THE MAGAZINE THAT FEEDS MINDS

HOW IT WORKS

SCIENCE ENVIRONMENT TECHNOLOGY TRANSPORT HISTORY SPACE

INSIDE THE NEW iPAD

EXPLAINED:
QUAD CORE, 4G NETWORKS & RETINA DISPLAY

SUPER HIGH-SPEED TRAINS

The engineering taking rail travel beyond 300mph

HOW TO BUILD A GAMING PC

Constructing high-end games machines at home

INCREDIBLE TECHNOLOGIES SEEKING OUT HABITABLE PLANETS

SEARCH FOR NEW EARTH

LOCATING ALIEN LIFE / BIZARRE NEW WORLDS / INTERSTELLAR TRAVEL

+ LEARN ABOUT

- STICKY TAPE
- VACUUMS
- BLISTERS
- CEMENT
- DAYGLO
- VELCRO
- BELFRIES
- AIRLOCKS
- CATS

995 FACTS AND ANSWERS INSIDE

AMAZING AMAZON!

EXPLORE THE WONDER OF THE PLANET'S MIGHTIEST RIVER

RUNNING SHOE TECH

Can advanced footwear improve your performance?

CELL DIVISION

How does a single cell become a whole human?

HUMAN TONGUE

How do these muscular organs enable us to talk?

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HOW IT WORKS
ISSUE 33

WELCOME

The magazine that feeds minds!

Get in touch

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

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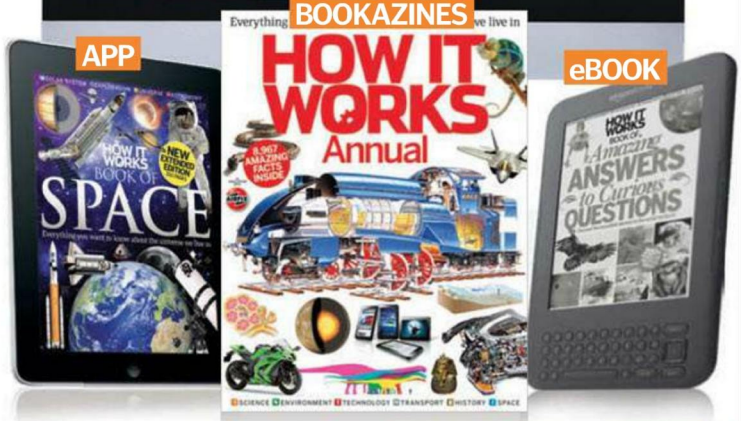

FEED YOUR MIND!

Fancy yourself as something of a planet hunter? The quest to find habitable Earth-like planets outside our solar system represents pretty much the pinnacle of space exploration. In the three years since the Kepler spacecraft was launched on a mission to survey the skies, the race to return vast quantities of radical new information has gathered pace and some seriously significant breakthroughs are being made every single week. But it's not just Kepler scanning the heavens; a selection of other super-telescopes located around the globe are also making great strides in this search for a new Earth. In fact, so much data has been captured that it would take forever to analyse it all.

In our planet-hunting feature this issue, we reveal the techniques used to locate and identify exoplanets. From the data gathered to date, far more is already known about possible life on other worlds, and in our article you'll read about all the most exciting discoveries 'unearthed' so far. Beyond this you'll find information on the size and makeup of exoplanets, plus what living conditions would be like on the surface of a habitable extrasolar body. We also spoke to the British Interplanetary Society about when they think interstellar travel will be possible.

Enjoy the issue

Helen Laidlaw
Editor

Meet the team...

Dave
Ed in Chief
Technology has to be my favourite section this issue, just for the sheer diversity of gadgets covered. It's great to see inside the new iPad, and also see how sniper rifles are made.

Robert
Senior Staff Writer
I really enjoyed the Amazon article – the diverse array of flora and fauna is awesome and we should make every effort to protect it, especially following my chat with Ed Stafford.

Jonny
Staff Writer
Are we alone in the universe? I tackled this question and more in our planet-hunting feature, delving into the technology and the people behind humankind's quest for a new Earth.

Adam
Senior Sub Editor
This month my vote goes to the 'Amazing Amazon' feature. From jungle cities to a host of indigenous species, it's incredible how much life can depend on a single river network.

THE SECTIONS

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

ENVIRONMENT
The splendour of the natural world explained

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

HISTORY
Your questions about how things worked in the past answered

SCIENCE
Explaining the applications of science in the contemporary world around us

TECHNOLOGY
The wonders of modern gadgetry and engineering explained

SPACE
From exploration of our solar system to deep-space adventures

WITH THANKS TO...

How It Works would like to thank the following organisations for their help

adidas · DK · NASA · SciencePhoto Library · asics

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The magazine that feeds minds!

MEET THE EXPERTS

Find out more about the experts in this month's edition of **How It Works...**

Luis Villazon
Cats

Taking one of the most popular pets on the planet and exploring their unique anatomy and behaviour, this issue Luis explains what makes our furry feline friend, the cat, such an amazing creature.

Jimmy Hayes
The new iPad

The editor of iCreate magazine, Jimmy Hayes, takes a look inside Apple's brand-new tablet to reveal the benefits of the super-punchy Retina display, quad-core graphics and more besides.

Shanna Freeman
Cell division

This issue, Shanna is here to help you understand the science of cell division and reveals just how a single cell can grow, repair itself and even become a human being made of several trillion new cells.

Kate Kemp
Ice-cream makers

Kate is a new face to the How It Works panel, but she hopes to impress you with her expert tech knowledge by bringing you the lowdown on ice-cream makers, plus the secrets of CAPTCHA tests.

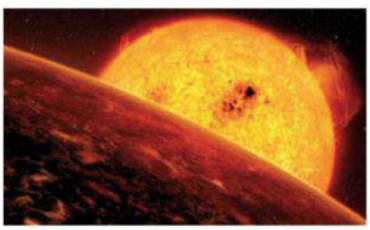
Nigel Watson
Vacuums

This month Nigel explains the pure science of a vacuum as well as revealing how the umbilical cord forms the vital link between mother and unborn baby. He also spills the beans on how our tongues help us to speak.

Dave Roos
Distillation

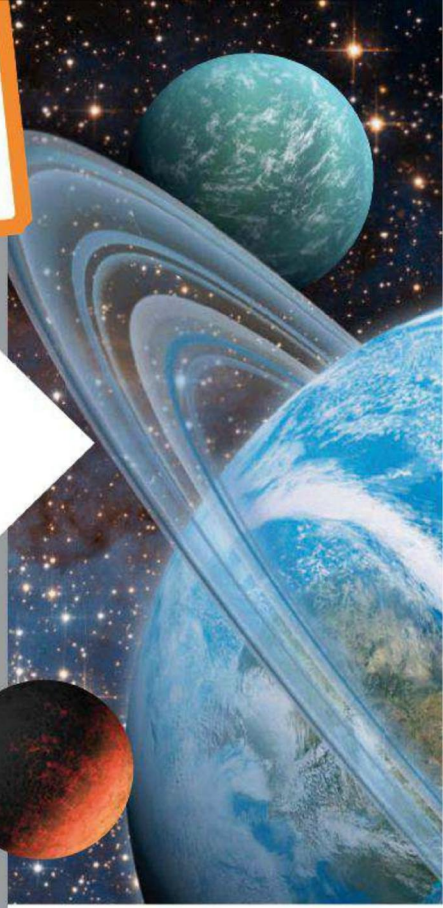
Turning his hand to chemistry, this issue long-time science writer Dave reveals how distillation can be used to separate liquid mixtures into component substances.

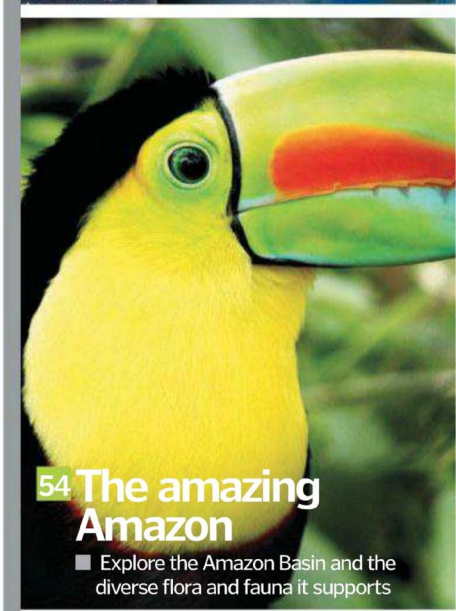
12 SPECIAL FEATURE



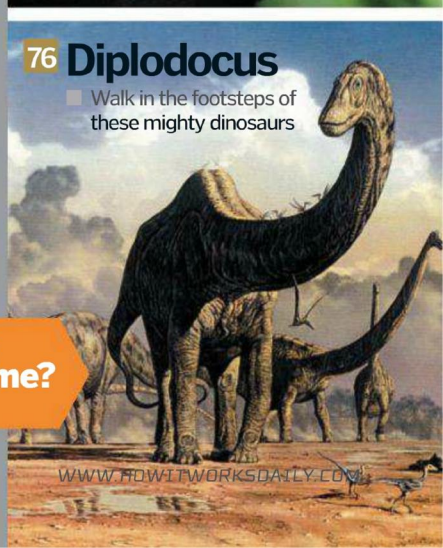
The search for new Earth

Discover the mammoth hunt for habitable planets taking place at various locations around the globe, as well as out in the cosmos, in our big feature this month





54 The amazing Amazon
Explore the Amazon Basin and the diverse flora and fauna it supports

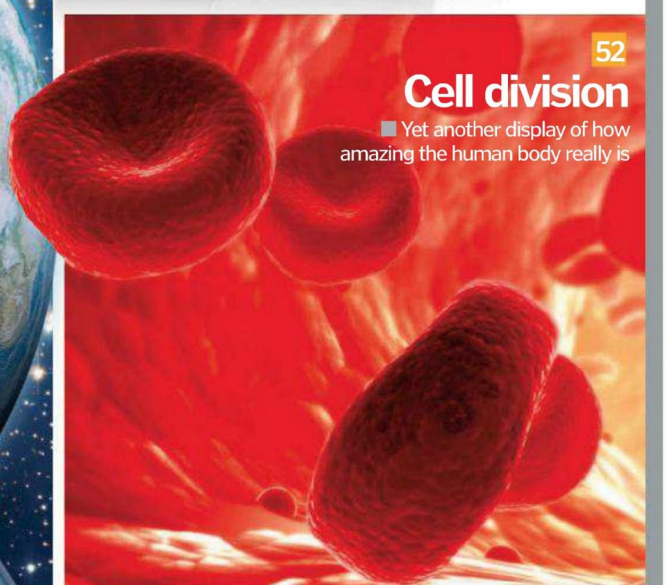


76 Diplodocus
Walk in the footsteps of these mighty dinosaurs

How are shoes helping athletes to up their game?

Go to page 28 to find out!

"There are thousands of known planetary candidates and potentially trillions more in our Milky Way alone"

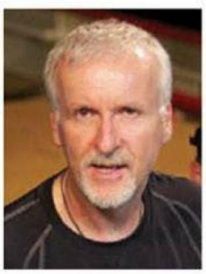


REGULARS

"I seem to have that curse that once I imagine something... I have to build it"

Deepsea Challenger completes record-breaking dive

Moviemaker and explorer James Cameron has completed a challenging journey to the very bottom of Earth's deepest ocean



James Cameron has made a record-breaking solo dive to the bottom of the Mariana Trench, the deepest part of any ocean on our planet. The trench, which is located 11 kilometres (seven miles) beneath the surface of the Pacific Ocean, had not been reached for over 50 years, with the only other successful manned visit undertaken by the now legendry Bathyscaphe Trieste submersible in January 1960 by Jacques Piccard and Don Walsh.

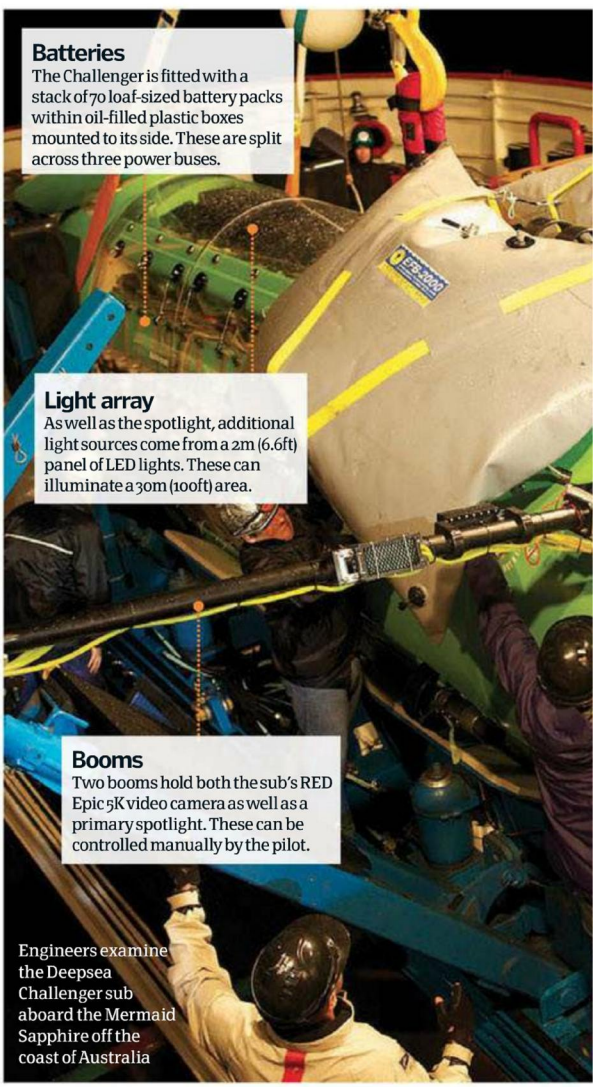
The Trieste has long since been retired however, with the new descent undertaken within a purpose-built submarine, the Deepsea Challenger. Cameron designed this one-man sub himself and, after a series of test dives, it has now taken the Hollywood director right down to the base of the underwater canyon.

Speaking to the BBC on the tropical island of Guam – which was the base of operations for the mission – Cameron explained what led him to build the sub in the first place: "I started to think about what it would take to go to full ocean depth – that was kind of the Holy Grail from an engineering standpoint. So [I started working] up designs, and thinking how it would be possible and what it would take. And then there is suddenly this moment that seems to transpire with no transition where you are suddenly doing it. I seem to have that curse that once I imagine something being built, I have to build it."

During the dive, Cameron was contained within a 109-centimetre (43-inch)-diameter steel sphere, from where he was able to control all aspects of the submarine (see annotations for the sub's hardware breakdown). The sphere had to be so small for both weight and strength reasons, needing to be light enough to be easily lifted back to the surface, but also strong enough to withstand over 1,000 atmospheres of pressure (1,000 kilograms per square centimetre/14,700 pounds per square inch).

The director – who has helmed blockbuster feature films centred on marine disasters such as *Titanic* and *The Abyss* – hoped to capture the Mariana Trench like never before, recording footage on the submarine's cutting-edge RED Epic 5K video camera. However, despite spending over 20 minutes on the floor of the Mariana Trench and three hours within it, little imagery and video was able to be taken, as the Challenger's landing caused large quantities of silt to be kicked up, obscuring the camera's view.

Speaking on Cameron's successful return to the surface, Dr Alan Jamieson of Oceanlab, told the BBC: "I think what James Cameron has done is a really good achievement in terms of human endeavour and technology. But my feeling is that manned submersibles like this are limited in scientific capabilities when compared to other systems, mostly due to the fact there is someone in it. Remote or autonomous systems can collect a far greater volume of useful scientific data for far less money."



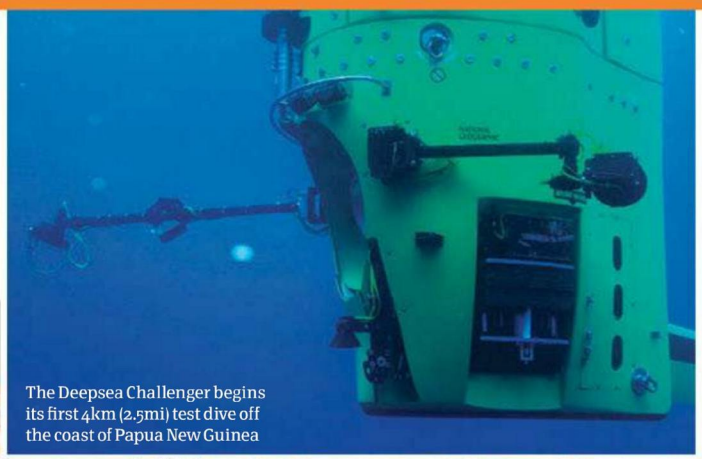
Batteries
The Challenger is fitted with a stack of 70 loaf-sized battery packs within oil-filled plastic boxes mounted to its side. These are split across three power buses.

Light array
As well as the spotlight, additional light sources come from a 2m (6.6ft) panel of LED lights. These can illuminate a 30m (100ft) area.

Booms
Two booms hold both the sub's RED Epic 5K video camera as well as a primary spotlight. These can be controlled manually by the pilot.

Engineers examine the Deepsea Challenger sub aboard the Mermaid Sapphire off the coast of Australia

The Trieste is the only other manned submersible to have successfully reached the Mariana Trench to date



The Deepsea Challenger begins its first 4km (2.5mi) test dive off the coast of Papua New Guinea

Pilot sphere
A 6.4cm (2.5in)-thick steel sphere where the Challenger's pilot sits. It is spherical so that it can withstand the intense pressures of the deep ocean.

Weights
More than 450kg (1,000lb) of steel weights are equipped to the Challenger so it can descend quickly; they are held in place by electromagnets.

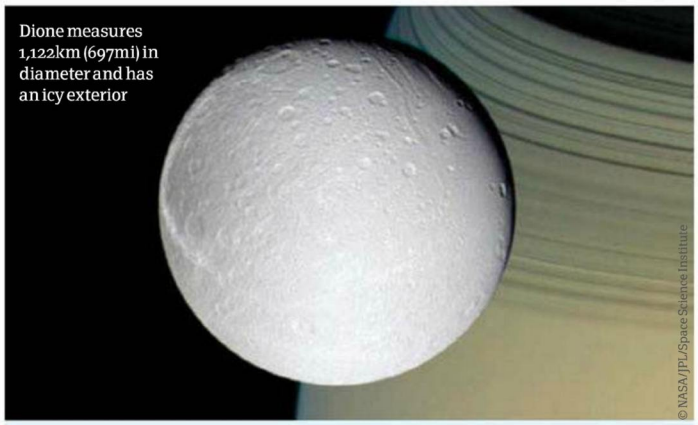
The statistics...

Deepsea Challenger

Length: 7.3m (24ft)
Weight: 11.8 tons
Ballast: 500kg (1,100lb)
Sphere size: 1.1m (3.6ft)

The crew prepares Deepsea Challenger for its first test in the ocean at Jervis Bay, south of Sydney, Australia

5x © Mark Thiessen/National Geographic



Dione measures 1,122km (697mi) in diameter and has an icy exterior

© NASA/JPL/Space Science Institute

Cassini spots activity on Saturn moon

NASA spacecraft records possible signs of geological activity on the icy moon Dione

NASA's Cassini probe has spotted features on Saturn moon Dione's surface that indicate ice volcanoes could be active on it. These findings are interesting as they run contrary to previously held scientific thought that the moon is an undynamic, frozen wasteland.

The findings, which were presented at the 43rd Lunar and Planetary Science Conference in Texas, USA, were delivered by Dr Bonnie Buratti from NASA's Jet Propulsion Laboratory (JPL).

Research into Dione's environment began when NASA discovered a stream of charged particles emanating from the moon's surface, with a thin layer of oxygen detected around it. The Cassini probe then proceeded to examine the moon in greater detail.

From a series of close flybys, the spacecraft detected that large areas of Dione's surface were largely devoid of any craters, while others were heavily pockmarked. As such, NASA believes that either material flowed into these craters, filling them in, or that they were covered by large amounts of debris from a nearby explosion. Both these theories seem to be supported by Cassini's discovery of an apparent cryovolcano. Cryovolcanoes, rather than erupting molten rock, spew water-ammonia and methane into their surroundings.

Speaking on the publication of the results, Professor William McKinnon of Washington University said: "I suspect that not a lot is going on on Dione right now. There's clearly been resurfacing... [so] we know something happened."

Cheltenham Science Festival 2012

This year's science bonanza promises to be the best yet

© Conor Cahill

Over 300 of the world's greatest thinkers, comedians, writers and scientists will come together to celebrate and explore all things scientific at 2012's Cheltenham Science Festival. This year the event will feature cutting-edge discoveries, cabaret, comedy and hands-on experiments. It will also host the International FameLab final, which is seeking the world's next big scientific stars.

For 2012, the festival's theme of 'regeneration' will be at the heart of the programme. From medicine to technology, economic recovery to energy, the festival will look at the role of science in our ever-regenerating society. Further, TV favourite Alice Roberts and star of the 2011 Royal Institution Christmas Lectures, Bruce Hood, are already confirmed to attend, with many more names to be revealed. It takes place 12-17 June and more information can be found at **www.cheltenhamfestivals.com/science**.

WHAT ON EARTH IS IT?

A close-up look at the world!

1

We reveal the true identity of the weird and wonderful images posted on HIW Daily, plus a few of your suggestions. Remember being right isn't everything – we're also looking for creativity!

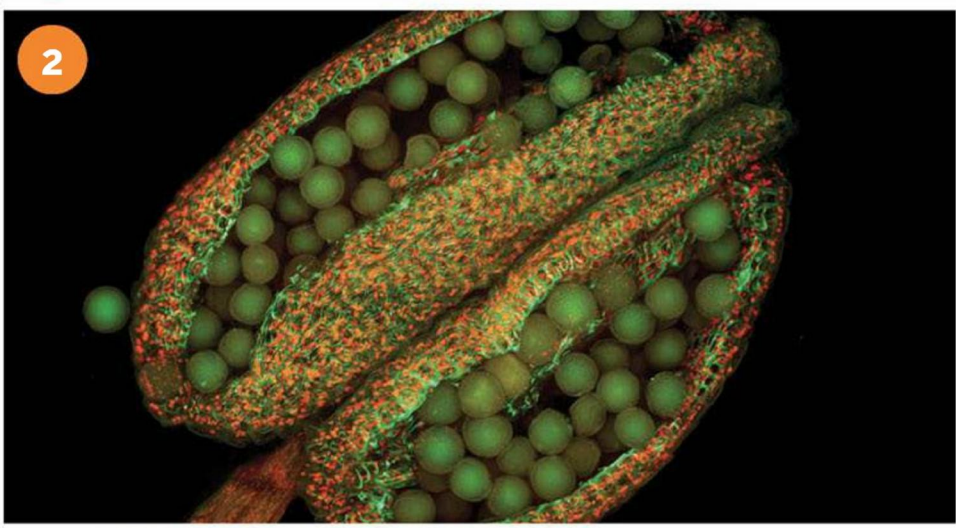
What is it?

1. Snail

This is the shell of a pontifical mitre (mitra stictica), a species of sea snail and marine gastropod mollusc in the mitridae family. The species, which is notable for its colourful shell, is widely distributed throughout the Indian and Pacific Oceans, particularly along the coasts of Fiji, Mauritius and Tanzania, and is popular among shell collectors.

Your best answers:

'A baby dinosaur turned on its side?' **Charles Windle**
'One very dodgy haircut' **James Gant**



2

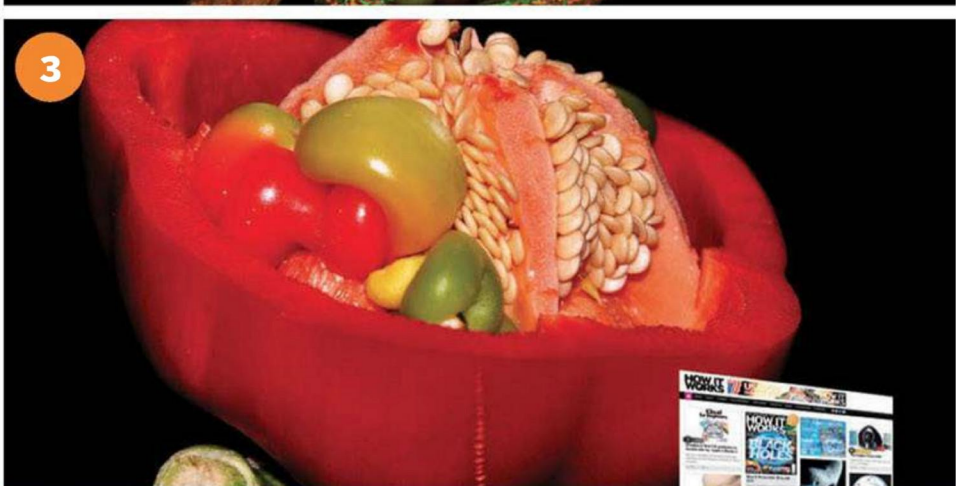
What is it?

2. Mouse

This is the anther – pollen-bearing part of the stamen – of a mouse-ear cress (arabidopsis thaliana), a small flowering plant native to Europe, Asia and northwest Africa. Interestingly, the cress can complete its entire life cycle in just six weeks.

Your best answers:

'Spider poo?' **SaiMun Wan** *'Bacteria or a virus?'* **Ashwin Kumaar**



3

What is it?

3. Bell

This is an interesting shot of both an adult and baby bell pepper (capsicum annuum), the latter being half-grown in the body of the former. There are three species of bell pepper, each native to North or South America and used as a hot or sweet ingredient in many dishes.

Your best answers:

'The inside of a mutant bell pepper' **Bethany Nicholson**
'It's a stuffed olive embedded in a guava...' **Gordon Muller**

To get involved, visit WWW.HOWITWORKSDAILY.COM to make your guess now!

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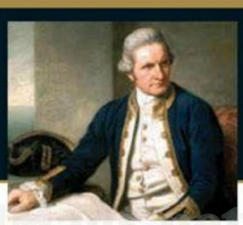
THIS DAY IN HISTORY

19 APRIL: How It Works issue 33 goes on sale, but what else

65CE Gaius Calpurnius Piso's plot to kill the Roman emperor Nero is foiled and all of the conspirators are arrested.

1587 Francis Drake's expedition sinks the Spanish fleet in the port of Cádiz.

1770 Captain James Cook (pictured right) first sights the eastern coast of Australia.



1839 The Treaty of London establishes Belgium as a kingdom.

1928 The 125th and final fascicle (instalment) of the Oxford English Dictionary is published.

1948 Burma (also known as Myanmar) joins the United Nations.


Stafford spent 860 days traversing the Amazon

Ed Stafford

The 2011 European Adventurer of the Year is famous for walking the entire length of the Amazon River, a feat that firmly placed him in the Guinness Book Of World Records

How It Works: Why did you decide to embark on a mission to walk the entire length of the Amazon?
Ed Stafford: [After leaving] the army I fell into a job of leading expeditions into jungles with film crews. So that was my career for roughly seven years prior to the Amazon [trek]. So as much as walking the entire length of the Amazon seems a bizarre thing to do, I had actually been leading expeditions for several years and I was in my early-thirties and felt I had the skills to do a really massive adventure.

In addition, I didn't have a wife or kids so I felt I could be a little selfish and do this, as it was going to take up a large chunk of my life. The majority of my expedition experience had come from the jungle yet I had never been to the Amazon, so it was appealing. I have to be honest though, I was just searching online for other expeditions that had done something like that, trying to see what kit they used and what lessons they had learned, however the more I looked, the more it seemed that no one had walked the length of the Amazon. So when I twigged that it could be a genuine world record I was hooked on the idea and determined that I would be the first.

HIW: What major dangers did you face during the journey?
ES: I was really lucky with disease – I didn't get any of the big tropical diseases like dengue fever, typhoid or malaria. I think humans were the biggest threat, even though I believe most would think that it would be jaguars, anacondas, venomous snakes, electric eels and all those [kind of] things. They were always there and you had to be aware, but in fact the drug traffickers and the indigenous tribes proved the biggest threat.

Drug traffickers because I was a white man and walking through their areas such as the 'Red Zone' in Peru, where two-thirds of the world's cocaine is grown. I mean, the national police force of Peru just leaves that region alone – it's literally lawless – and the traffickers put in place these [unofficial law enforcers], who police the area for petty crimes such as theft and violence but they allow all the drug trafficking to go on.

So, coming through those areas, the people in authority were those who were running the drug trafficking. They were also the people [from whom] I was asking advice and they were constantly saying that I was totally crazy – that I was going to walk out of this town and get shot. They had a reason for saying that as they wanted to discourage me from coming through, as I was carrying a video camera and was blogging all the time and that wasn't something they wanted. Overcoming those fears and essentially reading between the lines to decide that I wasn't actually going to get killed and that they were just saying these things to discourage me was tough. I have to admit that psychologically it was very difficult to stay positive and not get wrapped up in my own worries.

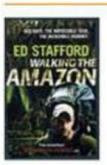
Coming through those drug-trafficking areas though led to very, very closed-off indigenous tribe settlements. These groups were heavily persecuted in the Seventies and Eighties, with many of their population killed, so unfortunately, even to this day, these tribes are living in a state of permanent alertness due to how they were treated. Most people over 20 have seen first-hand bloodshed and family killed so it was incredibly unsettling to walk [in these areas] as they were very suspicious, and rightly so. They were very defensive about their land so convincing those guys that I wasn't a threat or an oil prospector was tricky and I was pretty paranoid during that period.

"Reading between the lines to decide that I wasn't actually going to get killed and that they were just saying these things to discourage me was tough"

HIW: You have a book out, *Walking The Amazon*. Can you tell us how you approached writing it?
ES: I found it very rewarding actually. I think as you write you look back on things like this with rose-tinted spectacles and think how fantastic an adventure it was. But actually, being forced to go back into my journals was a dark and emotional experience as it brought back into focus the isolation. So writing the book was really valuable for me, to actually remember the expedition properly – [to recall] the highs and the lows. I mean it wasn't all about killing snakes and river crossings, it really is that mental battle of holding it together and staying in control. What was great though was that, while for the first three chapters I had to send my writing off to an editor, after that they said I could write well and just left me to it. So that was nice as I got to write the book myself, and in my own words.


Stafford believes the greatest threat was other humans

HIW: Finally, is there anything you can reveal to our readers about your next big project?
ES: There's a lot going on. I think my book is just now being published in the United States, which is nice. I am also in talks with the Discovery Channel at the moment regarding an authentic survival project that I am doing. And, finally, I have just become an ambassador for The Scouts, which I am really [passionate about], as if I hadn't been a scout when I was a kid I don't think I would have gone on to do the things I have done today.



Walking The Amazon by Ed Stafford is out now in the UK and US and is available online from, appropriately enough, www.amazon.com.

happened on this day in history?

1961 The Bay of Pigs invasion of Cuba fails.

1971 The first space station, Salyut 1, is launched.

1987 *The Simpsons* premieres as a short cartoon on *The Tracey Ullman Show*. The popular series is now in its 23rd season.

© Rustrojo

2011 Fidel Castro resigns from the Communist Party of Cuba's Central Committee after 45 years of service.


© Antonio Milena

10 COOL THINGS WE LEARNED THIS MONTH

AMAZING TOPICAL FACTS...

1 Avalanche research could improve ice cream

Scientists at the Institute for Snow and Avalanche Research in Switzerland have used an X-ray tomography machine, normally used to measure avalanches, to calculate how ice crystals form in ice cream. It's hoped the research will reveal why small crystals develop in ice cream when it is moved from a shop to a household freezer, often becoming slightly chewier in the process.

2 Voters prefer deeper voices

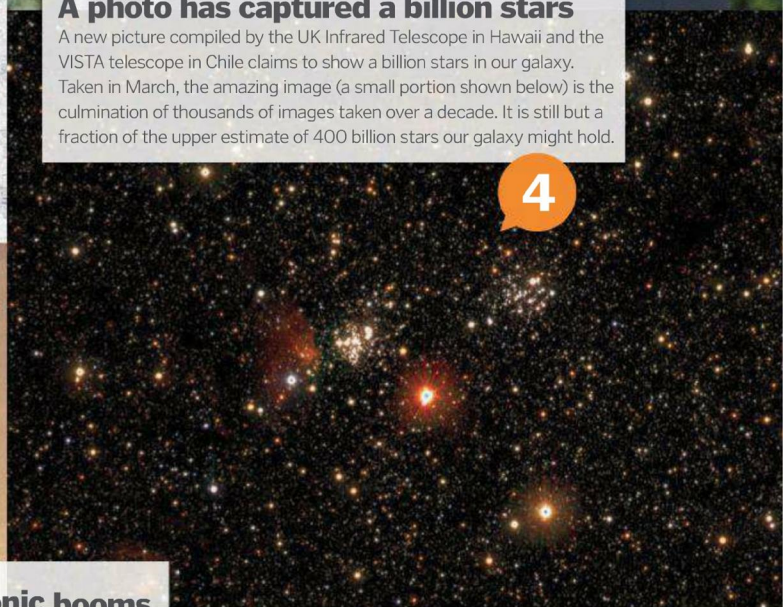
A study in *Proceedings Of The Royal Society B* suggests voters in elections are drawn more to candidates with lower voices. In the research, 27 men and women were recorded saying, "I urge you to vote for me this November." The voters then ranked the candidates in order of preference, with clear favouritism shown for those which were electronically altered to have a lower-pitched voice.

