The cold air produced by the coils is sent indoors by the blower"

Air conditioning

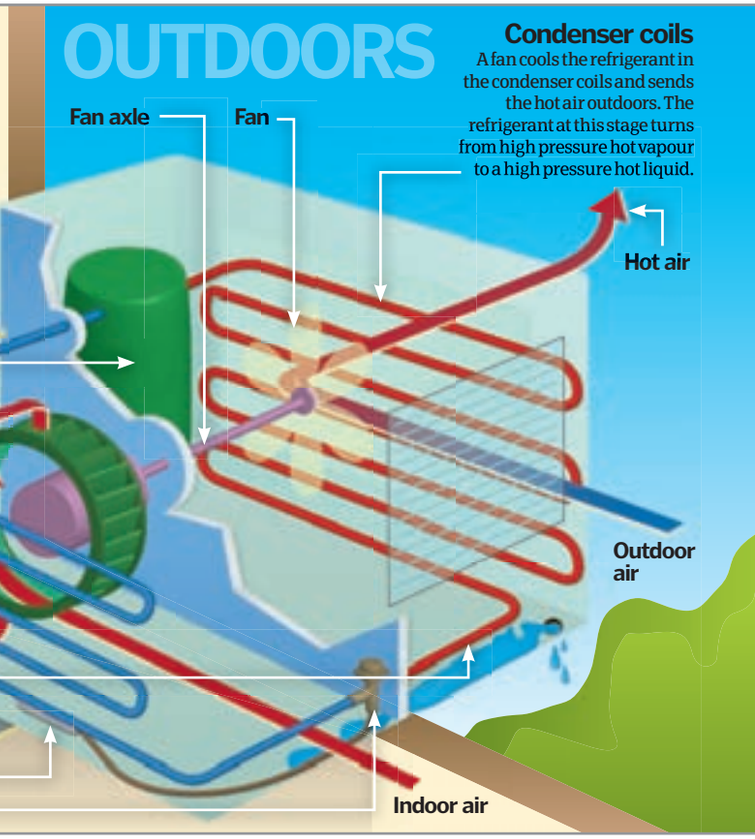
Technology that stops you getting hot and bothered

Compressor
Warm air drawn from the room by the blower turns the refrigerant in the cooling coils into low pressure vapour. The compressor pressurises the vapour, turning it into high pressure vapour that is sent to the condenser coils.

Cooling coils
Low pressure cold liquid refrigerant (such as Freon developed by DuPont) runs through the cooling coils. The cold air produced by the coils is sent indoors by the blower.

Filter drier (not shown)
This may be fitted between the condenser coils and the expansion valve, or between the compressor and the cooling coils. It can hold the correct amount of refrigerant for the system to ensure its steady flow.

Expansion valve
This only allows a small amount of refrigerant to pass through it, turning the high pressure hot liquid refrigerant into cold low pressure liquid. It separates the high pressure side of the system from the low pressure side.



5 TOP FACTS PROTECTING YOUR PRIVACY

Email is not secure
1 Sending an email is like sending a postcard. Anybody can read it so never include sensitive information. If you're concerned, try using an email encryption utility.

Clear your cookies
2 If you share a computer, clear your browser cookies after each internet session to prevent your passwords being stored. You can do this under your browser's settings menu.

Flash cookie
3 Adobe Flash stores cookies unaffected by web browser settings. To adjust, click on 'Global Privacy Settings Panel' via the Macromedia Flash Player settings website.

Advertising services
4 Many advertising networks track your surfing habits data to target their ads. Visit **www.networkadvertising.org** where you can opt out of over 40 programs.

Set up a disposable email
5 Your boss can legally monitor your work email activity. Manage a separate account for personal use. Set up anonymous accounts for sites you're concerned about.

DID YOU KNOW? *You can customise your settings so your friend lists can only view the information you choose*

Facebook's new privacy settings

What do Facebook's radically overhauled privacy settings mean for you?

To check out our Facebook page, simply search for 'How It Works' on www.facebook.com

If you are one of the 400+ million active Facebook users you may have noticed some changes to your privacy controls. Until recently, there were 170 options under 50 privacy related settings to sift through, but on 26 May, Facebook "drastically simplified and improved its privacy controls". The default public profile settings have been reduced to name, profile picture, gender and networks; 'friends' is no longer included automatically. Controlling what your friends, friends of friends and everyone else can access has been simplified and is adjustable from a one-click master interface. Any adjustments here will also apply to historical content as well as future content and applications. If you prefer more detailed customisation then do not worry as all the pre-overhaul detailed granular settings have been retained.

For the first time, Facebook platform applications (games, social widgets etc), which access the information you make available to everyone, can be completely turned off. You can also switch off instant personalisation which Microsoft, Yelp and Pandora (US only) use to personalise their applications.

Facebook advertisers can still target demographic profiles such as age, relationship status and location, but your personal information remains private as advertisers only receive anonymous aggregated data. With this new framework, Facebook intends to make privacy-related changes less frequent.

10 steps to Facebook privacy

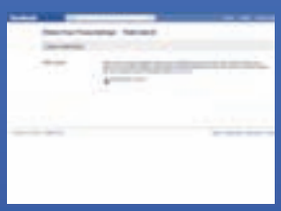
1. Basic Directory Information
From your profile page, click Account then choose Privacy Settings. Select Friends Only for each category apart from "Send me friend requests".

2. Customise settings
Next click on Customise Settings that appears beneath the list. We'd recommend you choose Friends Only for each of the categories apart from "Friends can post on my wall".

3. Back to privacy
Click the button marked Back to Privacy to return to the Privacy Settings page. Next click the Edit your settings link that appears under Applications and Websites to access these.

4. Applications, Games and Websites
Select Friends Only from the list next to Game and application activity. Click Edit Settings next to Info Accessible through your friends and untick every box.

5. Instant Personalization
Next click the Edit Settings button that appears next to Instant Personalization. Ensure this is turned off by removing the tick from the box at the bottom.



6. Public Search
Click the 'Back to applications' button. Now click the Edit Settings button that is next to Public Search. Untick Enable public search and your profile will not appear in any searches.

7. Block lists
Click the Back to Privacy button. Then click the 'Edit your lists' link that appears under Block Lists. Here you can add the names of any users who you no longer wish to correspond with.

8. Turn off applications
To turn off all the Facebook apps you've installed, locate the 'What you're using' category at the top of the Websites and Apps screen and click the 'Turn off' link.

9. Censor status updates
Click the Facebook logo in the top-left to return to your profile. Click the padlock symbol under the status box and you can choose which friends can see the update.

10. Change the Advertiser Settings
Click Account>Account settings>Facebook ads and select 'No-one' if you do not want adverts to show your information to friends.

"Prepared lead cores (a graphite and clay powder mix) are then inserted into the grooved channels"

How do they get lead in a pencil?

Ok, it's not lead but here's how pencils are made

1. Firstly, a block of wood (such as cedar) is cut from a larger wood source and shipped to the pencil factory.

2. Once at the factory the block of wood is cut down into slats and then stained.

3. Then the slat of wood is channel grooved to form the pencil's core carrying centre.

4. Prepared lead cores (a graphite and clay powder mix) are then inserted into the grooved channels.

5. A second slat is then glued on top of the grooved slat, sandwiching the lead cores within.

6. The pencil sandwich is then passed through a milling process to separate the individual pencils and create its circular appearance.

7. The finishing process involves painting, ferrule addition and eraser insertion.

DID YOU KNOW?

The Derwent pencil factory in Keswick, England, produces over 1 million pencils a week.

IMAX cinemas

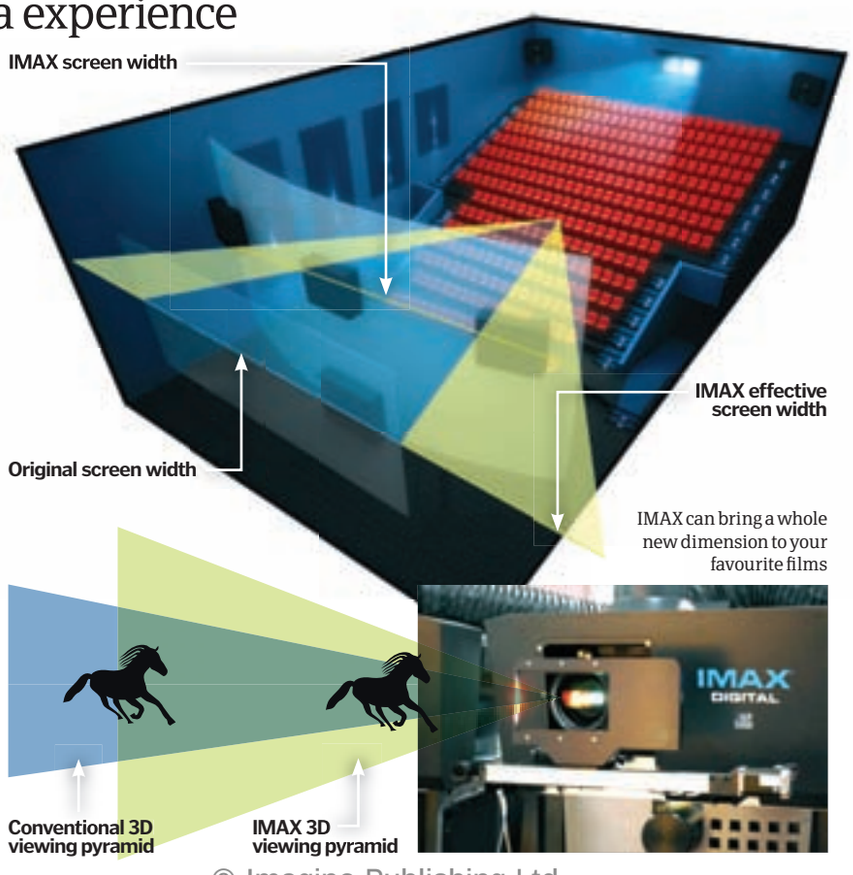
Making the cinema experience as real as possible

The IMAX system uses 70mm film, with 15 perforations per frame that runs horizontally rather than vertically through the cinema projector. It is ten times larger than standard 35mm film. That means huge 109kg cameras are needed to film IMAX movies. They can only shoot three minutes' worth of film at a time and take 20 minutes to reload.

IMAX cinemas employ a two-ton projector with a 15,000 watt lamp and a vacuum system to keep the film in alignment with the lens.

The IMAX screen is far larger than a normal screen and is positioned in the cinema to maximise the audiences' field of view. It has a special coating of silver paint to enhance the brightness of the picture, and has thousands of perforations to allow sound to pass through it.

Furthermore, each film has a specially mastered soundtrack that is compatible with the IMAX digital audio cinema system, so that each spectator enjoys clear and realistic sound as well as pictures.



IMAX can bring a whole new dimension to your favourite films

5 TOP FACTS
IMAX MILESTONES

1 The Dark Knight
Released in 2008, this is the first major Hollywood movie to include sequences filmed by IMAX cameras. They amount to 30 minutes of screen time.

2 Superman Returns
The first live-action movie to have sequences of it converted from the normal 2D format to IMAX 3D format. 20 minutes is in 3D when viewers are cued to put on their 3D glasses.

3 Polar Express
This is the world's first IMAX 3D Hollywood movie. It was digitally remastered from the original 2D film. IMAX is now developing special 3D cameras for future live action releases.

4 The Matrix Revolutions
This is the first Hollywood blockbuster to be simultaneously released in conventional and IMAX theatres. The action sequences especially benefited from being converted into this high resolution format.

5 Apollo 13
In 2002, the new IMAX DMR technology is used for the first time to digitally remaster this conventional format Hollywood movie into the IMAX format. It was rebranded as *Apollo 13: The IMAX Experience.*

5 TOP FACTS
POWER DRILL

Patent
1 Electrical engineer and Scotsman Arthur James Arnot registered the first patent for an electrically powered drill on 20 August 1889, at the age of just 23.

Duel
2 The first 'pistol-grip' electric drill – which is now the most commonly used – was created and patented by Black & Decker in Maryland, USA, back in 1917.

Primate
3 There is a type of primate called a Drill that is closely related to the baboon. It is Africa's most endangered mammal, with possibly only 3,000 left in the wild.

Primitive
4 The earliest form of drill to be found on Earth is the bow drill, which was primarily used to start fires and not to create holes. It could also be used for woodwork and dentistry.

Rose
5 Among the many Tudor-era artefacts to be salvaged when the Mary Rose warship was raised from the ocean floor was a selection of wooden drills.

DID YOU KNOW? *The world's largest drill is owned by Russian billionaire Roman Abramovich and is 63ft in diameter*

By using an electric motor-based drill, enough torque can be generated to drill through metal

Inside a power drill
The technology behind the tool

Drill head/bit
The hole-making part of the system, the drill head makes holes in material by first puncturing its surface and then feeding the threaded drill bit into it under pressure.

Hammer function (not shown)
On some power drills the in-built electric motor not only powers a rotor but also a hammering mechanism, which when used with a specialist drill bit, allows the drill to act as a pneumatic hammer.

Rotor
The circular mechanical cog that is rotated at speed by the electric motor, the drill's rotor rotates the drill head and bit.

Electric motor
The mechanism that converts electrical energy into mechanical energy, the electric motor rotates the drill's rotor by electromagnetic induction.

AC power connector
Supplying current to the drill's electric motor is either an AC power adapter or cell-based battery unit.

Conducting trigger
Most drill triggers are backed with metal plates that act as the conducting mechanism between the drill's power supply and its electric motor.

Power drills
How do they drill through metal?

Electrically powered drills (commonly referred to as power drills) work by turning electrical energy into mechanical energy in order to rotate a piercing drill bit. This energy transfer is achieved by sourcing electricity from an AC power supply and feeding it into an electric motor, which then converts the energy by electromagnetic induction – voltage production through a magnetic field – in order to spin a rotor at high speed. The main advantage that power drills have over their hand-powered brethren is their high torque, which allows for holes and screws to be drilled into tougher materials and at greater depth and speed.

The energy from the AC power supply is controlled by the user through the drill's trigger, which is a common feature of the pistol-grip electric drill. The trigger is backed with a metal plate which when pressed connects the drill's power source to its electric motor, supplying it with electrical energy to be converted into the mechanical energy that is necessary to rotate the drill bit. Modern drills employ multi-staged triggers, allowing pressure-sensitive control of the rotational speed dependent on how much electricity is directed to the drill's electric motor.

Construction apprenticeships start young these days

"Flammable toxic oil can gush out and combust, resulting in a massive fireball"

Cleaning up an oil spill

How do you deal with the threat of escaping oil?

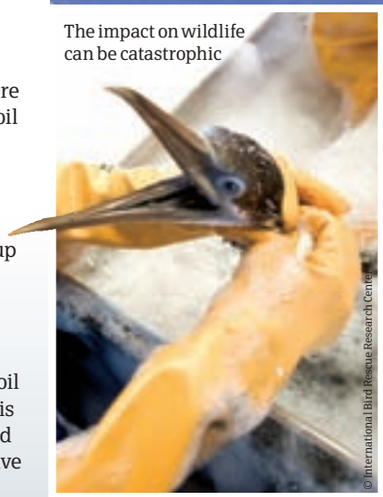
Offshore oil spills can occur in two ways – oil tanker leaks and oil rig blowouts. Over 9,000 oil tankers currently transport half of the 3.5 billion tons produced annually. If an oil tanker's hull becomes damaged from an explosion, collision or severe weather, millions of gallons of oil can leak into the ocean causing devastating consequences.

Oil rig disasters can be even more catastrophic. Offshore oil rigs extract crude oil from a well in the seabed via a long tube called a riser. Pressure at such extreme depths can be very high so blowout preventers (BOPs) are designed to cut the flow of oil if the pressure reaches a critical level. If this fails, as it did in the Deepwater Horizon disaster, flammable toxic oil can gush out and combust, resulting in a massive fireball.

A response co-ordination unit is instantly scrambled to formulate a response plan. The first priority is to seal the oil leak and stop the flow of combustible fuel feeding the fire while a crew contains and cleans up the escaping oil. Aerial reconnaissance establishes the extent of contamination. Parameters such as wind direction, tidal currents and temperature are processed by a modelling computer to predict oil trajectory. This information is vital for determining the response strategy.

The weather can play a significant role in a clean-up operation. High winds and strong waves can push the oil over containment booms and boats are unable to travel to affected areas and spray dispersants. Even sea temperature can influence the speed of recovery as oil takes longer to evaporate in cooler conditions. Tens of thousands of volunteers, government officials and local authorities are mobilised within days and can be involved in the clean-up operations for several months. During the Deepwater Horizon response, San Francisco charity Matter of Trust accepted thousands of hair and fur donations, which were used to absorb oil in local municipalities. The good news is that, given time, nature will recover and return to being as diverse and productive as before the spill.

The impact on wildlife can be catastrophic

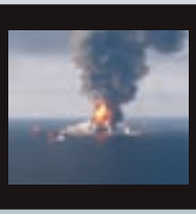


Deepwater Horizon – stemming the flow

The above illustration shows the installation of a Lower Marine Riser Package (LMRP) cap as installed on the Deepwater Horizon in June. The is one of the containment options for collecting the oil flowing from the MC252 well. The procedure involved removing a damaged riser from the top of the blowout preventer (BOP) cap. A remotely operated hydraulic shear was used to make two initial cuts before it was removed using a crane. A special diamond wire saw was then used to cut the pipe close to the LMRP, and the final piece of damaged riser could then be removed.

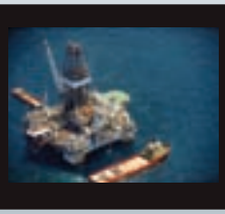
The LMRP cap was designed to seal on top of the riser stub. The seal decreases the potential inflow of seawater, not to mention improve the efficiency of the oil recovery. Lines carrying methanol are also connected to the device to help prevent the formation of hydrate (a substance which contains water). The device has been connected to a riser extending from the Discoverer Enterprise drillship.

Timeline of events following Gulf of Mexico oil spill

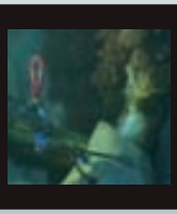


20 April
Massive explosion on Deepwater Horizon oil rig
Within just three hours, the NOAA provide oil trajectory support.

25 April
Oil slick expands
Overflights indicate the oil slick is rapidly growing. In five days it is 48 miles wide by 39 miles long.

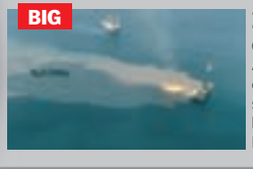


2 May
Drilling of relief well
The drilling of the first of two relief wells begins. It is hoped this will stop the flow within three months.



11 May
Clean-up begins
Over 1.4 million feet of booms, 460 vessels and 13,000 personnel tackle the on-going oil leak.

Head to Head BIGGEST OIL SPILLS



BIG

1. Ixtoc I
(1979, Gulf of Mexico)
Around 140 million gallons of oil lost after the Ixtoc I rig suffered a catastrophic blowout, similar to Deepwater Horizon.

BIGGER

2. Lakeview Gusher
(1910, California)
For 18 months an estimated 378 million gallons were spewed out up to 200 feet in the air.

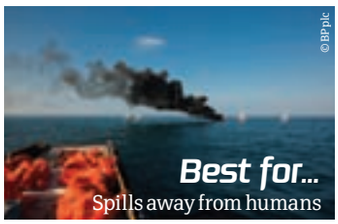
BIGGEST

3. Gulf War
(1991, Kuwait)
Up to 460 million gallons of oil was deliberately spilled after the Iraqi army sabotaged oil wells and tankers in Kuwait.

DID YOU KNOW? *Over 3,500 oil rigs in the Gulf of Mexico supply nearly a quarter of American oil production*

Containment and skimming
– the first line of defence

Containment and skimming secures the oil within a manageable area and removes it mechanically. Floating barriers called booms form a containment zone. 'Curtains' prevent the oil from sliding underneath and drifting further. The oil is later collected by skimming machines. In an oleophilic (oil-attracting) skimmer, the oil adheres to a rotating surface such as a conveyor belt, which is then scraped off and stored. Vacuum skimmers use powerful pumps to suck up surface oil. Weir versions allow the thin surface layer of oil to spill over into a container dish. The oil/water solution is then pumped into bladders for transport back to the shore.

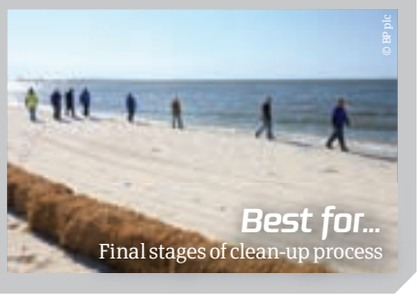


In-situ burning
– efficient but risky

In-situ burning is the process of igniting the freshly spilled oil at the incident location. Factors such as wind speed, emulsification (the amount the oil has mixed with the water) and wave activity determine the viability of its use. Igniting the oil is dangerous, methods include allowing lit vessels to drift into the oil slick; throwing handheld ignition devices and deploying a helitorch – a helicopter that drops a stream of burning fuel. In-situ burning is controversial because pollutants like carbon monoxide are released into the atmosphere. However, it is a fast, efficient and simple way of removing oil.

Sorbents – mopping up the mess

Sorbents can be both synthetic and natural materials that, when mixed with the oil-saturated waters, 'soak up' the oil like a sponge. Sorbents do not dissolve in water and can be scooped out by mechanical intervention after absorbing the oil. Various materials can be effective including straw, wood chips, cotton fibre and even human hair! To absorb the oil, the chosen material needs to be oleophilic and hydrophobic (water repelling). The main advantages of this method are that it is relatively cheap and environmentally friendly.



Biological agents
– feeding a huge army

Bioremediation is the process of adding materials to the environment to speed up natural biodegradation. Fertilisers like phosphorus and nitrogen multiply the population of the hydrocarbon-eating microbes already present in the ocean or on land. They attack the oil invading their natural habitat by decomposing it into natural harmless components. The main disadvantage of this method is that it takes years rather than months.

Dispersants
– giving nature a helping hand

The goal of dispersants is to speed up the natural biodegradation process by breaking up the oil into tiny droplets. The isolated droplets sink below the water's surface and become further dispersed by the agitating action of the waves. The diluted oil has an increased surface area, which facilitates natural evaporation. Bacteria are also able to biodegrade the smaller droplets. You can see a similar process at home by placing a drop of washing up liquid into a water/cooking oil solution. The oil repels and splits into smaller droplets. Although dispersants are toxic, a net environmental benefit is achievable.

Effects of an oil spill

The environmental and economical effects of a major oil spill are far reaching and can last for decades

1. Oil compromises the insulation of wildlife, increasing risk of hypothermia.

2. Shorebirds coated in oil struggle to fly, making them vulnerable to predators.

3. Preening animals ingest the toxic oil causing death by poisoning.

4. Sunlight is blocked, limiting photosynthesis of nutritional ocean plankton.

5. Fishing restrictions damage the seafood industry and its employees' livelihoods.

6. Wetland breeding and feeding grounds become uninhabitable and fatal for waterfowl.

7. Exports and imports get delayed during ship contamination inspections.

8. Fearing contamination, tourists will avoid affected coastal areas, reducing tourism revenue.

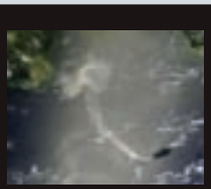
9. Less oil availability raises barrel prices, affecting the global economy.

10. Remnant oil particles continue to poison marine organisms for decades.

ON THE MAP

The world's most infamous oil spill disasters

1 Gulf War, Kuwait 1991 (800,000 tons of oil spilt)
2 Exxon Valdez, Alaska USA 1989 (40,000 tons, oil tanker)
3 Torrey Canyon, Wales UK 1967 (121,000 tons, oil tanker)
4 Castillo De Bellver, South Africa 1983 (250,000 tons, oil tanker)
5 Braer, Shetland Islands, UK 1993 (84,500 tons, oil tanker)
6 Fergana Well, Uzbekistan 1992 (299,000 tons, oil well)



16 May
Riser Insertion Tube installed
ROVs (Remote Operated Vehicles) attach a new riser to the severed end of the original riser in an attempt to channel the oil.

26 May
'Top Kill' operation
Heavy 'kill' mud and drilling fluid is injected into the well to reduce the pressure.

3 June
Lower Marine Riser Package (LMRP) cap deployed
The LMRP is sealed with a cap. Oil is successfully channelled to the surface.

"Up close the world's tallest bridge is no less stunning"

Megastructu

Bigger, taller, longer, heavier. We explain the record-breaking engineering behind the world's biggest man-made structures

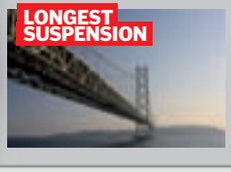
2. Making ends meet
Using hydraulic conveyors, the steel deck was glided into place from opposite directions, eventually meeting over the River Tarn.

1. World's tallest
Pier Two (P2) is the tallest support pier in the world at 244.96 metres (804 feet).

Since the reign of the pharaohs, the lure of the very large has proven irresistible to visionary architects and game-changing engineers. Ancient Egypt had its pyramids, the Chinese dynasties had their Great Wall and modern Dubai has its… well, pretty much everything. At the heart of every megastructure is a dare: how far can you go? And every few years or so some ambitious billionaire ups the ante, going higher, longer, deeper and more wildly expensive.

The 828-metre (2,717-foot) Burj Khalifa tower, profiled in issue 1 of **How It Works**, makes your palms sweat just looking at pictures from the observation deck. Not to be outdone, Dubai's Palm Islands are visible from space with the naked eye. None of these mind-blowing projects would be possible without quantum leaps in structural engineering, materials science, construction technology and logistics. On these pages, we'll explain the extreme engineering behind extraordinary structures.

