NEW

THE MAGAZINE THAT FEEDS MINDS

HOW IT WORKS

SCIENCE ENVIRONMENT TECHN… …ORY SPACE

IMAGINE PUBLISHING

INSIDE

INTERVIEW SIMON REEVE

+ LEARN ABOUT

- CROSSBOWS
- SUNBURN
- JETPACKS
- MIRRORS
- URANUS
- G-FORCE
- MICROSCOPES
- PINBALL TABLES
- AFTERBURNERS
- THE TAJ MAHAL
- SKY PLAYER
- VOLCANIC ASH

933 FACTS AND ANSWERS INSIDE

INSIDE THE NEXUS ONE

Google's latest and greatest smartphone exploded

THE WORLD'S MOST EXPENSIVE, LUXURIOUS SHIPS...

MEGA YACHTS

THE REAL IRON MAN

The science behind cyber-powered humans

SURVIVING EVEREST

Everything you need to make it to the summit

HOT AIR BALLOONS

How do these lighter-than-air aircraft fly?

TWINS EXPLAINED

Why are some of us born in pairs?

HOW IT WORKS

WELCOME

The magazine that feeds minds! ISSUE EIGHT

Get in touch

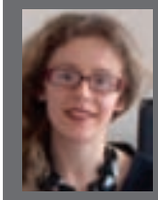
Have YOU got a question you want answered by the How It Works team? Get in touch by...

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

"FEED YOUR MIND!"

Meet the experts

How It Works writers are well-qualified experts in their field who are schooled in the fine art of entertaining while they educate...

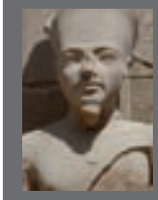


Vivienne Raper
Exploring the oceans

Vivienne gained a PHD by using radar and lasers to study the polar ice fields. Since then she's become a journalist and regularly writes for *The Financial Times*, *Science Careers* and many more.

Shanna Freeman
Types of star

Shanna returns after becoming a mum for the very first time! Somehow she's found time to write an article explaining the different types of star as well as caring for little Emilie Lenore.



Dr Bridget McDermott
Petra

Dr Bridget is an expert in the field of ancient military technology and had a long career working with museum collections around the world. Read her explanation of the city of Petra on page 78.

Dave Roos
The real Iron Man

When he's not growing organic produce on his farm in Pittsburgh, Dave is one of our go-to-guys for articles on tech and science. This issue he goes behind the mask and discovers the real Iron Man.

Andy Betts
Inside the Nexus One

Andy is the editor of one of our sister titles Smartphone Essentials, and is therefore perfectly qualified to explain the inner workings of the Nexus One that appears on page 60.

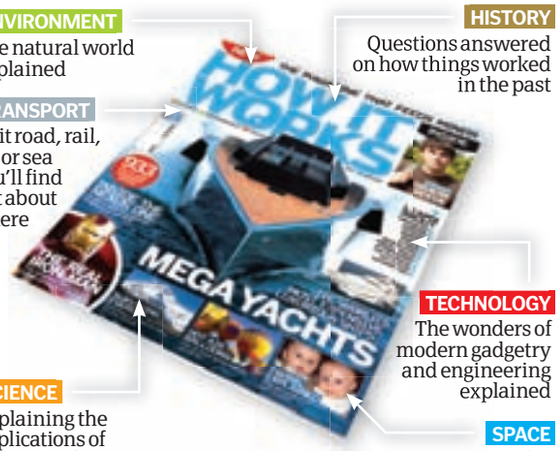
With thanks to

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

sciencemuseum REUTERS Google DK NASA dyson sky

The sections explained

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



ENVIRONMENT
The natural world explained

HISTORY
Questions answered on how things worked in the past

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

TECHNOLOGY
The wonders of modern gadgetry and engineering explained

SCIENCE
Explaining the applications of science in the contemporary world

SPACE
From exploration to the solar system to deep space

Editor's pick

I'm a fan of the beautiful game so the explanation of World Cup stadiums and kit technology (page 66) piqued my interest this issue. Soccer City looks fantastic and I can't wait to see some games here, even if I am tipping England for a quarter-final exit.

What you're saying about How It Works

This is my third issue of the magazine now and it still definitely has the wow factor. – **Kevin Gravill**

The variety of subjects covered is just right and all of it is excellently presented. – **Stephen Tuff**

I was amazed at all the facts, please keep up the good work, I love all the topics. – **Tracey Wainwright**

Thanks for the great job behind this extraordinary magazine! – **Mustafa Ruhomaun**

Just how do the mega-rich keep score? Eating swan for dinner and bathing in champagne is all very nice but when it comes to communicating your immense wealth to the rest of the world there's little more effective than an opulent super yacht. This issue of How It Works sees us set sail on some of the most expensive, luxurious craft ever to take to the seas, ships that make the adjective "super" seem positively underwhelming. So if you want find out how the other half lives when on the waves, turn to page 24 and take a look at three of the world's most expensive mega, or even giga, yachts now. You'll also be amazed at the equally high levels of splendour and technology that are on display.

The sea-faring theme continues in our Environment section too where you can find out all about the fascinating world that lies beneath the briny and catch up on the work of the world's oceanologists. However, if your exploratory tastes are more Jean-Luc Picard than Jacques Cousteau you can also discover how the European Space Agency plans to conquer the stars over the coming decade by reading our space feature on page 52. With NASA still reeling in the wake of drastic budget cuts from the US government, the smaller, less wealthy ESA has gained more significance in contemporary space exploration. But how is it funded and who is involved? You can find the answers to these questions and more info on current missions in the Space section. So, be it a super yacht or a spacecraft, welcome aboard this issue of How It Works!

Dave Harfield
Editor in Chief

HOW IT WORKS

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The magazine that feeds minds!

ISSUE EIGHT

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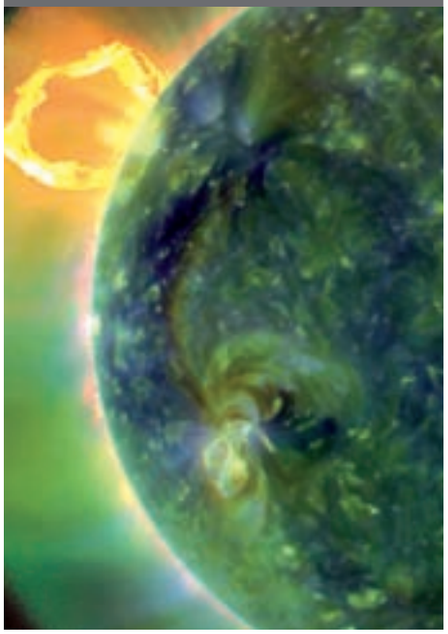
Kick-off the news section with some amazing photography from the spheres of science, technology, space, transport and the environment



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Discover the amazing world that lies beneath the Earth's oceans

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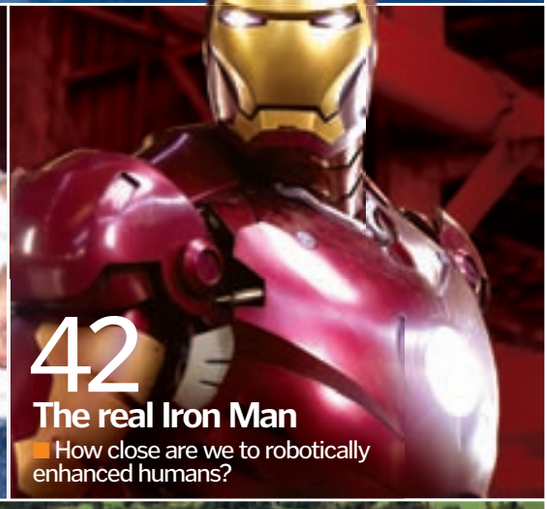
Identical or not, why do some humans come in pairs?



42 The real Iron Man
How close are we to robotically enhanced humans?

66 World Cup technology
The stadiums and kit on show in the 2010 World Cup

Sections

This is not an iPhone 4G!
But it does illustrate some of its alleged new features. We didn't want to get sued, that's all...

'iPhone 4G' left in bar

A missing iPhone prototype ended up in the hands of online tech blog Gizmodo – but was it the real deal?

While Steve Jobs intimated that we'd see new iPhone software this summer, it was something of a surprise to learn that new iPhone hardware might also be on the cards. It was even more of a surprise to learn that the normally fastidious level of secrecy surrounding Apple's new products had collapsed after a careless Apple engineer left a top-secret iPhone prototype in a bar.

The lost phone was picked up by an unnamed member of the public in America and reportedly sold, for $5,000, to American website Gizmodo whose team took the device apart and confirmed it as "genuine" on their tech blog. It's clear that the mysterious find features a cleaner, more industrial design with squared edges, rather than the 3GS's rounded lines. It also features a front-facing video camera ideal for video chat, a micro-SIM, an apparently higher-resolution screen, two separate metal volume buttons, and what appears to be a noise-cancelling mic.

At first there was speculation as to the authenticity of the story and the new 'iPhone 4G', but now it looks like this is prototype hardware for an iPhone that would've been announced later this year – after all, it's too early to see a practically finalised version of the 2011 model and it's too different from the 2009 3GS we're already familiar with. If this is the real deal, the now-customary Steve Jobs on-stage introduction of a never-before-seen product will have far less impact for the next iPhone incarnation.

As we go to press

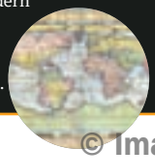
It's since been reported that the home of Gizmodo editor Jason Chen has been raided and his personal computers seized by police who believe they were used in connection to the deliberate handling of stolen goods. However, according to Gaby Darbyshire, COO of Gizmodo owner Gawker Media, "Under both state and federal law, a search warrant may not be validly issued to confiscate the property of a journalist." This has sparked debate surrounding whether a blogger comes under the definition of journalist or not.

This day in history

20 May: **How It Works** issue 8 goes on sale, but what else happened on this day in history?

1506
Christopher Columbus, the legendary explorer who discovered America, dies.

1570 The first modern atlas is created by Flemish cartographer Abraham Ortelius.



1883
Indonesian volcano Krakatoa erupts in one of the most violent eruptions on record.

1891 Thomas Edison's groundbreaking motion picture projector the kinetoscope is unveiled to the public.

1902
Cuba gains its independence from the US with Cuban statesman Tomás Estrada Palma (1835-1908) serving as the first president of the republic.

Robots clean up oil spill

BP deploys underwater robots to stop 42,000 gallons of oil from spewing into the Gulf of Mexico every day

Following the explosion and sinking of the semisubmersible Deepwater Horizon drilling rig, which left 11 personnel missing and presumed dead, an estimated 13,000 gallons of oil an hour was leaking from the Macondo oil well into the sea 41 miles off the coast of Louisiana.

The rig was lease operated by BP and owned by Swiss company Transocean who, together with the help of the US Coast Guard and a number of environmental groups, used a variety of water vessels and underwater remote-operated vehicles (ROVs) to both stem the flow of oil into the ocean and disperse the oil that had already spilled.

Equipped with cameras, several ROVs were sent to the sea floor to activate the blowout preventer (BOP), a 450-ton valve intended to seal off the oil well pipe. Like the robotic arms used on the ISS, the underwater bots can grasp, turn and adjust equipment to activate the huge valve.

Other vessels also used in the clean-up operation included skimming vehicles, tugs, barges and booms for scooping up and containing thousands of barrels of spilled oil. Hundreds of thousands of gallons of dispersants were also deployed from a variety of helicopters and fixed-wing aircraft, including Lockheed's C-130 Hercules.

Image of Gulf of Mexico captured on 25 April by NASA's Aqua satellite, using the trusty Moderate Resolution Imaging Spectroradiometer (MODIS). The silver swirl of the slick is clear because it is in the sunglint area – the Sun is reflecting off the ocean at the same angle at which the satellite is viewing the surface.

© NASA/MODIS Rapid Response Team

America's first unmanned spaceplane

The X-37B Orbital Test Vehicle is the first spacecraft, since the Space Shuttle Orbiters, capable of returning experiments to Earth from space

© United States Air Force

The vehicle has a large engine at the rear, which can be fired up ready for re-entry into the Earths's atmosphere

The United States Air Force launched the X-37B spaceplane from Cape Canaveral on board the Atlas-V rocket as part of its unmanned aerial system programme on 22 April. This autonomous spacecraft blasted off for a performance evaluation to ensure the technology on board functions as intended. The test flight will also prove whether the X-37B can conduct long-term operations.

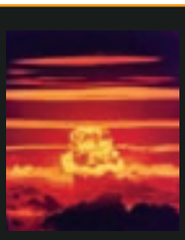
If this flight is a success the X-37B will achieve orbit, before de-orbiting and landing at the Vandenberg Air Force Base – or, in the event of an emergency, the Edwards Air Force Base. Although it's been in development for the USAF since 2004, the X-37B was originally a NASA project, and while it's been compared to NASA's Shuttle Orbiters, the X-37B is much smaller and can remain in orbit for 270 days.

The X-37B is the only unmanned spaceplane in the world capable of achieving re-entry with no direct human control, and although the vehicle's true purpose is top secret, it would make for an ideal moveable spy satellite.

1927 Taking off from Long Island, New York, Charles Lindbergh flies to Paris, France in the Spirit of St Louis. This is the first non-stop solo flight over the Atlantic.

1932 Five years later, female aviator Amelia Earhart becomes the world's first woman to fly solo across the Atlantic. She left Newfoundland on 20 May 1932 and landed in Ireland the following day – for this she received the Distinguished Flying Cross.

1947 The Hungarian-born physicist Philipp Lenard dies aged 84. Lenard won the Nobel Prize for Physics in 1905 for his contribution to research on cathode rays.



1956 In a series of nuclear test detonations known as Operation Redwing, America drops its first airborne hydrogen bomb (a thermonuclear device called Cherokee) over the Pacific Ocean.

MONTH IN FACTS

Short, concentrated bursts of facts and figures from April. Like expresso news...

€2.5bn

■ A spokesperson for the European Commission has estimated that grounded flights due to the ash cloud have cost the air industry €2.5 billion.

Obama is confident new NASA spacecrafts will be capable of venturing beyond the moon during his lifetime.

■ "By 2025, we expect new spacecraft designed for long journeys to allow us to begin the first-ever crewed missions beyond the moon into deep space... By the mid-2030s, I believe we can send humans to orbit Mars and return them safely to Earth. And a landing on Mars will follow. And I expect to be around to see it."

100,000

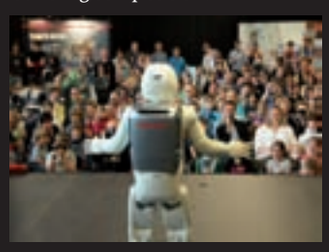
■ Over 100,000 flights were grounded during the airport shutdown, leaving 10 million passengers unable to fly.

"Because science matters"

■ That's the slogan for The Science Party founded in April 2010. Dr Michael Brooks, the new political party's leader, is standing as a candidate in the UK general election. "Science is not just an indulgence for the curious, but is vital to British life, culture and economic well-being," says Brooks. Here here!

ASMIO's awards

■ Honda's humanoid robot ASIMO visited some lucky children in Belgium where he handed out prizes to children who were taking part in the RoboCup Junior international robot-building competition.



© courtesy of Honda

CryoSat-2 launches

The European Space Agency's mission to study Earth's ice makes a successful launch from Kazakhstan

On 8 April the long-awaited second attempt to launch the ESA's CryoSat-2 ice satellite was successfully undertaken, with the satellite confirming it had separated from its launcher after 17 minutes of vertical lift.

This news came as a great relief to the ESA and the CryoSat-2 team as their earlier effort to get Europe's first dedicated ice satellite into polar orbit ended in disaster in 2005 as the upper rocket stages failed to disconnect from the launcher and crashed back to Earth.

No such problems took place this time, however, and on 13 April CryoSat-2 delivered its first data just hours after ground controllers switched on the satellite's sophisticated radar instruments for the very first time. Since then, CryoSat-2 has reportedly been performing exceptionally well as it gathers data on the Earth's shifting ice reserves.

CryoSat's lead investigator, Duncan Wingham said, "We switched [CryoSat-2] on and it worked beautifully from the very start. Our first data was taken over the Antarctic's Ross Ice Shelf, and clearly show the ice cover and reflections from underlying layers. These are excellent results at such an early stage and are a tribute to the hard work of the entire CryoSat community."

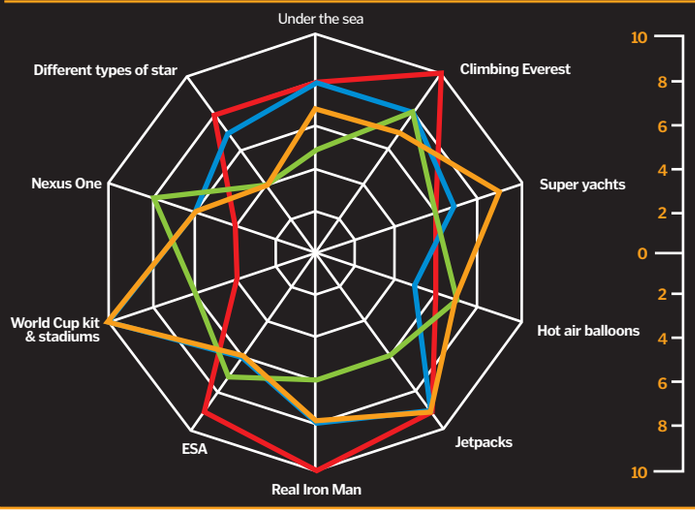
CryoSat-2 measures ice through its primary payload, a Synthetic Aperture Interferometric Radar Altimeter (SIRAL), which sends multiple pulse bursts to Earth every 50 microseconds, the resulting echoes then being received through an antenna system and decoded on board.

It took just 17 minutes to shoot the CryoSat into space

The CryoSat-2 successfully separated on 8 April

THE EXCITE-O-METER!

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



Dave
Ed in Chief
I love the World Cup stuff but I've already picked that on page five so the next thing I was most excited about was the Martin Jetpack. It's amazing that these are now available to buy, they'd certainly make the morning commute a lot more interesting.

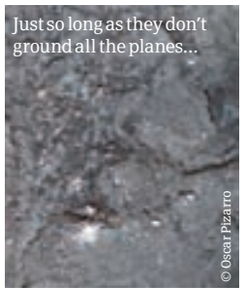
Helen
Deputy Editor
Well, I occasionally use the word 'intrepid' to describe myself, and so I will definitely be reading up on how to survive climbing Mount Everest. The idea of building my own superhuman Frankenstein's monster using real-world science also has me very excited.

Rob
Staff Writer
As a self-confessed gadget freak I really enjoyed taking a look inside the Nexus One smartphone, it'll be great to see the device giving the iPhone a run for its money. Next on my list was the climbing Mount Everest article, I think I may just give it a go...

Jon
Senior Sub Editor
With the recession over I've been thinking about the best way to invest my life savings, and thanks to this month's lead Transport feature, I think I've found the answer. A nifty little super yacht will do me nicely, I'm sure I've got a few million pound lying around...

AND THE VERDICT IS...

Bucking the trend from previous months, Snr Sub Editor Jon is super-excited this month about pretty much everything and joins Dave and Helen at the top end of the graph. Must be World Cup fever!



40,000-year-old volcanoes discovered

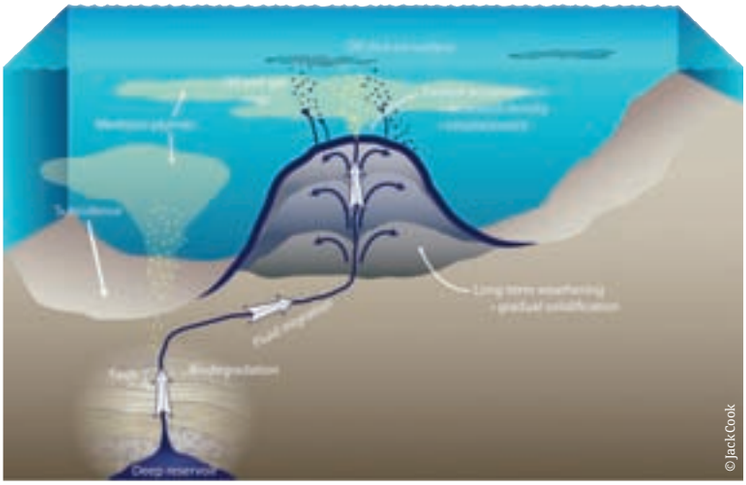
Ten miles of the coast of California, ancient volcanoes have been discovered in the murky depths of the Pacific Ocean

On 25 April, scientists funded by the National Science Foundation (NSF) discovered asphalt volcanoes ten miles off the coast of Santa Barbara, California.

The largest of these undersea Ice Age domes lies at a depth of 700 feet (220 metres) – too deep for scuba diving, explaining how they have remained undiscovered for so long – and is made purely from asphalt, the consequence of petroleum flowing from the sea floor about 30,000-40,000 years ago.

The team made the discovery thanks to their use of the research submersible Alvin and autonomous underwater vehicle Sentry, which through their abilities to dive to such low depths and provide cutting-edge on-board scientific equipment, allowed them to uncover and ratify the volcanoes' existence.

David Valentine, geoscientist on the project and at the University of California Santa Barbara said, "[The volcanoes] are larger than a football-field-long and as tall as a six-storey building. They're massive features, and are made completely out of asphalt." Using the robotic arm of Alvin the team were able to break of slabs from the volcanoes and take them for testing. Using a mass spectrometer, carbon dating, microscopic fossils and two-dimensional gas chromatography, the team determined the asphalt construction, Ice Age date, and natural cause. Chris Reddy, a member of the team, said their results indicated that, "the volcanoes underscore a little-known fact: half the oil that enters the coastal environment is from natural oil seeps like the ones off the coast of California."



Spotify gets 'massive' revamp

Following six months of hard work by engineers, music service Spotify receives a major redesign to challenge iTunes

Spotify's CEO Daniel Ek has revealed that the music streaming service is receiving a total revamp to include many of the social networking features common on Facebook and iTunes.

For the first time too, users of Spotify will be able to actively share their music collection – which will now be able to be imported from iTunes – with their friends and other Spotify users, allowing people to check out what others are listening to.

"We are marrying the best bits of Facebook and we are marrying the best bits of iTunes and we have moved them into Spotify," said Ek, as he commented on the revamp. "What this means is that you can actually discover your friends' music collection, you can browse it. It's almost like going back to the record shop or being at your friend's house."

The automatic update for Spotify was released on 27 April and offered to its 7 million users in the following week. "I think this is a massive step towards the next generation music industry," said Ek, "where it's about access to music and not about ownership any more."

Spotify was launched for public access on 7 October 2008 and you can read a full explanation of how the service works in issue 5 of **How It Works**. The new service certainly sounds exciting and offers a level of functionality over and above that of rival services like blip.fm and Last.fm.

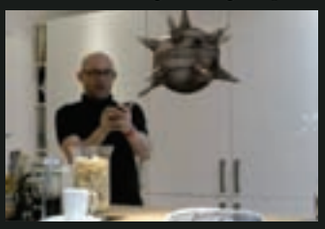
www.howitworksdaily.com

HOW IT WORKS TV

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

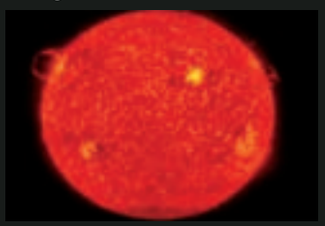
Jason Bradbury's Dot. Robot mini movie

Jason takes his Dot.Robot creation 'Punk' for a spin in his kitchen but things don't go to plan.



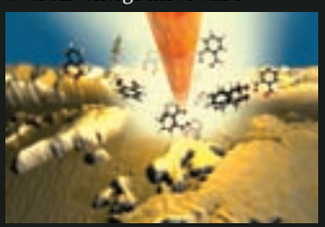
Awesome footage of the Sun released

Thanks to NASA's Solar Dynamics Observatory we were treated to this stunning new footage of the surface of our Sun.



IBM creates nano Earth

Watch how scientists at IBM managed to create a 3D map of the world so small that 1,000 of them could fit on a grain of sand.



Simon Reeve in Tropic Of Cancer

A short clip from the BBC television series *Tropic Of Cancer,* including a tasty goat-meat snack.

Simon Reeve

After visiting an exhausting 18 countries during his voyage around the tropic of Cancer, Simon Reeve had time to share his incredible experiences with How It Works. He also reveals how he came to be one of the most intrepid adventurers to some of the world's most tormented regions

How It Works: Please tell us a little bit about your latest series for the BBC, *Tropic Of Cancer*.
Simon Reeve: The tropic of Cancer journey is my third major trip circling the world and exploring the amazing tropics region, after travelling around the equator and the tropic of Capricorn, the southern border of the region. On my journeys I try to blend travel with current affairs, so it's an amazing adventure, but I also learn more about life in the developing world and in countries we rarely see on the TV. I don't follow the tropic obsessively, instead I zigzag along it using the line as a way of seeing a slice of life in the most fascinating and troubled part of our planet.

HIW: What was your most thrilling discovery on this latest adventure?
SR: So many! One thrilling bit of the trip was Bangladesh. We tend to just think of Bangladesh as a place of tragedy. And yes, it's packed and it's poor, but it's also beautiful and full of the friendliest, most hospitable people on the planet. That's really the story of the tropics: it's the region of the world with the greatest natural beauty and biodiversity, but also the greatest concentration of human suffering.

HIW: You've been described as an adventurer, an author, a broadcaster and an unexceptional student. How would you describe the job you do?
SR: The last description is definitely true! My job, if you can call it that, is a constant education. I was hopeless at school and never went to university, but my work has enabled me to explore and investigate issues, stories and places that fascinate me. Before working in TV I wrote books on terrorism, and again that was all about investigating and learning more about issues I wanted to know more about and I thought other people should know more about as well.

HIW: Please explain for the How It Works readers how you made your big break into writing and how that led to a remarkable broadcasting career.
SR: I did it the old-fashioned way. I left school with no real qualifications and was on the dole for a while running charity shops. I was sacked from a couple of dead-end jobs and was rejected for a job as a white-van driver on Wembley Park Trading Estate. That was a low-point. Then I got a job as a postboy on a national newspaper, and my world suddenly began to expand. I started doing basic research in my spare time, and my big break came when I tracked down two South African terrorists who were on the run in the UK. I was 20 years old and it was all very exciting: I was conducting surveillance on arms dealers and terrorists. In 1993 I started researching the first terrorist attack on the World Trade Center for the paper, and I realised there was a much bigger group lurking behind the bombers. So I left the newspaper and began researching a book on the group we now call al-Qaeda. Nobody read it when it came out in 1998, but it became a bestseller after the attacks of 9/11, and I started appearing on the BBC talking about the subject. Appearing on the BBC led to presenting TV programmes which blend travel with current affairs, in some fairly difficult parts of the world.

HIW: Having had the opportunity to enjoy/endure some truly exceptional experiences – such as being taught to fish by the president of Moldova, eating exotic foods, encountering unusual and dangerous animals, and entering highly dangerous

CAREER

1972 Born in 1972, West Londoner Simon Reeve admits he was an unexceptional student. However, after getting a job as postboy for *The Sunday Times* his passion for writing and investigative journalism was ignited.

1992 Simon spent much of his spare time practising his basic research skills until one day he traced two South African terrorists who were living in the United Kingdom.

1998 Following a terrorist attack on the World Trade Center in 1993, Simon wrote *The New Jackals: Ramzi Yousef, Osama Bin Laden And The Future Of Terrorism*, a book warning against al-Qaeda long before the events of 9/11. It later became a *New York Times* bestseller.

1999 Simon's book *One Day In September: The Full Story Of The 1972 Munich Olympics Massacre And The Israeli Revenge Operation 'Wrath Of God'* was turned into an Oscar-winning documentary film.

Simon takes a weekend break in Nottingham...

zones – what has been the most memorable so far?

SR: That's a tough one. I've been to around 70 countries for the BBC in the past six years alone, and there's been endless memorable moments. I can honestly say that when we're on the road there hasn't been a single day when I haven't learnt something new or been confronted by an extraordinary new sight. If I had to pick just one memory it would be dropping in to a refugee camp on the Kenya-Somali border and meeting a bright young woman called Fatimah, who had spent almost her entire life in the camp, forbidden to travel more than 4km from the centre by the Kenyan government. An accident of birth meant I have a magic British passport enabling me to flit around the globe. That encounter helps me to remember that travel is an enormous privilege.

HIW: You've tackled some hard-hitting serious subjects throughout your writing and presenting career, what has been the most disturbing experience of your investigations and have you ever feared for your safety?

SR: I've travelled through the Congo, which has endured the most violent conflict on the planet since the Second World War, and to Mogadishu, perhaps the most dangerous city in the world. I've been held up against a wall by militant supporters of bin Laden and arrested by the KGB. But one terrifying moment on the tropic of Cancer journey was travelling into Burma, on a covert, illegal little incursion with two colleagues to meet the forgotten Chin people, who suffer appalling human rights abuses at the hands of the Burmese military regime. We had to sneak through an area with more than 50 Burmese military bases and eventually had to flee through the night from a patrol of soldiers.

HIW: You've travelled the globe and visited more places than most, where is still on your "to visit" list.

SR: I've been amazingly fortunate and I've travelled to around 100 countries. But yes there are still lots of places on my wish-list. I'd love to visit Central America, west Africa, Russia, Japan, Canada, New Zealand and spend more time exploring the Middle East. It's an amazing world and there's so much more I'd love to learn about what makes it tick.

HIW: Which modern gadget would you not leave the house without? And when it comes to working in the field, do you carry one particular piece of essential kit?

SR: I'm big on kit. I always take a micro Streamlight torch attached to a Swiss Tech Utili-Key, and a CashStash capsule. When we're filming we're often days from a doctor, and I'm the main medic, so we have a full medical trauma kit with saline drip and fold-out stretcher. Personally I rely on a black Leatherman Wave. When we went into Burma covertly I used an amazing Gregory Z55 backpack and we had ropes, food, water, locator beacons, machetes, camouflage equipment and Hennessy hammocks, plus our camera equipment of course. And we had survival kits strapped to our legs in case we had to hide in the jungle from Burmese troops.


100 countries down, approximately 100 left!

HIW: What is next on your to-do list? Now you've completed your "Tropics" adventures, are there any new dangerous/globe-trotting projects coming up? Have you ever been to the poles?

SR: I was away for more than nine months last year so I need to spend some time at home with my family and friends. And I also have a rather long list of DIY jobs that need to be done first. However, when they're finished no doubt my feet will start to itch and I will get the maps out and try to think of another travel project. The poles? Now there's an idea... thanks, How It Works!


Author and broadcaster Simon Reeve travelled to 18 countries on his journey around the tropic of Cancer, which has now been released as a DVD boxset.

"I can honestly say that when we're on the road there hasn't been a single day when I haven't learnt something new or been confronted by an extraordinary new sight"

2005 BBC series *Holidays In The Danger Zone: Places That Don't Exist* saw Simon presented with a One World Award for his outstanding contribution to greater world understanding.

2008 After contracting and surviving malaria while making the BBC series *Equator* in Gabon, Simon became an ambassador for the Malaria Awareness Campaign.

2009 Following his similar shows exploring the equator and the tropic of Capricorn, in Simon's current six-part series for the BBC, *Tropic Of Cancer*, he travels to 18 countries as diverse as Bangladesh, Mexico and the Bahamas.

2010 > PRESENT This year Simon will be doing a spot of DIY and catching up with friends and family.

This month in **Environment**

If you were ever a fan of the television shows and films created by prolific undersea explorer Jacques Cousteau then the feature beginning on this very page will be right up your Gulf Stream! Cousteau had a desire to reveal unknown and inaccessible places beneath the sea. While we can't offer the insights that his illustrious film career provided, our Environment feature will give you a remarkable look into the work contemporary oceanographers are undertaking today.

© Alex Pang

Plunge into the mysterious depths of the world's final frontier

Exploring the oceans

The oceans cover 70 per cent of the Earth's surface and contain more than 90 per cent of its life, yet we have explored less of the deep ocean than the surface of Venus or Mars. Satellites and new technology like buoys mean marine scientists know more about the ocean than was even remotely possible 30 to 40 years ago. But we are still only skimming the surface. In 2004 alone, a Norwegian-led expedition found 300 new fish species and glimpsed a rather mysterious creature.

The abyssal depths – the ocean over 4km below the waves – are an alien world just a few degrees above freezing. The mass of water above extinguishes every last drop of light and, at the deepest point on Earth, exerts pressures similar to holding up 48 jumbo jets. Today, scientists mainly use robots to study bizarre deep ocean ecosystems and the ocean bed. Building manned submersibles to survive the intense pressures of the dark, icy, ocean depths is an engineering challenge comparable to space travel.

Yet the oceans are critical to the Earth's climate. They can store and release huge amounts of heat with only a small change in temperature. This makes the climate of coastal lands milder than the interior of the Earth's continents. Around half the excess carbon dioxide released by human activity over the last 200 years has been absorbed by the oceans, and is often locked up in the shells or skeletons of marine organisms. If these fossilise on the sea floor, the carbon dioxide can remain trapped for millions of years.

5 TOP FACTS CREATURES OF THE DEEP

Real-life Kraken
1 Colossal Squid are Earth's largest invertebrates. Rarely seen, they could be up to 15 metres long, weigh over 1,000lbs and can have beach ball-sized eyes.

Deadly jellyfish
2 Box jellyfish may be the world's most poisonous marine creatures. Their venom can kill a human in a matter of minutes if not treated swiftly.

Living fossil
3 Modern coelacanths are almost identical to fossil specimens from 65 million years ago. Extremely rare, their bodies exude oils even when dead.

See-through head
4 Barreleyed fish can rotate their eyes upwards inside a transparent dome on their head, most likely so they can distinguish the silhouettes of their prey.

Enormous appetite
5 The Gulper or Pelican eel has a hinged jaw and expanding stomach to swallow prey much larger than itself, and uses its whip-like tail for movement through the water.

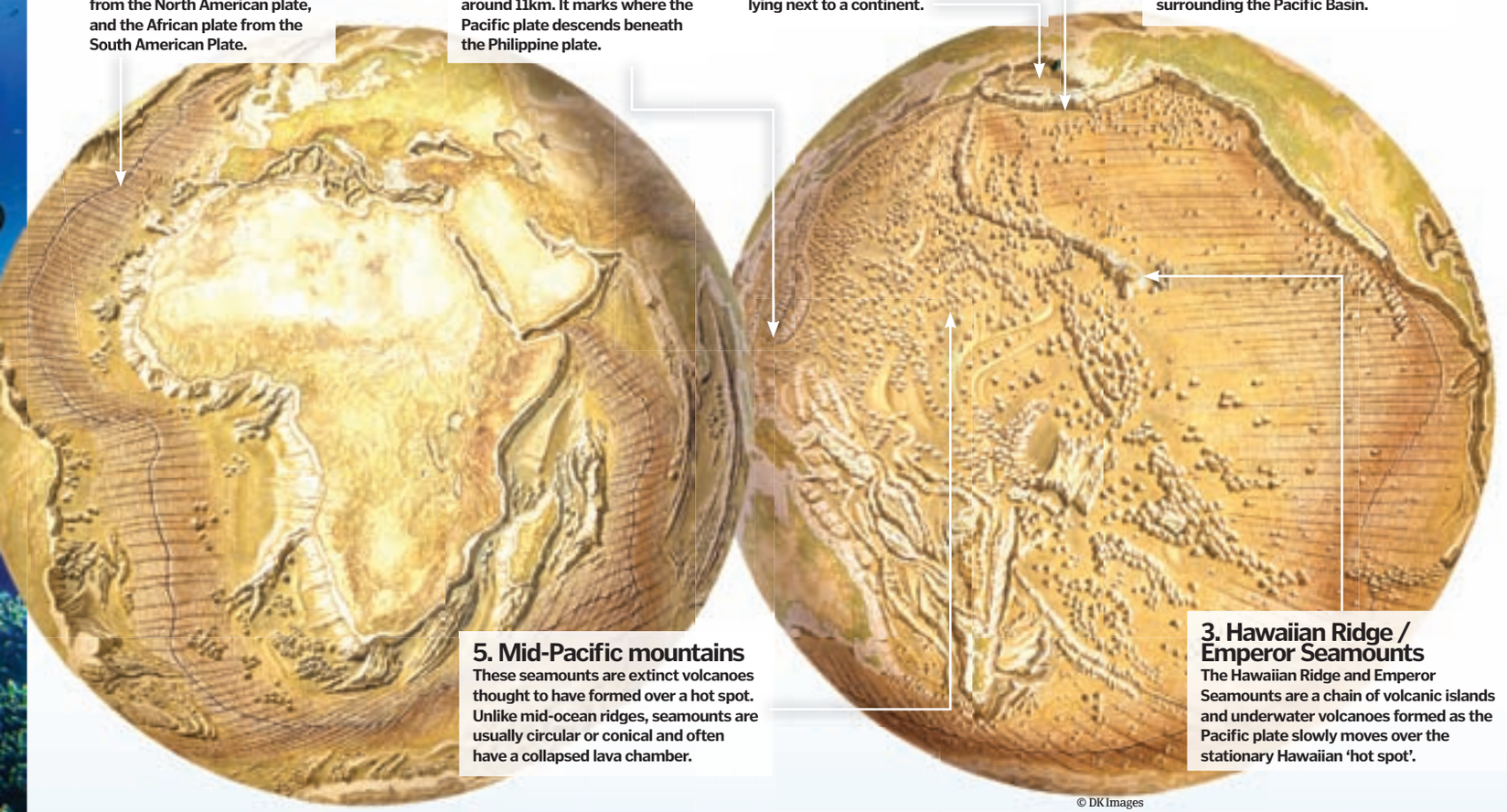
DID YOU KNOW? *Oceans contain around 1.36 billion cubic kilometres of seawater, more than 97 per cent of the Earth's water*

Bottom of the deep blue sea

The sea floor's hidden terrain as illustrated without the world's oceans

The mid-ocean ridge system that snakes around the continents is the world's largest volcanic feature and the longest mountain chain on Earth, stretching more than 56,000 kilometres. The Earth's outer shell is a jigsaw of huge, moving plates and at mid-ocean ridges the plates move apart. This causes molten rock from the Earth's interior to rise to the surface and cool into bumpy, new ocean floor.

Deep-sea trenches form when one plate slides under another. The descending ocean plate releases water, which reduces the melting point of the hot rock below the crust. Molten material rises to the surface where it forms seamounts – undersea mountains – or islands. The continuous creation and destruction of sea floor means the oldest ocean-floor rocks are just 180 million years old. Scientists can date rocks using magnetism. The Earth's magnetic field periodically flips and when new sea floor cools, it preserves a memory of the magnetic field at that time.



1. Mid-Atlantic Ridge
The Mid-Atlantic Ridge was the first mid-ocean ridge discovered. It separates the Eurasian plate from the North American plate, and the African plate from the South American Plate.

2. Mariana Trench
The Challenger Deep at the bottom of the Mariana Trench is the deepest point on Earth – around 11km. It marks where the Pacific plate descends beneath the Philippine plate.

4. Aleutian Basin
The Aleutian Basin is a 'abyssal plain' – a large area of flat sea floor at a depth of 3,000 to 6,000m, usually lying next to a continent.

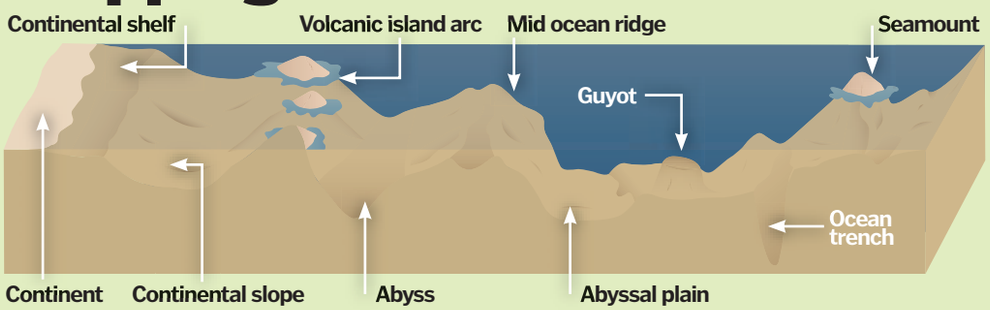
6. Aleutian Trench
The Aleutian Trench lies on the so-called Pacific 'Ring of Fire' – a series of oceanic trenches and active volcanoes surrounding the Pacific Basin.

5. Mid-Pacific mountains
These seamounts are extinct volcanoes thought to have formed over a hot spot. Unlike mid-ocean ridges, seamounts are usually circular or conical and often have a collapsed lava chamber.

3. Hawaiian Ridge / Emperor Seamounts
The Hawaiian Ridge and Emperor Seamounts are a chain of volcanic islands and underwater volcanoes formed as the Pacific plate slowly moves over the stationary Hawaiian 'hot spot'.

Mapping the sea floor

Sonar (sound navigation and ranging) technology revolutionised mapping of the sea floor. It uses sound waves to measure the distance to the ocean bottom. Typically, an underwater speaker towed behind a boat sends out pulses of sound. These sound waves travel downwards, bouncing off objects they hit like fish shoals, shipwrecks and the ocean floor. A microphone listens for reflected sound. The time echoes take to return from the ocean floor is roughly equal to its depth: echoes from undersea mountains arrive quicker than sound returning from deep-sea trenches. Sonar has also helped scientists discover undersea volcanoes, plains and the enormous ranges of underwater mountains called mid-ocean ridges.