3 Martian dust has hampered rover's sight

NASA's Mars Exploration Rover Opportunity took a self-portrait in late December 2011 to highlight the effects of Martian dust on its solar panels. As it approaches its fifth Martian winter, the accumulation of dust reduces the rover's power supply and limits its mobility. Only once winter is over, or wind clears the panels, will the rover be fully operational.

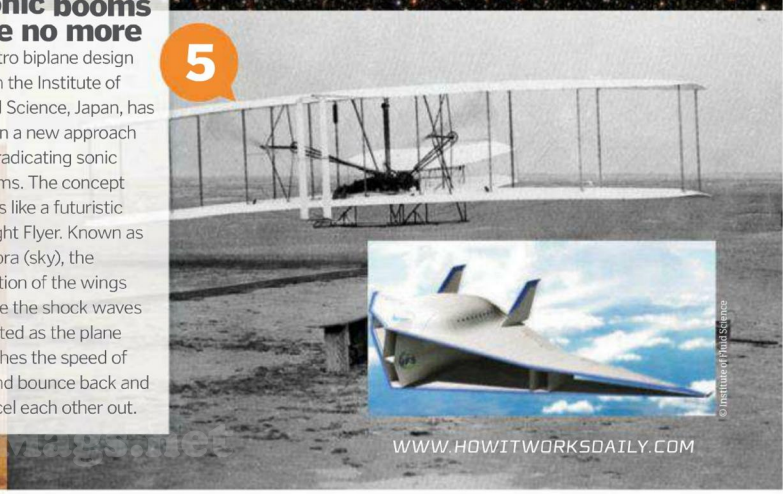
4 A photo has captured a billion stars

A new picture compiled by the UK Infrared Telescope in Hawaii and the VISTA telescope in Chile claims to show a billion stars in our galaxy. Taken in March, the amazing image (a small portion shown below) is the culmination of thousands of images taken over a decade. It is still but a fraction of the upper estimate of 400 billion stars our galaxy might hold.



5 Sonic booms are no more

A retro biplane design from the Institute of Fluid Science, Japan, has taken a new approach to eradicating sonic booms. The concept looks like a futuristic Wright Flyer. Known as Misora (sky), the position of the wings make the shock waves created as the plane reaches the speed of sound bounce back and cancel each other out.



6 Jupiter's heart is melting

New simulations suggest Jupiter's rocky inner core may be turning to liquid and mixing with the outer core. Previously, this gas giant was thought to have clearly defined layers from its gaseous atmosphere down to a rocky core. However, a new study indicates that some planets are much more complex, which may explain why certain exoplanets have the same mass as Jupiter but can be five times as big.

"New simulations suggest Jupiter's rocky inner core may be turning to liquid"

© Sergey Kustov

8 Biofuel plane is set to take off

As predicted by **How It Works** back in issue 29, Qantas is expected to have performed Australia's first biofuel flight by mid-April 2012. Using fuel primed with cooking oil, the Airbus A330 jet will fly between Sydney and Adelaide, heralding a new era of sustainable aviation fuel.

© Ben Tubby

9 King penguins flock to Birdland

Six king penguins have temporarily taken up residence in Birdland, Bourton-on-the-Water, UK, following renovation work at Edinburgh Zoo. The famous birds, who include Sir Nils Olav – the mascot of the Norwegian Guard – join 14 more of their kin at the avian park.

Gecko-tape could hold a TV

A new reusable adhesive inspired by geckos has been made at the University of Massachusetts. One patch can safely hold a 300kg(660lb) weight (or 107cm/42in television) hanging from smooth glass. It's made by placing a thin polymer layer on a fabric of rigid carbon fibres, staying in place due to the van der Waals force, which is what gives gecko toes their super-sticky quality.

7

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10 3D nanoprinting is finally here

A team at the Vienna University of Technology has broken the record for printing a 3D object via nanoprinting. The team printed a model of a Formula 1 racing car only 0.285mm (0.011in) in length in just over four minutes. Each of the 100 layers was composed of 200 single printed lines. The scientists say the technology could eventually be used to make small biomedical parts.

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FEATURE

SEARCH F
NEW EA

FROM HOT GIANT PLANETS TO THE MORE RECENTLY DISCOVERED EARTH-LIKE WORLDS, MODERN-DAY EXPLORERS ARE BRINGING US EVER CLOSER TO FINDING A WORLD OUTSIDE OUR SOLAR SYSTEM THAT COULD HARBOUR LIFE..

OR RTH

Planet hunting is a very new and exciting field of astronomy. In fact, the first planet outside our solar system was not discovered until the mid-Nineties, as the telescopes and methods needed to find planets were simply not advanced enough before then. Today there are thousands of known planetary candidates and potentially trillions more in our Milky Way alone. So far we've found gas giants larger than Jupiter, Earth-like planets more than twice as big as our world and even some rocky bodies smaller than our home planet. With each new discovery we learn a little bit more, not only about worlds outside our solar system (which are known as exoplanets or extrasolar planets), but also those inside it, including Earth.

However, as new as planet hunting may be, there's no doubt that the ultimate goal is to answer a question that has perplexed humanity for hundreds, or perhaps even thousands, of years: are we alone in the universe?

Statistically speaking, the chances of our planet playing host to the only life forms in the cosmos are incredibly small. Consider, first, our own solar system. In it are eight planets and five subsequent dwarf planets, although of these only Earth is known to harbour life. Some of these planets and their moons appear to have once had the capability to support life, such as Mars, or perhaps still do today, such as Jupiter's moon Europa, but so far we have found no concrete evidence that they do.

Missions such as NASA's Mars Science Laboratory, due to land on the Red Planet in August 2012, will give us a greater understanding of the ability of life to adapt to different environments, but even the most optimistic estimates don't expect us to find anything other than small microbial life in the solar system, and certainly not intelligent life forms.

So for our true walking, talking extraterrestrials we need to head out of the solar system. A study in early-2012 suggested that every star plays host to an average 1.6 planets, although some stars are too large or volatile to be thought to have orbiting exoplanets. However, upper estimates for the number of stars in the Milky Way reach a figure of 400 billion, so if even just one star in every 400 has a planet, that's still a potential one billion

DID YOU KNOW?

THE FIRST PLANETS – The first exoplanets were discovered in 1992 using a method called pulsar timing. This tracks the rapid rotation of a pulsar (a small neutron star) and observes perturbations in its regular spin due to the presence of a planet. However, as pulsars are rare, it is difficult to find many planets with this method. Indeed, habitable planets would likely not be found orbiting a pulsar, as the high levels of radiation emitted would prevent any life (at least as we know it) surviving on such a world.

FINDING AN EXOPLANET

There's a reason why the first exoplanets weren't discovered until the Nineties: finding them is incredibly difficult. While seeing stars with the naked eye in the night sky is easy, observing planets is much harder. Planets don't give out their own light, instead only reflecting that of nearby stars, and thus are far less luminous. As a result scientists needed to devise alternative methods to spot planets...

planets in our own galaxy. The mind truly boggles when you then consider that the universe is thought to comprise up to 200 billion galaxies, bumping our upper estimate of planets to 200 million trillion. If these figures turn out to be accurate, we've so far discovered much less than a millionth of all the planets in our galaxy and an even more incredibly small fraction of the planets in the universe.

Could it really be that out of all of these only one – Earth – had the necessary conditions for life to develop? Does only one of these orbit its parent star at a habitable distance? Is Earth really the only planet with water, vegetation, a temperate climate and a breathable atmosphere? It would take a hardened sceptic to unequivocally rule out even the slightest possibility of life elsewhere, and we're certainly not one of them. And neither are the thousands of scientists around the globe looking for planets that fit the criteria of being 'Earth-like' with the hope – and conviction – that one day we'll discover a planet that ticks all the boxes. We could then send a signal in anticipation of a response or, much further down the line, launch an interplanetary spaceship to explore this strange (or perhaps familiar) new world.

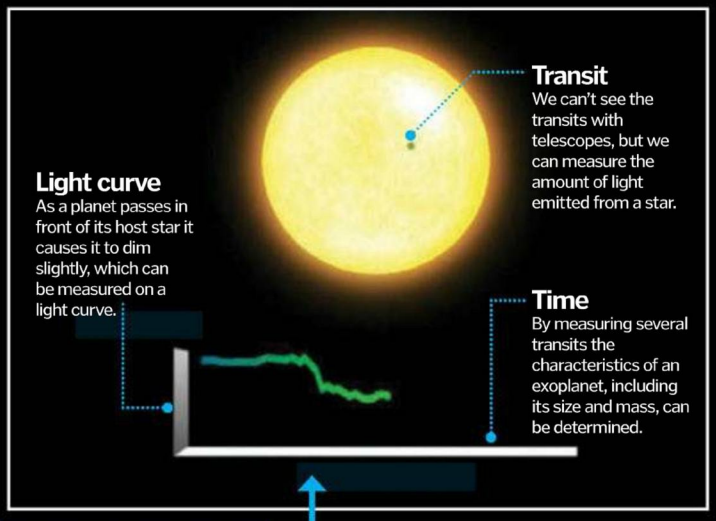
The hunt for ET life

Of course, we haven't taken into account other factors for life on a planet. It took roughly 4.7 billion years for intelligent life to flourish on Earth, and the constant threat of nuclear war, asteroid collisions and other disasters means that the window during which intelligent life is active is relatively small. Indeed, this might help explain a perplexing paradox: if intelligent life is so abundant in the universe, why has no one ever got in touch with us? This very paradox was first postulated by physicist Enrico Fermi in the Forties, when he said that the lack of extraterrestrial contact with our planet suggested that interstellar travel was impossible, but in truth we're no closer to the answer than he was then. However, there have been several efforts to disprove Fermi, which we'll touch on later.

On Earth we are increasing our capability to hunt for new planets with ever-bigger and more powerful telescopes, while our world is constantly emitting signals – both accidental and deliberate – from our multitude of electronics. If someone or something else is out there, wouldn't they have found us by now? Maybe we haven't been actively sending signals out long enough to reach a nearby planetary system, maybe we're being ignored, or maybe we truly are alone. The best way of answering these questions is through the search for planets outside our solar system, which

Transit method

This is the predominant method through which the majority of planets have been found. When a planet crosses in front of a star it causes a momentary dip in brightness. The amount the star dims is relative to the size of both the star and the planet; the size and mass of the star in question can be measured using a spectrometer. Although the planet cannot be directly observed, its mass and size can be estimated by measuring the star's fluctuation in luminosity.



DISADVANTAGES

For a planet orbiting a Sun-like star at 1 AU (the distance from Earth to the Sun), the probability that its orbit will transit in an observable manner in front of the star is about 0.47 per cent. Thus it can take more than 200 observations of one star to definitively confirm or deny the presence of a planet, and even then the speed of the planet's orbit could lower the probability further. The transit method also suffers from a high rate of false detections, and so a follow-up detection method such as the radial-velocity method is needed to confirm or refute the findings.

Radial velocity

Radial-velocity measurement, aka Doppler spectroscopy, observes the Doppler shifts in the spectrum of a distant star. To understand how it works, imagine the Sun-Earth system. We know Earth orbits the Sun, but the Sun actually orbits the Earth as well. For this reason, in the Sun-Earth system, there is a central point around which both objects orbit. However, as the Sun is so much larger, this point is much closer to the centre of the Sun; in fact, the point is only 450 kilometres (280 miles) from the centre of our solar system's star. Thus, the Sun only appears to 'wobble' around this point.

Radial-velocity measurements work by applying this principle to distant stars. Observations are made of the spectrum of light emitted from a star, and the intensity of the light will vary over time depending on the 'wobble' of that celestial body. By measuring changes in radial velocity, not only the presence of an exoplanet can be determined but also its mass.

THE KEY PLANETS

AND THEIR DISTANCE FROM EARTH IN LIGHT YEARS (LY)

10LY Epsilon Eridani b

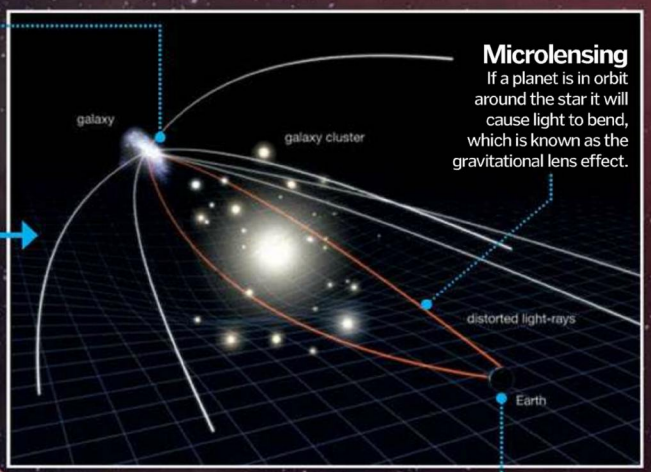
This unconfirmed exoplanet is the closest potential planet to Earth. However it is uninhabitable, as it is a gas giant with a mass about one and a half times that of Jupiter.

Gravitational microlensing

This method of finding planets is based on the gravitational lens effect. If a massive object, like a star, is directly in our line of sight of another massive body, then the star closest to us will bend and magnify the light of the background object. The two stars must be exactly aligned for this phenomenon to be observable, with the lensing event often lasting for no more than a few weeks. However, more than a thousand of these events have been observed in the past decade.

If there is an exoplanet in orbit around the star in the foreground, it will noticeably alter the lensing effect. This method is especially useful when peering towards the centre of the Milky Way, as there are many background stars which produce this effect. Its main advantage is that it is able to observe exoplanets at a habitable distance from their host stars, but unfortunately other planet-hunting methods will have difficulty confirming such planets at this distance.

In line
The foreground star must be directly in line with a distant star for the microlensing effect to occur.



Microlensing
If a planet is in orbit around the star it will cause light to bend, which is known as the gravitational lens effect.

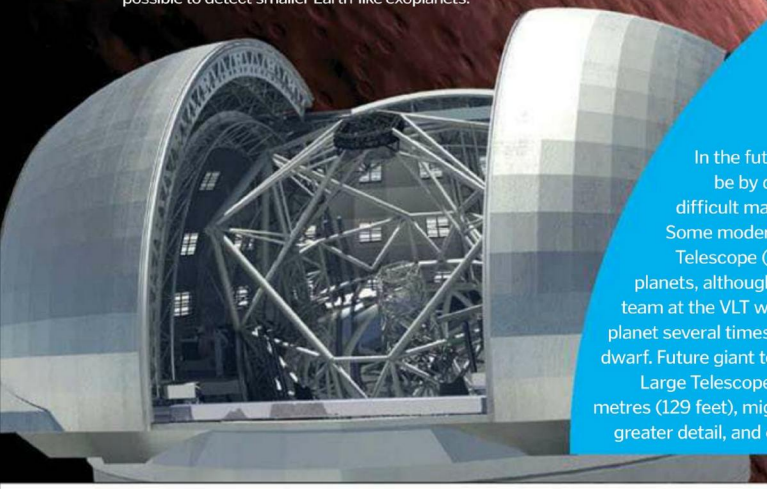
Earth
A telescope on Earth observes a star that is thought to host an exoplanet.

DISADVANTAGES

Of all the methods listed here, gravitational microlensing is probably the least useful. This is because the lensing of two particular stars can never be observed twice, as they will never align in the same way again, thus making confirmation an incredibly difficult process.

DISADVANTAGES

The problem with radial-velocity measurements is that they rely on the orbit of a potential exoplanet being directly in our line of sight. If the orbit is slightly tilted from the perceived horizontal plane, the star's 'wobble' will be exaggerated, and so the planet's mass will be overestimated. To counteract this, radial velocity is usually combined with astrometric observations, which track the motion of the star across the sky. Another flaw is that this method is only really useful for finding large planets orbiting close to a star, known as 'hot Jupiters'. However, by partnering this with the transit method, it is possible to detect smaller Earth-like exoplanets.



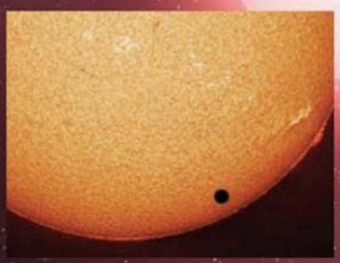
IN THE FUTURE...

Direct imaging

In the future, our best method of finding planets will be by directly imaging them. However, this is very difficult mainly as the planets themselves are so huge. Some modern telescopes, such as the ESO's Very Large Telescope (VLT), are able to produce images of distant planets, although only large 'hot Jupiters'. Indeed, in 2004 a team at the VLT was able to produce an image of 2M1207b, a planet several times larger than Jupiter in orbit around a brown dwarf. Future giant telescopes, such as the European Extremely Large Telescope (ELT), which has a mirror diameter of 39.3 metres (129 feet), might be able to observe distant exoplanets in greater detail, and even find some that are more akin to Earth.

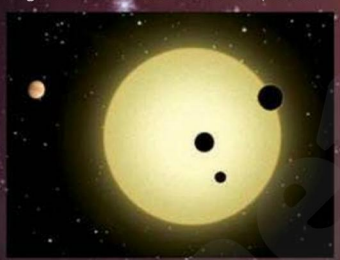
STAGES OF CONFIRMATION

How do scientists know they've found a planet?



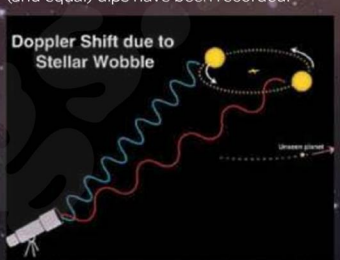
1. Transit method

First a telescope views thousands of stars and notes which ones experience a dip in brightness due to the transit of a planet.



2. Repeat transits

To be sure it's a planet, the star is observed for longer until three separate (and equal) dips have been recorded.



3. Doppler

The transit method alone can't determine a planet's mass. The radial-velocity method is employed to help work this out.

20LY

Gliese 581g
This terrestrial planet is the fourth of six in the Gliese 581 planetary system, and is believed to be the most Earth-like planet discovered so far.

25LY

Fomalhaut b
Found in the constellation of Piscis Austrinus, this unconfirmed planet has the longest-known orbital period, taking 876 Earth years to orbit its host star.

44LY

Upsilon Andromedae d
Found in 1999, this is part of the first multi-planetary system ever discovered outside the solar system.

THE TELESCOPES

Over the years many different telescopes have been hunting for planets. However, today there are three major ones used to pinpoint exoplanets. Others, like the VLT and the planned ELT have and will directly image stars rather than using one of the indirect methods discussed earlier...

is why it has become such an important area of astronomy despite the fact it's barely three decades old.

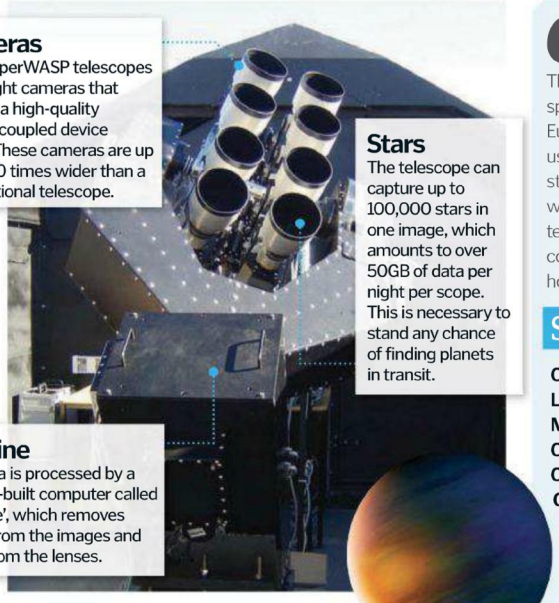
Hot Jupiters

The problem for a long time has been finding planets that are similar to Earth. At first, all we could find were large 'hot Jupiters', which are gas giant planets that orbit their star at a very close range in a very short period of time and thus are extremely hot. Our current methods of finding planets are limited and we have to rely on indirect methods – mainly observing the effect a planet has on a nearby star to detect an exoplanet. It was not until the arrival of NASA's Kepler telescope in 2009 that smaller planets were able to be spotted, as the use of the transit method proved largely successful. In the future, as bigger and better telescopes are built, it is likely we will be able to directly photograph exoplanets. This would be a massive leap for planet hunters, as a whole host of new data could be gleaned from planets, plus ever-smaller ones would be detectable.

Only in the past year have we truly started to make ground in finding Earth-sized planets. In fact, the first planet smaller than Earth was not discovered until 20 December 2011. This was Kepler-20e, a rocky planet with a radius 0.87 times that of Earth. Although it orbits too close to its host star to have liquid water on its surface, its discovery was one of the most important made thus far in the brief history of planet hunting. While we'd found gas giants and super-Earths – so-called giant terrestrial planets – we had yet to discover a planet similar in size to our own. Its discovery indicated that there could well be Earth-sized planets orbiting stars at a safe distance, much like Earth, and with

DID YOU KNOW?

EXOMOONS – We know that exoplanets exist, but what about other celestial bodies? As well as planets, scientists have been searching for smaller celestial bodies such as moons orbiting extrasolar planets, which are thought to be common through the universe. However, with current techniques their detection remains extremely tricky.



Cameras
Both SuperWASP telescopes have eight cameras that contain a high-quality charge-coupled device (CCD). These cameras are up to 2,000 times wider than a conventional telescope.

Stars
The telescope can capture up to 100,000 stars in one image, which amounts to over 50GB of data per night per scope. This is necessary to stand any chance of finding planets in transit.

Pipeline
The data is processed by a custom-built computer called 'Pipeline', which removes errors from the images and noise from the lenses.

SuperWASP

SuperWASP is the UK's main planet-hunting programme and is run by eight universities and institutions including Cambridge University. The programme consists of two near-identical telescopes. SuperWASP-North is located on La Palma, Canary Islands, and SuperWASP-South in Sutherland, South Africa. The telescopes found their first exoplanet on 26 September 2006, and since have found a further 66 exoplanets. The strength and size of the telescopes is such that they are unable to observe Earth-sized planets, but rather the gas giant types.

Stats

Organisation: Eight universities and institutions
Operational: 2004
Location: Canary Islands and South Africa
Weight: 400kg (882lb)
Camera: 200mm CCD (x8)
Aperture: 11cm (4.3in) (x8)
Operating temp: -50°C
Confirmed planets: 67

KEY PLANET

WASP-17b

One of the most interesting planets discovered by SuperWASP has been WASP-17b. This super-giant planet found in 2009 may be the largest in the universe (up to twice the size of Jupiter). It was also the first exoplanet discovered to have retrograde motion, which means that it orbits backwards relative to the spin of its host star.

COROT

The COROT (COnvection, ROtation and planetary Transits) space mission is run by French space agency CNES, the European Space Agency (ESA) and other global institutions. It is used to search for exoplanets and measure asteroseismology in stars and is in orbit around Earth. Unlike NASA's Kepler mission, which releases constant lists of candidate planets, the COROT team only announces the discovery of a planet once it has confirmed it is an exoplanet. It found its first two in 2007 – both hot Jupiter-like planets and has also located some super-Earths.

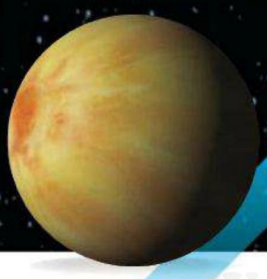
Stats

Organisation: CNES/ESA
Launch: 27 December 2006
Mass: 630kg (1,390lb)
Orbit: Polar, Earth orbit
Orbital period: 103mins
Operating temp: -50°C
Confirmed planets: 23
Diameter: 27cm (11in)
Collecting area: 0.1m² (1.1ft²)

KEY PLANET

COROT-7b

This planet, located 489 light years from Earth in the Monoceros constellation, was first reported by COROT in February 2009. At the time it was the smallest-known exoplanet, just 1.58 times the size of Earth. It was the first potential rocky terrestrial planet to be found, unlike the gas giants that had previously been discovered.



46LY — 47 Ursae Majoris b
This hot gas giant that's two and a half times the size of Jupiter is the innermost of three planets in a planetary system in the Ursa Major constellation.

50LY — 51 Pegasi b
This boiling hot, Jupiter-like planet was the first to be discovered in orbit around a Sun-like star. It orbits its star in roughly four Earth days.

126LY — KOI-961
This is the smallest-known exoplanet in the galaxy, at just half the radius of Earth. It is in orbit around a red dwarf star which is located in the Cygnus constellation.

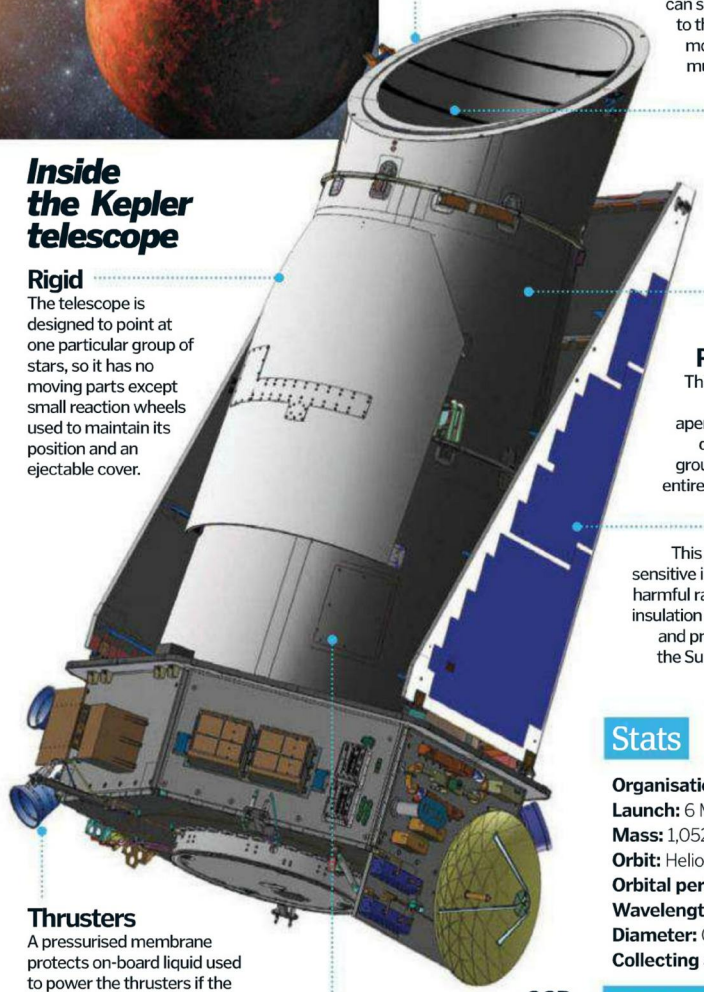
Transits

The data gleaned from the CCDs is analysed, and it can detect the transit of a planet across a Sun-like star in six and a half hours.

Stars

Data from each individual pixel that makes up part of the 100,000 stars Kepler can see is transmitted to the ground once a month, allowing for multiple stars to be studied at once.

Inside the Kepler telescope



Rigid

The telescope is designed to point at one particular group of stars, so it has no moving parts except small reaction wheels used to maintain its position and an ejectable cover.

Photometer

This instrument has a 0.95m (3.12ft) aperture and records data from a single group of stars for the entirety of the mission.

Sunshade

This protects Kepler's sensitive instruments from harmful radiation, provides insulation for the telescope and prevents light from the Sun interfering with its observations.

Thrusters

A pressurised membrane protects on-board liquid used to power the thrusters if the telescope's orientation needs to be slightly adjusted.

CCD

The photometer is composed of 42 charge-coupled devices (CCDs). Each is 2,200 x 1,024 pixels and returns observational data every six seconds.

Kepler

Kepler is without a doubt the most successful planet-hunting telescope to date, and has been responsible for finding thousands of potential exoplanets. It was launched on 6 March 2009, and since then its planet candidate count stands at over 2,000; however, as of March 2012, it had only confirmed just over 60 planets. To find exoplanets the Kepler telescope employs the transit method, as discussed previously. The ultimate goal of the Kepler mission is to determine an approximate ratio of planets to stars, specifically those within habitable zones. Its observational mission is due to end later in 2012, although the multitude of data it has returned is nowhere near being fully analysed.

Stats

Organisation: NASA
Launch: 6 March 2009
Mass: 1,052kg (2,230lb)
Orbit: Heliocentric
Orbital period: 372.5 days
Wavelength: 400-865nm
Diameter: 0.95m (3.1ft)
Collecting area: 0.7m² (7.5ft²)

KEY PLANET

Kepler-20e

This was the first exoplanet smaller than Earth to be found, with a radius approximately 0.87 times that of our own world. Is has a mass almost equivalent to that of Earth, but it orbits its host star at a distance just 0.05 that compared to the Earth-Sun system, completing its orbit, and thus a year, in just six days. For this reason it is scorchingly hot – about 1,040K (767°C/1,410°F), and not capable of sustaining water or life as we know it.

Interview Steve Howell

We speak to the deputy project scientist on NASA's Kepler Science team about the powerful telescope

How It Works: What makes Kepler unique?
Steve Howell: Kepler is the only current mission capable of finding Earth-size planets, especially those in the habitable zone of their stars. This means it can find true Earth-like planets that may be able to support life as we know it.

HIW: What technique does Kepler use to find planets?
SH: Kepler uses a technique called transit detection. We observe 150,000 stars continuously and search the signals we receive. We look for very small drops in light, which indicate that a planet has transited, or crossed, in front of its host star as it orbits around the star.

HIW: Where is Kepler looking?
SH: Kepler is looking near the plane of the Milky Way galaxy, a location in the sky that contains many stars. The exact central location is between the constellations of Cygnus and Lyra and we examine a field of view of over 100 square degrees on the sky.

HIW: What are the key technologies in the telescope?
SH: The telescope has a very simple design – a Schmidt telescope, and only one instrument: a large digital camera. The telescope has lightweight mirrors and the camera has specially built charge-coupled devices (CCDs), the digital detectors we all use in our phone cameras. Kepler's are far [more advanced though], being larger and more sensitive.

HIW: What are some of the most fascinating planets Kepler has found so far?
SH: Wow, this is a tough one. Kepler has found small planets, the size of Earth and even smaller. These planets are rocky – that is, they have a solid surface like the Earth. So far, we have only found these types of planets orbiting too close to their sun so their surface temperature is far too hot for life as we know it. Kepler has found planets larger than Jupiter too; scientists didn't know this [was possible]. Kepler has also discovered solar systems, stars with many planets orbiting them; the record so far is six planets. Kepler has found planets orbiting binary stars too, which remind us of *Star Wars* when Luke [is watching] the double sunset.

HIW: What kind of ET life can we expect to find?
SH: So far, probably none. We have found small, rocky planets but these are too hot. We have found planets within the right temperature range, but they are too large to support life, either by having a crushing gravity at their surface or being gaseous with no solid surface. Some may have large moons which could harbour life though. We simply do not know at present, but stay tuned...

HIW: What can we expect from Kepler in the coming few years?
SH: Well, at present we have discovered over 2,300 exoplanets, with over 400 near the size of the Earth. In the next year or two it is anticipated that we will find a number of Earth-analogues – that is, small planets with rocky surfaces, able to host liquid water on their surface, and orbiting their stars at the right distance to allow their surface temperature to be just right for our kind of life.

380LY

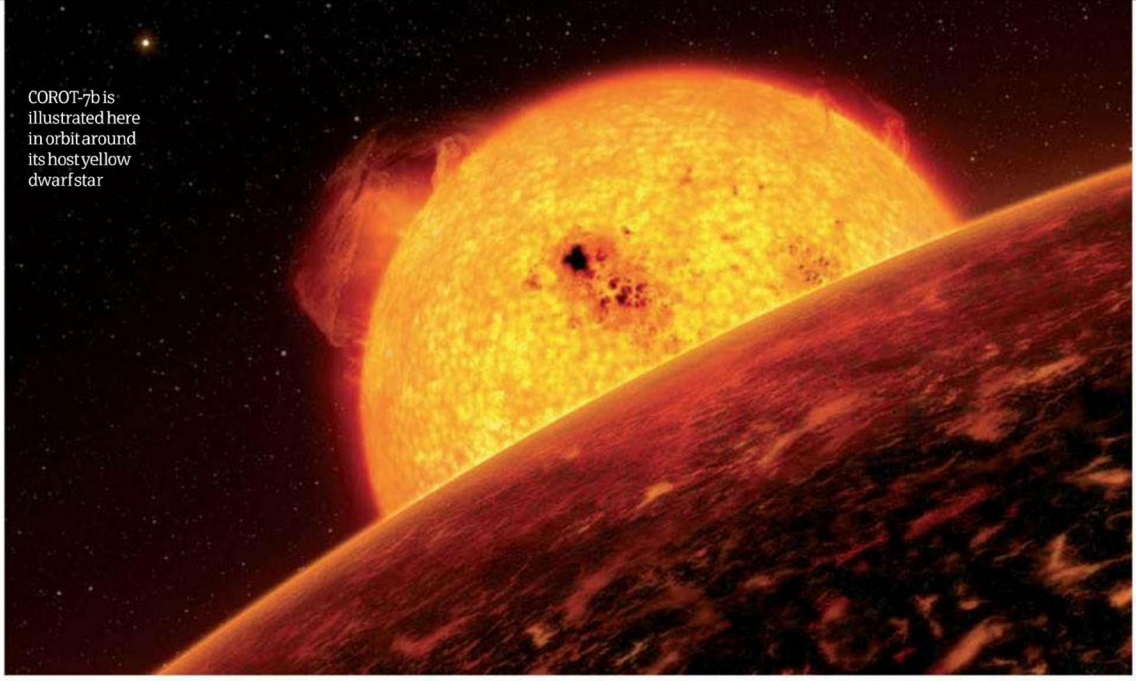
WASP-33b

This planet, which is 1.4 times the size of Jupiter and up to four and a half times its mass, is the hottest exoplanet yet found in the galaxy at a scorching 3,200°C (5,792°F).