Even the Eiffel Tower is dwarfed by the 343-metre high masts of the viaduct

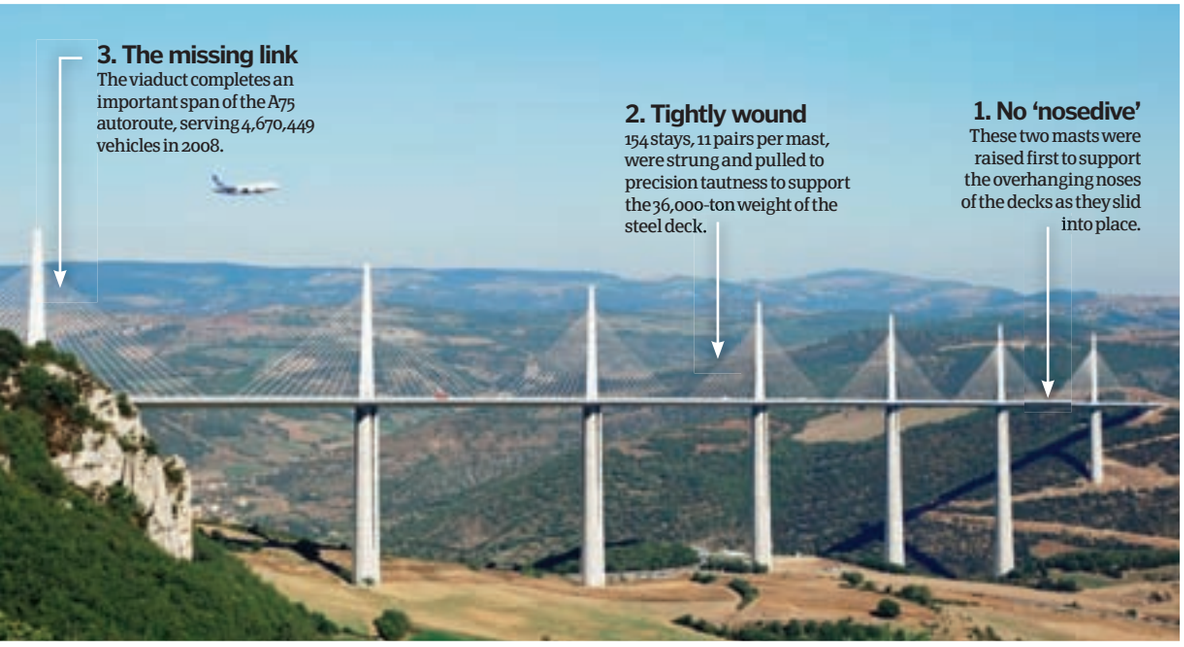


1. Akashi Kaikyo Bridge
At 3,900 metres long, this masterwork of Japanese engineering can survive an earthquake up to 8.5 on the Richter scale.

2. Dubai's Mile-Long Bridge
Leave it to boomtown Dubai to dream up a fantastically futuristic proposal for a mile-long double arch bridge spanning 12 lanes of traffic.

3. Bering Strait Bridge
The proposed 55-mile long bridge linking North America and Asia would carry vehicle traffic, a high-speed train and pipelines for natural gas and oil.

DID YOU KNOW? *The Millau Viaduct was officially opened on 14 December 2004*



The Millau Viaduct

Majestic and minimalist, the world's longest bridge is also one of the most beautiful

From a distance, the seven steel masts of the record-breaking Millau Viaduct in southern France look like billowing sails of a cosmic spacecraft. Up close, the tallest bridge in the world is no less stunning, a minimalist masterpiece that resembles an Apple iPad in bridge form.

The Millau Viaduct is a cable-stayed road bridge of concrete and steel with load-bearing masts stretching 343 metres (1,125 feet) into the air. Seventeen years in the making – at a cost of 400 million euros – the 2,460-metre (1.52-mile) span employed the very latest construction techniques and technologies during each of its six stages of fabrication and assembly.

First came the "legs" of the bridge, seven thick piers composed of 206,000 tons of poured concrete. The smooth, seamless surface of each pier was achieved using a machine called a self-climbing framework. Powered by hydraulic lifters, the concrete framework rises upward with the pier at a rate of three meters every three days. Pouring continuously, the piers rose from the valley floor, reaching their peak heights in ten months.

Next came the deck, built from 173 steel box beams forged in the Eiffel factory. Using two on-site metalworks, the steel floor was welded to the box beams to create 171-metre deck panels. The panels were then "launched" from both sides of the bridge using 64 hydraulic conveyors positioned atop the piers and temporary steel crutches. The two sides of the deck literally slid toward each other at a rate of 60cm per push, equal to nine metres an hour. The two sides finally met on 28 May 2004 at 2:12pm.

The seven steel masts support 1,500 tons of steel stays attached at 11 paired points. Each stay consists of up to 91 bound steel cables and each cable made from seven individual strands of steel. The stays are triply weatherproofed to avoid corrosion.

Before paving the road, workers used high-pressure blasters to scour the steel deck with millimetre-size ball bearings. Once all traces of rust were removed, special equipment laid a four-centimetre thick layer of tar thermosealed at 400°C, offering complete corrosion protection.

The bridge construction is guaranteed for 120 years and is continuously monitored for movements as small as a micrometer by dozens of fibre-optic sensors strung throughout the structure.

"A starter home begins at £1.3 million"

Extreme islands

Dubai recreates 'The World' from an ocean of sand

Sheikh Mohammed bin Rashid Al Maktoum has only one requirement for construction projects in his desert nation of Dubai: if it doesn't break a world record for tallest, biggest or most expensive, he's not interested. It shouldn't surprise, therefore, that the original design of the Palm islands – three man-made islands of colossal proportions off the coast of Dubai – came from the Sheikh's own pen.

But how do you build the world's largest man-made islands? Luckily, Dubai has almost as much sand as it does oil money. The state-run developer Nakheel hired the Dutch dredging firm Van Oord, specialists in "land reclamation", to suction up millions of cubic metres of sand from the sea floor and precision spray it into the shape of a huge date tree with 16 slender fronds extending into the sea. Van Oord's dredging equipment is guided by DGPS (differential global positioning system), NASA's new real-time positioning technology that's accurate down to ten centimetres.

The first stage of each of Dubai's artificial island projects – the three Palm islands, plus a 300-island cluster in the shape of the continents called "The World" – is to install an artificial barrier reef as a water break. The artificial wall for The World, composed of 34 million tons of carefully stacked rocks, is 27km long. The dredging team then builds each island or peninsula in stages, using heavier machinery for the island foundations and "rainbowing" sand sprayers to finish the above-water detail work.

To prevent erosion, the base of the islands is reinforced with a layer of geotextile fabric that absorbs the impact of waves. The huge piles of loose sand are also treated to vibrocompaction, a process that uses water saturation and high-intensity vibrations to "densify" the soil structure.

When complete, the Palm islands and The World will upgrade Dubai's beachfront property from a 37-mile stretch of condo-clogged real estate to 600 miles of pristine sand. In case you're wondering, a starter home on the smallest island starts at £1.3 million ($1.9 million).

The Statistics

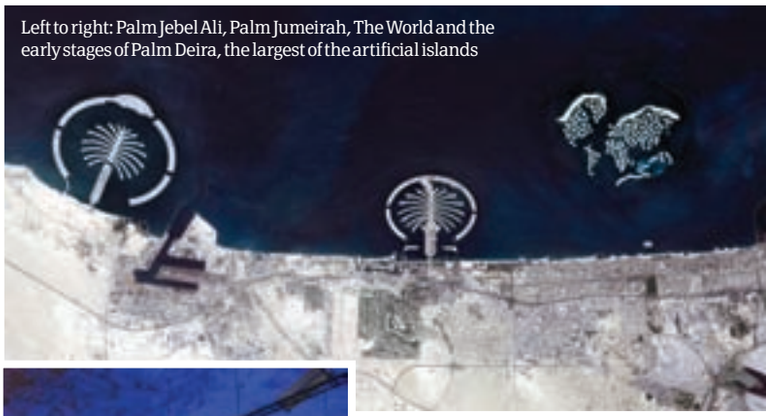
Palm Jumeirah

Nickname: The Eighth Wonder of the World
Opened/opening: Palm Jumeirah, the smallest island, was completed in 2006
Built by: Nakheel
Length: 5km
Width: 5km
Composition: 94 million m^3 of reclaimed sand; 7 million tons of quarried rock
Cost: £8.14 billion ($12.3 billion)

1. Meticulous
Each stone in the 11km breakwater was inspected by a diver and tagged with its own GPS co-ordinates.

2. Life's a beach
The "rainbowing" sand sprayers on the dredging equipment are designed to create beachfront with a precise and consistent slope.

3. Fresh water
Canals dug in the breakwater ensure that the water within the artificial bay circulates completely every 13 days.



Left to right: Palm Jebel Ali, Palm Jumeirah, The World and the early stages of Palm Deira, the largest of the artificial islands

Laerdal Tunnel

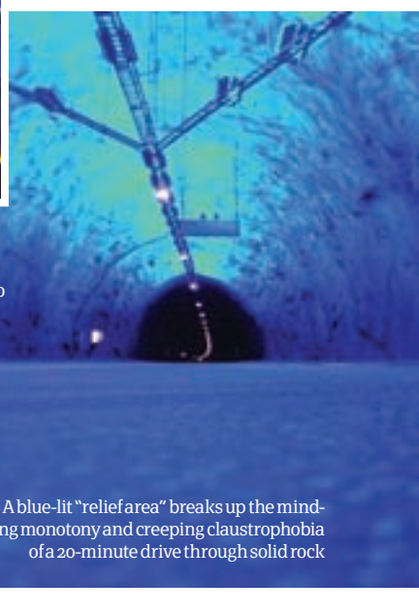
An ambitious dig gives drivers an unprecedented journey through the centre of the Earth

A decade ago, the drive from Oslo to Bergen, Norway required travellers to ferry multiple fjords and summit 1,600-metre peaks subject to rockslides and piles of snow. In 2000, King Harald V cut the ribbon on the Laerdal Tunnel, a 24.5km (15.2-mile) passage beneath the mountain ranges and waterways that had made travel between the two coastal cities so daunting and slow. Laerdal is by far the longest road tunnel in the world, beating the previous record-holder by seven kilometres.

Over five years, workers excavated 2.5 million cubic metres of rock. The tools of the trade were explosives and satellite-guided drilling jumbos.

The blasting crew executed over 5,000 precision explosions each requiring 100 individually drilled holes, 5.2 metres deep, filled with an explosive called Anolit. Drilling rigs were guided by satellite positioning and on-board laser beams. Without this technology, it would've been impossible for the two excavation teams to meet each other over 10km inside the heart of the mountains.

To break up the monotony of the 20-minute subterranean drive, engineers divided the tunnel into four distinct sections separated by three wide, blue-lit caverns that give the sensation of an artificial sunrise.



The nine-metre tunnel widens considerably in the cavernous relief areas, providing room for vehicles to turn around. The tunnel is equipped with 48 additional emergency pull-offs

A blue-lit "relief area" breaks up the mind-numbing monotony and creeping claustrophobia of a 20-minute drive through solid rock

5 TOP FACTS GIANT STRUCTURES

1 Great Wall of China
The original megastructure, the Great Wall stretches an incredible 8,851km (5,500 miles), making it easily the longest man-made structure on Earth.

2 Three Gorges Dam
The 2km dam spanning the Yangtze submerged 13 existing cities, 140 towns and over 1,300 villages, requiring the relocation of 1.5 million people.

3 Fresh Kills Landfill
This retired garbage dump covering 12 square kilometres (4.6 square miles) of New York's Staten Island was once piled higher than the nearby Statue of Liberty.

4 Banaue Rice Terraces
Built largely by hand over 2,000 years ago, these terraced rice paddies cover 10,360 square kilometres of steep mountainside in the Philippines.

5 Mirny Diamond Mine
This colossal open-pit mine located in Eastern Siberia, Russia is 525 metres (1,722 feet) deep and 1.25km wide. In the Sixties it produced two tons of diamonds per year.

DID YOU KNOW? *Taipei 101 cost approximately $1.8 billion to build*

Taipei 101

The world's second-tallest skyscraper has a 660-ton pendulum for a heart

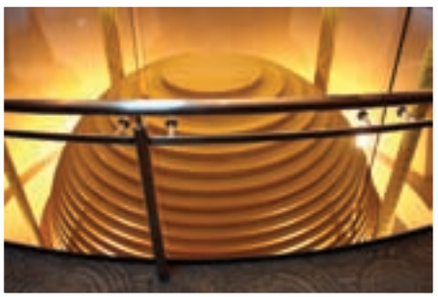
Building a skyscraper in Taipei is like playing Jenga on a trampoline. The Taiwanese capital, located along the famed Ring of Fire, sits atop an "active" seismological zone with a very long history of deadly earthquakes. As recently as 1999, a 7.3 trembler killed over 2,400 people. As if the earthquakes aren't enough, Taipei is also directly in the path of 26 annual tropical storms and typhoons, the Pacific equivalent of hurricanes.

Why would anyone attempt to build the world's tallest building on such shaky (and blustery) ground? You obviously don't know many engineers. The challenge of building a 508-metre megastructure in such an inhospitable location calls for elegant and ingenious solutions, two words that accurately describe Taipei 101, the 101-storey superscraper that was – until the completion of the Burj Khalifa in Dubai – the tallest man-made structure in the world.

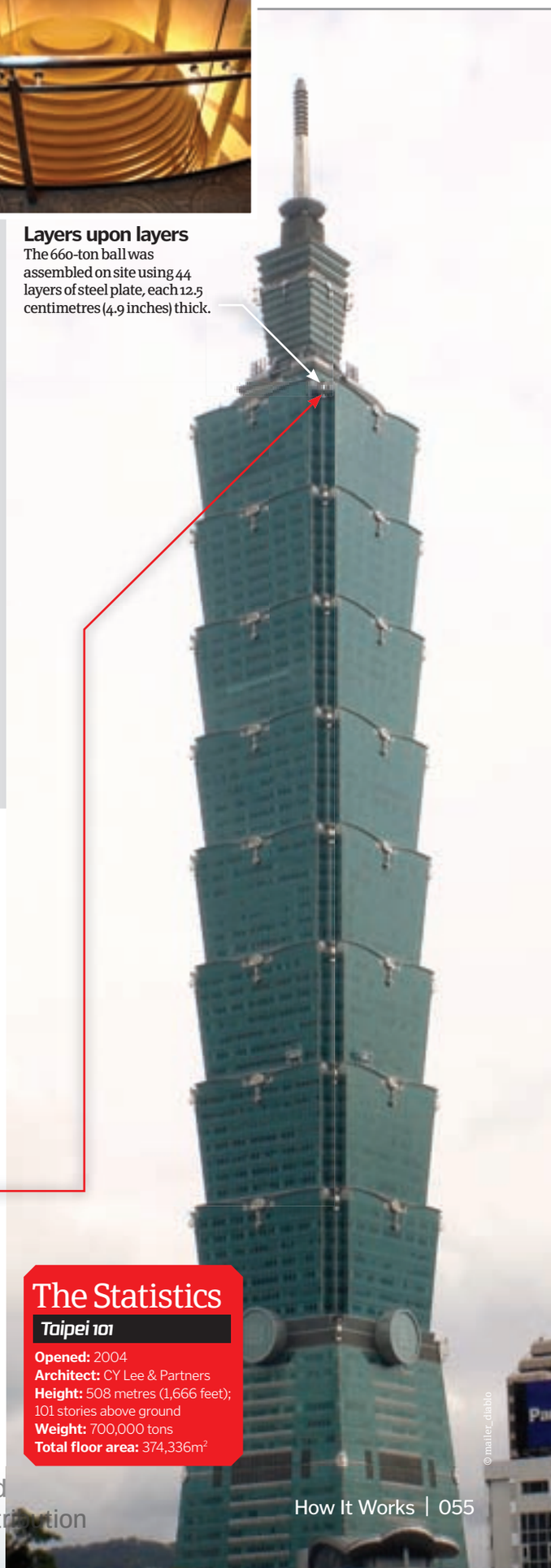
Taipei 101 was designed to resemble a bamboo shoot, rising upward in eight sections (a lucky number in Chinese) with walls angled outward at seven degrees. Like a slender stalk of bamboo, the record-breaking tower was designed to be both strong and flexible – bendable, but unbreakable.

Taipei 101's strength begins in its "roots", 380 concrete piles driven 80 metres through the island's thick clay sediment to reach solid bedrock. The building is widest at its foundation, narrowing at a five-degree angle for 25 floors before arriving at the first of the eight identical sloped sections. The tower's core stability comes from eight forged steel "megacolumns", each measuring three by 2.4 metres and filled with concrete. The megacolumns are trussed to the building's outward-sloping frame with ductile steel braces that bend in an earthquake.

At 700,000 tons of steel, concrete and glass, Taipei 101 is actually "light" for its height. To steady the tower in gale-force winds, it's equipped with an internal pendulum called a "passive tuned mass damper", whose massive weight – 660 tons – pulls instinctively in the opposite direction of swaying (see 'The Damper' boxout). The result is not only one of the tallest, but perhaps the most stable building in the world, designed to withstand a 2,500-year seismic shock.



Layers upon layers
The 660-ton ball was assembled on site using 44 layers of steel plate, each 12.5 centimetres (4.9 inches) thick.



The Damper

A massive pendulum fights the effects of skyscraper "seasickness"

Suspended from the centre of the 92nd floor of the world's second tallest building is a 660-ton, £543,000 ($800,000) steel ball hanging from four sets of steel cables. The function of the "tuned mass damper" isn't to keep Taipei 101 upright (its concrete-filled steel backbone is more than sufficient to do this), but to cancel out nausea-inducing swaying in a powerful storm.

If wind pushes the tower to the right, the dangling damper will provide an immediate and equal force to the left, cancelling out the motion. Like a shock absorber in a car, the damper is attached to a series of hydraulic pistons that convert dynamic energy – the swaying of the ball – into heat. Not only is the Taipei 101's damper the largest of its kind, but it's the only one in the world to be incorporated into the aesthetic design of the structure, easily visible from observation decks and restaurants.

Wide load
Taipei's damper is the largest in the world with a diameter of 5.5 metres (18 feet) and weighing as much as 10,000 people.

Cables
The damper hangs from four steel support lines, each composed of four individual steel cables.

Hydraulics
If the damper swings dramatically during an earthquake, 2m hydraulic pistons absorb and dissipate the energy as heat.

The Statistics
Taipei 101

Opened: 2004
Architect: CY Lee & Partners
Height: 508 metres (1,666 feet); 101 stories above ground
Weight: 700,000 tons
Total floor area: 374,336m²

This month in **Environment**

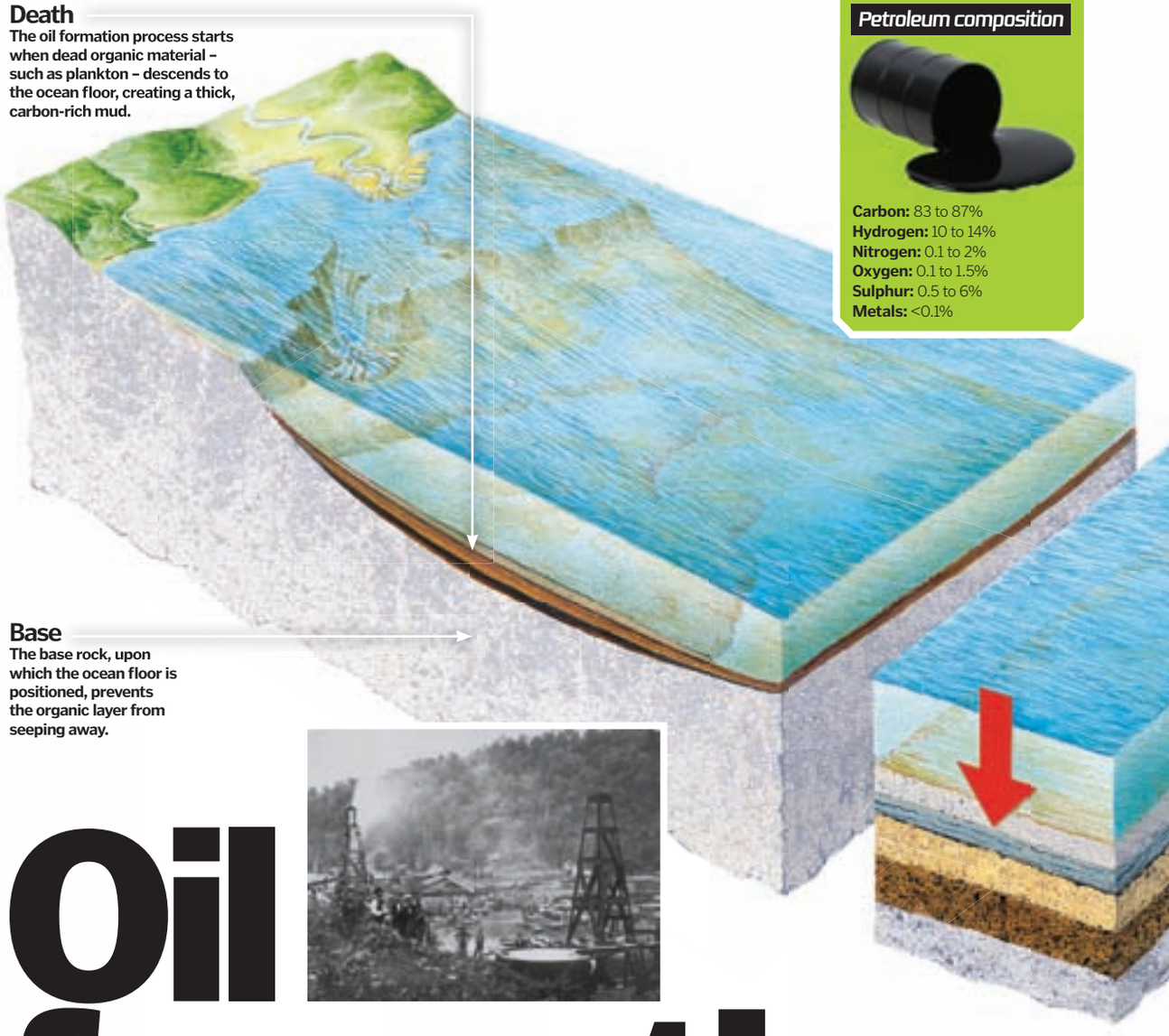
The kings of the swingers and the jungle VIPs are the subject of our main environment feature this issue, where we look at the differences and similarities between us and our nearest relatives from the animal world. If monkey business isn't your kind of business, then there's plenty more on offer, including how oil is formed, what you can tell from tree rings and what lies inside a beehive. We don't, however, reveal the secret of man's red fire… we did that in the last issue!

58 Starfish

61 Beehives

62 Primates

ENVIRONMENT



The Statistics

Petroleum composition

Carbon: 83 to 87%
Hydrogen: 10 to 14%
Nitrogen: 0.1 to 2%
Oxygen: 0.1 to 1.5%
Sulphur: 0.5 to 6%
Metals: <0.1%

Oil formation

The most precious and precarious energy supply on Earth, oil is in constant demand worldwide, with nations vying fiercely for the rights to mine its remaining reserves

Crude oil (petroleum) forms when carbon-rich organisms die and get compressed within an oxygen-starved environment over millions of years. The most common area for oil to begin to form is on the seabed, when plankton and other micro-organisms die and sink to the bottom of the ocean. From here, the organisms are compressed as further layers of sediment pile up on top of them, as well as by the immense water pressure present at such depths. Over millions of years the organisms are broken down by multitudinous chemical reactions into various hydrocarbon molecules, the lighter molecules forming natural gas, while the heavier ones form liquid petroleum.

After petroleum has been generated it migrates upwards through rock as it crumbles and buckles away under extreme pressure (liquid cannot be compressed, as with rock), before accumulating in a porous rock called a reservoir that has a non-porous seal or cap rock that prevents the oil from migrating farther. From these reservoirs humans then drill the cap rock in order to access the petroleum and pump it to the Earth's surface for processing and refinement.

5 TOP FACTS
OIL

24
1 The phrase 'petroleum' was first coined back in 1546 by a German scholar and mineralogist called Georg Bauer, who was also known as Georgius Agricola.

Shifty
2 Crude oil itself is not a singular, unchanging substance, but rather a molecular composition that actually varies from formation to formation.

Trek
3 Formed oil very often travels many kilometres horizontally underground before it eventually seeps and gathers into large underground reservoirs.

Beach
4 Not all oil is garnered from drilling oil wells, with a large amount acquired from tar sands – clay/sand/bitumen mixes that are found over the Earth's surface.

Business
5 The largest oil company in the world is the Saudi Arabian Oil Company, also known as Saudi Aramco, which currently has total reserves of over 300 million barrels of oil.

DID YOU KNOW? *The term petroleum means literally 'rock oil', after its Latin etymology petra (rock) oleum (oil)*

Mine
Finally, after the oil is located through seismology and satellite technology, drilling platforms are erected and the cap rock – the top-layer of rock separating the oil from the ocean bed – is drilled through so it may be extracted.

A deep-sea oil platform positioned off the coast of Brazil

Time
Over millions of years layers of sediment build up on top of this organic layer, compressing and heating it until it turns into crude oil, a hydrocarbon-rich liquid.

© Science Photo Library

Rise
Once formed, the oil – as it is lighter than the base rock which surrounds it – filters upwards as the layers buckle under the tectonic forces which are being impressed upon them.

A sample of refined bitumen, a sticky tar-like form of petroleum

Reservoir
As the base-rock crumbles away, the oil – which cannot be compressed as it is a liquid (this is, coincidentally, the fundamental theory behind how hydraulics work) – collects together and forms massive underground reservoirs.

"Over millions of years the organisms are broken down by multitudinous chemical reactions"

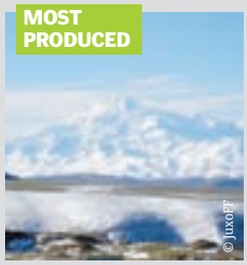
Head to Head
OIL PRODUCING COUNTRIES

MOST EXPORTED

© Wars

1. Saudi Arabia
The world's highest exporter of oil products, Saudi Arabia is the largest Arab country in the Middle East and ships over 9 million barrels of oil a day.

MOST PRODUCED



© JuxoFF

2. Russia
Russia, while only the second largest exporter of oil, is the world's largest producer. It is also the world's largest producer and exporter of natural gas.

MOST UPCOMING

©Globaljuggler

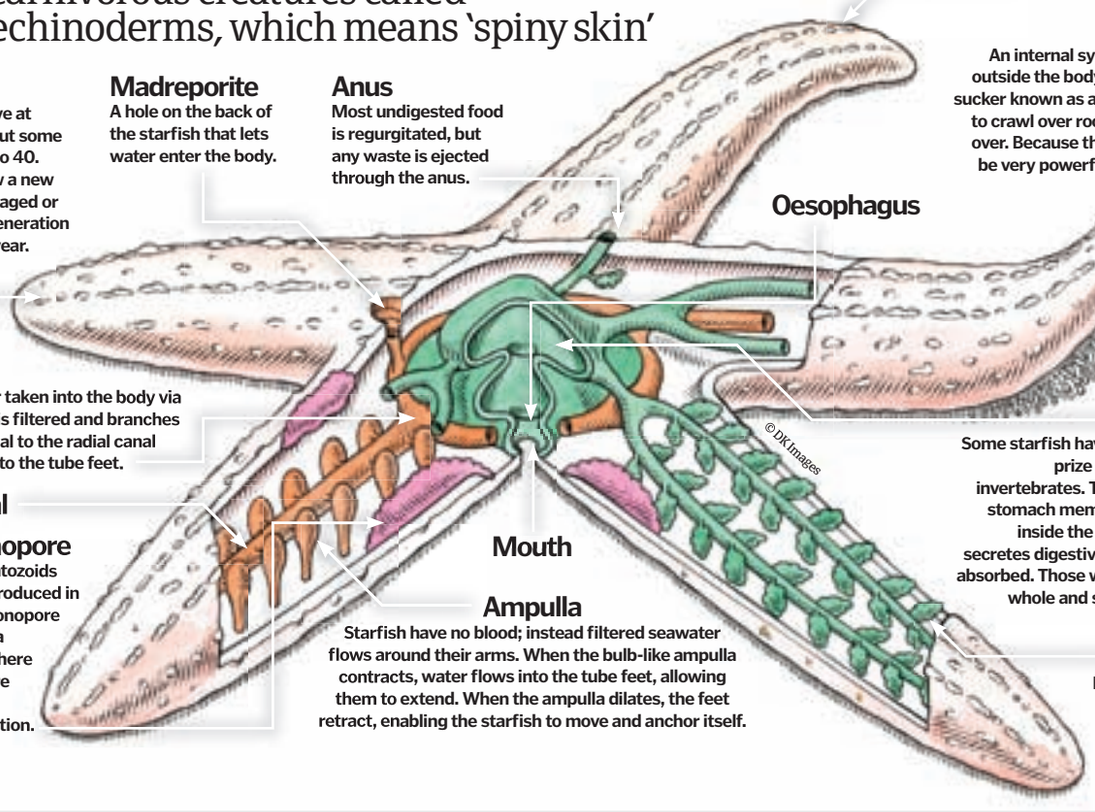
3. China
China produces almost 4 million barrels of oil a day and the company PetroChina is rated as number one in the world list of most valuable companies.