"Near-surface ocean currents are driven by the Earth's prevailing winds"

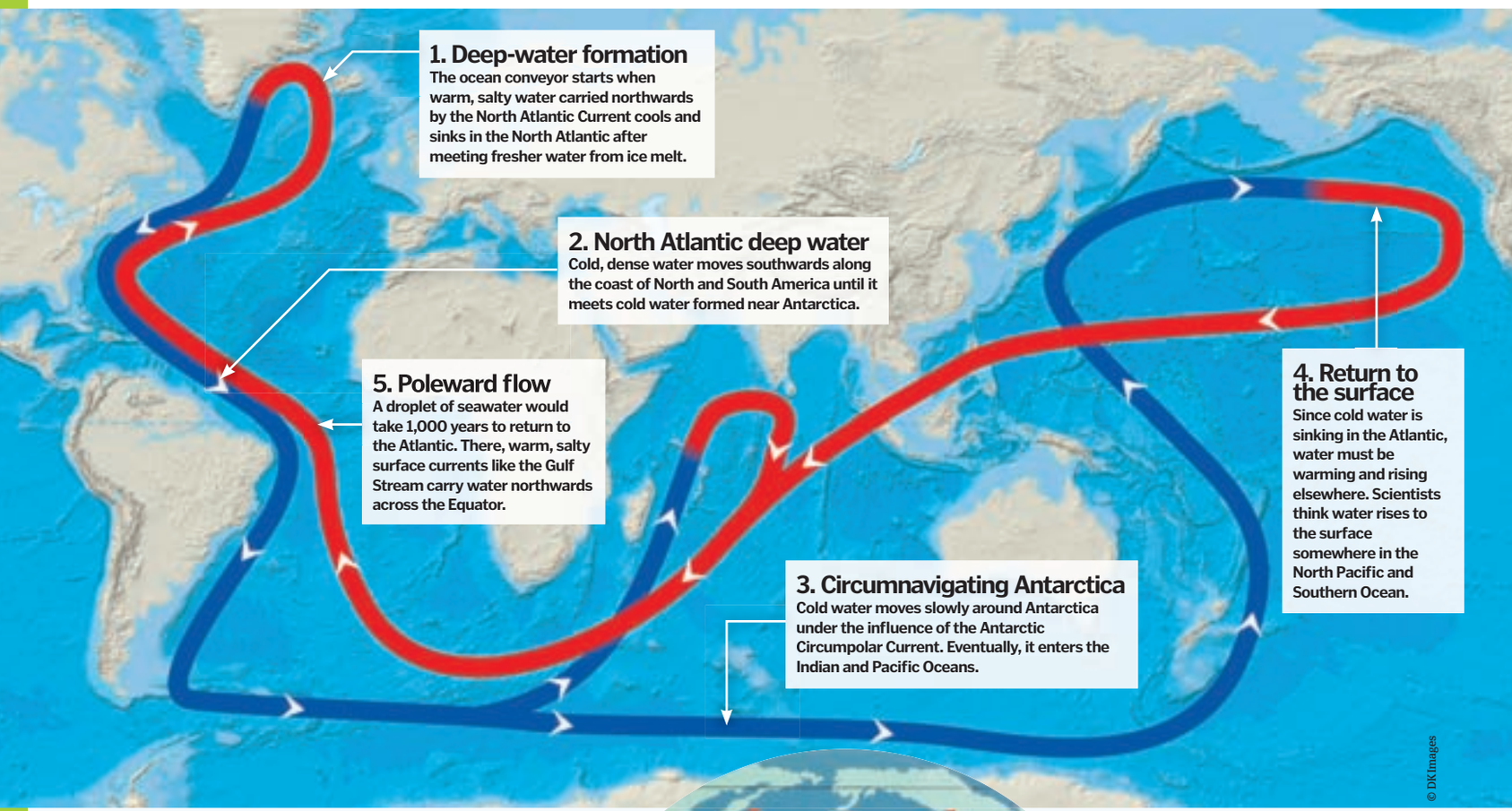
The motion of the ocean

Discover the Earth's constantly moving ocean currents

Ocean currents have a major effect on the Earth's climate, ultimately because they carry heat between the equator and the poles.

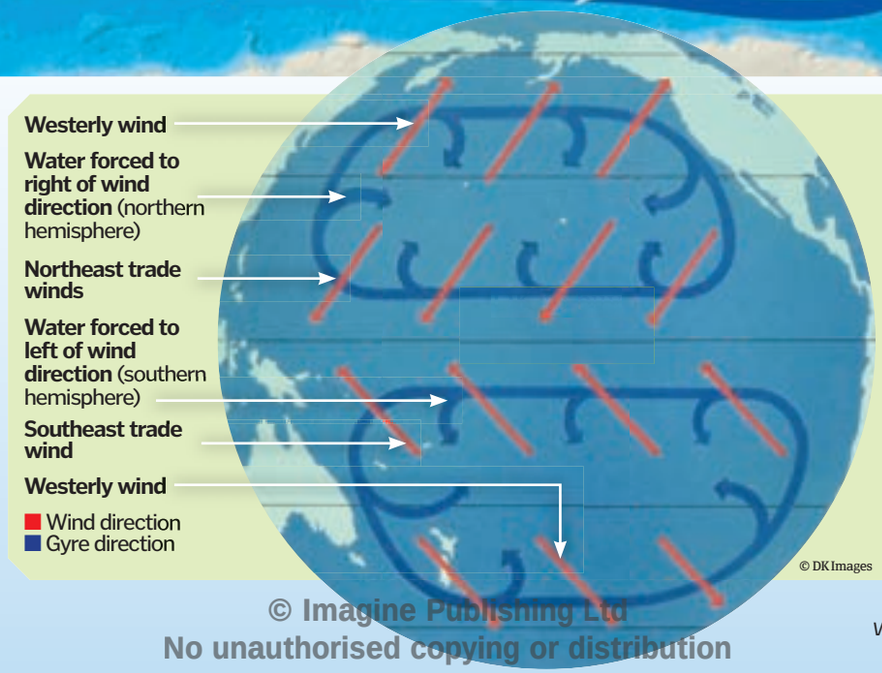
Near-surface ocean currents are driven by the Earth's prevailing winds, which are – in turn – powered by the Sun. The currents appear to flow along curved paths or in huge circles called gyres. This is partly because the prevailing winds curve due to the Earth's spin. It's also because the seawater moves in a spiral, which is down to friction between the surface water close to the winds and slower-moving water underneath.

Deep ocean currents are mainly driven by cold, salty water sinking when it comes into contact with warmer, fresher water. Cold, salty water is much denser than warm, fresh water. Water can also sink if the wind pushes it towards a coast, forcing it downwards. Evidence exists for a large-scale circulation involving deep-ocean and surface currents called the thermohaline circulation or global ocean conveyor.



The Gulf Stream

The Gulf Stream is a fast, northeast-flowing ocean current that carries warm, salty water from the Gulf of Mexico to the North Atlantic. Near Newfoundland, Canada, it splits into several currents. The largest is the North Atlantic Current, which flows towards Europe and is widely thought to warm UK winters by 5°C. The current cools as it travels north. Eventually, as salty water is denser than fresh, it sinks and flows back towards the equator.



Pacific gyres

Gyres are large current systems usually caused by major winds. There are five major ocean gyres on Earth and as you can see in this illustration of the two Pacific gyres – the North Pacific Gyre and the South Pacific Gyre – the two circular systems are driven by wind that pushes water at right angles to the wind's direction.

BIG

1. Indian Ocean

Total area: 68.556 million km²
Lying between Africa and Australia, the Indian Ocean is the world's warmest ocean, mainly because it lies mostly in the tropics.

BIGGER

2. Atlantic Ocean

Total area: 76.762 million km²
Often spilt into two sections – north and south – the Atlantic Ocean separates Europe and America and is the youngest of the world's oceans.

BIGGEST

3. Pacific Ocean

Total area: 155.557 million km²
The Pacific covers around a third of the Earth's entire surface. El Niño – a climate disturbance with worldwide effects – occurs in it.

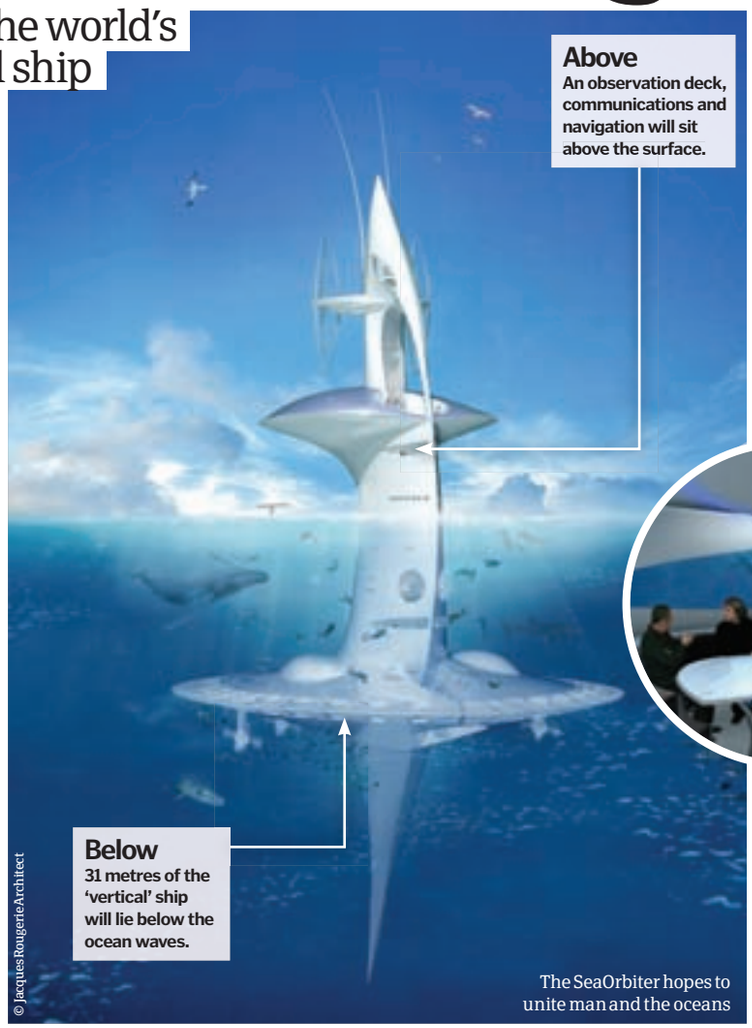
DID YOU KNOW? *The Earth's first oceans formed 4,000 million years ago*

SeaOrbiter – floating science lab

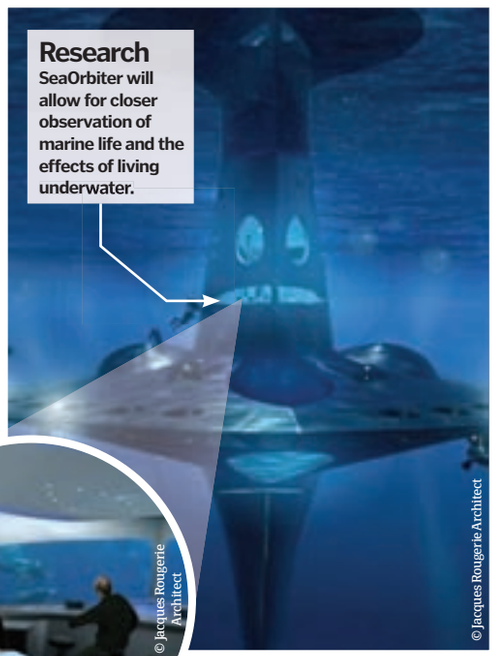
A closer look at the world's first ever vertical ship

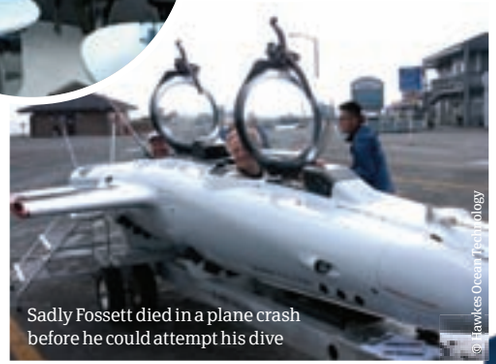
With France's first astronaut on the design team, SeaOrbiter could become the undersea equivalent of the International Space Station. Currently a prototype, its architect inventor Jacques Rougerie has already secured half the £32 million needed to build the first one. If he succeeds, it will be the world's first floating sea station and – at 51m high – the first 'vertical ship'. A lookout deck, communications and navigation will sit above the surface, while 31 metres of the station will lie beneath the waves.

If it sets sail, SeaOrbiter will host 18 crew including six scientists and six others, such as astronauts training in extreme conditions. As it drifts in the ocean currents, scientists will study marine life, pollution, how climate change affects the oceans, and the effects of long-term living underwater. A pressurised underwater deck will allow eight 'aquanauts' to dive underwater without needing to readjust to atmospheric pressure.



The SeaOrbiter hopes to unite man and the oceans





Sadly Fossett died in a plane crash before he could attempt his dive

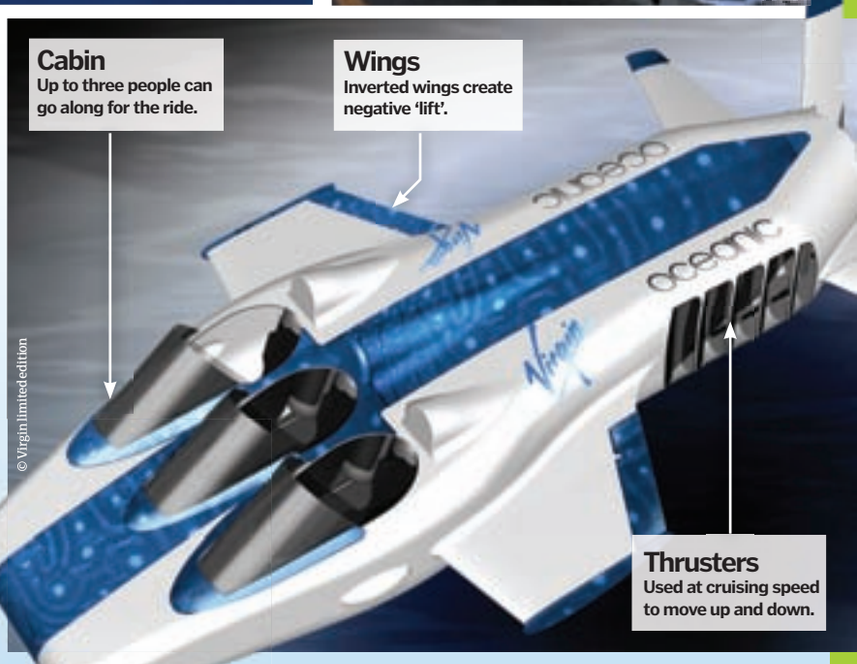
DeepFlight

DeepFlight is a revolutionary submersible that could allow scientists to fly around the deep ocean

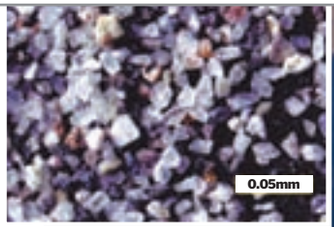
Created by engineer Graham Hawkes, DeepFlight submersibles don't use ballast to rise and sink, unlike traditional submersibles. Instead, they work a bit like an upside-down aeroplane. Inverted wings generate 'negative' lift and, at cruising speed, they use thrusters to manoeuvre up and down.

This means they can descend quickly: DeepFlight Challenger, a submersible built for adventurer Steve Fossett to attempt a record-breaking solo dive to 11,300m, can descend at 107m/s. Compare this to 42m/min for Alvin, a US research submersible. Faster descents mean more time spent investigating the ocean floor.

Hawkes Ocean Technologies (HOT) – the manufacturers of DeepFlight – could be a leading competitor for a £6 million 'Ocean X Prize' to be announced later this year. One challenge could be to build a vehicle able to carry scientists to the Challenger Deep. Today, only six manned research vessels can travel below 4,000m: Alvin, MIR-1 and 2 (Russia), Shinkai 6500 (Japan), Nautile (France) and Harmony (China).



"Side effects include a liquid-cement substance forming in the lungs"



A super close-up image of volcanic ash

© NASA

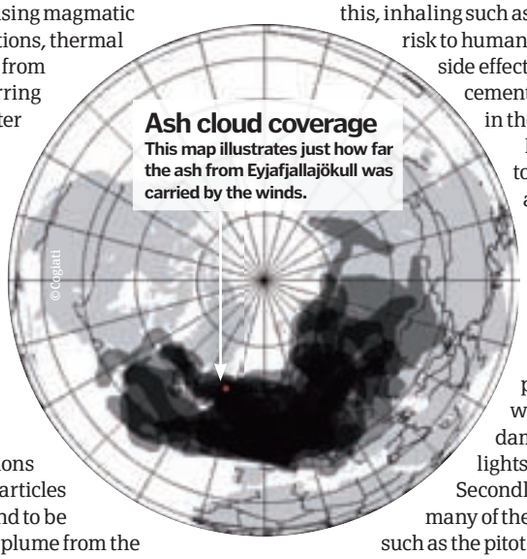
Mt Cleveland, a composite volcano, erupts sending volcanic ash spiralling into the atmosphere

Volcanic ash

What is volcanic ash, where does it come from and how did it disrupt Europe's entire airspace?

Volcanic ash consists of exceptionally small bits of pulverised rock and glass, no bigger than two millimetres in diameter, created when volcanoes erupt. The formation of volcanic ash can occur in three different ways: gas release under decompression causing magmatic (magma flow) eruptions, thermal contraction caused from quick cooling occurring on contact with water (this causes phreatomagmatic eruptions), and the ejection of entrained particles during steam-based eruption, leading to phreatic eruptions (highly explosive). In any case, the violent nature of the eruptions causes many tiny particles of rock, clay and sand to be projected in an ash plume from the volcano, as solid rock and magma is separated under the dynamic and explosive activity.

Volcanic ash is spread from its initial plume – which consists of a mixture of steam and ash particles – by weather systems, with ash often (as with the recent case in Iceland, Britain and Europe) being carried and sometimes deposited over hundreds of miles. If the ash is distributed in great quantity over one area then a powdery dust-layer is formed, a process referred to as ashfall. Unlike the ash typically formed when combustible materials such as wood are burned, this ashfall is hard and abrasive, and does not dissolve in water. Due to this, inhaling such ash is a severe health risk to humans and animals, with side effects including a liquid-cement substance forming in the lungs.



Ash cloud coverage
This map illustrates just how far the ash from Eyjafjallajökull was carried by the winds.

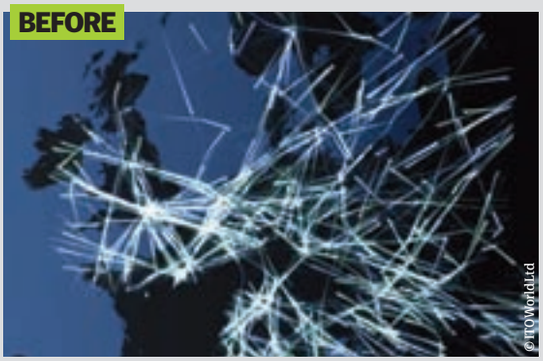
© Cojiati

Importantly and topically, volcanic ash also affects aircraft in a variety of ways. Firstly, the ash has a sandblasting effect on any aircraft, with the billions of particles colliding with its fuselage and damaging its landing lights and main body. Secondly, ash can clog many of the aircraft's sensors, such as the pitot tubes (pressure measurement) and, because the ash's particles are charged, communication radios. Thirdly, and potentially with the worst consequences, ash can cause combustion power failure (see 'Power loss' boxout), leaving the plane with no engine thrust and minimal chance of landing without a catastrophic crash.

Dead air

See how Britain and Europe's airspace was shut down due to volcanic ash

BEFORE



© ITOWorld Ltd

This image shows relatively normal airspace activity for Europe (data for the south of France is absent), with hundreds of flights departing and arriving over a 24-hour period.

AFTER

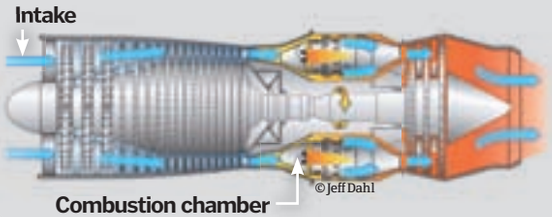
© ITOWorld Ltd

However, this image taken on 17 April – during the heart of the ash crisis – shows how few flights were in operation, with only a couple of aircraft managing to progress as usual.

Power loss

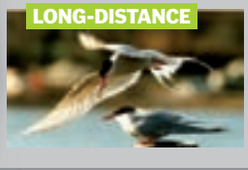
How volcanic ash shuts down jet engines

Volcanic ash is a very fine powder that consists of tiny particles of rock and glass. These particles are normally harmless to humans, however when jet engines are involved, they can prove a real danger to the safety of any plane. When the ash is sucked into the jet engine – a constant and large supply of air is needed for the engine to operate properly – its tiny particles are compressed and heated up within the combustion chambers, causing them to melt under the immense internal temperature and form molten glass on the turbine blades, jamming them and causing the plane to lose power.



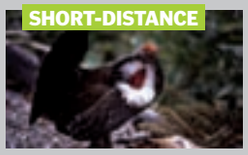
© Jeff Dahl

Head to Head MIGRATORY BIRDS



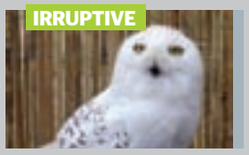
LONG-DISTANCE

1. Arctic tern
Arctic terns travel around 70,900km (50,000 miles) during their annual meandering migration from Greenland all the way to Antarctica.



SHORT-DISTANCE

2. American blue grouse
This species migrates a maximum of 480km (300 miles) to find wintering grounds that are rich with pine needles.

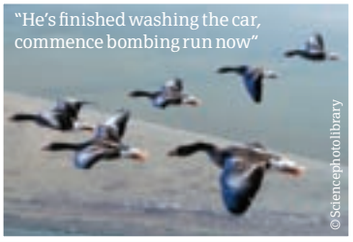


IRRUPTIVE

3. Snowy owl
When lemmings are scarce, these arctic predators will migrate as far south as Texas and Florida in search of prey, much to the delight of local birdwatchers.

DID YOU KNOW? *During its migration across Asia, the bar-headed goose cruises at an altitude of 9,000 metres (29,500ft)*

Bird migration



Guided by stars and driven by genes, birds embark on epic annual journeys

Birds don't migrate because of the cold. A little snow won't actually kill them, but a scarce food supply will. Birds migrate to follow the bugs, worms or baby rabbits, but the "why" of migration isn't nearly as fascinating as the "how".

There are two skills that all migratory birds must possess: orientation and navigation. Orientation is the ability to determine the direction in which you're travelling. Birds don't have compasses or GPS devices, but they can orient themselves using the position of the Sun by day and the stars at night. Some birds, like pigeons, can orient themselves against the Earth's magnetic field.

As for navigation, there are several theories, but no definitive answers. Some birds are believed to 'pilot' from one point to the next using large landmarks like coastlines, mountain ranges and even four-lane highways. Other birds learn the migration route by following older birds that have already made the trip. But the most remarkable birds are those who are born with a mental map imprinted into their DNA, able to make difficult long-distance journeys without any outside assistance.

Soaring birds like hawks and pelicans do most of their flying during the day to capitalise on rising thermal drafts. Smaller birds that rely on powered flight mostly fly at night when the atmosphere is more stable.

Birds orientate themselves using the sun by day and the stars by night

Migration routes

There are nearly as many migration routes as there are species of migratory birds. Almost all routes have a north-south orientation, since most birds are escaping their northern breeding grounds in the late fall to settle into their wintering territory further south. In North America, there are four main 'flyways' guiding birds from Northern Canada down to Mexico and South America. In Europe, many species breed near the arctic and follow dozens of routes to winter in the African plains.

Other routes aren't so easy. The short-tailed shearwater draws a looping figure of eight across the Pacific Rim. California gulls breed in Yellowstone National Park and fly west before turning south to their Southern California breeding ground (the direct route would take them over inhospitable desert.) But no migration route can top that of the tiny arctic tern, which travels from Greenland to Antarctica along the African and South American coasts, often covering more than 81,000km each year.

Innate vs learned behaviour

What we commonly call 'instinct' is the same thing that animal researchers term innate behaviour. The lives of most insects, birds and even mammal species is wholly dominated by behaviour that is biologically inherited through their DNA. Although we attribute bird migration to the change of seasons and temperature, even captive birds with no access to natural light or shifting temperatures exhibit zugunruhe or 'migratory restlessness' at the same exact time as their brethren in the wild.

Animals can, however, learn how to build on their own innate intelligences. Sheep dogs are natural herders, but become highly efficient when they are trained by a shepherd. Wild orangutans are born with excellent vocal and visual communications skills, but can be taught to apply those same skills using computer programs.

ON THE MAP

Which birds go where?

Northern wheatear 16,000km
Alaska to Africa

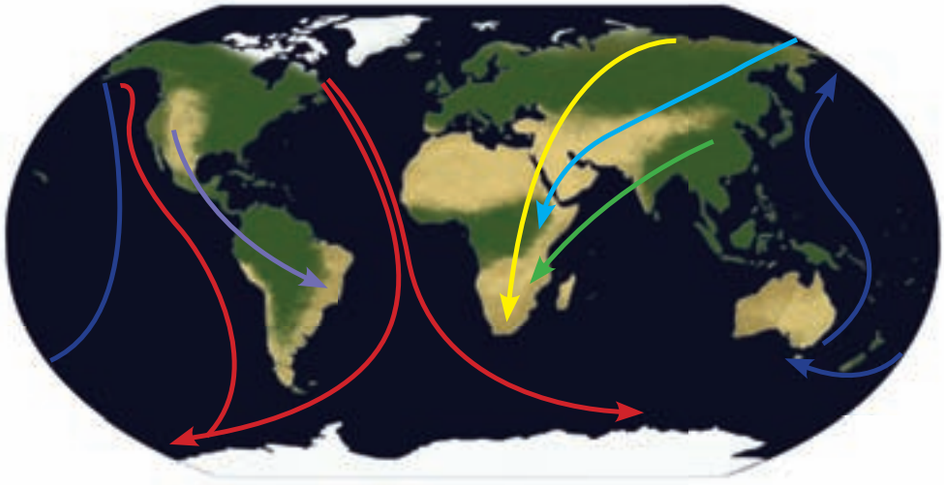
Arctic tern 80,000km
Greenland to Antarctica

Amur falcon 11,200km
North East Asia to Africa

Short-tailed shearwater 11,200km
South Australia to Alaska

Ruff 9,600km
Siberia to South Africa

Swainson's hawk 8,000km
North America to Brazil



"Camp IV is the point of no return for climbers attempting to reach the summit"

Mount Ever

How do climbers tackle the world's highest mountain?

There are two main routes used by climbers to reach the summit of Everest, the North Ridge Route – which begins in Tibet and is a technically harder climb – and the South Ridge Route, which starts in Namche Bazaar, Nepal, and is the easier and more popular way up top. Within these two routes there are roughly 15 different ways to reach the summit of the mountain, a choice that rests on the experience and number of people ascending.

The South Ridge Route, which is the focus of this guide, is split into five camps (including Base Camp) and takes on average four days for its climbers to reach the summit. This route technically begins at Base Camp (5,380m), a six to eight day hike from Kathmandu that allows climbers to acclimatise to the higher altitudes. Once acclimatised at Base Camp, climbers are then forced to cross the Khumbu Icefall, a treacherous series of ice sheets, crevasses and shifting blocks that have claimed the lives of many Sherpas and mountaineers. With the help of fixed ropes and metal ladders however, climbers can then progress up the Icefall to Camp I (6,065m).

From Camp I climbers then continue up the Western Cwm (Cwm is pronounced 'coom'), a relatively flat, gently sloping glacial valley nicknamed the 'Valley of Silence' due to its lack of wind, to the bottom of the Lhotse face where Camp II (6,500m) is situated. From there, climbers must then ascend the Lhotse face by a series of fixed ropes up to Camp III (7,470m), which itself is positioned on a small, narrow shelf of rock, snow and ice. 500 metres on from Camp III lies the last of the five camps on Everest's South Col (Camp IV – 7,920m) and at the start of the Death Zone, the point where the levels of oxygen cannot sustain human life over extended periods of time.

Camp IV is the point of no return for climbers attempting to reach the summit, and for many, this is the point where a summit ascent ends, as if the weather does not suit it is impossible to continue. Providing all is well however, climbers then make

South Col
The easier climb of both main routes is from the south and consists of five camps (including base camp).

North Col
The harder side to climb Everest from is to the north and begins in Tibet.

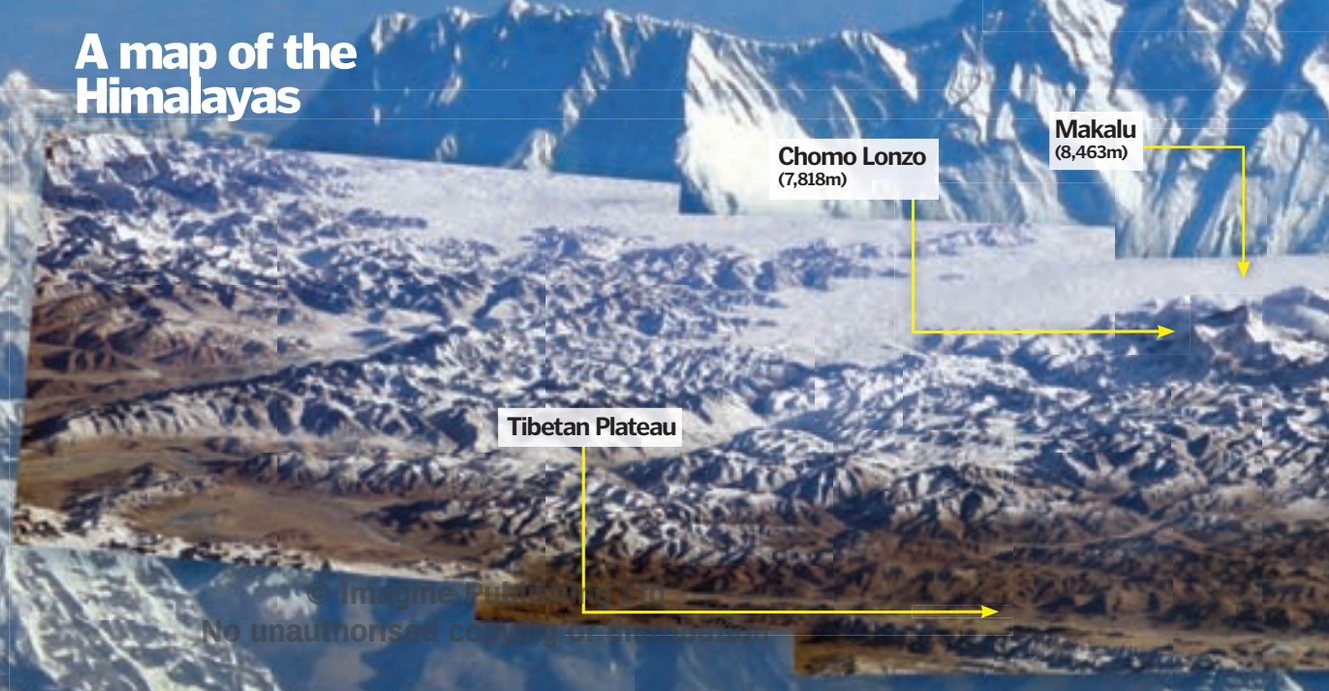
Highest
The summit of Everest is the highest position on Earth. The views are spectacular.

The Statistics

Mount Everest

Name: English – Everest
Tibetan – Chomolungma
Height: 8,848m (29,029ft)
Deaths: 216
Routes to summit: 15
Camps: 5
Climbing cost: $25,000 (average permit)
Climbing season: May, September and October

A map of the Himalayas



5 TOP FACTS EVEREST

Colonial
1 Mount Everest was named after the Surveyor General of India, George Everest, in 1865. Interestingly, Everest himself actually disapproved of the name.

Partnership
2 The first successful accent of Mount Everest was completed back in 1953 by New Zealander Edmund Hillary and Tenzing Norgay, a Nepalese Sherpa.

Close shave
3 The very first aircraft to fly over the peak of Mount Everest was an RAF Westland PV3 in 1933. Its crew recorded that they only just scraped over the summit.

Death toll
4 Out of the 216 people who have died on Everest, 150 of their corpses have never been recovered, with bodies purposely left due to safety considerations.

King of kings
5 Everest beats its closest competitor, Pakistan's K2, in raw height by 227 metres. This fact comes despite K2 being the harder climb out of the pair.

DID YOU KNOW? *There are only 14 mountains on Earth that are over 8,000 metres in height above sea level*

rest

their final and most dangerous push to the summit, a task which must begin between 12 and 1am in order for the ascent and descent to be made in a single day. Between the camp and the peak lies two imposing obstacles, the 'Cornice traverse' – a knife-edge horizontal ridge with the 2,400m southwest face on one side and the 3,050m Kangshung face on the other – and then, at the end of the traverse, the daunting 'Hillary Step' 12-metre high rock wall. Again through a series of fixed ropes, climbers must ascend this to reach the gentler – albeit heavily exposed – slopes that wind their way to the summit (8,848m).


© Luca Galuzzi

The summit of Everest lit up by the morning Sun

Base camp is surprisingly busy during climbing season


© Uwe Gill

Whatever you do, don't look down!

The kit...

Climbing Everest requires a host of essential equipment

- ☑ 5-7 x **Oxygen canisters**
- ☑ 1 x **Satellite phone**
- ☑ 1 x **Two-way radio**
- ☑ 1 x **Harness**
- ☑ 2 x **Ice axe**
- ☑ 2 x **Ski poles**
- ☑ 1 x **Altimeter**
- ☑ 1 x **Rappel device**
- ☑ 4 x **Crampons**

©Shrimpo1967

Surviving mountains

A selection of top tips from experienced mountain climbers

1. Training is key
Plan ahead and undertake strict cardiovascular and weight-based training consistently throughout the 12-month run-up to the climb. Taking supplements to your diet is also recommended.

2. Mentally prepare
It is going to be harder than you think. Despite the guide being present you're not going to be dragged up the mountain by them.

3. Be patient
There will be a lot of down-time in order to allow for acclimatisation. Learn to relax while you have the opportunity as you'll need the energy later.

4. Cost it out
Climbing any mountain over 8,000 feet is very costly, both in terms of equipment and permits, and the last thing you should do is compromise on your kit quality.

5. Understand the risks
Many climbers never return from mountains, while others suffer from side-effects such as alpine trench foot, hypothermia and frostbite, or even acute mountain sickness.

Despite the freezing temperatures, Sherpas wear very little

This month in **Transport**

Have you ever had problems displaying the extensive nature of your huge fortune to the rest of the world? If – somewhat improbably – the answer to this question is yes, then maybe you're in need of a mega yacht. Nothing screams "look at my wealth!" like a few million quids' worth of boat moored off your own private island, and our main feature this issue looks at the most luxurious, most powerful and most beautiful sea-faring craft that money can buy. So, which one do you fancy?

28 Hot air balloons

31 Crash test dummies

32 Martin Jetpack

TRANSPORT

Mega yachts

A statement of power and prestige, super yachts boast some of the most advanced designs, technology and equipment in the world

YachtPlus 40 'Signature Series' Ocean Pearl

Designed by the notable architect Norman Foster, the YachtPlus 40 'Signature Series' brings a contemporary style to nautical tradition

The 40-metre long Ocean Pearl, the latest iteration of YachtPlus's 'Signature Series' of super yachts, was the culmination of a design process that took over 15 months by a team of seven architects under the stewardship of Lord Norman Foster, and the technical prowess of the Rodriquez shipyard in Italy. The result is a yacht with over 30 per cent more space than on any other yacht in its category.

The Ocean Pearl is powered by twin 1,044kW Caterpillar C32 diesel engines, which allow a top speed of 17.5 knots and a regular cruising speed of 16 knots: at the latter speed allowing a maximum range of 2,400 nautical miles. Fuel consumption lies at 127 litres per hour at 12 knots. The hull and superstructure are both built from pure aluminium, allowing unparalleled lightness, and the Ocean Pearl's displacement lies at 205 tons at half-load.

On board there are a host of luxury amenities and facilities (bar, saloon, pool, full-beam owner cabin, two VIP cabins, two guest cabins) as well as a complex and fully integrated computation and lighting system. Powering the Pearl are twin 86kW generators, which keep the lighting, navigation and communication systems going, as well as its twin CRQ anchors, twin 3,100 litres per day water makers and submergible beach deck.

5 TOP FACTS
SUPER YACHTS

Billion-dollar man
1 The Eclipse yacht of Russian oligarch and football club owner Roman Abramovich cost an estimated $1.2 billion. It comes complete with missile warning system and submarine.

Gilbert and Sullivan
2 The Eclipse is also staffed by over 70 permanent sailors, crew members and cabin staff and features a floating harbour at the rear for the many tenders.

Master craftsmen
3 It would seem that the Germans are the kings of the super yacht. In fact, German ship builders built all but one of the top-ten largest yachts in the world.

Pass the binoculars
4 The second longest yacht in the world, the Dubai, is over one and half times longer than Manchester United's football pitch. It was built by Blohm + Voss & Lürssen.

Friend-ship
5 Le Grand Bleu, the world's 17th largest private yacht, was given away by Roman Abramovich to his compatriot Evgeny Shvidler. It wasn't gift-wrapped, however.

DID YOU KNOW? *There are only three yachts in the world with a length greater than 150 metres*

Lürssen Arkley

The latest and arguably most advanced yacht built by master craftsmen Lürssen, the Arkley super yacht aims to bring an unprecedented level of luxury to its owners

Lengthier and more voluminous than the smaller 40-metre Ocean Pearl, the Arkley by Lürssen is characteristic of the latest generation of super yachts.

In terms of raw stats the Arkley doesn't disappoint, sporting a 60-metre length and a displacement of 1,071 tons, the yacht is powered by twin Caterpillar 3512 B 1,455 kW diesel engines that produce a combined 3,958 hp. This colossal power allows for a top speed of 15.5 knots and a max range of 7,000 nautical miles. It is not short of juice either, with the yacht packing three Caterpillar C18 generators that provide the ship's electronics with a total 903kW of energy. Fuel capacity lies at 160,000 litres while fresh water capacity clocks in at 30,000 litres, both of which meaning refuelling is a rarity.

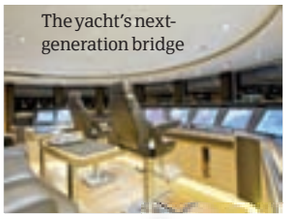
State-of-the-art technology comes in the form of its steel hull and aluminium superstructure, twin Reintjes WAF 742 gearboxes, twin Rolls Royce / Tenfjord SR562 FCP steering gears, Jastram 40 F BU 3038 – 200kW bow thrusters and Quantum QC 1800 stabilisers. On-board the integration of advanced technology continues with all guest suites' windows dressed with low noise electronic blinds, wall-integrated LCD televisions, a complex in-built speaker and audio system, single ducted air conditioning system, and even a fully functioning cinema.

The Statistics
Ocean Pearl

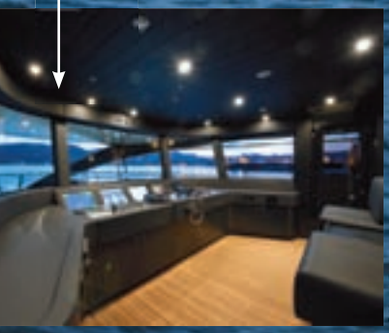
Designer: Foster + Partners
Builder: Rodriquez Cantieri Navali
Cost: $20 million
Length: 41m (134ft)
Propulsion: 2 x 1,044kW Caterpillar C32 diesels
Displacement: 205 tons (half-load)
Max speed: 17.5 knots
Range: 2,400Nm

Most luxurious
Here's what 60 metres and 1,071 tons of luxury looks like

The yacht's next-generation bridge



Captain's control room
The control station for the entire yacht; communication, direction and navigation systems are used here



© YachtPlus

Panoramic saloon
One of the most open areas of the yacht, the panoramic saloon offers aft, side and forward views

© Lürssen

Hot tub up top
The top deck features the obligatory jacuzzi and sun deck

The Statistics
Lürssen Arkley

Designer: Exterior – Espen Oeino / Interior – Mark Berryman
Builder: Lürssen Yachts
Cost: Undisclosed
Length: 60m (196ft)
Propulsion: 2 x 1,455kW Caterpillar C32 diesels
Displacement: 1,071 tons
Max speed: 15.5 knots
Range: 7,000Nm

"The 118 was raced against the Pagani Zonda hypercar"

118 WallyPower

So futuristic it was used in the Hollywood movie The Island, the 118 WallyPower takes yacht power and performance to a whole new level

Concealing its every function in order to maintain the high engineering content of the yacht, as well as preserve its futuristic and sleek lines, the 118 WallyPower has arguably the most advanced aesthetics of any yacht in operation today. While small – the 118 measures in at 36 metres – it boasts a massive power output, allowing it to cruise at speeds of 60 knots (70mph), a speed that obliterates other larger and statelier yachts. For this reason alone it must be classified as not just a 'motor yacht', but a 'fast motor yacht'.