600LY

Kepler-22b

Found by the NASA telescope of the same name, this planet was the first transiting exoplanet to be found in the habitable zone of a Sun-like star at the end of 2011.



COROT-7b is illustrated here in orbit around its host yellow dwarf star

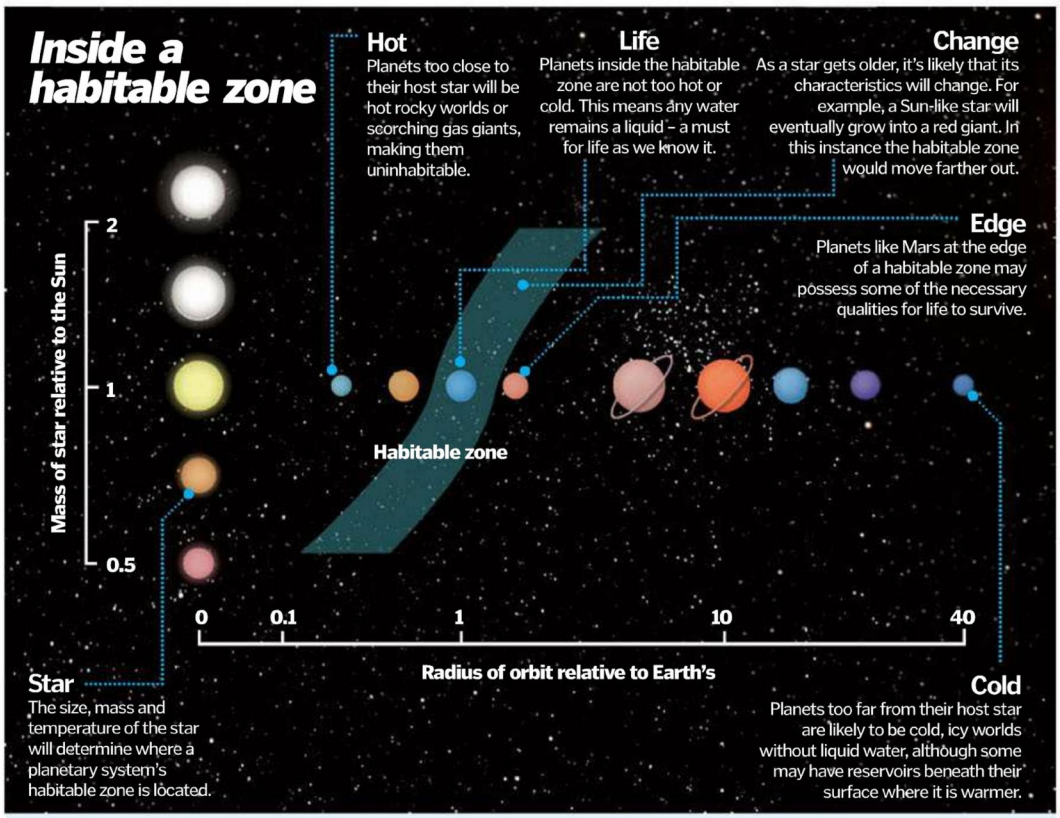
billions, or even trillions, of planets in the Milky Way alone, it's not unlikely that we'll find such a planet in the near future.

New worlds

Along with the discovery of familiar planets to those in our own solar system have been bizarre new worlds that have changed our understanding of planetary science. Of particular interest are super-Earths – exoplanets with a mass greater than Earth's but a composition that appears rocky. It was previously thought the larger a planet is the more likely it is to be a gas giant, but now it is generally agreed that a rocky terrestrial planet can be up to ten times the mass of Earth. What actual conditions on these super-Earths might be like, though, are still – for the most part – up for debate.

The first super-Earths to be discovered in a habitable zone were two planets in orbit around the star Gliese 581. The significance of being within the habitable zone is that this is the distance from the host star at which it is calculated that a planet can support liquid water, one of the known components needed for life to start or flourish. Designated 'c' and 'd', the former planet has a mass of about five Earths and the latter 7.7. While Gliese 581 c is probably too hot to support ET life, d sits squarely in its host star's habitable zone. However, due to its mass it is estimated to have a very strong gravitational pull, and its orbit of just 0.22 AU from its host star shows that even a planet within a habitable zone may not have all the prerequisites for life.

Apart from super-Earths there are countless other types of exoplanet that we are only just now beginning to understand. PSR J1719-1438 b, for instance, is a pulsar planet that appears to be so dense that it is thought to be made of diamond. Other planets orbit their star at such a close distance, or at such a high speed, that the surface conditions might be unlike anything we could imagine. As we discover more and more planets similar in size and composition to our own, the prospect of finding one that ticks all the boxes for being habitable grows increasingly likely. As it is such a new area of astronomy, the next few years will be a period of great anticipation for planet hunting. We won't be visiting one of our neighbours for the foreseeable future, but we can do our best to determine if other planets possess the ability to support life, or maybe even find evidence of life by finding artificial signals emitted like those from Earth, or breathable atmospheres that indicate the presence of life forms. With each new planet that is confirmed we take one step closer to determining if we are indeed alone in the universe, or one of many.



Habitable zones

For a planet to have the potential to support life, it must lie within a region known as the habitable, or 'Goldilocks', zone, around its host star. If it's too close it will be scorchingly hot, but too far away and it won't receive enough light and heat to support life. In addition, planets beyond the habitable zone of a star tend to be gas giants, as during the formation of a planetary system the colder, gaseous planets can only form farther out, while the rocky terrestrial planets form closer to the star. Our solar system is a prime example; beyond Mars, which is said to be at the edge of our habitable zone, you've got Jupiter, Saturn, Uranus and Neptune – all gas giants. However, between Mars and the Sun are Earth, Venus and Mercury. All are rocky terrestrial planets, although only one – Earth – is at the necessary distance for water, and so life, to exist.

The key to finding a liveable exoplanet is to find one located in the habitable zone of its host star. Due to the primitive methods of finding planets currently at our disposal, the majority of planets found so far have been large, hot gas giants orbiting very close to their host star. It is only recently that we have begun to find exoplanets of a similar size to Earth, while water-bearing planets have been much scarcer. The farther a planet is from its host star, the harder it is to find. As mentioned earlier, it's hoped that, eventually, when we are able to directly image exoplanets, Earth-like ones will appear more regularly.

LIVING ON AN EXOPLANET

Trying to set foot on one of the scorching massive Jupiter-sized exoplanets we've found might not be the best idea... If you survived being squashed to a pulp in the dense atmosphere, you'd only boil alive once you reached the surface – that is, if there even is one. However, rocky terrestrial planets do potentially offer a place for our descendents to land, walk and even live. Could we one day proclaim 'one small step for man, one giant leap for mankind' on the surface of an exoplanet?

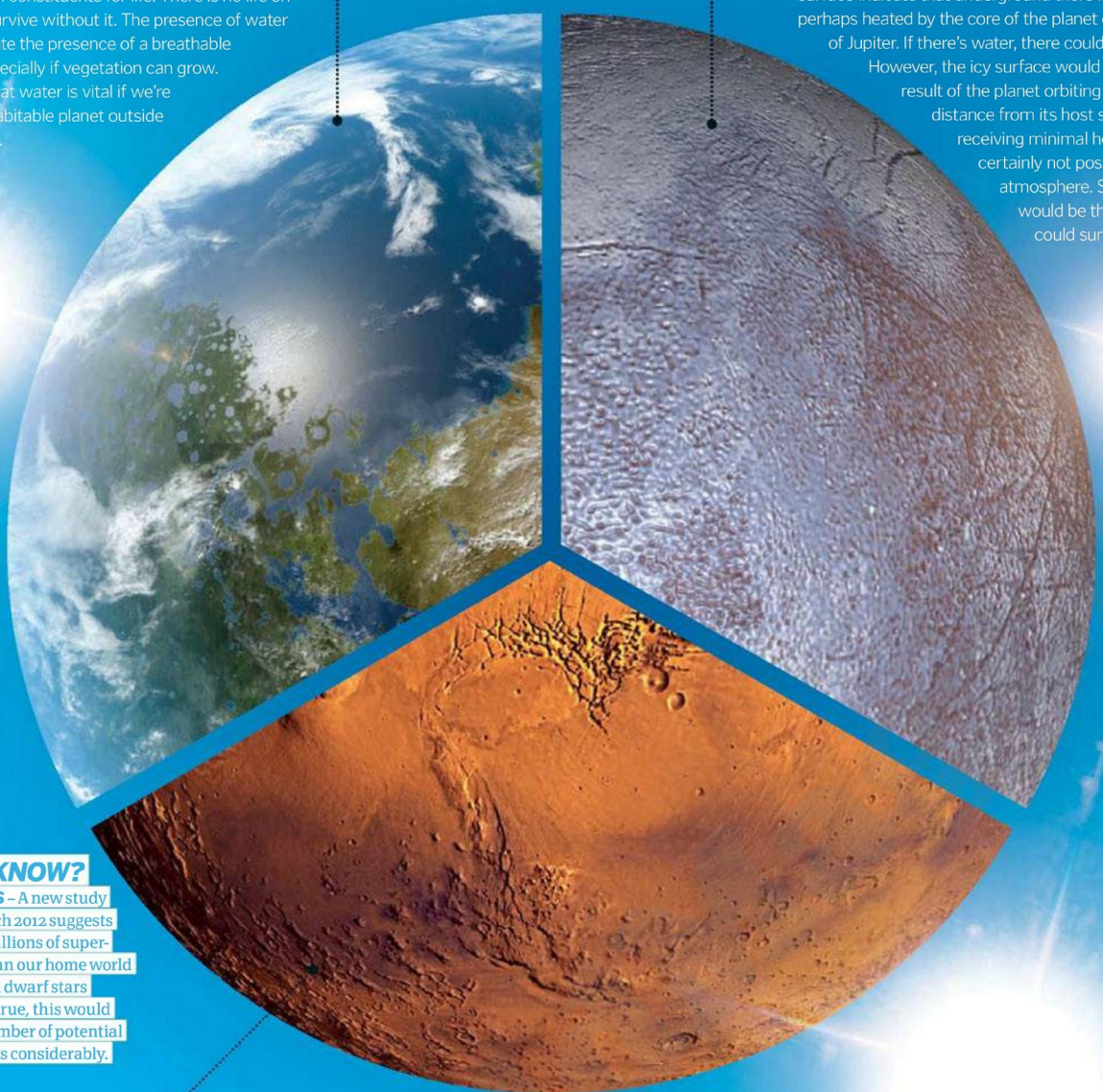
Water

The best bet for life flourishing on a planet is one that contains water, like Earth. This would indicate that the planet is not too hot or cold, as the water hasn't evaporated or frozen, respectively. In addition, water is one of the known constituents for life. There is no life on Earth that can survive without it. The presence of water might also indicate the presence of a breathable atmosphere, especially if vegetation can grow. It's safe to say that water is vital if we're going to find a habitable planet outside our solar system.

Ice

Could life reside beneath the surface of an icy world? It's definitely possible. The surface of Jupiter's moon Europa in our own solar system is known to be an icy, cold and inhospitable environment. However, cracks across its surface indicate that underground there is flowing water, perhaps heated by the core of the planet or the proximity of Jupiter. If there's water, there could be life.

However, the icy surface would likely be the result of the planet orbiting at a great distance from its host star, therefore receiving minimal heat and almost certainly not possessing a visible atmosphere. Subterranean life would be the only kind that could survive here.



DID YOU KNOW?

SUPER-EARTHS – A new study released in March 2012 suggests there could be billions of super-Earths larger than our home world circling faint red dwarf stars in our galaxy. If true, this would bump up the number of potential habitable planets considerably.

Rock

A planet might be rocky for two reasons. First, it could orbit too close to its host star and be too hot for any water (like Venus), thus making it impossible for life to form. More promisingly, it might be because the planet's atmosphere has slowly eroded, leaving any water on the surface to instantly boil. An absence of water should also indicate an absence of life, right? Well, not necessarily. Rocky terrestrial planets might be hiding secrets that we otherwise cannot see. Take Mars, for example; at its poles are vast swathes of ice, but elsewhere on its surface liquid water cannot flow as its atmosphere is too thin, instantly boiling any liquid water that makes it to the surface. But it's likely that, just like on an icy world, water (and maybe life) could be beneath the surface. The presence of a thin atmosphere on an exoplanet orbiting a star at a safe distance could point to the planet once being habitable, and thus signs of previous surface organisms or even current underground life could be present.

Distance

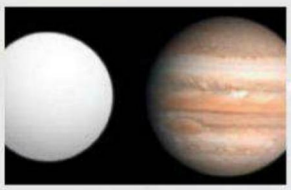
Generally the closer an exoplanet is to its host star, the rockier it will be, while farther-out examples tend to be gas based.

What's been found?

The large majority of exoplanets found to date are within just a few hundred light years of Earth. However, as we keep scouring the skies we are slowly finding new ones farther afield. Here, we've mapped some of the most notable planets across the Milky Way

MOA-2011-BLG-293L b

This planet, 2.4 times the size of Jupiter, is roughly 7,000 light years from Earth and orbits its host star at an Earth-like distance of 1 AU. Found in early-2012, it is one of the more recent distant planets to be discovered.



SWEEPS-04

This exoplanet is the most distant discovered to date. It is approximately 22,000 light years from us, and has a mass 3.8 times that of Jupiter despite being thought to only have 0.81 times its radius. It orbits very close to its host star, about 0.055 AU, taking just 4.2 days to complete an orbit. It was found using the transit method.

OUR SUN

KOI-428b

This hot Jupiter planet, in orbit around a red giant 8,800 light years away, was spotted using the transit method by Kepler. It is twice as big as Jupiter but up to 13 times its temperature, making it comparable in density to Neptune but hotter than Mercury. In fact, it orbits five times closer to its parent star than Mercury does to the Sun.

Kepler-22b

This exoplanet could be one of the most Earth-like discovered to date. Positioned 600 light years from our world, Kepler-22b is known to orbit comfortably within its host star's habitable zone.

KOI-961-02

This planet is part of a system of three orbiting the red dwarf star KOI-961, where KOI stands for Kepler Object of Interest. It is 0.78 times the size of Earth and 126 light years from the Sun. The planets were discovered by the Kepler telescope using the transit method. It was only the second system discovered to have planets which were less than Earth's radius. Its temperature is 728K (455°C/850°F) and it has the shortest orbital period we know of.

980LY

PSR B1257 +12 a

At just twice the mass of Earth's moon, this pulsar planet (pictured right) is the smallest-known exoplanet to date in our galaxy. It orbits its star at about 0.2 AU.

1,000LY

WASP-17b

This planet is about half the mass of Jupiter but is almost twice its size, making it both the largest planet found to date and the least dense.

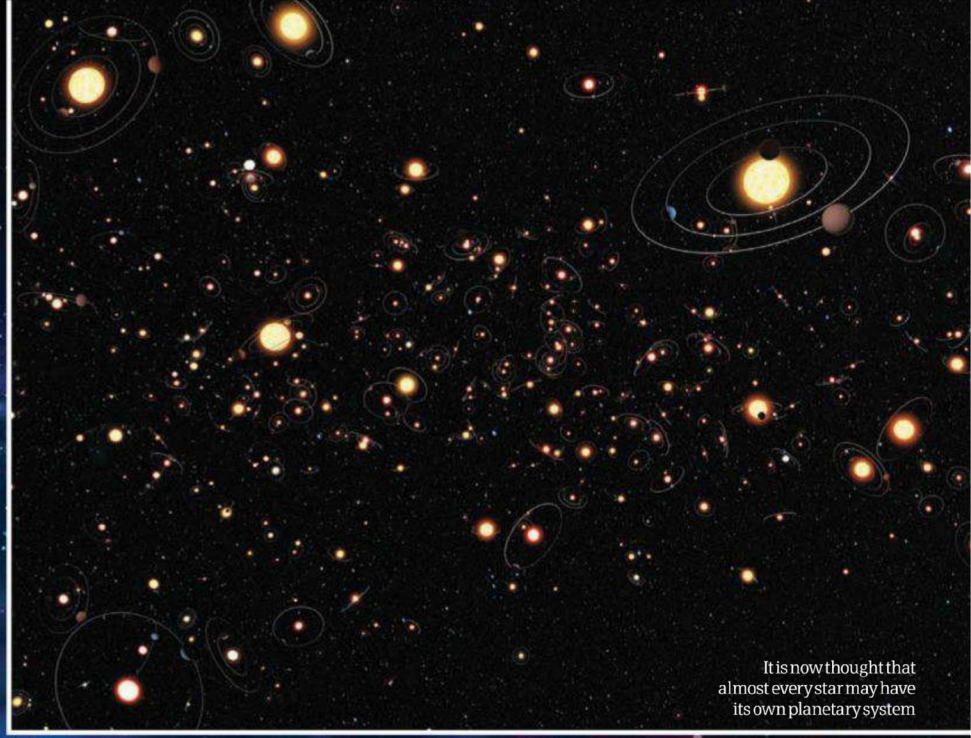
3,900LY

PSR J1719-1438 b

This pulsar planet, discovered around a millisecond pulsar (MSP) in late-2011, is the densest planet found to date and is thought to be possibly made of diamond.

OGLE-2005-BLG-0390Lb

This planet, in orbit around a red dwarf star, is the most distant planet found to date. It is a super-Earth located roughly 21,500 light years away near the centre of the Milky Way. It does not appear to have the capability to support life. It has a mass about five and a half times that of Earth. However, it is a super-chilly planet, with a temperature of only about 50K (-220°C/-370°F) and it takes ten Earth years to orbit its star.



It is now thought that almost every star may have its own planetary system

NGC 4349 No 127 b

This large gas giant 7,100 light years away, is up to 20 times the mass of Jupiter. For this reason it is possible that it could be a brown dwarf, but currently it is classed as a gas giant. Its orbit is quite elliptical, like Mercury in our solar system. It takes 678 days to orbit its star at a distance of 2.38 AU and was found using the radial-velocity technique.

"As the great Russian space scientist Konstantin Tsiolkovsky once said: 'The Earth is the cradle of mankind, but one cannot live in the cradle forever'"

Epsilon Eridani b

Discovered back in 2000 using the radial-velocity method, this gas giant with about 1.56 times the mass of Jupiter is the closest-known exoplanet to Earth. It orbits its host star at a distance of 3.4 AU in 2,500 Earth days.

HD 85512 b

This exoplanet in orbit around an orange dwarf called Gliese 370 is one of the most potentially habitable planets discovered to date. It is 36 light years from Earth, and has a mass about 3.6 times that of our home planet but, due to it being larger, has an estimated surface gravity of 1.4 g. Its predicted temperature is 24°C (75°F), though, which is well within the range for liquid water, and so life, to exist.

DID YOU KNOW?

RED DWARFS – 80 per cent of all stars in the universe are red dwarfs, so the discovery that they could host planets was very significant.

4,000LY

KOI-55 b

This terrestrial planet roughly four times the mass of Earth has the shortest-known orbit of its host star, completing a lap in just under six hours.

12,400LY

PSR B1620 -26 b

Also known as Methuselah or the Genesis planet, this exoplanet is estimated to be 12.7 billion years old, making it currently the oldest-known planet in the universe.

~21,500LY

OGLE-2005-BLG-390Lb

The most distant exoplanet discovered to date is this planet with a mouthful of a name. It is just over five times the mass of Earth but is quite far from its star so is believed to be very icy.

DAEDAL SPACEC

First designed back in the Seventies by the British Interplanetary Society, does this starship lay down the blueprint for interstellar travel?

How might we get there?

Simply put, our current methods of propulsion are nowhere near powerful enough to travel to an exoplanet on an unmanned mission, let alone a manned mission. But let's say that we did decide to up and leave our home world and travel to a nearby exoplanet – in this example the potentially habitable Gliese 581g which is 20 light years (or 188 trillion kilometres/117 trillion miles) away. We've taken a look at the various methods of propulsion available today to work out the journey time.

1 Engine
The two-stage engine would be powered by nuclear fusion, using deuterium and helium-3 pellets.

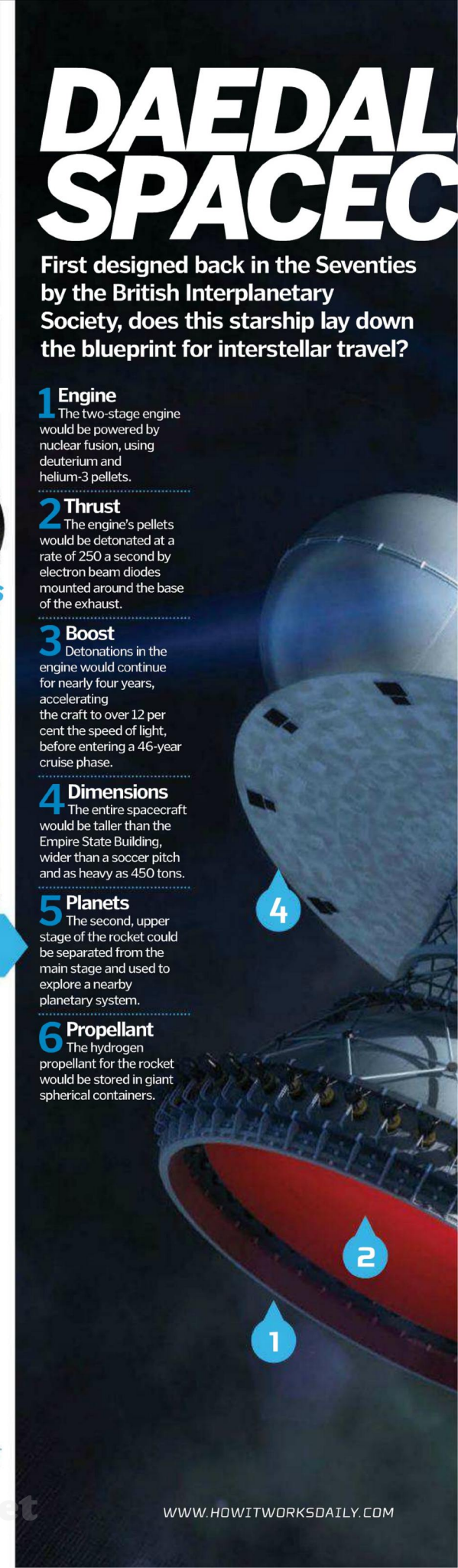
2 Thrust
The engine's pellets would be detonated at a rate of 250 a second by electron beam diodes mounted around the base of the exhaust.

3 Boost
Detonations in the engine would continue for nearly four years, accelerating the craft to over 12 per cent the speed of light, before entering a 46-year cruise phase.

4 Dimensions
The entire spacecraft would be taller than the Empire State Building, wider than a soccer pitch and as heavy as 450 tons.

5 Planets
The second, upper stage of the rocket could be separated from the main stage and used to explore a nearby planetary system.

6 Propellant
The hydrogen propellant for the rocket would be stored in giant spherical containers.



JOURNEY TO ANOTHER STAR

From 1973 to 1978, the British Interplanetary Society (BIS) conducted a study – Project Daedalus – into the plausibility of an unmanned interstellar spacecraft. It was the first study to propose such a mission, but ultimately proved that it could be done.

Project Daedalus was a direct response to a paradox proposed by physicist Enrico Fermi in the Forties. As we touched on earlier, Fermi suggested that interstellar travel was impossible, as statistically the universe should be teeming with intelligent life but no one had ever been in touch with us. This study was successful in disproving his theory.

The target selected for the theoretical spacecraft was Barnard's Star, a low-mass red dwarf six light years from Earth that could be the host of several terrestrial planets. The aim was to determine if a spacecraft with modern or upcoming technologies would be capable of reaching the star in 50 years, within a human lifetime. The result proved unequivocally that such a mission would be possible.

A whole host of factors were considered in the study including navigation, communications and overcoming interstellar dust. The rocket would have to be a two-stage, unmanned and autonomous vehicle powered by nuclear fusion. The nuclear-fusion drive would accelerate the rocket to 12 per cent the speed of light, but there would be no method to slow it down. Instead, after a journey time of 40 years, the probe would fly past Barnard's Star in just a few days. However, there would be considerable opportunity to also observe any surrounding planetary system.

Project Daedalus demonstrated that with modern or near-future technology, interstellar travel is feasible. The only obstacles are money and global stability. No one nation could undertake such an endeavour alone, and thus an international effort would be the only option – much like the case of building the ISS.

To date, Project Daedalus remains the most comprehensive and plausible engineering study ever conducted for an interstellar probe. Several other projects have aimed to build upon its findings and continue reaching for the stars. Project Icarus is a direct descendent, refining the technologies to make a more modern equivalent, while the 100 Year Starship study is examining the possibility of organising an interstellar mission by the 2100s.

US RAFT

DID YOU KNOW?

PLANET CONTENTION – Gliese 581g is a popular candidate for the name 'New Earth'. It is in the middle of the habitable zone of its host star and has a moderate temperature just below freezing. However, several survey teams insist the planet does not even exist and is merely an anomaly.

© Adrian Mann

Interview Nick Spall

HIW talks to a key member of the British Interplanetary Society who currently leads UK human spaceflight co-ordination efforts

How It Works: First of all, can you explain what the British Interplanetary Society (BIS) is all about?
Nick Spall: The BIS is the oldest space society in the world, being formed by space enthusiasts and rocket engineers back in 1933. Its membership has the common cause of promoting astronautics and space research internationally. It was the BIS which came up with a reasonably coherent lunar spaceship design in 1938 and, after WWII ended, unique work was undertaken covering moonbase concepts and orbiting space station design. The famous inventor of the communications satellite [and science-fiction writer], Arthur C Clarke, was an early member of the Society. Future interstellar flight is an inevitable component of this BIS work and the Project Daedalus of 1973-8 led the world in providing realistic starship technology proposals. This work was subsequently enhanced by the more recent Project Icarus study which was carried out in 2009.

HIW: Tell us more about Project Daedalus.
NS: Project Daedalus would use a massive pellet-driven nuclear pulse rocket engine to accelerate an unmanned probe to 12 per cent the speed of light to reach Barnard's Star in about 50 years. It would carry sub-probes and would be able to move on to other stars as part of an extended mission plan. With the emerging and exciting exoplanet research results providing new stars of interest, future targets for such a probe are multiplying all the time.

HIW: Do you feel that the current state of space exploration is hindering such a mission?
NS: Interstellar travel will be extremely expensive, so the first step is to reduce the cost of getting to Earth orbit – that is being achieved by cheaper capsule design right now.

Given time, once new propulsion techniques are developed, the cost of faster long-distance probes will come down to be more viable and, within this century, I see early unmanned probes going beyond the solar system.

In some ways, of course, this has already started with the Pioneer and Voyager deep-space probes of the Seventies, but it will be many thousands of years before they arrive near any star system.

HIW: If money wasn't an object, how soon do you think we could launch an interstellar mission?
NS: It would take at least 30-50 years to develop the starship design and build it. For the future, of course, whole communities may travel to stars on permanent missions. These would involve 'world ships', perhaps on converted asteroid bases, using solar sails etc, with closed-loop ecosystems to sustain crews for decades or even centuries.

HIW: Realistically, when do you think we'll send a manned spacecraft to another star or exoplanet?
NS: Assuming the Earth survives long enough – say, the next 100-150 years ahead – eventually humans will be living outside the confines of the planet, colonising the inner solar system, and eventually travel to the nearer stars will definitely occur, in a similar way to 16th-century navigators discovering the New World and going beyond. Interstellar travel is inevitable, given time. As the great Russian space scientist Konstantin Tsiolkovsky once said: "The Earth is the cradle of mankind, but one cannot live in the cradle forever."

Welcome to... TECHNOLOGY

Learn about some of the most cutting-edge gadgets from the sporting, military, domestic and entertainment fields. To kick off, explore the new iDevice that everyone's talking about...

LEARN MORE

THE NEW iPAD

Apple's third-generation tablet packs more punch than ever before

In the world of tablet computing there is one clear leader and that is Apple and the company's incredibly popular iPad. The new iPad, as it has come to be known, is the tech king's third iteration of the tablet computer and it has built on the considerable success of its predecessors with some extremely advanced technology.

For anyone who doesn't know, a tablet computer is one that can be held in the hands and manipulated with taps, swipes and other multitouch gestures made by the fingers. Apple's new iPad is no different, running on the company's proprietary operating system, iOS.

The biggest feature is a new screen which packs a whopping 2,048 x 1,536 resolution into a 24.6-centimetre (9.7-inch) screen. This amounts to 1 million more pixels than the average HD TV. Apple has had to do all kinds of technical wizardry to make this screen possible, including dealing with pixels in a totally new way.

Pixels are what make up the display. Each pixel consists of three colours, and the level of light in each colour makes up the finished colour that your eye sees. When all are lit fully you see white, for instance, and when none are lit you see black. There are four times as many pixels in the new iPad as there were in the previous one and to make sure that each one gets the correct signal to display the right colour at the right time they have had to lay them in a specific way on a different plane from the signal.

This is a breakthrough technology that no other display currently uses and you can really tell when you see the crispness of text and the richness of colours. The screen has been labelled a 'Retina' display because at the standard

KEY DATES
iOS HISTORY

1976
Steve Jobs and Steve Wozniak start Apple Computer, Inc, making PCs from a garage in California.

2008
Apple sets up the App Store through an update to its syncing software iTunes.

2010
The first iPad tablet computer is launched and sells 300,000 units on the first day alone.

2012
Apple announces that it has exceeded 25 billion apps downloaded from its App Store.

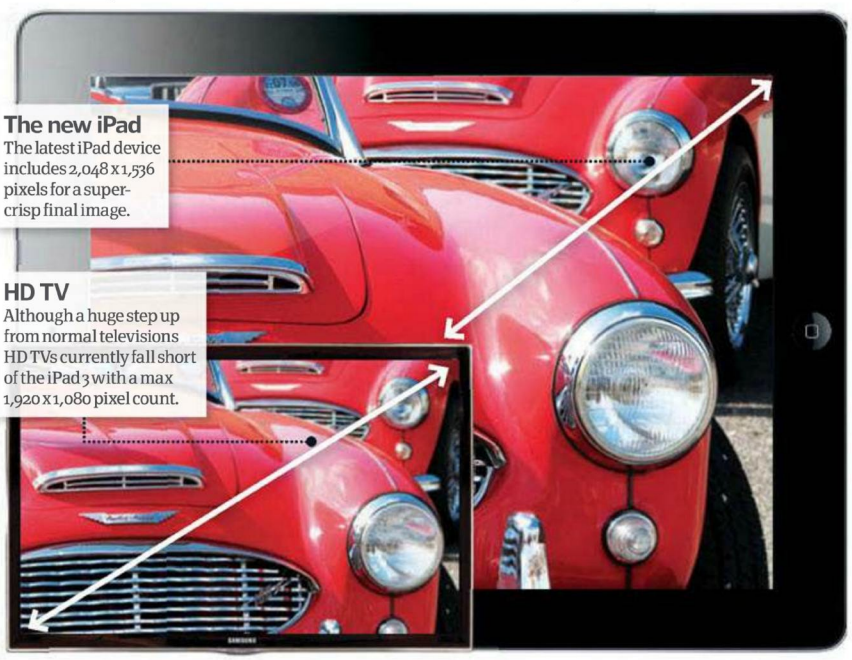
2012
Apple announces it has sold more than 3 million new iPads in the first weekend of sales.

DID YOU KNOW? *Apple's market cap ($547bn) is greater than the GDP of Belgium, Sweden, Saudi Arabia and Taiwan*

How a Retina display works

A closer look at the screen that packs a pixel punch

Apple's Retina display works by packing so many pixels close together that the human eye is unable to distinguish between them. There is a secondary variable in making this happen in as much as you have to observe a standard viewing distance, which in this case is 30 centimetres (12 inches) or so. Should you creep closer to the display you may begin to discern individual pixels. The resolution of the screen is 2,048 pixels along the longest edge and 1,536 across the shortest. This is far more than most HD TVs which average 1,920 x 1,080. The increase in pixels and their density together allows for much sharper images. The downside is that it is far more susceptible to flaws and requires much more power. Apple has attempted to counter these issues, however, as explained later in the feature.



The new iPad
The latest iPad device includes 2,048 x 1,536 pixels for a super-crisp final image.

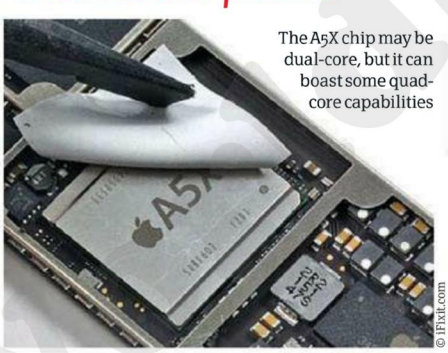
HD TV
Although a huge step up from normal televisions HD TVs currently fall short of the iPad 3 with a max 1,920 x 1,080 pixel count.

viewing distance of around 30 centimetres (12 inches) it is impossible for the eye to discern individual pixels. Everything looks smooth – as it does in print, which also has a very high resolution.