Learn more
The BP website is a great source of information on the subject of oil. At the time of writing it was dominated by the response to the Gulf of Mexico crisis, but there are also some great resources concerning the environment and sustainability, exploration, climate change and alternative energy. Point your browser over to **http://www.bp.com**.

"Some species of salamander have no lungs or gills"

Starfish anatomy

Discover the inner workings of these carnivorous creatures called echinoderms, which means 'spiny skin'



Skin
A starfish has no head and no brain; instead it uses sensitive skin cells to detect smells and chemicals from food, special eye spots at the end of each arm can also detect light. These remarkable sense cells send signals through a system of nerves.

Tube feet
An internal system of tiny flexible pipes extends outside the body. At the tip of each tube is a sticky sucker known as a tube foot, which the starfish uses to crawl over rocks and right itself if it gets flipped over. Because there are so many of them, they can be very powerful and even help them open shells.

Arms
Most starfish have at least five arms, but some species have up to 40. Starfish can grow a new arm if one is damaged or amputated – regeneration can take up to a year.

Madreporite
A hole on the back of the starfish that lets water enter the body.

Anus
Most undigested food is regurgitated, but any waste is ejected through the anus.

Oesophagus

Ring canal
Filtered seawater taken into the body via the madreporite is filtered and branches from the ring canal to the radial canal before passing into the tube feet.

Stomach
Some starfish have suction discs, which they use to prize open the shells of clams and other invertebrates. The starfish then pushes its supple stomach membranes out through its mouth and inside the shell of the prey. The starfish then secretes digestive enzymes, which allow food to be absorbed. Those without suction discs swallow prey whole and spit out anything they can't digest.

Radial canal

Gonad/Gonopore
Sex cells (spermatozoids and ovules) are produced in the gonad. The gonopore is an opening on a starfish's back where these gametes are released into the water for fertilisation.

Mouth

Ampulla
Starfish have no blood; instead filtered seawater flows around their arms. When the bulb-like ampulla contracts, water flows into the tube feet, allowing them to extend. When the ampulla dilates, the feet retract, enabling the starfish to move and anchor itself.

Pyloric duct/cecum
Here digestive juices are produced and digested food is stored.

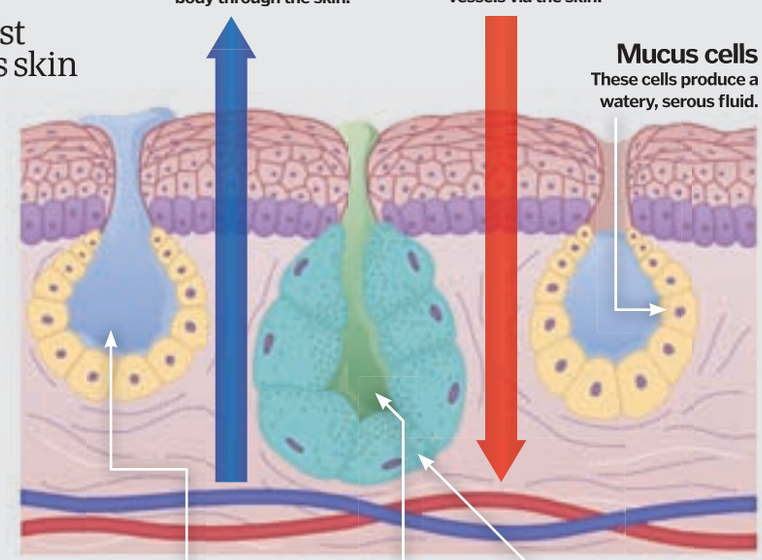
Amphibian skin

Skin is the body's main protective barrier against the outside world, and although an amphibian's skin is only very thin it has many qualities vital to keeping amphibians alive

Amphibians can breathe in and out through their skin – on land and under water – and they take in water not through their mouths but through absorbent skin on their underside called a seat patch. Most adult amphibians have lungs, but additional oxygen is taken in through the skin. Some species of salamander have no lungs or gills and breathe exclusively through their skin.

The reason amphibians feel slippery is that their skin is full of glands that produce mucus, which spreads across the surface of the skin. This mucus moistens the skin, making it softer and therefore more oxygen absorbent. Although amphibians have few defences against predators, they do have additional poison glands on their skin that secrete irritating toxins for repelling would-be diners. Most are only mildly poisonous, but some species, such as the poison dart frog, are deadly to the touch.

Amphibian skin must stay moist to prevent the body from becoming too hot or cold, and also to avoid desiccation (drying up), which spells the end for Mr Toad. This constant need for moisture means that, as well as producing mucus, amphibians should live close to a water source.



Breathe out
Carbon dioxide leaves the body through the skin.

Breathe in
Oxygen passes into blood vessels via the skin.

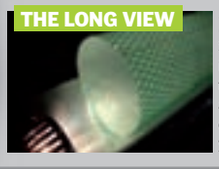
Mucus cells
These cells produce a watery, serous fluid.

Mucus gland
Mucus cells group together to form a sac-like gland.

Poison gland
Groups of poison glands are located in areas most likely to be attacked by predators.

Poison cells
The toxicity of the poison secreted is reliant on the amphibian's diet.

THE LONG VIEW



1. Ice core dating

Scientists bore 3,000 metres into the Arctic shelf to analyse thousands of years of atmospheric greenhouse gas data. Accuracy is down to two years either way.

THE LANDMARKS

© Greg Smith 05

2. Tephrochronology

Large volcanic events spew debris called tephra across continents. This leaves a clear marker in the fossil record around which to date nearby sedimentary layers. However, tephra layers are relatively rare.

THE BALLPARK FIGURE

3. Carbon 14 dating

Since carbon dating measures the amount of carbon 14 remaining in previously living tissue, it assumes that all tissue starts with the same levels of carbon 14, leaving a large margin of error.

DID YOU KNOW? *Dendroclimatologists use tree ring variations to reconstruct climate shifts over the millennia*

How tree rings work

Fractions of a millimetre wide, tree rings are an accurate biological archive of recent and ancient history

The concept of determining a tree's age by counting its rings is only half right; most trees in temperate regions produce a single visible ring every year. Wood is made of dead xylum cells – long, tubular, vertically oriented cells that transport nutrients from the roots to the rest of the plant. Early in the tree's annual growth season, xylum cells have thinner walls, producing the light-coloured section of tree rings called earlywood. By the end of the growing season, the cell walls have become thick and dense, leaving the telltale dark stripe (or latewood) that separates one tree ring from the next.

But dendrochronologists – people who study and date tree rings – say that the problem with ring-counting is that false rings and missing rings are common. Plus, counting individual rings will only give you the age of the tree when it was chopped down or died. How do you place the true age of that tree in the context of geological time? The solution is called cross-dating.

The cross-dating process starts with a young tree with a precisely known age. Maybe we know its exact planting date or its rings contain evidence of a well-documented drought or volcano. Dendrochronologists bore out a cross-section of the tree and measure the widths of its individual rings. This sequence of measurements can then be matched –by eye or with the aid of computer software – with the cross-sections of slightly older trees from the same geographical zone. Working backwards through time, scientists can create a master chronology of the region, an overlapping record of tree ring widths from today back through hundreds or thousands of years.

2. Cambium

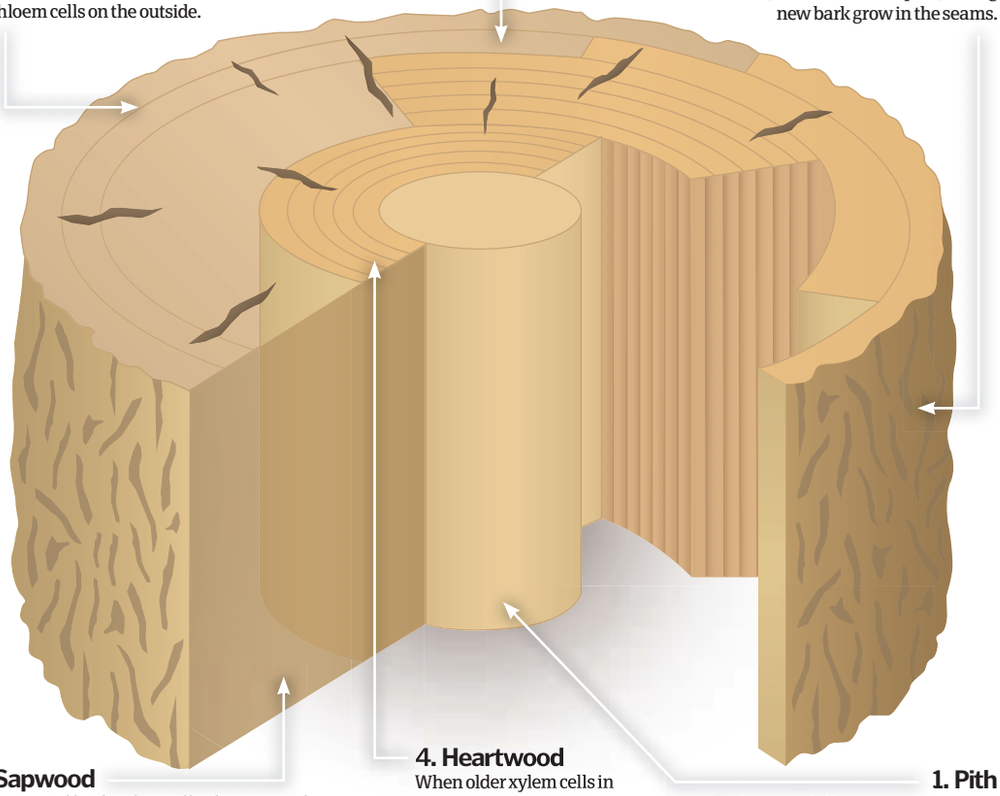
This thin layer between the inner bark and sapwood is where new growth occurs in a tree, producing xylem cells on the inside of the layer and phloem cells on the outside.

5. Phloem

Also known as the inner bark, phloem cells form on the outside of the cambium and help transport sugars from photosynthesis to wherever food is needed.

6. Bark

Bark is a collection of dead cork cells, a waxy material that protects the outermost layers of wood. Bark doesn't expand with the growing tree, so it cracks and splits, letting new bark grow in the seams.



3. Sapwood

Composed of fresh xylem cells, the sapwood serves as the active vascular system of the tree, pumping nutrient-filled sap from the roots to the branches and leaves.

4. Heartwood

When older xylem cells in sapwood become clogged or dried out, they stop actively transporting sap and become heartwood.

1. Pith

At the core of all stems – trees are just long, hard stems – is a spongy mass called pith. As the tree expands in diameter, the pith compacts and solidifies.

What tree rings tell us

Tree ring dating is a hot scientific field. Those stripes have proven to be accurate archives of biological data, giving us important clues to climatic conditions through the millennia. The width and colour of tree rings varies with the amount of rainwater it receives, average seasonal temperatures, pest and disease outbreaks and scarring events like volcanoes, forest fires and floods. In this way, a cross section of a tree is a biological snapshot of a certain time and place in the Earth's history.

Tree ring lingo

The concentric circles of tree rings represent the slow outward growth and death of xylem cells, which start as active sapwood then harden into solid heartwood. All true growth occurs along the cambium, the thin layer underneath the bark where fresh xylem and phloem cells are born.

5 TOP FACTS HONEY

Wax factories
1 In order to build their honeycomb, young worker bees must consume between eight to ten kilos of honey and pollen for every single kilo of wax.

Heavy hives
2 Don't let those small boxes fool you. A fully established beehive has the capacity to hold anywhere between 40,000 to 80,000 bees – that's a lot of buzzing!

Sea of gold
3 In the United States, the average annual honey production of both commercial and hobby beekeepers is 200 million pounds (that's 90,718,474 kilograms).

Sweet teeth
4 The per capita honey consumption in the United States is 1.29 pounds (0.59 kilos) a year – a lot less than that of Winnie The Pooh though we'd imagine!

A woman's world
5 Male bees, called drones, have only one function: to mate with the queen. When honey reserves run low in winter, all drones are driven from the hive.

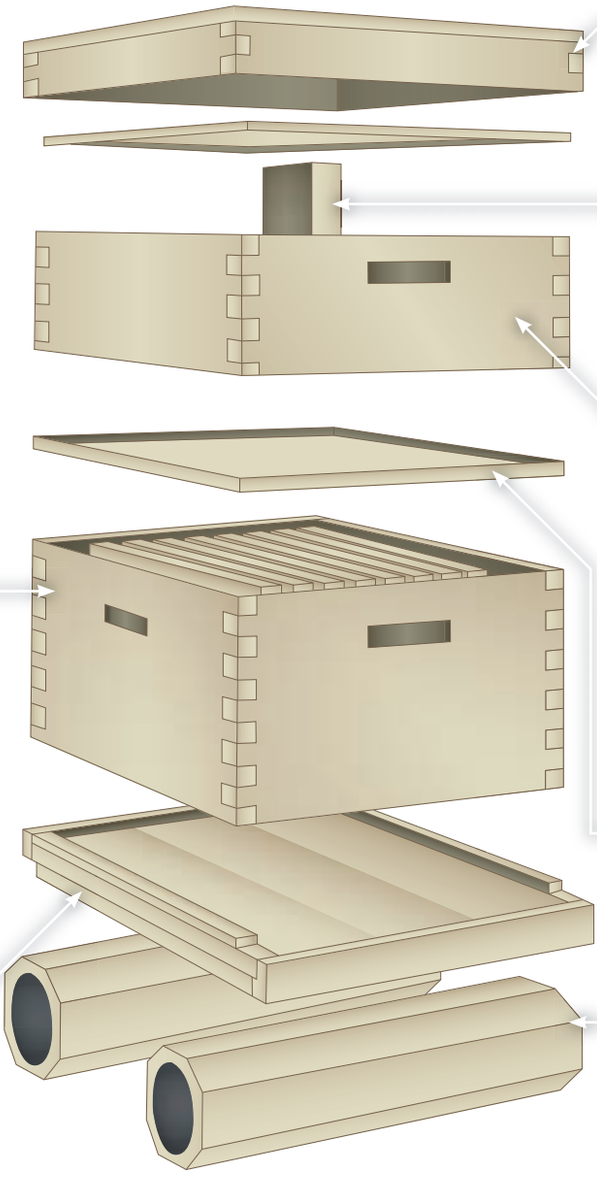
DID YOU KNOW? *Forager bees perform a 'dance' for other foragers to explain the distance and direction of the nectar source*

How beehives work

Grab your mask, start your smoke gun and lift out a honeycomb heavy with oozing goodness

Beehive breakdown

The design of a Langstroth beehive has remained nearly unchanged since the American preacher and apiarist invented his artificial hive in 1851. Langstroth's top-opening, stacked hive boxes contain removable frames that are spaced to maximise honeycomb production yet prevent the frames from sticking together with excess propolis, aka 'bee glue'.

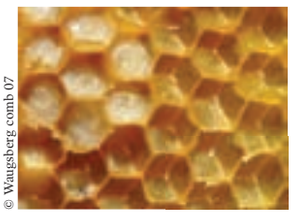


Top cover
'Telescoping' top covers hang down over the honey super to stay secure in windy weather. Beekeepers will often prop open the top cover slightly to aid ventilation.

Frames
Each frame is built with a plastic, honeycomb-shaped foundation upon which the bees construct their comb and store their honey. The beekeeper 'decaps' the honeycomb to extract the golden liquid.

Honey super
The honey supers are shallower versions of the hive body with ten removable frames. Since the queen can't reach the honey supers, all of the stored honey in this section will be harvested by the beekeeper.

Hive body
This deep wooden box fitted with ten removable frames is where the queen bee lays her eggs and where the worker bees live, raise their larvae and store their own honey reserves.



© Waugsberg comb 07

Queen excluder
This metal or plastic grill has spaces large enough for worker bees to pass through, but too tight for the queen or drones to fit, preventing the queen from laying eggs in the honey supers.

Bottom board
Made of either solid wood or a metal screen, the bottom section of the hive is also its front door. To keep out mice and other pests, beekeepers sometimes place a cleat across the bottom board opening to restrict its size.

Hive stand
A wooden pallet or even concrete blocks raise the hive ten to 15 centimetres off the ground, separating the hive from moist ground and saving the beekeeper's back.

Beekeeping has always been something of an extreme sport. Ancient apiarists with thick skins would 'rob' wild hives. The Greeks were the first to construct artificial hives out of overturned woven baskets, but the honey harvest was still an uncertain and invariably painful affair.

The modern artificial beehive takes the sting out of beekeeping and ensures an abundant harvest of nature's favourite sweetener. Those stacked wooden boxes on the edge of a farmer's field each contain ten removable frames. The frames hold a thin plastic foundation stamped with a honeycomb pattern and sprayed with a sugar water solution. When a new brood of bees enters the hive, they instinctively build their waxy honeycomb on the pre-stamped patterns, filling the hexagonal cells with the valuable honey. Some of the honey is reserved to feed the bees through the winter and the rest is harvested for your afternoon tea.

The genius of the modern artificial beehive, invented by L L Langstroth in 1851, is that the removable frames are spaced precisely 0.79 centimetres (3/8 inch) apart, the exact width of a worker bee. Given the proper "bee space", honeybees will build a comb that extends far enough from the frame to maximise honey production, but doesn't stick to the adjoining frame. This allows the beekeeper to easily remove and inspect individual frames periodically for comb development and pests.

© Muhammad Mahdi Karim

What is honey?

Honey is a super-concentrated form of nectar, the sugar water produced by flowering plants. The conversion of nectar to honey is the responsibility of worker bees, the female honeybee that forages for nectar and breaks it down into simple sugars using an enzyme in their gut called invertase.

The nectar is then regurgitated into hexagonal wax cells, where other worker bees fan the nectar furiously with their wings until its moisture level drops below 18.5 per cent, officially becoming honey. A single bee produces 1/12th of a teaspoon of honey during its entire lifetime, but the whole hive can generate over 90 kilograms of honey a year.

"Primates live longer than other mammals of the same size"

Primates

There's more to primates than just monkeys. This diverse group also contains some of the strangest and most specialised animals. How It Works goes looking for the King of the Swingers

Primates are mammals with grasping hands and feet, good vision and large brains for their body size. They evolved from squirrel-like tree-dwelling animals around 65 million years ago, just before the dinosaurs became extinct. Primates are divided into the lemurs (who only live in Madagascar), lorises, tarsiers and simians. Somewhere between 33 and 70 million years ago, a few simians made the journey from Africa to South America, probably floating on impromptu rafts of vegetation. From there, they evolved into the New World Monkeys, and they are the only primates native to that continent. The simians left behind became the Old World Monkeys – who have tails – and the apes – who don't.

There are approximately 424 species of primate currently known, mostly living in the midst of tropical rainforests. Primates are very successful mammals. Even ignoring the fact that the dominant species on Earth (homo sapiens) is a primate, this group of animals has spread across the tropical regions of the world; from the humid forests of Central America to the arid African savannah, and from the swamps of the Congo basin to the Ethiopian highlands, a massive 5,000m above sea level.

Primates account for as much as 40 per cent of the fruit-eating animals (by weight) in tropical rainforests and their preferences have had a major impact on the evolution of plants there. Bananas and oranges, for example, use monkeys to spread their seeds and so have evolved skins that are very hard to peel unless you have opposable thumbs.

Primates live longer than other mammals of the same size, partly because they are often able to co-operate to defend themselves against predators. They also reproduce more slowly though, with infants hugely dependent on their parents for much longer than most other animals. Their reasonably large brains require time to fully develop, and to fill with knowledge about their environment and its numerous dangers.

Although most primates eat fruit as part of their diet, many of them have specialised for other foods as well. Lemurs eat leaves, marmosets strip tree bark to eat the gum underneath and the aye-aye has an elongated middle finger to winkle insects out of trees, like a woodpecker.

Primates, our closest relatives... see the resemblance?

5 TOP FACTS PRIMATE FEATURES

Mouse lemur
1 Madame Berthe's mouse lemur weighs just 30 grams (1.1 ounces) and has a body that measures 9.2cm long (3.6 inches). It lives only in a small part of Madagascar.

Mountain gorilla
2 At the other end of the scale, the mountain gorilla weighs 200kg (440lb). Despite its ferocious bulk, it is completely herbivorous and mostly eats leaves.

Male proboscis monkey
3 The male proboscis monkey has a nose the size, shape and colour of a large sweet potato. Amazingly, it seems that this feature actually attracts females.

Gelada
4 The gelada is a grass eater. It has the most opposable thumb of any primate apart from humans, used to pick apart grass stalks to reach the most nutritious parts.

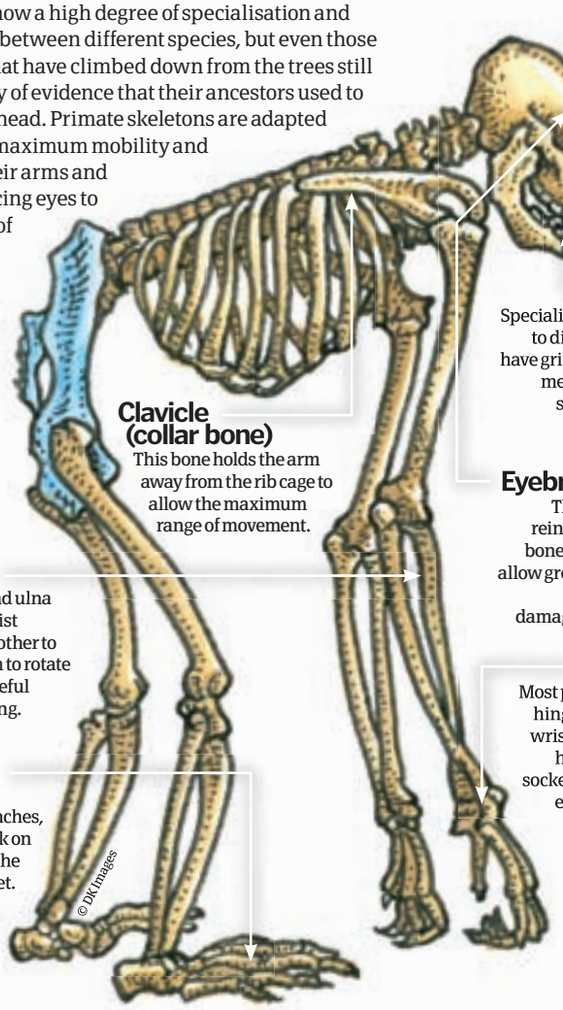
Howler monkey
5 The howler monkey is the loudest land animal. Using the enlarged hyoid bone in its neck, it makes a hooting noise that can be heard three miles away.

DID YOU KNOW? *Female lorises bathe their young with toxic saliva licked from patches near their elbows to discourage predators*


© Science Photo Library

The skeleton of a swinger

Primates show a high degree of specialisation and adaptation between different species, but even those primates that have climbed down from the trees still show plenty of evidence that their ancestors used to swing overhead. Primate skeletons are adapted to provide maximum mobility and reach in their arms and forward-facing eyes to give depth of perception.


© DK Images

Eye sockets
Tarsiers have eyes so large, they can't move in their sockets. They rotate the whole head through up to 180° instead.

Teeth
Specialised according to diet. Leaf eaters have grinding molars, meat eaters have sharp canines.

Clavicle (collar bone)
This bone holds the arm away from the rib cage to allow the maximum range of movement.

Eyebrow ridge
This bony ridge reinforces weaker bones in the face to allow greater chewing force without damaging the skull.

Forearm
The radius and ulna bones can twist around each other to allow the arm to rotate on its axis. Useful when swinging.

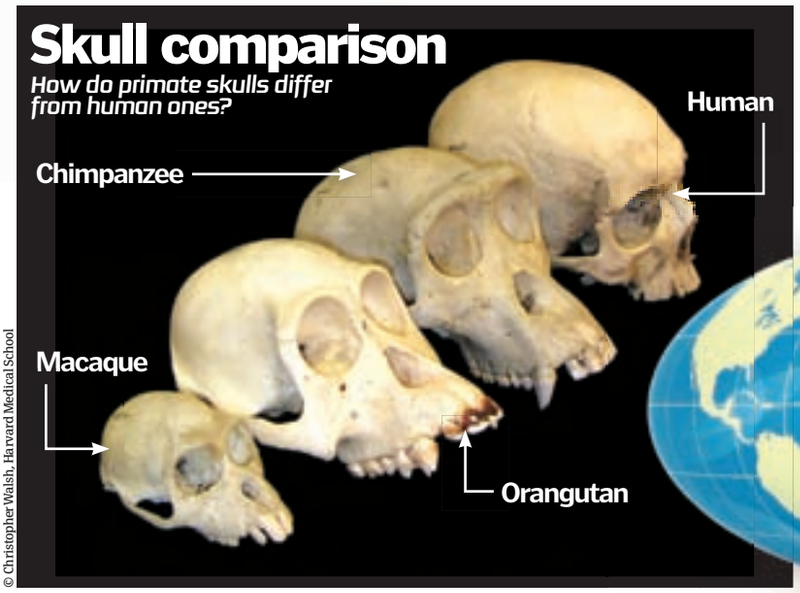
Wrist
Most primates have hinge joints at the wrist, but gibbons have a ball and socket joint, like an extra shoulder.

Fingers and toes
Elongated for gripping branches, primates walk on the palms of the hands and feet.


© Science Photo Library

Skull comparison

How do primate skulls differ from human ones?



© Christopher Walsh, Harvard Medical School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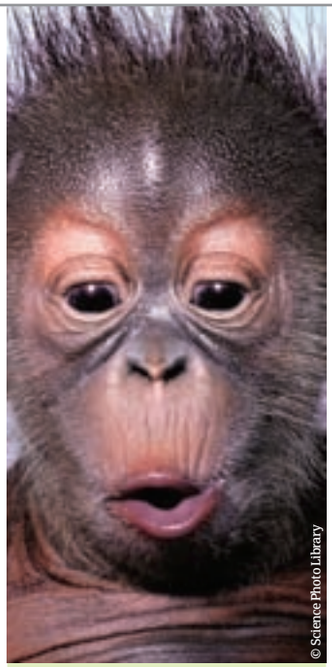
Where do they live?