Power, then, is central to the 118 and it supplies this colossal amount of thrust courtesy of three DDC TF50 gas turbine engines, each producing a max power of 5,600hp, a grand total of 16,800hp. This figure is astonishing in its own right, allowing awesome performance and range (at 60 knots the 118 has a max range of 380Nm, 437 miles on land – that's the distance from Monaco to Paris) however, this is especially impressive when you consider the number of luxury facilities and the advanced technology it is carrying.

Amenities include accommodation for six guests, two in the owner's stateroom – fitted with a king size bed, his and hers en-suite and large wall-mounted LCD television – and four in twin guest cabins, an extensive saloon with sculpted table and seats for 12, three crew cabins for the 118's six crew members, an advanced galley fitted with designer appliances, hydraulically operated aft gangway and swimming ladder, a Prestige 4.50 metre, 40hp tender with accompanying garage, a teak deck finish, and spacious social cockpit for group observation on the move.

In terms of advanced technology the 118 delivers a carbon fibre and laminated composite glass superstructure, Technav sound and vibration analysis, multiple interceptors, MedTec hydraulics, Max Power 450R bow thrusters, Frigomar air conditioning, C-Plath Navipilot V-HSC auto pilot, Furuno GP-80 GPS system, Pathfinder Radome 48 Raymarine radar, a C-Plath gyrocompass, a Furuno FM-2721 VHF and B&G depth-sounder and wind instruments.

Unsurprisingly, this level of next-gen technology has led to the 118 WallyPower being noticed on the world stage, and since its launch it has been featured in the film *The Island* and the hit BBC motoring show *Top Gear*, in the latter of which the 118 was raced against the Pagani Zonda hypercar.

That's an instruction manual worth reading

Not the comfort you'd get on the ferry to Calais

The Statistics

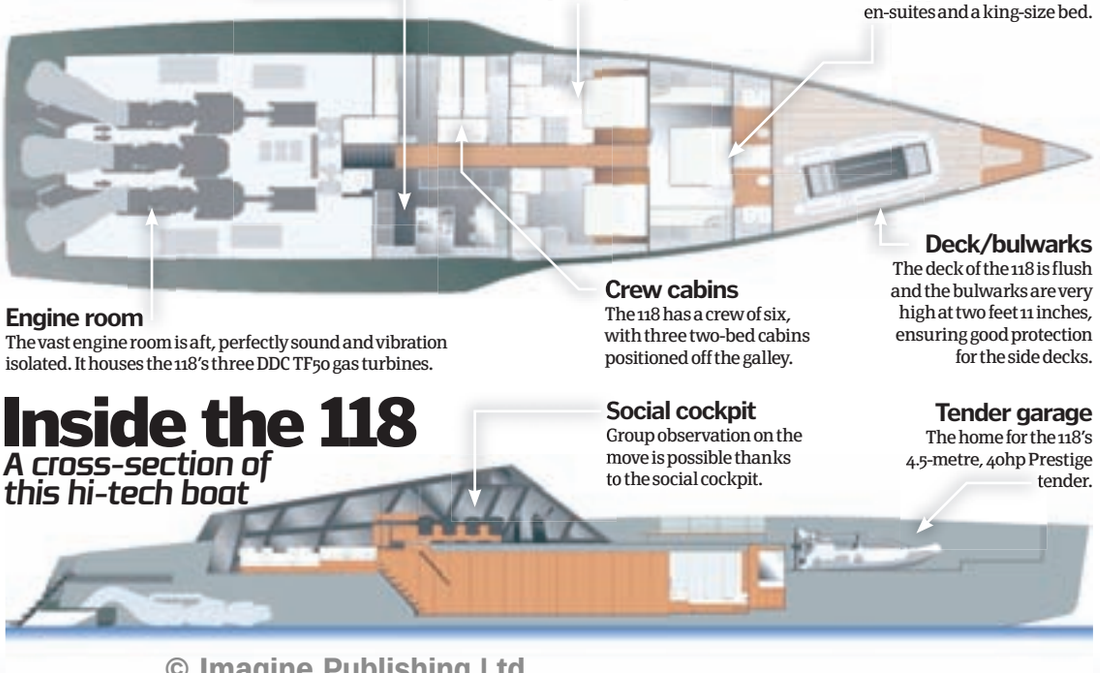
118 WallyPower

Designer: Wally with Lazzarini Picker
Builder: Rodriquez Intermarine
Cost: $33 million
Length: 36m (118ft)
Propulsion: 3 x DDC TF50 gas turbines
Displacement: 95 tons (half-load)
Max speed: 60 knots
Range: 1,500Nm

© WallyPower

Inside the 118

A cross-section of this hi-tech boat



Galley/crew mess
The galley is state-of-the-art and is equipped with designer equipment. The crew's mess is sizable and runs off the galley.

Guest cabins
Due to its smaller size the 118 can only accommodate four guests, who sleep here in queen-sized beds.

Owner's stateroom
The largest and most spectacular bedroom on the 118, the stateroom comes equipped with his and hers en-suites and a king-size bed.

Deck/bulwarks
The deck of the 118 is flush and the bulwarks are very high at two feet 11 inches, ensuring good protection for the side decks.

Crew cabins
The 118 has a crew of six, with three two-bed cabins positioned off the galley.

Engine room
The vast engine room is aft, perfectly sound and vibration isolated. It houses the 118's three DDC TF50 gas turbines.

Social cockpit
Group observation on the move is possible thanks to the social cockpit.

Tender garage
The home for the 118's 4.5-metre, 40hp Prestige tender.

LONGEST

1. Titanic

Three hours of your life that you won't get back. Rich girl and poor boy hook up on the much-touted 'unsinkable ship' the Titanic, which goes on to hit an iceberg. Sinks.

SMALLEST

2. Orca

They really should have got a bigger one. A shark hunter, police chief and oceanographer take their boat, the Orca, out to kill a massive shark. Sinks.

UPSIDE DOWN

3. Poseidon

At midnight on New Year's Eve the cruise ship SS Poseidon gets hit by a 90-foot tidal wave and capsized. Sinks... slowly.

DID YOU KNOW? *At 12 knots the Arkley can sail 8,055 miles on one tank, the distance from Berlin to Durban, Australia*

The ultimate yacht...

We combined three of the most awesome super yachts in existence today to create one ultimate yacht

Each of the three aforementioned super yachts is awesome in its own way. The Ocean Pearl brings the ultimate in design theory to the table, while the Lürssen Arkley is almost unparalleled by other yachts of its size in terms of luxury facilities, allowing many guests and its owners to travel vast distances in five-star surroundings and service. The 118 WallyPower, however, destroys both in terms of power, allowing for a blistering top speed of 60 knots and dynamic, speed-boat levels of performance.

Quite a tough decision then, isn't it, when picking that present to sail away on into retirement? Well, here at How It Works we don't like making compromises and demand the best of everything, be it sleek lines, marble floors or Jeremy Clarkson-levels of thrust, so we decided to combine the three to create the ultimate super yacht. By borrowing the best properties and parts of each yacht, we could create the SY Imagine, a yacht so awesome, so unsurpassable, that no yacht would ever need to be built again.

The Statistics

SY Imagine

Designer: How It Works
Builder: Imagine Publishing
Cost (estimated): $67 million
Length: 62m (203ft)
Propulsion: 3 x DDC TF50 gas turbines
Max speed: 30 knots (approx)
Range: 3,300Nm

Stern...

Power it up

By using the 118 WallyPower's triple DDC TF50 gas turbine engines, the SY Imagine, despite its larger size, would still have a high top speed of 30 knots, allowing you to leave other yachts its size for dust (or should that be droplets?).

Mid section...

All the luxuries

The facilities on the Arkley are staggering, so by taking its mid-section we get jacuzzis, king-sized beds, massive HD TVs, a well-stocked bar and a pantry so large you could get lost in it. In addition, the vast array of rooms would allow for many guests to be accommodated.

Bow...

Pearl of a front

With its open and sleek design, with lines to make Enzo Ferrari stand back in appreciation, the bow has to come from the Ocean Pearl. That 30 per cent more open space would also come in handy on sunny days and the superstructure's super hard frame would keep things light but crash-resistant.


© WallyPower


© Lürssen


© Yacht Plus

Future proof

In addition to its power advantages, the futuristic styling of the stern would future-proof the yacht, allowing you to not only outrun invading aliens, but do so in a contemporary style.

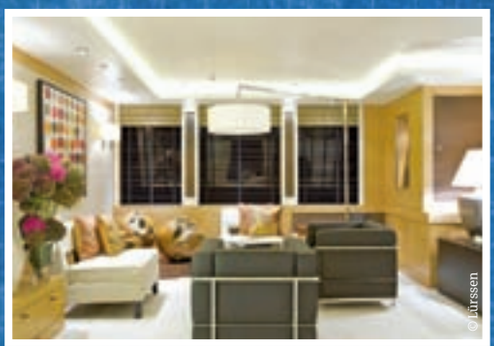
Staff quarters

It's no use having such a large yacht if you have no one to crew it, so by taking the mid-section of the Arkley you would also get plenty of room for the extensive staff quota. After all, it's pointless having the largest stock of martini on board if no one is there to shake it.

Tender up top

Due to the lack of room in the rear of the SY Imagine, we would transfer the yacht's main tender and jet skis to the bow, allowing for high-speed fun off the main yacht and provide a method of ferrying people to and from it.


© WallyPower


© Lürssen


© Yacht Plus

"A skilled balloonist can manoeuvre horizontally by altering their altitude"

Hot-air ballo

How do these gasbags get off the ground and return to Earth safely?

A hot-air balloon consists of three basic parts: an envelope big enough to displace a large amount of air, burners beneath the envelope to heat the air inside, and a basket in which to sit back and enjoy the ride. The scientific principle that enables this lift is convection, or heat transfer.

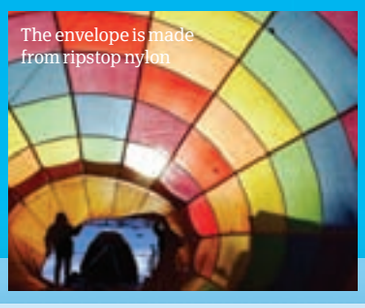
Heating the air inside the envelope causes it to expand, forcing some of the air out of the envelope. The weight of air inside then decreases, making the balloon lighter and giving it lift. Once the burner is shut off, however, the air inside cools and contracts, causing cold air to rush in from below, weighing the envelope down and causing the balloon to descend. If the burner is powered up intermittently, the balloon can maintain a pretty much constant altitude. Hot-air balloons have an upper limit because at very high altitudes the air is so thin that the lift is not actually strong enough to raise the balloon.

Because hot-air balloons have no real means of changing direction other than upwards and downwards, the vehicle will drift along with the wind. However, a skilled balloonist can manoeuvre horizontally by altering their altitude. You see, wind is known to blow in different directions at different heights and so the pilot can ascend or descend until they find the appropriate wind to send them in the direction they wish to travel.


An alternative to queuing at the airport...

Envelope
Reinforced ripstop nylon fabric (also used for kites, sails and sleeping bags) is the principle material used for hot-air balloon envelopes. This lightweight fabric can also be coated with silicone to make it more hard-wearing.

What goes up...


The envelope is made from ripstop nylon

1. Inflation
A balloon crew inflate the envelope using a powerful fan to blow air in from the base of the envelope for several minutes.

2. Erection
To get the inflated envelope off the ground, the propane-fuelled burner beneath the envelope is placed at the entrance to the envelope and blasted.

3. Burner on
The burner heats the air inside the envelope to a temperature of about 100°C. This causes the air particles to gain energy and move about faster and farther apart.

4. Air expands and rises
Warm air expands and rises, causing about a quarter of the air to exit through the bottom of the envelope.

5. Ascent
The balloon ascends because the air inside the envelope is lighter and less dense than cold air outside.

5 TOP FACTS
HOT-AIR BALLOON FIRSTS

First across the Atlantic
1 In 1978 the Double Eagle II became the first balloon to cross the Atlantic. It took 137 hours for Ben Abruzzo, Maxie Anderson and Larry Newman to travel 3,120 miles.

Highest altitude
2 The highest manned trip in a hot-air balloon ever recorded was back in 2005 when Vijaypat Singhania (who was 67 at the time) took his balloon to 21,027m.

First across the Pacific
3 In 1991 entrepreneur Richard Branson and Per Lindstrand flew 7,671.91km from Japan to North Canada in just 47 hours on board the Virgin Pacific Flyer.

First round the globe
4 In 1999 the Breitling Orbiter 3 – piloted by Bertrand Piccard and Brian Jones – embarked on the first successful round the world trip in a hot-air balloon. It took them 19 days.

First solo round the globe
5 On his seventh attempt, Steve Fossett became the first successful solo balloonist to circumnavigate the globe. It took him 320 hours 33 minutes in 2002.

DID YOU KNOW? *To lift a weight of 1,000lb you would need nearly 65,000 cubic feet of hot air*

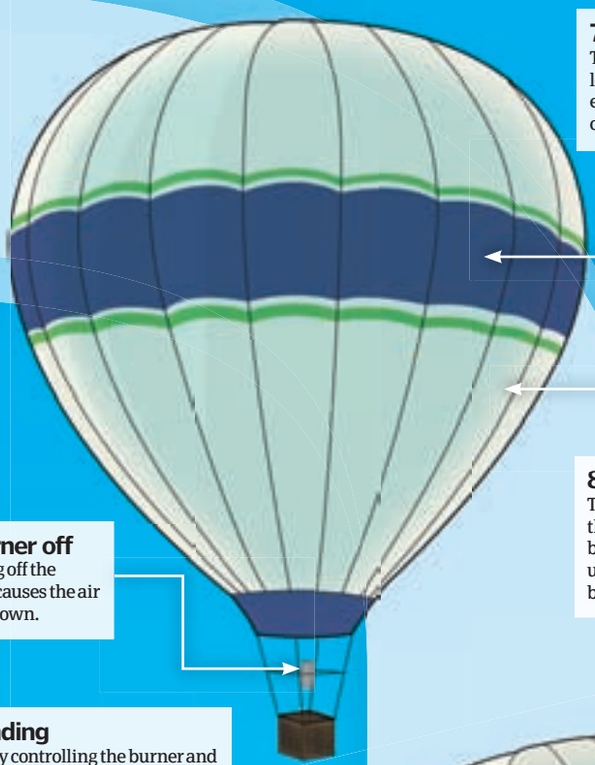
ons

Parachute vent
If the balloon needs to descend quickly, some colder air can enter via a parachute valve or vent in the top of the envelope controlled by a cord pulled by the pilot.

Gores
To create the balloon shape from a flat piece of material, it must be cut into long panels (from the crown to the base) called gores. These gores are then stitched together to create the shape.

Turning up the heat gets you airborne...

7. Air contracts
The cooler air contracts leaving space inside the envelope to suck in more cold air from below.



8. Descent
The increased weight of the cooler air inside the balloon exceeds the upthrust and so the balloon will start to sink.

6. Burner off
Shutting off the burner causes the air to cool down.

9. Landing
By gently controlling the burner and descent, the balloon will normally come in to land bouncing along the ground before stopping.

10. Landing site
Given the relatively uncontrollable nature of directing a hot-air balloon, the landing site cannot always be predicted and so the pilot must select a large enough area free from pylons and bodies of water where they can lay out the envelope.

Propane tanks
Compressed liquid propane is stored in lightweight tanks in the basket.

Skirt
The flame-resistant material at the base of the envelope is called the skirt. This stops the rest of the envelope from catching fire.

Burner
Liquid propane flows from the tanks through steel pipes coiled around the burner. When the balloonist triggers the burner, liquid propane flows out and is ignited by a pilot light. In the meantime this flame heats the metal pipes, turning the liquid propane into a gas that is more powerful and fuel-efficient than the liquid when it's cold.

Basket
Traditionally a hot-air balloon's basket is made of wicker because it's durable, flexible and lightweight. Today hot-air balloons can come with double-decker baskets that seat 50 people if necessary. Enclosed gondolas are also available for serious, long-distance ballooning.

"You can significantly increase the thrust of the engine without adding much weight"

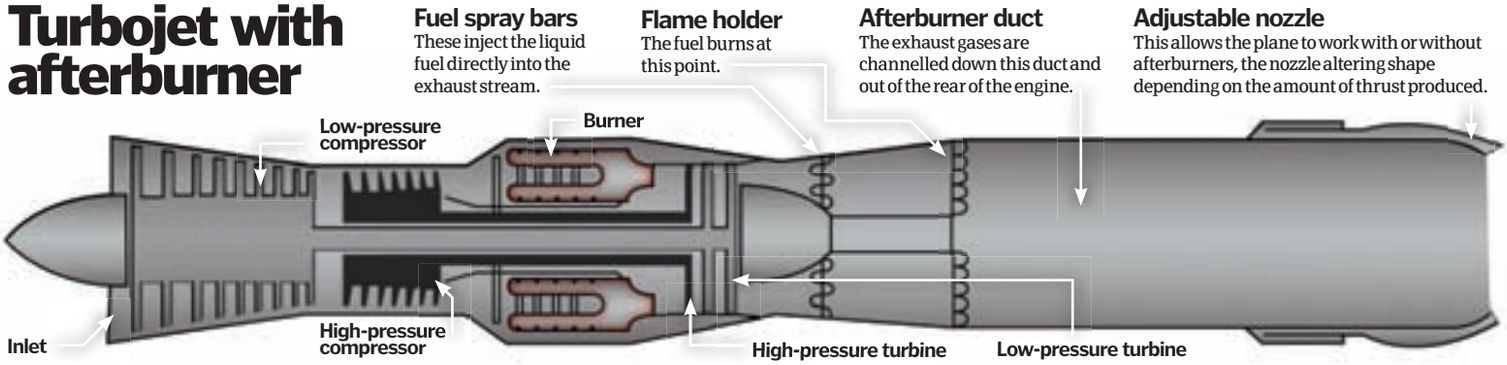

A US F/A-18 Hornet launching on full afterburners

Afterburners

What happens when you're going top speed but need more? Simple, kick in the afterburners

An afterburner cleverly uses the structure of a modern jet engine to increase its thrust without increasing its weight or complexity. They throw fuel directly into the exhaust stream of the engine where it ignites on contact with oxygen, increasing the thrust by 50 per cent or more. Afterburners are most commonly found on military fighter jets, although they have been present on a handful of commercial jets, including Concorde. However, they literally burn through a plane's fuel supply and pilots tend to use them sparingly.

Turbojet with afterburner



5 TOP FACTS
CRASH TESTS

Sensitive sensors
1 The sensors inside an ATD are so sensitive that they can give inaccurate data if exposed to extremes of temperature. The dummies are examined and recertified regularly.

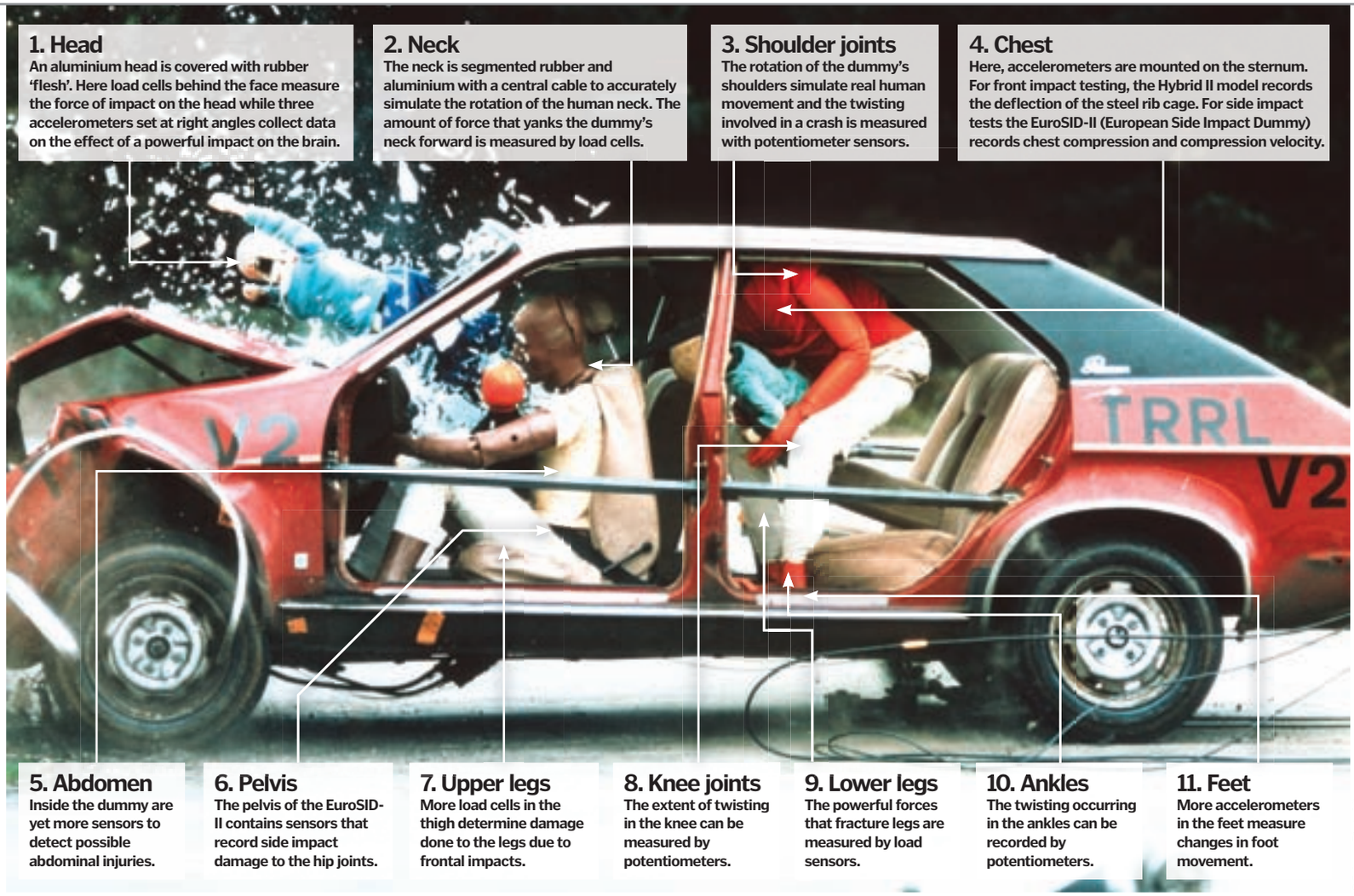
Five-star rating
2 This is determined by the worst score on head injury criteria, chest deceleration and femur load. All three must be below a ten per cent chance of severe injury for a five-star rating.

Safest cars
3 The Insurance Institute for Highway Safety states the safest cars currently in America are the Buick LaCrosse, the Audi A3, and the Honda Civic 4-door model.

NHTSA
4 The National Highway Traffic Safety Administration created the New Car Assessment Programme (NCAP) in 1979, encouraging manufacturers to build safer vehicles.

Notorious cars
5 Following its Euro NCAP crash tests, the Rover 100 received a lowly one-star rating back in 1998, the only vehicle at the time to perform that badly.

DID YOU KNOW? *An airbag can inflate at a speed of 200mph*



1. Head
An aluminium head is covered with rubber 'flesh'. Here load cells behind the face measure the force of impact on the head while three accelerometers set at right angles collect data on the effect of a powerful impact on the brain.

2. Neck
The neck is segmented rubber and aluminium with a central cable to accurately simulate the rotation of the human neck. The amount of force that yanks the dummy's neck forward is measured by load cells.

3. Shoulder joints
The rotation of the dummy's shoulders simulate real human movement and the twisting involved in a crash is measured with potentiometer sensors.

4. Chest
Here, accelerometers are mounted on the sternum. For front impact testing, the Hybrid II model records the deflection of the steel rib cage. For side impact tests the EuroSID-II (European Side Impact Dummy) records chest compression and compression velocity.

5. Abdomen
Inside the dummy are yet more sensors to detect possible abdominal injuries.

6. Pelvis
The pelvis of the EuroSID-II contains sensors that record side impact damage to the hip joints.

7. Upper legs
More load cells in the thigh determine damage done to the legs due to frontal impacts.

8. Knee joints
The extent of twisting in the knee can be measured by potentiometers.

9. Lower legs
The powerful forces that fracture legs are measured by load sensors.

10. Ankles
The twisting occurring in the ankles can be recorded by potentiometers.

11. Feet
More accelerometers in the feet measure changes in foot movement.

Crash test dummies

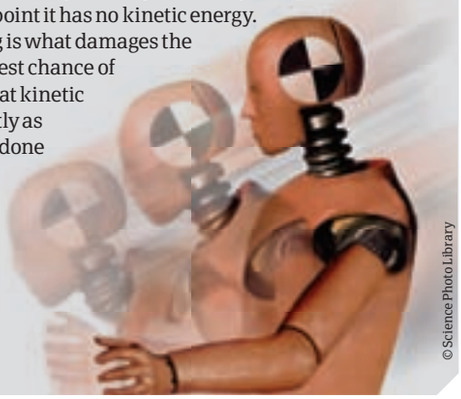
The lifesaving technology inside these plastic dolls belies their 'dummy' moniker

Anthropomorphic test devices (ATDs) – more commonly known as crash test dummies – are human simulators used to test the safety of vehicles in order to improve their overall design. ATDs have rigid, steel skeletons covered with rubber 'flesh' that makes them as lifelike as possible for the purposes of the test. The 'flesh' contains hundreds of sensors, and during controlled impact testing – smashing cars containing ATDs into brick walls/each other – these sensors collect precise data about the speed the dummy is travelling and the forces involved. Collecting this data would be impossible using a live human test subject.

An ATD uses three main kinds of sensor to gather data: accelerometers, load cells, and potentiometers. Accelerometers measure the dummy's change in speed in one particular direction as well as orientation, vibration and shock. If the sensor moves, tiny magnets slide past each other and generate electricity to show that the dummy has experienced a change in speed. Load cells are a kind of transducer that can convert a force on the body into a measurable electrical signal. They measure force using piezoelectric crystals, which are basically crystals capable of generating electricity when mechanical stress is applied. A potentiometer is an electrical instrument that measures the potential (or voltage) difference between two points in a circuit. The potentiometers in an ATD are motion sensors and generate voltage to indicate the amount of twisting or turning the dummy experiences during an impact.

Kinetic energy

When travelling in a moving vehicle your body has kinetic energy. In the event of a crash your body is brought to a very abrupt standstill, by which point it has no kinetic energy. This sudden stopping is what damages the human body so the best chance of survival is to bring that kinetic energy to zero as gently as possible. This can be done using seat belts and airbags to absorb some of the energy. Modern cars are all designed to crumple upon impact, absorbing a lot of the kinetic energy.



Martin Jetpack

Ever since the 1928 sci-fi serialisation *The Skylark Of Space*, the jetpack has been a fantasy for many. Fast forward over 80 years and a fully functional jetpack is just around the corner after decades of failed attempts. The Martin Jetpack, the world's first commercial personal flying machine, will begin to ship orders this year. It can fly at speeds of up to 63mph for 31.5 miles at an estimated maximum altitude of 8,000 feet – a vast performance improvement on the compressed gas jetpacks of the past.

To create lift, a 200 horsepower engine drives two ducted fans to force out air at up to 200mph. Newton's law states that for every action, there is a reaction in the opposite direction, which, in this case, lifts the pilot into the air. Two joysticks adjust the angles of flaps called vanes which are strategically located to deflect the fast-moving airflow generated by the rotor blades. When the jet of air hits a vane's surface, the pressure pushes it (and the rest of the jetpack) in a different direction. By manipulating the angle of each vane, the pilot can control the pitch (forward and backward tilting motion), roll (left and right tilting motion) and yaw (the left and right twisting motion).

To gain altitude, the pilot generates more thrust by increasing the rotor's revolution speed. A computer-aided 'fly by wire' system can complement manual piloting by intelligently adjusting the vanes for optimum results – highly reassuring for any new pilots.

The Statistics

Martin Jetpack

Designed by: Mr Glenn Martin
Vehicle category: An ultralight aircraft (US)
Dimensions: 5ft x 5.5ft x 5ft
Weight: 535lbs
Engine: Martin Aircraft 2.0 litre V4 2 stroke 200hp engine
Maximum thrust: 600lbs+
Range: 31.5 miles at a maximum speed of 63mph depending on pilot's weight
Materials: Carbon fibre composite
Price: Approx $100,000 (£65,000) excluding any export costs

9. Rotors
Lightweight but strong Kevlar-coated rotors slice the air, forcing it downwards towards the vanes. More speed means more thrust and greater altitudes.

7. Right joystick
Rotating the right joystick like a motorcycle throttle will rev up the engine, lifting the jetpack up to higher altitudes.

1. Ducted fans
Housed in cylindrical ducts, two fans force air downwards. They help reduce any loss of thrust required for upward lift.

4. V4 200hp engine
The Martin Aircraft five gallon capacity engine uses regular petrol to drive two fan belts connected to the rotor shafts.

8. Pitch and roll vanes
The jet stream deflects off the pitch and roll vanes, forcing the jetpack forwards, backwards, left or right depending on which vanes are upright.

3. Energy-absorbing carriage
A key safety feature, the energy absorbing carriage is designed to absorb the forces of impact during a hard vertical drop.

2. The spine
The spine holds the engine. By subtly swinging like a pendulum, the spine helps the jetpack remain stable.

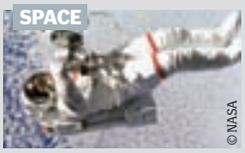
How a sci-fi dream became a reality

How the Martin Jetpack works

Head to Head
TYPES OF JETPACK

© JetlevSports Inc

1. The Jetlev
The engineless Jetlev forces pressurised water downwards via two nozzles at great velocity to provide lift up to 8.5 metres.



© NASA

2. The S.A.F.E.R. device
NASA'S S.A.F.E.R. device is a life-jacket for spacewalks. 24 small nitrogen-jet thrusters can steer a lost astronaut back to safety.

© Blaise Chapuis

3. The jet-powered wing
This 6.5 foot carbon fibre wing is powered by four jet engines. It was successfully flown across the English Channel in 2008.

DID YOU KNOW? *The Martin Aircraft Company's signed a $12 million deal to make 500 jetpacks for use in disaster relief missions*


Vanes are strategically located to direct airflow

Staying level-headed in mid-air

Stability is essential for safety and a pilot's confidence. The Martin Jetpack's natural stability is due to the pendulum-like motion of the spine. The spine is where the jetpack's engine is stored and where the centre of mass lies – the centre point of its entire weight. Above the spine are the ducted fans which act as a pivot point. If the jetpack tilts forward, the centre of mass will force the spine to also swing forward, returning the jetpack to an upright position. This neutralises the tilting motion. The company has recently developed a computer-controlled automatic stability system.

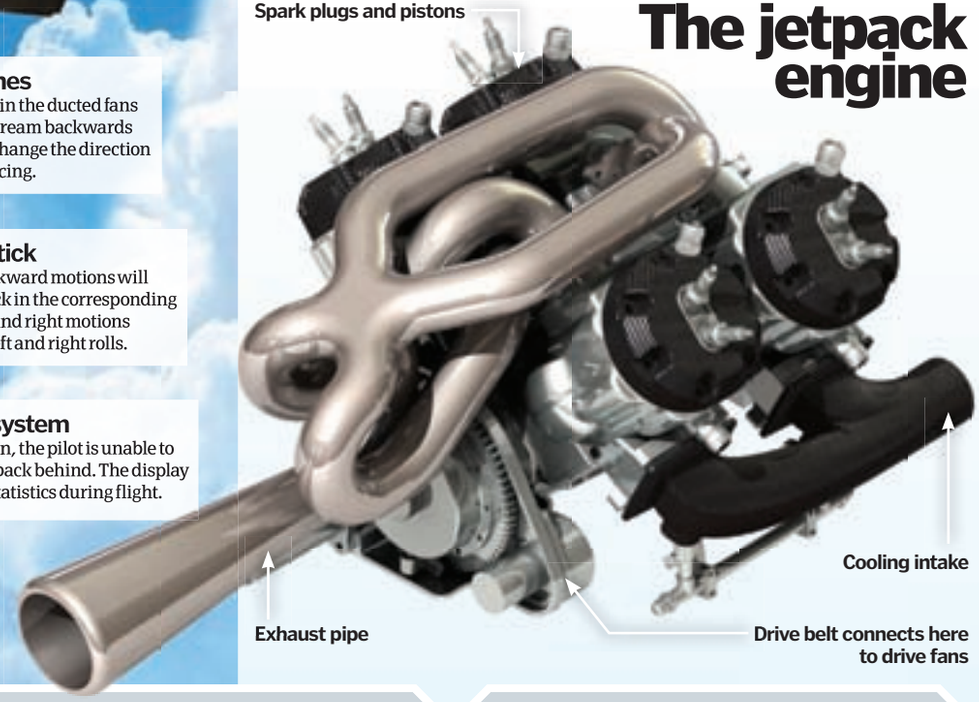

Two ducted fans force air out at 200mph

10. Yaw vanes
Yaw vanes within the ducted fans deflect the jet stream backwards or forwards to change the direction the jetpack is facing.

5. Left joystick
Forward or backward motions will move the jetpack in the corresponding direction. Left and right motions translate into left and right rolls.

6. Display system
Once strapped in, the pilot is unable to monitor the jetpack behind. The display provides vital statistics during flight.

The jetpack engine



Interview

We spoke to engineers and designers at the Martin Aircraft Company to find out more about flying one of these amazing vehicles

How It Works: How long does it take to successfully complete the Martin Jetpack Training Programme?
Martin Jetpack: Initially we envisioned it could take a week or two to train to fly. However, with the new automatic stability system that is currently in development, we think we have cut this down to two to four days depending upon the pilot. In fact, most people can fly hands-free after two or three short flights.

HIW: Has anyone flown to the theoretical maximum altitude of 8,000 feet?
MJ: Safety is a primary focus with the Jetpack development and we would never let someone fly that high without the ballistic parachute fully tested and on the machine – that would be madness. There is no reason why it could not fly to 8,000 feet but this has not been tested in the field. We have recently added a remote control feature to the machine allowing us to safely expand the flight envelope to fly at higher altitudes.

HIW: For people who will not be able to afford to buy a Martin Jetpack, are you planning to offer jetpack 'experiences'?
MJ: Yes. We have our own plans to develop jetpack experience operations around the world to allow everyone to have a go.

HIW: How noisy is the Martin Jetpack during operation?
MJ: Another area of development is indeed noise reduction. Generally the helmet is enough to keep out most of the noise and once flying you leave the noise behind you. Earplugs are optional!

HIW: You have recently incorporated a 'fly by wire' system. How does this work?
MJ: Fly by wire now allows us to change which aspects of the control are automatically stabilised and which aren't. We can set limitations upon speed, thrust, pitch, roll and yaw so the machine is much more intuitive. This is a great training system. Previously the machine was 100 per cent pilot controlled.

HIW: How wind- and rain-proof is it?
MJ: Some of the current R&D focuses on how to improve the abilities of the machine to fly into winds and withstand gusts. Components which are susceptible to rain will be sufficiently protected in the final production model of the Jetpack.

HIW: You say you are only accepting commercial customers right now. In what time frame do you think you may be accepting regular customers?
MJ: We anticipate that we will be in a position to supply 'regular' customers in a couple of years.

All main article pictures © Martin Aircraft Company

What protects a pilot from plummeting?

To achieve commercial success, the Martin Jetpack aims to appeal to more than just adrenaline junkies by incorporating several new safety features. If an engine fails, the pilot can launch a ballistic parachute – a parachute that is deployed quickly by a mini explosion. The structure has an internal roll cage for lower altitude impacts. The impact from a direct vertical drop would be cushioned by an energy-absorbing carriage at the base which operates in a similar way to a sprung pogo stick.

The jetpack Highway Code

The Martin Jetpack has yet to be evaluated by the UK's Civil Aviation Authority, but the Martin Aircraft Company plans to seek regulatory approval in the future. However, in America the Martin Jetpack complies with the Federal Aviation Administration classification as an ultralight vehicle. Ultralight vehicles can be operated without any type of pilot's licence and any aeronautical knowledge or experience.

Monozygotic twins are a rarity

This month in **Science**

If you've recently been to the cinema and marvelled at Robert Downey Jnr's performance as Iron Man (2) then this issue's big science feature may pique your interest as we look at the science behind augmented humans on page 42. Find out just how close we currently are to the on-screen antics of the cyborg superhero. Other highlights include how twins are created and why our feet get smelly on a hot day.

36 Smelly feet

39 Microscopes

41 G-force

SCIENCE

What are twins?

Twins are becoming more prevalent due to medical developments, but how and why do they occur?

The number of twins, or multiples, being born is actually on the rise due to the increase in use of fertility treatments such as IVF as people wait longer to have children. The number of twins surviving early births is also increasing due to improved medical knowledge.

However, twins are still a relatively rare occurrence making up only around two per cent of the living world's population. Within this, monozygotic twins (from one ovum) make up around eight per cent with dizygotic (from two ovum) seen to be far more common.

While there is no known reason for the occurrence of the split of the ovum that causes monozygotic twins, the chances of having twins is thought to be affected by several different factors. It is believed twins 'run in the family', often seeming to skip generations, while the age, weight, height, race and even diet of the mother are thought to potentially impact the chances of conceiving dizygotic twins. Also, if the mother is going through fertility treatments, she is much more likely to become pregnant with multiples.

A yawn, or trying to eat their sibling's head?

It will become apparent quite early on that a mother is carrying twins as this is often picked up during early ultrasound scans. There can be other indications such as increased weight gain or extreme fatigue. Although twins are often born entirely healthy and go on to develop without problems later in life due to medical advances, twins can be premature and smaller than single births due to space constrictions within the womb during development.

Strange, but true...

There are many stories of identical twins being separated at birth and then growing up to lead very similar lives. One example described in the 1980 January edition of *Reader's Digest* tells of two twins separated at birth, both named James, who both pursued law-enforcement training and had a talent for carpentry. One named his son James Alan, and the other named his James Allan and both named their dogs Toy. There were also the Mowforth twins, two identical brothers who lived 80 miles apart in the UK, dying of exactly the same symptoms on the same night within hours of each other.

One occasion where it's okay to dress the same

5 TOP FACTS MULTIPLE BIRTHS

1 12 foetus world record
Although sadly this pregnancy did not reach full term and no babies survived, a woman in Argentina was observed to have 12 foetuses inside her womb from natural conception.

2 Nonuplets exist
A Malaysian mother gave birth to five boys and four girls in March 1999 – none survived over six hours. Another set of nonuplets suffered a similar fate in Sydney in 1971.

3 Race affects conception
With regard to DZ twins, there is seen to be a higher prevalence of these twins in black Africans, and a lower incidence than to be expected in Oriental mothers.

4 Most children
The highest recorded number of children had by one woman is the first wife of Feodor Vassilyev, who lived in the 1700s. She gave birth to an incredible 69 children.

5 Quad gestation
With regard to quadruplets, the average gestation period is just 32 weeks – that's eight weeks shorter than usual, primarily due to the size restriction of the womb.

DID YOU KNOW? *Female monozygotic twins are more common due to the increased likelihood of male mortality in the womb*

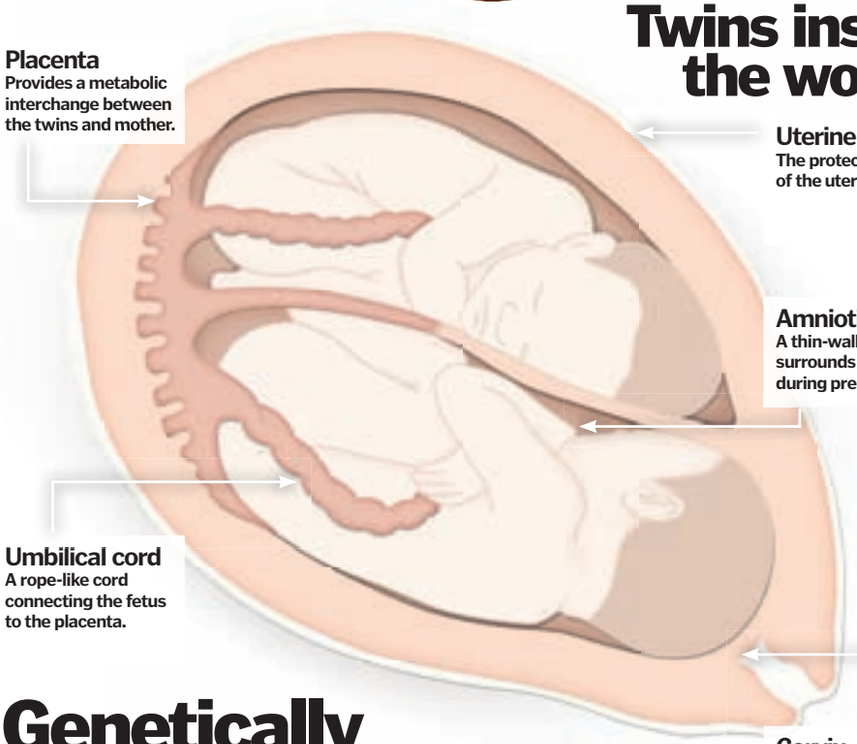
Multiple pregnancies, multiple problems?