Other advances in the new iPad are a 70 per cent bigger battery, and by bigger we are talking capacity, not size (though the new iPad is marginally thicker than its predecessor). There is also a new camera which has some impressive lens technology coupled with a five-megapixel sensor. The same camera is capable of shooting 1080p video. In terms of pure computing power the new iPad uses a dual-core chip with integrated quad-core graphics, which has been dubbed an A5X chip. Apple builds its own custom silicon processors for handheld devices. This allows them to optimise the way the tablet works, controlling both the software and the hardware.

There is also an increase in the amount of RAM in the new iPad; it now packs 1GB and comes with three different storage options – 16GB, 32GB and 64GB – as well as coming in both Wi-Fi and 4G variations.

"At the standard viewing distance of around 30cm (12in) it's impossible for the human eye to discern individual pixels"

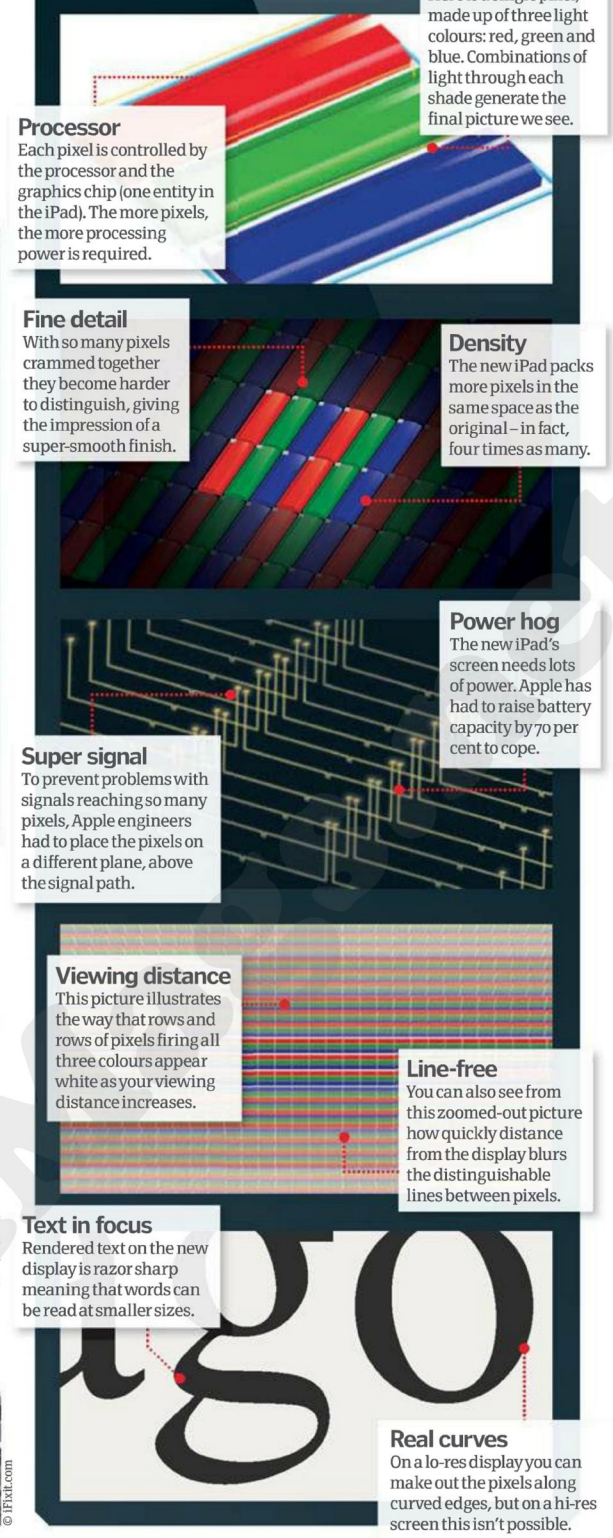


The A5X chip may be dual-core, but it can boast some quad-core capabilities

© iFixit.com

PIXEL BREAKDOWN

So how do pixels work on a microscopic scale?



RGB colours
Here is a single pixel, made up of three light colours: red, green and blue. Combinations of light through each shade generate the final picture we see.

Processor
Each pixel is controlled by the processor and the graphics chip (one entity in the iPad). The more pixels, the more processing power is required.

Fine detail
With so many pixels crammed together they become harder to distinguish, giving the impression of a super-smooth finish.

Density
The new iPad packs more pixels in the same space as the original – in fact, four times as many.

Power hog
The new iPad's screen needs lots of power. Apple has had to raise battery capacity by 70 per cent to cope.

Super signal
To prevent problems with signals reaching so many pixels, Apple engineers had to place the pixels on a different plane, above the signal path.

Viewing distance
This picture illustrates the way that rows and rows of pixels firing all three colours appear white as your viewing distance increases.

Line-free
You can also see from this zoomed-out picture how quickly distance from the display blurs the distinguishable lines between pixels.

Text in focus
Rendered text on the new display is razor sharp meaning that words can be read at smaller sizes.

Real curves
On a lo-res display you can make out the pixels along curved edges, but on a hi-res screen this isn't possible.

"The A5X chip is 36 per cent larger than the one in the previous iPad"

4G TECHNOLOGY

4G is the next generation of cellular mobile communications. It supersedes 3G offering speeds that could reach ten times that of current capabilities

The question that everyone wants to know is: just how fast is 4G? Well, standard 3G connections today offer around 7.2Mbps although in reality most of us won't experience much more than 1-2Mbps. True 4G technology could potentially increase these speeds significantly to beyond 100Mbps, but there are several competing technologies that offer varying pros and cons. Below we take a closer look at the main 4G contenders...

LONG-TERM EVOLUTION (LTE) 300MBPS

This is the most popular of the technologies currently planned for widespread rollout. It is behind most of the planned strategies in the US and the UK. Scientific theory suggests that there could be a top speed as high as 300Mbps for LTE, although the current speeds being achieved in the US – where some 4G LTE services have gone live – are around the 6-12Mbps mark. While not getting anywhere near the theoretical speeds it does offer a huge uplift in the real-world speed, especially when you consider that this is a mobile service.

WiMAX 128MBPS

This technology, while also offering a bumper speed of around 128Mbps, isn't particularly popular, with no UK operators as yet planning to use it and only one US carrier – Sprint – adopting it. Sprint has claimed that its real-world speeds will reach the 3-6Mbps mark.

HSPA+ 21MBPS

This technology can't offer as much speed as LTE but has become a popular alternative as the upgrade cost is far cheaper and the implementation is far simpler. HSPA+ has been in use in the US by operator T-Mobile which claims that real-world speeds are around the 1-7Mbps mark and that eventual top-end speeds could reach 21Mbps. In the UK, Three Mobile will be using this technology through a dongle called Huawei E367. Much like the advance to 3G, 4G rollout will be taking place over the next few years. America is already readying its networks with some live now. The UK, however, is behind the times waiting for the two bands of spectrum to be auctioned off by regulatory body Ofcom.

APPLE'S A5X CHIP

Apple develops its own processors for its mobile devices. This is because Apple can optimise the performance of the chip in order to suit the device in question.

The new iPad is a perfect example of this in action with a dual-core chip that has quad-core graphics. It's no coincidence that the quadrupling of graphical processing coincides with a custom-built quad-core graphics processor. It has been specifically designed to make sure the iPad screen is fed with data in a timely fashion. Each of the processing tasks for the graphics is now split into four parts meaning that four times as many tasks can be completed in a time that is snappy enough to deal with the games, pictures and apps that customers want to run.

The dual-core portion of the processor is reserved for purely computational tasks and having two cores means the workload is halved across two processors, making for a speedy experience. Interestingly the A5X chip is 36 per cent larger than the one included in the iPad 2.

Inside the new iPad

So what exactly makes up the world's most popular tablet?

Glue
The screen is glued to the rest of the device so removing it is a case of heating the glue up and then using suction to prise the two elements apart.

Toshiba NAND memory
The iPad ships with either 16GB, 32GB or 64GB of memory. It's incredible how such a large amount of storage can be packed into so small a space.

RAM
RAM is built onto the A5X chip and has been doubled from 512MB to 1GB. This provides the random access memory needed to run apps smoothly.

ON THE MAP

Who's using 4G to date?

1 Perth, Australia
2 Bangladesh
3 Belgium
4 Cameroon
5 Canada
6 Fiji
7 Ghana
8 Jamaica
9 Japan
10 South Korea
11 Nigeria
12 Norway
13 Panama
14 Peru
15 Russia
16 South Africa
17 Sweden
18 Taiwan
19 USA

WHO'S WHO?

SIR JONATHAN IVE

Apple senior VP of product design (born in 1967)

Ive is responsible for the design of all of Apple's recent products starting with the iMac in 1998. He went on to design such iconic products as the iPod, iPhone and all three iPad models.

"I discovered at an early age that all I've ever wanted to do is design"
Sir Jonathan Ive

DID YOU KNOW? *Apple sold out of pre-orders for the new iPad in less than a week*

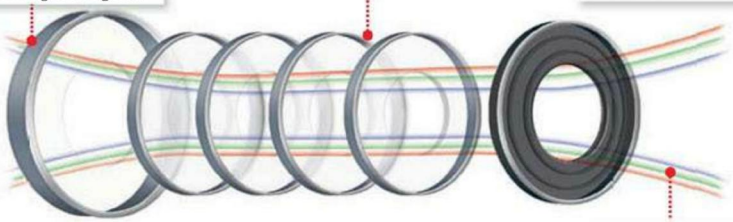
Front-facing camera
Apple labels the front-facing camera as a FaceTime camera as it is primarily used with its FaceTime video chat app.

Bespoke connectors
Apple designs everything inside the iPad with the same care as it does outside, so all connectors are tailored to save space.

microSIM
For those people who buy the 4G version of the iPad they will need a contract with a microSIM which is inserted here.

Radiant results
With the light filtered and the sensor working hard images look great.

Five filters
The light is filtered five times before it reaches the sensor.



More light
The more light that gets into a camera the clearer the pictures.

IMPROVED iSIGHT CAMERA

The camera in the new iPad has been upgraded to a five-megapixel sensor and, while this may not seem like a lot, Apple is keen to point out that lens tech is as important as megapixels. In the new iPad Apple has utilised the same five-element lens that currently resides in the iPhone 4S. This works by filtering light five times to ensure that the colours you see on screen are the same as those you see in real life. This is done by cutting out frequencies we can't see like infrared and ultraviolet.

Communication
This tiny chip located on the logic board handles most of the communications on the device. It's a Broadcom BCM4330 802.11a/b/g/n MAC/baseband/radio with integrated Bluetooth 4.0+HS and FM transceiver.

Dock connector
The iPad, iPhone and iPod all use Apple's proprietary 30-pin connection plug. You need a specific charger to recharge the iPad.

BETTER BATTERY

Apple has managed to up the capacity of the new iPad's battery by a whopping 70 per cent. The iPad battery is made of a 42.5-watt-hour rechargeable lithium-ion and delivers an impressive ten hours of web surfing, video watching or listening to music. Lithium is used as it is the lightest metal and its properties allow it to be recharged at any time. Additionally it doesn't suffer from crystal buildup, which can affect other forms of battery. As you can see from the teardown the battery occupies more space than anything else inside the tablet.

iPAD 2010

The original iPad set the tablet computing market ablaze when it was released with a form factor and feature set unrivalled at the time.

Display size: 24.6cm (9.7in)
Resolution: 1,024 x 768, 132ppi
OS: iOS 3.2
Processor: 1GHz Apple A4
Memory: 512MB
Battery: 25-watt-hour lithium-polymer battery
Camera: None
Connectivity: Wi-Fi, 3G, Bluetooth
In-built storage: 16GB, 32GB, 64GB
Pricing: £429 ($499)

Defining feature
The whole feature set was a revelation but the iPad's stunning battery life meant it was always on.

Worst feature
The lack of cameras was immediately noticeable and requested en masse.

iPAD 2 2011

The iPad 2 was a big leap forward, not only greatly slimming down the original but also hiking up power.

Display size: 24.6cm (9.7in)
Resolution: 1,024 x 768, 132ppi
OS: iOS 5.1
Processor: 1GHz dual-core Apple A5
Memory: 512MB
Battery: 25-watt-hour lithium-polymer battery
Camera: 0.7MP
Connectivity: Wi-Fi, 3G, Bluetooth
In-built storage: 16GB, 32GB, 64GB
Pricing: £329 ($399)

Defining feature
The star feature of the iPad 2, compared to its forerunner, was the enhanced, super-speedy processor.

Worst feature
Disappointingly, the cameras used on this model were woeful to say the least.

New iPAD 2012

A similar shape but with an improved screen, battery, processor and camera.

Display size: 24.6cm (9.7in)
Resolution: 2,048 x 1,536, 264ppi
OS: iOS 5.1
Processor: A5X dual-core processor with quad-core graphics
Memory: 1GB
Battery: 42.5-watt-hour lithium-polymer battery
Camera: 5MP
Connectivity: Wi-Fi, 3G, 4G LTE, Bluetooth 4
In-built storage: 16GB, 32GB, 64GB
Pricing: From £399 ($499)

Defining feature
Without a doubt the feature that makes this version stand out is the pixel-packed Retina display.

Worst feature
Although the rear camera is better, the front-facing camera is still pretty poor.

"The level of performance attainable by wearers can be increased significantly"

Advanced trainer tech explained

Each Gel-Nimbus 13 weighs just 326g (11.5oz), which is about a third of the weight of a typical bag of sugar

From smart materials to the integration of electronic monitoring systems, today's trainers offer both enhanced performance and minimal weight

Modern trainers, as exemplified here by the Asics Gel-Nimbus 13 and adidas Supernova Glide 4, are fast becoming platforms that demonstrate some of the most advanced manufacturing and engineering in the shoe industry. By introducing new materials, altering existing materials' properties and redesigning standard designs, the level of performance attainable by wearers can be increased significantly. So read on for a detailed breakdown of the technology that allows today's trainers to be comfortable, lightweight and packed with intelligent features.

Trainer teardown

We break down an Asics Gel-Nimbus 13 to see what makes it so well-suited to running

miCoach Speed Cell

The miCoach Speed Cell monitoring system allows users to track acceleration, distance and pace while exercising

The miCoach Speed Cell by adidas is a small electronic tag that can be equipped to a variety of compatible athletic shoes. The tag is slotted directly into the shoe's base and, once activated, automatically records the user's acceleration, pace and total distance covered. Most handily, however, the Speed Cell also automatically uploads collected data to a user's mobile phone, which can then be analysed in-app or via a personal computer.

The tracker works by partnering a CR2032 lithium battery with an integrated transmitter running off an ANT+TM protocol, ANT-FS (2.4GHz) band. This enables the Speed Cell to transmit data wirelessly to a receiver (such as a user's mobile) as well as maintain a high speed and distance accuracy of over 97 per cent regardless of whether the user is walking, jogging or running. Further, the battery is rated as capable of supplying power for up to five months, judging on a five times one-hour workout routine per week.

Dimensions
The Speed Cell measures 35x25x8mm (1.4x1x0.3in).

Memory
Seven to eight hours of recording capacity can be stored.

Weight
The tracker weighs 9g (0.3oz) when shoe mounted.

RECORD BREAKERS
MAKING ICE CREAM

10:34SEC

FASTEST TO MAKE ICE CREAM

The world record for making a litre of ice cream was set by Andrew Ross in Sheffield when he used liquid nitrogen to make the dessert in just 10.34 seconds on 6 June 2010.

DID YOU KNOW? Former PM Margaret Thatcher was one of a team of chemists credited for inventing the 'Whippy' ice cream

Electric ice-cream maker

Inside the machine that transforms a handful of ingredients into the much-loved frozen dessert

An ice-cream maker works by simultaneously freezing your ingredients while churning them together. The ice-cream mixture is placed in a double-walled bowl, which has a coolant sandwiched between its two layers. Some more snazzy devices let you remove and pre-chill this chamber before you start, while older versions use a combination of ice and rock salt, which melts the ice to lower its freezing point.

As the ice-cream ingredients (ie eggs, sugar, cream and flavouring) make contact with the frozen interior of the bowl, the mixture freezes. A set of paddles driven by a motor continually churns the contents to circulate the frozen particles within the mixture. This motion breaks down any ice crystals that form, while introducing air to encourage a creamy texture recognised as 'soft scoop' ice cream. If you hanker after a harder scoop, or you're blending a boozy dessert, you may need to refrigerate your ice cream in order to complete the freezing process.

Making ice cream step by step

1. Pre-chill
Chill the inner chamber or introduce a blend of ice and rock salt to establish a frosty environment.

2. Deep freeze
Add your ice-cream mixture to the bowl and the freezing temperatures start chilling it immediately.

3. Frost-free
Switch it on, and the motorised paddles mix the ice cream as it cools to avoid the formation of ice crystals.

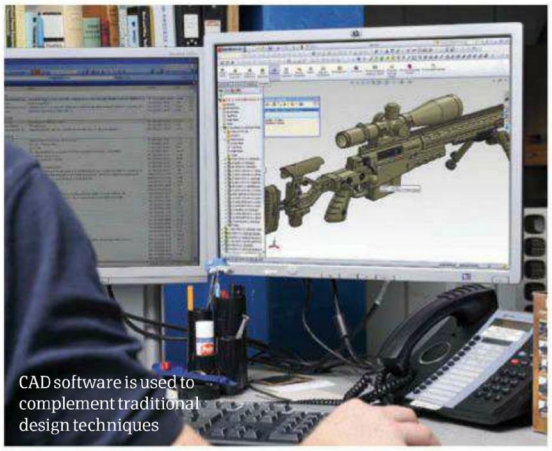
4. Cool to touch
As the mixture makes contact with the frosty walls, the liquid ice cream starts to freeze.

5. Keep it moving
The paddles keep the frozen particles circulating to guarantee an even freeze and soft scoop.

"CAD designs for components and entire weapons are fed into a rapid prototyping machine"

AX338 PSR sniper rifle

Accuracy International's AX338 PSR sniper rifle is, arguably, the best long-range rifle in the world. HIW went to AI's headquarters to see how it is designed and constructed



CAD software is used to complement traditional design techniques

Anatomy of an AX338 PSR

We look at the tech that makes this gun so state of the art

Modular bolt
A 22mm (0.9in)-diameter close-fitting steel bolt, bolt head, locking head and barrel tenon ensure enhanced durability and maximum temperature threshold.

Recoil pad
The 338's butt pad features a quick-adjust button, allowing users to rapidly customise its length.

Folding chassis
The rifle's stock can be folded for ease of transportation, reducing overall length by 235mm (9.3in).

Safety
In the three-stage safety mechanism, stage one blocks the firing pin and locks the bolt, stage two blocks the firing pin but allows bolt operation, while stage three allows the weapon to be fired.

Trigger assembly
A battle-proven two-stage mechanism is fitted as standard, sporting adjustable pull weights of 1.5-2kg (3.3-4.4lb).

Stock
A brand-new stock design grants the user enhanced freedom of movement.

Pistol grip
A streamlined grip delivers improved ergonomics over the traditional rifle thumbhole variant.

Magazine
The PSR uses compact, ten-round, military-grade steel magazines. These are surface toughened and finished with an anti-corrosive coating.

Accuracy International (AI) is unique in its approach to designing any rifle, blending traditional engineering skills and techniques with cutting-edge design and manufacturing technology.

The completion of any rifle at the AI production plant, including its latest AX338 PSR model – a long-range precision sniper rifle boasting a raft of next-generation features (see the 'Anatomy of an AX338 PSR' illustration) – begins, naturally, with user feedback and analysis of any required specification. These can sometimes differ, so finding the optimal balance between the two, as well as between those and the learned experience of the team's designers, is essential.

This process of manual design runs concurrently and in a loop with the weapon's computer-aided design, with first individual components and, eventually, the entire weapon and modifiers designed electronically. The CAD-focused software is an excellent – and relatively recent – addition to AI's production method, enabling the team's head designers to visualise new prototypes much quicker than previously possible.

Of course, a 3D computer model can only take you so far in the creation of any weapon, especially one as refined as a sniper rifle. This is where the first of AI's many advanced machines comes into play. CAD designs for components and entire weapons are then fed into a rapid prototyping machine (RPM), which decodes the CAD drawing and proceeds to lay down physical layers of liquid plastic in a series of cross-sections. These layers gradually build up and, when finished, create a physical version of the CAD schematic ready for handling in the real world. This is a particularly useful tool, as it enables Accuracy International's designers to quickly get their hands on a new item without the huge cost or time penalty of constructing it out of metal.

As soon as a design is finalised, it is parsed down into its requisite parts and tools (quality tools are vital for construction of precision weaponry, as parts need to be constructed identically each and every time) before being sent through for manufacturing at AI's dedicated construction centre. Taking the AX338 PSR as an example, this process involves the creation of core components such as the rifle's

5 TOP FACTS ACCURACY INTERNATIONAL

Gold
1 One of Accuracy International's founders was Malcolm Cooper, a British Olympic shooting champion who won gold in the 50m (164ft) rifle three positions event in 1984 and 1988.

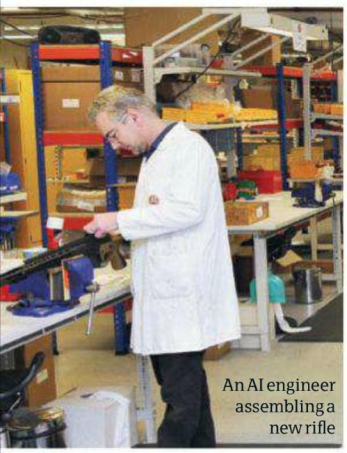
Designers
2 AI's key designers are Dave Walls and Dave Caig, who both helped found the company in 1978. Today, both are major contributors to each new rifle that is produced at AI.

Renaissance
3 The original company fell into liquidation in 2005, but was immediately bought back by a British consortium that included the original company's designers and now director, Tom Irwin.

.50 BMG
4 Accuracy International introduced its first .50-calibre, semi-automatic sniper rifle (the BMG) in 2005 at the NSSF SHOT Show in Las Vegas, USA.

AX
5 Currently, AI's most advanced rifle is the AX338 PSR, which is part of the AX series as introduced in 2010. The rifle is hand built in Portsmouth, UK.

DID YOU KNOW? *Accuracy International was founded in 1978*



An AI engineer assembling a new rifle

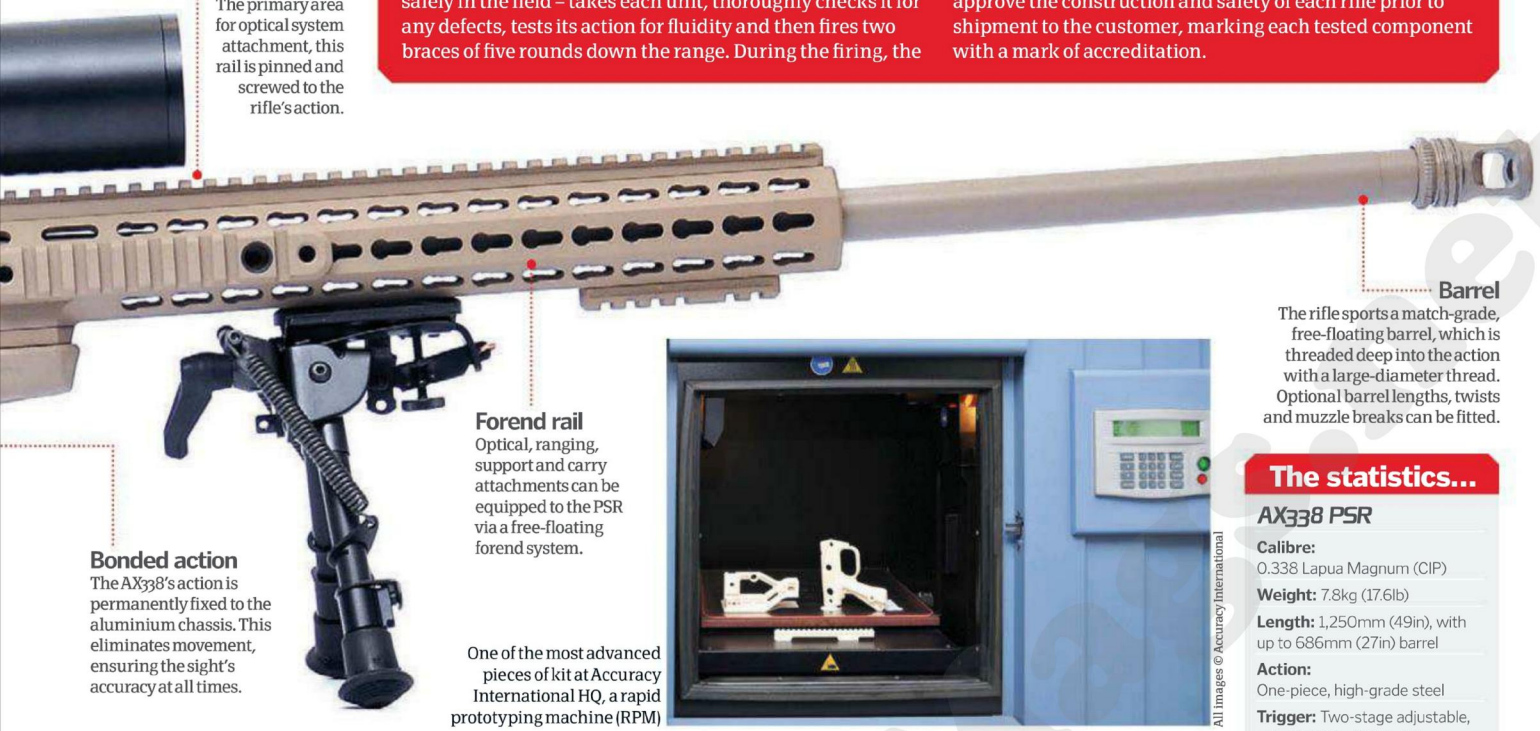
Testing times

AI rigorously tests all of its rifles, ensuring safety, reliability and its reputation as a world-class producer of cutting-edge weaponry

All the weapons produced are put to the test at a 100m (328ft) firing range

Upon build completion, each rifle produced by Accuracy International is put through its paces in a dedicated, secure testing facility. This includes a workshop, a 100-metre (328-foot) firing range and, most importantly, an ex-British military sniper. The sniper – who took up the role due to Accuracy International's commitment to improving the tools needed to operate effectively and safely in the field – takes each unit, thoroughly checks it for any defects, tests its action for fluidity and then fires two braces of five rounds down the range. During the firing, the sniper can measure the rifle's accuracy as well as other key actions such as cartridge ejection.

Once the sniper is content with the rifle's quality, it is passed through to the armoury. From the armoury, each deposited gun is then examined by an external official in AI's proof house. The proof house is another dedicated testing room where the governmental representative can approve the construction and safety of each rifle prior to shipment to the customer, marking each tested component with a mark of accreditation.



Picatinny rail
The primary area for optical system attachment, this rail is pinned and screwed to the rifle's action.

Barrel
The rifle sports a match-grade, free-floating barrel, which is threaded deep into the action with a large-diameter thread. Optional barrel lengths, twists and muzzle breaks can be fitted.

Forend rail
Optical, ranging, support and carry attachments can be equipped to the PSR via a free-floating forend system.

Bonded action
The AX338's action is permanently fixed to the aluminium chassis. This eliminates movement, ensuring the sight's accuracy at all times.

One of the most advanced pieces of kit at Accuracy International HQ, a rapid prototyping machine (RPM)

All images © Accuracy International

chassis, action, magazines, bolt and firing mechanism, as well as many smaller, though equally as vital, parts such as pins and rails. The elements are created in milling machines, hydraulic presses and spark erosion cutters, each bending, cutting or fining metal into the desired objects. Individual components are removed of rough edges and any debris collected during manufacture through rumblers – large vats filled with smooth stones that rotate and, once parts are dropped in, ensure a smooth and blemish-free finish. When free from imperfections, components are covered with an anti-corrosion coating for extra durability and longevity.

After all the rifle's elements have been created – which are done in batches and according to predicted resource demand to reduce cost – the assembly process can begin. Accuracy International has spent a good deal of time maximising the assembly flow of all its rifles, creating a U-shaped assembly line that reduces logistical gaps between the various stages. Importantly, at this point each weapon is partnered with its own identity tag and paperwork, the latter specifying its build stage, bespoke options – such as a folding stock – and final destination (which is most commonly a military contractor or private individual).

Finally, as each weapon is completed, it is sent through to AI's dedicated in-house testing facility and proof room (for more detailed information on this stage see the 'Maximum testing' boxout). Here, each rifle is tested for mechanical operation as well as component/full-weapon quality. Rifles that meet the exacting standards are officially stamped and then sent to the company's armoury for storage prior to shipment. The ability to have rifles proofed in-house is relatively unique within the industry, negating the need to transport the guns to London for approval and, as a result, reducing costs and improving security.

The statistics...

AX338 PSR

Calibre: 0.338 Lapua Magnum (CIP)

Weight: 7.8kg (17.6lb)

Length: 1,250mm (49in), with up to 686mm (27in) barrel

Action: One-piece, high-grade steel

Trigger: Two-stage adjustable, set at 1.5-2kg (3.3-4.4lb)

Safety lever: Three-position safety

Barrel: Stainless steel match grade, various lengths and twist rates

Chassis material: Aluminium

Chassis features: Adjustable cheekpiece, rear support leg, sling loops, movable forward accessory rails and sight rail extensions to MIL-STD 1913

Rear support leg: Height adjustable design with quick and fine adjustment

Carriage: Four sling attachment points; two adjustable forward mounts

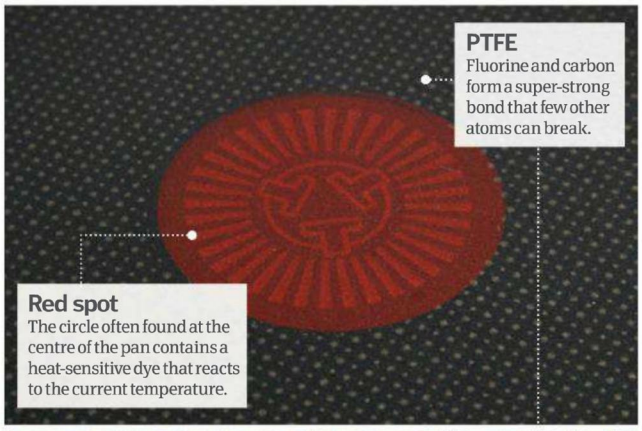
"The more hooks and loops that are attached per unit area [of Velcro], the stronger the bond"

Teflon explained

Find out why coating cookware in Teflon gives it an amazing non-stick finish

Teflon is made from polytetrafluoroethylene (PTFE) and is used to coat cooking pans giving them wonderful non-stick properties.

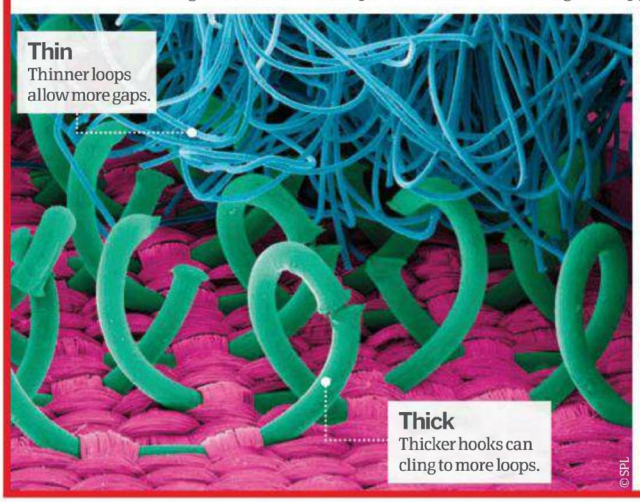
PTFE is composed of carbon and fluorine atoms which form very strong chemical bonds with each other. Fluorine also has the highest electronegativity of any element, meaning the overall electrical forces, known as van der Waals forces, cause compounds containing fluorine to repel any other atoms that come near. The fluorocarbon molecule is structured in a way that the fluorine surrounds the carbon so no other outside atoms can get anywhere near the carbon. As a result Teflon is highly unreactive causing it to have a very low coefficient of friction allowing things to slide across its surface very easily. Due to PTFE's reluctance to react with anything, it is also used to coat containers of highly reactive chemicals and, interestingly, is the only known material that a gecko can't stick to.

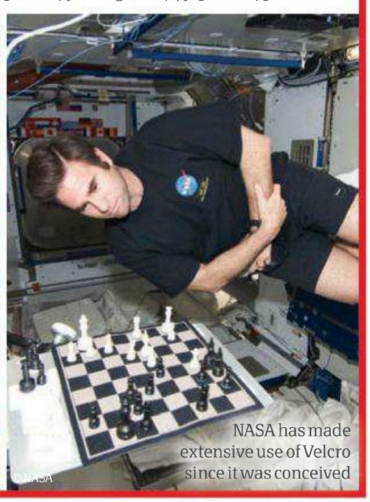


What makes Velcro stick?