Primates evolved from tree-dwelling animals. In South America, where forests tend to be very dense with lots of trailing lianas, most species still spend all their lives high in the trees, away from predators. In the Old World, colobus monkeys and gibbons live in the trees but the great apes spend a lot of their time on the forest floor. Baboons and mandrills don't climb much at all.

Primates mostly live in tropical regions, avoid water and are active during the day. But with such versatile animals, there are always exceptions. Galagos, or bushbabies, are nocturnal; Allen's swamp monkey has webbed feet and can swim; and the Japanese macaque lives in an area that is snow-covered for eight months of the year.

ON THE MAP
Where to find primates

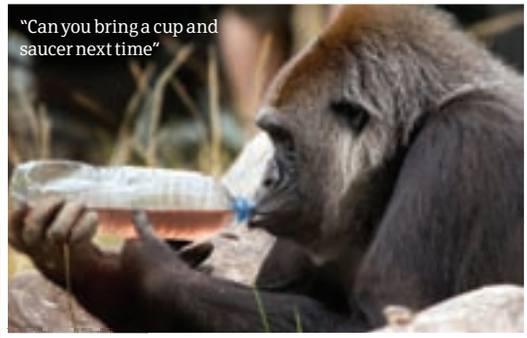
1 New World Monkeys – South/Central America
2 Old World Monkeys, Apes – Sub Saharan Africa
3 Gorillas – Congo
4 Barbary macaques – Atlas Mountains
5 Gibbons – South-east Asia and India
6 Lemurs – Madagascar
7 Japanese macaques – Honshu, Japan
8 Gelada baboon – Ethiopian highlands


© Science Photo Library

All fingers and thumbs

Primates evolved in the trees and even those species that have since climbed down to solid ground still carry the legacy of hands and feet that were designed to grip branches. Primates have five fingers and toes on each foot with nails, rather than claws, an opposable thumb and often an opposable big toe as well. Primate fingers are much longer than in other mammals and tend to curve inwards when relaxed, so their natural position is a loose grip.

As well as being good at gripping, primates have long arms with very freely rotating shoulders and wrists. This makes it easy to swing from branch to branch. This form of movement is called brachiation. Gibbons can brachiate at 55km/h, travelling 6m with each swing.


"Can you bring a cup and saucer next time"


Thumbs up!
The opposable thumb is considered by many as the pinnacle of evolution.

Get a grip
A primate's grip is essential for swinging and eating.

© Science Photo Library

Wise monkeys

Monkey see monkey do

Primates have binocular vision and fingers and thumbs that can grip small objects with precision. This is useful enough already, but it is their large brains that allow them to explore and manipulate the world around them in more complex ways. Chimpanzees use sharpened sticks to poke for termites and as weapons; gorillas carry a walking stick to gauge the depth of the water as they cross a river; Japanese macaques wash their food in seawater to remove dirt and season it with salt. These behaviours aren't innate; they are passed from generation to generation.

Most primates are highly social, with complicated power struggles and sexual relationships worthy of any soap opera. The New World species form monogamous relationships and look after the young together. In Africa and Asia, only gibbons do this. Old World monkeys and great apes have dominance hierarchies to establish one male in a group with mating access to most of the females.


Depth perception is vital to aid swinging

© Science Photo Library

Taste the rainbow

The complex, three-dimensional world of the forest makes accurate depth perception essential. This requires forward-facing eyes and a flattened nose that won't get in the way. For this reason primates rely much more on their vision than their sense of smell. Most mammals can see just two basic colours but primates have evolved a three-colour vision sensitive to red, green and blue wavelengths. This allows them to easily distinguish which fruits are ripe.

In New World monkeys, the males all have two-colour vision, which is slightly better for identifying succulent leaves, while most females see three colours, so they can find fruit. Most species gather food co-operatively, to get the best of both worlds.


Brushing twice a day keeps those teeth pearly white

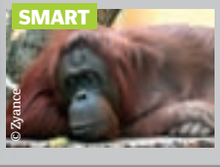
© Science Photo Library

A gripping tail

Apart from the apes, most primates have tails, but *prehensile* tails are unique to the New World monkeys. Prehensile means 'gripping' and the howler, spider and woolly monkeys have a bare pad of skin on the end of their tails that lets them grip food and small objects. The capuchin monkeys don't have this pad and only use their tail as a fifth arm when climbing. Old World monkeys only use their tails for balance.


There's a good chance his eyes are bigger than his stomach

SMART

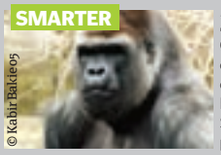


© Zyance

1. Orangutan

The fluffy orangutans have been seen using leaves as makeshift megaphones, to amplify the 'kiss squeak' sounds that they make.

SMARTER

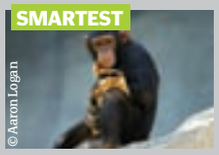


© Kabir Bakie05

2. Gorilla

Gorillas show complex emotional attachments to each other in the wild and Koko, a female gorilla at San Francisco Zoo, has pet cats.

SMARTEST



© Aaron Logan

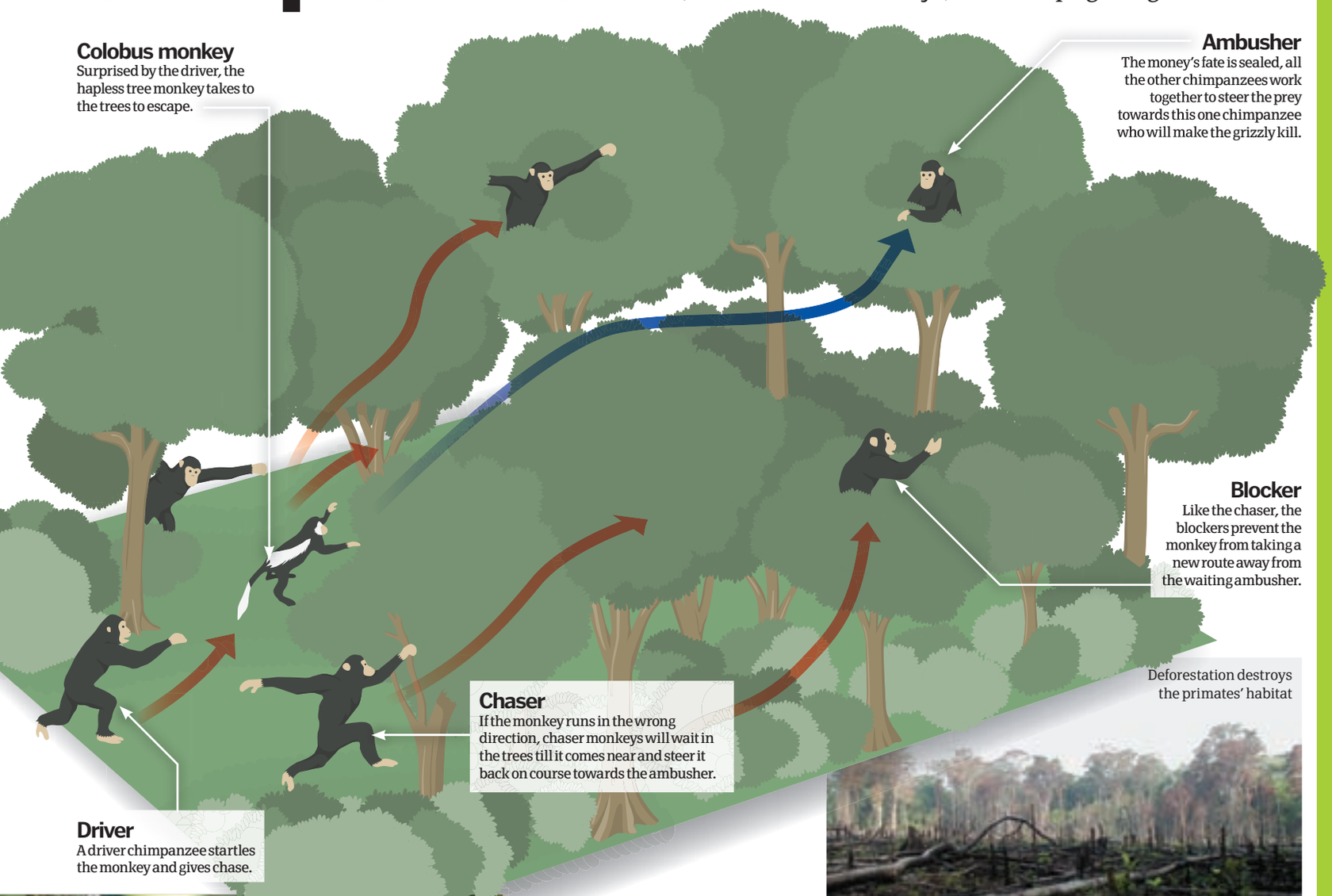
3. Chimpanzee

Captive chimpanzees have been taught to use American sign language to ask for food and can remember the numbers one to nine as well as their values.

DID YOU KNOW? *In 2005 the naming rights for the newly discovered Callicebus aureipalatii were auctioned off for £450,000*

Chimp chase

Chimps will eat almost anything. In fact, they're also partial to the odd small tree-dwelling monkey. In order to catch these far swifter, more nimble monkeys, the chimps get organised



Colobus monkey

Surprised by the driver, the hapless tree monkey takes to the trees to escape.

Ambusher

The money's fate is sealed, all the other chimpanzees work together to steer the prey towards this one chimpanzee who will make the grizzly kill.

Blocker

Like the chaser, the blockers prevent the monkey from taking a new route away from the waiting ambusher.

Chaser

If the monkey runs in the wrong direction, chaser monkeys will wait in the trees till it comes near and steer it back on course towards the ambusher.

Driver

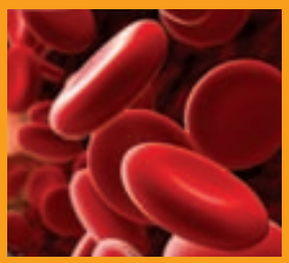
A driver chimpanzee startles the monkey and gives chase.

Deforestation destroys the primates' habitat

Threats to primates

More than a third of primate species are critically endangered or vulnerable. Deforestation accounts for a lot of this, mainly through forest clearance for agriculture. But poaching is a significant problem as well. The smaller primates are captured to supply the pet trade, larger animals are hunted for traditional medicine and for their meat. In some African cities, half of all the protein eaten is 'bush meat', which includes primates. Armed conflict in the Democratic Republic of Congo has made poaching much worse because of general lawlessness. Primates reproduce much more slowly than other mammals so populations take a long time to recover.

In Madagascar, at least 15 species of primate have become extinct since humans first settled there 1,500 years ago, including a lemur larger than a gorilla.



This month in **Science**

"Phew! It's a scorcher!" is a tabloid headline that many of us don't mind seeing at this time of year. With any luck just such a headline will appear soon and when it does, you can find out all about heatwaves and the effect of heat on the human body by reading our main feature on page 70. Once you've familiarised yourself with the facts about good weather you can learn how dry cleaning gets your clothes looking like new or why chlorine is put in pools.

70 Heatwaves

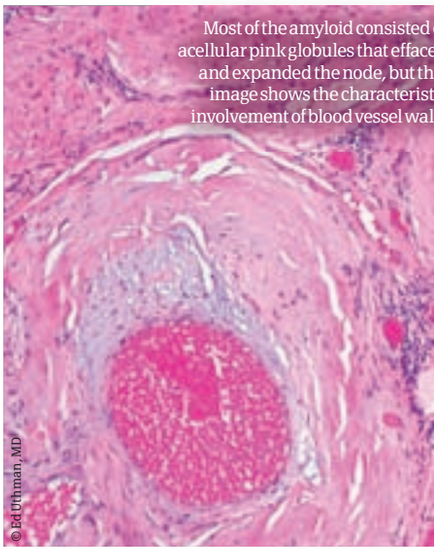
72 Adrenaline

73 Oil refineries

SCIENCE

Blood vessels

Arteries and veins form the plumbing system of the human body, carrying blood through a complex system of different sized and shaped pipes. We find out how they work...



Most of the amyloid consisted acellular pink globules that efface and expanded the node, but th image shows the characterist involvement of blood vessel wal

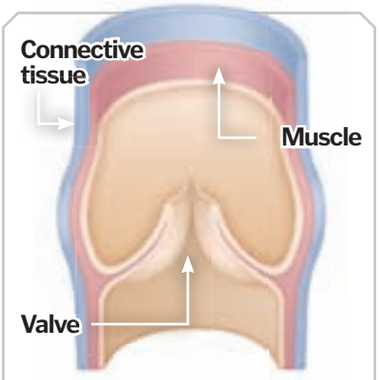
© Ed Uthman, MD

The network of blood vessels in the human body must cope with different volumes of blood travelling at different pressures. These vessels come in a multitude of different sizes and shapes, from the large, elastic aorta down to tiny, one-cell-thick capillaries.

Blood is the ultimate multitasker. It carries oxygen for various tissues to use, nutrients to provide energy, removes waste products and even helps you warm up or cool down. It also carries vital clotting factors which stop us bleeding. Blood comes in just two varieties; oxygen-rich (oxygenated) blood is what the body uses for energy, and is bright red. After it has been used, this oxygen-depleted (deoxygenated) blood is returned for recycling and is dark red (not blue, as is often thought).

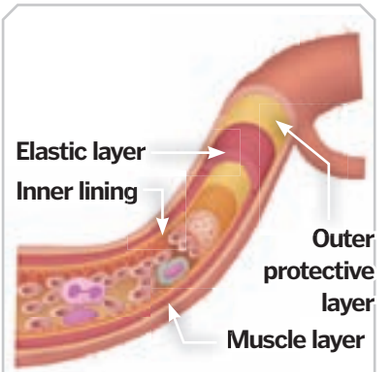
Blood is carried in vessels, of which there are two main different types – arteries and veins. Arteries carry blood away from the heart and deal with high pressures, and so have strong elastic walls. Veins carry blood back towards the heart and deal with lower pressures, so have thinner walls. Tiny capillaries connect arteries and veins together, like small back-roads connecting motorways to dual carriageways.

Arteries and veins are constructed differently to cope with the varying pressures, but work in perfect tandem to ensure that the blood reaches its final destination. However, sometimes things go wrong which can lead to medical problems: varicose veins from failing valves; deep vein thrombosis from blood clots blocking the deep venous system; heart attacks from blocked arteries; and life-threatening aneurysms from weak artery walls.



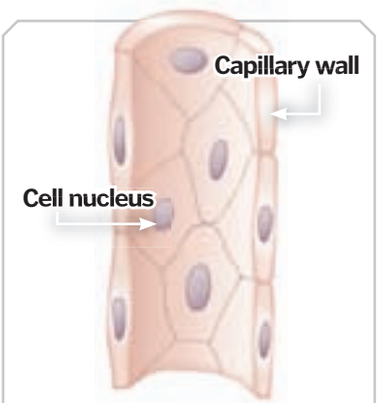
How do veins work?

Veins carry low pressure blood. They contain numerous one-way valves which stop backwards flow of blood, which can occur when pressure falls in-between heartbeats. Blood flows through these valves towards the heart but cannot pass back through them in the other direction. Valves can fail over time, especially in the legs. This leads to saggy, unsightly veins, known as varicose veins.



Arteries – under pressure!

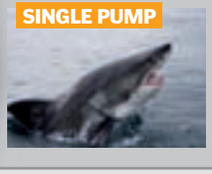
Arteries cope with all of the pressure generated by the heart and deliver oxygen-rich blood to where it needs to be. The walls of arteries contain elastic muscles, allowing them to stretch and contract to cope with the wide changes in pressure generated from the heart. Since the pressure is high, valves are unnecessary, unlike the low-pressure venous system.



Connecting it all together

Capillaries are the tiny vessels which connect small arteries and veins together. Their walls are only one cell thick, so this is the perfect place to trade substances with surrounding tissues. Red blood cells within these capillaries trade water, oxygen, carbon dioxide, nutrients, waste and even heat. Because these vessels are only one cell wide, the cells have to line up to pass through.

Head to Head CIRCULATION SYSTEMS



SINGLE PUMP

1. Sharks

Like other fish, a shark's heart has one pumping system, made from two chambers arranged in an S-shape. Blood is pumped to the gills where it is oxygenated, from where it flows directly to the other body tissue.

NO CIRCULATION

2. Flatworm (platyhelminth)

Flatworms have no true circulatory system. Oxygen diffuses into them and carbon dioxide out of them, from surrounding water.

THREE CHAMBERS

3. Amphibians

Frogs and lizards have hearts made up of just three chambers – as opposed to a human's four-chambered heart – which represents a less evolved stage compared to the human heart.

DID YOU KNOW? *Vascular surgeons can bypass blocked arteries using either the patient's own veins or synthetic grafts*

A game of two halves

In human beings, the heart is a double pump, meaning that there are two sides to the circulatory system. The left side of the heart pumps oxygen and nutrient-rich blood to the brain, vital organs and other body tissues (the systemic circulation). The right side of the heart pumps deoxygenated blood towards the lungs, so it can pick up new oxygen molecules to be used again (the pulmonary circulation).

Arteries
All arteries carry blood away from the heart. They carry oxygenated blood, except for the pulmonary artery, which carries deoxygenated blood to the lungs.

Lungs
In the lungs, carbon dioxide is expelled from the body and is swapped for fresh oxygen from the air. This oxygen-rich blood takes on a bright red colour.

Aorta
The aorta is an artery which carries oxygenated blood to the body; it is the largest blood vessel in the body and copes with the highest pressure blood.

Veins
All veins carry blood to the heart. They carry deoxygenated blood, except for the pulmonary vein, which carries oxygenated blood back to the heart.

The right side
The right side of the heart pumps deoxygenated blood to the lungs, where blood exchanges carbon dioxide for fresh oxygen.

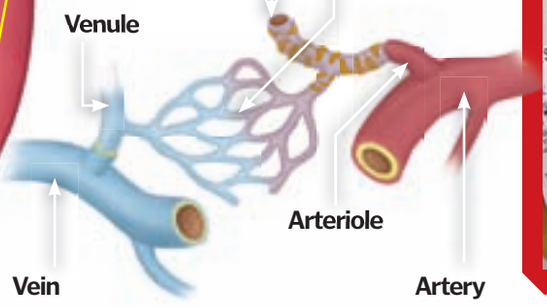
Capillaries
Tiny capillaries connect arteries and veins together. They allow exchange of oxygen, nutrients and waste in the body's organs and tissues.

The left side
The left side of the heart pumps oxygenated blood for the body to use. It pumps directly into arteries towards the brain and other body tissues.

Blood vessels
Different shapes and sizes

Capillary sphincter muscles
These tiny muscles can open and close, which can decrease or increase blood flow through a capillary bed. When muscles exercise, these muscles relax and blood flow into the muscle increases.

Capillary bed
This is the capillary network that connects the two systems. Here, exchange of various substances occurs with surrounding tissues, through the one-cell thick walls.



What's in blood?

It's only the iron in red blood cells which make blood red – take these cells away and what you're left with is a watery yellowish solution called plasma. Plasma carries all of the different types of cells and also contains sugars, fats, proteins and salts. The main cell types are red blood cells (formed from iron and haemoglobin, which carries oxygen around the body), white blood cells (which fight infection from bacteria, viruses and fungi) and platelets (tiny cell fragments which stop bleeding by forming clots at the sites of any damage).

Not what you want to see down the frozen aisle at Tesco…

"The only scientific method to avoid hangovers is to moderate the amount of alcohol consumed"

Chlorine

The ultimate pool cleaner

Chlorine is a successful cleansing agent because on contact with water it breaks down into several different chemicals including hypochlorite ion and hypochlorous acid, both of which kill bacteria by attacking their cell walls and destroying the enzymes and structure of the bacteria, oxidising them and rendering them harmless. Interestingly, this happens at different times depending on what compounds it is, with hypochlorous acid oxidising in seconds while hypochlorite ion can take up to half an hour.

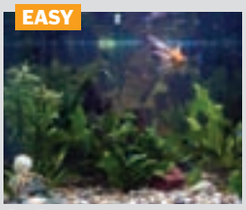
There are some problems to using chlorine though, ranging from its smell to the fact that certain skin types can have a strong reaction to it. Even worse, high levels of chlorine gas collecting above a pool can be actively hazardous to the health of its users and the hypochlorite is actively hazardous to fabrics, causing many to fade if not washed off quickly after leaving the pool.

Head to Head
WATER PURIFICATION

EASIEST

1. Boiling
Boiling will kill bacteria but it's not a permanent solution as new bacteria can enter the water once it's cooled.

EASY



2. Granular activated carbon filtering
Carbon with a high surface area can absorb many pollutants and toxic compounds and is often used in fish tanks.

NOT EASY

3. Reverse osmosis
A flashback to those science lessons at school, an impure solution is forced through a semi-permeable membrane, filtering out many of the impurities.

Hangovers

What are they, what causes them and can they be avoided?

A 'hangover' is the common term used to describe a delayed negative reaction by the human body to excessive exposure to alcoholic substances. Symptoms generally include a myriad of physiological effects such as headaches, nausea, tiredness, dysphoria, diarrhoea and severe thirst, as well as many psychological symptoms including depression and anxiety. Current scientific theory states that the main chemical causes of a hangover are a mixture of hypoglycemia (low blood sugar), dehydration, acetaldehyde intoxication (a chemical compound produced by the oxidation of ethanol) and vitamin B deficiency.

Currently, the only scientifically backed method to avoid hangovers is to moderate the amount of alcohol the human body is exposed to, reducing the negative effects. However, it is commonly accepted that through a mixture of rehydration and replenishment of vitamin B, the length and severity of a hangover can be mitigated.

Someone had one Babycham too many last night...

DID YOU KNOW?
The ancient Romans treated hangovers by consuming raw owl's eggs and fried canaries.

Transformers

Hundreds of thousands of volts are passing above your head, right now

The power lines that crisscross the country can carry up to 750,000-volt charges, an astonishing amount of raw power that's extremely dangerous. So how do you transmit the power from the lines to the electrical wiring and appliances of a house without destroying them? Simple, by using a transformer. These work off the principle of electromagnetic induction, where an alternating electrical field or AC current in a coil of wire will generate an electrical current in a second coil placed next to it. If the number of coils of wire is the same, the current will be virtually the same, and it can be increased or decreased by changing the number of coils. In this way, current can be 'stepped down' to levels where it can be used safely.

If you're waiting for it to come alive you're thinking of a different type of transformer

Don't believe everything you hear...

Pouring white wine on your carpet to cancel out a red wine stain is a myth. Experts suggest you blot the area with kitchen towel, pour on sparkling water and blot again. Repeat before sponging with soapy water.

DID YOU KNOW? *Early dry cleaning involved the use of such volatile highly flammable solvents as kerosene and gasoline*

Dry cleaning

We take our grubby garments to dry cleaning specialists who return them a few days later, spick-and-span, but what actually goes on behind those dry cleaners' doors?

The first surprise about the dry cleaning process is that it's not done dry at all, your clothes get just as wet as they do in your washing machine at home. In this respect, however, 'dry' simply means the clothes are cleaned without using water.

The reason some items of clothing require specialist cleaning is usually that certain stains do not come out in a normal home wash. While stains that are 'wet' or water based are generally removable at home, 'dry' stains, which contain grease or oil require the use of special organic solvents. However, these shouldn't be mistaken for natural substances as the word 'organic' would suggest, but rather hydrocarbon solvents, which are classed as 'organic' because they contain an element of carbon.

The most commonly used solvent in the dry cleaning industry is a chlorocarbon called perchloroethylene, or perc, used for its effective grease cleaning and non-flammable properties.

1. Delivery and inspection

The soiled garment is delivered to the cleaner, who inspects the item for any loose parts or tears that they could be blamed for post-clean. The item is also tagged so it can be reunited with the correct owner.

2. Pretreat

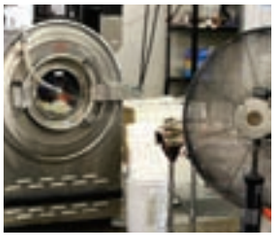
Just as you might at home, the dry cleaner searches for stubborn stains and treats them with stain removal chemicals specific to the type of stain. Water-based stains should be treated with water while a solvent is best for removing greasy marks.

3. Dry clean

A modern dry cleaner resembles a washer-dryer in the sense that clothes are spun in a steel drum and then dried off. The pretreated clothing is sprayed with the perc throughout the wash while also getting bashed about by paddles to dislodge soil particles.

4. Recycled solvent

Perc works at an ambient temperature of 20°C and the washing machine is not heated in any way until the drying stage. Dirty perc is constantly pumped out of the drum, filtered, and evaporated off. It then gets condensed back into liquid form.



5. Dry cycle

After the solvent is drained away and the drum is spun to remove excess solvent from the garment using centrifugal force, warm air passes into the machine. Residual solvent fumes are vapourised by the heat, condensed over cooling coils and then drained away.

6. Spot check

Once the garment is removed from the machine, the operator checks it for persistent stains, which can then be treated with additional stain removers – unless of course they are untreatable marks. The clothes are also aired using fans.

7. Finishing touch

Cleaned clothing is then treated to a round of steaming, reshaping and ironing before being returned to the owner. The dry cleaner will protect your clothes with a plastic garment cover, which you should remove upon getting home, allowing the item to air.

Know your care labels

Machine wash
Dots or figures inside advise temperature

Do not machine wash

Dry clean
Letters advise whether stable in perc (P) or in hydrocarbons (F)

Do not dry clean

Iron
Dots inside advise suggested heat level

Do not iron

Tumble dry
Dots advise heat (low is one dot, high is two dots)

Do not tumble dry

Drip dry

Dry in the shade

Dry flat

Line dry

May be chlorine bleached

Do not bleach

May not be chlorine bleached

"A heatwave is a period of unusually hot or humid weather"

Heatwaves

If you can't stand the heat… the Met Office suggests you stay indoors

Although, according to Met Office meteorologist John Hammond, there's no official definition of a heatwave, these hot-weather phenomena take their toll not only on a population's health, but also business and infrastructure – such as power, water and transport. A heatwave is a period of unusually hot or humid weather that lasts at least two or three days – and remaining hot throughout the nights – that affects large areas. Heatwaves are caused by a system of higher atmospheric pressure, whereby air from upper levels of the atmosphere descends and rotates out. As it descends, it compresses, increasing the temperature. The outward flow, meanwhile, makes it difficult for other systems to enter the area, and the large size and slow speed of the hot air causes the heatwave to remain for days or even weeks. The lack of clouds means that an affected area is struck with strong sunlight.