There are many difficulties with twin pregnancies – mainly due to the limited size of the mother's womb. Multiple pregnancies rarely reach full term due to these limits, twins averaging at around 37 weeks. Also, because of the lack of space and eggs splitting in the womb, further complications such as conjoined twins can occur. Conjoined twins can be a problem dependant on where they're joined. If it is by a vital organ or bone structure, one or both may die following birth as they grow – or during an operation to separate them.

It is also suspected that as many as one in eight pregnancies may have started out as a potential multiple birth, but one or more of the foetuses does not develop through to full term.

It's a tough start to life for many twins

Twins inside the womb



Placenta
Provides a metabolic interchange between the twins and mother.

Uterine wall
The protective wall of the uterus.

Amniotic sac
A thin-walled sac that surrounds the fetus during pregnancy.

Umbilical cord
A rope-like cord connecting the fetus to the placenta.

Cervix
The lower part of the uterus that projects into the vagina.

Genetically identical, but why do twins differ?

From studying identical, monozygotic twins, we can attempt to decipher the level of impact environment has on an individual and the influence genes have. As the genetics of the individuals would be identical, we can say that differences displayed between two MZ twins are likely to be down to environmental influences.

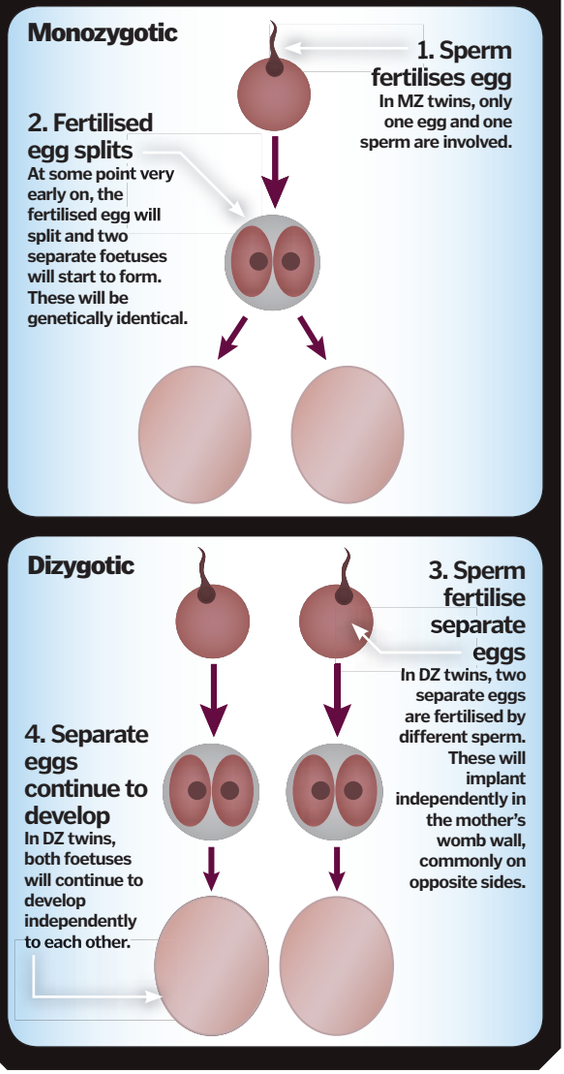
Some of the most interesting studies look at twins that have been separated at birth, often when individuals have been adopted by different parents. Often we see a similar IQ and personality displayed, whether or not they grow up together, but even these and other lifestyle choices can vary dependant on environment.

Ultimately, it is hard to draw firm conclusions from twin studies as they will be an unrepresentatively small sample within a much larger population and we often find that both environment and genetics interact to influence an individual's development.

Formation of identical and fraternal twins

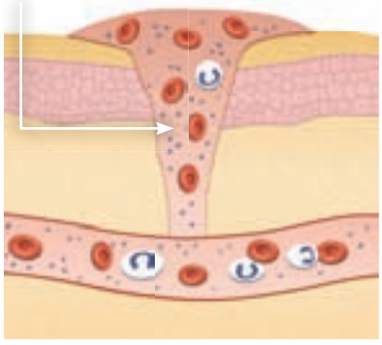
Monozygotic (MZ), or identical, twins are formed by the egg splitting soon after fertilisation, and from those identical split groups of cells, two separate foetuses will start to grow. Monozygotic twins are therefore genetically identical and will be the same sex, except when mutations or very rare syndromes occur during gestation. No reason is known for the occurrence of the split of the ovum, and the father has no influence over whether identical twins are produced.

Dizygotic (DZ) twins, however, are produced when the female's ovaries release two ovum and both are fertilised and implanted in the womb wall. They can be known as fraternal twins as genetically they are likely to only be as similar as siblings. They will also have separate placentas, where MZ twins will share one, as they are entirely separate to each other – they are just sharing the womb during gestation. This kind of twin is far more common.

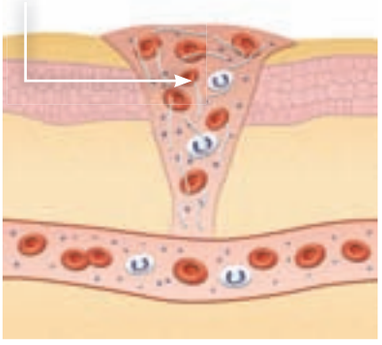


"Healing involves the removal and replacement of damaged tissue"

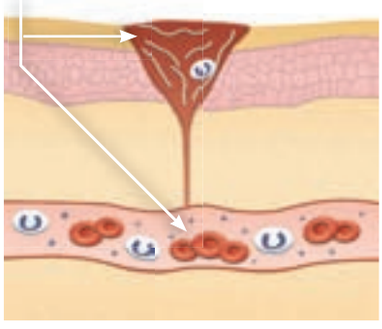
1. Skin injury
Blood vessels in the dermis become damaged when the skin is broken which results in bleeding at the site of the injury.



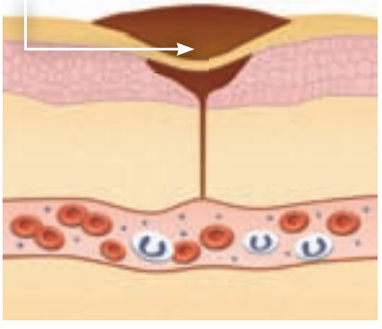
2. Clotting
The body's repair cells, which include fibroblasts, travel towards the injury site and the blood forms a clot.



3. Plugging
A plug of fibrous tissue is formed within the clot by the fibroblasts. This allows new tissue to form beneath the protection of the plug.



4. Scab
A scab is formed by the fibrous plug hardening. It will eventually fall off but may leave some scarring at the location of the wound.



How do we heal?

We always expect our bodies to heal when we injure ourselves, but how does this happen?

Healing can be defined as the restoration of injured tissue back to usual function. There are two main ways in which tissue heals; regeneration and repair. Healing involves the removal and replacement of damaged tissue, and most organs will use both methods to fix damage – although cardiac muscle cells and neurons are examples of cells that cannot use regeneration.

Regeneration is when cells replicate within the same tissue mass that was damaged. These then replace the cells that have been damaged or died. Most cells in the body can repair damage in this manner, but the surrounding collagen network must remain in good condition for this to be able to occur.

Repair takes place when the damaged tissue cannot replicate cells of the same type, and scar tissue is then formed. Repair is made up of three stages; the inflammatory phase, the proliferative phase and the maturation phase. The inflammatory phase is when bacteria is killed off by macrophages and phagocytic cells and growth hormones released encourage cell growth in the area of damage. The following stage is when the wound starts closing up and filling with collagen, which will form the scar tissue. During the final maturation phase, healing tissue is replaced with stronger collagen and unnecessary tissue produced during the earlier phases is removed.

Why do feet smell?

Producing up to a pint of sweat each day, no wonder your feet get a bit whiffy

Sweat actually keeps the skin of our feet moist and flexible to cope with the constantly changing pressure when we walk. Without this moisture the skin would dry and crack, and walking would become extremely painful.

Despite the huge number of glands (250,000 per foot) and amount of sweat that comes from our feet, it's still just salt and water. The odour comes from the bacteria that live on human skin which, while unsettling, are perfectly natural. Our socks are a dark, moist feast for them as they eat sweat and dead skin and the waste products they excrete are what smells bad. The more the bacteria eat the worse our feet smell. To keep the smell down, make sure you change your socks and let your shoes air for 24 hours if you can. Also, wash your feet and spray them with antiperspirant!

Head to Head
SMELLIEST ANIMAL, PLACE AND PLANT

ANIMAL

1. Striped Skunk
Facts: Well known for their ability to secrete a liquid with a strong, foul smelling odour which they can use as a defensive weapon. They can shoot it up to 5 metres.

PLACE

2. Rotorua, New Zealand
Facts: Located in the most geologically active area of New Zealand, Rotorua is surrounded by mud pools, geysers and steam vents.

PLANT

3. Titan arum
Facts: This monstrous, three-metre tall plant smells like a combination of rotten eggs and rotting meat to attract insects.

The wonderful smell of freshly cut grass, daisies and feet...

5 TOP FACTS SUNBURN

Is sunscreen really waterproof?
1 No sunscreen is truly waterproof. They can be water-resistant but will need to be re-applied every few hours. Even sweat can affect it!

Danger times
2 UV radiation is most intense between 10am to 2pm In Australia, sunburn can occur in less than 15 minutes on a fine January day. UV radiation is not related to temperature.

Peeling
3 Peeling is the body's way of ridding itself of damaged skin cells that might develop into cancers. Damaged skin cells self-destruct and peel off in sheets.

How we tan
4 Skin colour depends on a pigment called melanin which protects your skin by absorbing UV radiation and it darkens when doing so, leaving you with a sun tan.

Hidden dangers
5 On a cloudy day 30 to 50 per cent of the Sun's UV rays reach your skin, so it's still possible to burn. You may not feel the Sun's rays if it's windy, but they still cause damage.

DID YOU KNOW? *Romans developed crude mirrors by pouring boiling lead over the back of blown glass*

Mirrors

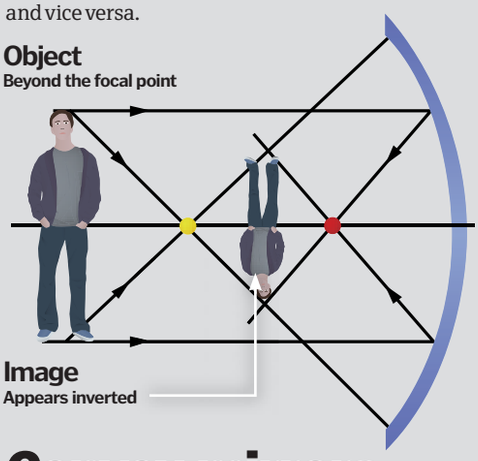
How do mirrors reflect light?

Mirrors work by reflecting photons, which behave like waves in this instance, back to us. Whereas photons bounce off rough surfaces chaotically, scattering along many angles of incidence and creating what's called a diffuse reflection, they bounce off smooth surfaces at the same angle they hit them, with a single angle of incidence. This is specular reflection and the smoother the surface, the better the reflection will be. Modern mirrors use either aluminium or non-toxic silver as their reflective surface.

Oddly, mirrors don't reverse right and left, they only appear to because that's how our brains interpret them. In reality, mirrors reverse front and back, so if you have a scar on the right-hand side of your face, it appears on the right of the mirror. We're used to turning through 180 degrees to face people so we mentally rotate the image in the mirror through those 180 degrees and perceive the image as reversed. In turn, writing appears reversed, because we actually see it as though we're looking at it from behind instead of in front.

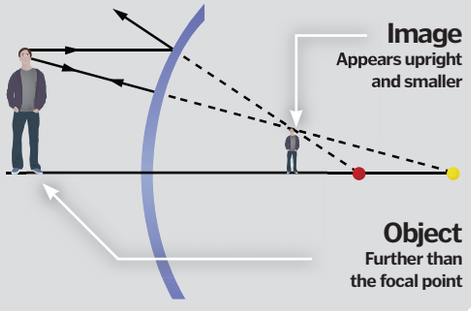
Concave mirrors

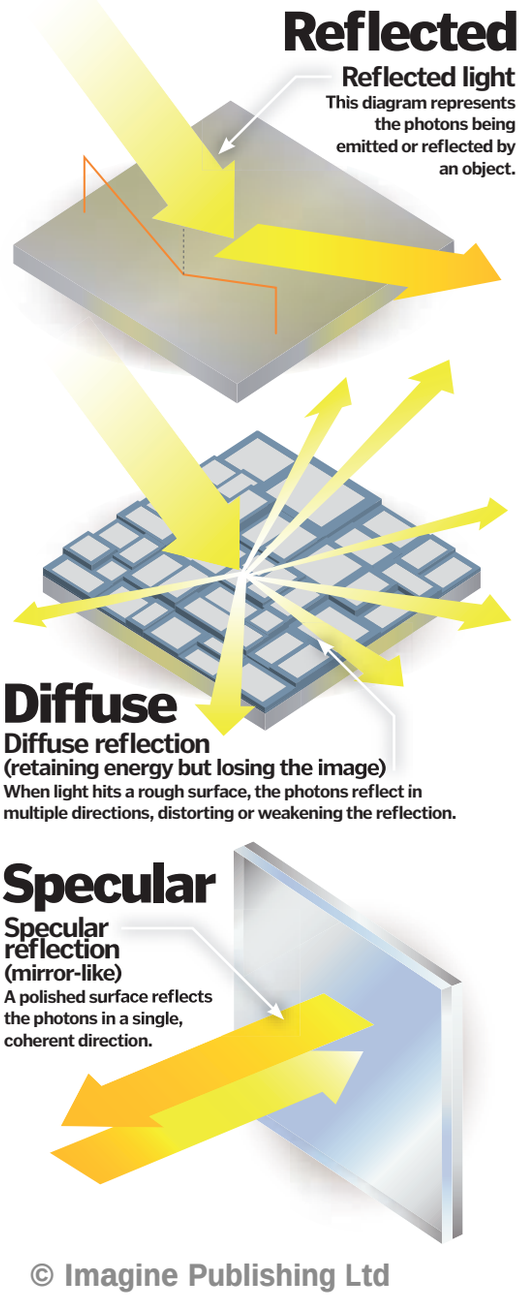
Instead of the angle of reflection being the same as the angle of incidence, the angles of reflection converge on a central point. If the object is between the mirror and that focal point, it will appear magnified until the object is moved away and past the focal point. At this point, the photon waves that were at the bottom of the image will be at the top and vice versa.



Convex mirrors

Convex mirrors distort outwards instead of inwards and as a result, offer a greater field of view. However, the mirror also distorts reflections, making objects appear closer than they actually are. Convex mirrors are commonly used in cars and as a security measure in shops.






At least he wore sunglasses...

Sunburn and its effects

We can often go red in the sun, but what causes this and what damage does it do to our skin?

Sunburn is caused by an overexposure to either sunlight or artificial UV rays. Sunburn doesn't occur every time the skin is exposed, indeed low-level exposure often causes tanning, a darkening of the skin caused by an increase in levels of melanin, a pigment already present in skin.

Burning is a reddening of the skin caused by groups of blood vessels expanding and breaking as blood rushes to the surface to attempt to heal the burn to living tissue. More severe sunburn can cause blistering of skin and often we see dehydration, dizziness and tiredness displayed alongside damage to the skin.

Skin damage caused by sunburn can sometimes cause non-malignant tumours and skin cancer to occur as the skin's DNA becomes so damaged it cannot repair itself properly. We can lessen the chances of this by not exposing our skin for long periods of time and using sun creams which give the skin extra protection.

DID YOU KNOW?

Australia has the highest rate of skin cancer due to the majority of individuals being of Northern European descent and the intense sun commonly seen across the continent.

"A malignant melanoma is a rare kind of skin cancer that can occur in melanocytes"

What are moles?

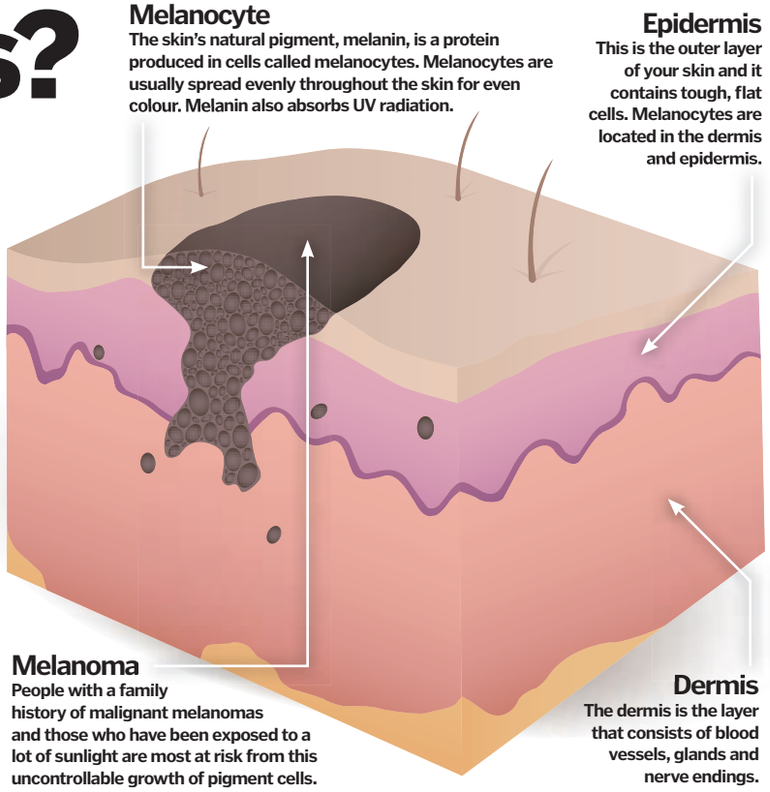
These small skin blemishes are common, but what are they and why must we keep a close eye on them?

A mole on the skin, or a melanocytic naevus, is an abnormal collection of the pigment cells called melanocytes. Some moles can be present at birth (congenital melanocytic naevi) but most develop spontaneously later in life, usually as a result of exposure to sunlight. Moles are often brown or black (pigmented naevi) and are usually round or oval, but they can be a variety of different shapes and sizes. Growth and change over time is quite normal.

Moles sound pretty unremarkable and are harmless in nature, and yet we must be vigilant if a new one appears on the skin or if an existing mole begins to change. A malignant melanoma is a rare kind of skin cancer that can occur in melanocytes. Although rare, malignant melanomas cause the majority of the deaths related to skin cancer. If you're particularly moley you're more susceptible to melanoma and should try to avoid too much sunlight.

Moles to watch are dysplastic naevi, which are large, irregularly shaped moles of mixed colouration. They often have paler, jagged edges with darker centres and tend to be accompanied by a lot of other moles on the body.

A malignant melanoma can spell trouble



Head to Head UNDER THE MICROSCOPE

EASIEST TO SPOT

1. Paramecium

There are over 75,000 different species of this bean-shaped blob that propels itself along with tiny cilia and sucks up other protozoa with its food vacuole.

HUNGRIEST

2. Amoeba

It may not make the National Geographic Channel, but there's something primal about watching the amoeba slowly extends its pseudopodia to engulf its prey.

CREEPIEST

3. Helicobacter pylori

Half of the world's population has this flagellate bacteria embedded in the mucus lining of their gastrointestinal tract. There's a nice thought...

DID YOU KNOW? *The Large Hadron Collider is the world's largest and most powerful microscope*

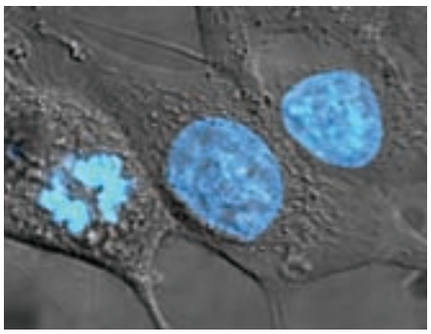
How 'fluorescent' microscopes work

High-end research microscopes can record the reflected glow of a single molecule

Microscopes have come a long way from the battery-powered piece of plastic you used as a kid to magnify your sister's eyelash. Instead of shining a beam of light up through the specimen from below, the Olympus BX51 and other 'epi-fluorescent' microscopes shine precise wavelengths of filtered light onto the specimen from above and record the faint, but incredibly detailed, fluorescent glow.

Some biological materials naturally 'fluoresce' – when they absorb a short wavelength of light, they emit a longer one. This is why black lights cause certain materials to 'glow' in the dark. Using that same principle, scientists inject microscopic specimens with special dyes called fluorophores that can highlight a detail as small as a single molecule. Each fluorophore reacts to a different wavelength of light. With that information, researchers can adjust the filters on the microscope to bathe the specimen in that precise wavelength.

The results can be stunning, especially with the aid of digital imaging. Since the fluorescent light emissions can be faint, it's often difficult to discern minute details with the naked eye. That's why professional microscopes like the BX51 come with a built-in, super-sensitive 12.8-megapixel camera to capture sharp images at extremely low light.



Get a close-up look at the world

8. Camera housing

A 12.8-megapixel digital camera can capture near-infrared fluorescent light images in 2.5 seconds, routing them to a computer for closer analysis.

7. Eyepiece

The "trinocular" eyepiece of the BX51 allows for a "super-wide" viewing field of 26.5mm, meaning less movement of the specimen.

2. Excitation filters

Incoming light waves pass through one of several dichroic filters (or excitation filters) that block all but the desired wavelength of light.

1. Episcopic light source

Epi-fluorescence microscopes require powerful, compact light sources like 200-watt mercury burners or 150-watt xenon lamps.

3. Beam splitter

The dichromatic beam splitter reflects short wavelengths and passes longer ones. Positioned at a 45-degree angle, it bounces short wavelengths down toward the objective, but lets the longer-wavelength fluorescent light pass upward for observation.

5. Objective

Objectives are selected for both magnification strength (from 10x to 100x) and numerical aperture or focal length. The higher the focal length, the greater the resolution.

6. Condenser

In epi-fluorescent illumination, the objective doubles as a light condenser, both focusing light and capturing the reflected wavelengths. In transmissive illumination, the condenser tightens the beam of light before it passes through the source material.

4. Transmissive light source

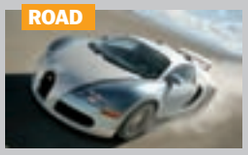
The BX51 is equipped with two light sources. The transmissive lamp produces light that is filtered and reflected upward through the objective rather than relying on the natural fluorescence of the material.

Head to Head G-FORCES

AIR

1. F-35C
The world's most advanced multi-role fighter can generate forces between 7.5g and 9g when turning, diving or banking.

ROAD



2. Bugatti Veyron
Drive the fastest car on the planet and you'll be treated to 1.2g pushing you back in your seat as you accelerate away.

SPACE

3. SpaceShipOne
Those who can afford to book a seat on Virgin's space plane will find themselves subject to forces up to 5g as they travel to an amazing altitude of 10,000km.

DID YOU KNOW? *Some scientists believe that gravity fields are made up of massless particles called gravitons*

He's smiling now, but wait until he realises he left his parachute in the plane...

You spin me right round baby right round...

G-force explained

Intense acceleration in fast cars, fighter planes, rockets and roller coasters

When you're hurtling down the steel track of a roller coaster, it might seem that your stomach is climbing into your throat, and your eyes are squishing deep into your skull. Several forces are at play when you feel that way. Earth is constantly pulling down on every one of us. It has a great deal of mass, and that gives it a large gravitational field. And when we take a sharp turn on a fast ride, blast off in a rocket, or slam on the brakes, we're thrown around by forces far stronger than Earth's gravity. But why?

Engineers rate those experiences with numbers called g-forces, to explain how strong they are. One g is the amount of force that Earth's gravitational field exerts on your body when you are standing still on the ground. Every particle that makes up our planet is tugging on you simultaneously. Each one of those pulls is quite weak, but combined they are strong enough to keep your feet on the ground. Five g acceleration, something that race car drivers regularly experience, is five times as intense. Any time that an object changes its velocity faster than gravity can change it, the forces will be greater than one g. At zero g, you would feel weightless. And past 100g, you're almost certainly dead. Forces that intense can crush bones and squash organs.

Gravity is not the only source of g-forces. They take hold whenever a vehicle, like a car or a plane, suddenly changes its velocity. Speed up, slow down, or make a turn, and your velocity will change. The faster it happens, the more force you will experience.

© Bugatti

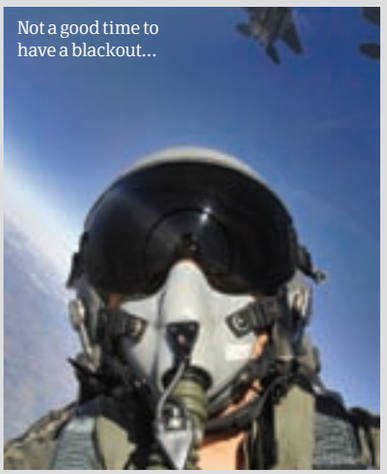
Understanding g-forces

To find out how many gs you experienced during an intense acceleration, take your maximum speed, divide it by the time it took to hit that rate, and then divide by 9.81m/s². The resulting number is how many gs you experienced.

Example: Put the pedal to the metal in a Bugatti Veyron and you will go from 0-100kph in 2.3 seconds.

100kph is 28m/s, 28 / 2.3 = 12m/s², 12 / 9.8 = 1.2g

Not a good time to have a blackout...



Acceleration can knock you out

If you are riding in a jet while it is making sharp turns, the blood in your head may rush out into your lower body. As the plane turns, all of the fluids in your body will act as if they were in a centrifuge, moving toward your feet, or whatever part of your body is on the outer edge of the turn. When that happens, your eyes will not get enough oxygen and you may experience a greyout, a sudden loss of colour vision, or a full blackout, temporary blindness. Accelerate harder and you will lose consciousness as blood retreats from your brain, depriving it of oxygen. Some people will experience these effects below 5g, but seasoned fighter pilots can take a bit more because they are very physically fit. They train themselves to resist the forces, and wear special suits that squeeze blood up into their heads.

Revolutionary science and 'evolutionary' technology is poised to give the human race a serious upgrade

Tony Stark is a modern-day Six Million Dollar Man. Nearly killed by a mortar attack, Stark is rebuilt with a powerful electromagnet strapped to his heart. With his supergenius tinkering skills (and a handy stockpile of palladium), Stark installs a rudimentary fusion reactor in his chest with which he powers his ultimate weapon, the Iron Man suit of armour.

One of the reasons Iron Man is so appealing is that he's a "super hero from scratch" – the ultimate realisation of the technologically augmented human. But perhaps what's most amazing about Iron Man is that he's equal parts science fiction and science fact. In the name of medical science and military might, researchers around the world are giving the human race an upgrade.

We have learned how to control machines with our minds. We can grow replacement organs in a lab. We can strap on headsets that enhance our perception or strap into robotic exoskeletons that give us Hulk-like strength and tireless endurance. We have personal jet-powered backpacks, mind-reading prosthetics and an emerging understanding of our genetic blueprint.

The Iron Man of the movies is a near-future fantasy. Somewhere, a certified mad genius (funded by a military research grant, of course) is having a Tony Stark moment that will alter the human experience forever. Let's just hope it costs less than an iPad.


© courtesy of Honda

Augmented reality

Synthetic organ augmentation

Exoskeletal machines

Humanoid robotics

Super humans

Personal flight

The real Iron Man

© Paramount Studios

5 TOP FACTS AUGMENTED HUMAN ABILITY

Mind control
1 Researchers working with Dean Kamen's "Luke Arm" prosthetic have figured out how to control the arm using infrared sensors to read neural activity through the skull.

Memory chip
2 Neural engineer Ted Berger is working on a brain implant called a 'biomimetic device' that can replace the signal processing functions of damaged neurons.

Eye doctor
3 Medical researchers in Cambridge, England have developed contact lenses that can detect drops in blood sugar levels and alert their diabetic wearers.

Out of the darkness
4 Retinal prostheses that record digital imagery with eyeglass-mounted cameras and route electric impulses to the brain have already restored partial vision to the blind.

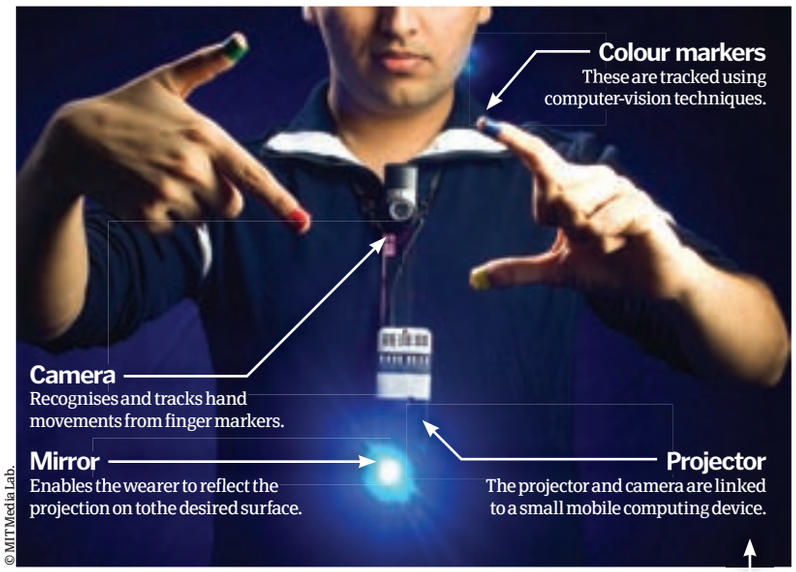
Miracle muscles
5 Electrodes have been implanted into the dead muscle tissue of paralysed patients to mimic motor neural impulses and stimulate the muscles to contract.

DID YOU KNOW? *SixthSense enables the user to take photos by recognising the 'framing' gesture*

Brain-machine interface

The ultimate goal of brain-machine interface (BMI) technology is to allow humans to intuitively control robotic limbs and other mechanised tools by simply "thinking" them into action. For years, a US company called Cyberkinetics has been testing its BrainGate technology, a sensor that "plugs into" the motor cortex of the user's brain to analyse neural activity. Quadriplegics have used BrainGate to control computer cursors and even play *Pong*. In 2009, BMI researchers at Honda demonstrated a non-intrusive mind control technology by using a neuron-sensing helmet to send rudimentary instructions to an ASIMO robot.

Most recently, inventor Dean Kamen – creator of the Segway – introduced his "Luke Arm," an advanced prosthetic that was initially controlled by sensors in the user's shoes, but can now be connected directly to healthy nerve tissue and controlled intuitively by normal thought. Kamen's research was funded by the US Department of Defense to help military amputees from Iraq and Afghanistan, but it's not hard to imagine other military applications of a mind-controlled robot…



© MIT Media Lab.

Augmented reality

Imagine interacting with your world the same way you navigate the internet. Touch a product in the grocery store and get access to user reviews and price comparisons. Hold up an airline ticket and get up-to-the-minute departure and gate information. Meet someone in a coffee shop and see them surrounded by a "tag cloud" of interests and keywords from their Facebook profile.

Incredibly, this technology is already a reality. Called augmented reality (AR), it's being programmed into gadgets and applications that allow you to overlay real-time data – text, images, video, audio – on real-world experience. A prototype called SixthSense strings together a camera, a mini-projector and a cell phone and lets you point and click at the world with simple fingertip gestures. Form a square with your thumbs and index fingers and the camera takes a picture. Trace a circle on your wrist and the projector overlays the image of a watch on your arm. Touch a book and read the user reviews projected on its cover.

The world's your computer
SixthSense bridges the gap between digital devices and personal interaction, making digital information tangible.

Projected
Visual information can be projected on to nearby surfaces, making even hands into interfaces.

iPhone apps

The iPhone was practically made for augmented reality. With an AR app like Layar, simply snap a photo of your location and the software will use GPS data to access interactive maps, city guides, nearby restaurant reviews, metro schedules, geotagged Flickr photos and more.

ARMAR

Maintenance workers in the US military can now wear head-mounted displays that project interactive repair instructions – moving graphics, diagrams and text – onto real-life machinery.

Eye Tap

Futurist and self-proclaimed 'cyborg' Steve Mann has been tinkering with computer-mediated reality since the Seventies. His Eye Tap wearable computers can alter the user's reality – bending visual perception to the beat of a musical soundtrack or overlaying real-time information from the internet.


©www.eyetap.org

Synthetic organ augmentation

There is something unmistakably Frankensteinian about a fully formed human ear floating in a petri dish. Cue the creepy organ music: "It's aliiiive!" Yet in university labs around the world, researchers are building synthetic moulds of human organs and body parts – bladders, livers, fingers, ears, heart valves – and 'seeding' them with healthy cells from patients' bodies. In six to eight weeks, fresh tissue envelops the mould and the functioning body part is ready for transplantation.

Another technique uses a powdery material called extracellular membrane (ECM) – cultivated from discarded pig bladders – to trick the body into re-growing dead tissue or missing organs. When this 'pixy dust' is sprinkled on severely wounded muscle, the remaining healthy cells are convinced they are back in the foetus and begin to generate replacement muscle tissue. The Wake Forest Institute for Regenerative Medicine recently grew a synthetic heart valve that really beats. And you thought the floating ear was creepy.

Bladder

Physicians at Wake Forest University were the first to implant wholly lab-grown organs – synthetic bladders – into human patients.

"Printed" organs

Researchers at University College London have developed a technique to spray a fine thread of stem cells over a 3D mould to create custom-made shapes for synthetic body parts.

Beating hearts

Researchers start with a pig's heart valve and strip it down to its 'skeleton', the matrix of collagen and elastic that gives it shape. After repopulation with human heart cells, the synthetic valve is pumped open and closed in a bioreactor.


© Wake Forest University Baptist Medical Center

"A soldier straps himself into the robotic arms and legs and grabs two supersensitive hand controllers"

The real Iron Man

Increased agility
The Sarcos exoskeleton is constructed using sensors, actuators and controllers.

Exoskeletal machines

Robotic exoskeletons are real. The red suit that transforms Tony Stark into Iron Man is only a flashy Hollywood version of full-body exoskeletons in development – and even production – in not-so-secret labs around the world.

Back in 2001, the US Defense Advanced Research Projects Agency (DARPA) poured $75 million into a programme called Exoskeletons for Human Performance Augmentation. That's a fancy way of saying, "Make us an Iron Man!" The most impressive product of the DARPA initiative is the Sarcos XOS, a powered robotic suit that moves intuitively with the wearer while giving him the strength to lift hundreds of pounds repeatedly without fatigue.

A soldier straps himself into the robotic arms and legs and grabs two supersensitive hand controllers that detect not only motion, but force. The sensor data is transmitted to a central processor thousands of times per second. The processor, worn on the soldier's back, relays the motion commands to dozens of hydraulics that mimic muscle and joint movements in real-time.

Robot Suit HAL

Developed in Japan for people suffering from degenerative muscle disease, this full-body "cyborg" suit detects faint biosignals – motor neuron impulses – on the user's skin to control its movements.

Courtesy of Boston Dynamics

Raytheon Sarcos Exoskeleton

This full-body robotic exoskeleton enables a soldier to lift a 200lb weight over 500 times without breaking a sweat and has the sensitivity of movement to run, play sports and even dance.

Why not?
The project leader says: "if humans could work alongside robots, they should also be able to work inside robots".

Courtesy of Raytheon Company

HULC

Developed by Lockheed Martin, the Human Universal Load Carrier is a body frame made of lightweight titanium and allows a user to effortlessly haul hundreds of pounds while running, bending, leaping and even crawling.

Tough terrain
The anthropomorphic design enables the wearer to navigate difficult environments.

Hydraulic power
A hydraulic-powered titanium frame gives soldiers super abilities.

Courtesy of Lockheed Martin

Personal flight

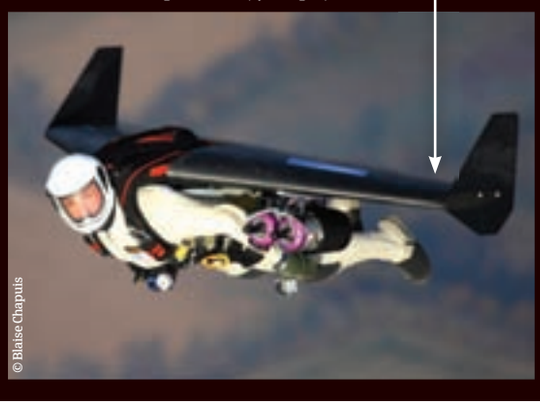
Iron Man's rocket boots are cool. A little too cool. Writing for *Wired* magazine, physicist James Kakalios said that the fuel requirements for personal flight would keep Iron Man grounded for any trip longer than a few minutes. But before we give up on our superhero flight fantasies, let's check out some of the best contenders for solo flight.

Jetpack International

Based on the original Bell Aerosystems design from the Sixties, this commercially available jetpack (a mere £130,000) can go 11 miles in nine minutes on a five gallon tank of jet fuel.

Jet Man

In 2008, Swiss pilot Yves Rossy crossed the English Channel strapped to a set of wings with four mini jet engines. The jetpack cruises at 220 kilometres per hour (130 mph).



© Blaise Chapuis

Birdman Inc.

In 2005, the makers of the original wingsuit – the "flying squirrel" style skydiving suit – strapped some jet engines to their feet to prolong horizontal flight.

© Birdman Inc/Mark Harris, www.bird-man.com

1. Batman
Batman's bullet-proof bodysuit is accessorised with Kevlar gloves, a microphone-implanted mask, "memory fibre" cape, and of course that nifty utility belt complete with throwing stars.

2. Iron Man
Powered by a arc reactor implanted in Tony Stark's chest, the Iron Man exoskeleton is fitted with repulsor rays in his palms, missile launchers and two rocket boots.

3. Doctor Octopus
Thanks to a massive dose of radiation, Dr Otto Octavius' eight-metre telescoping laboratory arms were fused to his body, allowing him to control the appendages with his mind.

DID YOU KNOW? *ASIMO stands for Advanced Step in Innovative Mobility*

BigDog
Fine, this one isn't humanoid, but the four-legged BigDog from Boston Dynamics can scale snowy, icy terrain and regain its balance when pushed hard from the side. Again, equal parts impressive and insane.

Humanoid robotics

The Japanese cornered the market on humanoid robots starting with Honda's remarkable ASIMO, the first self-balancing, walking/running robot that can also recognise gestures, faces and simple commands. Recently, Japanese researchers have developed robots with highly realistic facial expressions, hoping to use the robots in hospitals, nursing homes or other settings where empathetic feedback (no matter how creepy) is key.

If only real humans were as willing to please as ASIMO

© courtesy of Honda

Robo-anatomy
Not only has ASIMO been an exercise in science, he's also a lesson in human anatomy.

Mind control
ASIMO is an example of a major breakthrough in non-intrusive mind control.

ASIMO
Honda's groundbreaking humanoid robot is designed to assist people in their homes and is programmed to speak, understand instructions, turn on lights, open doors, serve trays of food, push carts and more.

© courtesy of Henny Boogert

Wim "The Iceman" Hof
Using only his iron willpower, this man can raise his body temperature to resist hypothermia, even when buried for hours in ice.

Super humans

We've all heard stories of feats of hysterical strength – the man who lifts the car from an injured teen, the mother who fights off a bear to save her child. Tales like these lend credence to the belief that the average human only uses a fraction of his or her potential powers. But what about those rare individuals who are much more than average?

A man in Germany known as the "human calculator" can out-figure a pocket calculator, even up to dozens of digits. Other people feel no pain, can eat glass, sustain tremendous electric shocks or memorise every single zip code in the world. Some were simply born that way while others have trained themselves to master their physical bodies and tap into their superhuman potential.

Mr Eats Everything
The late Michel Lotito gained worldwide fame for his record-breaking feats, such as eating hundreds of bikes and even an entire Cessna aircraft.

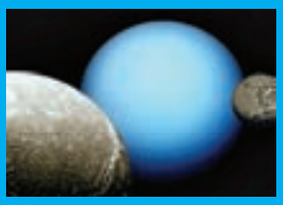
The Electric Man
Slavia Patjic of Serbia can withstand electric currents up to 20,000 volts without sustaining any injuries or feeling any pain.

This month in **Space**

You'd be forgiven for thinking that things are looking bleak for space travel. The recent cuts to the NASA budget might lead some to think that humanity's jaunts to the stars have been put on hold. However, that would be doing a great disservice to the efforts of the European Space Agency. There's plenty of activity and lots to look forward to and our main space feature this issue focuses on the many missions currently being undertaken by its members.