Discover the small-scale engineering behind this fastener

Velcro comprises two strips of material – one with lots of tiny hooks, and one with lots of thinner loops – that lock when they are pressed together. This mechanism of sticking was inspired by the way tiny hooks on the seeds of burdock, known as burrs, attach to animal fur and human clothing. The hooks and loops in Velcro are commonly made from nylon and polyester with the hooks being more rigid and thicker than the loops. The more hooks and loops that are attached per unit area, the stronger the bond; heavy-duty Velcro contains up to 400 hooks and loops per square inch. In some cases a five-centimetre (two-inch) square piece of Velcro is enough to support a 79-kilogram (175-pound) person.




NASA has made extensive use of Velcro since it was conceived

CAPTCHA technology: human vs computer

We investigate the digital test with designs on distinguishing Joe Bloggs from joke blogs

CAPTCHA technology, or Completely Automated Public Turing test to tell Computers and Humans Apart, is waging war on spam bots blagging their way into our inboxes. But how can these randomly generated, cryptic codes hope to get the better of this sinister cyber-culture?

CAPTCHAs rely on the fact that computers struggle to decode human languages as they are too irregular. So couple an unusual word, image or number puzzle with some design morphery and, in theory, the bots should be flummoxed. But for every randomly generated test follows code designed to crack it. The recent digitisation of literature, from ancient scriptures to back copies of your local newspaper, using optical character recognition (OCR), unwittingly created a computer-proof directory of words already being put to use. Google's reCAPTCHA project works with OCR castoffs to pair up these digitally distorted dregs, then further warp them, to guarantee the confusion of those unsavoury programs intent on infiltrating private online space.

Distortion
CAPTCHAs often take normal words and morph them into unfamiliar shapes. Both visual and audio tests are used.

How It Works

Patterns
The human mind can pick out patterns a lot more easily than a computer can.

Get all the internet you'll ever need.
On any phone.
On any plan.
From £18 a month.
Goodbye data limits.
Hello Three.

From the UK's fastest growing mobile network.

Three.co.uk

24 month contract applies. Tethering your phone to another device to connect to the internet is not included, see www.three.co.uk for tethering options. Ofcom Communications Market Report.

"Gaming PCs work by increasing the bandwidth, stability and cooling properties of the core components"

What's inside a gaming PC?

Making a console-crushing gaming PC that delivers insane visual fidelity is easier than ever. Read about how they work, then learn how to put one together yourself...

Today, the gaming industry is dominated by consoles – such as the Xbox 360 and PlayStation 3 – with large install bases worldwide. However, these machines, arguably, do not deliver users with the best gaming fidelity possible at any one time, with large seven-year-plus hardware cycles leaving games developers to constantly pare back titles in order for them to run on old hardware. Essentially, the hardware is closed and restricted, only changing when a new version of the system is released.

Gaming PCs are different. Aside from being an open platform in which users can continuously upgrade individual components to ensure maximum visual fidelity and gaming performance, they arguably offer one of the best ways to play games of any platform in the world. Almost all the games a user can play on consoles are available on PC and, due to their vastly superior hardware and control methods, they can be experienced in high-definition and with optimised input (see 'Maximum control' boxout).

Gaming PCs work, put simply, by increasing the bandwidth, stability and cooling properties of the system's core components, such as the CPU, GPU, RAM and motherboard. Enlarged bandwidth is necessary so that gaming data can be relayed between components as quickly as possible, increasing the title's frame rate and therefore responsiveness. Increased speed of data transfer often requires more electrical energy and therefore heat, which, if not properly dealt with, can cause a machine to overheat. Manufacturers of gaming PC components tackle this through modifying the system's heat sinks, fans and cooling loops. Enhancements include stock coolers replaced with integrated liquid-cooling loops, cases specifically designed to maximise out-of-system airflow and high-calibre heat-dissipating materials used throughout.

Typically, however, a key stumbling block to more users taking up gaming on the PC has been the machine's construction, with prebuilt models costing a premium and the skills and tools needed to build one yourself difficult to attain for the uninitiated. That has changed massively over the last decade though, with manufacturers redesigning components, cases and wiring layouts to simplify any potential build. Indeed, far from a full day's labour with a comprehensive toolkit, a system can now be put together in a couple of hours (to learn how to build this computer see our DIY guide on page 94).

Of course, assembling a PC is only half the battle for any user, with selecting the best components being the first task. Here How It Works reveals the core equipment of any gaming PC build, some of the best tech currently on the market, along with some of the new, user-friendly features.

Processor

A PC's CPU is its computational heart. Intel's Z77 platform has been designed to take advantage of existing Sandy Bridge Intel processors, which have been the standout chips of recent years. For this build we used an Intel i5-2500k, which as well as boasting good overclocking capabilities, is pretty decent value. We also applied an integrated liquid cooling loop to ensure everything stays at an optimal temperature.

Motherboard

The spine of the gaming PC, a good motherboard is essential, as you need a piece of hardware that can handle the speed and power of the system's CPU, GPU and RAM effectively. Intel's new Z77 platform offers this, especially so when built upon by MSI, which with its Z77A-GD55 motherboard has gone to extra lengths to improve cooling and stability capabilities across the board. It comes with a boatload of ports, heat sinks and software features.

Graphics card

Modern motherboards come with an integrated graphics chipset, which is good for video playback and other low-key functions, however in order to play titles such as *Mass Effect 3* and *Crysis 2* on full settings, a dedicated card should be acquired. AMD's 7000 series of cards has just been released and here we used a R7950 Twin Frozr 3GD5 GPU, which besides being ridiculously fast, has been designed with a unique fan architecture to remain super-cool and quiet when in use.

Both the K90 and M60 boast an aluminium chassis

5 TOP FACTS
PC GAMING

Indie
1 PC gaming can boast the most vibrant 'indie' games development community of any platform, with a host of innovative titles released each month through digital download services such as Steam.

Winning
2 One of the most popular and lucrative games in the world is the PC's *StarCraft II*. Here, teams of gamers compete in international tournaments for figures upwards of $100,000.

Cheap
3 Gaming on PC has one of the lowest entry points of any platform, with even low-end desktops, laptops and netbooks capable of playing many console titles.

Evolution
4 Unlike consoles, gaming PCs can be continuously upgraded by swapping out components. This allows them to evolve over many years and keep pace with the latest gaming titles.

Output
5 Modern gaming PCs sport graphics cards capable of outputting over HDMi, allowing users to hook their machines up to large TV screens, rather than just a desktop monitor.

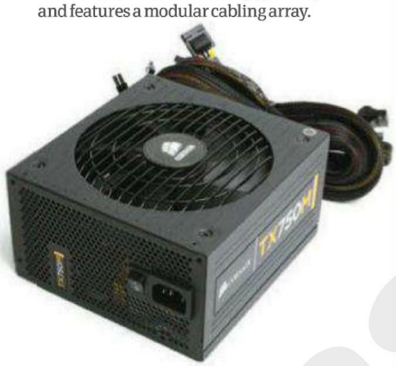
DID YOU KNOW? *More modern PC gaming cases position the PSU bay at the bottom of the case to improve airflow*

Anatomy of a gaming PC

The key components of a games machine explained

Random access memory
RAM may look like an insignificant part of the machine, consisting of just a couple of small rectangular sticks, but in fact it is a central part of any machine. In gaming PCs its role is even more important, receiving and temporarily storing data for the system's CPU to process – obviously, if a user's system's RAM isn't fast enough, or there isn't enough of it, then a user will experience stuttering and slowdown when playing. 6GB of RAM should be opted for ideally in any build, as demonstrated here in our choice of 8GB of Corsair's Vengeance LP memory.

Power supply unit
All these components require a fair amount of electrical energy, which needs to be supplied by a PSU. It is critical that any gaming PC carries a PSU capable of stably outputting enough juice to power all of the machine's components – especially so if a user overclocks their system – as otherwise it will suffer instability issues. We used a Corsair TX750M, as each unit is tested and qualified at 50°C (122°F) in an oven at 100 per cent load; it delivers a healthy 750W of power and features a modular cabling array.



Hard drive
Traditional disk-based hard drives are common in gaming PCs and any 5,400 or 7,200 RPM hard drive is just fine for installing and playing games. However, there have been great advances in recent years in solid-state hard drives, which aside from being almost silent (no fan) offer an order of magnitude more speed than their disk-based compatriots. We used a Corsair 128GB Force GT solid-state hard drive in this build, which offers a good gigabyte-to-cost ratio.

Learn how to assemble this computer on page 94!

Maximum control

A powerful gaming PC is nothing without the means to control it

While a gamepad is fine on consoles, to maximise the fluidity of control on a PC a good keyboard and mouse are crucial. Luckily, dedicated gaming peripherals are now manufactured by many companies, offering better speed, accuracy and durability.

Corsair's Vengeance series of peripherals epitomises these, offering unique features and top-end build quality. For example, the K90 gaming keyboard comes with Cherry MX Red mechanical keyswitches for speed and accuracy, 100 per cent anti-ghosting and a 20-key rollover on USB. These features are vital when gaming as every second can make a difference.

Equally impressive is the M60 gaming mouse, which comes with an integrated 5,700dpi sensor and Omron switches. The sensor is first-class, offering a huge improvement in accuracy over that of a standard mouse. Both the M60 and K90 are made of aluminium, which gives them a lightweight and smart finish.

© MSI

Overclock master

Overclocking used to be a 'dark art', requiring pro tools and techniques. But today speeding up PC components couldn't be simpler

One of MSI's Z77A-GD55 motherboard's best features is its overclocking-friendly design, with large, integrated heat sinks, a super-ferrite choke, highly conductive polymerised capacitors and generally industrial build quality.

Of course, many motherboards that have come before the Z77A-GD55 sported similarly impressive hardware, however most of them still relied on the user opening the PC's BIOS menus and tampering with a series of complex features, altering voltages and timings in a trial-and-error manner.

Handily, MSI has gone a long way to negate the need for any BIOS wizardry by introducing its Control Center II and OC Genie II software. These are user-friendly programs that anyone can run in their desktop environment to enable real-time overclocking, allowing for – in optimal conditions – an over 30 per cent performance increase. Further, because the overclocking can be done on the fly, users can discover their system's optimal configuration far quicker than before, with no endless reboots needed to achieve a stable overclock.

"Wet cleaners employ the use of either steam or chemicals to kill germs and pick up dirt"

Inside the Vax Rapide Ultra 2

This wet carpet and upholstery cleaner uses high-powered jets to pump the water and detergent into a material to flush out even ground-in grime

Carpet cleaners

How these machines shampoo your carpets and upholstery to get them looking as good as new

In addition to just sucking up dust and other surface dirt from the pile in your carpets and furniture, specialised carpet and upholstery cleaning machines can also remove deeper stains and other grime, using either wet or dry techniques.

Wet cleaners employ the use of either steam or chemicals to kill germs and pick up dirt and remove stains. Hot water or steam is most effective at breaking down the grime as applying heat destroys the structure of microbes so they cannot survive. These wet variants work by first adding clean water to a dirty carpet. The water is then absorbed by the muck before being sucked back up by the machine with powerful suction technology. It's important not to get the carpet too wet, however, as depending on the solution used, this can alter the colour, and even shrink it in the case of wool-based carpets.

Dry cleaners, meanwhile, deposit a dry chemical on to the carpet, which is then absorbed by the dirt and sucked back up by the cleaner, but this type is less effective at giving a heavily soiled carpet a really deep clean. Because these cleaners apply a strictly controlled amount of moisture this can ensure the carpet remains virtually dry.

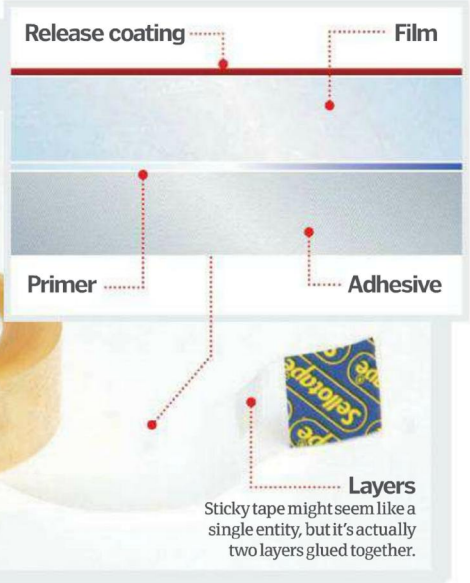
How is adhesive tape made?

Discover the amazing properties of sticky tape and how it works

Pressure-sensitive adhesive tape is so versatile because it can stick two surfaces – ideally flat ones – together without the need for heat, solvents or other substances in order to make it tacky. Instead, this amazing invention uses something as simple as a little pressure to make it stick fast. Synthetic transparent cellulose acetate film (historically this was made of natural cellulose derived from plants like cotton or hemp) is made sticky through the addition of synthetic rubber resin, but how are these layers adhered together in the first place?

By first applying a primer to the side of the cellophane film that will host the adhesive, the manufacturers can then apply a very thin layer of the rubber-based glue. Next, by heating or applying hot air to the tape, any liquid present in the adhesive will evaporate, leaving behind a purer dose of glue. Some other types of sticky tape involve laminating the glue to the tape using extreme pressure. The tape is then rolled onto a cardboard barrel for easy dispensing – often with the use of a clever device which keeps that elusive end of the tape accessible for the user.

The first rubber-based adhesive tape was invented by surgeon Horace Day in 1845



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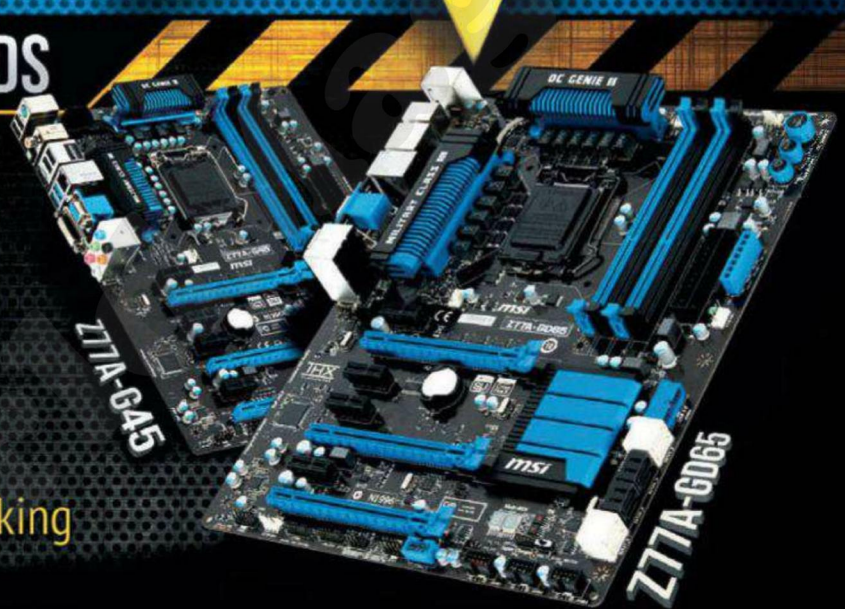

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"The Xperia S's front fascia is over 90 per cent glass panel"

The Sony Xperia S

Sony's latest and hottest smartphone delivers media and gaming fidelity like never before as well as some innovative new gadgets

The Xperia S is a new smartphone produced by Sony (recently separated from Ericsson) that, aside from offering a handset optimised for high-resolution media playback, has been designed to blur the lines between a phone and a portable gaming console.

The former is delivered by a large 10.9-centimetre (4.3-inch) TFT capacitive touchscreen display, which is capable of presenting 1080p hi-def videos. The videos can be taken directly on the device through its integrated 12.1-megapixel camera, or downloaded/uploaded to the phone from a content source. Further, if media would benefit from being presented on a large television or monitor screen, the content can be played through an HDMI 2.0 port. The screen itself is powered by Sony's mobile BRAVIA engine, a hardware standard designed to enhance both audio and visual media playback.

The latter role as a gaming console is delivered by the Xperia S's PlayStation certification, a tag that represents the device's hardware and software has been optimised for compatibility with Sony's PlayStation Suite, an online repository of videogames that can be downloaded and played on the phone. These titles, along with the rest of the media content, can also be streamed over HDMI to a larger screen if desired.

The innovative SmartWatch offers the user some freedom from the Xperia handset

Talking of screens, the Xperia's front fascia is over 90 per cent glass panel, only separated from the casing at the bottom via a thin transparent strip. This bar acts both as the device's antenna as well as a visible area for the handset's main buttons. The screen, as with the surrounding case, is curved; at its fattest part, the Xperia S is just one centimetre (0.4 inches) thick.

Juice to run the device, which is mainly consumed by the aforementioned screen, is supplied by a 1,750mAh battery. This delivers a stated 450 hours of standby time, 25 hours' worth of music playback and 6.5 hours of video playback. Talk time varies depending on connected network, but ranges from 7.5-8.5 hours.

The Xperia S has also been designed to maximise on-phone photography, bolting on a selection of technologies to its rear-facing camera. Foremost of these is an Exmor R camera sensor, a back-illuminated, solid-state CMOS sensor tweaked to handle low-noise shots and low-light situations. This sensor works by receiving light onto a silicon substrate from behind, allowing it to be used with a level of efficiency not possible by conventional front-illuminated pixel structures.

Finally, Sony has ensured the Xperia S is compatible with a broad selection of communication platforms, the most notable being its implementation of near-field communication (NFC) on the device. NFC is a set of standards for smartphones that enables wireless radio communication with other compatible devices in close proximity. This technology is currently gaining popularity as a cashless payment method for products and services – for example, the Google Wallet app.

Casing

The Xperia S features a large – 128 x 64 x 10.6mm (5 x 2.5 x 0.4in) – plastic case, which is heavily curved to accommodate its screen and to aid grip. Segmenting the case front from the screen is a transparent strip which serves as the device's antenna.

Screen

Despite being a TFT panel, the display of the Xperia S is one of its most advanced features, delivering a 10.9cm (4.3in) capacitive touchscreen capable of outputting a resolution of 1,280 x 720 at 338 pixels-per-inch, which is the highest of any handset on the market. The screen can display over 16 million colours.

5 TOP FACTS
XPERIA S

Launch
1 The Xperia S handset was launched at the 2012 Consumer Electronics Show in Las Vegas, USA, which took place 10-13 January at the Las Vegas Convention Center.

Brand
2 The Xperia S is the first pure Sony-branded smartphone, with prior models branded under Sony Ericsson. This is due to Sony's acquisition of Ericsson's stake in the partnership.

PlayStation-ready
3 The Xperia S is PlayStation Certified, which means it is directly compatible with the PlayStation Suite, a software framework via which users can download and play games.

Curvy
4 Over 90 per cent of this smartphone's front display and casing is curved. This is an intentional design decision in order to aid ergonomic comfort and grip when in use.

Hi-def
5 The capacitive touchscreen of the Xperia S supports 1080p video recording and playback. Thanks to integration of Sony's BRAVIA engine, the screen can display 16,777,216 colours.

DID YOU KNOW? *The Xperia S went on sale in the UK on 8 March 2012*

Sony Xperia S in detail

Take a look at the main features of this cutting-edge smartphone

Processors
The device is powered by a combination of a Qualcomm 1.5GHz dual-core CPU and Adreno 220 GPU. Combined, these allow the Xperia S to record and play 1080p high-resolution video as well as take shots with its integrated 12.1-megapixel rear camera quickly and efficiently.

Software
The Xperia S runs off Android 2.3 Gingerbread, which is the precursor to Android's current flagship OS, Ice Cream Sandwich. The handset is PlayStation Certified, a feature that enables it to access the PlayStation Suite, a software framework that delivers downloadable games.

Connections
A plethora of connections are available on the Xperia S, including an HDMI 2.0 port for directly connecting the device to a television or monitor for video, audio and picture playback. Other notable ports include microUSB and a 3.5mm (0.12in) audio jack. The handset also packs near-field communication (NFC) technology for contactless abilities.

The statistics...

Sony Xperia S

Height: 128mm (5in)
Width: 64mm (2.5in)
Depth: 10.6mm (0.4in)
Weight: 144g (5.1oz)
OS: Android 2.3 Gingerbread
CPU: Qualcomm MSM8260 (1.5GHz S3 dual-core)
GPU: Adreno 220
Memory: 1GB RAM
Storage: 1-1.5GB
Removable storage: 32GB
Battery: 1,750mAh
Display: 10.9cm (4.3in), 1,280 x 720px touchscreen
Cameras: 12.1MP rear (1080p); 1.3MP front (720p)
Connections: microUSB, HDMI 2.0, 3.5mm (0.12in) audio, Bluetooth 2.1, Wi-Fi 802.11 b/g/n, aGPS, GLONASS, NFC, DLNA

SmartTags come in bundles of four

All images © Sony

SmartTags

While near-field communication (NFC) has yet to be widely adopted, Sony has taken the technology to a more personalised level with its creation of SmartTags.

SmartTags are small keyring-sized tags that, when swiped with an Xperia smartphone, automatically alter its profile. The profiles can be customised on the handset, allowing users to select a variety of options such as turning on/off Wi-Fi, GPS or Bluetooth, launching news and weather apps, turning the handset's sound on/off, launching the phone's calendar, playing a certain music track and a lot more besides.

These options enable users to customise individual tags to initiate certain context-specific profiles. For example, by hanging a SmartTag in a car, a user can quickly pass the phone over it to turn on the GPS software, which would be handy if driving. In addition, if a user places a tag in their bedroom, then by sweeping the phone over it they can automatically mute their phone so they are not disturbed while sleeping.

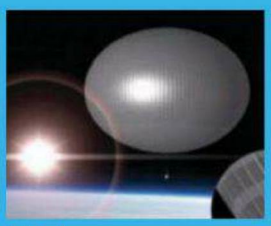
SmartWatch

As with Sony's SmartTags, the SmartWatch is an extra piece of kit designed to complement any Xperia smartphone. It consists of a micro, square-shaped display that can be clipped to either a watch strap or an item of clothing. The display and system is loaded with a stripped-down Android operating system, which once paired via Bluetooth, can communicate with a user's handset.

This allows data and music to be streamed between the two and stored on the watch's internal memory, a feature designed to let users listen to music while exercising without having to carry their expensive smartphone.

In addition, the watch comes pre-installed with text message, Facebook and Twitter applications, which enables users to access their personal accounts discreetly and/or without having to get their phone out and unlock it. Finally, due to its Android operating system, the watch has access to the Android Market (now known as the Google Play store), allowing additional tailored applications such as weather and news programs to be downloaded and installed.

The SmartWatch runs on an Android operating system



Welcome to... SPACE

To kick off the Space section this issue you can learn about the UK project that is set to send a mega-balloon out to the border between our world and the cosmos. Not only this but you'll also discover how the airlock on the ISS works. Other features include an explanation of the strange shifting 'spot' on Neptune as well as a look at how NASA created 2012's incarnation of the iconic Blue Marble image.

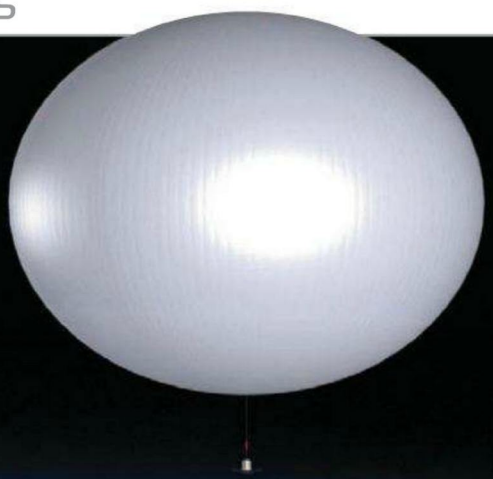
42 Airlocks

42 Great Dark Spot

44 The Blue Marble

LEARN MORE

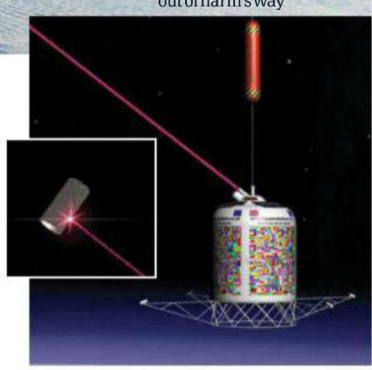
The target altitude is 40,000m (130,000ft)



"The balloon will be almost 75 metres (245 feet) tall and, once it has expanded in the thin atmosphere, it will reach a diameter of 100 metres (330 feet)"

Big Space Balloon

A laser may be installed in order to push space debris out of harm's way



How will this giant balloon perform experiments at the edge of space?

The Big Space Balloon will be Britain's largest high-altitude research balloon, taking experiments up to the edge of the cosmos and exploring the upper echelons of our atmosphere. It is set to launch mid- to late-2014, carrying a capsule full of scientific experiments to study the Earth and its atmosphere, before returning to our planet and possibly being re-launched in the future.

The balloon will be almost 75 metres (245 feet) tall and, once it has expanded in the thin atmosphere, it will reach a diameter of 100 metres (330 feet) and a volume of 400,000 cubic metres (14 million cubic feet). It has been designed to provide a low-cost alternative to taking a payload into orbit compared to an expensive rocket launch. The entire balloon and capsule system will be roughly twice the height of Nelson's Column and almost as wide as the height of the most powerful rocket of all time, the Saturn V. The design is a super-pressure balloon envelope, which is designed to survive several days at the border of space. The balloon material will be made from 100 per cent recycled polythene.

Attached to the balloon by a cable will be a capsule 2.9 metres (9.5 feet) tall and two metres (6.5 feet) wide. This will be made from the latest composite materials for strength and durability. Filled with scientific instruments, the capsule will study the Earth and its atmosphere from a height of 40,000 metres (130,000 feet). At the end of its mission the capsule will parachute safely back to Earth, where it will be recovered and potentially used again in other similar missions.

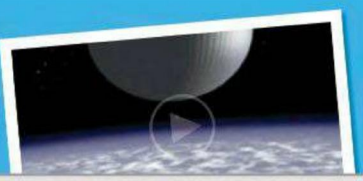
A concept shot of the balloon envelope at the launch site

AMAZING VIDEO!

SCAN THE QR CODE FOR A QUICK LINK

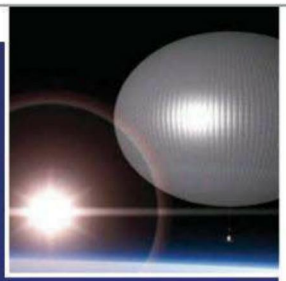
Watch a concept video of the balloon's mission

www.howitworksdaily.com



DID YOU KNOW? *The Big Space Balloon is raising funds by selling advertising space for logos on the exterior of the capsule*

Inside the capsule



Parachute
The landing parachute is secured on the cable that attaches the capsule to the balloon.

Upper
The upper section of the capsule will be kept at sea-level pressure by steadily releasing nitrogen, which will help to protect the more sensitive scientific instruments.

Debris
One proposed experiment is a laser turret, which could be used to push pieces of space debris out of the way.

Central
The majority of the capsule's experiments are located in the central section. The capsule's doors can be opened to expose the experiments to space if needed.

Cameras
The capsule will be monitored by four cameras surrounding it, which will also highlight sponsorship logos on the outside of the capsule.

THE MISSION STEP BY STEP

We take a look at the Big Space Balloon's proposed seven-day journey

4. Target
After two hours the balloon will have reached its target altitude of 40km (25mi) and a maximum volume of 400,000m³ (14m ft³).

3. Stratosphere
On the envelope is a series of photovoltaic cells, which convert solar energy into electricity as the balloon rises.

5. Descent
To begin the journey home, an explosive panel detonates a hole in the envelope so the balloon's return to Earth can be controlled.

2. Ascent
As atmospheric pressure drops the balloon starts to swell, because the gas inside is able to expand more easily and pushes out the thin polythene material.

6. Parachute
At about 3km (1.9mi) the landing parachute is released, returning the capsule safely to the surface so it can be recovered.

7. Landing
The deflated balloon lands separately and is also recovered after completing its mission.

1. Launch
On the ground, a crane will hold the capsule stationary as the balloon is filled with a mix of hydrogen and helium gas.

All images © www.bigspaceballoon.co.uk

Interview Richard Curtis

We speak to the project director of the Big Space Balloon mission

How It Works: How and why did you get involved with this project?
Richard Curtis: The Big Space Balloon is an idea I've been working on for a couple of years. I was part of the generation growing up during the Apollo missions, Skylab, Soyuz and then the Space Shuttle, so I've had a lifelong interest in space and space tech. It would be very exciting to use some of the latest technologies such as printed solar cells and additive layer manufacturing to build a substantial vehicle and send it on its way to the edge of space and see the images of the Big Space Balloon flying above the Earth's atmosphere.

HIW: Why did you pick a balloon for this project?
RC: A big stratospheric balloon allows you to lift a reasonably substantial payload of up to several tons into a space environment. The Big Space Balloon will be aiming for a total payload weight – including the science capsule – of around one ton. This should allow us to carry up to half a ton of science equipment. Although there is now a lot of great science being done with mini-payloads and balloons, there are still areas where the bigger the kit the better, particularly with imaging and sensing devices.

HIW: Is there any danger in launching this balloon?
RC: There is a range of challenges [we may face]. The main one is the balloon fabric tearing during launch. The material used for most large stratospheric projects tends to be a very lightweight polythene, similar in thickness to a supermarket carrier bag. Hopefully we've arrived at a size that's [thin enough but durable]. I'm also hoping that by combining the fabric with printed solar cells we can make a stronger composite balloon material. This will probably mean a heavier fabric, but as we're not trying to break any altitude records, it's not too critical if we only achieve, say, [38,000 metres] 125,000 feet instead of [41,000 metres] 135,000.

HIW: What does the future hold for space balloons?
RC: The hope is that the Big Space Balloon's science capsule could be reused in further missions. I'm keen for the Big Space Balloon to act as a platform to test out new technologies in the space environment, such as printed solar cells on the balloon envelope, which could pave the way for a new way of powering future spacecraft or stations. Additive layer manufacturing (aka 3D printing) is another process I'm aiming to use in the fabrication of the science capsule, as this allows fairly complex and bespoke structures to be manufactured straight from the computer.

There's also the possibility of using the technology for interplanetary missions. One of the instruments the science capsule may carry could be to detect micro-organisms in the Earth's upper atmosphere – technology that could be then transferable to a future Mars or Venus mission.

"Neptune's spots are anticyclonic super-storms, intense cyclones that produce 1,500mph winds"

The Quest airlock module of the International Space Station being prepped prior to launch

3x © NASA

NASA astronaut Garrett Reisman inside the Quest Joint Airlock

Airlocks explained

How do these chambers safely transit astronauts from a spacecraft out into the vacuum of space?

Airlocks, typified by the International Space Station's (ISS) primary Quest Joint Airlock, are designed to permit safe passage of people and objects between a pressurised vessel and its surrounding environment. Further, they are designed to minimise pressure and air-level changes within the host craft.

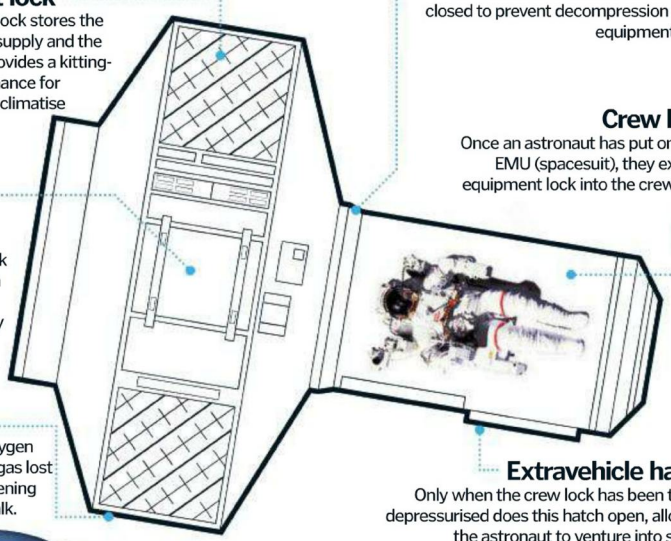
The Quest airlock of the ISS is split into two main sections: an equipment chamber and crew lock chamber. The former connects to the ISS and supplies an auxiliary holding bay for any essential equipment, such as Extravehicular Mobility Units (EMUs – or spacesuits), as well as other key gear. It also supplies a staging area where astronauts can prepare for a spacewalk – namely get in and out of their spacesuits.

Connected to the equipment compartment is the crew lock, a smaller cylindrical chamber into which astronauts enter prior to any spacewalk. Once inside this section, the interior hatch between the equipment lock and the crew lock is shut. This provides a sealed environment for the suited astronaut and allows depressurisation to proceed. When the crew lock is fully depressurised, an external hatch becomes operational, providing an exit for the astronaut to enter space.

Importantly, before any spacewalk is attempted, astronauts must 'camp out' within the equipment chamber of the airlock in a reduced-nitrogen environment in order to purge nitrogen from their blood stream. This ensures that astronauts avoid decompression sickness in the low pressure experienced within the pure-oxygen atmosphere of the spacesuit. Nitrogen and oxygen are supplied and replenished via four externally mounted gas tanks, which ensures that the lock does not need to draw upon the host ISS's own gas supplies.

Inside an airlock

Discover the key areas of the International Space Station's Quest airlock



Equipment lock
The equipment lock stores the airlock's power supply and the spacesuits. It provides a kitting-up area and a chance for astronauts to acclimatise to the EMU.

Intravehicle hatch
This provides a sealed barrier between the equipment and crew locks. As an astronaut enters the crew lock, it is closed to prevent decompression in the equipment lock.

Crew lock
Once an astronaut has put on their EMU (spacesuit), they exit the equipment lock into the crew lock.