Hammond reveals that the hottest temperatures in the UK are likely to be over parts of central and southern England, away from immediate coastal areas, which are cooled by sea breezes. "Temperatures have exceeded 30°C in the UK," he explains, "[but around] Europe and the world, weather conditions can bring temperatures exceeding 40°C. This has happened in Mediterranean regions, the Middle East and Australia among other areas."

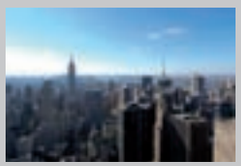
Heatwaves are relative to an area's climate – temperatures that would constitute a heatwave in one area might not in another location – and the health effects on the individual are also relative to a range of risk factors. People adapt and become accustomed to their long-term temperature patterns, making a heatwave a relative experience.

The Met Office Heat Health Watch is a warning system that issues alerts – levels 1-4 – if a heatwave is imminent. "[We] can identify weather patterns that might bring hot temperatures to the UK several days in advance," explains Hammond. "When high temperatures are expected, detailed advice will go to the relevant health organisations, so they can inform people affected by the heat. Met Office forecasts on TV, radio, newspapers and online will also provide temperature forecasts for the public."

TYPES OF… HEATWAVE

1 Dry heatwaves
Occurring in continental or Mediterranean regions, dry heatwaves are linked to clear skies and high solar radiation, as well as windy conditions, which can increase stress at excessive heat levels.

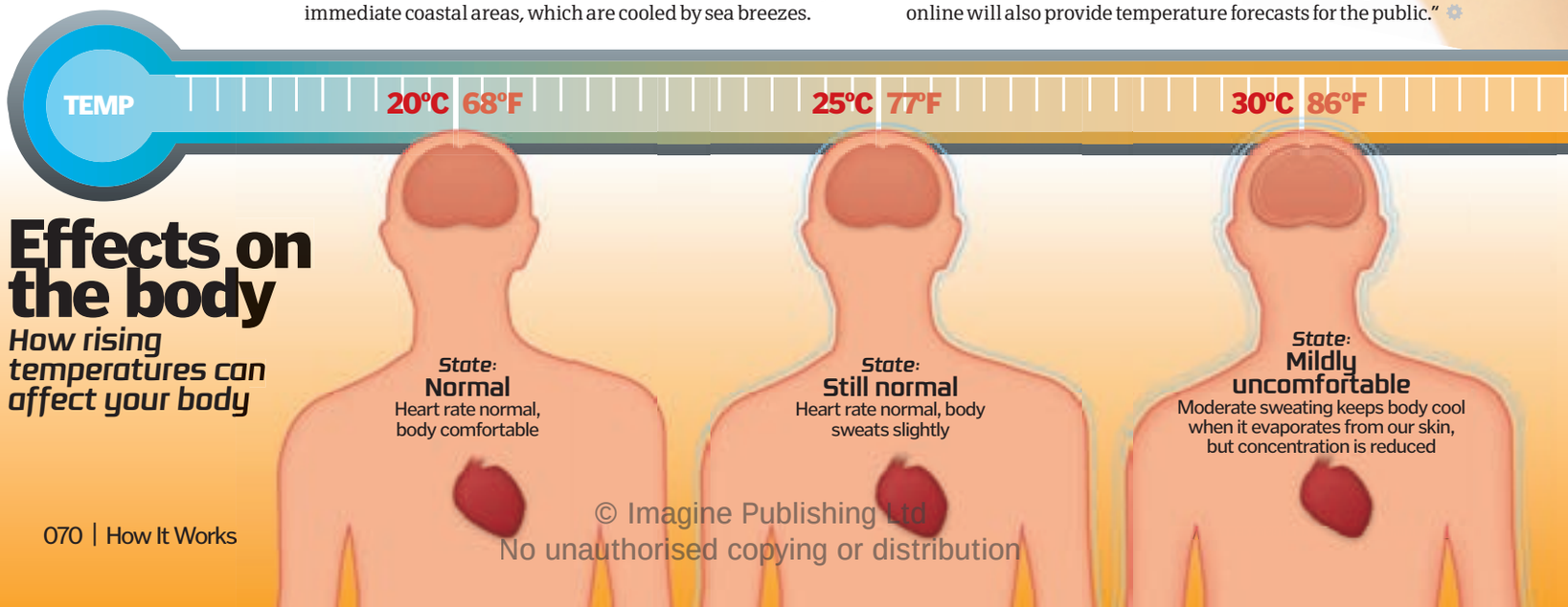
2 Moist heatwaves
Moist heatwaves bring hot and humid conditions during the day with nighttime cloud that prevents heat from escaping. These muggy heatwaves are mostly found in mid-latitude temperate and maritime regions.



3 Heat island effect
Large urban areas can experience a kind of microclimate known as the heat island effect. Here, conditions during a heatwave tend to be worse because the Sun's heat is stored in the tarmac of roads and cement of buildings and is unable to escape until the night.

Effects on the body

How rising temperatures can affect your body



5 TOP FACTS HEATWAVES

1 Power outage
Heatwaves threaten resources due to increased water and electricity consumption. For example, power outages have been known to occur due to increased use of air conditioning.

2 Hyperthermia
Unlike hypothermia (core temperature drop), hyperthermia is a condition caused by heat stroke whereby you absorb more heat than can dissipate.

3 Hottest recorded temp
John Hammond informed us that the highest recorded temperature in the world was a whopping 58˚C in Libya back on 13 September 1922. Scorchio!

4 Sunny side up
The Met Office records show that in terms of average annual sunshine, the sunniest place on the planet is Yuma, Arizona, which enjoys 4,300 hours each year.

5 Meltdown
Roads melted in England in July 2006 when temperatures reached 37˚C (official heatwave conditions as the average max temp for that week is usually 21-23˚C).

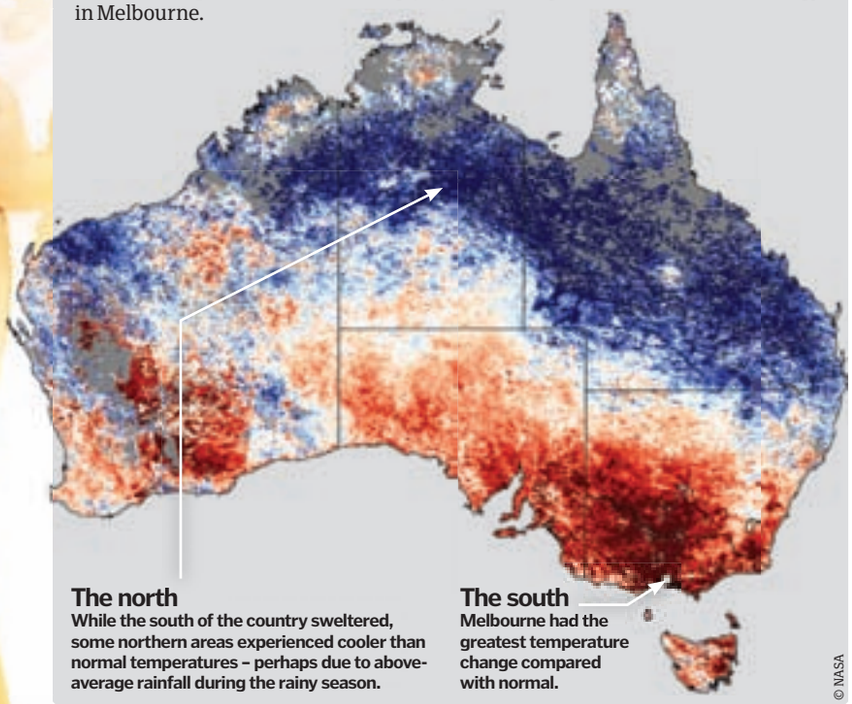
DID YOU KNOW? *In the UK's heatwave of 1967, penguins from Chessington Zoo went to the local ice rink to cool off*

Australia heatwave breaks records

This map of Australia captured by NASA's Moderate-Resolution Imaging Spectroradiometer (MODIS) compares January-February 2009's average land temperature with previous years. Red areas are warmer than previously while blue areas are cooler. The darker the colour the more extreme the temperature change. Really dark red or dark blue areas reveal where the difference in temperature is 10ºC higher or lower than previously.

The abnormally hot temperatures here – the highest recorded being 48.8°C in Hopetoun, Victoria – indicate a severe heatwave. Slow-moving high pressure lingered over the Tasman Sea and conditions conspired to cause hot tropical air to blow across south-east Australia. The extreme heat worsened the country's already-dangerous bushfire season, and led to the Black Saturday bushfires, which caused the deaths of 173 people on Saturday 7 February, also destroying homes and towns in the process.

South-east Australia's January heatwave set the record for Melbourne's highest recorded temperature of a blistering 46.4ºC according to the Bureau of Meteorology in Melbourne.



The north
While the south of the country sweltered, some northern areas experienced cooler than normal temperatures – perhaps due to above-average rainfall during the rainy season.

The south
Melbourne had the greatest temperature change compared with normal.

Interview

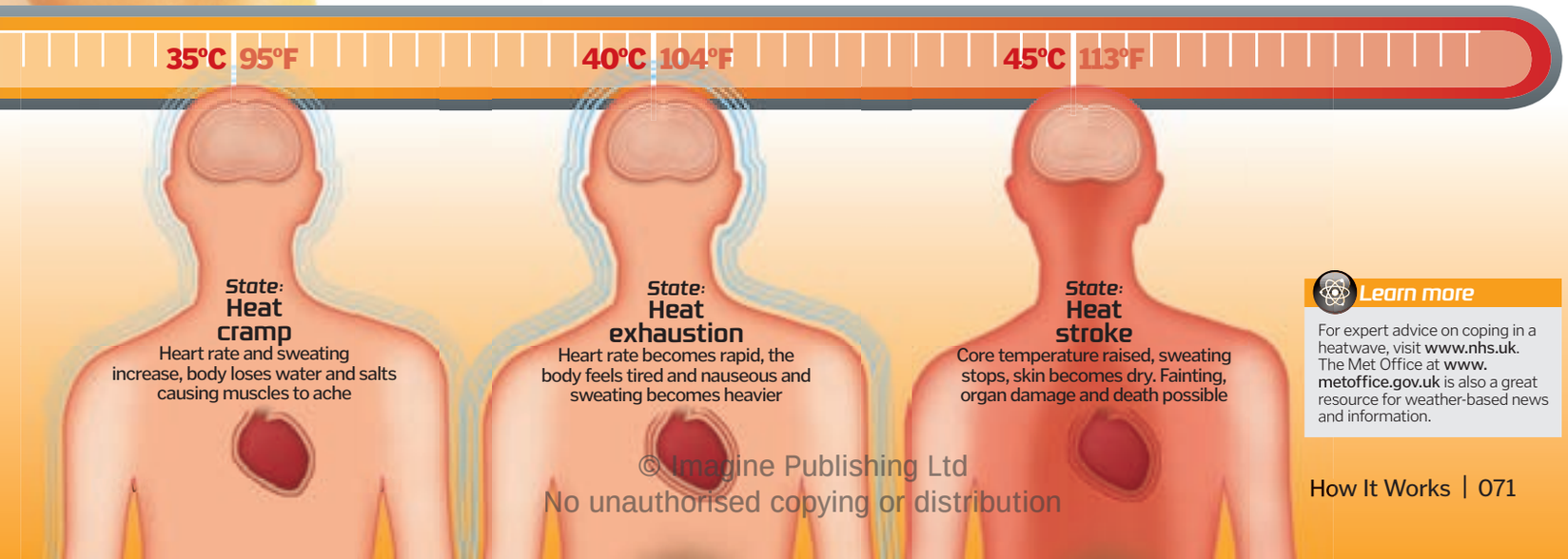
For advice on heat health, we spoke to the Met Office's Patrick Sachon, Health Service Development Manager

How It Works: At what temperature does the body begin to notice negative effects from heat?
Patrick Sachon: The effects of heat on people's health in the UK starts at relatively modest temperatures. Epidemiological studies have shown that maximum air temperatures of only 23-24˚C are associated with excess summer mortality. Physiologically, when the ambient temperature is higher than the skin temperature, the body has to regulate its temperature by losing heat through sweating. At this stage if any other factor reduces the body's effectiveness of sweating – such as dehydration, close fitting clothing or taking certain medications – it can cause the body to overheat. Acclimatisation and adaptation play an important part in how well people can tolerate different levels of heat. This is why people in somewhere like Madrid are more accustomed to higher temperatures than people in London.

HIW: What is the highest temperature a human body can tolerate?
PS: There are currently no studies that we are aware of that have identified a maximum temperature. As I say, acclimatisation and adaptation have an important part to play in how well people can tolerate different levels of heat. In England, relatively modest maximum temperatures are associated with excess mortality.

HIW: Why does heat make us dehydrated?
PS: In order to lose heat we need to sweat, this leads to fluid loss. If we do not replace this fluid we can become dehydrated. One of the most important things to do in hot weather is to drink sufficient fluids, such as water or fruit juices.

HIW: How do people living in much hotter countries than the UK cope with/grow accustomed to excessive the heat in the long term?
PS: Their bodies are more acclimatised to the heat and their way of living – the clothes they wear, the houses they live in and the way they live their lives – are more adapted to hot weather.



Learn more
For expert advice on coping in a heatwave, visit **www.nhs.uk**. The Met Office at **www.metoffice.gov.uk** is also a great resource for weather-based news and information.

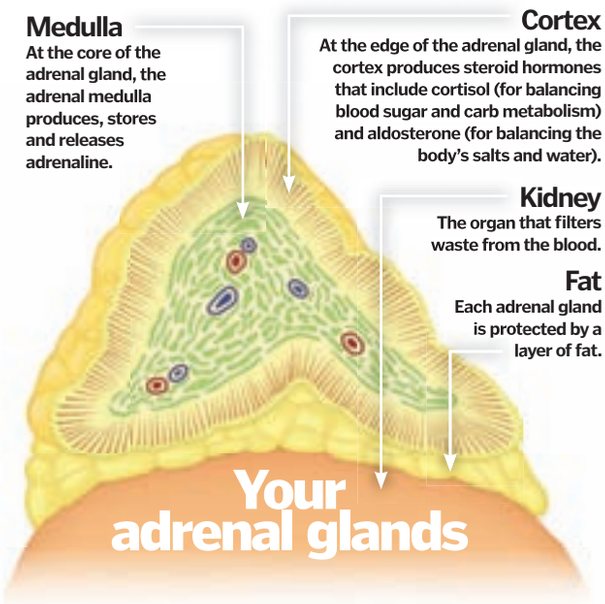
"Adrenal glands consist of two main layers of hormone-secreting cells"

Adrenaline

Discover the science behind your body's amazing chemical coping mechanism

Nestling on a layer of fat located just above each of your kidneys are the body's adrenal glands. Around 8cm long, the adrenal glands produce hormones that affect your body's consumption of energy as well as your stress responses.

Adrenal glands consist of two main layers of hormone-secreting cells: the outer cortex and the inner medulla. While the cortex produces energy-balancing hormones, the medulla produces a chemical called epinephrine, which we know better as adrenaline. Identified in 1900, adrenaline is a fast-acting hormone that helps the body deal with unexpected stresses – not to mention excitement – by upping your heart rate and the flow of blood to your muscles. Your blood vessels and air passages dilate, meaning that more blood passes to the muscles and more oxygen gets to the lungs quicker, temporarily improving the body's physical performance and potentially saving your life.



5 TOP FACTS ADRENALINE

1 Welcome to the world
A baby's stress level during birth is high and as a result their adrenaline level is also very high at this time.

2 When you need to breathe
Due to its blood-vessel-constricting properties, adrenaline is also used to treat breathing difficulties associated with anaphylactic shock caused by allergic reactions.

3 And relaaax
After stressful situations, it's often a good idea to physically work off the adrenaline in your body so it doesn't stay in your system, keeping you awake at night, for example.

4 Amino what now?
Adrenaline can be obtained from animals or synthesised in the lab. The chemical name for it is aminohydroxyphenylpropionic acid, with the chemical formula $C_9H_{13}NO_3$.

5 Fight or flight
The saying 'fight or flight' is associated with adrenaline because when we're stressed we produce the hormone in order that we can either get ready to defend ourselves or make a run for it.

5 TOP FACTS OIL REFINING

Catastrophe
1 The Deepwater Horizon offshore drilling rig has been leaking over 1,000 barrels of crude oil a day into the Gulf of Mexico, becoming the US's largest offshore oil spill ever.

Deep
2 The Deepwater Horizon rig, operated by BP, drilled the deepest oil well in history back in September 2009, measuring 35,050 feet in vertical depth.

Operation
3 The world's first large-scale oil refinery – the Ploiesti plant in Ploiesti, Romania – was repeatedly bombed as part of Operation Tidal Wave during World War Two.

Peak
4 The point when the maximum rate at which oil is extracted tops out is referred to as the 'oil peak' – it is predicted by scientists that it will occur between 2030 and 2050.

Stringent
5 Any American-based refinery must pass rigorous air and water cleanliness standards set by the Environmental Protection Agency in order to maintain its operations.

DID YOU KNOW? *The average cost of a single barrel of oil as of May 2010 is $75*

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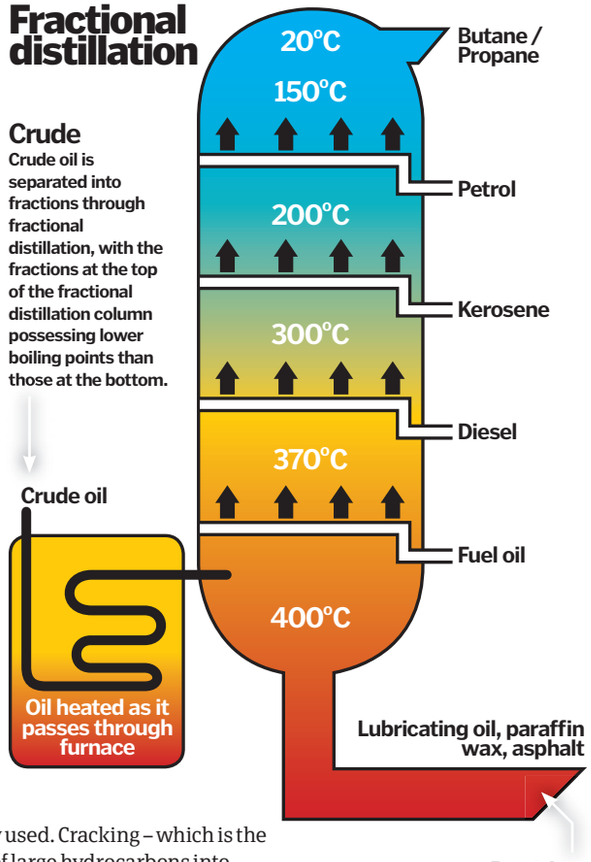


Oil refinery

How do they turn crude oil into gasoline?

Crude oil, a mixture of differing types of hydrocarbons, is refined mainly through fractional distillation – a process that allows for the oil to be broken down and siphoned off into useful derivative substances. These fractioned products include petroleum gas, gasoline, kerosene and diesel distillate, some of the most in-demand energy sources in the world.

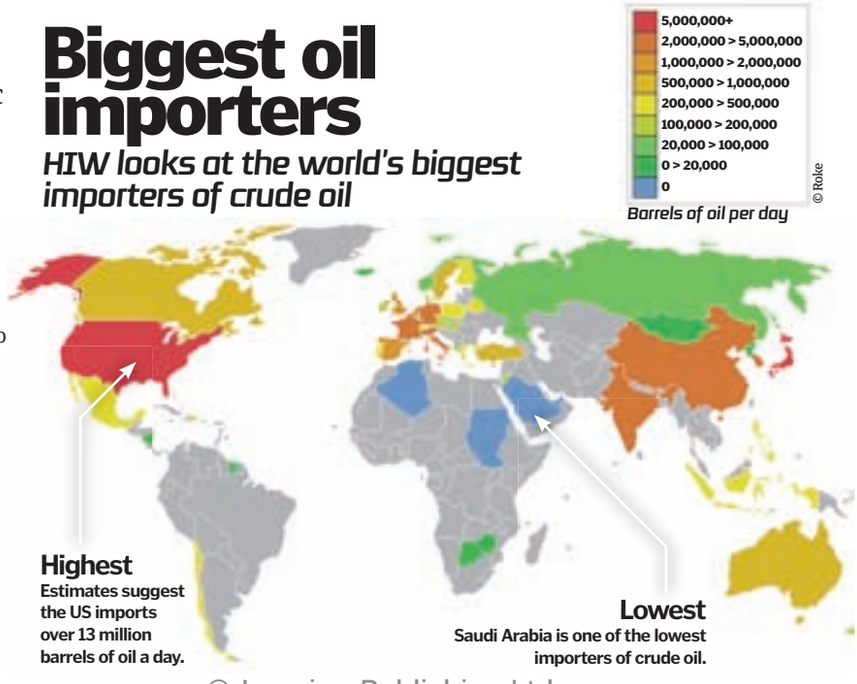
Fractional distillation is the most common method used to separate crude oil. The process involves heating a crude oil mixture to a temperature above 600°C with a steam boiler so it vaporises, streaming that vapour into a large fractional distillation column (a cylindrical structure heated at the bottom and cooled at the top, with intermittent tray meshes running up its inside) where it slowly rises and the substances within it condense at their differing boiling points turning back into liquid form, before then catching that liquid in large metal trays and filtering it out of the column into storage tankers.

Once the various derivative substances from the crude oil have been separated, they are then chemically processed to remove impurities and make them ready to be sold on the market. Often, during this chemical processing, lesser derivatives are broken back down and combined to make more useful and in-demand substances. For example, only 40 per cent of distilled crude oil is gasoline (used to power cars all over the world) yet it is one of the most demanded substances on Earth, so instead of there being a high percentage of left-over distilled substances, these are recombined to produce more gasoline.

In order to change one fraction into another, one of three methods is commonly used. Cracking – which is the breaking of large hydrocarbons into smaller pieces, unification – the combining of smaller hydrocarbons to form larger ones, and finally alteration – which is the rearranging of various hydrocarbon strands to make others. These tasks are undertaken with cracking units, reformers and alkylation machines respectively.

Biggest oil importers

HIW looks at the world's biggest importers of crude oil



Head to Head

WORLD'S LARGEST OIL REFINERIES

1. Jamnagar refinery
Owner: Reliance Industries Ltd
Location: India
Barrels per day: 1,240,000

2. Yeosu refinery
Owner: GS Caltex
Location: South Korea
Barrels per day: 700,000

3. Jurong Island refinery
Owner: ExxonMobil
Location: Singapore
Barrels per day: 605,000

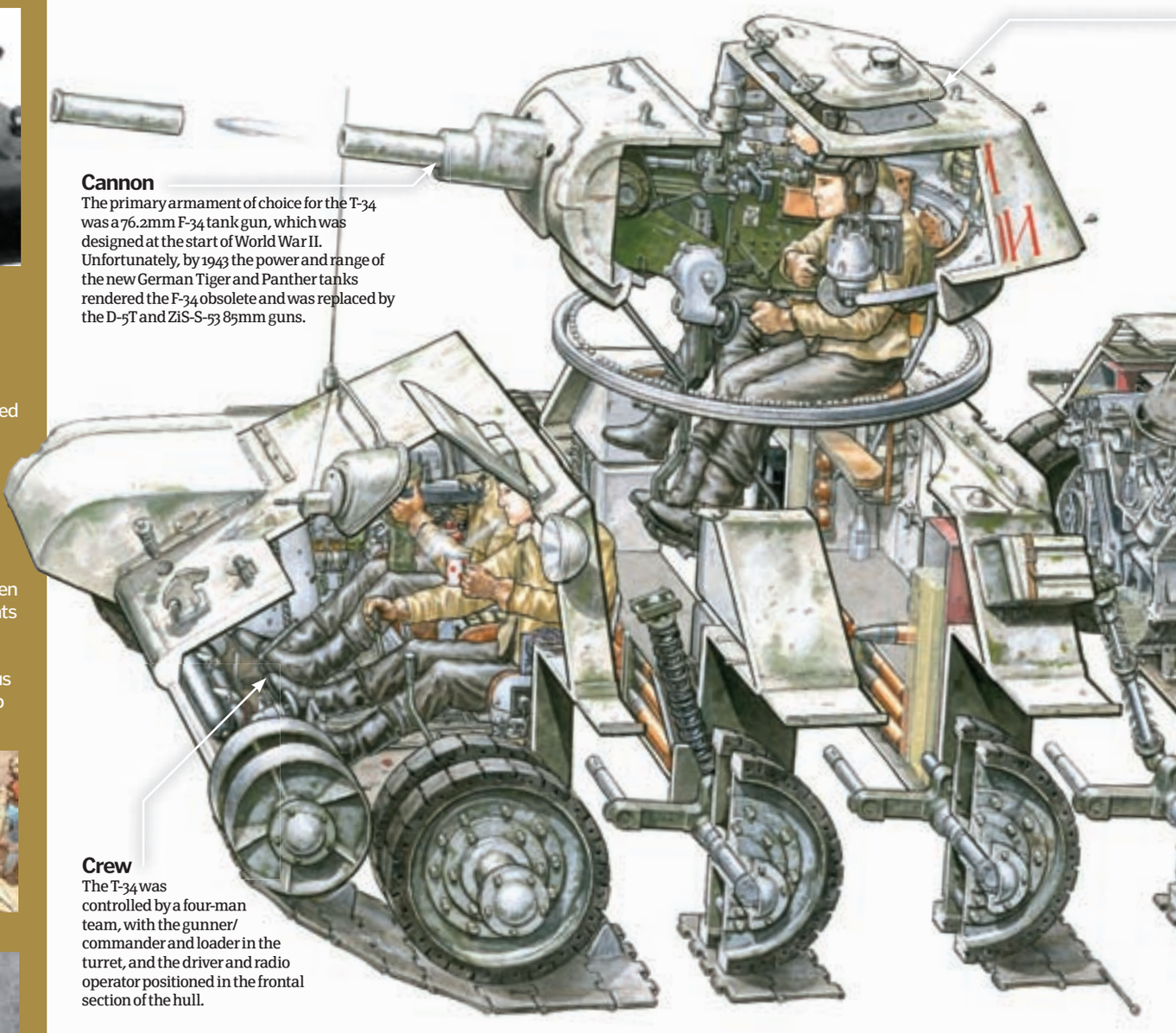
4. Baytown refinery
Owner: ExxonMobil
Location: USA
Barrels per day: 557,000

5. Ras Tanura refinery
Owner: Saudi Aramco
Location: Saudi Arabia
Barrels per day: 525,000

This month in History

Bigger is better in the history section this month. Despite it dropping a few pages compared to last issue we've compensated by bringing you twin behemoths in the shape of the Russian T-34 tank and a woolly mammoth. The first was one of the most effective weapons of World War II and the latter surely must have been one of the most imposing sights of the ancient ice age. If you disagree with our choices, you're welcome to challenge us to a duel and you can brush up on your etiquette on page 76.

HISTORY



T-34 tank

One of the most numerous armoured vehicles during World War II, the Soviet Union's T-34 medium tank is considered by military historians to be one of the most important and influential tanks ever to be built.