50 Spacesuit visors

52 The ESA



56 Uranus

SPACE

How the sea

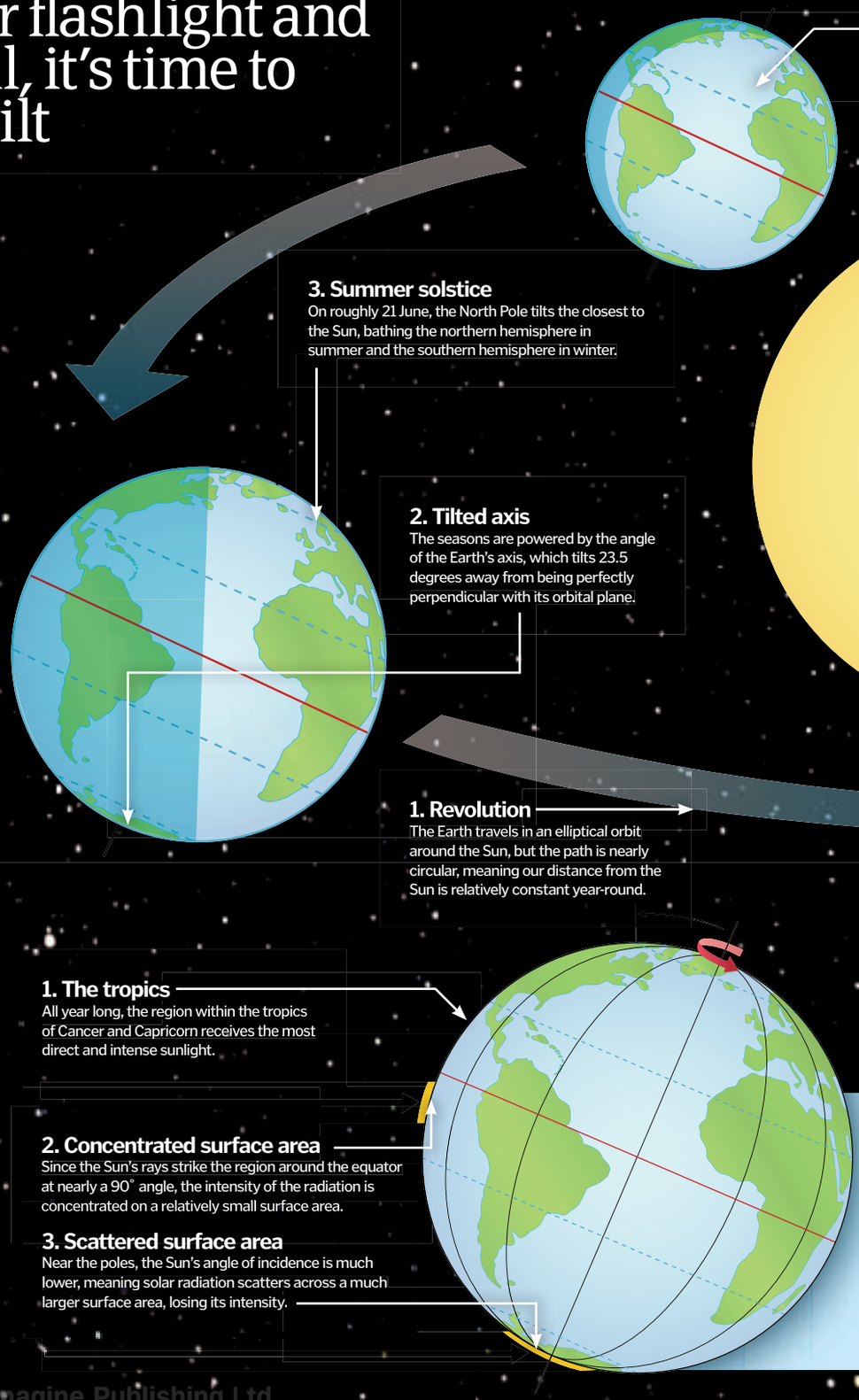
Get out your flashlight and a beach ball, it's time to talk about tilt

The Earth is a wonky planet. Every year we make a complete near-circular revolution around the Sun, but every day our planet spins around a lopsided axis. This imaginary line that runs through the centre of the planet from the North Pole to the South Pole is tilted at a 23.5° angle, and this wonky tilt is the reason for the seasons.

During June and July in the northern hemisphere, the North Pole is tilted toward the Sun and South Pole tilted away. This means that solar radiation hits the northern hemisphere "head on" and is absorbed in a more concentrated area. Because the southern hemisphere is angled away from the Sun, the same amount of solar radiation is spread across a much larger surface area.

But differences in solar intensity aren't enough to create summer and winter. The tilt of the axis also creates radical differences in the length of solar exposure, what we define as daylight. If we go back to our June and July example, the northern hemisphere is directly facing the Sun, which means the Sun carves a high path across the sky, creating longer daylight hours. In the southern hemisphere, the Sun travels much closer to the horizon, which limits daylight hours significantly.

The combination of longer days and concentrated sunlight gives us summer. Shorter days and dispersed solar energy gives us winter. Autumn and spring mark the transitional periods when days are getting longer or shorter and temperature variations tend to be less extreme.



5 TOP FACTS SEASONS ON OTHER PLANETS

Long summer
1 Because Neptune is so far away from the Sun, it takes over 164 Earth years to complete a revolution. That makes its summer around 40 years long.

"Tropical" Venus
2 Since Venus' axis only tilts at a 3° angle, all of its seasons are roughly the same, which results in a rather steamy 750K all year round.

Serious tilt
3 Uranus spins on an axis tilted at 98°, and much of the planet is bathed in continuous darkness or continuous light for 20 years at a time.

Springtime on Uranus
4 There are no April showers on Uranus. When spring arrives after 20 years of darkness, the warming atmosphere generates violent storms.

Long days
5 Due to its slow rotation on its axis and rapid movement around the Sun, a day on Mercury is the equivalent of 176 Earth days.

DID YOU KNOW? *Contrary to common sense, the Earth is closest to the Sun (147,300,000km) on or around 3 January*

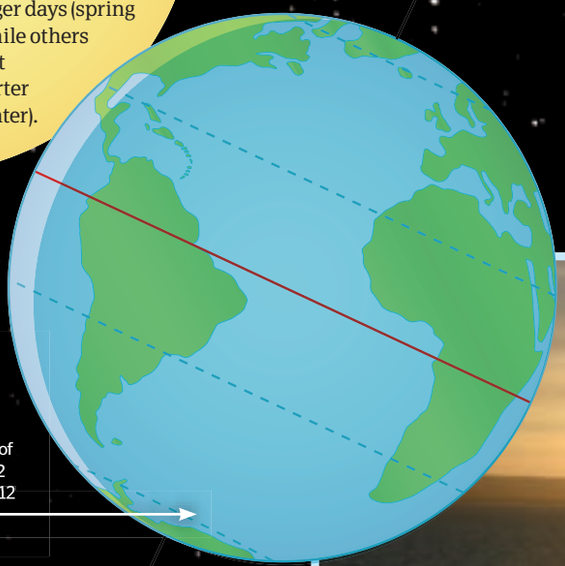
asons work

5. Vernal equinox
At this point in the orbit, the Sun shines evenly across the entire face of the Earth, neutralising the effect of the tilted axis.

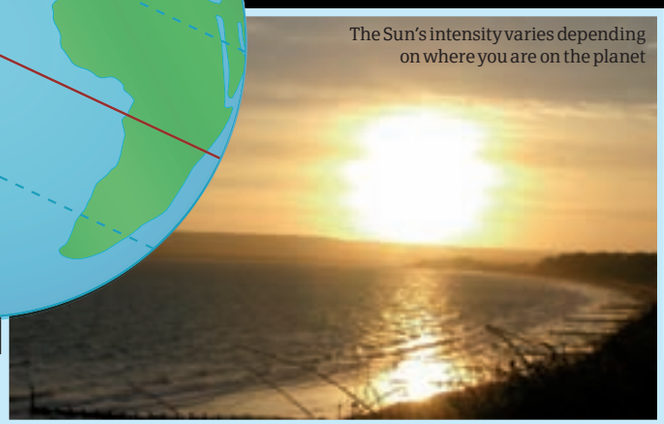
4. Winter solstice
At the opposite end of the Earth's orbit, it's the southern hemisphere's turn to receive the most direct sunlight while Europe and the United States enter winter.

The cycle of seasons

The seasons correspond not only to the Earth's position in orbit around the Sun, but your physical location on the Earth. At different times of the year, different parts of the planet receive more direct sunlight and longer days (spring and summer), while others receive less direct sunlight and shorter days (fall and winter).



6. Autumnal equinox
As with the vernal equinox, the first day of autumn has exactly 12 hours of daylight and 12 hours of darkness.



The Sun's intensity varies depending on where you are on the planet

Solar intensity

It gets hotter as you move closer to the equator because the region between the tropic of Cancer and the tropic of Capricorn receives more direct and concentrated solar radiation.

The reason for this is not because the tropics are 'closer' to the Sun than other parts of the planet. It has to do with something called the 'angle of incidence'. During the vernal and autumnal equinoxes, the Sun's rays strike the equator at a precise 90° angle. Since the solar radiation rains down on the Earth so directly, its intensity is concentrated in a relatively small area. Compare this with the solar exposure of Iceland, which sits right on the Arctic circle at roughly 66° north of the equator. During the autumnal equinox, the Sun's rays hit Iceland on a much shallower angle of 70°, spreading their radiation across a much larger surface area, thereby decreasing their intensity.

Solstice vs equinox

The winter solstice is commonly referred to as the "shortest day of the year". Although 21 December is still 24 hours long, it has the fewest hours of sunlight. On this day, the North Pole is tilted the furthest from the Sun, causing the Sun to trace a low path in the sky. As the months pass, the Sun's course drifts upward until we reach the vernal equinox, a day with exactly 12 hours of light and 12 hours of darkness. Around 21 June, the North Pole tilts closest to the Sun, the Sun rides high in the sky and we have the summer solstice, the longest day of the year. As the Sun's path sinks back toward the horizon, we reach the autumnal equinox, the second time all year when day and night are perfectly equal.

Here comes the Sun... flower

Seasons at the top of the world

For people living at the equator, seasons are virtually meaningless. The closer you are to the equator, the less your weather is affected by the tilt of the Earth. If you tilt a globe back and forth, the top and bottom appear to move further away from you, while the middle will remain relatively central.

In high-latitude regions the differences between seasons are extreme. In the dead of winter in northern Norway, the northern hemisphere is tilted so far away from the Sun that it doesn't peak over the horizon for two months. In the middle of summer, the Sun travels directly overhead, tracing a loop through the sky that holds back the night for 2.5 months.

Background image courtesy of NASA

"This year the budget for the ESA lies at £3.3 billion"

Radar dishes at the ESA's ESAC headquarters in Villanueva de la Cañada, Spain

An image of the ESA's headquarters in Paris, France. While centred at the heart of Europe, the ESA has bases all over the world, and co-operates on many missions undertaken by NASA, the FKA and the CNSA

European Space Agency

Europe's gateway to space, the European Space Agency is revealing the wonders of our Earth, solar system and the universe

The purpose of the European Space Agency (ESA) is to develop and advance Europe's space capability, while ensuring such research directly benefits those who fund it – the citizens of Europe. As such, the ESA is an international organisation comprised of 18 member states, which collectively pool their resources, be that financial or intellectual, in order to draw up the European space programme and carry it through – something that would be impossible to achieve if they simply worked as singular nations.

The ESA draws up programmes designed to explore, analyse and actuate information garnered from the Earth's immediate space environment, our solar system and even further a field into distant galaxies, in addition to developing satellite-based technologies and services constructed by European companies and industries. The size and financial/intellectual commitment a member state makes to the ESA is directly proportional to the amount of service contracts for technological construction and mission funding it receives, ensuring that the money spent by the county's government directly benefits its citizens.

The average investment per person per annum of an ESA member state is roughly eight pounds, which collectively provides the yearly budget for space expenditure. This year the budget for the ESA lies at £3.3 billion and will be spent across a wide gamut of missions, divisions and departments, including: the European Astronauts Centre, European Space Astronomy division, European Space Operations Centre, the ESA Centre for Earth Observation, and the European Space Research and Technology Centre.

The majority of space launches occur at the ESA's launch base in French Guiana (a 96,000 hectare base employing 1,500 people), where probes, satellites and rockets carry astronauts and equipment into space either to dock with the International Space Station, orbit the Earth and collect and transmit data, or on a far-off trajectory to monitor distant phenomena. Indeed, the ESA boasts one of the most active and successful mission profiles in the world and is currently embarking on a host of cutting-edge programmes – including the notable recent launch of CryoSat-2, an orbiting satellite designed to monitor the effects of global warming on Earth's ice reserves.

Head to Head SPACE AGENCIES

AMERICA

1. NASA

Established: 1958
Budget: £11.4 billion / $17.6 billion
Divisions: 15
Primary spaceport: Kennedy Space Center

EUROPE

2. ESA

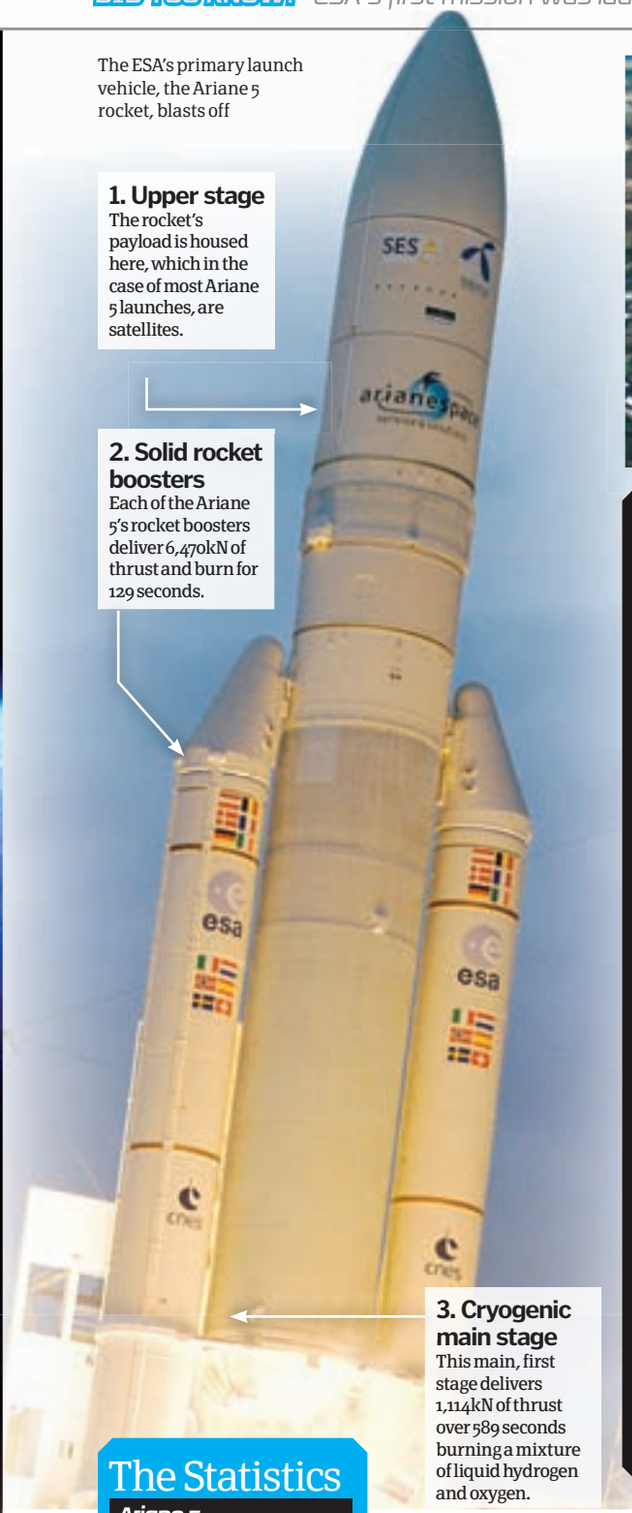
Established: 1975
Budget: £3.3 billion / $5.4 billion
Divisions: 5
Primary spaceport: Guiana Space Centre

CHINA

3. CNSA

Established: 1993
Budget: £850 million / $1.3 billion
Divisions: 4
Primary spaceport: Jiuquan Satellite Launch Center

DID YOU KNOW? *ESA's first mission was launched in 1975 and was a space probe designed to monitor gamma-ray emissions*



The ESA's primary launch vehicle, the Ariane 5 rocket, blasts off

1. Upper stage
The rocket's payload is housed here, which in the case of most Ariane 5 launches, are satellites.

2. Solid rocket boosters
Each of the Ariane 5's rocket boosters deliver 6,470kN of thrust and burn for 129 seconds.

3. Cryogenic main stage
This main, first stage delivers 1,114kN of thrust over 589 seconds burning a mixture of liquid hydrogen and oxygen.

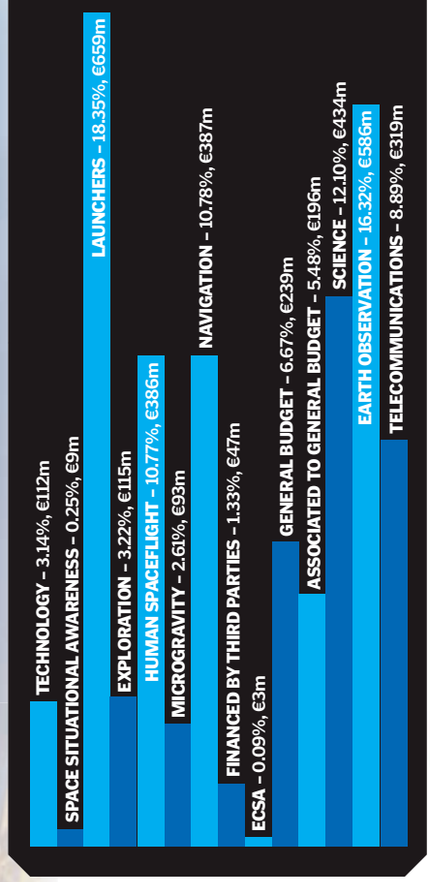
An aerial shot of the sprawling ESTEC division in Noordwijk

Divisions of the ESA

The ESA employs over 2,000 individuals, including scientists, engineers, information technology specialists and administrative personnel, across its five main divisions. These divisions are based all over Europe and are linked by the ESA's headquarters in Paris, France. Two of its larger divisions include ESOC, the European Space Operations Centre in Darmstadt, Germany, which since its creation in 1967 has operated more than 50 satellites, ensured spacecraft meet their objectives and co-ordinated ground-based communications. There's also the ESTEC in Noordwijk, The Netherlands, whose remit includes being the primary test centre for European space activities and all technical preparation and management of ESA space projects (ESTEC is the largest division of the ESA). Other divisions can be found in Frascati, Italy (ESRIN), Villanueva de la Cañada, Spain (ESAC) and Cologne, Germany (EAC).

ESA budgets

Breakdown of the ESA budgets (using 2009 figures)



Member countries

- ESA member countries
- ECS (European Co-operating state)
- Signed Co-operation Agreement countries

© Ssolberg

The Statistics

Ariane 5

Function: Heavy launch vehicle
Height: 46-52m (151-170ft)
Mass: 777,000kg
Stages: 2
Max payload: LEO – 21,000kg / GTO – 10,500kg
Maiden flight: 4 June 1996

1. Site
An Ariane 5 heavy launch vehicle stands on-site.

2. Access
The large approach road is necessary considering the size of the equipment being transported.

Europe's spaceport, the Guiana Space Centre, covers 96,000 hectares and is operated by more than 1,500 personnel

All uncredited images © ESA

"The CryoSat-2 satellite is orbiting Earth from an altitude of just over 700km and latitudes of up to 88 degrees"

Space for Europe

Learn about the three main missions currently being undertaken by the ESA

CryoSat-2

The ESA's most recent launch, CryoSat-2, is imaging and analysing the effects of global warming like never before

The ESA's Earth Explorer CryoSat-2 mission, which was launched on 8 April 2010 on a Dnepr rocket, is concerned with the precise monitoring of the changes in the thickness of marine ice floating in polar oceans and variations in the thickness of Greenland's ice sheets. This is a highly important and timely mission as currently Earth's ice fields are diminishing at an expediential rate.

The CryoSat-2 satellite – which boasts a state-of-the-art SAR/Interferometric Radar Altimeter, which measures ice by sending a series of cloud-piercing radar pulses down to Earth – is orbiting Earth from an altitude of just over 700km and latitudes of up to 88 degrees, a record for this type of platform. It is powered by two angled sheets of solar panels, which each contain hundreds of highly sensitive gallium arsenide solar cells that supply power for the batteries.

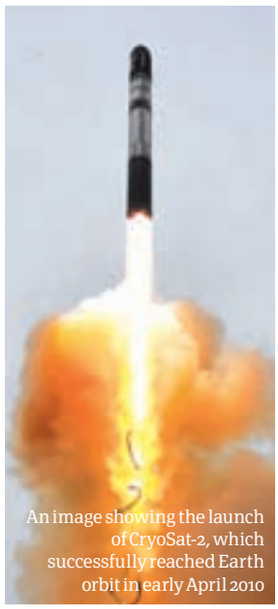
The CryoSat-2's technique of transmitting a series of radar pulses works as when they reach Earth they are scattered off the variable slopes of the ice sheet margins and the returned echo comes from the closest surface location with respect to the satellite. These are then received by the CryoSat-2's antennas – which are wrapped in multi-layer insulation – and decoded.


The dedicated control room for CryoSat-2 operations at ESOC, Darmstadt

1. Dnepr rocket head
The launch vehicle for the CryoSat-2 satellite was a Dnepr rocket, provided by the International Space Company Kosmotras. Housed in the top section of the rocket, CryoSat-2 separated successfully from the rocket after 17 minutes of vertical lift.

2. SAR/Interferometric Radar Altimeter
The primary payload of the CryoSat-2 is designed to meet the nuanced measurement requirements for ice-sheet elevation and sea-ice freeboard data acquisition. This highly advanced approach works by sending thousands of cloud piercing radar pulses to the ground each second and then measuring the time it takes for their echoes to return to CryoSat-2's antennas.

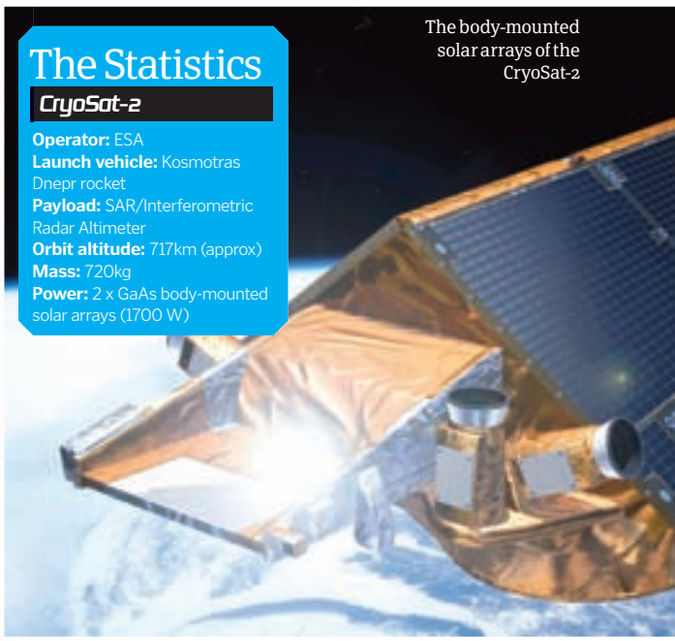
3. Solar panels
In order to power the imaging and data recording systems on the CryoSat-2 satellite, it is covered with two large sheets of solar cells, which produce power for the on-board batteries. Unlike many other satellites, these panels are fixed and non-deployable due to financial restrictions, however they are positioned on optimal angles for the capturing of solar energy throughout an orbit.

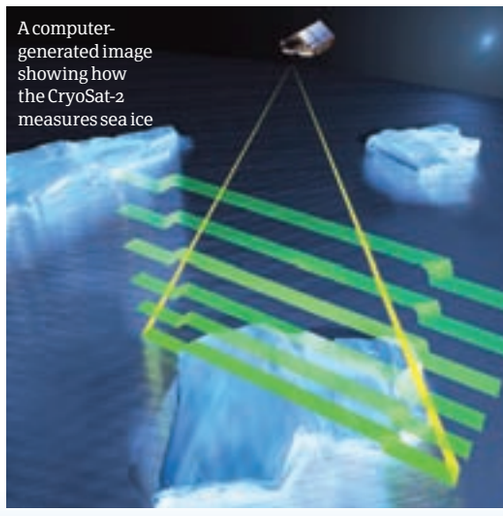

An image showing the launch of CryoSat-2, which successfully reached Earth orbit in early April 2010

The Statistics

CryoSat-2

Operator: ESA
Launch vehicle: Kosmotras Dnepr rocket
Payload: SAR/Interferometric Radar Altimeter
Orbit altitude: 717km (approx)
Mass: 720kg
Power: 2 x GaAs body-mounted solar arrays (1700 W)


The body-mounted solar arrays of the CryoSat-2


A computer-generated image showing how the CryoSat-2 measures sea ice

5 TOP FACTS ESA

Jobbing
1 Out of 10,000 people who registered back in 2008 for an ESA astronaut recruitment drive, only six made the cut. That's just a one in 1,666 chance of being successful.

Year-on-year
2 Since 2005 the annual budget of the European Space Agency has grown rapidly from £2.5 billion to the £3.3 billion it currently has at its disposal today.

Canada
3 Since 1 January 1971, Canada has acted as an associate member to the ESA. This means it takes part in the decision-making processes and its programmes.

Corps
4 There are currently 14 astronauts in the European Astronaut Corps, 13 of which are men and only one is a woman. The sole Brit is Timothy Peake.

Spot-on
5 The European Space Agency's spaceport in French Guiana is ideally positioned for space launches due to its proximity to the Earth's equator.

DID YOU KNOW? *The original CryoSat mission failed in 2005. The separation mechanism on its carrying rocket broke at launch*

An image showing the multiple parts of the Mars-500 simulated spacecraft

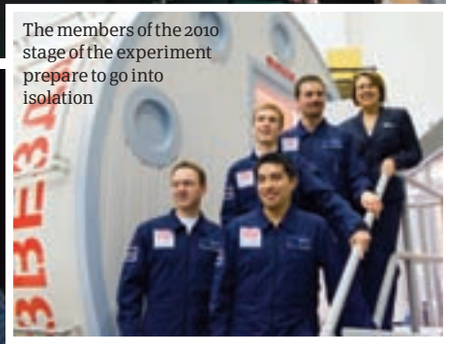
Mars-500

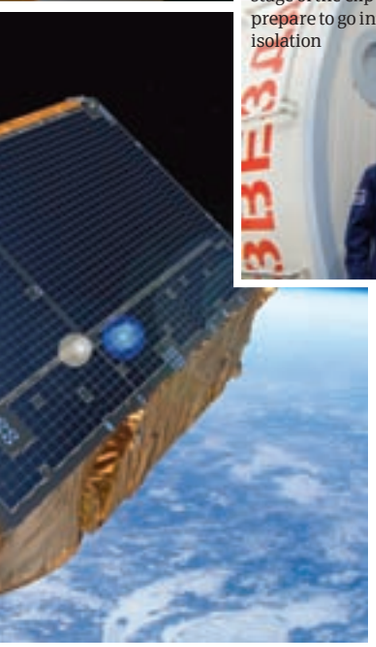
Deep within the Institute of Biomedical Problems in Russia's Academy of Sciences, an experimental facility is putting astronauts-in-training on Mars

The ESA's Mars-500 project is a three-stage experiment to replicate a manned mission to Mars on Earth. It consists of a multi-chambered replica spacecraft within the Russian Academy of Sciences in Moscow and it is currently being used to test the mental and physical characteristics of potential astronauts. The programme takes in volunteer astronauts who wish to be considered for future manned missions to Mars and encases them within the completed locked-down replica spacecraft. Here, communication is limited – only being undertaken at certain times and with delays to the watching control room of 20 minutes (this is the time it would take for messages to reach Earth if they were actually on the Red Planet) – as are consumables, forcing them to ration supplies and produce their own water.

Presently the programme has just entered its third and longest stage, a simulated 520-day mission to Mars. Here, six astronauts are aiming to live, exercise and work in the five modules of the simulated spacecraft, four sections replicating parts of the spacecraft (habitable area, exercise room, medical module etc) and one larger module that recreates the surface of Mars.

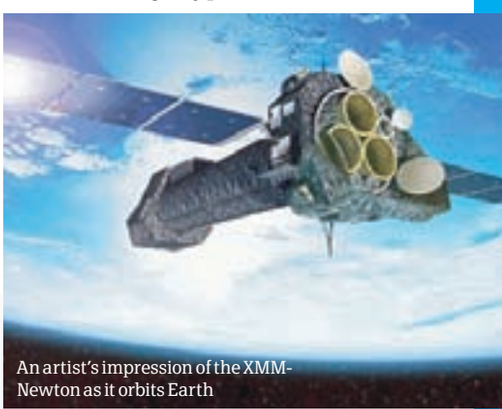
The crew are to be monitored and their psychological, medical and physical signs recorded throughout the mission. During the replicated surface operations, the crew will be split in two, with three operating in the Martian surface simulator and three remaining in the simulated spacecraft. An average day in the Mars 500 project will include the astronauts conducting maintenance, scientific experiments, daily exercise regimes and, occasionally, simulated emergency procedures.


The members of the 2010 stage of the experiment prepare to go into isolation




Training facilities are included to help keep the astronauts fit and healthy

All uncredited images © ESA


An artist's impression of the XMM-Newton as it orbits Earth

XMM-Newton

The primary x-ray telescope of the ESA, the XMM-Newton is increasing our knowledge of black holes, the formation of galaxies and the origins of the universe

Launched from the ESA's Guiana spaceport in 1999 on an Ariane 5 rocket, the XMM-Newton is the ESA's largest and most active x-ray observatory and orbiting satellite. It orbits the Earth on a highly eccentric and elliptical orbit of 40 degrees and boasts three x-ray telescopes each containing 58 Wolter-type concentric mirrors. It is powered by twin extendable solar arrays that give the XMM a span of 16 metres. In addition to its three x-ray telescopes, the XMM also includes two reflection-grating spectrometers (used to measure light intensity) and a 12-inch in diameter Ritchey-Chrétien optical/UV telescope (a specialised telescope used to mitigate aberration in images).

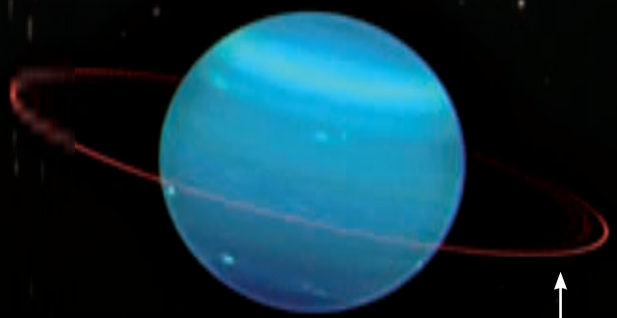
The XMM-Newton's name comes from the design of its mirrors, the highly nested x-ray multi-mirrors, and in dedication to the great scientist Sir Isaac Newton. These mirrors are enabling astronomers to discover more x-ray sources than with any of the previous space observatories. In one day, for example, the XMM-Newton sees more sources in one small area than lesser satellites managed in years. Thanks to its orbit, the XMM-Newton has been able to measure the influence of the gravitational field of a neutron star on the light it emits. This was a first in astronomical observation and helped give a valuable insight into these super-dense objects.

"Uranus has a complex ring system and a total of 27 moons"

Uranus

Seventh planet from the Sun, third-largest and fourth most massive in the solar system. Uranus was the first planet to be discovered by telescope

Four times the size of Earth and capable of containing 63 Earths inside it (it is only 14.5 times as dense however, as it is a gas giant), Uranus is the third largest and forth most massive planet in our solar system. Appearing calm and pale blue when imaged, Uranus has a complex ring system and a total of 27 moons orbiting its gaseous, cloudy main body. Due to its distance from the Sun the temperature at the cloud-top layer of the planet drops to -214°C and because of its massive distance from Earth it appears incredibly dim when viewed, a factor that led to it not being recognised as a planet until 1781 by astronomer William Herschel.



1. Atmosphere

Uranus's blue colour is caused by the absorption of the incoming sunlight's red wavelengths by methane-ice clouds. The action of the ultraviolet sunlight on the methane produces haze particles, and these hide the lower atmosphere, giving the planet its calm appearance. However, beneath this calm façade the planet is constantly changing with huge ammonia and water clouds carried around the planet by its high winds (up to 560mph) and the planet's rotation. Uranus radiates what little heat it absorbs from the Sun and has an unusually cold core.

2. Rings

Uranus's 11 rings are tilted on their side when viewed from Earth and they extend out from 12,500 to 25,600km from the planet. They are widely separated and incredibly narrow too, meaning that the system has more gap than ring. All but the inner and outer rings are between 1km and 13km wide, and all are less than 15km in height. The rings consist of a mixture of dust particles, rocks and charcoal-dark pieces of carbon-rich material. The Kuiper Airborne Observatory discovered the first five of Uranus's rings in 1977.

Inside Uranus

A cross-section of the blue planet

Upper atmosphere, cloud tops

Core
Made up of rock and ice

Oberon
The first Uranian moon to be discovered.

Umbriel
The darkest of the major moons, reflecting only 16 per cent of light.

Titania
Uranus' largest moon appears grey with an icy surface.

Ariel
The brightest and with the youngest surface of the major moons.

Miranda
Features a scarred, piecemeal structure.

5 TOP FACTS URANUS

Old man
1 Uranus is named after the Greek deity of the same name who, in Greek mythology, was Zeus's grandfather and the father of Cronus.

Passing wind
2 Uranus is one of the solar system's most windy planets, with speeds that can reach up to a monumental 250 metres per second.

Bonus
3 Upon discovering Uranus, William Herschel was gifted an annual stipend of £200 by King George III, on the condition he moved to Windsor.

Elementary
4 The element uranium was named in dedication to the discovery of Uranus eight years prior to the element's discovery in 1789.

Lone ranger
5 The only space probe to examine Uranus to date was the Voyager 2 in 1986, when it passed with 82,000km of the planet's cloud-tops.

DID YOU KNOW? *Many of Uranus's moons are named after characters from the plays of Shakespeare*

Miranda is littered with impact craters and is heavily scarred with faults

Miranda

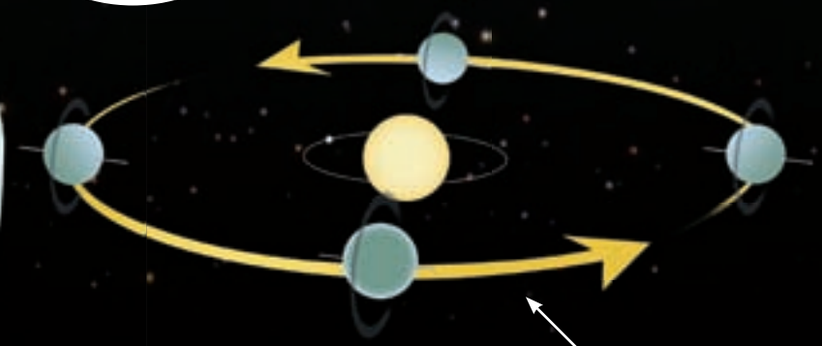
The smallest and innermost of Uranus's five major moons, Miranda is like no other moon in our solar system

When the Voyager 2 passed by Uranus in 1986 it not only observed the planet but also many of its moons, coming close to its innermost Miranda at a distance of 32,000km. However, the images it recorded were not what were expected as on closer inspection it showed the satellite's surface consisted of a series of incongruous surface features that seemed to have been crushed together and butted up unnaturally. Miranda was an ancient terrain that seemed to have been constructed from various smaller segments from different time periods, instead of forming as one distinct whole at one time. Scientists have theorised that this was probably caused by a catastrophic collision in the moon's past that caused it to shatter into various pieces before then being reassembled in this disjointed way.

Verona Rupes
Found on Uranus' moon Miranda, this cliff face is estimated to be ten kilometres deep, almost ten times the depth of the Grand Canyon. This makes it the tallest known cliff in the entire solar system.

Atmosphere
Consists of hydrogen, helium and other gasses

Mantle
A large layer of water, methane and ammonia ices



4. Orbit

Uranus takes 84 Earth years to complete a single orbit around the Sun, through which it is permanently tilted on its side by 98° – a factor probably caused by a planetary-sized collision while it was still young. Due to its sideways positioning each of the planet's poles points to the Sun for 21 years at a time, meaning that while one pole will receive continuous sunlight, the other will receive continuous darkness. The strength of the sunlight that Uranus receives on its orbit is 0.25 per cent of that which is received on Earth. There is a difference of 186 million kilometres between Uranus's aphelion (furthest point on an orbit from the Sun) and perihelion (closest point on an orbit from the Sun).

3. Structure

Uranus consists of three distinct sections, an atmosphere of hydrogen, helium and other gases, an inner layer of water, methane and ammonia ices, and a small core consisting of rock and ice. Electric currents within its icy layer are postulated by astronomers to generate Uranus's magnetic field, which is offset by 58.6° from the planet's spin axis. Its large layers of gaseous hydrogen and constantly shifting methane and ammonia ices account for the planet's low mass compared to its volume.

Sizes...
Uranus' diameter is nearly five times that of Earth, with a mass that's equivalent to 14 and a half Earths.

12,756.3km

51,118km

Images courtesy of NASA

"The Sun, a type G yellow-white star with a radius of 700,000 kilometres and a temperature of 6,000 kelvin"

A star is born

A star is b

There may be as many as 10 billion trillion stars in the 100 billion galaxies throughout the universe, but "only" about 100 billion in our galaxy, the Milky Way. Most stars comprise plasma, helium and hydrogen. They form when giant molecular clouds (GMCs), also known as star nurseries, experience a gravitational collapse. This increase in pressure and temperature forces fragments into a body known as a protostar. Over the course of its life, a typical star goes through continuous nuclear fusion in its core. The energy released by this fusion makes the star glow.

Stars are classified according to the Hertzsprung-Russell Diagram, which lists their colour, temperature, mass, radius, luminosity and spectra (which elements they absorb). There are three main types of star: those above, below and on the main sequence. Within these types, there are seven different classifications. We're most familiar with the main sequence star that we call the Sun, a type G yellow-white star with a radius of 700,000 kilometres and a temperature of 6,000 kelvin. However, some stars above the main sequence are more than a thousand times larger than the Sun, while those below the main sequence can have a radius of just a few kilometres.

LOW-MASS STARS

Red dwarf

The cool star

Red dwarfs are small and relatively cool stars, which while being large in number tend to have a mass of less than one-half that of our Sun. The heat generated by a red dwarf occurs at a slow rate through the nuclear fusion of hydrogen into helium within its core, before being transported via convection to its surface. In addition, due to their low mass red dwarfs tend to have elongated life spans, exceeding that of stars like our Sun by billions of years.

Giant molecular cloud

Proto-stars

SUN-LIKE STARS

Red giant

A star explodes

If a star has enough mass to become a supergiant, it will supernova instead of becoming a white dwarf. As nuclear fusion ends in the core of a supergiant, the loss of energy can trigger a sudden gravitational collapse. Dust and gas from the star's outer layers hurtle through space at up to 30,000 kilometres per second.

Almost a star

A protostar is a ball-shaped mass in the early stages of becoming a star. It's irregularly shaped and contains dust as well as gas, formed during the collapse of a giant molecular cloud. The protostar stage in a star's life cycle can last for a hundred thousand years as it continues to heat and become denser.

HIGH-MASS STARS

Brown dwarf

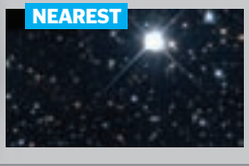
Star or planet?

A brown dwarf is sometimes not even considered a star at all, but instead a sub-stellar body. They are incredibly small in relation to other types of stars, and never attained a high enough temperature, mass or enough pressure at its core for nuclear fusion to actually occur. It is below the main sequence on the Hertzsprung - Russell Diagram. Brown dwarfs have a radius about the size of Jupiter, and are sometimes difficult to distinguish from gaseous planets because of their size and make-up (helium and hydrogen).

The rarest star

Supergiants are among the rarest types of stars, and can be as large as our entire solar system. Supergiants can also be tens of thousands of times brighter than the Sun and have radii of up to a thousand times that of the Sun. Supergiants are above the main sequence on the Hertzsprung-Russell Diagram, occurring when the hydrogen of main sequence stars like the Sun has been depleted.

Head to Head TYPES OF STAR

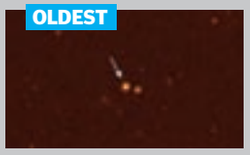


1. Proxima Centauri

Other than our Sun, the closest star to Earth is Proxima Centauri. It is about four light-years from the Sun.

2. VY Canis Majoris

The largest known star, VY Canis Majoris, has a radius of between 1,800 and 2,100 times that of the Sun.



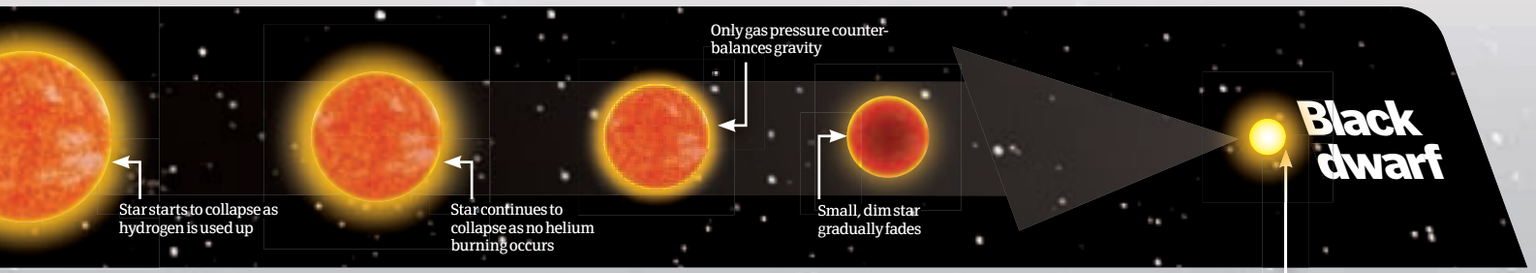
3. HE0107-5240

HE0107-5240, a giant star in the Milky Way, may be nearly as old as our universe at about 13.2 billion years old. It could've once been part of a binary star system.