Power supply assembly
The entire airlock is powered from a central power supply assembly located in the equipment lock.

Gas tanks
Nitrogen and oxygen tanks replenish gas lost during hatch opening for any spacewalk.

Extravehicle hatch
Only when the crew lock has been totally depressurised does this hatch open, allowing the astronaut to venture into space.

Neptune's Great Dark Spot

What is this odd feature on the farthest planet from the Sun?

The Great Dark Spot (GDS) is an elliptically shaped region of Neptune around 13,000 kilometres (8,100 miles) wide and 6,600 kilometres (4,100 miles) high. Technically, it is a series of spots that generate and dissipate every few years, which differentiates it from Jupiter's Great Red Spot, which has been singular and constant for centuries. However, as with Jupiter's spot, Neptune's spots are anticyclonic super-storms, intense cyclones that produce 2,400-kilometre (1,500-mile)-per-hour winds. These winds are the fastest to have been recorded in the solar system and are believed to occur in the planet's troposphere. Currently, there is a new GDS on Neptune in its northern hemisphere that has been fittingly dubbed the Northern Great Dark Spot (NGDS).

Neptune's Great Dark Spot as imaged by the Voyager 2 spacecraft in 1989

2x © NASA

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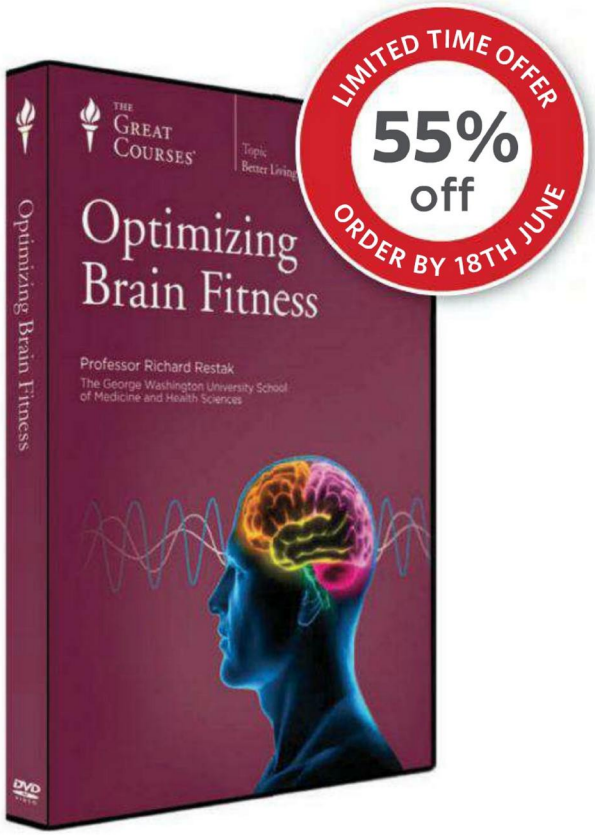

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"There are five different instruments on board Suomi NPP, but by far the most important is the VIIRS"

Imaging Earth

How are iconic pictures of our planet like the Blue Marble photographed?

Taking an image of Earth is no easy feat. Since NASA's Explorer 6 satellite first took a blurry photo of our world back in 1959, methods and techniques to snap that perfect picture of our home have come on leaps and bounds, and the images often become very famous. In fact, 2002's Blue Marble image was so popular that it eventually ended up as the default background on Apple's iPhone.

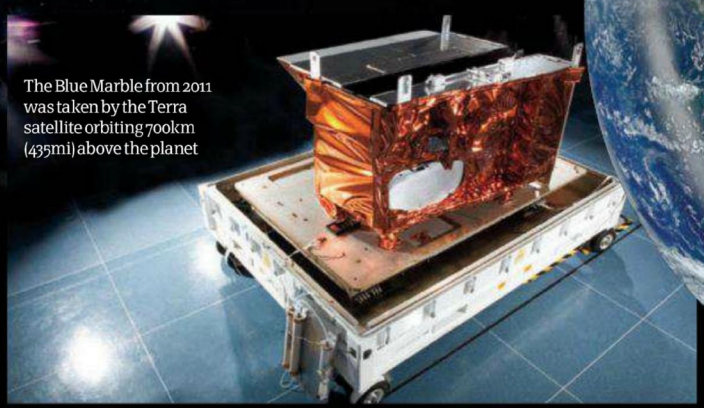
The first Blue Marble image of the entire Earth – coined for apparently portraying our planet as a marble-like object – was taken by Apollo 17 astronauts in 1972 as they made their way back from a mission. The image they took 40 years ago was just a single snapshot, but today image-editing software such as Photoshop is used to enhance the picture, though great pains are gone to not to detract from the reality of the shot.

NASA's most recent Earth portrait, dubbed 'Blue Marble 2012', was taken by an Earth observation satellite called Suomi NPP. For the satellite to shoot this image technicians on the ground had to take a picture of Earth six times as the satellite passed over one point, allowing them to combine several layers into one image.

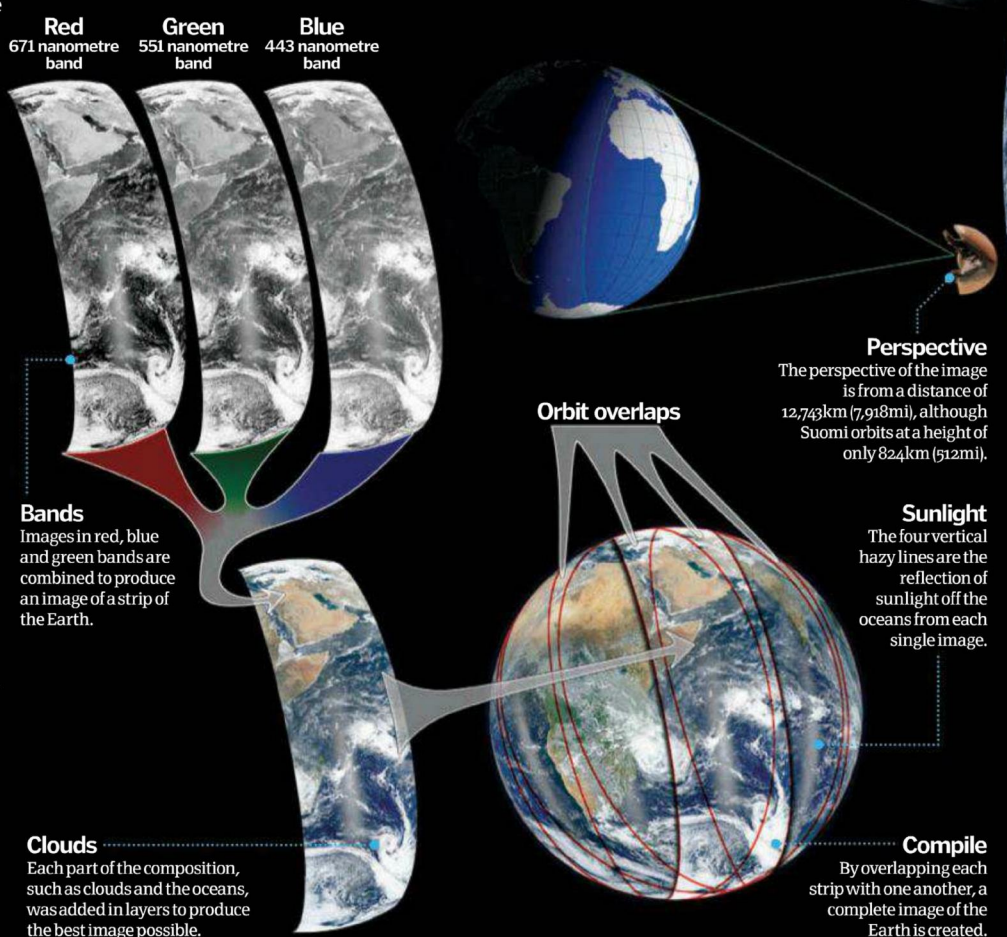
There are five different instruments on board Suomi NPP, but by far the most important for this task is the Visible/Infrared Imager Radiometer Suite (VIIRS). This scanning radiometer can collect visible and infrared imagery of Earth in addition to measurements of the planet's atmosphere, land mass and oceans.

The image was taken in January 2012 and compiled by NASA scientist Norman Kuring. The satellite flies in a polar orbit at a height of 824 kilometres (512 miles). However, the perspective of the image is from an altitude of 12,743 kilometres (7,918 miles) at a point ten degrees south latitude and 45 degrees east longitude, owing to the nature of the composite image.

For a scale representation of how far Suomi NPP is from the surface, imagine our planet as a basketball. The Earth has a diameter of about 12,756 kilometres (7,926 miles), while a basketball has a diameter of 25 centimetres (ten inches). If you hold the basketball 1.5 centimetres (half an inch) from your face, that's how close Suomi NPP is to Earth. The width of each section of Earth the VIIRS images as it flies over is about 3,001 kilometres (1,865 miles). In comparison, the Apollo 17 astronauts who captured the first Blue Marble were about 76 centimetres (30 inches) away from the basketball (45,000 kilometres/ 28,000 miles from Earth).



The Blue Marble from 2011 was taken by the Terra satellite orbiting 700km (435mi) above the planet



RECORD BREAKERS
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3.1m

MOST-VIEWED IMAGE

The Blue Marble 2012 image of Earth's western hemisphere racked up 3.1 million views on Flickr in just a week upon its release in January 2012, making it one of the most-viewed images of all time.

DID YOU KNOW? *In 2004's Next Generation mission to image Earth's surface each hi-res pixel represented 500m on the ground*

NASA claims that this is the most high-resolution image of Earth ever taken

Images through the ages

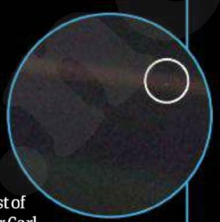
1959 Explorer 6

This is the first-ever image of Earth taken from space. It was captured by the Explorer 6 satellite on 14 August 1959, from a height of about 27,000 kilometres (17,000 miles). Our capability to image Earth has come a long way since.

1972 Apollo 17

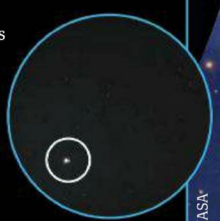
The first 'Blue Marble' image of Earth was taken by astronauts on the Apollo 17 mission. They snapped the image in one take as they were on their way back to the surface.

1990 Pale Blue Dot



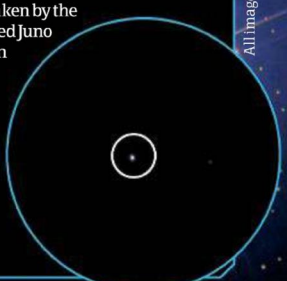
This famous image of Earth was captured by the Voyager 1 spacecraft from Saturn at the behest of the late astronomer Carl Sagan, who coined it the 'Pale Blue Dot'.

2011 Messenger



NASA's Messenger spacecraft took this image of the Earth and moon from Mercury. The two are so close that they look a little like a binary star.

2011 Juno



This picture of the Earth and moon was taken by the solar-powered Juno spacecraft en route to Jupiter. It is expected to reach the gas giant by 2016, where it will take many more images.

Welcome to... SCIENCE

You might think of distillation as something that goes no further than the lab, but a world without its many products is hard to imagine. Also explore vacuums and whether they're as empty as we're told. For biology fans, learn about tongues, how cells divide and why blisters form.

LEARN MORE

The science of distillation

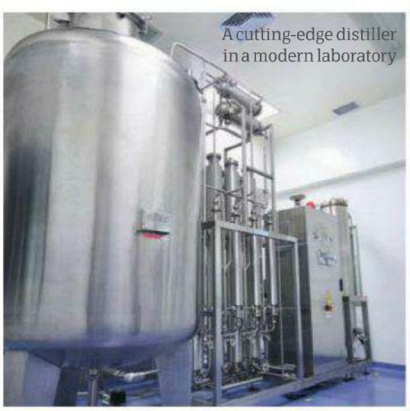
The revolutionary ancient discovery that enables us to make gasoline from crude oil and vodka from potatoes

In many ways, during the Middle Ages, distillation was the alchemist's greatest tool. Through controlled heating of a liquid or solid source material, the alchemist could draw out and isolate pure vapours that were cooled, condensed into liquid and employed in the mystical medicinal research. Distillation also helped the Ancient Greeks to purify fresh drinking water from the sea. It drew pungent oils out of flowers and herbs for perfumes and early medicines. And it took humble beer and homemade wine and refined them into finely crafted, high-octane spirits that earned the name aqua vitae, or the water of life.

Today, distillation remains a critical chemical process for isolating pure compounds from a mixed solution. The science of distillation is rooted in the fact that every molecular compound has its own unique boiling point and dew point. The boiling point is reached when the vapour pressure of a liquid equals the atmospheric pressure above it, allowing molecules within the liquid to freely escape as vapour. The dew point is the temperature at which the vapour cools enough to condense and return to a liquid state.

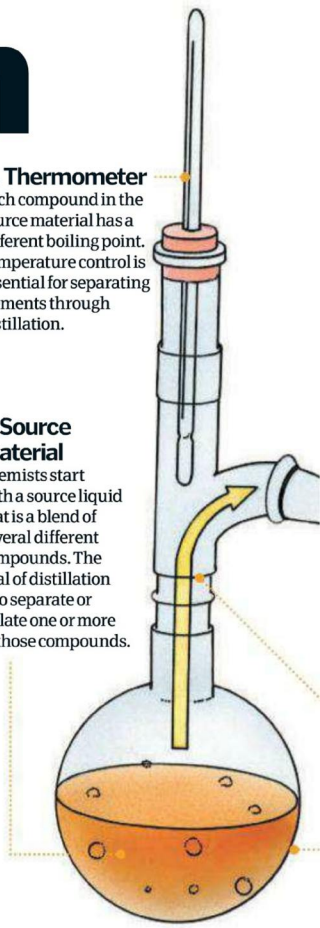
Since compounds have unique boiling points, they can be vaporised out of a mixed solution at different temperatures. First, you slowly heat the solution to the boiling point of the compound you want to isolate. The vapour that rises from the mixture will still contain a blend of the compounds in the solution, but a far greater concentration of the desired compound. The rising vapour is channelled into a condensing tube, where it is cooled by a circulating water bath and then condensed back into a purified liquid.

Simple distillation is taught in school chemistry labs, but industrial-strength distillation supplies the world with everything from whisky and perfume through to gasoline and liquid nitrogen, plus a lot more besides.



A cutting-edge distiller in a modern laboratory

> "Every molecular compound has its own unique boiling point and dew point"



4. Thermometer
Each compound in the source material has a different boiling point. Temperature control is essential for separating elements through distillation.

1. Source material
Chemists start with a source liquid that is a blend of several different compounds. The goal of distillation is to separate or isolate one or more of those compounds.

3. Heat source
In laboratories, chemists use a hot plate or Bunsen burner to heat the source material. The still pot can also be submerged in a hot water or oil bath.

Making alcohol

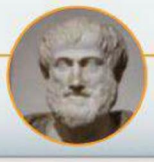
The alcohol found in wine, beer and hard liquor is really ethanol, the same stuff that powers alternative-fuel vehicles. To make ethanol (alcohol), all you need is a sugary (high carbohydrate) feedstock like grapes, corn or malted barley, plus water and yeast. Yeasts are microscopic organisms that metabolise the carbohydrates in the feedstock and produce two by-products: ethanol and carbon dioxide. The carbon dioxide produced by yeast is what makes bread dough rise. To encourage ethanol production, brewers cover vats of fermenting material and allow only the carbon dioxide to escape. Wine, beer and other fermented brews – like the grain mash that's used to make whisky – can be distilled to concentrate their alcohol content, creating more potent spirits like gin, vodka, brandy and rum.

KEY DATES DISTILLATION

2000BCE – Perfume makers in Mesopotamia distil essential oils and herbal waters from flowers, herbs and spices.

800BCE – The earliest evidence of alcoholic distillation is a spirit distilled from rice beer in China.

400BCE-200CE – Fresh water is first distilled from seawater, as described by Aristotle in his *Meteorologica* and later by Alexander of Aphrodisias.



1300s-1400s – Distilled liquors are popularised by the Dutch (gin), the Scottish and Irish (whisky) and the French (brandy).

1500 – Physician Hieronymus Brunschwig publishes the authoritative treatise on distillation, the first to apply chemistry to pharmacology.

DID YOU KNOW? *An azeotrope is a solution that can't be 'broken' through conventional distillation*

Fractional distillation

In simple distillation, a single distillate is vaporised out of a solution and condensed in a single batch. Fractional distillation, meanwhile, is a technique for carefully separating multiple different components of a solution in a continuous process. The separation process occurs in a fractionating column that sits above the heated source material. The column is packed with tiny glass beads and contains multiple levels of condensing trays. An important characteristic of the fractionating column is that internal temperatures are hotter at the bottom and cooler at the top. As each component of the source material reaches its boiling point, it vaporises upward through the column. The components with the lowest boiling point rise higher in the column before cooling enough to condense back into liquid. The glass beads provide extra surface area to promote condensation, and the condensing trays collect each liquid component, which can then be siphoned out. Crude oil is separated into its useful by-products – eg kerosene, diesel fuel, natural gas and more – in towering fractionating columns.

8. Cooling water out
The water is constantly circulated out of the cooling bath in order to maintain its low temperature.

6. Condenser
This angled glass tube is where vapour emitted from the source material is cooled and condensed back into liquid.

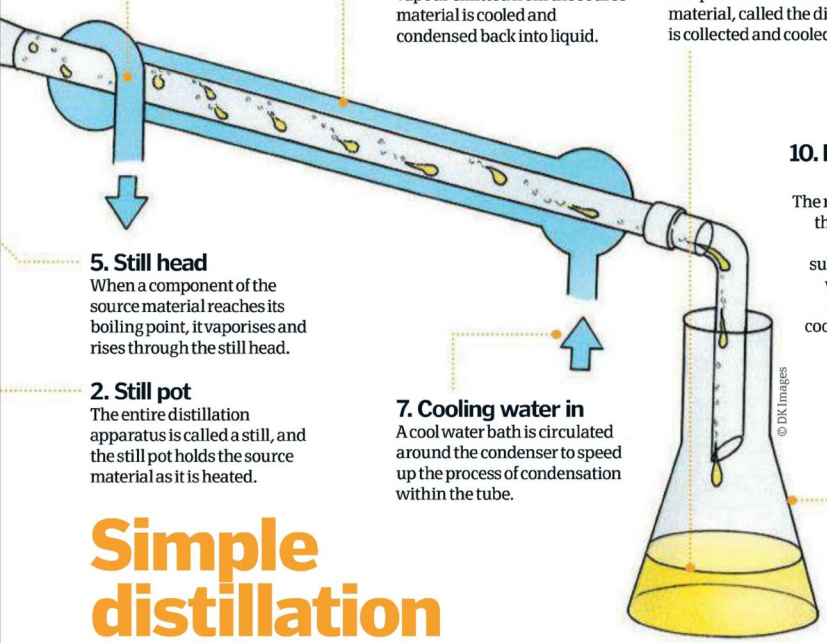
9. Distillate
This is where the isolated component of the source material, called the distillate, is collected and cooled.

10. Receiving flask
The receptacle for the distillate is sometimes submerged in a water bath to speed up the cooling process.

5. Still head
When a component of the source material reaches its boiling point, it vaporises and rises through the still head.

2. Still pot
The entire distillation apparatus is called a still, and the still pot holds the source material as it is heated.

7. Cooling water in
A cool water bath is circulated around the condenser to speed up the process of condensation within the tube.



© DK Images

Simple distillation

How a single compound can be extracted from a mixed solution

© Arlen

5 USES OF DISTILLATION

Distilled water

By boiling water and condensing its vapour, you achieve a purified water with lower levels of trace minerals and other impurities. Originally, distillation was used to make fresh drinking water from seawater, but now the purified liquid is used in car batteries and other chemical-electrical systems where the minerals found in tap water would disrupt the reaction.

Alcoholic spirits

© Antoni Lecram

Beer and wine pack a pleasant alcoholic punch, but the alcohol content of such beverages is never more than 20 per cent by volume. Taking their cue from Arab alchemists, European brewers from the 14th century distilled beer and wine to concentrate ethanol content, creating potent spirits like brandy and gin.

Oil refining

© Luigi Chiesa

The crude oil that we pump out of the ground is useless as a fuel. First, it must be refined through fractional distillation and separated into its component parts: diesel fuel, kerosene, gasoline and natural gas. Crude oil is heated to 600 degrees Celsius (1,112 degrees Fahrenheit) and its vapours ascend through a cooling column of air. As each component of crude oil reaches its boiling point, it condenses and flows out of the distillation column.

Separation of air

Air can be separated into its component elements – mainly nitrogen, oxygen and argon – via a process called cryogenic distillation. In cryogenic distillation, gaseous air is pressurised and cooled to temperatures approaching -200 degrees Celsius (-328 degrees Fahrenheit), at which point its components condense and separate into purified liquid nitrogen, oxygen, argon and so on.

Perfume making

Persian alchemist Ibn Sina (aka Avicenna) is credited with first distilling essential oils to create rose water. Today, compounds come from flowers, herbs, resins and even some animal-based substances like ambergris, a musky grey lump regurgitated by sperm whales.

Blisters shouldn't be burst as they are the body's way of protecting deeper skin layers

What are blisters?

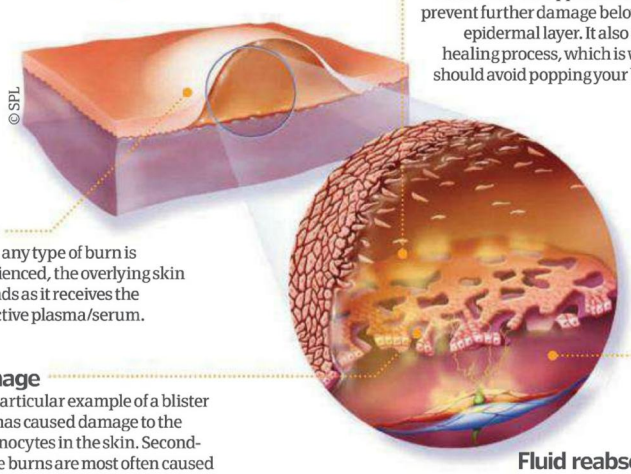
Why do burns cause bubbles to develop below the surface of the skin?

Though our skin is an amazing protector against the elements, it can become damaged by such factors as heat, cold, friction, chemicals, light, electricity and radiation, all of which 'burn' the skin. A blister is the resulting injury that develops in the upper layers of the skin as a result of such burns.

The most common example of a blister, which we've no doubt all experienced at some time, is due to the repeated friction caused by the material of a pair of shoes rubbing against, and irritating, the skin. The resulting water blister is a kind of plasma-filled bubble that appears just below the top layers of your skin. The plasma, or serum – which is a component of your blood – is released by the damaged tissue cells and fills the spaces between the layers of skin in order to cushion the underlying skin that is being rubbed and protect it from further damage. As more and more serum pours into the space, the skin begins to inflate under the pressure, forming a small balloon full of the serous liquid. Given time to heal, the skin will reabsorb the plasma after about 24 hours.

Similarly, a blood blister is a variation of the same injury where the skin has been forcefully pinched or crushed but not pierced, causing small blood vessels to rupture, leaking blood into the skin. All blisters can be tender but should never be popped in order to drain the fluid as this leaves the underlying skin unprotected and also invites infection into the open wound.

Blister caused by second-degree burns



Plasma
Serum is released by the damaged tissues into the upper skin layers to prevent further damage below in the epidermal layer. It also aids the healing process, which is why you should avoid popping your blisters.

Skin
When any type of burn is experienced, the overlying skin expands as it receives the protective plasma/serum.

Damage
This particular example of a blister burn has caused damage to the keratinocytes in the skin. Second-degree burns are most often caused when the skin comes into contact with a hot surface, such as an iron or boiling water, or even after exposure to excessive sunlight.

Fluid reabsorbed
After a day or so the serum will be absorbed back into the body and the raised skin layers will dry out and flake off in their own time.

How DayGlo ink glows

What makes fluorescent ink shine brighter than ordinary ink?

Fluorescent ink, such as that made famous by DayGlo, is known for being brighter than normal types of ink, especially under ultraviolet light. DayGlo ink contains fluorescent pigments, which absorb and reflect more light than conventional inks. Normal pigments cause materials to be a certain colour because they absorb some parts of the visible spectrum, while reflecting the wavelengths of light corresponding to the colour you see. Fluorescent pigments absorb visible light too, but they are also very sensitive to the higher energy of ultraviolet light. Ultraviolet light absorbed by these pigments excite electrons surrounding the atoms of the pigments, giving them energy. This energy is then released in the form of a photon which happens to be of a lower energy corresponding to visible light, meaning the ink emits more light in total making it brighter. Fluorescent pigments are often combined with conventional pigments to develop a wider range of colours that fluoresce.

How does cement harden?

What chemistry makes cement set?

Cement is a very fine powder made from limestone and clay, heated in a kiln to form binding compounds such as tricalcium silicate. The terms cement and concrete are often used interchangeably, but they are not the same; cement is the binding ingredient used to make concrete. Tricalcium silicate in cement reacts with water, in a process called hydration, releasing calcium and hydroxide ions and a great deal of heat. This heat perpetuates the reaction until the mix is saturated with the ions, at which point the calcium hydroxide begins to crystallise forming a more rigid structure. Crystals of calcium hydroxide begin to thicken making it harder for the water to reach the unhydrated tricalcium silicate. Therefore the reaction slows as the mixture sets. The less water-to-cement ratio, the stronger the concrete will be.

"The maternal blood supply divides inside the baby to distribute blood to the liver and heart"

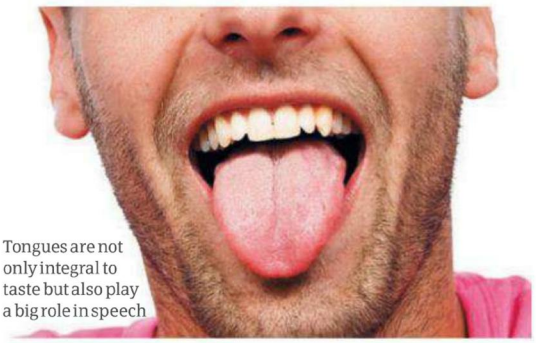
The human tongue

A versatile organ that allows you to both taste and talk

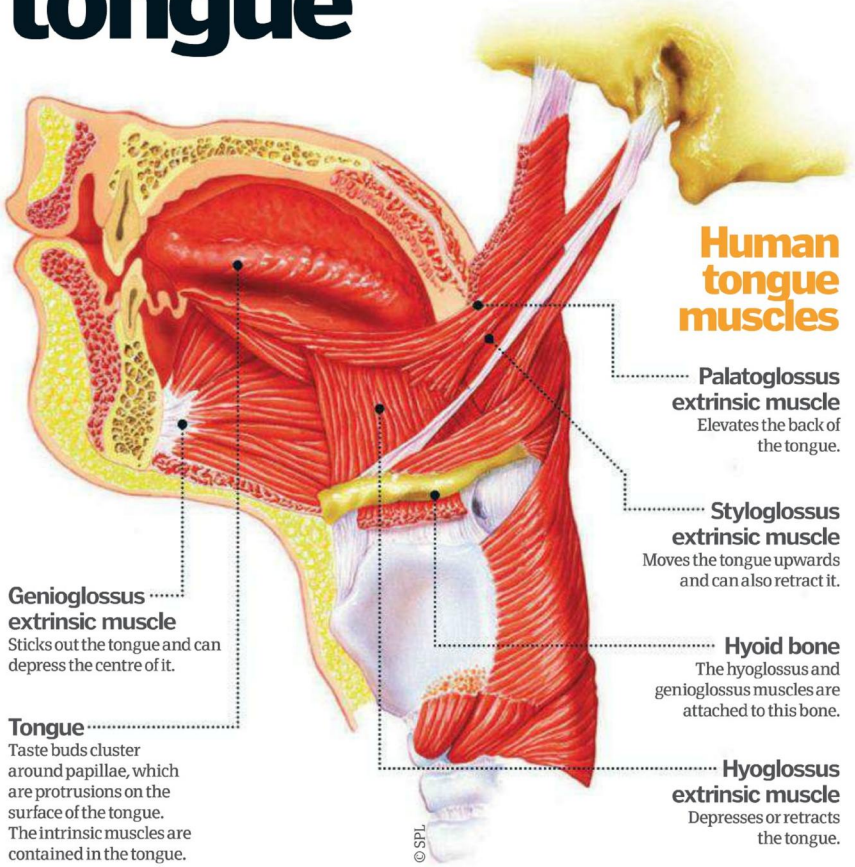
On our tongues, we have up to 10,000 taste buds that can distinguish between sweet, sour, bitter, salty and savoury flavours. As food is dissolved by our saliva, it meets taste receptor cells inside the taste buds that, when stimulated, send signals to the cerebral cortex. Receptors in the tongue also respond to other stimuli like pain, temperature and pressure.

The tongue consists of eight muscles: four of them are extrinsic muscles that are anchored to bone and change the position of the tongue, and four are intrinsic muscles that are not anchored to bone and change the shape of the organ.

Besides guiding food as we chew and swallow it, these muscles also give us the ability to speak. In combination with the mouth, jaws and cheeks the tongue moves to articulate sounds that emanate from the vocal folds of the larynx.



Tongues are not only integral to taste but also play a big role in speech



Human tongue muscles

Palatoglossus extrinsic muscle
Elevates the back of the tongue.

Styloglossus extrinsic muscle
Moves the tongue upwards and can also retract it.

Hyoid bone
The hyoglossus and genioglossus muscles are attached to this bone.

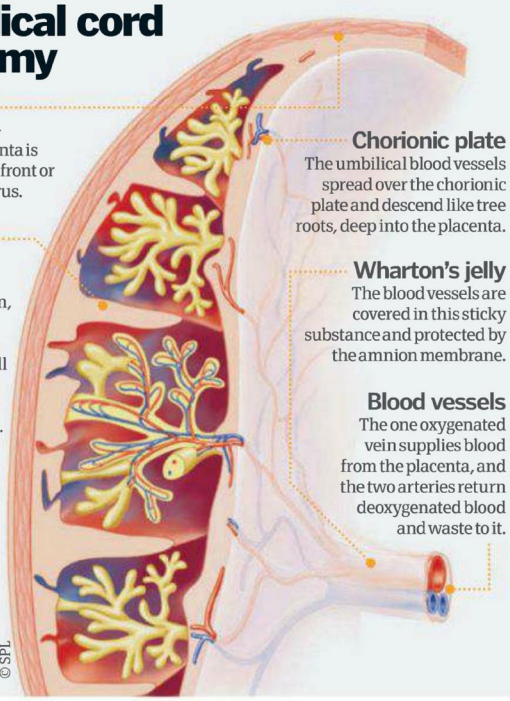
Hyoglossus extrinsic muscle
Depresses or retracts the tongue.

Genioglossus extrinsic muscle
Sticks out the tongue and can depress the centre of it.

Tongue
Taste buds cluster around papillae, which are protrusions on the surface of the tongue. The intrinsic muscles are contained in the tongue.

© SPL

Umbilical cord anatomy



Uterus
The 20cm (8in)-diameter placenta is attached to the front or back of the uterus.

Placenta
The placenta stores and provides oxygen, nutrients and hormones to the baby, as well as processing the returned waste products.

Chorionic plate
The umbilical blood vessels spread over the chorionic plate and descend like tree roots, deep into the placenta.

Wharton's jelly
The blood vessels are covered in this sticky substance and protected by the amnion membrane.

Blood vessels
The one oxygenated vein supplies blood from the placenta, and the two arteries return deoxygenated blood and waste to it.

© SPL

What does the umbilical cord do?

The essential link between mother and baby explained

The 50-centimetre (20-inch)-long umbilical cord runs from the centre of the mother's placenta to an opening in the baby's stomach. It consists of an umbilical vein and two arteries, which spiral around it. The vein supplies the baby with nutrients and oxygenated blood from the mother's placenta, while the two arteries return carbon dioxide and other waste products and deoxygenated blood back to the placenta. They are coated with protective Wharton's jelly, and sheathed with a smooth transparent membrane called amnion.

The maternal blood supply divides inside the baby to distribute blood to the liver and heart. This oxygenated blood circulates rapidly to renew the baby's oxygen levels, and this role is taken over by the lungs after birth.

WHO'S WHO?

BLAISE PASCAL 1623-1662

In his 1647 work, *New Experiments Concerning Vacuums*, Pascal argued that the space above the liquid in a barometer is a vacuum. This went against long-held scientific and religious opinion that a vacuum is impossible, or even outright heresy.

"[Pascal] has too much vacuum in his head"

Philosopher René Descartes' view of Pascal's theories as put to Christiaan Huygens

DID YOU KNOW? *If exposed to a vacuum for more than a couple of minutes, the chances of survival are slim to non-existent*

What is a vacuum?

Is empty space really empty?

A vacuum is a space that has less gaseous pressure than the standard atmospheric pressure at sea level on Earth. A partial vacuum can be easily created by pumping air out of a container. If the container is not sealed, though, the air will be replaced fairly quickly.

In everyday life, vacuums are used in light bulbs, cathode ray tubes, cleaning appliances, and to package and protect food. Creating a vacuum drove the piston mechanism in the Newcomen steam engine and was also used in the braking systems of trains. Household vacuum cleaners work by sucking in air, which creates a lower air pressure than that outside the device. To restore the partial vacuum the outside pressure forces air, and with it dirt/dust etc, into the appliance.