Evolving out of the BT series of fast tanks (Soviet cavalry tanks with thin armour and high mobility), the T-34 at its introduction was the first tank to sport a complete balance between firepower, mobility, protection and longevity – something that modern tanks now take for granted. Further, it was an especially refined and simple design that allowed for costs (135,000 rubles) and production time frames to be kept low, meaning that many tanks could be produced in very little time and allow Russia to mitigate its higher-than-average losses quickly and cheaply. Indeed, this became a very important factor towards the end of the war when the superior – but hard and expensive to manufacture – German Tiger and Panther tanks could not be replaced fast enough.

The T-34 was fitted with a good balance of weaponry, sporting a 76.2mm F-34 tank gun – ideal for taking down medium and light armoured enemy vehicles – and twin 7.62mm DT machine guns, perfect against unarmoured targets and to suppress advancing soldiers. Its armour also offered a great balance between protection and weight, with up to 63mm of armour plating standing between its crew and the shells

5 TOP FACTS
T-34 TANK

Numerous
1 From 1940 to 1958 a total of 84,070 T-34s were produced, running through five different design variants and operated in over 20 countries across the entire globe.

Ukrainian
2 The T-34 was primarily built at the Malyshev Locomotive Factory in Kharkiv, Ukraine. The factory was named after Soviet politician Vyacheslav Malyshev in 1895.

Local
3 Many T-34s still exist today, including those that have been decommissioned. An example can be found at the corner of Mandela Way and Pages Walk in Bermondsey, London.

Bazaar
4 The going rate for a working T-34 is $30,000 and can be often bought in demilitarised auctions. Apart from Third World militaries, most T-34s are privately owned.

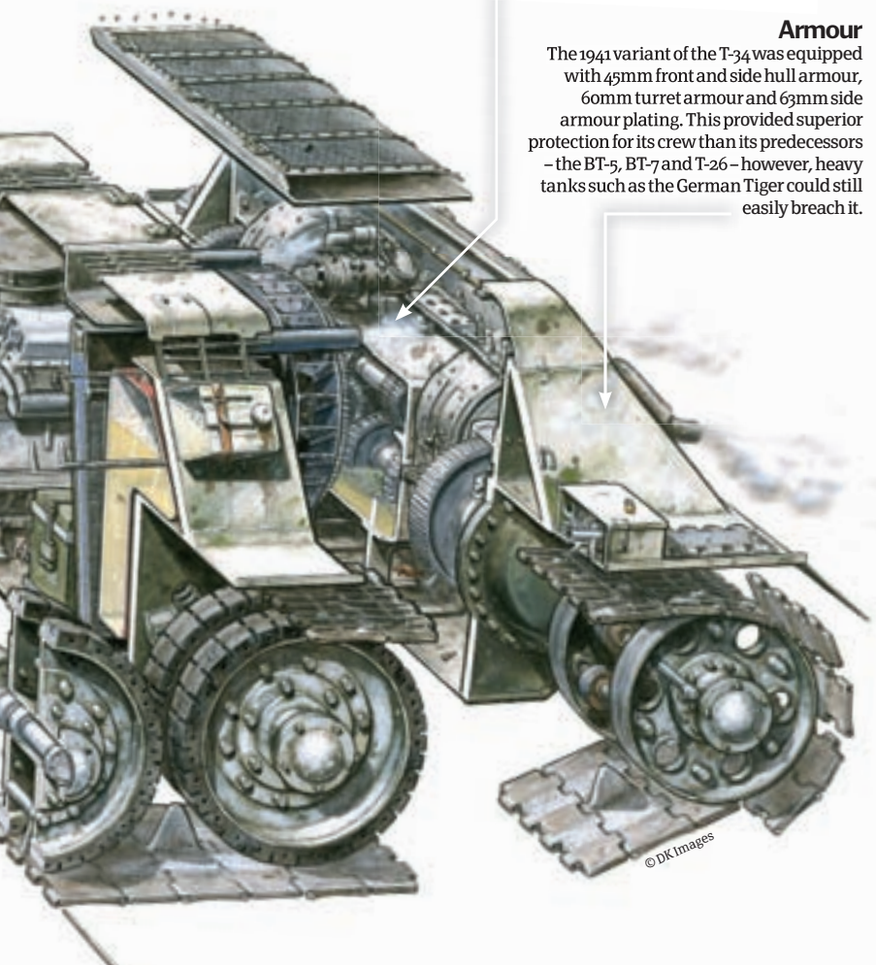
Bog
5 The latest T-34 to be recovered was a 1943 model, found at the bottom of a bog in Estonia. The tank had been captured and dumped by retreating German troops.

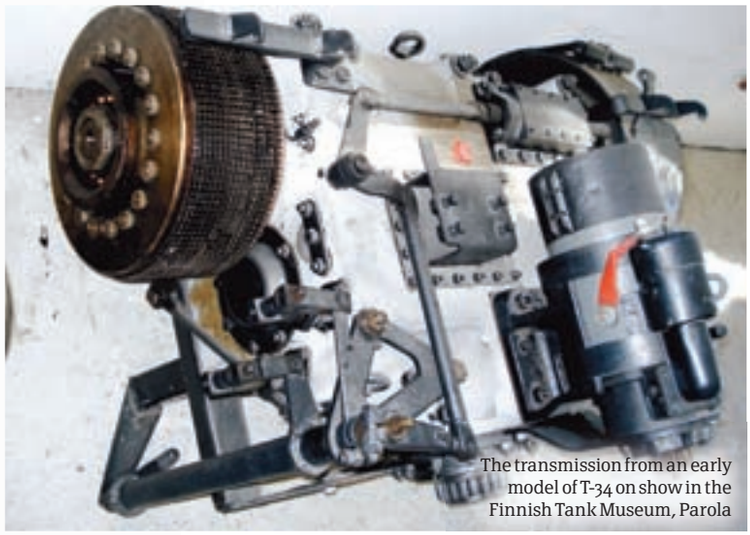
DID YOU KNOW? *Two T-34s were made to resemble German Tiger tanks in the movie Saving Private Ryan*

Turret
The T-34 used a two-man turret crew system where the tank's commander also served as the gunner. This was common in Soviet tank designs during World War II, despite three-man turret crews proving superior in the field. Later models of the T-34 expanded the turret ring to allow for three-man turret crews.

Engine
The T-34 used a 12-cylinder Gaz diesel V-2 engine, which was capable of churning out 500hp. Due to the tank's relatively light weight compared to its heavier contemporaries, this gave the T-34 a power to weight ratio of 17.5 horsepower per ton and, as a result, a good top speed of 33mph.

Armour
The 1941 variant of the T-34 was equipped with 45mm front and side hull armour, 60mm turret armour and 63mm side armour plating. This provided superior protection for its crew than its predecessors – the BT-5, BT-7 and T-26 – however, heavy tanks such as the German Tiger could still easily breach it.

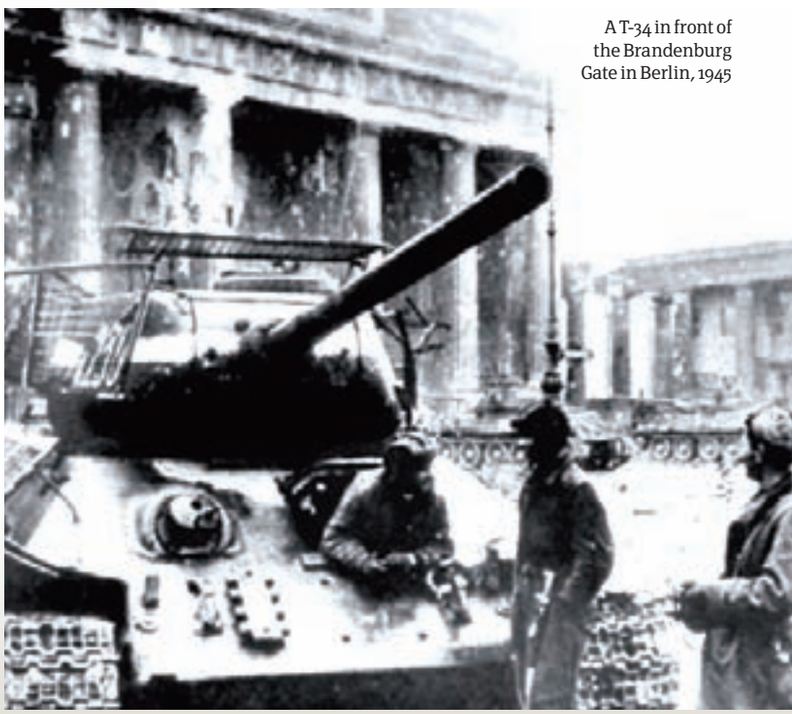



The transmission from an early model of T-34 on show in the Finnish Tank Museum, Parola

The Statistics
T-34 tank

Weight: 26.5 tons
Length: 6.68m (21.9ft)
Width: 3.00m (9.8ft)
Height: 2.45m (8.0ft)
Engine: 12-cylinder Gaz diesel model V-2 500hp (370kW)
Max range: 250 miles (400km)
Max speed: 33mph (53km/h)
Crew: 4


The interior of a T-34-85 variant


A T-34 in front of the Brandenburg Gate in Berlin, 1945

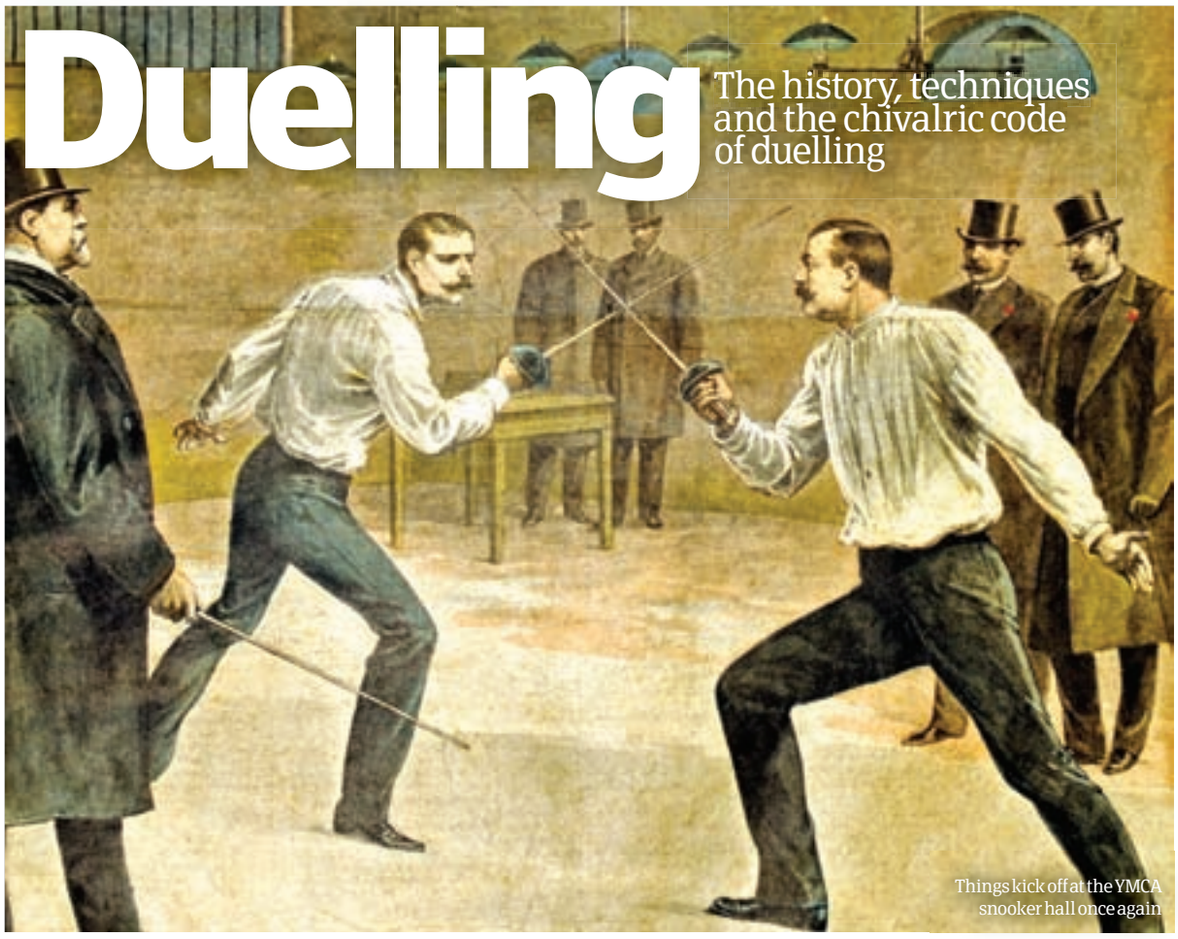
Often credited as the most effective and influential tank of World War II, the T-34 brought a solid mix of speed, agility and stopping power to the theatre of war

and bullets of the enemy. This meant that only the largest of enemy cannons – such as the 88mm beast fitted to the German Tiger tank – could breach its hull or turret and, considering its high top speed of 33mph, this was only possible if it became entrenched or caught unawares. By keeping the armour thickness to a medium level though, the total weight of the T-34 was kept down to 26 tons, under half that of the German Tiger and allowing the T-34 unrivalled dynamism in the field.

Historically, the T-34 will be remembered as the vehicle that swept German forces from Russia, advancing from Stalingrad all the way to Berlin in 1945. However, its usage continued right up to 1958, when it was finally replaced by its successor the T-54. Despite its official retirement however, the T-34 has continued to be used in Third World militaries right up to the present day and has also found itself bought and operated by both private collectors and military museums.

Duelling

The history, techniques and the chivalric code of duelling



Things kick off at the YMCA snooker hall once again

Duelling is intrinsically associated with the chivalric code of honour practised by medieval knights. Although often linked with the royal courts of France and England, duelling is also known in the ancient world and is depicted in Greek and Egyptian iconography.

Once engaged, duellists rarely actually killed their opponents. Bound by a strict code of conduct, a gentleman would use the duel to defend his honour and demand satisfaction. A duel was proposed when an individual deliberately insulted someone of the same rank, or possibly to defend a woman's reputation.

The time and place was arranged by a second appointed by each individual – they also agreed upon a suitable location. The duel would be undertaken in a remote area during the early morning or late evening, ensuring that the event remained unchallenged by the authorities and free from legal consequences if death ensued.

Guns at dawn

Duelling with pistols was dangerous and often resulted in serious injury. Participants employed prized single-shot flintlock pistols kept in pairs. No respectable Englishman travelled without his guns for protection.

The two men select a gun, which they held upright in their hand, and are asked to walk a short distance until they reached a marker in the ground. Here they would turn, advance and shoot.

When is it over?

Although the dishonoured party was able to stop the duel at any point it was often the drawing of first blood that ended the proceedings.

Using blades

Various swords were used during duelling matches – the most common weapons being basket-hilted swords. However, many gentlemen were trained with the rapier and short sword which were designed as thrusting weapons. The duellists used cutting and thrusting actions that enabled them to lunge at their opponent's body. The contestants aimed at vulnerable areas of the body, namely the neck and the thigh.

When is it over?

Before combat, the swordsmen often agreed to a code of practice. However, the code duello states that the duel must end when the opponent is 'well blooded'.

Other weapons

In ancient Egypt duels took place in temples as entertainment. The weapons used included sledgehammers, maces and chains. But the most dramatic duels took place in ancient Rome. The Retiarius was armed with a net and a trident, his only protection a shoulder guard. He used his weapon to create a distance between himself and his opponent. His attack was designed so that he could snare his opponent in the net.

When is it over?

Once the enemy was disabled or disarmed he would use the trident to puncture his neck. Duels could also be fought using daggers.

Duel legends

Legendary duel – pistols

The Burr-Hamilton duel involved two famous American politicians. Aaron Burr, who held the rank of Vice President, shot and killed Secretary of the Treasury Alexander Hamilton after the latter made a slur on Burr's character.

Legendary duel – swords

One of the most ferocious duels in history was that of Achilles versus Hector. After Achilles killed Hector with his sword, he tied the tendons of his heels to his chariot and ripped his body to shreds.

Legendary duel – in a hot-air balloon

In 1808 two Frenchmen, Monsieur de Grandpre and Monsieur de Pique, fought over a woman. Believing themselves to have 'elevated minds', they fought the duel in hot-air balloons. As they fired their pistols, one of the balloons burst, it fell to the ground killing the occupant.

OLDEST ANTISEPTICS

1. Wine and balsam
Plant-based antiseptics like balsam have been used for centuries. The Greek physician Hippocrates used wine and vinegar to treat wounds.

POPULAR

2. Germolene
This pink-coloured ointment was formulated by cough mixture tycoon Sir William Henry Veno. It contains phenol as its active ingredient and is now sold as a cream.

TONGUE TWISTER

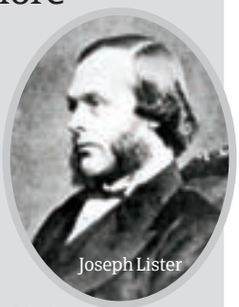
3. TCP
As its main ingredient was Trichlorophenylmethyliodosalicyl, it made sense to shorten this to TCP. Since the Fifties this distinctive smelling liquid has phenol as its active ingredient.

DID YOU KNOW? *Listerine antiseptic mouthwash was named after Joseph Lister, as is Listeria which causes food poisoning*

The discovery of antiseptic made surgical procedures much safer

The first antiseptics

Killing germs before they kill us



Joseph Lister

The theory that germs, in the form of microscopic organisms, are responsible for infection encouraged the use of antiseptics in conjunction with better standards of hygiene.

The widespread use of antiseptics in hospitals was heralded by the work of British surgeon Joseph Lister, who was the professor of surgery at the University of Glasgow in the late 1860s. He was inspired by French chemist Louis Pasteur, who claimed that gangrene is caused by micro-organisms that can be killed off by heat, filtration or the application of chemicals.

Lister experimented with various forms of chemical antiseptic. He discovered that a solution of carbolic acid (phenol) applied to dressings, wounds and his surgical instruments greatly improved recovery from surgical procedures.

Phenol kills germs by disrupting their cell walls, which causes their cellular contents to leak out. If the solution is too strong it can also be damaging to skin. German bacteriologist Heinrich Koch, proved that tuberculosis was caused by bacterium in 1882. This helped bring about the acceptance of antiseptic procedures throughout the world.

The Leyden Jar

A handy and portable way to bottle static electricity

The Leyden Jar was independently invented by the Dutch physicist Pieter van Musschenbroek and Ewald Georg von Kleist, Dean of the Kamin Cathedral in Pomeranian, in 1745. Musschenbroek, based at the University of Leiden (Leyden), kept better records and it became known as the Leyden Jar.

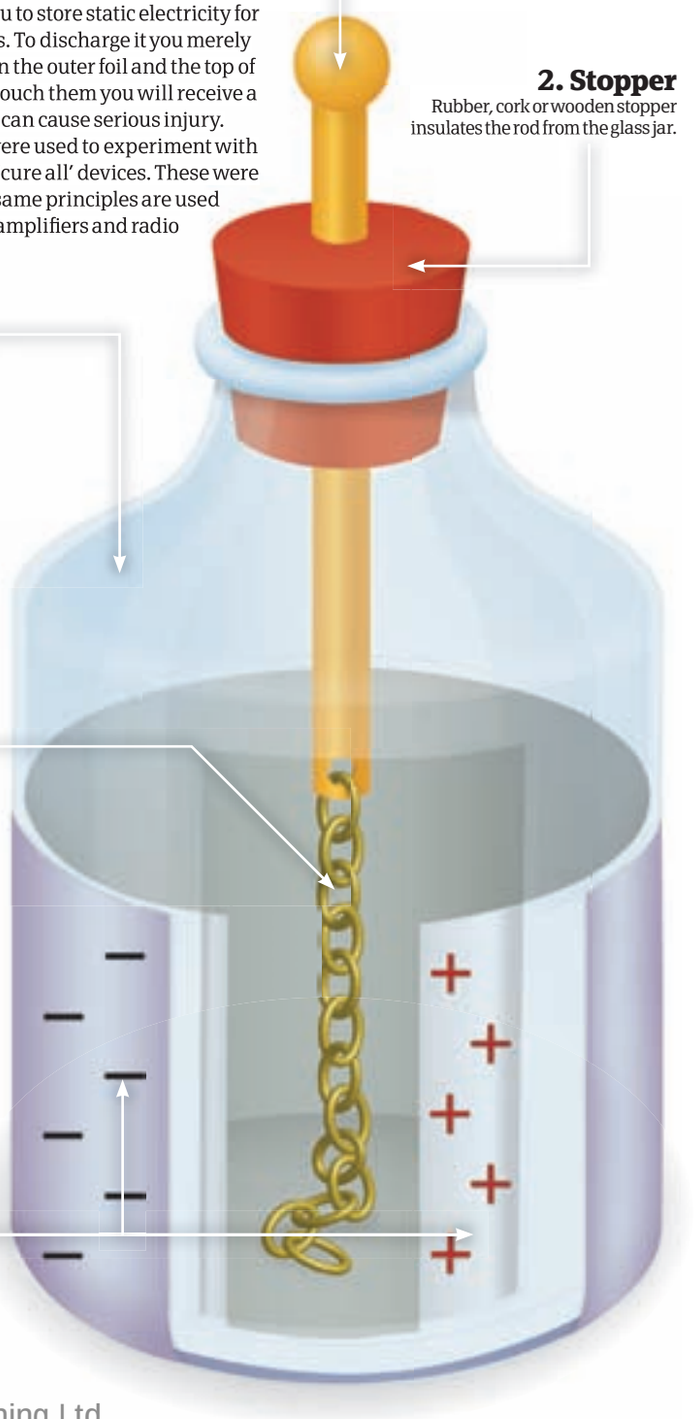
The Leyden Jar enables you to store static electricity for several minutes or even days. To discharge it you merely complete the circuit between the outer foil and the top of the rod. If, for example, you touch them you will receive a powerful electric shock that can cause serious injury.

In the 19th Century they were used to experiment with electricity and promoted as 'cure all' devices. These were the first capacitors, and the same principles are used for capacitors used today in amplifiers and radio equipment.

1. Brass rod
This is connected to a hand-cranked static generator or any other device that can supply electricity to it. This supply is removed when the jar is charged.

2. Stopper
Rubber, cork or wooden stopper insulates the rod from the glass jar.

4. Glass jar
Half-filled with water. Originally the electrical charge was thought to be stored inside the water. It was also thought the glass jar retains the charge but it is actually kept on the inside layers of the metal foil. The glass acts as an insulator or dielectric.



3. Metal chain
The chain links the rod to the metal foil at the bottom of the jar. Here the electrical charge is unable to discharge because of the presence of the glass. Instead, the positive and negative electrons of the charge repel each other to the outer and inner metal foil. These forces stay in equilibrium until they are discharged.

5. Metal foil conductors
A metal coating or foil is applied half-way up the inside and outside of the jar. The outside foil must be connected by wire to the ground.

"Until their extinction 4,500 years ago, mammoths were a highly successful and widespread species"

Mammoths

Now extinct, mammoths used to roam the Earth with the frequency and variety of their modern relatives, elephants

Until their total extinction, mammoths were a highly successful and widespread species, found from central Africa, through Europe onto North America. Indeed, Mammuthus lived throughout the entire Pliocene and Pleistocene epochs – over 5 million years – and diversified into many species of various appearances and sizes. However, through a myriad of factors including climate change, disease and human hunting, the majority of the last mammoths – which were woolly mammoths living in Siberia – were wiped out between 8,000 to 10,000 years ago. From the frozen remains of examples found in the 20th and 21st Centuries (specimens are preserved in mummified states in Siberian permafrost), mammoth DNA has been ratified by scientists to be almost identical to that of modern elephants, with their appearance being closely linked.


The preserved carcass of a baby mammoth discovered in 1977

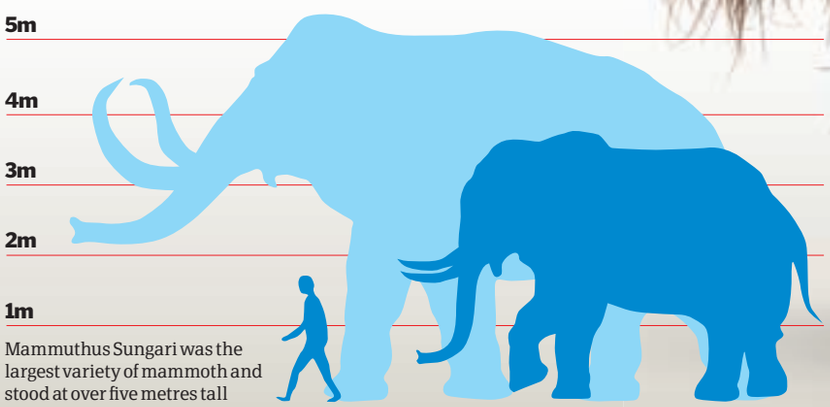
A mammoth excavation in Siberia

Fat
Mammoths tended to sport a fatty lump at the top of their spine that was used to store energy. This, as with the camels of today, allowed them to traverse many miles with no food or water.

Back
The hind legs of mammoths were shorter than those at the front, the consequence of which is a sloping back running from the shoulders to hips.

Legs
Due to their mighty weight (over eight tons) and colossal height (over five metres), the legs of mammoths were massive columns of flesh, muscle and bone.

Feet
Mammoths had four-toed feet, splayed outwards like those of a human to aid balance.



Mammuthus Sungari was the largest variety of mammoth and stood at over five metres tall

Head to Head
EXTINCT PREHISTORIC ANIMALS

MOST MASSIVE

1. Mammoth
So big and heavy that only large groups of predatory animals such as humans or sabre-toothed tigers could take it down, the mammoth was a hulking colossus.

MOST DEADLY

2. Sabre-toothed tiger
A fierce hunter of the prehistoric period, it was named after the size and shape of its maxillary canines.

MOST USELESS

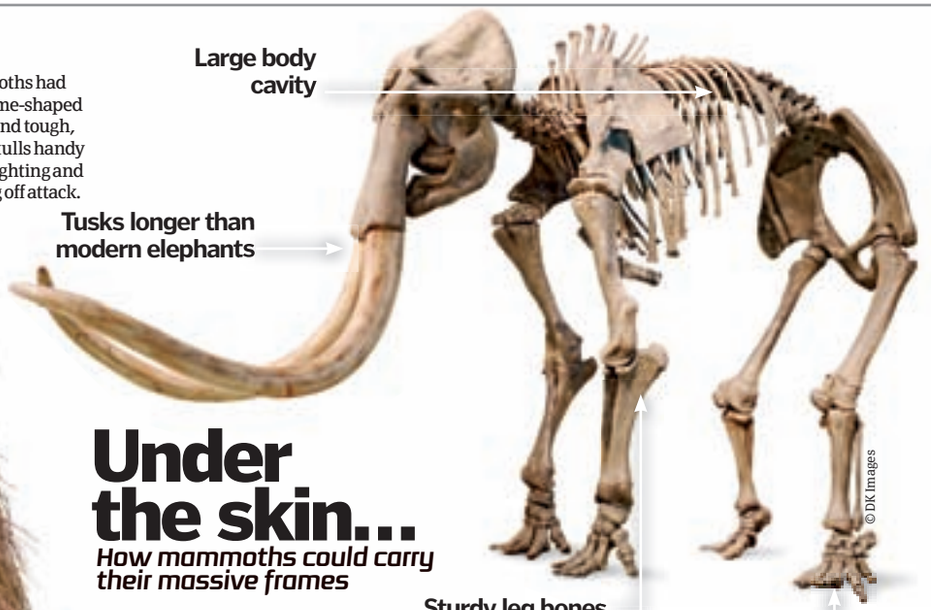
3. Dodo
A one-metre high flightless bird that is closely related to the pigeon, the dodo existed from 12,000 years ago up until the end of the 17th Century.