DID YOU KNOW? *A star may have a life cycle of millions to trillions of years. The larger the star is, the shorter its life cycle*

om

Compared to other stars, the Sun is in the middle of the pack when it comes to size and temperature



Catch a dying star

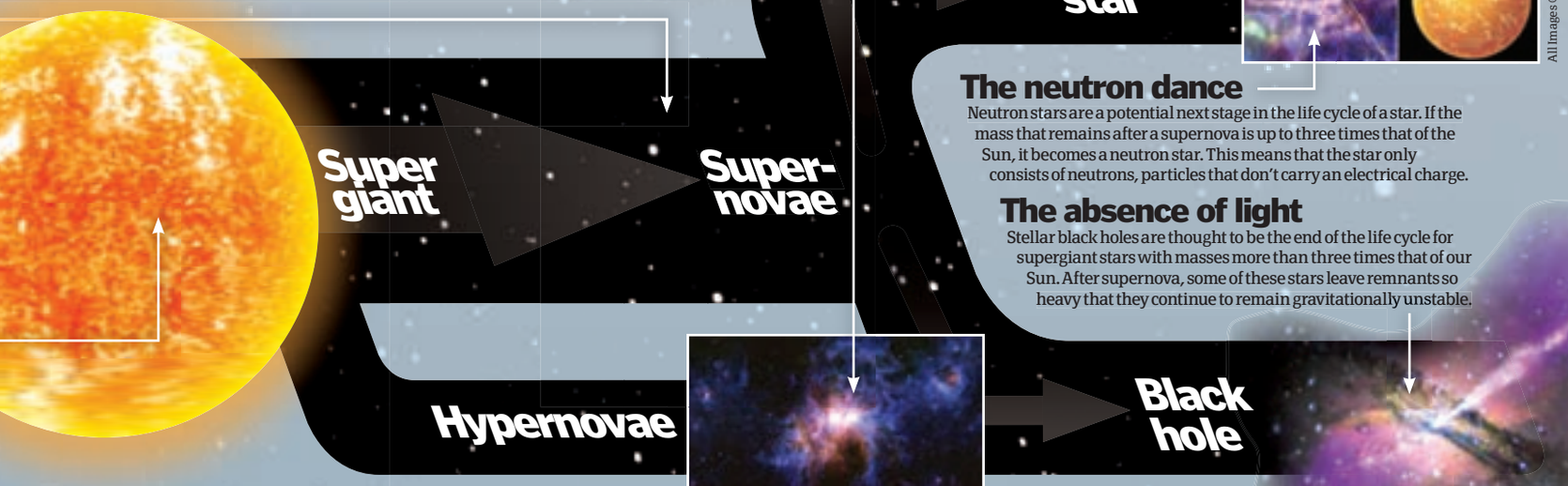
White dwarfs are considered the final phase in a star's life cycle unless it attained enough mass to supernova (and more than 95 percent of stars don't). The cores of white dwarfs typically comprise carbon and oxygen, left over after the gas is used up during nuclear fusion and occurring after a main sequence star has gone through its giant phase. A white dwarf is small, with a volume comparable to that of Earth's, but incredibly dense, with a mass about that of the Sun's. With no energy left, a white dwarf is dim and cool in comparison to larger types of stars.

The stellar remnant

Black dwarfs are the hypothetical next stage of star degeneration after the white dwarf stage, when they become sufficiently cool to no longer emit any heat or light. Because the time required for a white dwarf to reach this state is postulated to be longer than the current age of the universe, none are expected to exist yet. If one were to exist it would be, by its own definition, difficult to locate and image due to the lack of emitted radiation.

Beyond the supernova

A hypernova is a supernova taken to an even larger degree. Supergiant stars with masses that are more than 100 times that of the Sun are thought to have these massive explosions. If a supergiant were close to Earth and exploded into a hypernova, the resulting radiation could lead to a mass extinction.



All Images © NASA

The neutron dance

Neutron stars are a potential next stage in the life cycle of a star. If the mass that remains after a supernova is up to three times that of the Sun, it becomes a neutron star. This means that the star only consists of neutrons, particles that don't carry an electrical charge.

The absence of light

Stellar black holes are thought to be the end of the life cycle for supergiant stars with masses more than three times that of our Sun. After supernova, some of these stars leave remnants so heavy that they continue to remain gravitationally unstable.

This month in **Technology**

The World Cup is here and along with the best of the planet's football action, this unique tournament also offers a host of technological innovations that can be enjoyed by even the most anti-football gadget fans. We've chosen to take a look at one of the most impressive stadiums of the competition along with the shirts, shorts, boots and other kit worn by the players. If that doesn't grab you then take a look inside the Nexus One instead.

65 Pinball tables

68 World Cup technology

70 Dyson Air Multiplier

TECHNOLOGY

© Google

The Statistics

Nexus One

Dimensions: 119mm x 59.8mm x 11.5mm
Weight: 130g (100g without battery)
Display: 3.7-inch touch screen
Processor/speed: 1GHz Snapdragon processor
Camera: 5 megapixels, auto focus, LED flash, location tagging from AGPS receiver
Memory: 512MB Flash, 4GB microSD card (expandable to 32GB)
Ports: 3.5mm stereo headphone jack with four contacts for inline voice and remote control
Battery: Removable 1400mAh
Extras: GPS and compass, accelerometer, light sensor that changes screen brightness to conserve power, personalised laser engraving (up to 50 characters on the back of the phone)

Inside Google's super phone

Not content with dominating the internet search industry, Google has set its sights on the mobile phone business with the Nexus One, a self-styled super phone

When Google announced that it was entering the mobile phone market in January, it dubbed its new Nexus One device as the world's first 'superphone'. The device was aimed at users of existing smartphones like Apple's iPhone or the popular BlackBerry models, but added a whole new array of features that would make it not just smart, but super.

The Nexus One runs on Google's own Android operating system. This is a platform designed for touch-screen devices, and is already seen on handsets from companies like HTC, Motorola and Sony Ericsson. But the phone's key features are unavailable on other devices.

The most exciting is the speech-to-text technology that runs throughout the system. Wherever a text entry box appears you can simply speak into your phone and your words will be transcribed into text. This speech

5 TOP FACTS GOOGLE PRODUCTS

Google Search
1 Developed in 1997, this is the product that started it all. Google's search engine revolutionised the internet search, and is by far the most used website on the planet.

Gmail
2 A free web-based email service offering, effectively, unlimited storage as well as powerful features that can match the best desktop email clients.

Google Docs
3 Google's online word processing and spreadsheet applications give you the functionality of Microsoft Office, but runs on virtually any web-enabled computer.

Google Maps
4 This project includes Street View, with high-res 360-degree street level views of 95 per cent of the UK, and Navigation, a free turn-by-turn satnav tool for US phones.

Google Goggles
5 A next-gen visual search engine for smartphones. Take a photo of an object and Goggles will analyse the picture and instantly find the object on the web. Genius!

DID YOU KNOW? *The Android OS is open source, meaning anyone can download it, tweak it and build their own version*

Camera
The Nexus One has a five megapixel camera located at the rear. Being so small its quality is not able to match that of a dedicated digital camera.

LED flash
A small LED flash helps the camera take pictures in poor lighting conditions. Smaller than a 5p piece, it is somewhat less effective than a Xenon flash in a dedicated camera.

Battery
The 1400mAh battery has enough capacity to withstand about a day's heavy use, and will need a nightly charge to keep the phone running.

Processor
Among the various chips on the phone is Qualcomm's Snapdragon processor. It runs at 1GHz frequency and is fast enough to play HD video.

Buttons
Touch-sensitive buttons and trackball are found here.

Screen
The screen is 3.7" large and fully touch-optimised, making it easy to navigate the Nexus One's interface.

Casing
Houses an impressive amount of features in such a small space.

Trackball
Although a touch screen phone, the Nexus One has a trackball beneath the screen. Roll this around to move in all directions – it is most effective when navigating webpages.

The Android Market

Google's Nexus One runs on the Android operating system which uses the Android Market for downloading and installing third-party software. The App Market is growing to the tune of several thousand per week, and is set to hit the 50,000 mark later this year. Android is increasingly cementing its position as number two for developers and businesses wishing to move into mobile applications, and we're seeing more and more of the popular iPhone apps begin ported across to this platform.

Google Nexus One V Apple iPhone 3GS

Google Nexus One
Screen size: 3.7"
Processor: Snapdragon 1GHz
Memory: 512MB
Apps: 30,000 via Android Market
Camera: 5MP
Battery: 1400mAh

Apple iPhone 3GS
Screen size: 3.5"
Processor: 600MHz
Memory: 256MB
Apps: 150,000 via App Store
Camera: 3.2MP
Battery: N/A

Verdict In a simple comparison of hardware specs the Nexus One is a long way out in front: bigger, higher-resolution screen, faster processor, more memory. But where the iPhone continues to dominate is in apps, with five times as many available as on Google's device.

recognition software works not by recognising actual words, but rather by piecing together sounds to form words. It's pretty accurate, although prone to hilarious context-free misinterpretations.

The Nexus One also sports two microphones offering dynamic noise suppression, which filters out extraneous noises when you are making a call. Here, sounds are analysed by frequency in a way similar to how the human ear works – how you can tell the difference between speech, music and background voices at a party, for example – and can enhance the voice of the caller while removing or toning down everything else.

In addition the Nexus One has an AMOLED display, which uses less power and has richer colours than a traditional TFT screen, and features Qualcomm's Snapdragon processor, a processor so powerful that it can even run HD video. With all these features combined, the Nexus One truly is super.

Learn more
For more info and images on the Nexus One, visit the gadget surgeons at **ifixit.com**.

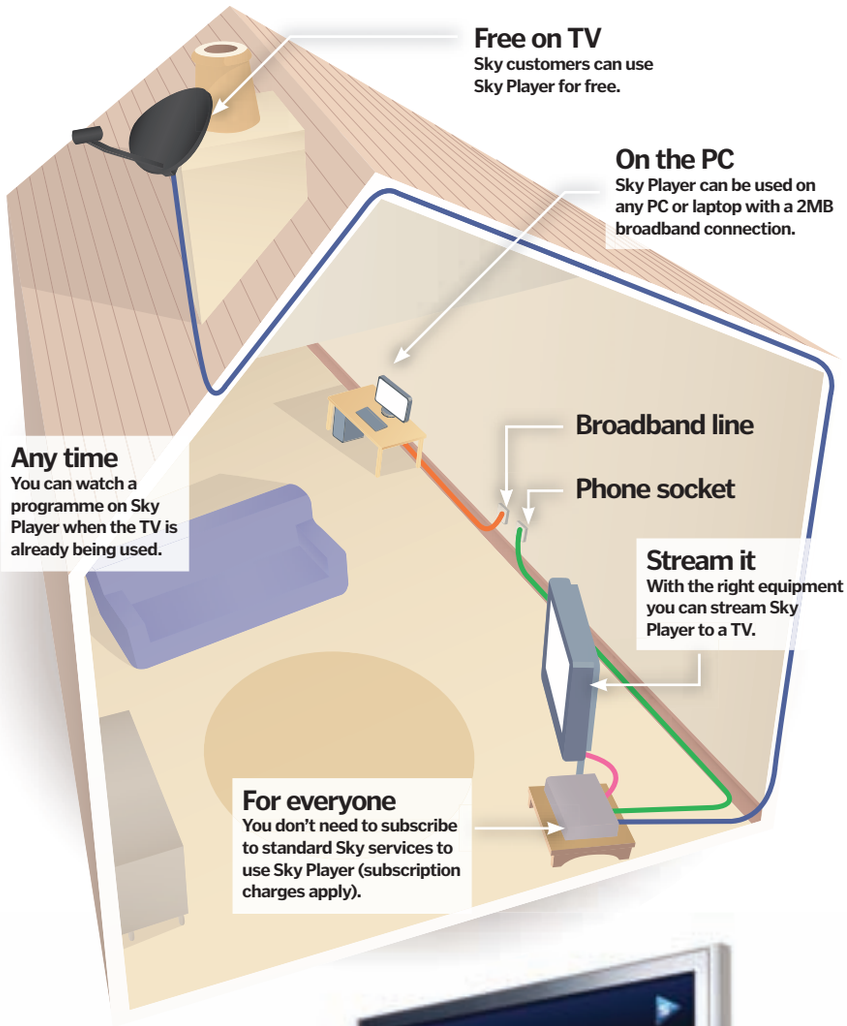
"The process behind the system is surprisingly simple and is centred on racks of PCs in a server room"

How does Sky Player deliver TV?

Sky Player delivers live TV over the internet continuously. So, how does it do it?

Sky Player is a spin-off from Sky's main set-top box service which delivers live TV to computers and the Xbox 360 on demand to anyone who wants to use it. Customers can stream live TV from a selection of more than 40 channels and can also catch up on TV shows they may have missed for up to 30 days.

The process behind the system is surprisingly simple and is centred on racks of PCs in a dedicated server room which act as the hub of the operation. Shows are uploaded in three formats – MPEG-2, QuickTime and Windows Media – onto an FTP server where they are encrypted to ensure that only valid subscribers can view them. At this point the Sky Player software will push requests direct to it for streaming on the user's equipment. With thousands of requests live at any one time the bandwidth consumed is huge by any standards. In short, the system works by delivering digital information like most other internet services such as websites, but the security involved and the equipment required to deliver such a huge amount of content is without doubt at the high-end of what is possible today.



The Player is a spin off from the set-top service

A brief history

Sky can trace its roots all the way back to 1982 and some significant milestones have been achieved since

1982
Super Station Europe makes its first broadcast to cable customers in Norway and Finland. Two years later it becomes 'Sky Channel'.

1990
British Sky Broadcasting is formed following a merger between Sky Television and British Satellite Broadcasting.

1992
British Sky Broadcasting signs exclusive rights to the FA Premier League and brings live football to the masses for the first time.

1998
Astra satellites launched which pave the way for Sky Digital to provide digital satellite television across the country.

2001
Sky+ launches which offers digital video recording alongside the ability to pause and rewind live TV.

2006
Sky HD launches with ten high definition channels. Sky expects 50 HD channels to be available by the end of 2010.

2009
Sky Songs launches offering MP3 downloads on a subscription basis and unlimited streaming of over 4 million tracks.

2010
The Sky 3D channel is expected to start broadcasting imminently and is the latest innovation in Sky's short, but fascinating history.

TOP FACTS WEB HOSTING

Internet provider hosting
1 Everyone has it but very few use it. Check with your internet provider to see what hosting package comes free with your broadband connection, although it's usually limited.

Shared hosting
2 A server at your hosting company runs your website for you, but the server is shared across many sites. Inexpensive, but only suitable for low-traffic sites.

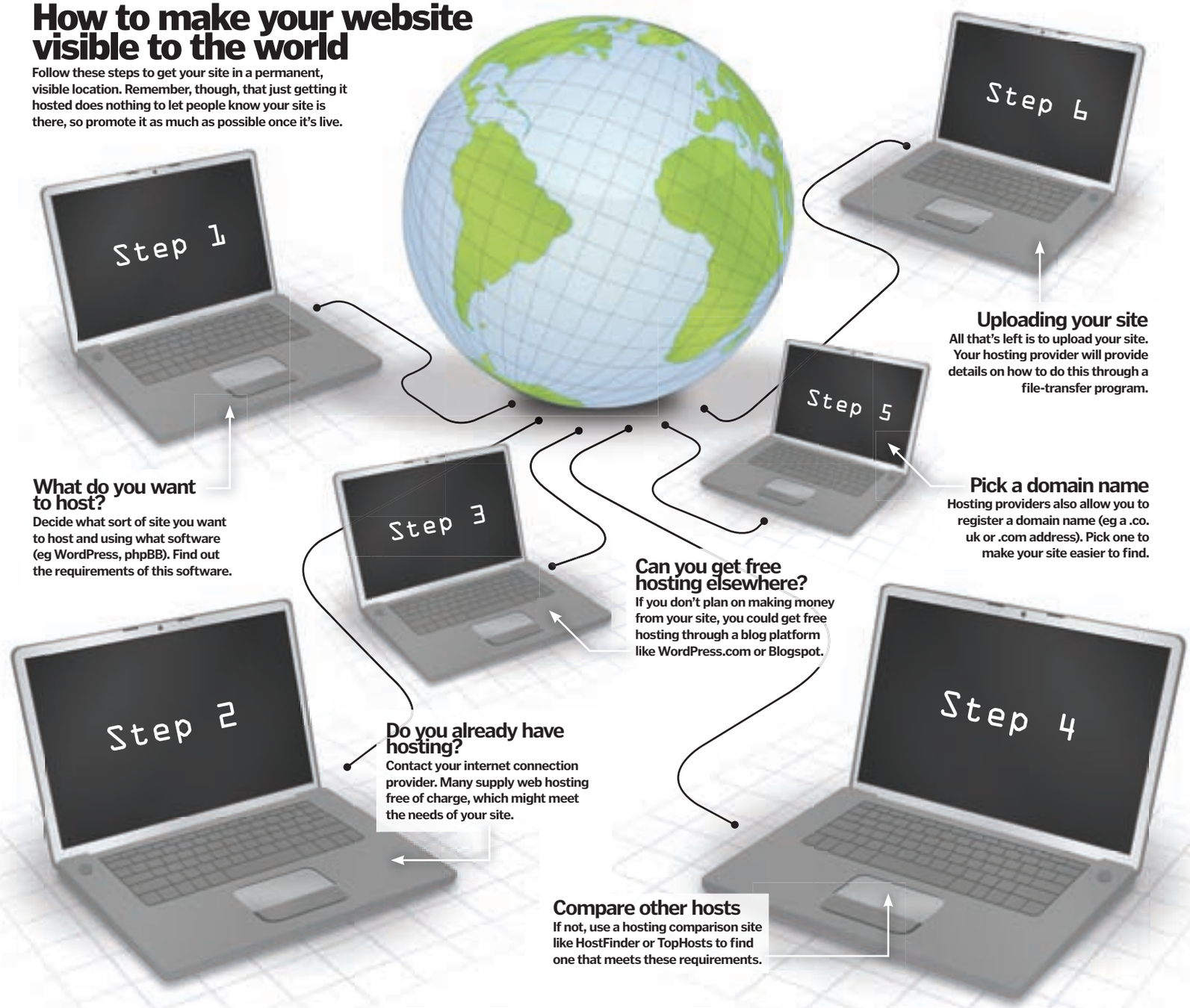
Dedicated hosting
3 Popular mostly with businesses, the hosting company provides a server solely for your website. This results in increased site speed but comes at a hefty premium.

Co-location
4 The site owner supplies their own server, which sits in the hosting company's data-centre. Less expensive but requires hardware to be bought up front.

DID YOU KNOW? *The free blogging platform WordPress.com now hosts over 9 million individual blogs*

How to make your website visible to the world

Follow these steps to get your site in a permanent, visible location. Remember, though, that just getting it hosted does nothing to let people know your site is there, so promote it as much as possible once it's live.



What do you want to host?
Decide what sort of site you want to host and using what software (eg WordPress, phpBB). Find out the requirements of this software.

Do you already have hosting?
Contact your internet connection provider. Many supply web hosting free of charge, which might meet the needs of your site.

Can you get free hosting elsewhere?
If you don't plan on making money from your site, you could get free hosting through a blog platform like WordPress.com or Blogspot.

Compare other hosts
If not, use a hosting comparison site like HostFinder or TopHosts to find one that meets these requirements.

Pick a domain name
Hosting providers also allow you to register a domain name (eg a .co.uk or .com address). Pick one to make your site easier to find.

Uploading your site
All that's left is to upload your site. Your hosting provider will provide details on how to do this through a file-transfer program.

How web hosting works

How do web hosting companies cater for the world's websites?

Every time you visit your favourite website, you're in contact with a web server – a program that figures out what content you're asking to see and then sends it to your browser. Any computer can act as a web server, but the trend is to have a company that runs servers that host your site for you.

Web servers need to be on all the time so visitors can access the site – hosting companies specialise in keeping servers running and connected to the internet 24 hours a day. It's also much cheaper for a hosting company to run one server that could potentially host hundreds of sites than it would be for each of those sites to be hosted privately. Finally, the hosting company takes a lot of the worry out of hosting a site by making sure their servers are secured to the highest standards.

Most of the world's websites use a 'virtual hosting' system. In this case, a server at a particular internet address holds many websites. All the domain names (the names in words that end with, for example, .com) for those sites point to that one server. Whenever you visit a page, your browser makes a point of telling the server which domain name it used to find it, allowing it to figure out which of the thousands of pages on its disk to send back to you.

"The cigarettes are tobacco and tar free, which is beneficial to their users as they contain zero carcinogens"

A packet of electronic E-Lites cigarettes

The cigarette's all-important atomiser

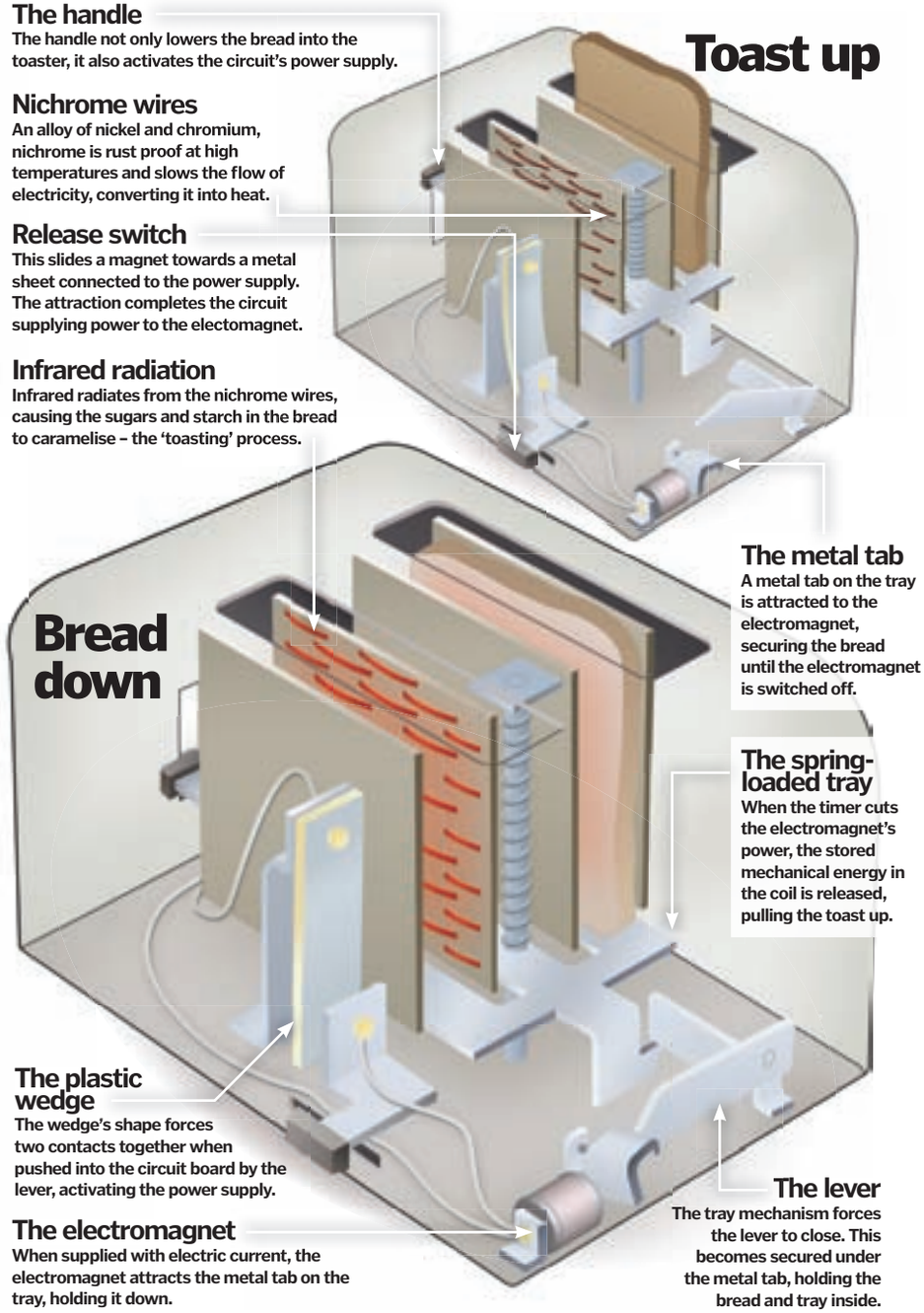
Electronic cigarettes

How do these zero tar, zero tobacco cigarettes work?

Electronic cigarettes, such as the E-Lites brand, work by turning liquid nicotine into vapour by heating it up in an atomising chamber, allowing it to then be inhaled by the user through a plastic inhaler. The cigarette consists of five main components: an indicator light on the tip of the cigarette, which lights up when nicotine is inhaled, a battery encased in the cigarette's body to power the atomiser, the atomiser itself – a small piece of equipment used to convert liquid to vapour – a microchip regulator and indicator to control the amount of nicotine atomised and inhaled in one go, and the plastic inhaler.

Out of the box, in order for users to smoke the electronic cigarette they must first charge its battery component. The battery on the electronic cigarette is charged up through a USB connection hub – a process that takes approximately 30 minutes for a full charge. Once the battery is charged – this is necessary to power the atomiser – users can then connect the atomiser and nicotine cartridge. Each nicotine cartridge provides 12 cigarettes' worth of nicotine, with each cigarette constituting 12 inhalations through the inhaler.

The cigarettes are tobacco and tar free, which is beneficial to their users as they contain zero carcinogens and no harmful additive chemicals. Further, they are smoke free, with only a sweet smelling vapour exhaled by their users. As with regular cigarettes, the electronic variant is not for sale to anyone below 18 years of age.



Toasters

What transforms a slice of bread into tasty toast?

When the handle lowers the bread, a wedge forces two contacts together which connects the power supply to nichrome wires wrapped around plates called mica sheets. Nichrome is a highly resistant material which converts electrical current into heat. The spring-loaded tray forces a lever down which snaps into place under a metal tab, holding the bread inside. Sliding the release switch moves a magnetic element towards a metal sheet connected to the power supply. Once they make contact the completed circuit activates the electromagnet, attracting the metal tab towards it. The lever is released, allowing the tray mechanism to spring back up. Out pops the toast!

DID YOU KNOW? *A typical modern pinball machine consists of over 3,500 components including over half a mile of wiring*

Pinball machines

What lies beneath these mechanical marvels?

Pinball machines have evolved into complex, computer-controlled mechanical games over the decades, but the layout has nearly always consisted of an inclined playfield and a backbox – the machine's brain. To score points, players aim for targets, bumpers and slingshots. When a ball hits one of these, two contacts are forced together in an electro-mechanical switch, completing a circuit and registering a strike. Every switch is wired to a unique reference point within a switch matrix. A microprocessor locates a strike by detecting the change in electrical current at a particular grid reference point. It then processes the instruction dictated by the software stored in an EPROM chip (to increase the score for example).

Most of the moving elements, like the flippers, are controlled by solenoids. Solenoids are electromagnetic tubes that, when powered, attract metal actuators towards it. This attraction can be manipulated into quick movements by rapidly switching the power on or off to certain solenoids – handy for kicking balls away from bumpers. Tilt sensors detect deliberate tilting and excessive shaking while a weighted metal rod swings like a pendulum within a conductive ring, this means that over-enthusiastic players will cause the rod to swing and make contact with the ring, activating a warning.

The backbox
The upright unit that contains the master circuit boards, dot matrix score display and enticing artwork to lure players.

Wiring
One set of wiring provides power to the lamps and the other controls the solenoids and switches on the playfield.

The playfield
Where the ball rolls. Some machines even feature a smaller raised gaming platform and are known as multi-level playfields.

Ramps
Ramps are inclined surfaces which often lead to smaller raised playfields or habitrails – paths made of steel wire.

Targets
Targets are specific locations on the playfield that, when hit, reward the player. Drop targets are lowered after impact.

Slingshots
Two triangular-shaped objects located above the flippers that kick the ball towards each other upon impact.

Holes
Kick-out holes fire the ball back into play. Sinkholes lose the ball forever.

Outlanes
Lanes nearest the player that direct the ball towards the dreaded centre drain.

Bumpers
Bumpers register hits when struck by a ball. Active bumpers rebound the ball away unlike the less common passive type.

Electromagnetic flippers
Two main flippers are located above the drain and additional shorter flippers are often located further up the table.

The ball
A steel ball, usually 2.7cm in diameter. Rarer ceramic balls, known as powerballs, add a different dynamic to gameplay.

Inlanes
Lanes that guide the pinball towards the top of the flippers and are usually located behind the slingshots.

The centre drain
To be avoided at all costs, the centre drain is the gap where a ball can be irretrievably lost.

The launch line
A lane which directs the trajectory of launched balls onto the playfield.

A HISTORY OF PINBALL

1700s In the game of bagatelle, players use cue sticks to hit balls up an inclined playfield which rebound off pins into scoring holes.

1871 Patent awarded for Montague Redgrave's "ball shooter" – a coiled spring ball launcher, similar to today's plungers.

1931 Coin-operated pingame machines like Whiffle, and Baffle Ball surge in popularity. Pingames start to be referred as pinball machines.

1933 Pinball machines go electric. Pacific Amusements Company's 'Contact' machine features electric bells and solenoids, adding momentum to the ball.

1939 American cities begin to outlaw pinball machines. As 'games of chance' they are classified as illegal gambling devices.

1947 Gottlieb's Humpty Dumpty machine features the first electromechanical flippers, billed as "the greatest triumph in pingame history".

1976 New York ban overturned. Editor Roger Sharpe proves pinball requires skill by correctly predicting a shot in front of journalists.

1977 Solid state microprocessors are introduced, bringing new game innovations, reliability and design elements.

1991 The Adams Family machine is released and becomes the most successful pinball game of all time.

1999 Pinball 2000 is launched, featuring interactive 3D holographic videogame characters. It achieves limited success but is discontinued.

2010 Just a handful of pinball manufacturers remain, the largest being Stern Pinball, Inc. It produces three to four titles a year.

"Inside Soccer City lie 94,000 polycarbonate seats over three colosseum-style seating tiers"

Welcome to S

Soccer City in Johannesburg, South Africa, is the foremost of an impressive selection of football stadia, each incorporating advanced technologies

In preparation for the FIFA World Cup 2010, a new generation of stadia has emerged in South Africa, boasting more seats, advanced technology and radical new design principles. The foremost of these is the newly rebuilt Soccer City in Johannesburg, a 94,700-seater behemoth designed to showcase not only the power and position football has on the world stage but also the cultural roots and rich heritage of the host country.

Designed under the inspiration of the African calabash – a pot/bottle gourd used traditionally in South Africa for cooking – Soccer City is encircled by an open fire (a ring of security and turnstiles separating the outer areas with those of the inner, secure sections) so at night, when many of the games at the tournament will be played, the stadium will appear to glow. This effect is achieved through a façade outer shell constructed from fibreC glass fibre concrete, divided into ten vertical sections of six different colours and three different textures. Covering the outer shell and select sections of the interior seating is the newly built and highly complex roof structure. This consists of 12 huge 54-ton A-frame steel structures as well as a PTFE membrane polycarbonate cover (used for its light weight, high porosity and great laminating strength).

Inside Soccer City lie 94,000 polycarbonate seats over three colosseum-style seating tiers, 230 private boxes, 184 suites, a dedicated media section with eight TV presentation studios, new fully equipped changing and medical facilities, new floodlights, dedicated football and 'African Pot' museums, and a 300-seater restaurant. Outside of the stadium, Soccer City is equipped with 32 turnstiles, 71 concession kiosks, a 15,000 capacity overground car park, a 4,055 VIP underground car park, as well as its own train station, bus depot and taxi rank.

Soccer City was originally built in 1987 – when it was named the FNB Stadium and sported a capacity of 80,000 – and since its construction it has been central to the nation of South Africa, displaying sport of all kinds as well as public addresses – most notably Nelson Mandela's first speech after his release from prison in 1990 – and other state events. During the FIFA World Cup 2010, Soccer City will host the opening ceremony and match, four first-round matches, one second-round match, a quarter final and the final itself.

5 TOP FACTS SOCCER CITY

Elite
1 There are six football stadiums in the world with a bigger capacity than Soccer City. The largest is the Rungrado May Day stadium in North Korea which has a capacity of 150,000.

Top trumps
2 Soccer City is the largest stadium in the whole of South Africa, easily beating off its nearest rival in seat capacity by a rather staggering 24,000.

Big spender
3 It has cost approximately £285 million to transform the 80,000 capacity FNB Stadium into the 94,700 capacity Soccer City, the focal point of the 2010 World Cup.

Busy bee
4 The transportation hub for Soccer City has a projected hourly capacity limit of 23,280 people, so there's no excuse for being late for a game!

Medieval
5 Originally, Soccer City – previously known as the FNB Stadium – had a two-metre wide moat separating the pitch and players from the spectators.

DID YOU KNOW? *Soccer City hosted the finals of the African Cup of Nations in 1996*

Soccer City


© DENKIKE

3. Calabash-styled fibreC glass fibre outer shell
Made from ten vertical sections of material in six different colours and three different textures, the outer shell was designed to look like the 'calabash' African cooking pot.


© Ndaba Dlamini, MediaClubSouthAfrica

The supports are housed within the glass fibre shell

2. Steel A-frames
Supporting the roof are a series of 12, 54-ton steel A-frames. The steel was flown in from Italy and designed in France.

7. Pitch
Planted in situ four months before the stadium was finished in 2009, seeding for the pitch has been done on site to ensure deeper grass roots and a lusher finish.

The Statistics
Soccer City

City: Johannesburg
Built: 1987
Cost: £285 million / $440 million
Construction: Major upgrade
Completion: 2009
Gross capacity: 88,460

Head to Head
OTHER STADIA OF SOUTH AFRICA

MOST ARTISTIC


© Rodger Bosch, MediaClubSouthAfrica

1. Green Point Stadium
City: Cape Town
Construction: New
Completion: 2009
Gross capacity: 66,005

BIGGEST


© Rodger Bosch, MediaClubSouthAfrica

2. Moses Mabhida Stadium
City: Durban
Construction: New
Completion: 2009
Gross capacity: 69,957

OLDEST


© Emily Visser, MediaClubSouthAfrica

3. Ellis Park Stadium
City: Johannesburg
Built: 1982
Construction: Minor upgrade
Completion: 2009
Gross capacity: 61,639

MOST PRINCELY


© LOC Organising Committee, MediaClubSouthAfrica

4. Royal Bafokeng Sports Palace
City: Rustenburg
Built: 1999
Construction: Minor upgrade
Completion: 2010
Gross capacity: 44,530

BOLDEST


© Rodger Bosch, MediaClubSouthAfrica

5. Nelson Mandela Bay Stadium
City: Port Elizabeth
Construction: New
Completion: 2009
Gross capacity: 46,082

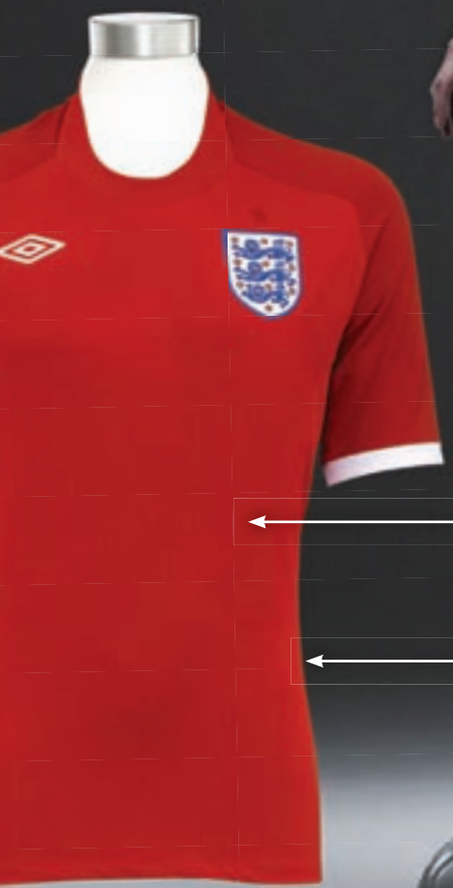
"Allowing their wearer to run faster, move freer and stay cooler"

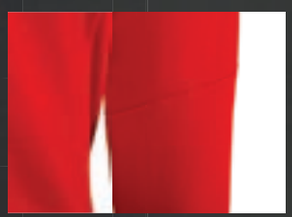
World Cup 2010 football kits

Football kit technology

Expertly designed and rigorously tested, modern football kits are packed with advanced sports technology

During this year's FIFA World Cup, players from all nations will be wearing the latest iteration of their nation's official strip. However, these will be no ordinary shirt, shorts and socks, as increasingly complex levels of sports technology is being incorporated into them, allowing their wearer to run faster, move freer and stay cooler during energy expenditure. We take a look at England's new Umbro-designed kit and some of the technology that is pushing football towards new levels of performance.





4. Sleeves
The new England shirt's sleeves have a high elastane content which allows maximum player movement.

1. Front panel
Cotton rich in order to provide maximum comfort.

3. Mesh tech
Smart meshes are incorporated into the back and side panels of the shirt to improve ventilation and take moisture away from the player's skin.

2. Sloping neck
This increases ventilation to the player's body, helping them to stay cool.

8. Placket collar
Designed with comfort in mind, the collar is specially designed to remain rigid and not flap about in the wind.

6. Base layer
Base layers are actively encouraged and the strip has been designed to work in tandem with them and their expandable components.

7. Perforated holes
Under the arms and on the lower back are rose-shaped ventilation holes designed to create an effective airflow.

5. Socks
Seams around the foot have been removed to reduce blistering and specially constructed ankle joints ensure stability.

The new England kit is specifically tailored to the individual player's build and requirements

5 TOP FACTS KITS

Conjoined
1 Umbro is a portmanteau of its previous name Humphrey Brothers. It has always been England's kit manufacturer, except between 1974 and 1982 when it changed to Admiral.

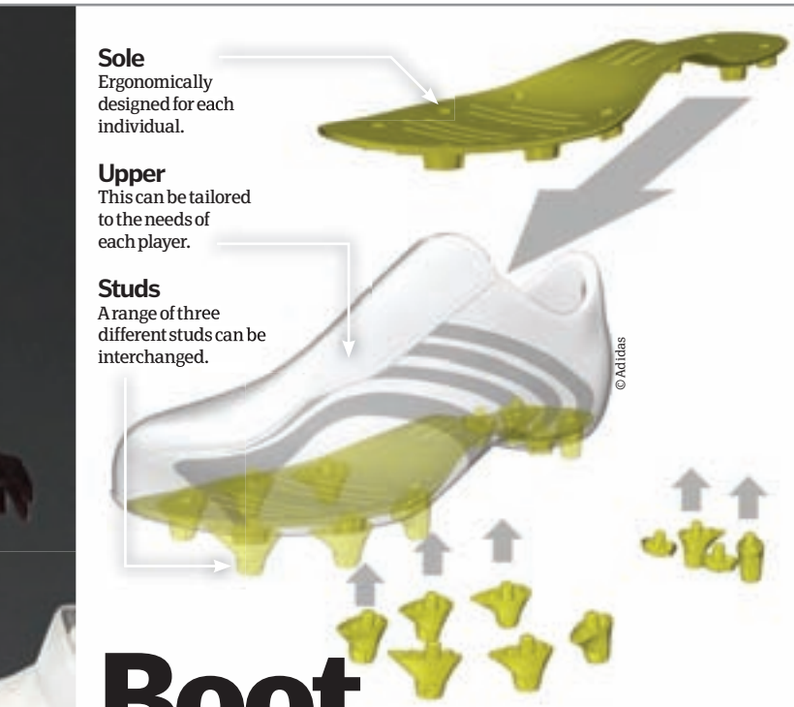
Monopoly
2 During the 1966 FIFA World Cup all but one of the 16 participating teams wore Umbro kits. It is also the official sponsor of the new Wembley Stadium.

Protection
3 Shin pads are a compulsory part of a footballer's attire, and protect against damage to the tibia. Shin pads for football were first used in Nottingham in the late 19th Century.

Kingly
4 The very first recorded entry of football boots comes from back in 1526 when King Henry VIII ordered a pair for the royal wardrobe. Unfortunately they no longer exist.

Back to the future
5 The 2010 England strip is modelled on that from 1966, the last time England won the tournament, which will hopefully be a good omen this year in South Africa.

DID YOU KNOW? *The first international FIFA World Cup was played in Uruguay, 1930*



Boot technology

Worn by international footballers of many nations, the Adidas F50i are at the forefront of boot design

The Adidas F50i represent a new type of customisable and tailored boot that is becoming increasingly popular with professional footballers. The F50i come segmented, with the chassis, studs, sole and upper all interchangeable depending on the user's preference and the context in which they are being used. For example, depending on the hardness of the surface the game is being played on, three different stud types can be attached (short, normal or long) allowing better grip and therefore greater stability and acceleration.