The purest vacuums can be found in outer space. Between galaxies, the vacuum density drops to ~0.001 atoms per cubic centimetre, while in the void between stars in the Milky Way, the vacuum is ~0.1-1 atoms per cubic centimetre. This is in contrast to a vacuum cleaner that produces a vacuum of around 10^{19} molecules per cubic centimetre, though sophisticated extreme-high vacuum (XHV) lab chambers have achieved a vacuum of fewer than 1,000 molecules per cubic centimetre.

Whether manmade or natural, there is no such thing as a perfect vacuum. Even in a virtually complete vacuum, physicists have discovered the presence of quantum fluctuations and vacuum energy.

Vacuum packing food reduces the amount of oxygen in order to make it harder for bacteria to survive

Characteristics of a vacuum

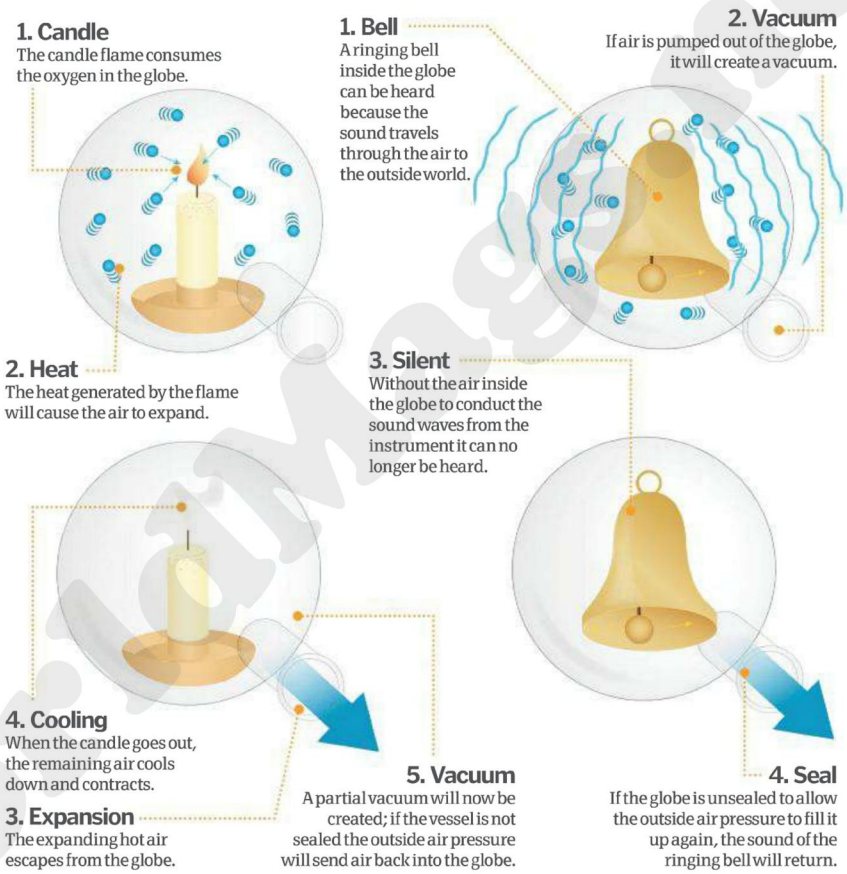
The amount of air pressure on our planet reduces the higher you travel in the atmosphere. At sea level, we experience one kilogram per square centimetre (14.7 pounds per square inch) of pressure produced by air molecules. At 15 kilometres (ten miles) air pressure reduces to 0.12 kilograms per square centimetre (1.6 pounds per square inch), and in outer space, there's no air pressure. This means it's easier to obtain a vacuum the further you travel from Earth's surface. Another characteristic of a vacuum is that it does not transfer heat by convection nor conduction; this property inspired vacuum flasks, which use a vacuum sandwiched between an outer and an inner wall to keep liquids hot/cool for extended periods.

Finding something in nothing – the science of the vacuum

© NASA

Flames inside a vacuum

The lack of air in a vacuum starves a naked flame of oxygen causing it to extinguish



Sound in a vacuum

Vacuums induce silence because sound waves require air to travel

"As eukaryotes, our cells undergo two different types of cell division"

How does cell division work?

Like parent, like daughter – every multi-celled organism started out as a single cell

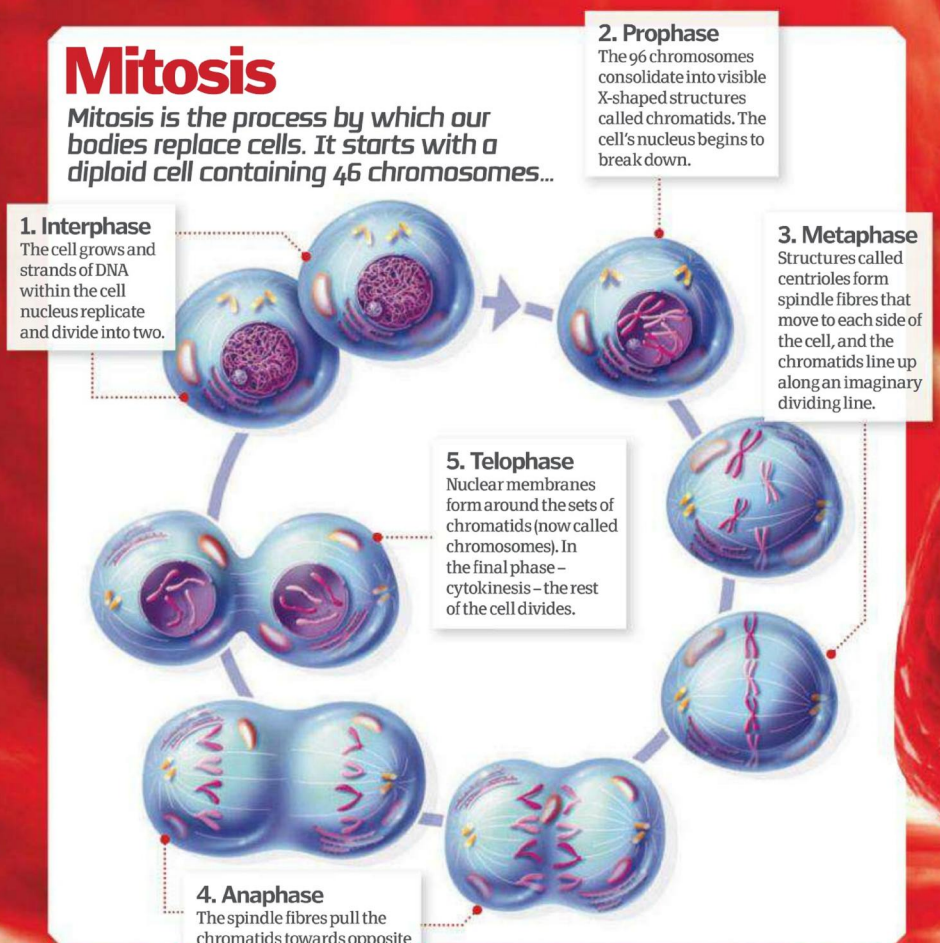
There's an old joke that goes, 'Let's make like an amoeba and split'. Every organism goes through cell division, although in the case of the humble amoeba, cell division means creating another amoeba. Amoebas are a type of cell known as a prokaryote (which also includes things like bacteria). It doesn't have a nucleus, but has its DNA and other genetic material floating around inside the cell. It reproduces asexually through binary fission or a process called budding.

On the other hand, us humans – and every other multi-celled organism in existence – are quite a bit more complicated. As eukaryotes, our cells undergo two different types of cell division depending on the type of cell: meiosis and mitosis. Both are complex, multi-step processes that happen very quickly. In order to sexually reproduce, our bodies create special sex cells called gametes (in animals we call these sperm in males, and eggs in females). Gametes are haploid cells because they contain 23 chromosomes, which are considered a single set. During reproduction, they merge to form a cell containing 46 chromosomes, called a diploid. But first, meiosis splits the original diploid cells, with the chromosomes duplicating, shuffling and reforming into four unique haploid cells.

In contrast, mitosis produces two identical haploid cells. It's a different process from the prokaryotic asexual reproduction, but in humans and other multi-celled organisms it's a sort of maintenance programme. Your body is undergoing mitosis constantly as all sorts of cells die and are replaced. Each human has between 50 and 75 trillion different cells and about 200 different types of cell.

Mitosis

Mitosis is the process by which our bodies replace cells. It starts with a diploid cell containing 46 chromosomes...



KEY DATES
CELL HISTORY

1665
Natural philosopher Robert Hooke first finds cells while studying cork under a microscope, naming them after monks' cells.

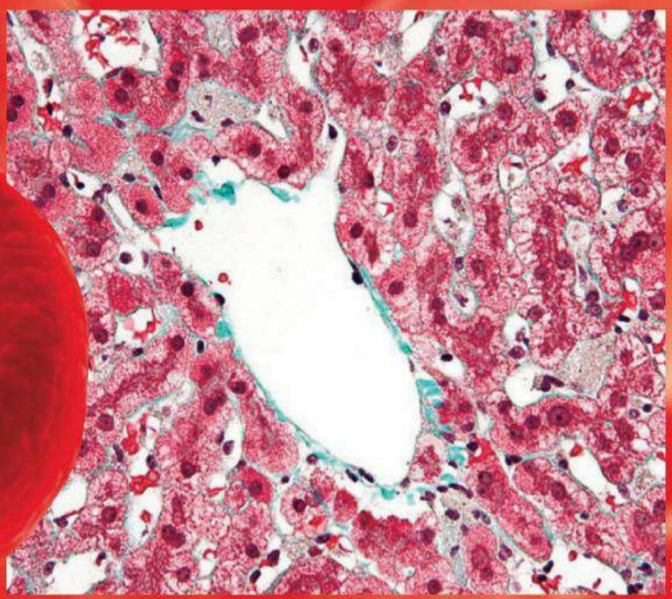
1835
Physiologist Jan Purkinje observes cells in both animal and plant tissue; he refers to them as 'granules'.

1839
The theory that cells are the building blocks of life is proposed by physiologist Theodor Schwann (left) and botanist Matthias Schleiden.

1855
Doctor Robert Remak (left) proposes all cells come from pre-existing ones that divide.

1869
Nucleic acid, which includes DNA and RNA, is first isolated by doctor Friedrich Miescher.

DID YOU KNOW? *Mitosis in female sex cells ends after the first round of division unless the cell is fertilised by a male sex cell*



© Nephron

A normal cell in humans can only divide 52 times before dying, known as the Hayflick limit

Meiosis

Meiosis is the process by which our bodies create sex cells so we can reproduce

1. Parent cell
Meiosis starts the same way as mitosis – with a diploid cell containing 46 chromosomes. The DNA strands replicate and divide.

2. Prophase
The chromosomes match up with their corresponding strand. Enzymes remove pieces of DNA from each and genes swap between the chromosomes before re-pairing.

3. Metaphase
At this point, unlike in mitosis, chromosome pairs line up on either side of an imaginary line in the cell.

4. Anaphase
Next, the chromosome pairs separate, with half moving to one side and half moving to the other.

5. Telophase
Nuclei start to form around each chromosome as the cell divides into two daughter cells, each with 46 chromosomes.

6. Daughter cells
The two daughter cells go through the entire process again, ultimately forming four daughter cells, each with 23 chromosomes.

3 x © SPL

Tumours

Tumours can be malignant (cancerous) or non-malignant, and at their most basic are the result of abnormal cell growth. The nucleus of every cell contains material that tells the cell when it's time to grow and divide (mitosis). There's a strict balance so that the new healthy cells are always replacing old, dying or damaged cells. Sometimes, however, cells get the message to grow and divide more often than they're supposed to, throwing off the equilibrium. Typically this comes from a genetic mutation – that is, there's a problem with the programming. These genetic mutations can be caused by anything from environmental factors to viruses. In cancerous tumours, the cells don't die like normal cells – instead, the mutation allows them to replicate indefinitely.

Welcome to... ENVIRONMENT

From how seahorses buck the trend when it comes to looking after the kids, to the advanced senses of your cat, and how the Giant's Causeway in Ireland formed, we explore all these and more in a fun tour of the natural world.

60 Dust storms

59 Algal blooms

64 Cat anatomy

LEARN MORE

THE AMAZING AMAZON

Bridging the Amazon
No bridge crosses the river for over 4,000km (2,500mi). The lack of towns makes it hard to justify the project.

Brackish sea
The Amazon's massive freshwater outflow dilutes the salty Atlantic Ocean up to 1,600km (1,000mi) offshore.

Something fishy
A whopping 15 per cent of the world's fish species – that's 3,000 freshwater fish – live in the Amazon.

Amazing Amazon Animals

Freshwater dolphin

These pink dolphins detect prey in the muddy river waters with echo-location. Necks twistable at right angles help them slither between flooded trees. Males sometimes twirl sticks to impress females.

THE STATS
THE AMAZON

TEMPERATURE 26°C (79°F) ANNUAL RAINFALL **250cm (100in)**

APPROXIMATE AGE **100 million years** RAINFALL DAYS 250

DID YOU KNOW? *Explorer Francisco de Orellana named the Amazon after likening tribeswomen to mythical all-female warriors*

The way is blocked
The Amazon emptied into the Pacific until 15 million years ago. The rising Andes range blocked its route so it had to divert.

Floods, ahoy
The Amazon's water level can fluctuate by a staggering 15m (50ft) each year – enough to submerge 3.5 double-decker buses.

Jungle city
Manaus, a port city home to 1.6 million, is among Earth's remotest cities. It's accessible only by river or one paved highway.

© SPL

Discover Earth's mightiest river and the rainforest wilderness that surrounds its banks

The Amazon is one of Earth's two longest rivers. It stretches an incredible 6,800 kilometres (4,225 miles) west to east across South America – the approximate distance between New York and Rome. It's also the world's largest river by volume, transporting 20 per cent of the freshwater on Earth and more than the world's seven next largest rivers combined.

Feeding this gigantic torrent is the rain and snow falling across around 40 per cent of South America. This area is called the Amazon's drainage basin and is surrounded by three mountain ranges: the Andes to the west, Guiana Highlands to the south and Brazilian Highlands to the north. The Amazon Basin takes its name from the river. It is the world's largest lowland with an area of around 7 million square kilometres (2.7 million square miles) – almost the size of Australia. At its widest, the basin stretches 2,780 kilometres (1,725 miles) from north to south.

Around 85 per cent of the Amazon Basin is filled with the Amazon rainforest, Earth's biggest tropical forest. This densely vegetated region contains around half of the world's remaining rainforest and is sometimes called the 'lungs of the Earth'. An estimated 20 per cent of Earth's oxygen is produced by the Amazon's foliage, which draws in carbon dioxide and releases oxygen via mass-scale photosynthesis.

Rainforests form in the Amazon Basin because of its equatorial climate; it lies within 15 degrees of the equator. Conditions are warm and wet year-round with little difference in weather between seasons. Average temperatures are about 26 degrees Celsius (79 degrees Fahrenheit) and rain falls, on average, 250 days a year.

The steady tropical climate encourages varied fast-growing plants. In just one hectare (2.5 acres) of Amazon rainforest in Ecuador, scientists found an incredible 473 tree species. The tallest trees can reach heights of 46 metres (150 feet) and live for thousands of years. Their huge leafy canopies harvest perhaps 70 per cent of incoming light and 80 per cent of rainfall, preventing it reaching the forest floor. When a tree topples, saplings race ▶

Manatee
A relation of elephants, these aquatic mammals can weigh a massive 600 kilograms (1,300 pounds), reach four metres (13 feet) long, and eat 15 per cent of their body weight in vegetation on a daily basis.

© Luc Viatour

Red-bellied piranha
Piranha fish have sharp, tightly packed teeth for tearing meat. They pinpoint struggling or bleeding animals in the water by smell and with an organ that detects changes in water pressure.

Scarlet macaw
Among the world's largest parrots, they can measure almost one metre (three feet) from beak to tail and weigh more than a kilogram (2.2 pounds). Highly intelligent, some have lived for 75 years.

"A 4°C temperature rise would see 85 per cent of the forest destroyed by drought within a century"

upwards to fill the space. Beneath these is a shrub layer and a second forest layer – 20 metres (65 feet) tall, the height of British deciduous trees. When the trees and shrubs die, rapid leaf decay releases nutrients that fuel the ecosystem.

The Amazon Basin teems with life. More than one in ten species live in the Amazon – many found nowhere else. These include around 20 per cent of Earth's bird species, 370 reptile species, thousands of tree-dwellers, and 7,500 butterfly species compared to about 60 in the UK. Many more species remain undiscovered. An average three new plant and animal species were catalogued each day between 1999 and 2009, according to conservation group WWF. These included a four-metre (13-foot)-long snake, a bald-headed parrot and a blind crimson catfish.

The Amazon is threatened by deforestation and climate change. A future temperature rise of four degrees Celsius (39 degrees Fahrenheit) would see 85 per cent of the forest destroyed by drought within a century. What's more, in the last 50 years, at least 12 per cent of the trees in this remote wilderness have been cleared for agriculture. Around 80 per cent of these areas are now occupied by cattle ranches and more forest may have been selectively logged. The rainforest is so huge that it produces around 50 per cent of its rainfall by releasing water from its leaves. Cut down enough trees and the remaining rainforest would dry out, and die of drought or forest fire.

The WWF warns the Amazon's flora stores between 90 and 140 billion tons of carbon. If each dying plant were to release its carbon into the atmosphere, the increase in greenhouse gases would greatly accelerate global warming.

JOURNEY DOWN THE AMAZON

The Amazon starts its journey to the Atlantic Ocean in Peru. Its ultimate source is high in the Andes, Earth's longest mountain range that extends 9,000 kilometres (5,592 miles) along South America's west coast. From there, it flows eastwards through the lowlands of Colombia, Ecuador, Brazil and Bolivia. Joining it on the way are more than 1,000 tributaries with sources in the Andes, as well as the Brazilian and Guiana Highlands.

© Dean Jacobs

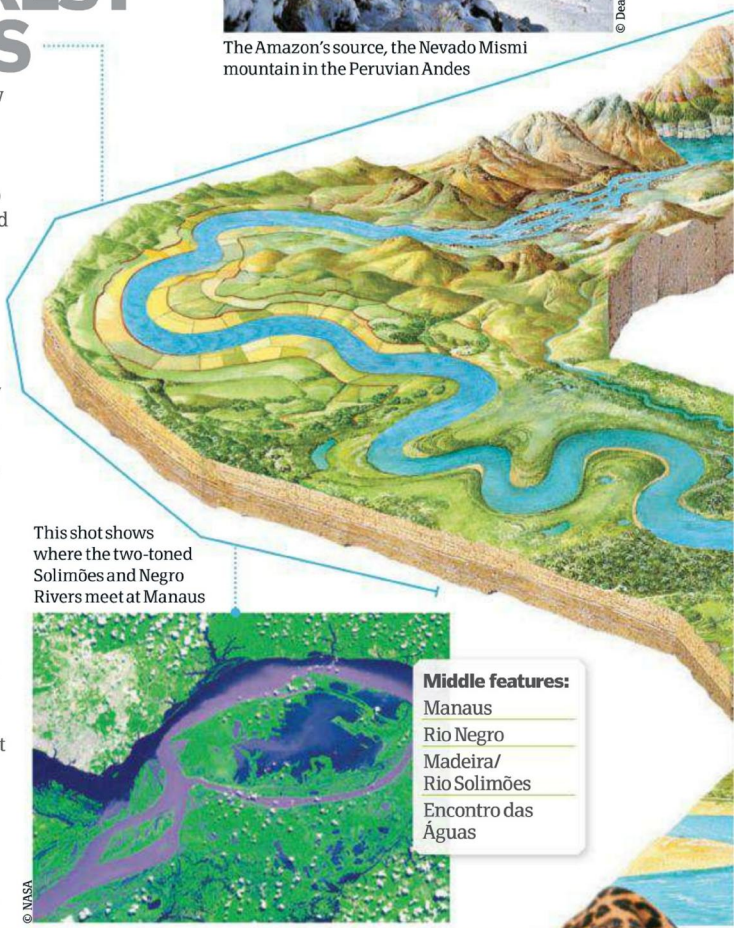
The Amazon's source, the Nevado Mismi mountain in the Peruvian Andes

RAINFOREST REACHES

More than 1,000 tributaries flow into the Amazon as it winds from Iquitos 3,700 kilometres (2,300 miles) downhill through the lowland rainforest. The two biggest are the Rio Solimões and Rio Negro, which join the Amazon downstream of the jungle port of Manaus, 1,600 kilometres (1,000 miles) from the ocean. Sea-going ships can travel upriver to Manaus.

Rio Negro means 'black river' because the waters are stained tea brown by decaying forest leaves. This river contains little sediment because it begins on the hard ancient rocks of the Brazilian Highlands.

The 3,380-kilometre (2,100-mile)-long Solimões, meanwhile, originates in the Andes, which are eroding rapidly. Its waters are yellowed by around 400 million tons of sediment each year, which is equivalent to the annual weight of Britain's discarded rubbish. When the Solimões and Negro meet, their different-coloured waters remain unmixed and flow side-by-side for about five kilometres (three miles); this is the Encontro das Águas.



This shot shows where the two-toned Solimões and Negro Rivers meet at Manaus

© NASA

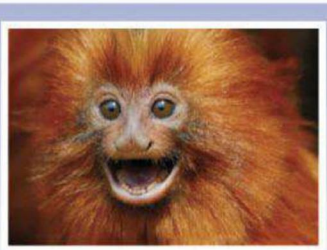
Middle features:
- Manaus
- Rio Negro
- Madeira/ Rio Solimões
- Encontro das Águas

Amazing Amazon Animals

© Jens Rasschendorf

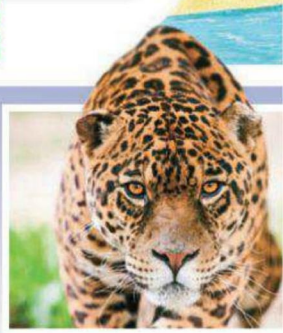
Boa constrictor

These snakes kill by crushing creatures in their coils before swallowing them. Up to a staggering four metres (14 feet) long, they can eat prey whole by dislocating their jaws.



Golden lion tamarin

These squirrel-sized monkeys are among Earth's most endangered species with fewer than 1,500 left in the wild. Around 90 per cent of their habitat has been cut down.



5 TOP FACTS
LONG RIVERS

1 Amazon
6,800km (4,225mi) – The Amazon is the biggest river in the world by flow, and arguably Earth's longest river. Its more than 10,000 tributaries drain the Earth's largest river basin.

2 Nile
6,695km (4,160mi) – The Amazon's rival for the title of longest river, the Nile is typically considered the winner. It has two main tributaries: the White and Blue Nile.

3 Yangtze
6,300km (3,915mi) – Asia's longest river and Earth's third-longest. China's Three Gorges Dam holds back the Yangtze behind a wall stretching over 2km (1.2mi).

4 Mississippi-Missouri
5,971km (3,710mi) – The Mississippi and its tributaries are Earth's fourth-longest river system. The Mississippi Basin covers more than 32 per cent of the US's land area.

5 Yenisei-Angara
5,539km (3,442mi) – The Yenisei in Russia is Earth's seventh-longest river, depending on where you start measuring. The river's tributaries arguably flow via Lake Baikal, Earth's deepest freshwater lake.

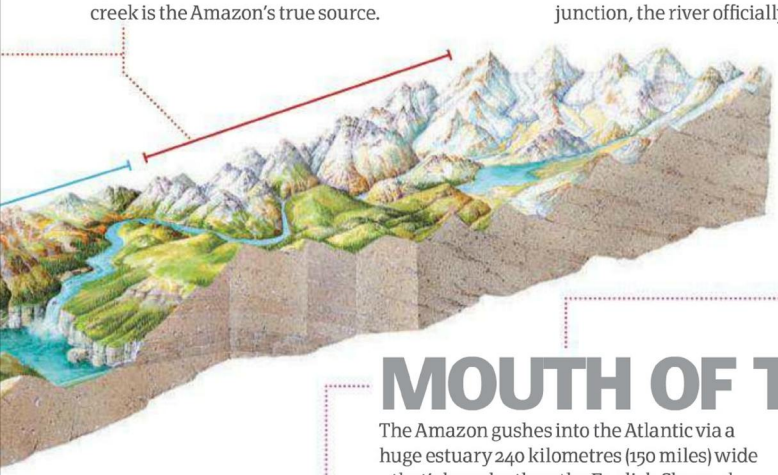
DID YOU KNOW? *Half the world's approximately 100 undiscovered tribes of people live in the remote Amazonian rainforest*

THE UPPER AMAZON

The Amazon's source is on the ice-covered slopes of Nevado Mismi, a 5,597-metre (18,363-foot) mountain in southern Peru. Trickles of snowmelt become hundreds of tiny rivulets, which grow into creeks as they run downhill. Amazingly, no one had pinpointed the Amazon's origins more accurately than 'the Andes' until as short a time ago as the Nineties. Scientists still debate which creek is the Amazon's true source.

These creeks merge to become the Apurímac River, which cascades through Earth's third-largest canyon as white-water rapids. The Apurímac joins the Urubamba, which flows beneath the Incan city of Machu Picchu to form the Ucayali. This meanders northwards through thick forests east of the Andes until it joins the Marañón River, southwest of Peruvian port Iquitos. At this junction, the river officially becomes the Amazon.

Upper features:
- Nevado Mismi
- Iquitos
- Apurímac Canyon
- Ucayali River
- Machu Picchu



The longest chain of barrier islands in the world (54 in total) sit south of the river's mouth

MOUTH OF THE AMAZON

The Amazon gushes into the Atlantic via a huge estuary 240 kilometres (150 miles) wide – that's broader than the English Channel. Here the river drops its sediment as a maze of islands, salt marshes and sandbanks.

The estuary is split into several smaller channels. North of Marajó, an island larger than Denmark, the main river divides into two. A smaller arm of the Amazon runs south of Marajó past the Brazilian port city of Belém.

The estuary has no delta. Ocean currents carry the 1.3 million tons of sediment that the Amazon discharges daily north-west to form an underwater debris cone.

Tides flow up the estuary, changing river levels perhaps 970 kilometres (600 miles) from the ocean. Before spring tides, a tidal bore called the pororoca roars upriver at speeds of more than 24 kilometres (15 miles) per hour forming a four-metre (12-foot) water wall.

Lower features:
- Marajó Island
- Belém
- Tocantins River
- Pará River

THE AMAZON RIVER

Length: 6,800km (4,225mi)

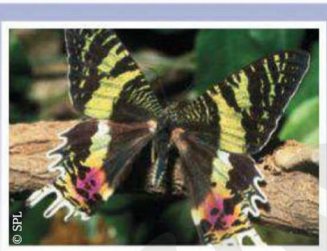
Discharge: > 119,000m³/s (4,200,000 ft³/s)

Maximum elevation: 6.5km (4mi)

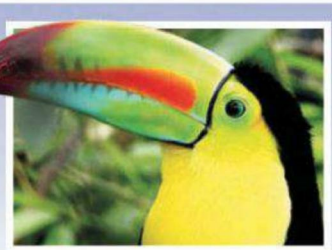
Drainage/ basin area: 7,050,000km² (2,720,000mi²)

Outflow: Atlantic Ocean

Jaguar
Earth's third-biggest cat after tigers and lions, jaguars can be 1.8 metres (six feet) long and weigh 550 kilograms (250 pounds). Once widespread, they're now common only in remote regions like the Amazon.



Urania moth
These vivid, iridescent moths are active during the day – unlike the vast majority of moths – and live along rainforest riverbanks. They are migratory, often flying along the course of rivers.



Toucan
The toucan's bright-coloured bill can reach a huge 19 centimetres (7.5 inches) long – that's 30 per cent of the bird's body length! The beak is very light though because it's honeycombed with air.

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5 TOP FACTS
ALGAE

Iron fertilisation
1 Deliberately triggering huge plankton blooms by scattering powdered iron into ferrous-deficient oceans could help algal blooms to absorb excess CO_2 in the atmosphere.

'Oilgae'
2 Algae can be turned into biofuel by cultivating special oily species and crushing them (or adding chemicals) to extract the oil. This becomes biodiesel, which can then be used as a green fuel.

Snow blooms
3 Another colourful consequence of algae occurs on the surface of Arctic ice. Also known as watermelon snow due to its pink appearance, this bloom is down to a green algae that contains a red pigment.

Alien algae
4 It has been suggested that there could be algae present in the subterranean ice on two of the four Galilean moons of Jupiter: Ganymede and Europa.

Edible algae
5 A common form of algae is seaweed, which is very good for you. It's high in protein, low in fat and also contains a number of health-promoting minerals.

DID YOU KNOW? *Human activity, such as agricultural runoff, can also be to blame for the excess nutrients that can cause red tides*

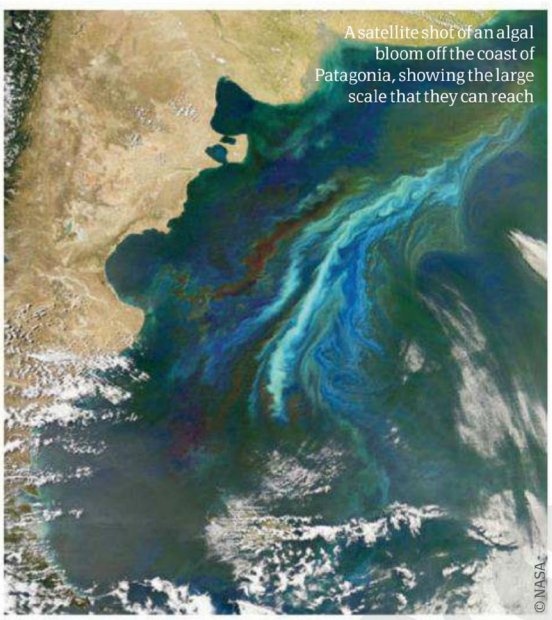
What causes red tides?

Why crimson seas are not as unbelievable a sight as you might first think...

A red tide is the rapid accumulation of a mass of aquatic algae made up of mobile single-celled micro-organisms called dinoflagellates – which means 'whirling whip' due to the nature of the tail-like projections that propel them through the water. The algae grows, or blooms, more rapidly than usual in order to consume nutrients that have suddenly risen up from the colder depths of the ocean below. The red hue is down to the presence of a certain species of dinoflagellate, or phytoplankton.

Together with the more abundant diatom algae, dinoflagellates make up the majority of ocean plankton. Despite the rather startling appearance of a sea turned red, many algal blooms are actually harmless. However, you shouldn't consume seafood following a red tide as certain phytoplankton can release harmful substances into the water. Some dinoflagellates can produce toxins when eaten by other creatures and the harmful substances then concentrate inside the creatures that feed on them, and subsequently any humans who go on to dine on the contaminated seafood.

The billions of microscopic dinoflagellates in a red tide can also cause spectacular bioluminescence at night. One species in particular – the lingulodinium polyedrum – can create its own light from within. When the organism is jostled or collides with something in the ocean, a chemical reaction occurs when an enzyme called luciferase and a substrate called luciferin, both contained within the organism, combine. This is the catalyst for a chemical reaction that releases a flash of blue light. When this occurs millions of times simultaneously, the effect is quite remarkable for onlookers.


A satellite shot of an algal bloom off the coast of Patagonia, showing the large scale that they can reach

© NASA


A dinoflagellate algae in all its bioluminescent glory

2X © SPL

"Despite the startling appearance of a sea turned red, many algal blooms are actually harmless"

"Amazingly, it's the male seahorse that bears the young"

Dust storms / Lithops / Seahorses

Some of the biggest dust storms take place in the Middle East where they're known as haboobs

Dust storms

What causes immense clouds of dust to form and sweep across the land?

Although common in the American Southwest, dust storms occur all over the world. They form when the wind in a dry sandy region – without the moisture needed to hold the earth together – is high enough to dislodge the top layers of dirt.

When the wind displaces these soil particles, silt, and sand they can be transported huge distances via a number of processes, including suspension and saltation. Suspension involves the smallest particles of dust that can literally be suspended in the air and carried on the wind. Saltation, meanwhile, occurs when larger grains bounce along the ground, picking up and dislodging more particles along the way.

In the Thirties, a series of major dust storms tore through the Great Plains of North America. Known as the Dust Bowl, these storms were caused by a combination of serious drought and high winds, as well as a more human factor. During WWI, a high demand for food led farmers to work the land intensively, doing away with crop rotation, leading to loose, dry topsoil. This, together with arid conditions and high winds, resulted in many dust storms that left the landscape unrecognisable.

Living stones

Why do these plants look like pebbles?

© Succa

The lithops (from lithos, meaning stone) genus of flowering plant, similar to the cactus, is a remarkable species that – although entirely organic – looks like a small pebble. Botanist William Burchell found the plant while exploring Africa in the early 1800s. So-called living stones, these plants grow mainly in the sandy soils of the southern hemisphere, where a rocky appearance serves as a great disguise.

The structure of the living stone consists of two oversized fleshy leaves that have evolved to retain moisture. The leaves have a split in the middle from which a daisy-like white or yellow bloom appears during the summer in its native territory, such as South Africa.

Horse-like appearance

Unlike actual horses, seahorses are not speedy sprinters. In fact it's quite difficult for this creature to get around

Brood pouch
The female deposits her eggs here for the male to fertilise in his body. The eggs remain in the brood pouch until they hatch into baby seahorses and venture out.