DID YOU KNOW? *One variety of dwarf mammoth survived on Wrangel Island, Alaska, up until 4,500 years ago*

Head
Mammoths had tall, dome-shaped heads and tough, thick skulls handy when fighting and fending off attack.

Large body cavity

Tusks longer than modern elephants



© DK Images

Under the skin...
How mammoths could carry their massive frames

Sturdy leg bones

Four toed feet

Tusks
Mammoth tusks were considerably longer and more curved than those of elephants, curling inwards at the tip. They were used to scrape away snow and ice from the ground when feeding, as well as for protection and in dominance rituals.

Trunk
Akin to those of elephants today, mammoth trunks were used to drink and grab flora.

Hair
The woolly mammoth, a variety of mammuthus native to northern Europe and Russia, evolved so that it was completely covered in 90cm long hair. Mammoths in warmer climates, such as those of Africa, had less hair.

© DK Images

ON THE MAP

Where did mammoths roam?

1. M. africanavus – Africa
2. M. armeniacus – Armenia
3. M. columbi – Columbia
4. M. exilis – West America
5. M. imperator – North America
6. M. jeffersonii – Central America
7. M. trogontherii – Siberia
8. M. meridionalis – Central Europe
9. M. subplanifrons – South Africa
10. M. primigenius – Siberia / North America
11. M. lamarmorae – Sardinia
12. M. sungari – North China

BRAIN DUMP

Because enquiring minds want to know...

Send us your questions!

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

HOW IT WORKS EXPERTS

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

Alison Boyle
Curator of Astronomy and Modern Physics

Alison Boyle is responsible for a range of collections spanning most of the space-time continuum. She is currently researching particle accelerators.

Josh Moore
Science Museum Explainer

First-timer Josh has a background in zoology and before joining the Science Museum he worked as part of a conservation team in Madagascar.

Tanya Dean
Science Museum Explainer

Tanya is passionate about encouraging people to enjoy learning in fun and creative ways. She is easily excited by the way science unravels the wonders of the world.

Debi Linton
Science Museum Explainer

When she's not working, Debi is next door at the Natural History Museum working on her PhD in palaeontology. In her spare time she reads a lot of Batman comics.

How do multivitamins work?

Debbie Green

The human body requires a number of vitamins and minerals to function properly. Examples include vitamin A, which is required by the retina in the eye, vitamin D which is required for maintaining healthy bones, and vitamin E which helps form red blood cells.

A diet lacking enough essential vitamins is likely to result in vitamin deficiency syndromes. Scurvy, rickets and beriberi are examples of such syndromes.

Eating a healthy, balanced diet typically provides enough vitamins for the body's needs. Some people, however, like to take multivitamins to ensure that they receive their required amounts. Multivitamins contain a range of different vitamins and minerals usually including magnesium, zinc, vitamin C and vitamin A in varying amounts. After ingestion the multivitamin's casing is broken down by the gut, the vitamins are absorbed and pass to where they are needed.

Care must be taken not to take too many vitamins. In 2004, the Danish government was so worried about people overdosing on vitamins that it banned Kellogg's breakfast cereals which had been enriched with extra vitamins! The effectiveness of multivitamins is often disputed by scientists. Most experts agree that the best and safest way to ensure that you receive all the vitamins you need is to have a healthy and balanced diet.

Josh Moore

How do Bonsai trees stay so small?

Miles Denton

Bonsai is the Japanese art form, but the word is also used to cover any practice of growing very small trees in containers. Unlike dwarf plants, which are genetically small, Bonsai uses 'normal' trees and cultivates them to keep them small. The containers in which Bonsai trees are grown limit the expansion of their root system and place a cap on the amount of nutrients available to them, limiting their growth above the pot. Rigorous pruning and artificial shaping helps them mimic the shape of much bigger trees, resulting in living scale miniatures.

Debi Linton

What makes us faint?

Hayley Lewis

■ Fainting, or 'syncope', is a temporary loss of consciousness due to a lack of oxygen to the brain. It is usually preceded by dizziness, nausea, sweating and blurred vision.

The most common cause is overstimulation of the body's vagus nerve. Possible triggers of this include intense stress and pain, standing up for long periods or exposure to something unpleasant. Severe coughing, exercise and even urinating can sometimes produce a similar response. Overstimulation of the vagus nerve results in dilation of the body's blood vessels and a reduction of the heart rate. These two changes together mean that the body struggles to pump blood up to the brain against gravity. A lack of blood flow to the brain means there is not enough oxygen for it to function properly and a fainting episode occurs. However, shortly after fainting, the blood flow to the brain is restored (usually from simply lying down as a result of the fainting) and the brain functions normally again.

Heavy bleeding, diabetes, drugs and low blood pressure can similarly reduce blood flow to the brain causing a lack of oxygen and fainting.

Josh Moore

© Science Photo Library

Who invented the mobile phone?

Ken Poole

■ The invention of the first handheld mobile phone is credited to Dr Martin Cooper and his team at Motorola in April 1973. The first call he made was to his rival inventor, Joel Engel at Bell Laboratories, who had also been racing to invent the first mobile phone. Before this time, radiophones on-board ships and in cars were available, however Dr Cooper's phone was the first truly handheld modern mobile phone. It weighed in at around two kilograms and had a battery life of only 20 minutes. According to Cooper, this didn't matter as you couldn't really hold the phone up for that long!

Josh Moore

Why do we blush?

Toni Baldry

■ Blushing occurs when an excess of blood flows into the small blood vessels just under the surface of the skin. Facial skin has more capillary loops and vessels, and vessels are nearer the surface so blushing is most visible on the cheeks, but may be seen across the whole face. The small muscles in the vessels are controlled by the nervous system.

Blushing can be affected by factors such as heat, illness, medicines, alcohol, spicy foods, allergic reactions and emotions. If you feel guilty, angry, excited or embarrassed, you will involuntarily release adrenaline, which sends the automatic nervous system into overdrive. Your breathing will increase, heart rate quicken, pupils dilate, blood will be redirected from your digestive system to your muscles, and you blush because your blood vessels dilate to improve oxygen flow around the body; this is all to prepare you for a fight or flight situation. The psychology of blushing remains elusive; some scientists even believe we have evolved to display our emotions, to act as a public apology.

Tanya Dean

sciencemuseum

What's on at the Science Museum?

Fake ID

■ 26 July – 3 September ■ Free

Find out how to deceive your dad, mislead your mum, and fool your friends! Join us on this fun interactive trail where you can try to steal an identity and discover what makes everyone different. The event will be located in the Who am I? gallery.

Launchpad Science Shows

■ Now showing ■ Free

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

Fast Forward: 20 ways F1™ is changing our world

■ Until summer 2010 ■ Free

A new, free exhibition at the Science Museum showing how Formula 1™ technology can be applied to different fields of research and innovation to offer new solutions to our everyday lives. Find out how sophisticated composite materials, telemetry systems and rigorous pit-stop strategies devised by British teams are currently being applied to improve safety and efficiency in our hospitals, homes and workplaces.

Cosmos & Culture: how astronomy has shaped our world

■ Now showing ■ Free

Cosmos & Culture traces 400 years of telescope technologies, explores our changing perceptions of our place in the cosmos, and examines the role astronomy has played in our everyday lives. Objects on display include Thomas Harriot's drawings of the Moon, Jupiter's satellites and sunspots and the telescope William Herschel used to discover Uranus.

sciencemuseum

What's on at the Science Museum?

Dan Dare and the Birth of Hi-Tech Britain

■ Now showing ■ Free

Parents and grandparents can enjoy a nostalgic hour looking back at an era when Britain was at the forefront of technological innovation after World War II. Alongside seminal objects of the time, from both the state and in the home, is a collection of Eagle comic artwork and Dan Dare memorabilia reflecting the optimism of the post-war years.

Legends of Flight at the IMAX 3D Cinema

■ Showing from 12 July
■ Charges apply

Legends of Flight is a captivating new film showcasing some of history's most amazing aircraft. Soar over the highest peaks, feel the gut-wrenching force of take-off, and loop and roll above the ocean. From one of the first passenger airliners to make long range flying practical, to the Boeing 787 Dreamliner which seeks to take its place among aviation greats, Legends of Flight brings together the past and future of air travel.

Atmosphere: exploring climate science

■ Opening November 2010
■ Free

The climate science gallery 'atmosphere' will transform the second floor of the Welcome Wing in the Museum, making it the destination to explore the science of climate change. Atmosphere will combine interactive exhibits with objects from the Science Museum's collection and on loan from around the world.

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

Visit the Museum

Exhibition Road, South Kensington, London SW7 2DD. Open 10am – 6pm every day. Entry is free, but charges apply for the IMAX 3D Cinema, simulators and some of the special exhibitions.

Why is Pluto not a planet any more?

Harriet Davis

■ Well, it's still a planet of sorts. Since 2006 Pluto has been classified by the International Astronomical Union as a 'dwarf planet'. In recent decades, powerful telescopes have enabled astronomers to discover several Pluto-sized objects beyond Neptune's orbit, and there are probably lots more out there. So, either they had to expand the list of planets (which would mean you'd have to remember a lot more for your science exams) or it was time to come up with an official definition of what counts as a planet.

After some fierce debate, the international committee agreed a condition that a planet must be the biggest thing in its orbital neighbourhood. Pluto and the newly found similar objects are all in the same neighbourhood, so that rules them out. However, the definition of 'planet' is controversial, so the 'Save Pluto' campaigners hope it will be re-instated one day.

Alison Boyle

What does a car handbrake actually do?

Gavin Winton

■ A car's handbrake is the lever to a completely mechanical braking system, which will bypass the primary hydraulic system if it fails. When the handbrake is applied, the brake cable passes through an intermediate lever, to increase the force of your pull; this force is then split evenly between your brakes by an equaliser.

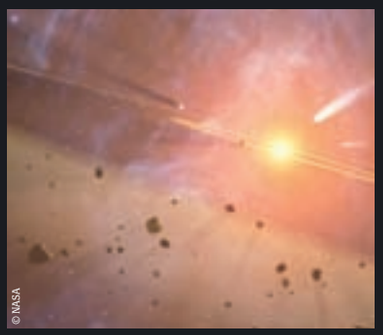
Typically, a mechanical lever is added to the existing disc or drum brakes on the car. In drum brakes, the handbrake cable runs directly to a lever on the brake shoes. In disc brakes an additional lever and corkscrew is added to the existing calliper piston. When the handbrake is pulled, the lever forces the corkscrew against the piston, which would normally be activated by the hydraulic foot pedal system.

Although it is reassuring to have a secondary braking system for emergencies, the primary use of the handbrake tends to be when parking as they remain engaged until a release button is pressed; stopping your car potentially rolling away. This is good practise, as it keeps your brake cable from seizing up, ready for when you really need it. In fact, using your handbrake to stop a moving car can actually damage the brake system, so it is best to save this for real emergencies!

Tanya Dean

FROM THE FORUM

*Every month we'll feature a reader's question from our fantastic forum at **www.howitworksdaily.com/forum***


© NASA

Will the James Webb Space Telescope see clear images of Epsilon Eridani?

Mustafa

Epsilon Eridani, a star about 10.5 light years away, is of interest to astronomers because observations show that it is surrounded by discs of debris, similar to what the planets and other bodies around our Sun would have formed from. By studying it we can learn what our solar system might have looked like in its early days. There are also indications that there may be one or more planets orbiting the star – if so, these would be the nearest known extrasolar planets to Earth.

The JWST, due to launch in 2014, isn't a like-for-like successor to Hubble, as it will mainly operate in the infrared (Hubble concentrates on visible and ultraviolet wavelengths). Infrared is useful for seeing past obscuring dust clouds and to study planets forming. The telescope should have the capability to detect Jupiter-sized planets fairly far from the star, although it won't be able to see sharp images.

It's not yet decided if the JWST will study Epsilon Eridani – astronomers will have to compete for telescope time. But looking at planetary systems is one of the JWST's priorities, so it's a likely target. Before 2014, the infrared Spitzer Space Telescope or a ground-based telescope might shed more light on the Epsilon Eridani system.

Alison Boyle

Why can ants carry items much heavier than themselves?

Neil Goodchild

The reason that ants can lift so much is due to a concept of physics known as scaling. In fact the muscles of ants are no stronger than human muscles, but it is their small size that provides their advantage. Ants can lift so much because of the ratio between their body size and body mass; their small size means they do not have a large body mass and the proportion of their mass that is muscle is very high.

As a result they are able to lift weights that are many times larger than their own body weight. In comparison elephants have massive size and the proportion of their mass that is muscle is quite low; although they are able to lift incredible weights they are unable to lift or carry their own body weight. Humans have utilised the laws of physics to our advantage and we use levers and hydraulics to enable us to lift as capably as ants.

Stuart Hine, centre manager, Angela Marmont Centre for UK Biodiversity, The Natural History Museum

What is St Elmo's fire

Al Baxter

St Elmo's fire can be described as a more or less continuous, luminous electrical discharge in the atmosphere, which emanates from elevated objects above the Earth's surface. These objects can include lightning conductors, wind vanes, or on the wings, tips or propellers of aircraft in flight. This electrical charge can also occur on an aircraft where a static charge has been produced by the frictional impact of ice, snow, rain, dust or sand. The phenomenon is usually of a bluish colour and has been seen as white or violet. When St Elmo's fire is present, it can be accompanied by a crackling sound which occurs when the electrical field close to the object becomes very strong. St Elmo's fire can also been termed 'corposant', which means 'holy body'. There are several other types of electrical phenomenon including sprites and elves.

The Met Office

HOW IT WORKS EXPERTS

How it Works is proud to welcome the experts from International Year of Biodiversity in the UK (IYB-UK) to the Braindump panel

IYB-UK is made up of over 400 major organisations, charities, universities, businesses, schools, museums and arts practitioners. Dr Robert Bloomfield, the director of International Year of Biodiversity in the UK, will be marshalling a range of experts from across the partnership to answer your questions.

Dr Robert Bloomfield
Director IYB-UK/Head of Innovation and Special Projects, Natural History Museum

Bob is Head of Innovation and Special Projects at the Natural History Museum where he has delivered Darwin200 and is now directing IYB-UK during 2010. With a PhD in Genetics, Bob has pursued a career in science and public engagement, leading major science communication projects. In 2002 Bob was awarded a NESTA Dream Time Fellowship which he ultimately used to retrace the first voyage of Captain James Cook.

International Year of Biodiversity – What's On June and July 2010

The long summer days and nights offer a host of fantastic opportunities to learn more about biodiversity, and the species local to where you live, or where you are holidaying in the UK. There are activities for all ages. Here's a small selection – find out what's on near you throughout 2010 by logging onto www.biodiversityislife.net.

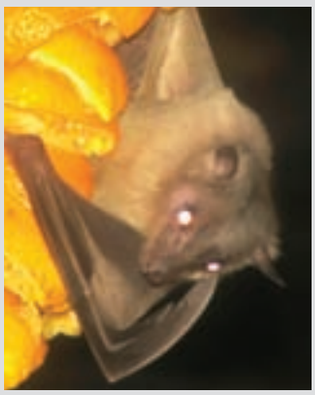
If you are near the coast there's lots to do and enjoy on and around the seashore. In August there are seaweed searches and rockpool rambles; cliff walks to

identify butterflies, insects, birds and fossils; or wildlife boat safaris to view cetaceans, basking sharks, seals and sunfish.

Bat action

■ August

August is a big month for bat action. From bat walks in Barnstaple, Bridgwater, Dover, Garstang and Gwynedd to Bat Days and Nights in Musselburgh, Barrhead and at Castle Fraser in Inverurie, or the opportunity to help the Snowdonia National Park with a survey for Greater Horseshoe Bats on 20 and 21 August.



OPAL water survey

■ Online

You can find out how healthy your local lake or pond is, and about the animal life that lives there, by taking part in the OPAL water survey. Download OPAL's free survey pack, which includes full instructions and identification guides, and then upload your results online at: http://www.opalexplorenature.org/?q=WaterSurvey.

Festival of Wildlife

■ 21 and 22 August

■ Sevenoaks Wildlife Reserve

On 21 and 22 August, the Sevenoaks Wildlife Reserve and

How can we predict what the weather will be?

Dave Salter

■ Forecasts from the Met Office begin by taking observations from around the world, which come from observations on the land and at sea, weather balloons and commercial shipping and aircraft. Perhaps the most important source for weather predictions is the uninterrupted supply of data that comes from satellites.

Observations from space have helped to revolutionise how weather forecasts are produced. All this data pours into the supercomputer at the Met Office headquarters, where global predictions are made every six hours. The supercomputer uses the observational data and then calculates billions of equations every second, as to how the atmosphere may change over the coming days in the form of charts and graphics. Once the unmodified forecast is produced, the Met Office chief forecaster then assesses the various graphics where modifications will be made as and where is necessary. Once the chief forecaster and his deputy have finalised the forecast, guidance is produced that provides specific details for the next five days and in broader terms out to day 30. The guidance is used on the Met Office website and is used by broadcast meteorologists for the UK media, including the BBC and ITV.

The Met Office

Why don't trains have seat belts?

D. Innes

■ With a quick Google of the subject we found that back in 2005 the Rail Safety and Standards Board (RSSB) recommended against installing airline-style seat belts as they could cause more injuries to passengers than they prevent. It would also see prices rise to cover the cost of installing them and standing on trains would be prohibited. A seat belt is of most use where a collision causes rapid deceleration. Trains carry so much momentum that they do not stop rapidly, even in very severe collisions.

HIW

How do chameleons camouflage themselves?

Mark Lawrence

■ Chameleons camouflage themselves in a variety of different ways but most famously by changing the colour and pattern of their skin. Most chameleons can change colour and they do this by expanding or contracting cells in their skin that contain different pigments. They can blend into their surroundings by altering the colour of their skin to match the background. Chameleons will also use their ability to switch colour during social displays when they alter their colouration and pattern dramatically from the background.

Their body shape also helps with camouflage as well as the way they move. The high arched back gives their body a leaf-like shape and their slow movements make it difficult for predators and prey to detect them. Some chameleons, for example the stump-tailed chameleon, rock back and forward to look like leaves being blown by the wind.

Jackie Dodworth, education officer, ZSL Whipsnade Zoo

How can owls see so well at night?

Nina Sutton

■ In total darkness an owl has no better ability to see than any of us. However, 100 million years of evolution allows this group of birds to squeeze enough light out of their nocturnal world to enable them to hunt, which they do as effectively as any other predator. Owls' reputation for being able to see well at night is richly deserved.

Owls' eyes are packed tightly with light receptors (known as rods). This allows owls the power of vision in extremely dimly lit locations. Owls that are the most nocturnal, such as the widespread tawny owl, have the highest number of rods in their retinas. Owls can also see well in daylight because their irises can close tightly, allowing only a tiny amount of light to pass.

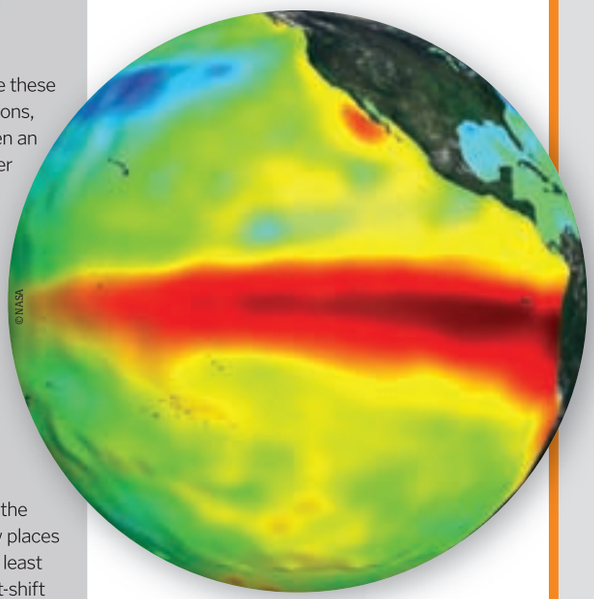
Like us, owls have forward-facing eyes, giving them exceptional binocular vision. This permits them to focus on a smaller area – a little like focusing the beam of a torch – but it also allows them to judge distances well: a vital trait if you have to pluck prey from the woodland floor in moonlight.

Highly developed eyes give these birds the edge in most situations, but there are times when even an owl is blind. Then, like a fighter pilot, owls switch to other systems to locate their targets. Slightly non-symmetrically placed ears allow owls to find prey by listening when sight alone is not quite enough. Tests have shown that owls can successfully pounce on a mouse that is under inches of snow or in complete darkness.

From the Arctic wastes to the searing deserts there are few places on earth that doesn't have at least one of these impressive night-shift hunters. However, many owls are threatened, proving that a history 30 times longer than man is not enough to combat the threats these birds now face.

Grahame Madge, conservation spokesman, RSPB

The El Niño phenomenon has a huge impact on environmental conditions and marine life



©NASA

What is El Niño and how does it affect the environment?

Carley Hampton

■ El Niño is the oceanic component of the El Niño Southern Oscillation, a climate pattern that occurs naturally across the tropical Pacific every two to seven years. Scientists still do not fully understand what causes this oscillation.

In non-El Niño years the Pacific, especially off Peru and Ecuador, is characterised by cold water from the deep sea welling up to the surface and bringing with it the nutrients that sustain high growth rates of phytoplankton and marine plants. The phytoplankton supports the rest of the food chain, giving rise to rich fisheries and diverse communities.

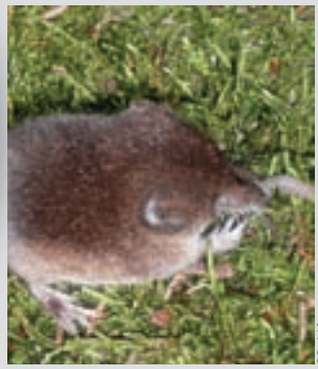
During El Niño years, however, warm water spreads from the western Pacific and the Indian Ocean eastwards and contains much lower nutrient concentrations. This means that the marine life is periodically starved for many months and has to be able to survive changing conditions. The effects are not restricted to organisms on the coast of the Pacific Ocean but have knock-on effects even for life in the deep sea.

Sea water acts as a heat reservoir that drives global wind patterns. The El Niño temperature changes therefore affect the weather worldwide. 'El Niño' is Spanish for 'the boy' and refers to the Christ child as the Pacific coast of South America experiences the warming around Christmas.

Dr Anuschka Miller, Scottish Association for Marine Science

International Year of Biodiversity – What's On June and July 2010

Kent Wildlife Trust are holding a Festival of Wildlife with free guided walks and tours, live music and entertainment. You can discover how to identify small mammals and take part in one of the many family activities that are taking place all weekend. Visit www.kentwildlifetrust.org.uk for more information, or phone 01622 662012.



©Soricida07

Rainforest Life

■ London Zoo

If you are in the capital you can visit ZSL London Zoo's exciting new exhibit Rainforest Life where you can come face to face with a variety of amazing rainforest species including monkeys, sloth, armadillo, tamandua, bats and rats. While at the Natural History Museum London you can journey through the magnificent butterfly house, explore habitats and continents across the world and discover the spectacular butterflies that live there.

©Ironmanx1

2010 has been declared the International Year of Biodiversity (IYB) by the United Nations

Visit the website

www.biodiversityislife.net This is the website of IYB-UK, which is the UK partnership supporting IYB. It's a great source of news and events concerning biodiversity and the environment.

THE HOW IT WORKS KNOWLEDGE

For [illegible]urs of kit and savants of stuff

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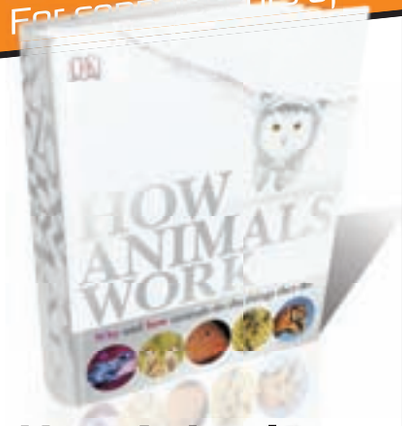

How Animals Work

Price: £14.99 / $24.99
ISBN: 978-1-40535-192-8
Providing DK's usual high level of photography, *How Animals Work* provides a great guide to the most notable animals across the world, revealing where they live, how they survive and what makes them tick. Overall, a good reference book with a clean, modern presentation that stops it being dry and academic.
Verdict: ✪✪✪✪

Dunk Your Biscuit Horizontally

Price: £6.39 / $9.99
ISBN: 978-1-84953-053-8
Another compendium of strange and weird scientific facts, such as that on the cover which reveals how a scientist in Bristol, England, worked out that by dunking your biscuit horizontally instead of vertically in your drink you get roughly four times the longevity.
Verdict: ✪✪✪

It's alive! ALIVE!

Mechanical Robot Arm

HOW IT WORKS EDITOR'S CHOICE AWARD ✪✪✪✪✪

Price: £29.99 / $39.99
Get it from: www.amazon.com
TIRED OF PICKING objects up with those outdated organic hands? Well, if so, this Mechanical Robot Arm from the Thumbs Up! company is a suitable and (cough) handy replacement. Capable of picking up any object of less than 100 grams in weight, the arm comes unassembled and in kit form, allowing its owner to build it themselves before unleashing its mechanised cherry-picking awesomeness. It's educational too, with a detailed step-by-step assembly guide that walks you through the construction process and helps highlight how the mechanisms and controllers work to make the arm move.

The arm itself is powered by five independent motors, each powering a different joint for multi-directional control, and features base rotation, shoulder, elbow and wrist motion as well as a functioning gripping claw. It is also fitted with an integrated LED spotlight for low-light operation and guidance easability.