The uppers (the top ball-striking area of the boot) also come in three varieties (ClimaCool, SprintSkin and leather), which depending on the temperature, type of player and striking preference, can be interchanged to suit context. For example, faster wing players may choose the SprintSkin, as they are designed with acceleration in mind, being more streamlined and made from a lighter fabric. Strikers, on the other hand, may prefer the leather upper, as they are designed to maximise ease of contact with the ball, especially in wet conditions where striking it cleanly can become problematic.

Chassis and sole preference is largely ergonomic, with both often being sculpted to the athlete's foot to increase comfort during extended use.


The F50i allow users to alter almost everything on the boot

TECHFIT™ PowerWeb

Designed to maximise athletes' movements, the TECHFIT™ PowerWeb is an underlayer with a difference

Utilising a series of seamless compression fabrics that stabilise muscles and ensure heightened freedom of movement, many top players now wear an additional, highly technical underlayer beneath their strip. The TECHFIT™ PowerWeb from Adidas is a notable example of this type of garment as it incorporates compression, webbing and climate technology (keeping athletes cool and sweat-free).

Compression in this sense refers to the ability to wrap muscles in tight-fitting fabric, focusing on the larger muscle groups in order to aid oxygen delivery and prevention of muscle vibration or distortion. For example, around the lungs and key joints the material is designed to be as flexible as possible in order to create greater comfort and performance in exhaustive conditions, while around the thighs and calves the material is sculpted to follow the muscle lines, supporting them and keeping them compact under stress.

Benefits of compression technology on the football pitch generally include enhanced proprioception and body awareness, reduced muscle vibrations and enhanced protection and longevity.

The webbing technology works by pressing a series of thermoplastic urethane bands onto the base layer of the underlayer. These bands work by being anchored at key points over the body, following the contours of major muscle groups, and stretching and contracting in unison with them. This mimicry action stores elastic energy throughout its stretch on the extension side before releasing it when the muscles contract, snapping back like an elastic band delivering more power to the athlete.

Advanced technology allows footballers to run quicker and use less oxygen

© Adidas

"Sir James Dyson is delivering a 100 per cent bladeless fan with awesome cooling capabilities"

Dyson Air Multiplier

Bladeless, tiltable and hygienic – introducing the future of fan technology

When first created back in the late 19th Century, electrically powered mechanical fans were all the rage. However, due to their basic design and physical components, accidents involving their fast rotating blades soon became common, with children and adults alike injuring themselves. Luckily, today we have inventor extraordinaire Sir James Dyson, who is branching out from the vacuum cleaner and delivering the next stage in fan technology with the Dyson Air Multiplier, a 100 per cent bladeless fan with awesome cooling capabilities.

The Air Multiplier draws in air at its base using a mixed flow impeller similar to those found in turbochargers and jet engines. It forces it into the loop amplifier where it is pushed through a 3mm aperture and accelerated over a 16 degree airfoil-shaped ramp. As the air passes over the ramp it speeds up and draws more air in from behind, in phenomena know as inducement. As the air continues to move forward it also entrains more air from the surroundings. This means that it amplifies the air 15 times, expelling 400 litres of cool, smooth and uninterrupted air every single second.

The cone of air that is flowed outwards from the Air Multiplier is continuous, as it is not dictated by any rotating blades. This eliminates the buffeting effects users would traditionally receive if sitting too close to a fan or if it was on a high setting, being continuously pummelled by a series of air waves. Due to the nature of the airflow generation of the Air Multiplier, however, the cooling effects received are continuous and uninterrupted.

Design-wise the Air Multiplier is created with ease of use and portability at the fore, something represented in its clean, minimalist styling. The unit's upper body can be tilted forwards and backwards by 20 degrees – something aided by the motor being near the structure's centre of gravity, allowing minimal force to be expended to operate – and the amplification loop can easily be detached from the base unit. Further, due to the unit's lack of protective grille or complex blade structure, cleaning the Air Multiplier is easy and helps minimise the amount of dust and dirt projected around its surrounding environment and onto its users.

5. Airflow inlet
Air for the impeller is drawn into the unit here.

4. Twist-fit
The Air Multiplier comes in two main sections which twist-fit together here. This aids ease of transport.

7. Solid build
Built from toughened thermoplastic, the Air Multiplier is light yet shock resistant, ideal if it is accidentally knocked over or needs to be moved quickly.

5 TOP FACTS
FANS

Anorak
1 Fans are highly collectable and in the US there is an Antique Fan Collectors Association. The materials from which the fans are made often make them more desirable.

Fan-tastic
2 The first mechanical fans were driven by belt systems powered by water wheels. By the turn of the 20th Century, heat convection fans fuelled by alcohol or oil were common.

Usurper
3 Unfortunately, sales of traditional fans have decreased over the past 40 years thanks to the proliferation of air conditioning units.

Heads-up
4 Philip Diehl created the first electric ceiling fan in 1882. In 2009, the Hunter Fan Company developed the very first ceiling fan/wireless speaker combo system.

Icenet
5 Hundreds of millions of fans are used in machines and computers, keeping them cool to maximise their computational ability, and often preventing them from overheating.

DID YOU KNOW? *The Dyson Air Multiplier expels 400 litres of air every second*

2. Safe and hygienic
Thanks to the smooth brushed coating and minimalist, open design, the Air Multiplier is simple and easy to clean. Plus, with no blades come no severed fingers.

1. No buffeting
Due to the absence of blades, the Dyson Air Multiplier is not privy to air buffeting, allowing a smooth and continuous flow of air.

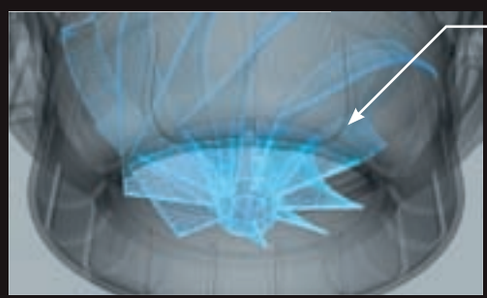
6. Variable airflow
Traditional fans have limited speed settings, often proving either too powerful or too weak for users' preferences. The Dyson Air Multiplier, however, utilises an energy-efficient brushless motor that allows speed to be set much more precisely.

3. Touch-tilt
Unlike conventional top-heavy fans, which are built from weighty metals and plastics, the Air Multiplier is heavier at the bottom than at the top thanks to its ingenious design, and therefore can be tilted easily with a mere press of a finger.

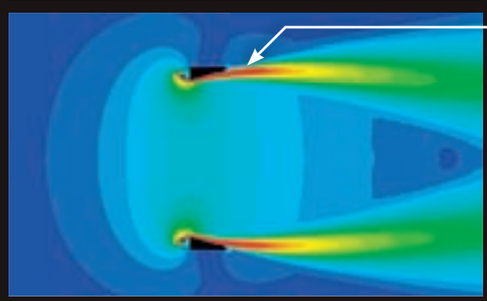
Step-by-step cooling

A visual guide to how the fan works

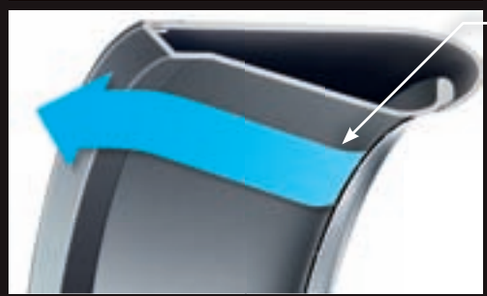
The secret to Dyson's Air Multiplier lies in its ingenious impeller-driven design, which not only generates airflow itself, but is also the catalyst for additional second and third-tier airflow multiplication. These five steps show how the Air Multiplier achieves this...



Step 1
The Air Multiplier's mixed flow impeller – a combination of technology used in turbochargers and jet engines – draws air into the base of the unit discretely and quietly.

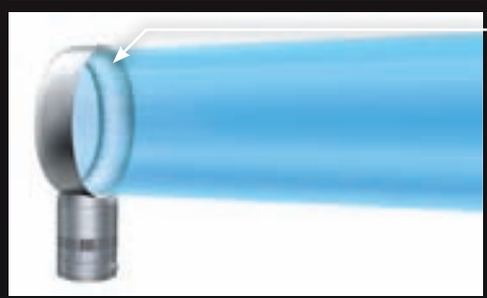


Step 2
The air is driven upwards through the unit's loop amplifier and is accelerated out through an annular aperture, creating a strong jet of air.



Step 3
Out of the aperture the air is then guided over a 16-degree airfoil-shaped ramp, accelerating and channelling its direction forwards.

Step 4
As the air passes over the ramp from the aperture, it draws in extra air from behind the unit (inducement), as well as even more air from in front of the fan (entrainment) once channelled outwards.



Step 5
The resulting airflow has been amplified 15 times and because there are no blades there is no buffering, resulting in a smooth column of air.

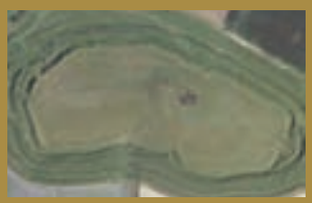
All images © Dyson

This month in **History**

We travel to many different places in the course of this month's History section, where we explain how things worked rather than how things work. India is our first stop, where we take a look at how the Taj Mahal was built. After that we whizz to Jordan for an explanation of the ancient city of Petra. Finally it's off to the green and pleasant land of Britain to learn about the functions and origins of the Iron Age hills forts. Unfortunately, there's no duty-free on the way.

76 Crossbows

78 Petra



79 Iron Age hill forts

HISTORY

The Taj M

A beautiful monument to his late wife, find out how the Mughal emperor built India's Taj Mahal

Three acres of land was carefully excavated for the foundations of the Taj Mahal, and replaced with dirt and rubble to reduce seepage from the nearby river. In the area that was to house the tomb, deep wells were dug down to water level and later filled with stone to form the secure footings that would hold the building firmly in place. One well remained unfilled to track the water changes over time, but the rest of the 580m x 300m site was levelled to 50 metres (160ft) above the river bank.

A construction team of over 20,000 labourers was recruited from the north of the country to build the monument and included a creative contingent of 37 artisans who were disciplined in the arts of sculpting, calligraphy, inlaying, stone cutting, turret building and marble art carving. Furthermore, over 1,000 elephants were used to transport the sourced materials from all over India and Asia. In order to transport the materials to the site a 9.3 mile (15k) ramp of tampered earth was carved into the land allowing smoother access for the teams of up to 30 oxen and mules that were used to heave the blocks of marble on specially designed wagons.

It was typical at this time to use bamboo scaffolding for the workers to construct buildings, but for this project the architects fashioned a revolutionary brick-based framework, favoured for its longevity and rigidity. To elevate the blocks into position a post and beam pulley system was employed; to hoist two upright marble posts to hold a marble beam horizontally across the top, resulting in a free-standing framework which was gradually extended.

3. Dome
The marbled dome roof of the tomb is 35m and is known as the onion dome. The iconic dome sits on a 7m cylindrical tower to accentuate its height.

5. The finial
Crafted originally from gold, the main finial was replaced by a gilded bronze copy in the 19th Century. It is decorated with a moon which points to the heavens.

2a. Minarets
Four minarets are pinned around the tomb, just off each corner of the square plinth, used by the muezzin to call the Islamic people to prayer.

1a. The tomb
The most obvious and central focus of the Taj Mahal is the tomb. Constructed of white marble, the symmetrical building stands on a square plinth and features a prominent arched doorway, domed roof and finial.

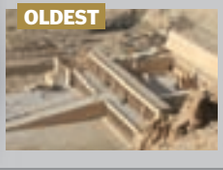
9. Gateway (not shown)
The marble gateway's arch mirrors the shape of the tomb's and features vaulted ceiling and walls exhibiting elaborate geometric designs, mimicking those found inside more of the complex's sandstone buildings.

1b. The tomb
The tomb is a multi-chambered cube with chamfered corners to form an unequal octagon approximately 55 metres on each of the four longest sides.

Water supply

Drawn from the riverbed by a series of purs (an animal-powered rope and bucket mechanism), water was deposited into a large storage tank; from this over a dozen other purs raise the liquid to a large distribution tank above the ground. The water flowed from the tank to three subsidiary containers and was piped into the complex. A pipe hidden 1.5m underground travelled parallel to the main walkway, filling the main pools of the garden. Extra copper pipes were utilised to disperse the water to the fountains in the north-south canal and subsidiary channels were created to irrigate the rest of the grounds.

Head to Head ARTISTIC TREASURES

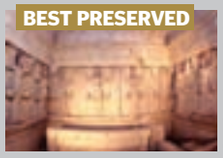


OLDEST

1. Temple of Hatshepsut
Location: Egypt
Three tiered mortuary temple dedicated to Hatshepsut, the fifth pharaoh of the eighteenth dynasty of Ancient Egypt.

MOST INFLUENTIAL

2. Minaret of Jam
Location: Afghanistan
The 65m tall structure played an important role in the development of construction in the Indian sub-continent.

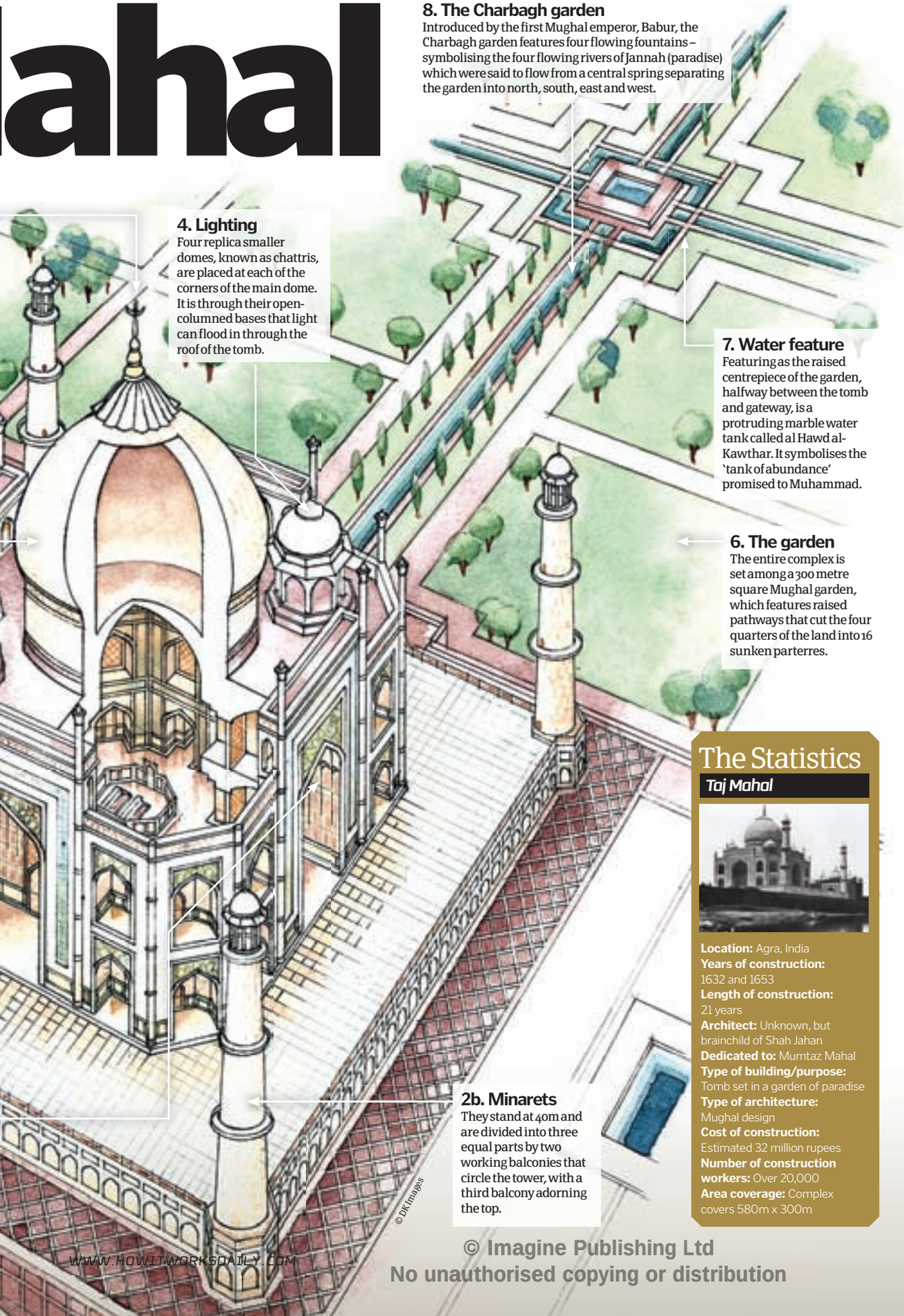


BEST PRESERVED

3. Thracian Tomb of Sveshtari
Location: Bulgaria
A 3rd Century tomb reflecting the architectural principles of Thracian cult buildings from the culture of the Getae.

DID YOU KNOW? *When translated, the name Taj Mahal means 'crown palace'*

ahal



8. The Charbagh garden
Introduced by the first Mughal emperor, Babur, the Charbagh garden features four flowing fountains – symbolising the four flowing rivers of Jannah (paradise) which were said to flow from a central spring separating the garden into north, south, east and west.

4. Lighting
Four replica smaller domes, known as chattris, are placed at each of the corners of the main dome. It is through their open-columned bases that light can flood in through the roof of the tomb.

7. Water feature
Featuring as the raised centrepiece of the garden, halfway between the tomb and gateway, is a protruding marble water tank called al Hawd al-Kawthar. It symbolises the 'tank of abundance' promised to Muhammad.

6. The garden
The entire complex is set among a 300 metre square Mughal garden, which features raised pathways that cut the four quarters of the land into 16 sunken parterres.

2b. Minarets
They stand at 40m and are divided into three equal parts by two working balconies that circle the tower, with a third balcony adorning the top.

© DK Images

The Statistics
Taj Mahal

Location: Agra, India
Years of construction: 1632 and 1653
Length of construction: 21 years
Architect: Unknown, but brainchild of Shah Jahan
Dedicated to: Mumtaz Mahal
Type of building/purpose: Tomb set in a garden of paradise
Type of architecture: Mughal design
Cost of construction: Estimated 32 million rupees
Number of construction workers: Over 20,000
Area coverage: Complex covers 580m x 300m

Why was it built?

While the country was enjoying great prosperity in 1631, Mughal emperor Shah Jahan was grief stricken by the death of his third wife Mumtaz Mahal, who had died during the birth of their fourteenth child. Built in loving memory of Mumtaz, work began on the Taj Mahal in 1632 and ended in 1653 in an unused area in the south of the walled city of Agra, India. The emperor divided the grounds into four distinct sections: the Taj gateway, the Taj garden (Charbagh), the tomb and the Pietra Dura (the crypt and cenotaphs).

Design inside and out

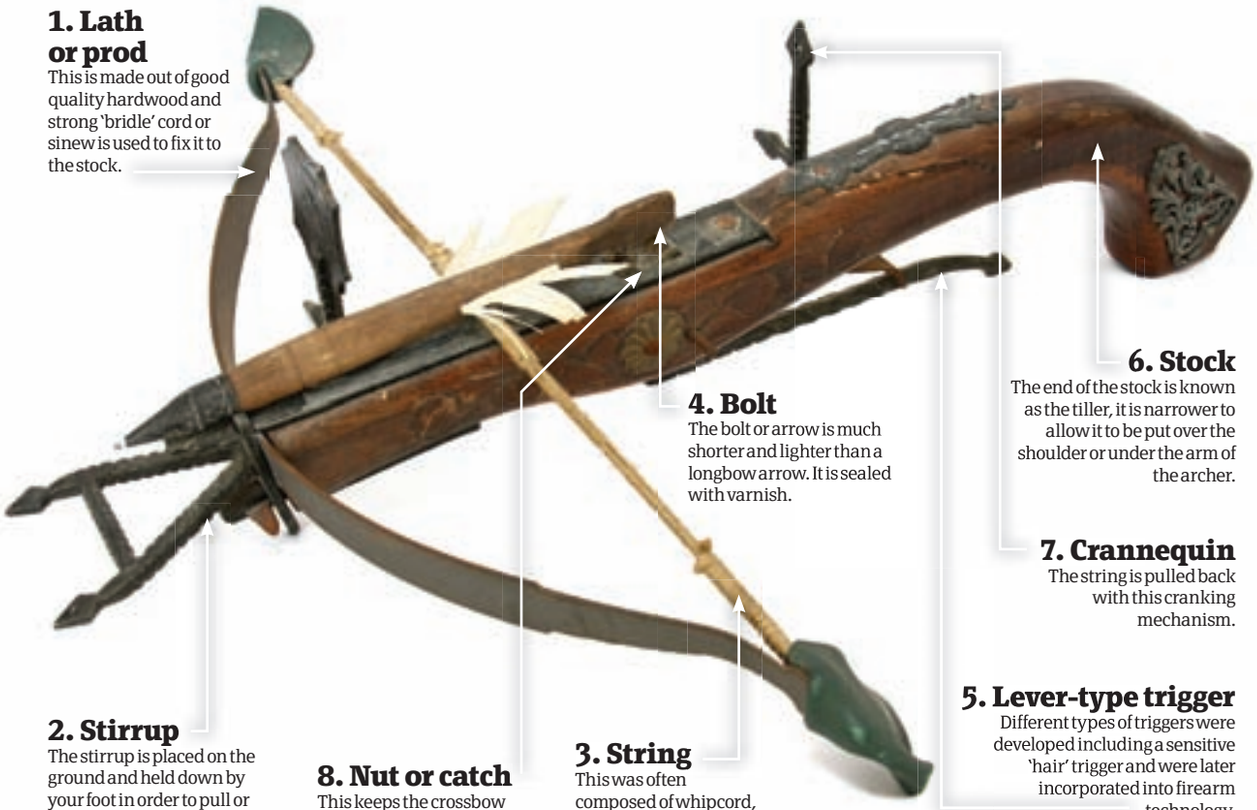
The building features what is considered the best example of Mughal design; a fashion which fused the styles of Persian, Indian and Islamic architecture of the time. However, Shah Jahan broke with tradition in a bid to reach unprecedented levels of sophistication by using vast quantities of white marble inlaid with semi-precious stones, instead of the more traditional red sandstone. Employing a fleet of mules, oxon and elephants Shah Jahan imported white marble from Rajasthan, jade and crystal from China, jasper from Punjab, turquoise from Tibet, lapis lazuli from Afghanistan, sapphire from Sri Lanka and carnelian for Arabia.

The tomb is enclosed in a garden of fountains, segmented flowerbeds and ornamental trees and the entire complex was intended to be riddled with reflections, symmetry, symbolism and hierarchy to emphasis the key elements of the property. In total the plinth took 12 years to finish, whereas the minarets, mosque and jawab, and finally the gateway, took an extra decade.

"It requires little strength to accurately aim at a target compared to a longbow"

The crossbow

A powerful and easy-to-use lethal weapon



1. Lath or prod
This is made out of good quality hardwood and strong 'bridle' cord or sinew is used to fix it to the stock.

2. Stirrup
The stirrup is placed on the ground and held down by your foot in order to pull or wind back the string.

3. String
This was often composed of whipcord, hemp or linen.

4. Bolt
The bolt or arrow is much shorter and lighter than a longbow arrow. It is sealed with varnish.

5. Lever-type trigger
Different types of triggers were developed including a sensitive 'hair' trigger and were later incorporated into firearm technology.

6. Stock
The end of the stock is known as the tiller, it is narrower to allow it to be put over the shoulder or under the arm of the archer.

7. Crannequin
The string is pulled back with this cranking mechanism.

8. Nut or catch
This keeps the crossbow 'cocked' and ready to shoot.

A crossbow is basically a horizontal bow fitted with a trigger mechanism. A stirrup at the front of the crossbow enables the user to hold it down with their foot as they pull the string back. The crannequin was developed to make it easier to draw the string. This consists of a crank attached to a toothed wheel that engaged with a ratchet bar. By turning the crank, the string is pulled back by the bar and held back by a trigger mechanism. After removing the crannequin a bolt or arrow can be inserted in a groove that runs along the tiller body of the crossbow.

Since the trigger mechanism keeps the bow cocked until it is released, it requires little strength to accurately aim at a target compared to a longbow, where muscle power alone keeps the string taught and ready to fire.

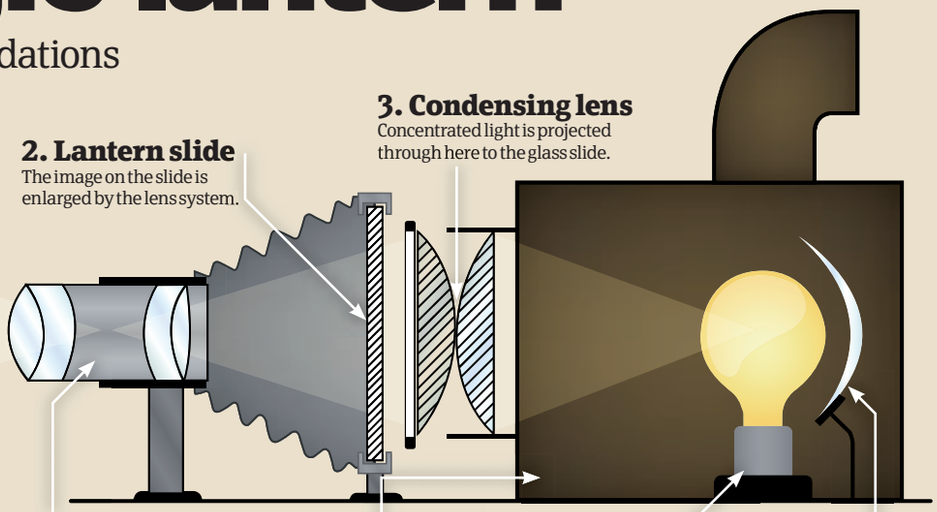
The magic lantern

An optical toy that laid the foundations for modern cinema

The body of a magic lantern contains a light source that is reflected by a concave mirror that projects the concentrated light through a condensing lens to a glass slide. A lens system enlarges the image from the slide and throws it onto a screen positioned in front of the lantern. The glass slide is put in and out of the lantern body via horizontal runners.

The first working lanterns in the late-1600s used candles and oil lamps as the light source. In 1784 the Argand lamp enabled the lantern to be used for public performances. In the 19th Century magic lanterns used powerful limelight (hydrogen and oxygen were used to burn a calcium oxide) for public shows and by safer electric lamps from 1892 onwards.

Using a selection of different lenses, and by adding mechanical features to the glass slides, projectionists were able to zoom, fade, mix and even animate their picture presentations.



1. Lenses
Used to enlarge, focus, zoom and fade images.

2. Lantern slide
The image on the slide is enlarged by the lens system.

3. Condensing lens
Concentrated light is projected through here to the glass slide.

4. Housing
Encasing the inner workings.

5. Lamp
Invention of limelight made brighter images.

6. Mirror
Would reflect the light through the lens.

LARGEST

1. Enercon E-126

The largest turbine model built to date, with a hub height of 135m, rotor diameter of 126m and a total height of 198m.

OLDEST

Jim Woodward-Nutt

2. Outwood post mill

Built in 1665 in Outwood Surrey, this is Britain's oldest working windmill . It was once one of a pair, the other collapsed in 1960.

MOST FAMOUS

Ana_Crisis 07

3. Holland's windmills

The Netherlands are so closely associated with windmills that they have become part of their national identity. However, most of these windmills were used for drainage rather than for grinding corn.

DID YOU KNOW? *Until Henry VIII dissolved the monasteries, villagers had to have their corn ground at their local lord's mill*

Windmills

Before steam and electric power, windmills were used to grind grain

A windmill uses an array of sails to convert the energy of the wind. The horizontal motion of the shaft attached to the central hub of the sails is converted, through a gearing system, to turn the vertical shaft. The vertical shaft is attached to a runner grindstone. Beneath the rotating runner stone is the bed grindstone that is fixed in position. Grain is fed between the two stones and the grinding process produces flour. The fineness of the flour can be adjusted by using different grindstones or adjusting the distance between them.

The first designs used in Britain were basically post mills, which consisted of a wooden structure built around a vertical post. In 1745 Edmund Lee invented the fantail that was mounted on the cap opposite the sails, enabling the mill to automatically face the wind. Tower mills were made of brick and could reach a greater height and were not such a fire hazard, but were more expensive to build. They featured sails attached to a rotatable cap.

1. Sails
These sails have a lattice construction with windboards fitted on the inner half of the leading edge. This is known as a 'common' sail.

2. Cap
The sails are attached to the rotating cap of the mill. The horizontal shaft from the sails is called a windshaft.

3. Brakewheel
The brakewheel is mounted on the windshaft and turns with it. The cogs on its edge engage with the wallower wheel.

4. Wallower
This is mounted on the upright vertical shaft. The wallower engages with the brakewheel causing the upright shaft to turn.

5. Great spur wheel
The great spur wheel is mounted at the bottom end of the upright shaft and drives the stone nuts.

6. Stone nut
The stone nut engages with the great spur wheel. It turns a shaft that drives the runner stone.

7. Grindstones
The runner stone turns above the bed stone to grind grain. The flour from this process is dropped down chutes to grain sacks.

© DK Images

Catching the wind

The first windmills had vertical sails that were fixed to a vertical axis that turned a grinding stone.

The horizontal axis design proved more efficient and powerful. The optimum speed for a windmill grindstone is 150 revolutions a minute; any faster is dangerous and slower is inefficient. To achieve this, sail cloths were attached to lattice-style sails to speed them up, or removed to slow them down. In the 18th Century sails featured adjustable shutters that could be used to control their speed.

"The stone was cut from a local quarry and transported to the site by a sledge that was dragged over rollers"


© UserMarkv

Petra – the rose red city

From the time of its modern discovery in 1812, Petra has been immortalised by artists, poets and filmakers

The capital city of Petra (which means `rock`) lies in a natural basin that accessed water through a permanent tract. The area was prone to flooding and the city dwellers used dams, wells, cisterns and water conduits to direct and store water. The Nabataens (the inhabitants of Petra) lived in a natural oasis and enjoyed great prosperity. Some of their buildings were free-standing while others were carved from the natural rock. The Nabataens used sandstone to create complex structures such as vaults, domes and arches. The stone was cut from a local quarry and transported to the site by a sledge that was dragged over rollers. The Nabataens also used luxury materials such as juniper and olive wood, marble and limestone.

During the building process the craftsmen used pulleys, ladders and ropes to carve their monuments. Working from top to bottom they used picks, hammers and claw chisels on the outer surfaces. Influenced by the craftsmen of Alexandria, the Nabataens created a complex city compound that included houses, tombs, a treasury and an amphitheatre.

The Statistics

Petra

Location: Petra is situated in the Jordanian governorate of Ma`an. It lies on the slope of Mount Hor.
Length of construction: Building began around the 6th Century BC, but dates and building phases are largely unknown.
Function: Petra was a capital city of the Nabataens. It was a major trading site.
Architecture: The ancient Egyptians, the Greeks and the Romans had enormous influence on the architecture of Petra.
Rule: In 106 BC Petra became a part of the Roman Empire. Almost a century later, the trade routes vanished and the city went into decline.
Size: Petra is built within a large area of open land that is first approached by a gateway to the Siq, a narrow winding path flanked by tall rocks and crags. From here you can catch a first glimpse of Petra in the form of the 40-metre high treasury facade. The treasury is surrounded by more than 800 monuments.

Life at Petra

Petra was built on an important point on the trading route between Asia and Arabia. Because of this, Petra was a cosmopolitan and cultivated city that was well sustained by commerce, agriculture and water. The population, believed to have been about 20,000 people, was familiar with foreign migrants, their crafts and trading goods. Artistic merit is visible in the decoration of the elaborate buildings and tombs.

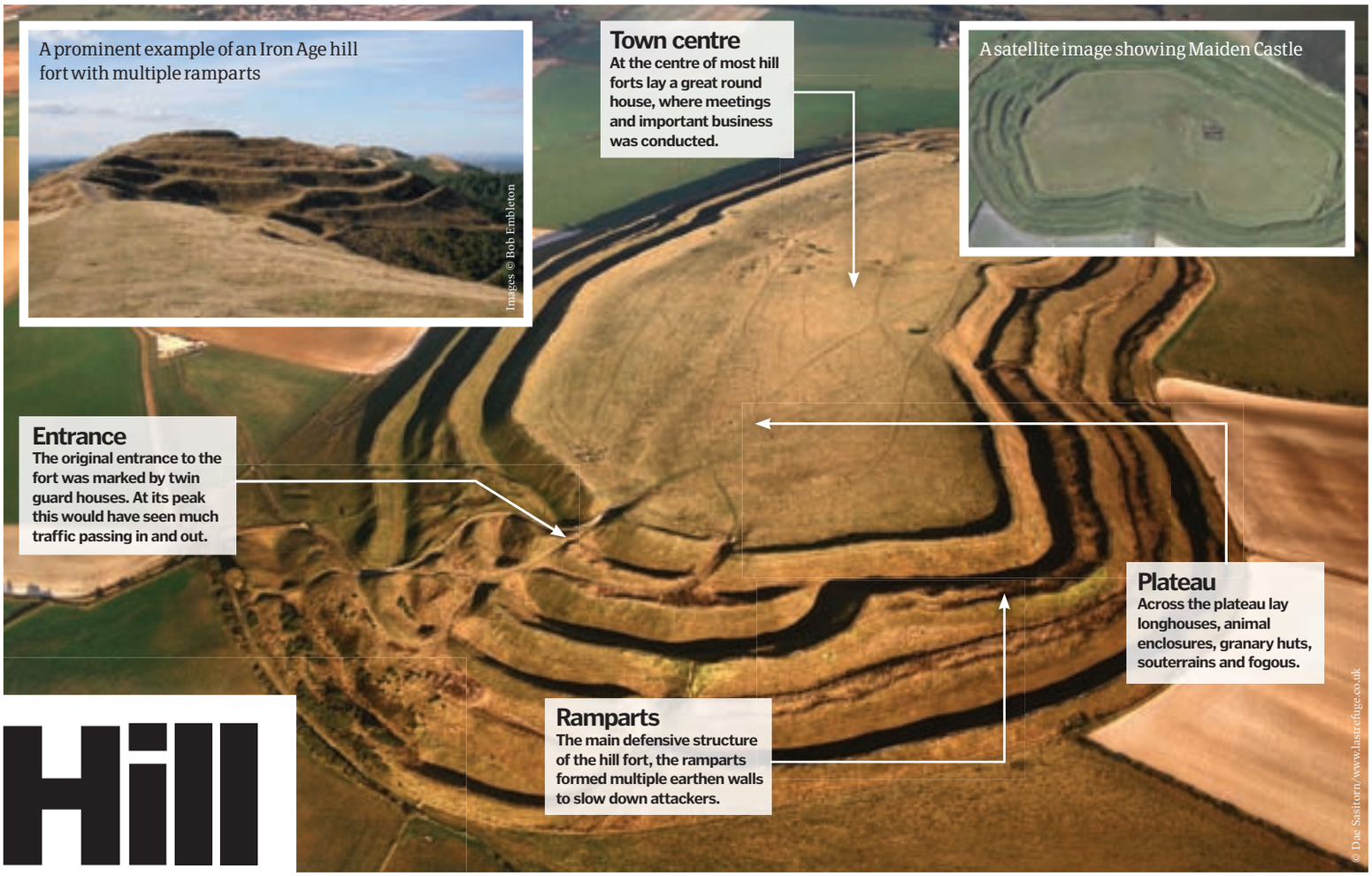
Keeping Petra safe

The Petra National Trust was established in 1989. Its aim is to protect this World Heritage Site. Petra is now recognised as one of the world's most endangered archaeological centres. Not only is it damaged by flooding and salt erosion, but also by tourism. Planes and helicopters, once used for aerial tours, threatened the stability of the area. Thanks to the work of the Trust they have now been banned. The Trust deals with issues that concern the local inhabitants who use the site as homes, storehouses and stables.


Fantastic weather but a long walk to the nearest shops...

© Brad Mering

DID YOU KNOW? *Julius Caesar called hill forts oppida, the Latin term to describe a large enclosed space*



Hill forts

Providing invaluable defensive strongholds, hill forts were a common feature of Bronze and Iron Age Europe

Hill forts were raised defended settlements, often built on cliff tops or large knolls and spurs, that provided trading centres and secure enclosed habitats for humans during the Bronze and Iron Ages. Their construction came to a peak in Britain during the last 500 years BC, where numerous improvements were made to their defensive structures – such as extra lines of earthworks, stockades and defensive walls – due to the multiple invasions the country was subjected to that culminated in the Roman occupation from AD 43 onwards.

Many hill forts have their origin in the Neolithic period and were originally not used as centres of trade and dwelling but instead to pen and protect agricultural animals, which were an invaluable source of food and drink. During the Bronze Age hill forts evolved to include roundhouses, longhouses and granary huts, as well as underground souterrains and fogous (underground cave structures used for food storage and preservation), before becoming more military focused through the Iron Age with guarded entrances, guard houses and ramparts integrated into them.

Indeed, the main structure that characterises most hill forts is its ramparts. These large man-made mounds of rock, wood, earth and dead animals, served as valuable fortifications against attacking forces and created a series of ridged circular ditched rings that proved difficult to circumvent. These fortifications were hardly impregnable however, and a number of invading forces – such as the Belgic invasions of Britain in the 1st Century BC – took many of them under sustained pressure and either inhabited them themselves, or burnt and sacked them. Instead, the native Britains and Europeans relied on the natural positioning of the fort to repel invaders.

The largest and most complex of all Iron Age hill forts in Britain is Maiden Castle in Dorchester. This large raised hill fort was first laid out in 600 BC over the remains of an earlier Neolithic settlement. Its multiple rampart enclosure is larger than the area of 50 football pitches and at its peak this colossal fort housed over 700 people.

5 TOP FACTS HILL FORTS

1 Ye olde
The 'golden age' for hill fort construction was between 500 BC and AD 50.

2 Widespread
There are the remains of over 2,000 Iron Age hill forts in Britain today.

3 Defensive
Alfred the Great built a series of hill forts along the coastal hills of Wessex to guard against Viking attack.

4 Habitable
The ancient hill fort of Old Sarum was lived in up till the 19th Century.

5 Heritage
Maiden castle, an Iron Age hill fort once occupied by the Celtic Durotriges tribe, is now protected as a Scheduled Ancient Monument.

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

Claire Butler
Science Museum Explainer

Claire Butler is a new addition to the Explainer team and this is her first time answering questions for **How It Works**, but she jumps straight in, providing the answers to questions related to silica gel, mass versus weight, and fire. Claire recently graduated from York University with a degree in chemistry. Her favourite hobby is singing, which she took up while still a student.

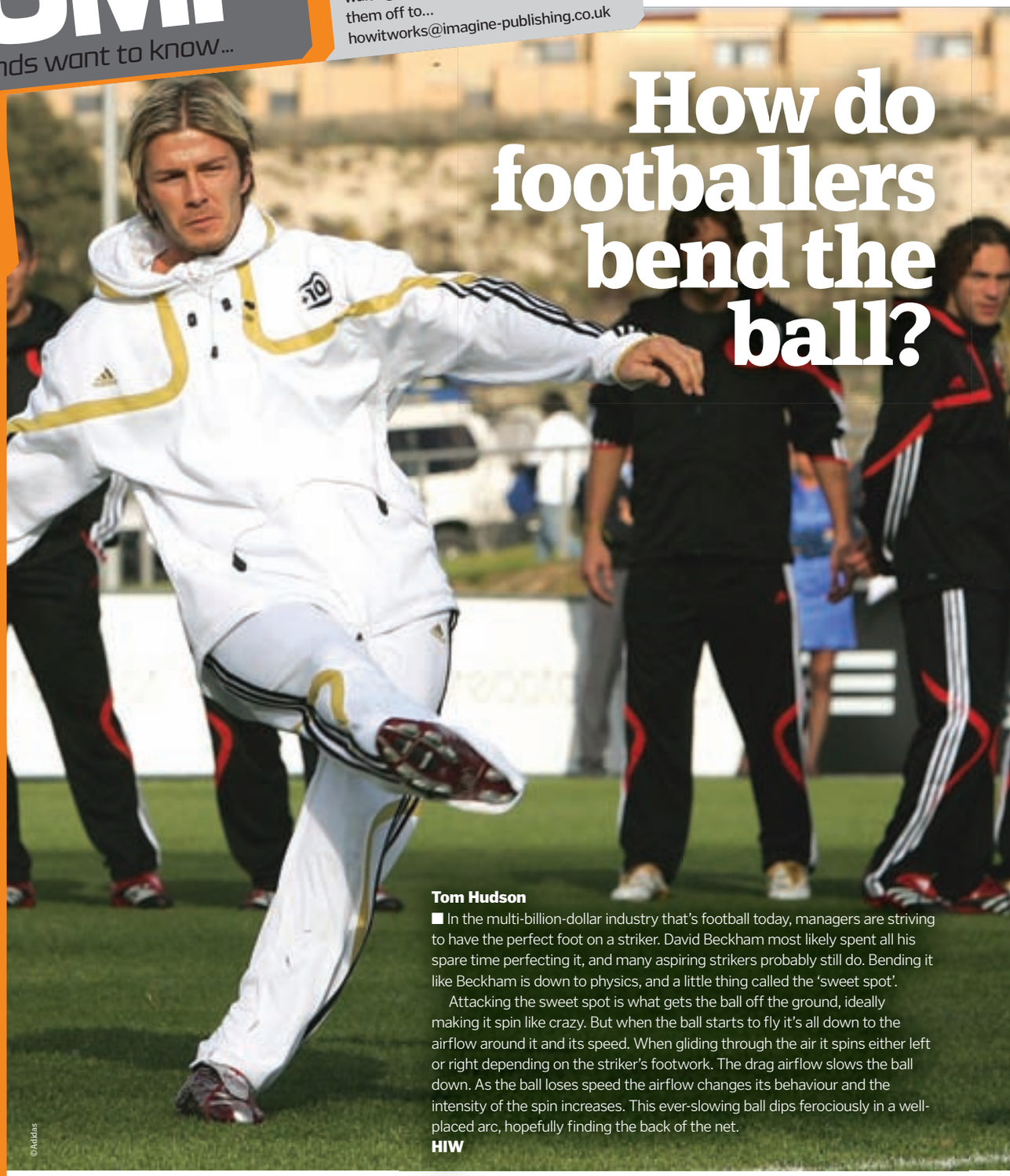
Chi Wing Man
Science Museum Explainer

Chi Wing Man is a recent addition to the Explainer team and is making his second appearance on the panel. His background is in biochemistry and teaching and Chi loves to make science engaging and fun, and he can also make an excellent doner kebab. This month Chi explains why people suffer from deep vein thrombosis.