The arm itself is operated by a wired remote controller, which connects to a microchip board installed in the arm's base, and provides five separate two-way switches for control of all of the arm's motors. The kit also includes all the screws, springs, cogs and cables needed for the build; the only thing not included is a screwdriver.
Verdict: ✪✪✪✪✪

Sensia

Egg-shaped egg-cellence

Price: £209.99 / $309.99
Get it from: www.amazon.co.uk
PURE RADIOS CONTINUES its good form with the new Sensia portable. Offering FM, DAB, DAB+ and internet radio, the Sensia offers every format a music lover could wish for and, crucially, does so in a sleek egg-shaped casing with touch-screen technology. The slickness of the interface is the main selling point here, banishing any buttons, knobs, wheels and sliders that have been the mainstay of radio control for years, instead providing a crisp, high-resolution screen operated purely by touch. Using the touch screen users view and interact by a mixture of scrolling and spinning lists, sliding controls and swiping to change views.

Aesthetically the Sensia is stunning. A white, black and chrome egg flanked by twin fabric conical speakers. Ergonomically it is also superb, with a solid build quality, fitting snugly in the accompanying stand. It also includes Pure's Clearsound technology, a functional RF remote control and rear-mounted ports for iPod and other MP3 players for direct music streaming. In addition, when steaming music the album artwork and track lists are displayed for quick selection.

Verdict: ★★★★

Pogoplug

A cloud, in your living room

Price: £79.99 / 118.99
Get it from: www.firebox.com
CLOUD COMPUTING IS here to stay – allowing files and content to float in cyberspace for the enjoyment of all instead of encased within the narrow confines of a hard drive – and the Pogoplug from Cloud Engines now lets that fluffy cumulonimbus drift into your very own residence.

The Pogoplug is a router-shaped box that allows you to connect up to three external hard drives directly to the internet, giving you and anyone else full web access to their contents wherever they may be. Once connected, any content stored within can then be immediately downloaded or streamed over other computers, smartphones, consoles or iPads. In addition, the Pogoplug also allows you to only share selected files with friends, family or work colleagues, remaining locked unless you send them an invitational link to access the content.

Of course, this technology already exists and is in use in home and office servers all over the world. The key thing here, however, is that the Pogoplug is a plug and play device, requiring no complex set-up or maintenance. On test we simply had to connect the Pogoplug to a router, connect a USB hard drive to it and activate the unit online to achieve full functionality.

Verdict: ★★★★

Game reviews

Metal Gear Solid: Peace Walker

- **Price: £17.91 / $36.99**
- **Format: PSP**

There is something very refreshing in how the *Metal Gear Solid* franchise continues to refine its own very unique formula. This latest addition – an exclusive to the PSP – while retaining the uniqueness and heritage, boils it down for a portable market, simplifying the controls, shortening the cut-scenes and reducing the mission times. The result is superb – delivering adrenaline shots of *Metal Gear Solid*-ness but with the authenticity and style of its full-blown predecessors.

Verdict: ★★★★★

Alpha Protocol

- **Price: £29.99 / $52.43**
- **Format: PS3**

Forgetting the game's awkward title, *Alpha Protocol* is a decent FPS and good RPG. Obsidian, the developer, has a strong history of RPG development and it shows through here, with well-written conversation and a depth of characters and decisions that few games replicate. Combat is the weakest element of the title, however it is functional and the extensive customisation of weapons, gadgets and appearance help mitigate its failings.

Verdict: ★★★

Green Day: Rock Band

- **Price: £29.70 / $48.93**
- **Format: Wii**

Quick checklist to see whether you should buy this game. Like *Rock Band*? Like Green Day? If you have selected 'YES' to both those questions then this title is for you. *Green Day: Rock Band* offers the same package as previous titles with a decent selection of Green Day's greatest hits, however the absence of anything from the band's fist two albums as well B-sides is annoying and while the full band mo-cap performances are a nice touch, it doesn't feel as special as Harmonix's Beatles effort.

Verdict: ★★★

Tiger Woods PGA Tour 11

- **Price: £37.91 / $57.99**
- **Format: Xbox 60**

Rut. As stuck in one, is the simple verdict here. Unfortunately, despite last year's iteration being criticised for adding nought but gimmicks to broken gaming mechanics and last-gen visuals, the team at EA Tiburon seem not to have listened. So what's new this year? Well, more gimmicks. *Tiger 11* brings nothing of note to the licence and considering you can get last year's pretty much identical version for a few quid, we cannot possibly recommend it.

Verdict: ★★

THE HOW IT WORKS KNOWLEDGE

For connoisseurs of kit and savants of stuff

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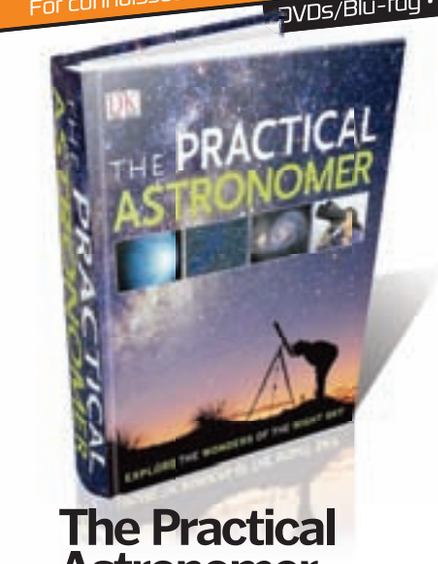


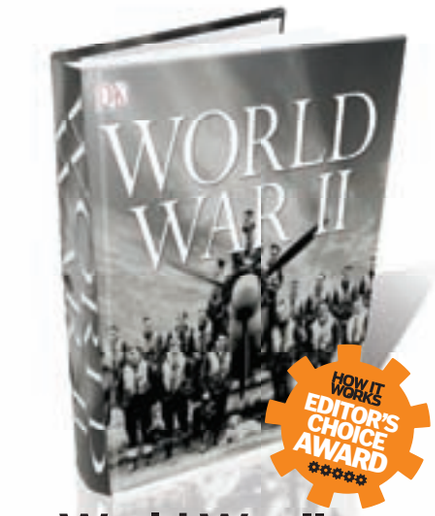
The Practical Astronomer

Price: £14.99 / $19.99

ISBN: 978-1-4053-5620-6

The Practical Astronomer provides a wealth of information on observing the night sky, including: constellations, sky maps, star charts, technology and equipment. In addition, the title is stocked full of hi-res imagery of the various phenomena in the solar system and provides key facts and figures for planets, stars, asteroids, comets and moons.

Verdict: ✪✪✪



World War II

Price: £19.99 / $28.99

ISBN: 978-1-4053-3520-1

A comprehensive visual guide to the Second World War, *World War II* provides a detailed historical reading of this most important of conflicts, delivering challenging analysis of the war's causes and momentous consequences. Stretching from the battlefronts of Europe through Africa and onto the Pacific, this is an approachable, one-stop shop for information on World War II.

Verdict: ✪✪✪✪

Griffin A-Frame

Accessorise like its 2007 all over again

Price: £34.99 / $49.99

Get it from: www.griffintechnology.com

AS WITH THE iPhone, the iPad is prime stomping ground for third-party manufacturers looking to release supporting products and accessories – with an absolute barrage of good and, more worryingly, bad products now inevitable over the next couple of years.

This desktop stand for Apple's latest and greatest, from Griffin Technology, gets things off to a good start however, delivering an attractive and stable platform for you to place your pad. The heavy aluminium A-Frame swings open to hold the iPad upright in either portrait or landscape view and cushions the device with soft silicone cradles, preventing it from being scratched or scuffed. The legs can also be left closed for when users wish to use it on a flat surface and, thanks to the minimalist design, the stand allows easy access to the iPad's dock connector, ideal for when syncing and charging. Overall, the A-Frame is stable, aesthetically and ergonomically pleasing, and decent value for money.

Verdict: ✪✪✪✪

SmartSwipe

Protect card details by swiping not typing

Price: £34.99 / $49.99

Get it from: www.amazon.com

THE SMARTSWIPE ALLOWS users to protect their credit card information when shopping online by allowing them to simply swipe-in their card details from home when traditionally they would have to type them out to complete a transaction. Essentially, the device is a small, portable, personal card reader that can operate on any machine and simply plugs in via USB.

On test, the SmartSwipe did exactly what it said it would do on the tin, automatically and securely logging your details with online retailers' checkout and payment systems. It is built well too, resembling a shiny black egg and sitting inoffensively on desktops like a mouse. However, for the price you have to pay we felt that apart from the extra security the system adds to protect your online transactions, the device was of slightly limited value to all but those who purchase online as a matter of course day-to-day.

Verdict: ✪✪✪

Powermonkey eXplorer

Recharge drained devices… on Everest!

Price: £65.00 / $95.00
Get it from: www.powertraveller.com
IF YOU LIKE to travel to the far-flung reaches of the world then this product is for you. The Powermonkey eXplorer is an all-in-one portable, solar/mains powered, charging unit for a vast array of smartphones, cameras, games consoles, MP3 players and PDAs. Indeed, with up to 96 hours of standby energy available at your fingertips, you may never be without your beloved electronic device ever again.

The eXplorer package contains a solarmonkey portable solar panel (used to collect the Sun's rays), Powermonkey portable charger (the storage cells for captured energy), mains charger with interchangeable heads for UK, Europe, US and Australia, over 13 adapters and a protective storage case.

On test the eXplorer impressed, although its full functionality could not be demonstrated very well due to Britain's cloudy and rainy weather. Despite this, when the Sun did come out the charger was dutifully supplied with energy from the solar panel and, considering its small size and portability, it was easy to see how this would be an ideal companion to a traveller in hot climates and distant countries, attaching the panel and charger to their backpack to collect energy throughout the day.

Verdict: ✪✪✪✪

Televisor Kit

Watching television has never been quite so retro

Price: £27.00 / $39.99
Get it from:www.mutr.co.uk
ANOTHER GREAT KIT from the guys over at Middlesex University Learning Resources, the Televisor Kit allows youngsters to build and operate a working television just like John Logie Baird's original. Historically accurate TV footage is encoded on a CD included in the kit and when the Televisor is attached to a CD player, can be viewed as it used to be in days gone by.

Verdict: ✪✪✪

PowerDock 4

Less wires, more charging

Price: £22.91 / $27.50
Get it from: www.amazon.com
A UNIVERSAL DOCKING platform for all iPod and iPhone models, the PowerDock 4 allows for multiple models to be charged at one time. The dock itself features a brushed metal base with four Apple docks, eight universal dock inserts for the various models of device and rubberised feet.

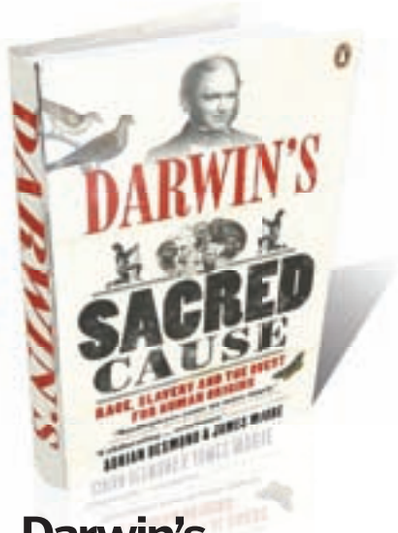
The platform is powered by a mains connection to a 120VAC power outlet and is well built. On test the unit performed as expected, quickly charging both an iPhone 3GS and iPod touch. However, the lack of syncing options while charging – common in other singular docking platforms – seemed a trade-off too far for the ability to charge multiple devices at one time.

Verdict: ✪✪

Ship

Price: £19.99 / $28.99
ISBN: 978-1-4053-5336-6
Detailing 5,000 years of maritime adventure, *Ship* takes its reader on a chronological journey from the banks of ancient Egypt through to the dockyards of the 21st Century, showing how the simple boat has evolved into the massive, complex constructions we are familiar with today. Want to know anything about boats and ships? Then buy this.

Verdict: ✪✪✪✪



Darwin's Sacred Cause

Price: £8.44 / $13.87
ISBN: 978-0-1410-3220-0
An exploration of the contextual circumstances surrounding Darwin in the run-up to his writing of his seminal *On The Origin Of Species*, *Darwin's Sacred Cause* charts his quest to abolish slavery and unite all races of people across the world. A book which helps recreate his personal drive, public hesitancy and scientific radicalism with renewed vigour.

Verdict: ✪✪✪✪

GROUP TEST Audio systems

Become wired for sound thanks to these top stereo systems

Sony CMT-BX77DBi

Price: £129.99 / $189.99

Get it from: www.play.com

The more conventionally styled CMT-BX77DBi from Sony delivers good stereo sound with FM and DAB digital radio, CD and iPod audio playback for a penny shy of £130. The unit also charges any iPod connected to it and track selection can be controlled from afar with the included remote. On test, the BX77DBi impressed, with the twin speakers pumping out 50W of sound throughout the office, which – while we felt was not as defined as the SOUND 53 – was powerful and dealt with a number of test tracks just fine.

Verdict: ✿✿✿

Pure AVANTI Flow

Price: £249.99 / $369.99

Get it from: www.play.com

Kicking off the group test this month is the AVANTI Flow from Pure, a table-top digital audio system that provides digital and FM radio, Wi-Fi music streaming, internet content integration – such as podcasts and listen again programmes – and iPod docking and playback. The build quality of the unit is good (if a little Nineties in styling) and, powered by Pure's Clearsound technology, the Class D amplifiers provide crisp audio. The 5.25" downward-firing subwoofer also provides the unit with plenty of oomph when playing bass-heavy tracks.

Verdict: ✿✿✿✿

Roberts SOUND 53

Price: £279.99 / $415.99

Get it from: www.amazon.com

The bigger brother of the Roberts radio SOUND 43, the SOUND 53 provides a DAB/CD/FM/Digital sound system with integrated iPod dock. The 53's design is sleek and minimalist, with an acoustically tuned wooden cabinet coated in a gloss piano black finish contrasted with an ice blue backlit display. Sound quality on test was very good, punching out bass-heavy tracks with gusto and delivering clear speech when tuned to BBC Radio 4. The added feature to record from radio and CD directly to an SD card or PC via USB was also greatly appreciated.

Verdict: ✿✿✿✿✿

HOW IT WORKS GROUP TEST WINNER

Bose WAVE®

Price: £499.99 / $499.95

Get it from: www.bose.com

Bose is renowned around the world for its awesome audio reproduction and its WAVE® series delivers like usual, providing fantastic sound quality from a small and sleekly designed unit. This, the base model, comes with CD player, FM/AM tuner and alarm clock, however DAB functionality can be added for an extra £100 ($150). On test the system provided the best audio quality out of all the units, delivering rich and well-defined audio throughout the frequency spectrum; the quality was equally high with the build. However, its astronomical price (for our wallets at least) loses it marks.

Verdict: ✿✿✿

HOW TO MAKE
A balsa wood plane

GET INVOLVED!
Think your plane could defeat ours in a dogfight? Then why not send your pictures to howitworks@imagine-publishing.co.uk and we'll show it to the world!

Balsa wood p

Reach new flights of fancy with this groovy glider

There is no doubt that paper planes are super fun, making boyish dreams of slipping the surly bonds of Earth a reality in an effective and affordable manner. However, when taken outside of their natural environment (the office, of course, in a coworker's hair) their performance is questionable, often being buffeted to a quick crash landing by the gentlest of breezes. Why not then take those flights of fancy to a new level with a plane of larger proportions and of sturdier countenance?

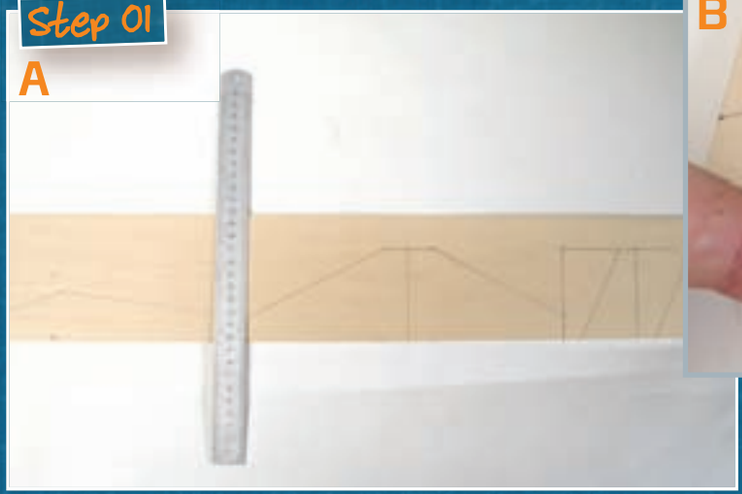
Introducing the balsa wood glider, a model aircraft simple enough for the youngest pilot in waiting to construct but with multiple-times the flight performance of your conventional paper plane. To take-off, just follow these simple seven steps.

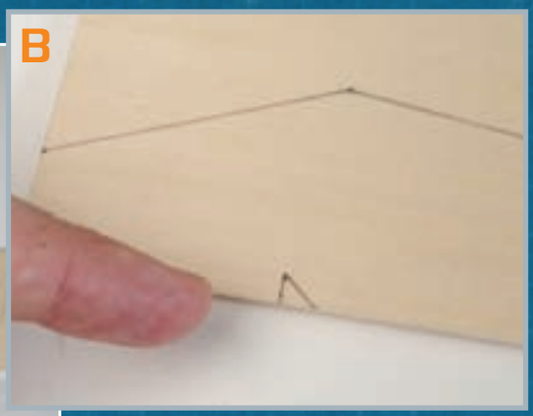
Construction materials:

- 1 x Balsa wood sheet (2 to 5mm)
- 1 x Craft knife / scalpel
- 1 x Ruler
- 1 x Pencil
- 1 x Balsa cement / glue
- 1 x Blu Tack pack
- 1 x Elastic band
- 1 x Coloured pens / paint (optional)

All construction materials can be acquired at HobbyCraft

Step 01





1. To start, take your sheet of balsa wood and mark out the requisite dimensions on it with your pencil and ruler. You need to mark out the glider's fuselage, wings, tail and fin (A). The design can be of your choosing, however it is best to keep the measurements of the wings, fin and tail as precise as possible as this will aid its aerodynamic stability. Importantly, in order to catapult your completed glider with elastic band, a small cut must be marked out in the bottom front of the fuselage like this (B).

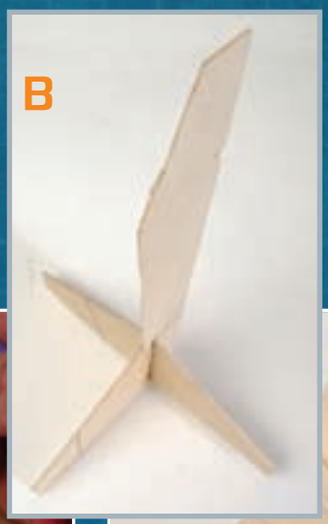
Step 02

2. Now cut out your parts – it is best to do so with a sharp craft knife or scalpel as this will mitigate the chances of the balsa wood splitting (A). In addition, it is advisable to cut along a solid object such as your ruler in order to maintain an even cut (B).

Step 03

3. Time to get creative. With all parts cut out, take your coloured pens or paint and decorate your glider to your liking.

lane



Step 04

4. When your decorations have dried and the parts are capable of being handled once more, the construction of the glider may begin. Take your fin and glue it onto the fuselage, making sure it is in line (A). Once dried, take the plane's tail pieces and glue them onto the back along the guideline running parallel to the base, at right angles and as accurately as possible (B).

Step 05

5. Once the tail pieces and fin have been attached and are dry, glue the wing under the fuselage, making sure to keep it as square as possible (it is also possible to attach the wing by carving a thin whole in the centre of the fuselage and threading it through).

Step 06

6. Finally, take some Blu-Tack and coat the nose of the glider with a strip of it. By doing this you are not only providing protection to the glider but also shifting its frontal weight, aiding the stability of its flight path once in the air. It is worth experimenting with different amounts of Blu-Tack on the nose from flight to flight, as this will affect the glider's performance (ie the more Blu-Tack the more like a dart the plane will behave, the less Blu-Tack the longer and more unstable its flight will become).

Step 07

Launch tips:

1. If throwing the glider from hand, a long gentle throw will be more effective than a sudden jerky launch.
2. If launching from elastic band, elevate your trajectory by 20-30° to achieve longer and more spectacular glides.
3. Use any spare balsa wood to create replacement tail and fin pieces, as then any repairs that are needed out in the field can be completed quickly.

Completed!

7. Congratulations! You have made your very own balsa wood glider. Now take it outside and attach a plastic band to its small notch, pull back, and watch it fly.

HOW IT WORKS INBOX

Feed your mind. Speak your mind

To the best of our knowledge, our letter of the month was not, in fact, supplied by a kangaroo or wallaby

Letter Of The Month

Love from Down Under

I just wanted to say that your magazine **How It Works** is totally wicked and one of the best mags I've ever bought! I never really planned on buying it, but I did because I liked the cover on issue 6 and I wanted to take a juicy mag home for my partner to balance the ledger for the four chick mags I'd just bought myself at the time. The sad thing is, my partner hasn't been able to read it yet because I won't give it up. Seriously! I just love it. It's not too blokey (Aussie slang) or too overwhelming with facts and statistics; it's just perfect. A visual delight and the content is as stimulating as it is fascinating. It's wickedly coffee table worthy and I thank you for your contribution to the simple things (like good magazines) which make life that little bit more interesting and enjoyable. I wait in anticipation for issue 7.

Tania Butterworth

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...

Cruickshank interview

I have read most issues of **How It Works** and there's not many magazines like this I read from cover to cover! I really enjoyed reading some of the recent interviews such as Adam Hart-Davis and Johnny Ball and I could almost hear their excitable, informative and passionate-about-their-subject voices when reading. Along similar lines – unless I have missed it – do you have any plans to try and interview Dan Cruickshank?

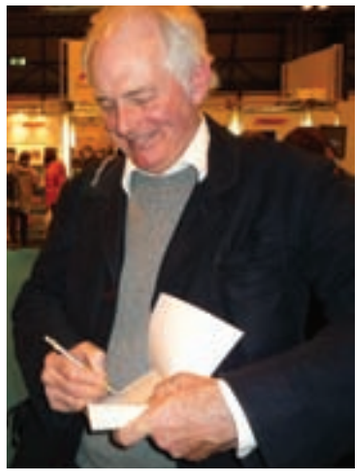
Adrian Stallworthy

HIW: Not yet Adrian but we'll add his name to the list.

Feet of clay

This is my first "own" copy of **How it Works**, delivered to me in Australia after reading an earlier copy at a friend's place. I was very surprised to find an error in issue 8. Page 23 point four on Surviving Mountains, you state that "Climbing any mountain over 8,000 feet is very costly..." Seems like this should read 8,000 metres instead of feet as our highest peak in Australia is Mt Kosciuszko at 7,310 feet high (2,228 metres) and can be climbed in summer with a drink bottle and an old pair of hiking boots.

Daniel Nixon



Fon-et-iks for all

First of all, what a great mag. I unfortunately only discovered it at issue 3 but subscribed right away. I love the fact that it's packed full of articles, unlike a lot of publications these days that have one article per three pages of adverts.

For me, however (maybe I'm just thick), there is one small thing that would make reading some of the articles more enjoyable, and that is with some of the subject-specific words (especially in biology articles). If you could include in brackets a phonetic version so I can be sure I'm pronouncing it right.

Keith Henderson

Mount Everest – taller than 8,000 feet

Can't get enough of How It Works?

Signing up to the forum couldn't be easier, just take a few minutes to register and then start sharing your questions and comments. The How It Works staff will be on hand to answer your questions and initiate debate.

www.howitworksdaily.com/forum

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.

HIW: Hi Keith. Very often we're trying to pack a huge amount of information into a limited space so including the phonetic spellings of the terms would be a luxury we can ill afford. Plus, we're also on sale in the United States where pronunciation of certain terms can be completely different. A good idea though, but hard for us to implement.

Mad Men

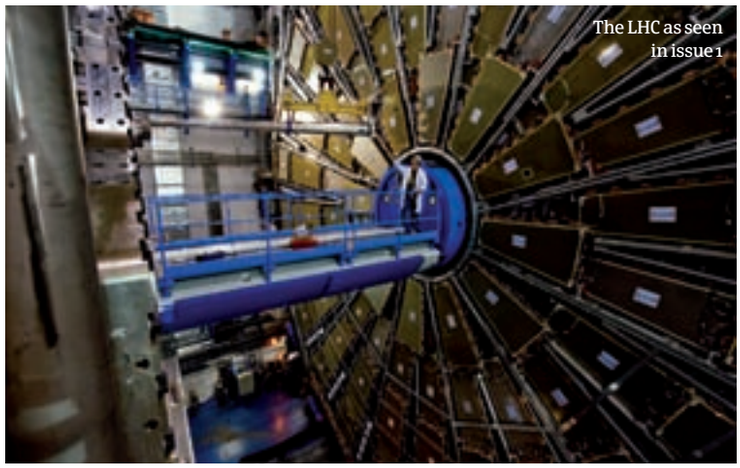
I have all eight issues and at first was highly impressed with the quality and content... BUT, you are on the slippery slope to becoming nothing more than a glorified advertising magazine. In this day and age where adverts are force fed to us on TV, billboards, phones etc to name a few, it would be nice to read a magazine free from this "propaganda". Issue 8 had 14.5 pages of advertisements out of 100, a very poor return where more quality articles are just waiting to be explained, ie how about an article on the two most important Houses in England, namely Parliament and Lords with diagrams of the Houses.

Another negative for me is the over-the-top number of articles on space and planets, there are more on that than any other topic. To be honest, none of us are going into space and your articles are borderline boring.

Please, drop the adverts and put some more articles in. I am being driven away from what was a good mag but is now just mediocre.

I. Jennings

HIW: Take a look at some other magazines available from your newsagent Ian and you will find that the ratio of ads to editorial is pretty low by comparison. Besides, if you take the remaining 85.5 pages and divide this by the cover price, you're actually getting a huge amount of knowledge, facts and statistics for just four pence a page. Surely that's not a bad return?



The LHC as seen in issue 1

Must see the LHC

Have just read the interview with Professor Brian Cox, good job. Would love more about how this thing actually works and how it keeps us all safe should it accidentally create a black hole.

Capn Howard

HIW: Look in issue 1 Capn Howard, we covered the Large Hadron Collider in detail with a four page feature! We also cover all the latest news related to the LHC on the website, so make sure you keep checking www.howitworksdaily.com for any updates to the project.

How do fish swim?

Your latest edition (issue 8) further confirms my decision to order my monthly copy of HIW from my newsagent. I am impressed by the quality of the whole production, but especially so by the standards of the illustrations.

I have a suggestion, will you explain the physics and mechanics of "fish propulsion"? It appears that by waving their tails the creatures can propel themselves at a great velocity. Very impressive indeed!

Mr Lowe

DVT doubts

Not sure I was happy with the answer to this question. It basically puts DVT down to lack of movement, yet medical science now knows that DVT is really much more related to poor quality air present in aircraft cabins. The lack of movement helps DVT develop no end but it was much less a danger when people still smoked on commercial flights because the constant renewal of air actually kept it cleaner (not including the addition of chemicals from cigarette smoke of course).

If DVT were simply down to a lack of movement, people travelling long distances in cars and trains, sat at office desks without moving for hours etc, would be adding to the DVT statistics...

Clarkee79

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