Rik Sargent
Science Museum Explainer

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

How do footballers bend the ball?



©Adidas

Tom Hudson

■ In the multi-billion-dollar industry that's football today, managers are striving to have the perfect foot on a striker. David Beckham most likely spent all his spare time perfecting it, and many aspiring strikers probably still do. Bending it like Beckham is down to physics, and a little thing called the 'sweet spot'.

Attacking the sweet spot is what gets the ball off the ground, ideally making it spin like crazy. But when the ball starts to fly it's all down to the airflow around it and its speed. When gliding through the air it spins either left or right depending on the striker's footwork. The drag airflow slows the ball down. As the ball loses speed the airflow changes its behaviour and the intensity of the spin increases. This ever-slowing ball dips ferociously in a well-placed arc, hopefully finding the back of the net.

HIW

What is silica gel?

Ali Miller

■ Silica gel is a highly porous form of silica which is synthetically processed into grain or bead form. Silica gel is a desiccant (drying agent) or hygroscopic substance which means that it can remove water from the environment it is in and absorb it. Silica gel is a particularly good desiccant as it has a very large surface area of about 800m²/g. Some products can be ruined or spoiled by excess water or humidity so silica gel packets are put in to absorb excesses. Silica gel is particularly good for this use as it releases no by-products during absorption.

Claire Butler

© Silver Spoon, 2008

Why do I need an electrical adaptor when I travel?

Gemma Aston

■ If you travel to a different country, one of the first things you might look for in your hotel room is a plug socket. Only there is a good chance it will look different, maybe bigger, smaller or have a different number of holes. This is because back when electricity grids were first being introduced, many countries decided to develop plugs and sockets of their own rather than adopting a world standard.

As well as the shapes and sizes of the plug sockets changing depending on the country, the voltage and frequency of the AC current varies too. For example Europe and most other countries in the world use a voltage which is twice that in the US. Plug an appliance from the US into a power supply in Europe without an adaptor and you will probably see a spectacular yet highly dangerous firework display as the voltage will be too high.

It is worthwhile to check the power outlets of the country you are visiting before you travel, then you can make sure you take the correct adaptor.

Rik Sargent

How does dry ice work?

Sarah Smee

■ We assume for this question you may have seen dry ice change from a solid into a gas giving off a smoky effect and you are asking why this happens. Well, dry ice is the name given to solid carbon dioxide (CO_2), and it looks a bit like water ice, except dry ice is much colder. This is because CO_2 sublimes (turns straight from a solid to a gas) at around -78°C, so you wouldn't want to be holding this stuff as a solid for the risk of experiencing quite a bad cold 'burn'.

Now, when you see the smoky effect given off when dry ice sublimes, you are not seeing the CO_2 gas because CO_2 gas is invisible. What you are seeing is water vapour in the air which has condensed as it comes into the vicinity of the cold CO_2 gas, a little bit like the water vapour we breathe out on a cold day, which condenses to form a visible cloud.

Rik Sargent

Why do our ears 'pop' on planes?

James Wells

■ The eardrum is a thin membrane that helps to transmit sound. Air pressure is exerted on both sides of the eardrum; with the surrounding atmospheric pressure pushing it inwards while air being delivered via a tube between the back of your nose and the eardrum pushes it outwards. This narrow tube is called the Eustachian tube, when you swallow the tube opens and a small bubble of air is able to move causing a 'pop'.

Rapid altitude changes in planes make the 'pop' much more noticeable due to bigger differences in pressure. Air pressure decreases as a plane ascends; hence air must exit the Eustachian tubes to equalise these pressures, again causing a 'pop'. Conversely, as a plane descends, the air pressure starts to increase; therefore the Eustachian tubes must open to allow through more air in order to equalise the pressure again, causing another 'pop'. So there's no need to worry, although popping ears are uncomfortable they're part of a completely natural process.

Chi Wing Man

What's on at the Science Museum?

1001 Inventions

■ Till 30 June ■ Free

Tracing the forgotten story of 1,000 years of science from the Muslim world, from the 7th Century onwards. Featuring interactive exhibits, displays and dramatisation, the exhibition explores the shared scientific heritage of diverse cultures and looks at how many modern inventions can trace their roots back to Muslim civilisation.

Who am I?

■ Coming soon – opening June 2010 ■ Free

To mark the end of its centenary year, the Science Museum will open an upgraded 'Who am I?' gallery in June. Currently one of the most popular galleries in the Science Museum, Who am I? presents the latest in brain science and genetics through a mixture of interactive exhibits and object-rich displays.

Antenna

■ Coming soon – opening June 2010 ■ Free

Antenna hosts a series of events allowing visitors to get up close with new developments in science and breakthrough technologies. A new concept for Antenna will be unveiled in June 2010 providing an innovative new way for the public to engage with contemporary science.

Launchpad Science Shows

■ 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. Find out how the world works by testing out the 35m long Echo Tube, the beautiful Icy Bodies and over 50 more brand new interactive exhibits demonstrating light, sound, electricity and magnetism and more amazing physics phenomena.

BRAIN DUMP

Because enquiring minds want to know...

FROM THE FORUM

*Every month we'll feature a reader's question from our fantastic forum at **www.howitworksdaily.com/forum***

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Why does smoke come from a fire?

Tom Wilson

■ When you can see smoke coming from a fire, what you are actually seeing are volatile hydrocarbons. Hydrocarbons are compounds existing of hydrogen and carbon. When hydrocarbons become volatile they become a gas from a solid or liquid state.

Combustion (burning) of hydrocarbons is a process in which the hydrocarbons react with oxygen to produce water, carbon dioxide and energy.

Hydrocarbon (eg methane) + oxygen = water + carbon dioxide + energy

eg $CH_4 + 2O_2 = 2H_2O + CO_2$ + energy

When this combustion is incomplete there is not enough oxygen present and the carbon dioxide cannot form, leading to production of carbon monoxide or carbon.

Hydrocarbon + oxygen = carbon monoxide or carbon + water

Smoke is seen when the carbon is present in the combustion as this will show a visible gas. When there is complete combustion you cannot see any smoke because water and carbon dioxide produce colourless gases.

Claire Butler

What is the difference between mass and weight?

Jon Digby

■ The mass of an object is the amount of matter it contains; the weight of an object is the measure of the force exerted on that object by gravity.

Weight (newtons) = mass (kilograms) x gravity

For example, your mass on Earth and on the moon will be the same, but your weight will change as the force due to gravity on the Earth is greater than that on the moon.

Claire Butler

Got that itchy feeling?

How can fleas jump so high compared to their size?

Richard Collins

■ If you have ever watched a flea jump, you may be startled to see that they can jump astonishingly high (and far) compared to their size. This is down to a combination of strong leg muscles and pads of a rubber-like protein called resilin which is located above the hind legs of the flea.

When the flea prepares to jump, it crouches which squeezes the resilin. This resilin is able to store energy and release it suddenly in one go, a little bit like a spring. This launches the flea as if from a catapult allowing the flea to jump up to around 35 centimetres in length and 20 centimetres in height.

Rik Sargent

What is deep vein thrombosis?

Margaret Harris

■ Veins are blood vessels that carry blood back to the heart. Deep veins are those found deep inside the body as opposed to veins closer to the surface (superficial veins). If a blood clot (thrombosis) forms in one of your deep veins, normally in your leg, this condition is called deep vein thrombosis (DVT). Clots can cause swelling and pain and may lead to complications such as a pulmonary embolism (ie the initial blood clot gets transported and deposited in the arteries supplying the lungs causing a blockage). Immobility for long periods, such as plane journeys, decreases the blood flow rate through your deep veins as the muscles surrounding these blood vessels are not contracting; this promotes the formation of blood clots.

Chi Wing Man

Iceberg, right ahead! And to your left... and right

How cold would the sea have to be to freeze?

Alex Wood

■ Pure water (H_2O) contains no impurities and freezes at 0°C (32°F). However, seawater – on average – contains 3.5 per cent of dissolved salts, which lowers the freezing point; this phenomenon is called freezing point depression. Freezing point depression is a colligative property of matter, which means it depends on the number of molecules present, not on the specific type of molecule or their mass (ie the dissolved substance doesn't have to be salt, but any soluble substance, it's the amount of dissolved molecules that is important). In terms of seawater, the average freezing point is about -2°C. However, it does vary around the world due to differing amounts of chemicals (eg salts) dissolved.

Chi Wing Man

Do women have an Adam's apple?

Bill Turner

■ Everyone has an Adam's apple, but men's are usually easier to see. It's a bump on the neck that moves when you swallow, named after the biblical Adam. Supposedly, it's a chunk of the Garden of Eden's forbidden fruit stuck in his descendants' throats, but it's actually a bump on the biggest piece of cartilage – thyroid cartilage – surrounding the voice box (larynx). The thyroid cartilage is shield-shaped and the Adam's apple is the bit at the front. Why do men's stick out more? Partly because they have bonier necks, but also their larynxes grow differently from women's during puberty to accommodate their longer, thicker vocal cords, which give them deeper voices.

HIW

What is a stink plant and why does it stink?

Steve Champion

■ The titan arum (or stink plant) is an odd plant however you look at it. Known as the 'Corpse Flower' in Indonesia, it's a colossal organism, the central column or 'spadix' growing up to three metres tall. The plant's corm – the underground root system where it stores its food – is the largest in the world, the one at Kew Gardens weighing in at an astonishing 91kg when it was repotted last year.

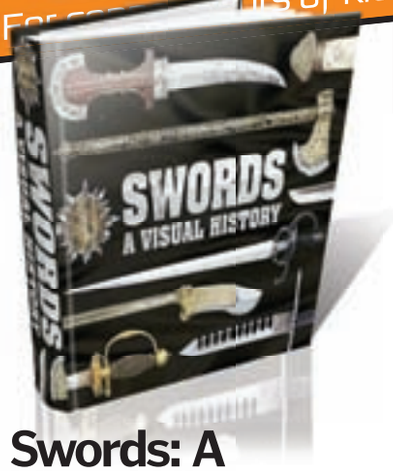
Once the flowers around it are ready for pollination, the spadix begins to generate the disgusting smell to attract sweat bees, beetles and other carcass-eating insects. Thinking they've found a meal, or somewhere to lay their eggs, the insects arrive, crawl over the flower and while they go away hungry, they also ensure pollination occurs. To make certain of this, the spadix's tip heats to near human body temperature while the red colouration and texture of the lower section completes the illusion.

HIW

THE HOW IT WORKS KNOWLEDGE

For [illegible]urs of kit and savants of stuff

DVDs/Blu-ray • Books • Gadget

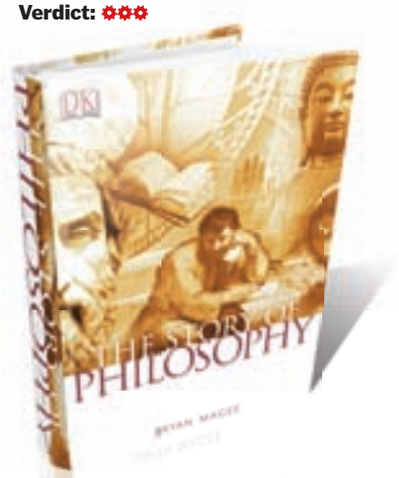


Swords: A Visual History

Price: £14.99 / $22.95
ISBN: 978-1-4053-5136-2

Following on from last month's excellent *Weapon*, DK delves into the delights of swords throughout history to produce an authoritative guide to their types, construction methods and users. *Swords* presents page after page of glorious high-resolution images of the evolution of this most personal of weapons.

Verdict: ✪✪✪



The Story Of Philosophy

Price: £15.99 / $24.95
ISBN: 978-1-4053-5333-5

The Story Of Philosophy provides 2,500 years of philosophy in one illustrative volume, from the ancient Greeks to the present day. The book is separated in chronology and by school, so beginning with classical thought, the author Bryan Magee then takes the reader on a journey through early religious and renaissance thinking, then on to enlightenment philosophy and beyond to the outlook of today's brightest minds.

Verdict: ✪✪✪✪

You have to be serious about sound to buy a pair

Beats by Dr Dre Studio headphones

Price: £198.99 / $303.99
Get it from:
www.purelygadgets.co.uk

THESE DAYS, HIGH-PROFILE musicians just aren't worth their royalties if they're not slapping their brand on something other than a CD. While Dr Dre hasn't quite the marketing ambitions of Puff Daddy, P. Diddy, Diddy or whatever he's rebranding himself these days, endorsing a simple pair of headphones isn't beyond him. And when we say simple, we mean quite the opposite: we've never worn quite so ostentatious a sound system before, with a matching price tag that puts it beyond the purse of the casual music lover and firmly into enthusiast and hardcore leagues.

You are getting what you pay for though. Beats by Dr Dre claims to recreate the "intricacies" produced in a recording studio. We've never been to one, but the sound quality of these headphones is nothing short of stunning. It couples precision-engineered speakers with powered noise cancellation for superb clarity and quality. Press a button on the side of the headset and it will actively cancel unwanted external noise via a clever piece of technology that produces an 'antinoise' signal. It easily trumps the best of Sennheiser's headphone range, though at twice the price you have to be serious about your sound to invest in a pair.

Verdict: ✪✪✪✪

Hexbug

Is that a robot in your pocket...?

Price: £14.45 / $12.99
Get it from: www.purelygadgets.co.uk

THE ORIGINAL HEXBUG started out as a beetle that reacted to touch and sound, changing direction according to sharp noises, verbal commands and obstacles in its path. The range expanded and now brings us the Crab, which moves and feels just like the bottom-feeding crustacean.

Once switched on this Hexbug reacts to light and sounds, scurrying away from loud noises and actively seeking out dark crannies to hide in. You can even re-enact your rock-pooling days with this one, because any change in light will cause it to flee to the next shady place. The technology inside isn't top end, but it is an amusing and very reasonably priced toy.

Verdict: ✿✿✿

Vado pocket HD video camera

Easy video for the YouTube generation

Price: £84.99 / $129.89
Get it from: www.purelygadgets.co.uk

SLIPPING SOMEWHERE IN-BETWEEN the mobile phone camera and camcorder market, Creative's Vado HD video camera didn't impress us initially. It's a lightweight pocket camcorder that takes HD quality video with a basic 2x digital zoom. However, in a generation obsessed with recording every facet of life and communicating it to the world via social networking media, its blissful ease of use makes it a perfect choice for amateur filmmakers.

It holds up to 8GB of film, which equates to over an hour of video and can easily be uploaded to a PC via the integrated USB port, or wired directly into your HD telly using the supplied mini-HDMI cable. Operating it is no more complicated than pointing the lens in the appropriate direction and pressing the shoot button, and it's actually even less complicated than recording video on a mobile phone. The output can be viewed on-the-fly on the two-inch LED screen, though the quality isn't impressive. But that's not the point of the Vado: the image is more than clear enough for a YouTube video production and it's a quick and easy way of getting your amateur production from device to the internet.

Verdict: ✿✿✿✿

Tropic Of Cancer

- **Price: £24.99 / $35.99**
- **Get it from: www.bbcshop.com**

Simon Reeve – author, broadcaster and explorer – embarks on his most ambitious journey yet as he sets off on an epic trip to circle the world along the northern boarder of Earth's tropical region. Ranging from the beaches of Mexico's Pacific Coast, through the Caribbean, North Africa and onto the jungles of Asia, Reeve discovers some fantastic cultures, amazing animals and spectacular surroundings. This is a fascinating series that has an strong emphasis on ecological, cultural and economic issues.

Verdict: ✿✿✿✿

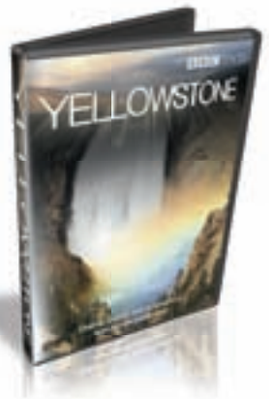
Museum Of Life

- **Price:£24.99 / $35.99**
- **Get it from: www.bbcshop.com**

Presented by Jimmy Doherty as well as a host of academics and scientists – including Kate Bellinham from *Tomorrow's World* – in *Museum Of Life* the BBC is given unprecedented access to the vaults and treasures of the Natural History Museum and great finds are discovered and brought to life. This is a good series that demonstrates the extraordinary work undertaken both front and rear of house by the Natural History Museum in preserving these most valuable of artefacts.

Verdict: ✿✿✿

Yellowstone



- **Price: £13.75 / $19.99**
- **Get it from: www.bbcshop.com**

Yellowstone, the world's first national park, is scrupulously detailed in this multi-part documentary, detailing its wildlife, climate, geology and fauna in unprecedented detail. Narrated by the charismatic Peter Firth, *Yellowstone* takes a wide view of such a unique environment and continues the BBC's exemplary record in environmental documentaries. Each episode is informative, entertaining and well shot, with the type of stunning high resolution and close-up footage that are now par for the course.

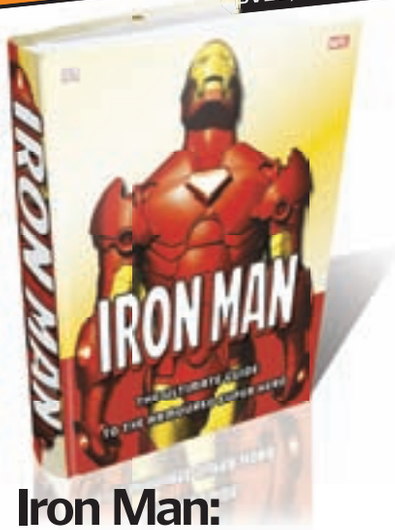
Verdict: ✿✿✿

Planet Earth: The Complete Series (Blu-ray)

- **Price: £25.00 / $34.99**
- **Get it from: www.bbcshop.com**

Arguably the greatest environmental documentary ever produced, *Planet Earth: The Complete Series* is, as with the more recent *Life* boxset, stunning. Narrated by the legendary Sir David Attenborough, the series presents the epic story of life on Earth, a feat that took over five years in production, 2,000 days in the field, and 40 camera operators filming in over 200 locations. Filmed completely in high definition, this is a superb series and cannot be recommended enough.

Verdict: ✿✿✿✿✿

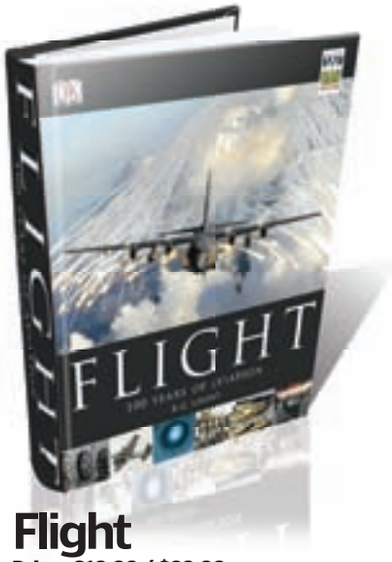


Iron Man:
The Ultimate Guide To The Armoured Super Hero

Price: £17.99 / $23.99
ISBN: 978-1-40534-851-5

To compliment our awesome feature about the real Iron Man that can be found on page 42, DK's compendium to the comic book is every fan's dream come true. Detailing Iron Man's history, suits, technology, creation, episodes, issues, enemies and trivia, this is the ultimate guide to a much-loved superhero.

Verdict: ✪✪✪✪



Flight

Price: £19.99 / $29.99
ISBN: 978-1-4053-5342-7

Charting the men, machines and technology that have pushed aviation to the heights it has reached today, *Flight* provides an extremely in-depth and illustrative guide to its history. Charting the trailblazers, jet test pilots and constant progress at the cutting-edge of aviation research, every aspect of flight is explored in the book – a fact that makes it easy to recommend to all you flight enthusiasts out there.

Verdict: ✪✪✪✪

Astrolux Reflector Telescope

Bringing astronomy to all

Price: £70.00 / $108.00
Get it from: www.sciencemuseumshop.co.uk

THE SKY-WATCHER series of telescopes is one of the best around, delivering great-quality telescopes at a wide variety of price points that help even the youngest person get involved and interested in astronomy. This, the Astrolux Reflector Telescope, is recommended by none other than legendary astronomer Sir Patrick Moore and sits right in the centre of Sky-Watcher's amateur range, allowing incredible views of the night sky through a 76mm-diameter mirror and magnifying optics.

The telescope is a Newtonian reflector and comes equipped with a alt-azimuth mount, 6x24 finderscope, 10mm and 25mm eyepieces, and x28, x56, x70 and x140 optics, which combined provide a power potential of x152 and offer a great selection of ranges for younger astronomers. Aperture size lies at 76mm, focal length at 700mm and the scopes focal ratio is F/9.2.

In addition, the Astrolux comes equipped with Sky-Watcher's Aspherical Technology – a tech usually only found in more expensive scopes – which allows its primary mirror to bring light rays onto a common focal plane, resulting in sharper, brighter (up to 131 per cent more starlight than an average 50mm toy telescope) and more detailed images. Combine all this with its good price point and it is not hard to recommend.

Verdict: ✪✪✪✪

Ecobutton

Rube Goldberg goes green

Price: £12.95/$19.77
Get it from: www.purelygadgets.co.uk

WE'VE ALL BEEN guilty of it at some point in our lives and if we're not leaving the lights on, or the telly on standby, then it's that semi-permanent part of our lives, the PC. With around 30 million PCs in the UK alone, the energy-conscious people who have created the Ecobutton have calculated that the average PC wastes £50 in electricity every year left idling, with the UK pumping 3 million tons of carbon into the environment because of it.

The Ecobutton is simply an easy stand-by switch that aims to cut this: whenever you hit the button it puts your PC to sleep, with a simple keyboard tap to wake it back up again to show how much power you've saved. It's a bit of a novelty really, but one that's good fun and that will help demonstrate your commitment to saving the environment too.

Verdict: ✪✪✪

Headphonies micro speaker

Big noise, small package

Price: £19.90 / $19.95
Get it from: www.purelygadgets.co.uk
THIS IS CUTE: a small and very portable speaker that easily fits into your pocket or on the end of a keychain with the provided loop. A gimmick, right? Wrong. The one thing we never expected from this product was the quality of output the Headphonies micro speaker has. Now we see why it won the CES innovations award.

It hooks up to any portable device – laptop, MP3 player, Nintendo DSi – via the standard headphone jack in the base and can also be charged using the same port, with the USB to 3.5mm jack cable provided. This hassle-free device auto-powers off and can also be hooked up in tandem with multiple Headphonies to a single source using a stereo splitter. There's no volume control, but with the number of features already packed in that's something we can forgive.
Verdict: ✪✪✪✪

HOW IT WORKS EDITOR'S CHOICE AWARD ✪✪✪✪✪

Solar buggy

Don't let the Sun go down on me

Price: £9.99 / $15.99
Get it from: www.mutr.co.uk
"THIS IS NOT A TOY" declares the side of the curiously shaped box, though we beg to differ. No one said science experiments couldn't be fun, but this Natural History Museum Solar buggy is so easy to put together that we couldn't imagine it not making a good birthday present for anyone of any age. Sure, small parts and electronic components make it unsuitable for very young children but once constructed, it's basically a toy car powered by the Sun.

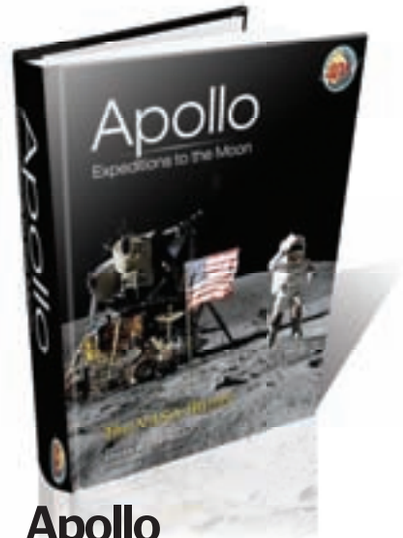
Inside the box is a Meccano-style kit that includes several wheels, a piece of PVC that doubles up as a chassis plate, a solar panel and a solar gearbox as an engine. It takes ten minutes to put it all together, the only sticking points being the wheels, which take a bit of a hammering to slide onto the axle, and the wires that lead from our solar panel, which needed stripping properly to make electrical contact and create the circuit.

Once it's ready, the buggy will continue to move as long as the solar panel is in direct sunlight or under a bright beam. Half the pleasure is the satisfaction of building it yourself, but the instructions suggest a range of experiments you can perform with it, so there's more longevity than meets the eye.
Verdict: ✪✪✪✪

Why Didn't I Think Of That?

101 Inventions That Changed The World By Hardly Trying

Price: £9.99 / $13.95
ISBN: 978-1-4405-0010-7
Not all inventions are big and spectacular, in fact many of the most popular are mundane and rather dull, such as the paper clip which is just a piece of bent wire that has sold over an estimated 100 trillion units worldwide. A light-hearted look into some of the most successful and uninspired inventions in use today.
Verdict: ✪✪



Apollo Expeditions To The Moon: The NASA History

Price: £23.99 / $29.95
ISBN: 978-0-4864-7175-4
Edited with accessibility in mind, this book provides a collection of essays, articles, illustrations and comments from astronauts, engineers and administrators on the monumental task and challenges faced in putting a man on the moon. Together this is an in-depth and exciting look at the Apollo space programme.
Verdict: ✪✪✪

Digital Metal Detector

Get down the beach and dig up a fortune!

Price: £30.00 / $45.99
Get it from: www.sciencemuseumshop.co.uk
AFTER THE UNEARTHING of the Staffordshire Hoard – the largest hoard of Anglo-Saxon gold found on Earth – metal detection has seen a large boom in activity, with many treasure hunters seeking their fortune anew. Considering this then, this Digital Metal Detector from National Geographic is sure to increase fortune finders' prospects of success. Designed to find all different types of metal, and coming with a height adjuster (perfect for younger treasure seekers), large search coil, a backlit digital LCD screen, tuneable sensitivity and a loud audio tone alert when materials are passed over, this detector delivers great bang (or should that be beep?) for your buck.
Verdict: ✪✪✪✪

GROUP TEST Rockets

Create a launch pad in your own back garden with these reasonably priced rockets

Reliant Robin Rocket

Price: £24.99 / $38.99

Get it from: www.amazon.co.uk

For serious power, unsurprisingly, this pressurised air effort from *Top Gear* is by far and away the best overall on test, with its rockets capable of flying hundreds of feet into the air. In the box you get the infamous Reliant Robin shaped rocket, four normal rockets, a rocket base, foot pump, instructional manual and 100 membrane boosters to increase launch pressure. This is a good package and plenty of fun for teenage rocketeers and older.

Verdict: ✿✿✿✿✿

Super Stomp Rocket

Price: £8.99 / $13.49

Get it from: www.amazon.co.uk

The simplest and cheapest rocket on test this month is capable of flying up to 400 feet by air pressure alone. Aimed squarely at the younger generation of rocketeer, the Stomp requires its user to jump on its air-filled bladder to deliver a sudden burst of pressure to the attached plastic rocket, sending it hurtling upward. Cheap, effective and reusable but lacking a traditional launch platform, appearance and edutainment material.

Verdict: ✿✿

Remote Control Rocket

Price: £13.99 / $19.99

Get it from: www.smartlabtoys.com

A solid step up from the Cosmic Rocket is SmartLab's Remote Control Rocket, which allows users to activate a baking soda and vinegar-primed rocket from distance thanks to an included wired launch control. Of better build quality than the Cosmic Rocket but with a heftier price tag, the extra money delivers a glossy booklet on space exploration and rocketry, a Fifties-styled rocket and remote controlled launch platform. Performance was pretty decent, averaging between 35 and 50 feet.

Verdict: ✿✿✿✿

Cosmic Rocket

Price: £10.00 / $15.00

Get it from: www.amazon.co.uk

At £10, the Cosmic Rocket from the Science Museum falls in the middle of our selection in terms of price. In the pack you get a simple if stylish rocket, with three fins and launch platform, as well as an instructional and educational pamphlet on the principles of rocketry. Baking powder and vinegar are not included however, which are required to launch it. In terms of performance the average flight was roughly 40 feet, so all in all, a good all-rounder.

Verdict: ✿✿✿

HOW TO MAKE
An illuminated 'ON AIR' sign

Illuminated 'ON

Build a switch-powered glowing sign with our simple step-by-step guide

It's a fact that sometimes a regular old-fashioned sign just won't do, they are easily missed, often unintelligible and... well, they just have no razzmatazz. Las Vegas understands this and so does How It Works. In fact, here at Imagine Towers every sign must glow by decree and, considering our new podcasting studio has just been completed and needed an 'On Air' sign, we decided to share our expertise with the world.

Here, then, is a simple step-by-step guide to building your very own glowing sign.

Construction materials:

- 1 x Box switch
- 1 x Project box (plastic is good)
- 1x Open battery holder
- 10x AA batteries
- 1 x Bulb (we used a single 6V 0.6W)
- 1 x Bulb holder
- 1 x Thin insulated copper wire (1 metre will suffice)
- 1 x Blu Tack pack
- 1 x Red gel sheet
- 1 x A4 black card
- 1 x Sharp cutting implement
- 1 x Screwdriver

All construction materials can be acquired at Maplins

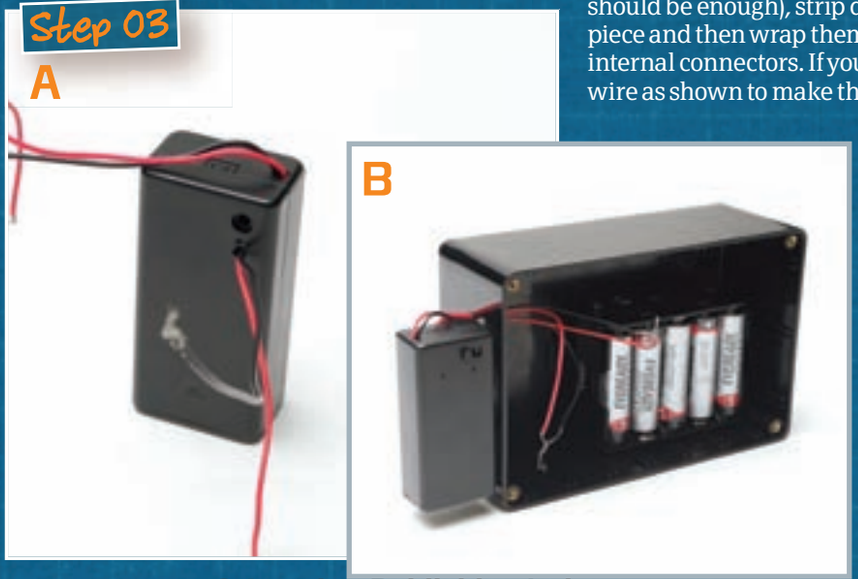
Step 01

1. Take the lid of your project box and put it and its four screws to one side. Then, with the open side facing you, drill or cut a small hole in the left-hand wall. (A) Then slot your batteries into the battery holder and, with a large strip of Blu-Tack, stick it into the opposite lower-right corner of the box with its external connectors facing upwards. (B)

Step 02

2. Take your box switch and remove its lid, then once more drill or cut a small hole in the body's base (under where the battery should be). (A) This is needed as we are going to be connecting the switch to the larger external battery casing, not just using the small square one as we need more juice to light the sign. Once done, cut two pieces of wire (20 cm should be enough), strip down both ends of each piece and then wrap them around the switch's internal connectors. If you wish you can buy capped wire as shown to make this process easier. (B)

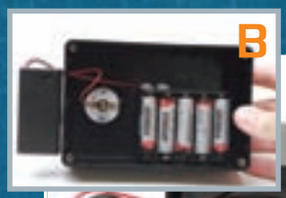
Step 03



3. Your switch box should now have four wires coming out of it – the original two from the switch and the extra two from the battery compartment. (A) Feed all four of these wires through the hole in the side of the project box and then, with the switch box's cover reconnected, Blu-Tack it to the side of the project box. You should now have this. (B)

AIR' sign

GET INVOLVED!
Have you created an amusing illuminated sign that you want to share with the world? Send your pictures to howitworks@imagine-publishing.co.uk and we'll see what we can do!



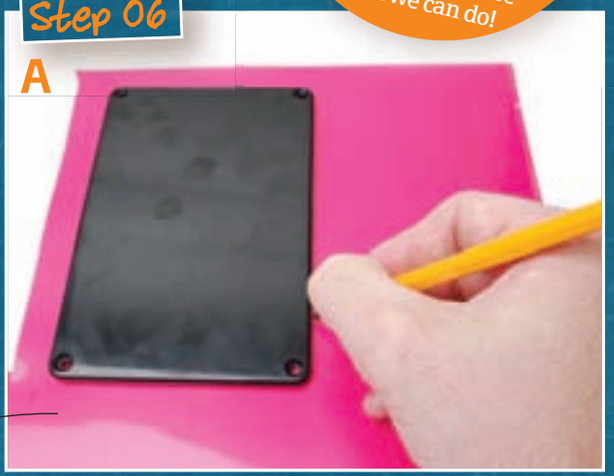
Step 04

4. Next take your bulb holder and connect the two wires leading from the switch end of the switch box and then Blu-Tack its base to the centre-left side of the project box, like this (A). Now insert the bulb and, ensuring the switch on your switch box is off, connect the remaining two wires to the external battery holder's top-mounted connectors. You should now have your sign's full circuit completed. (B)

Step 05

5. Ensure no wires are touching or obstructing the bulb and then flick the switch to on to see if it lights up. If not check your connections. If it does, then progress onto the next step.

Step 06



6. Place your project box with attached switch box to one side and pick up the project box's lid that was placed to one side in step one. Now use the lid to trace around onto the red gel and cut out the resultant shape. (A) Then, placing the gel over the open side of your project box, mark the point in its four corners where the screw holes are situated and drill/pierce the gel. This will allow the gel to be fixed over the open side of the project box with its four screws. (B)

Step 07

7. As with the gel take your black card and trace around the project box's lid and cut out. Then with a ruler (or a steady hand) draw onto the left-hand side of the card the words or message you want the sign to have, we used 'ON AIR' but you can choose anything. (A) You can use the whole width of the card however then you will be able to see the external battery holder when the light is turned on. If you only use the left hand side however, the black card handily masks it.

Step 08

8. Finally cut out the letters with your sharp cutting implement (we used a scalpel) and pierce four more holes in the corners of the card and attach over the gel with the project box's screws. Congratulations! You have made your very own illuminated sign.

Congratulations!

You've now built your very own 'On-air' sign, go you!

Completed!

HOW IT WORKS INBOX

Feed your mind. Speak your mind

Get in touch!

If you've enjoyed this issue of How It Works, or have any comments or ideas you'd like to see in a future edition, why not get involved and let us know what you think. There are several easy ways to get in touch...

The perfect way to read the latest issue of HIW

Letter Of The Month

Getting an eyeful on the iPad

I'm a self-confessed early adopter and unashamed gadget-head so I was one of those "fools" who went to great lengths to get an iPad from the States. To say I was impressed with this amazing device would be an understatement and I was equally impressed with the How It Works app that I downloaded as one of my first app additions. I reckon this device and others like it are the natural successors to paper magazines and apps like yours are the perfect showcase for this new breed of gadget. Well done for being at the cutting-edge!
Tony Moran

HIW: Well done yourself Tony, for bagging what is easily the hottest gadget of the year before any of your peers. We understand how important that is here at How It Works. Congratulations too for downloading the app. We've played with it too (yes, we also have an iPad in the office!) and as good as the iPhone version is, this app really comes into its own on the larger iPad screen. Keep your eyes on the App Store as we may well add some special editions soon.

Enquiring minds want to know!

This is my third magazine and it still has the wow factor. I'm not a big reader but found that now I'm older (37) I have a thirst for knowledge. Your magazine works perfectly; short articles that keep you hooked. I've always wanted a magazine like this, I tell myself I'll read this page and then stop, but turn the page and think oh, that looks interesting and read on. So a big thank you.

Please please don't stop and don't go the way of other new magazine ideas of filling it full of adverts and no features. As they say if it ain't broke, don't fix it... and it certainly ain't broke! I've always wondered how people put scaffolding on very high structures! I mean who puts the scaffold up for the scaffolders? I was passing a small emissions tower (it was high though) and there was a ring of scaffold around the top. I just looked and tried to work out how they got all the stuff up there and how dangerous it must have been. Maybe you guys can shed some light on this for me?
Kevin Gravill

HIW: We like you Kevin, you have an enquiring mind and your question reminds of us a lyric from a superb but little-heard-of indie band "There are questions in corners of my mind that lurk / Like how do the road gritters get to work". Seriously though, we'll look to answer your question in a coming issue. We love getting reader questions, so send them to howitworks@imagine-publishing.co.uk.

Give us a Tickle

I live in Germany and while visiting friends in the UK last New Year I saw your magazine in the shops. I am so glad that I decided to buy a copy. When I got home I instantly subscribed. Although some of the articles are a little too short and superficial for my liking I do understand the reasoning behind it. The variety of subjects covered is just right and excellently presented.

I do enjoy the personality interviews especially the Vicki Butler-Henderson (hot babe) feature. I would very much like to see Jon Tickle featured at some point as I used to be a big fan of *Brainiac* until Vic Reeves took over from Richard Hammond. I like the gadget reviews, but I have to agree with Mr Redfearn that the computer games reviews really do not fit and leave me personally cold. Keep up the good work!
Stephen Tuff

HIW: Thanks for the suggestions Stephen, you'll notice that the games reviews have been replaced with DVD reviews as of last issue. We always try to listen.

The magazine that stays current...

Shocking error

I'm just emailing to let you know about a mistake in issue 6, on page 60, in the "Circuit Jargon" box – you've put that current is measured in volts (V) and voltage in amps (A). Someone's probably already mentioned this to you, but it gave me an excuse to email to say I love the magazine – this is the first issue I've bought, and I think it's great, I've been looking for something like this for a while!
Jack Preston

HIW: You're not the first to point this out Jack, and we've a feeling you won't be the last. The titles in the circuit jargon box are the wrong way round. While we make every human effort to ensure the info in our mag is factually correct, this slipped by us. Many, many apologies.

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.

Nice work if you can get it

I'm a Macintosh technician and I work for an Apple Authorised Service Provider in Mauritius, a small island lost in the Indian Ocean, which I call paradise. Yes, your magazine has even reached paradise! I'm just writing to let you know to what extent I'm being entertained by your articles concerning Apple products. I'm eagerly awaiting issue 7 to relish the teardown of the much-hyped iPad having been entertained by a previous article about how touch screen on the iPhone actually works! Developing an app for the iPhone/iPad is simply genius! Hope to have more surprises like this in the future. I haven't missed a single issue since the fabulous magazine has been issued as you may have expected, and I'm looking forward to subscribing, even though £60 is not a small amount when converted to Mauritian rupees.

I participated in the survey (even though I know that I will not win an iPad), just to help to improve the magazine standard. Thanks for the great job behind this extraordinary magazine!

Mustafa Ruhomaun

Crane crazy

I would be really interested to know if any other readers struggled in following the instructions printed in issue 7 of your magazine for this. After step one everything just seemed confusing – and the accompanying photos didn't help! Could you please reprint with clearer pictures and 'clearer' instructions. Love the magazine so keep up the great work.

Nathanael

HIW: Sorry that the origami crane didn't bring you the peace and enlightenment that we intended Nathanael! We always test the How To Make section out on various staff members before we commit to print and they all managed to make it. That said, origami is a matter of patience and isn't easily mastered. If you're still struggling try visiting http://tinyurl.com/27gsdxu where you can see a video of someone making a crane very much like ours.

Has our origami master left you confused too?

Questions you've been asking... and that we'll answer soon

How do ice breaker ships work? G Trepp What is artificial intelligence? M Mason What's Halley's Comet made of? H Howard **How does our body produce adrenaline?** C Fredricks Why does the Leaning Tower of Pisa lean? W Hales How do komodo dragons kill? B King Why is there so much flooding? G Presley What is a "stealth aircraft"? T Samba

Send your questions to howitworks@imagine-publishing.co.uk

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