Body
The entirety of a seahorse's body – except for the male's brood pouch – is protected by plates of bony armour, so predators tend to leave seahorses alone. Their size ranges from 1.5-35cm (0.6-14in) long.

Dorsal fin
For propulsion the seahorse has a small dorsal fin, which can flutter around 35 times per second. The creature moves vertically up and down through the water by increasing or decreasing, respectively, the volume of gas that's inside its swim bladder.

Seahorses explained

Discover what makes this equine marine creature so unusual

Usually found in the sheltered shallows of warm coastal areas, the seahorse is a breed of bony fish that mates for life. They swim upright and have a distinctly horse-like appearance, hence their name. Amazingly, it's the male of this species that bears the young. The female deposits her eggs into the male's brood pouch on its ventral side, which he then fertilises internally. The eggs later hatch into tiny seahorses inside this pouch.

Stomach (not shown)
That's a bit misleading as the seahorse actually doesn't have a stomach. Instead the food they eat – note, they have no teeth – passes straight through their system. This is why they must consume so much.

Prehensile tail
The seahorse uses this tactile appendage to cling to corals, reeds and other marine vegetation so they can catch passing tiny sea creatures.

© TasS

THE STATS
GIANT'S CAUSEWAY

AVERAGE COLUMN DIAMETER 45cm (17.7in)

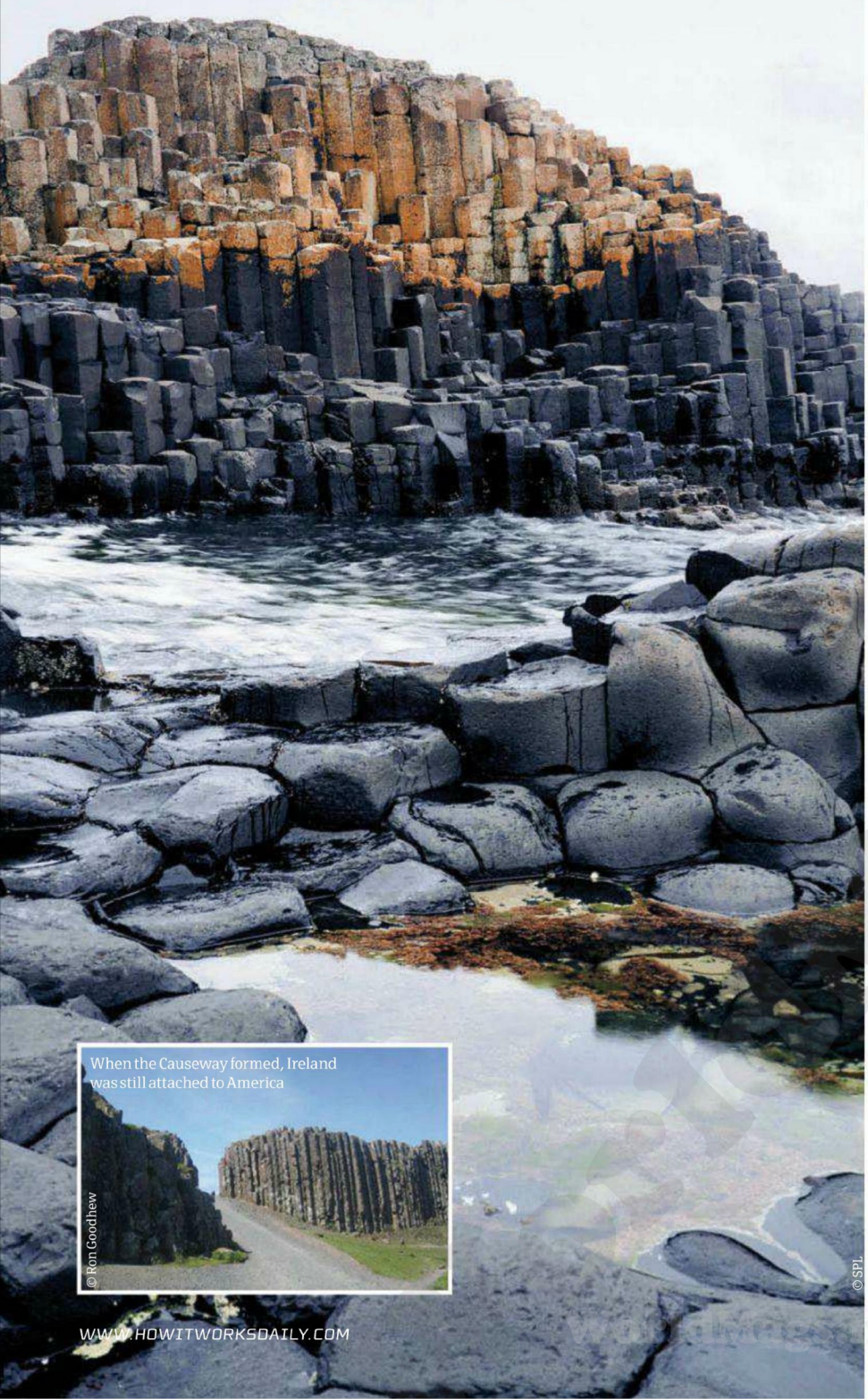
APPROX AGE **62-65m yrs**

ANTRIM PLATEAU AREA **3,800km² (1,467mi²)**

TALLEST COLUMN 12m (36ft)

DID YOU KNOW? *Local legend says that the Giant's Causeway was created by a giant called Finn McCool*

How was the Giant's Causeway formed?



When the Causeway formed, Ireland was still attached to America

© Ron Goodhew

© SPL

Discover the origins of this geological phenomenon in Northern Ireland which consists of around 38,000 basaltic columns

On the north-east coast of County Antrim in Northern Ireland lies an unusual rock formation which draws in millions of visitors from around the world every year. They flock to see a vast plateau of polygonal basalt columns – commonly known as the Giant's Causeway – which looks like a carpet of enormous stepping stones extending out into the Irish Sea. The basalt pillars that make up this amazing rock formation dramatically range in size from a matter of centimetres to several metres high.

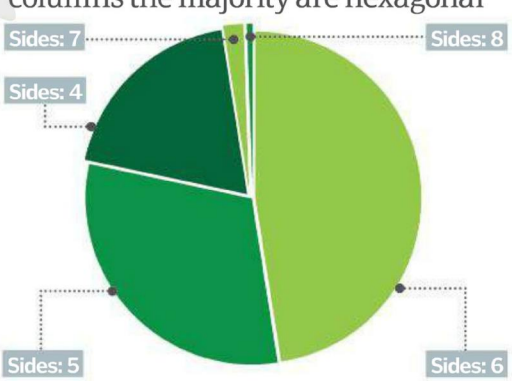
Although the Giant's Causeway is so-named due to an ancient legend, its formation actually began up to 65 million years ago during the Tertiary period when volcanic activity forced tectonic plates to stretch and break. This caused magma to spew up from inside the Earth and spill out across the surface as lava.

The temperature of erupting lava can range from between 700 and 1,200 degrees Celsius (1,292 and 2,192 degrees Fahrenheit). However, upon contact with the surface it will immediately begin to cool. At first this cooling is extremely rapid and this results in a hardened crust forming on top of the superhot substance, which insulates the still liquid lava below. Because the lava is now insulated the cooling becomes increasingly slow over time. While you could probably walk on the crust after just half an hour or so, thick lava flows can take many years to cool completely and solidify all the way through.

While the temperature falls the lava dries out, and it's this drying that causes the solidifying lava to crack and form regular pillars of basalt rock. The size and shape of each column is determined by the rate at which the lava cools and dries, and therefore the speed at which what's called the 'drying front' moves. Scientists from the University of Toronto discovered that the slower the cooling rate the larger the basalt columns that formed.

Polygonal pillars of rock

Though the number of sides to each pillar varies, of the 38,000 basalt columns the majority are hexagonal



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5 TOP FACTS
PYTHONS

Record breaker
1 The longest python recorded was a reticulated python called Fluffy. Although native to SE Asia and the East Indies, Fluffy lived at a zoo in Ohio, USA, and measured a whopping 7.3m (24ft).

The pits
2 Before killing their prey through constriction, pythons seek out their warm-blooded dinner with special heat-sensing pits located in their mouths, between their eyes.

Mini me
3 Pythons can lay up to 100 eggs at a time – usually in the vacated burrows of other animals. The baby pythons are born alive and look just like miniature versions of their adult counterparts.

Pythons can swim
4 There are some 30 different species of python, all of which are good swimmers. Most species are ground-based, but some climb trees while others burrow underground.

Vestigial hind limbs
5 Like boas, pythons possess visible pelvic spurs, which are the evolutionary remnants of back legs. These tiny bones towards the tail end suggest they descended from lizards.

DID YOU KNOW? *The African rock python is a protected species which plays a vital role in controlling rodent populations*

Rock pythons have a diverse diet which includes everything from small antelopes to crocodiles

©SPL

©GJ Alexander

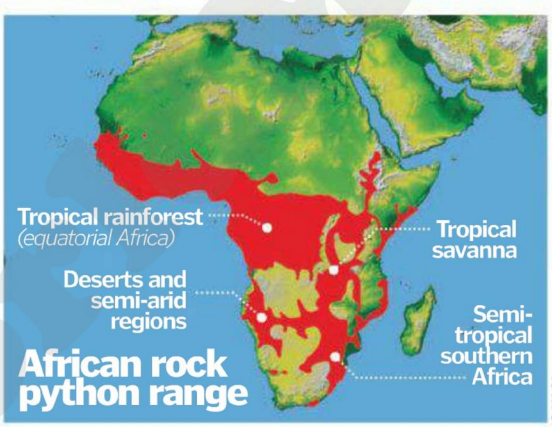
Rock pythons

Discover how Africa's largest snake kills and consumes its prey

Despite being non-venomous, the python remains one of the world's most dangerous serpents. The African rock python, in particular, is a very deadly assassin, also notorious for being ill-tempered.

Pythons incapacitate their prey by literally squeezing the life out of them, coiling their long – sometimes seven-metre (23-foot) – bodies round the victim and tightening their grip until the animal, unable to breathe, eventually suffocates. That done, the python then sets about consuming their meal... in one go.

Equipped with a set of highly flexible jaws, stretchy skin and ribs hinged with extra-supple tissue, the African rock python can down its quarry whole. First the python slides its mouth over the head of the prey and then gradually moves its body along the length of the animal with the help of an expandable throat and abdomen. The animal is then digested over a matter of hours, or even days if it's particularly large. Following such a meal, the python need not eat again for several weeks.



©NASA

The statistics...

©Tigerpython

Rock pythons

Type: Reptile
Genus: Python sebae
Diet: Carnivore
Life span in wild: Up to 25 yrs
Weight: Up to 100kg (220lb)
Size: Up to 7m (23ft)

"There are now roughly 500 million domestic cats around the world"

Domestic cats

The tricks, skills and amazing features of the world's most popular pet

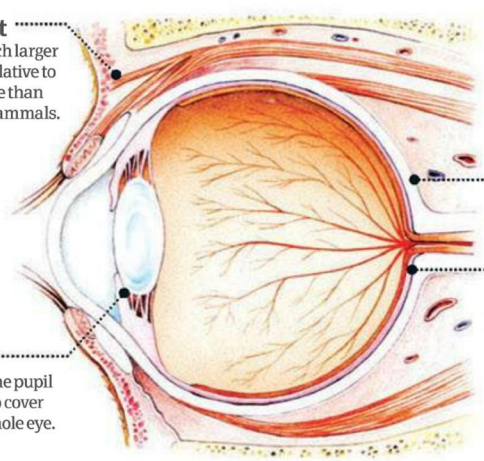
Cats originated in the Middle East, descended from the African wildcat. They were domesticated sometime in the Stone Age, probably around the development of agriculture, when grain stores began to attract rats and other pests to human settlements. Cats in the wild make almost no sounds to one another, but among humans they have a wide repertoire of purrs, hisses, mews and yowls. These are all designed to communicate with us and research has shown that stroking a cat stimulates the hormone oxytocin in humans, which helps us feel relaxed and happy. A 9,500-year-old grave in Cyprus has been found of a Neolithic human buried next to a cat. There are now roughly 500 million domestic cats around the world but genetic analysis has revealed that they are all descended from just five females.

Many domestic cats have a semi-feral lifestyle where they will take food from several different households as well as hunting for themselves. To this end, cats still retain most of the hunting skills and instincts of their ancestors. Cats are quite hardy and can get all the water they need from eating meat. Interestingly, they can also drink seawater. Cats mainly hunt at twilight; their eyes can operate with just one-sixth of the light that we would need to see by and their hearing is among the most acute of any mammal. In the UK, cats kill 64.8 million birds a year; indeed, 30 per cent of all sparrow deaths are down to a feline culprit.

HEARING

Cats can point their ears forwards or backwards independently to pinpoint sounds. The complex folds and flaps help with this as well, by cancelling out certain frequencies of sound and amplifying others. Cats can hear frequencies a whole octave higher than even dogs.

How cats' eyes work

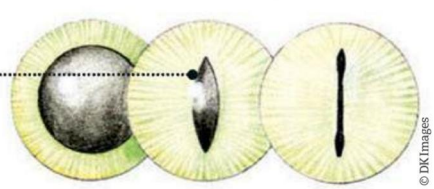


Eye socket
Cats have much larger eye sockets relative to their skull size than most other mammals.

Tapitum lucidum
A reflective layer on the back of the retina. Light is bounced back for another opportunity to be absorbed.

Pupil
In low light, the pupil can expand to cover almost the whole eye.

Retina
Cats can distinguish blue and yellow-green colours but have limited sensitivity to red.



Slit pupils
To prevent image distortion in bright light, cats contract their pupils to a slit instead of a point.

1. FLUFFY

Maine Coon
According to folklore, this North American breed is the result of feral cats mating with raccoons. Alas, that's genetically impossible.

2. FLUFFIER

Turkish Angora
This ancient breed has medium-length fur with no undercoat. In Turkey, the breed is considered a national treasure.

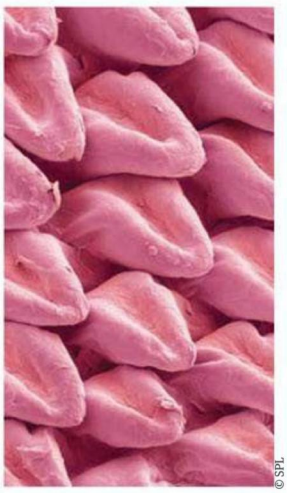
3. FLUFFIEST

Persian
The very long coat is a recessive mutation. Originally Persian cats had longer muzzles, until breeders selected for the flatter face.

DID YOU KNOW? *Cats are extremely tolerant of heat and can survive up to 56°C if they have access to water*

SMELL

The inside of a cat's nose has twice the surface area of a human's and their sense of smell is 14 times more sensitive than ours. Catnip contains the chemical nepetalactone, which is similar to cat pheromones and cats can detect this at concentrations of less than one part in a billion.



© SPL

TASTE

All members of the feline family lack one of the genes needed to be able to taste sweet things. Cats have very rough tongues, but when they drink only the smooth tip is dipped into the water. Cats are lactose intolerant and milk can cause stomach upsets.

TOUCH

Cat whiskers have sensitive nerve endings that allow the animal to build a three-dimensional map from air currents and contact with objects. When a cat bites, the whiskers bend inward to form a basket so that it can pinpoint the location of its prey even when it is too close to see.

How do cats land on their feet?

The self-righting reflex develops at seven weeks old. In a 30cm fall, cats can perform a midair 180° turn

1. Curl up
The cat starts by bending in the middle, so the front and back halves rotate around two different axes.

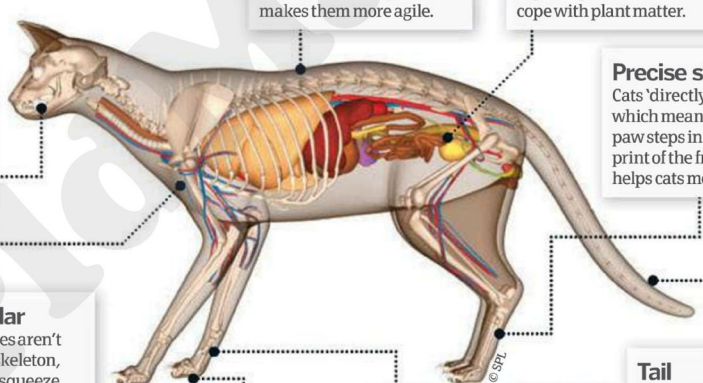
2. Tuck and spread
The front legs are pulled in and the back legs spread out wide.

3. Half twist
When the spine twists, the front half rotates faster than the back, like an ice skater tucking in for a spin.

4. Repeat
Pulling in the back legs and spreading the front allows the cat to repeat the procedure to rotate the rear.

© DK Images

Cat anatomy



© SPL

Extra vertebrae
Cats have one more thoracic vertebra and two more lumbar vertebrae than humans in their spine. This makes them more agile.

Short intestine
Cats are obligate carnivores. Their short intestine is specialised for digesting meat and can't cope with plant matter.

Precise steps
Cats 'directly register', which means the hind paw steps in the paw print of the front. This helps cats move silently.

Teeth
The canine teeth are very closely spaced. Cats kill by severing the spine at the neck.

Floating collar
The clavicle bones aren't attached to the skeleton, allowing cats to squeeze through any space that will fit their head.

Paws
Cats are digitigrade, which means they walk on tiptoes, rather than the flat of the foot.

Carpal pad
Resembling a sixth toe, this pad on the wrists provides extra grip when landing.

Tail
The tail helps with balance when jumping, but even cats without tails can right themselves if they fall.

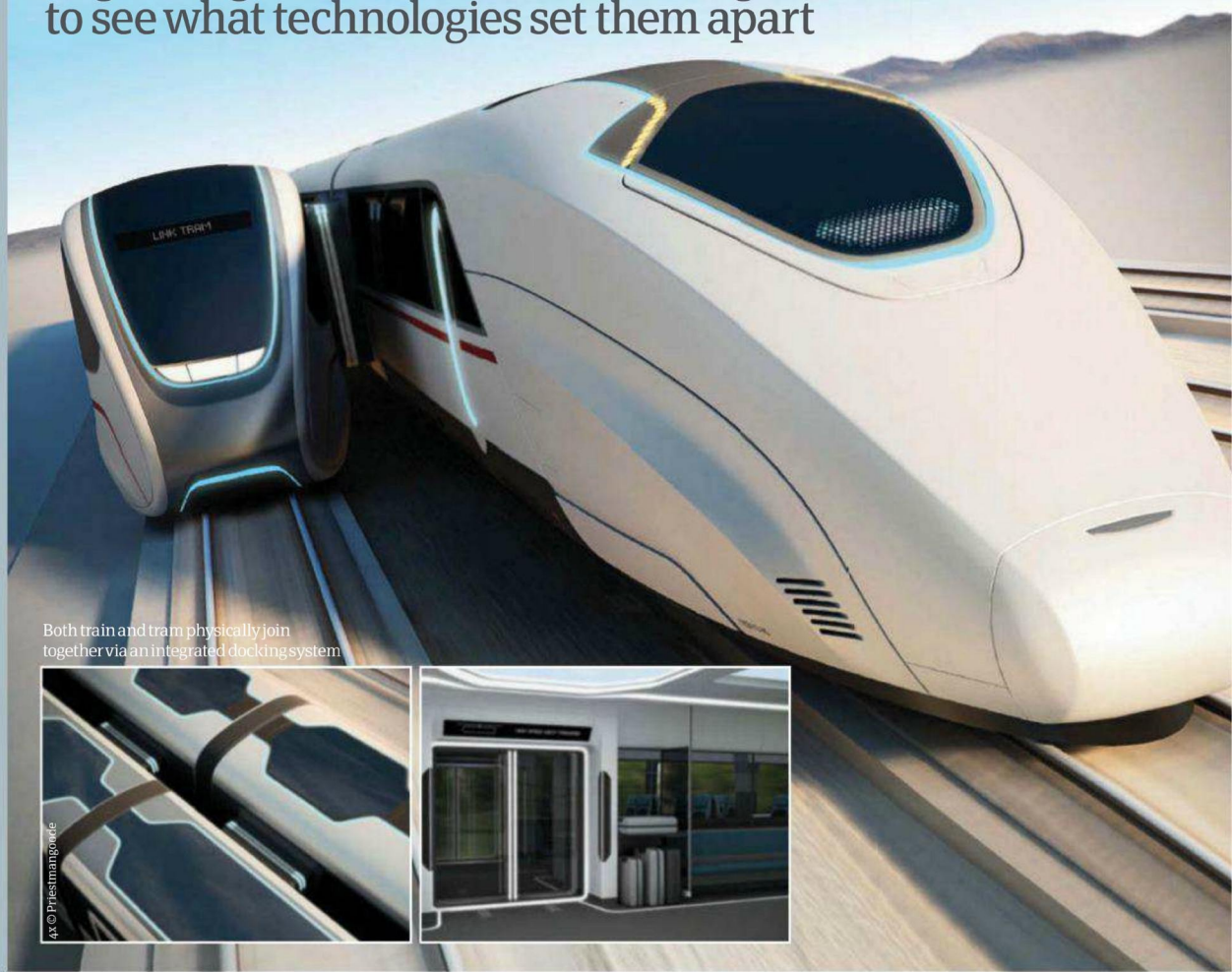
Welcome to... TRANSPORT

Trains have come a long way since the days of chugging steam locomotives. This issue we see all the cutting-edge tech powering the next generation of supertrains, so they're faster, safer and more efficient than ever before. We also celebrate a veteran plane, the C-130 Hercules, and learn how the Cayago F7 can zoom both on and under the sea.

LEARN MORE

SUPER HIGH-SPEED TRAINS

A new series of advanced supertrains are beginning to roll out. How It Works gets on board to see what technologies set them apart



Both train and tram physically join together via an integrated docking system

4x © Priestmangoode

For over 200 years trains and rail travel changed very little. New lines were built and trains travelled on them to and from stations. Sure, speed has increased, with steam engines making way for petrol ones, and those replaced by electric varieties, but fundamentally, there has been little innovation in the field. Compare the evolution in the car or aviation industries in just the last 100 years, and suddenly this becomes more obvious; think of the Wright brothers' biplane to the F-35 Lightning II – the technological advancement is mind boggling.

Excitingly though, with the turn of the first decade of the 21st century, there promises to be a revolution in the field of rail travel. Driven by a need for cheaper, faster and more environmentally friendly forms of travel, the rail industry suddenly finds itself in the spotlight once more, with new designs, technologies and infrastructures aiming to radically overhaul the industry. From novel network structures, to tilting train engineering and on to electronic, fully automated control systems, rail travel is evolving faster than a runaway express. So it's all-aboard as we run through some of the speediest and most innovative rail tech currently on the market as well as what's in the pipeline.

5 TOP FACTS
ALSTOM AGV

Configurations
1 The AGV is offered in trainset configurations of 7, 8, 10, 11 and 14 cars. Up to three seven-car trainsets can be bolted together to form one supertrain before detaching later.

Customised
2 Each AGV trainset is designed basically as a hollow tube that operators can then fit out. Areas for leisure, work, meetings, reading and rest can all be installed accordingly.

Connected
3 AGV trains are equipped with an Ethernet backbone. This delivers both on-board internet as well as Wi-Fi and a host of multimedia services. The system is also modular.

Peaceful
4 The driver's cabin has been optimised for noise reduction, with the result of intensive acoustic studies bringing levels within the cab down to 78dB at 330km/h (205mph).

Savings
5 Each AGV delivers energy savings of 15 per cent compared to older models. This is due to a reduction in weight, the number of bogies (wheel trolleys) and reduced aerodynamic drag.

DID YOU KNOW? *The first AGV fleet is currently in operation by Italy's Nuovo Trasporto Viaggiatori (NTV)*

Moving Platforms

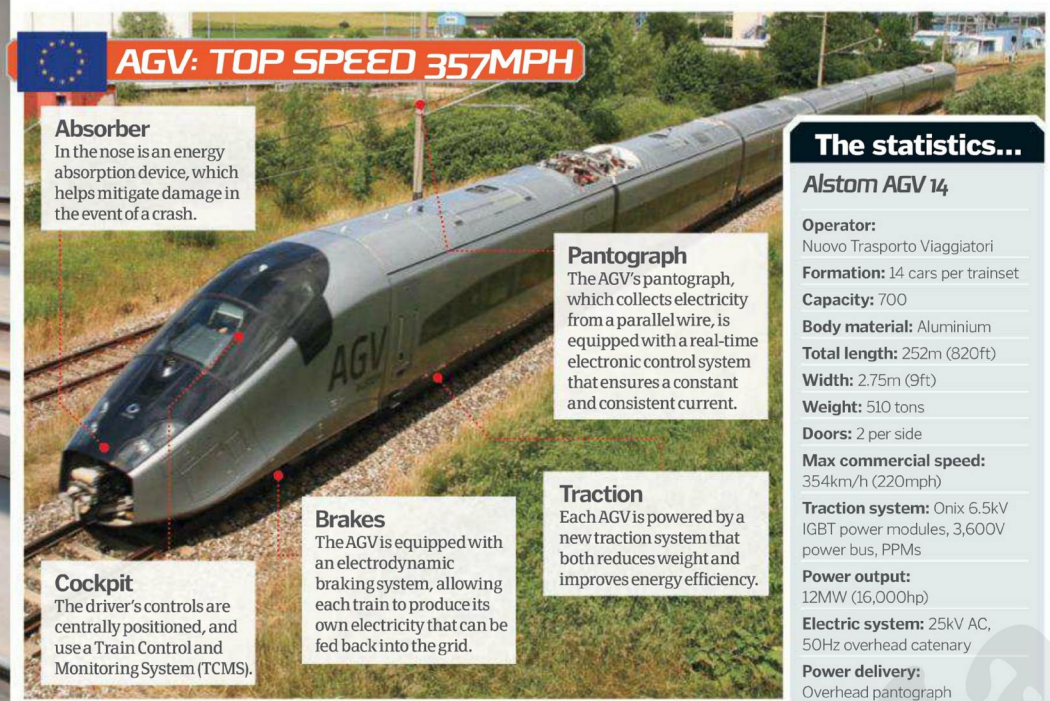
Britain's leading transport designer has unveiled a next-gen concept for an interconnected rail network


Once both vehicles are joined, passengers can transfer from one to the other

Moving Platforms is a brand-new concept for the future of rail travel. Designed by Paul Priestman – creator of the Mercury high-speed concept train – the idea is based on a completely joined-up rail network that allows passengers to transfer from local trams to high-speed trains without ever stopping.

The system works as follows. A network of high-speed trains (like that of the Japanese Shinkansen) runs continuously on a nationwide level. This network runs via major cities and key commuting destinations, carrying many passengers at high speeds. However, as each of these trains passes by a destination, rather than pulling into a station and stopping to let off and let on passengers, it instead merely slows down a little.

As the high-speed train slows, a local lower-speed tram draws alongside it, temporarily matching its speed. Next, the vehicles connect via a dock, before opening their doors to allow passengers to transfer from one to the other. Finally, the train and tram separate again, and proceed on their separate lines, with trams stopping at local stations to allow passengers off the network.



The statistics...

Alstom AGV 14

Operator: Nuovo Trasporto Viaggiatori
Formation: 14 cars per trainset
Capacity: 700
Body material: Aluminium
Total length: 252m (820ft)
Width: 2.75m (9ft)
Weight: 510 tons
Doors: 2 per side
Max commercial speed: 354km/h (220mph)
Traction system: Onix 6.5kV IGBT power modules, 3,600V power bus, PPMs
Power output: 12MW (16,000hp)
Electric system: 25kV AC, 50Hz overhead catenary
Power delivery: Overhead pantograph

EUROPEAN FLYER

The Alstom AGV is a bleeding-edge piece of kit, wrapping up many of the best technologies currently available into a train that can not only cruise at almost 360 kilometres (225 miles) per hour, but do so while delivering a 30 per cent energy reduction over its predecessor.

Indeed, although it boasts other features, speed cannot be overlooked with the AGV. Commercially the train is artificially limited to 354 kilometres (220 miles) per hour, but in a test undertaken by Alstom in April 2007, the AGV's traction and bogie system (a chassis that carries the vehicle's wheels) propelled a test model to a blistering 575 kilometres (357 miles) per hour, which today in 2012 has yet to be topped anywhere in the world. For a little perspective, that is a speed that would get you from London to Istanbul in just under five and a half hours.

This top speed comes courtesy of a water-cooled traction system capable of outputting 11,930 kilowatts (16,000 horsepower). This traction system is composed of multiple Onix 6.5 kilovolt IGBT power modules, a 3,600-volt power bus and, most intriguingly, a selection of in-bogie-mounted permanent magnet motors (PMMs). These magnetic motors are of the asynchronous type and are supplied with electricity via converters in partnership with a high-voltage switch. The motors are arguably key to both the improved top speed of the AGV as well as its huge reduction in energy consumption. This is because they are both lighter and more compact than previous versions, but also because they offer an improved power-to-weight ratio of over one kilowatt per kilogram in addition to sport-simplified ventilation circuits.


© FranMonks

Interview
Paul Priestman

We speak to the designer of the Moving Platforms rail infrastructure concept about the future of trains

How It Works: What was the inspiration for Moving Platforms?
Paul Priestman: I thought why do trains have to stop and, then, why is there such a problem of connectivity between trains? Also that, by their very nature, you can't run high-speed lines through the centre of cities because of the disruption and cost, so how do you get to those stations as they are on the outskirts of cities? Further, stations take up a large quantity of land and are only really used by people for minutes each day, requiring car parks and, as a direct consequence, more cars and buses on the road to get people to them.

HIW: Could you tell us a little about how the Moving Platforms docking system works?
PP: So the idea is that the lower-speed tram travels round a city picking people up and then it moves out and joins a main, higher-speed commuter line that runs parallel in part to the primary high-speed line that the train utilises. Then the high-speed train – which is passing by the city – slows down to 70-80 kilometres [40-50 miles] per hour and the tram speeds up to the same speed, pulling alongside it, and then the two vehicles' systems electronically link to become one, opening an aircraft-style boarding gate between the two. This allows passengers from both vehicles to move into the other.

HIW: What would be the main advantages of such a system if it were to be put in place?
PP: There is both [substantial] speed and energy savings – the latter especially so – as you don't have to keep stopping these large vehicles at fixed stations and then accelerating them once again each time that a passenger transition is made.

"The train has cut commuting times between Shanghai and Hangzhou from 1hr 18mins to just 45mins"

The statistics...

CRH380AL

Operator: Chinese Ministry of Railways
Formation: 16 cars per trainset
Capacity: 1,066
Body material: Aluminium
Total length: 401m (1,317ft)
Width: 3.38m (11.1ft)
Height: 3.7m (12.1ft)
Doors: 2 per side
Max commercial speed: 356km/h (221mph)
Traction system: IGBT-VVVF inverter control
Power output: 20.4MW (27,410hp)
Electric system: 25kV AC, 50Hz overhead catenary
Power delivery: Overhead pantograph

CHINESE DART

The CRH380A is one of the world's fastest trains. Why? Well, a test run top speed of 513 kilometres (319 miles) per hour and artificially limited commercial top speed of 356 kilometres (221 miles) per hour certainly help, as does a maximum power output of a titanic 20,440 kilowatts (27,410 horsepower), but in reality it is due to the collaboration of a number of low-visibility yet integral state-of-the-art technologies.

Let's start with the 380A's aerodynamics and stability. A low-resistance, streamlined head delivers a nose resistance coefficient of less than 0.13 and allows a direct reduction in aerodynamic resistance, aerodynamic noise and aerodynamic lift over its CRH2A predecessor.

This is partnered with a new rigid, pressurised body – which keeps the pressure change rate inside the train at less than 0.002 kilograms per square centimetre (0.029 pounds per square inch) per second – and lightweight aluminium alloy body. Another system also reduces vibrations at high speed to ensure passengers get a smooth ride.

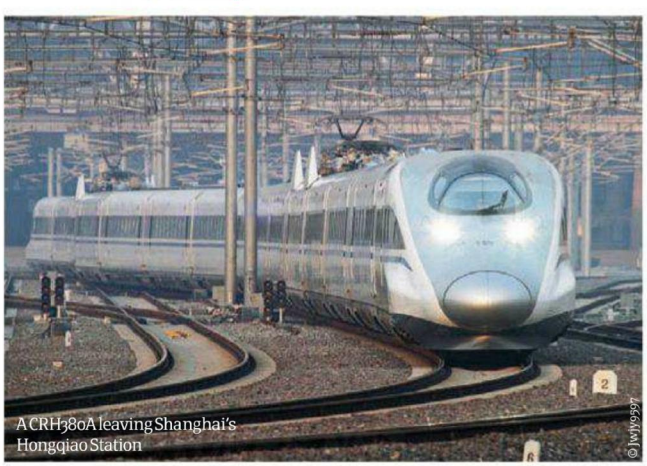
Traction and bogies follow suit. Each 380A is equipped with SWMB-400/SWTB-400 bolster-less bogies, which have been totally redesigned to deliver a critical instability speed of 550 kilometres (342 miles) per hour and a derail coefficient of 0.34 at 386 kilometres (240 miles) per hour. The traction system uses Zhuzhou Electric YQ-365 motors and CI11 converters, which are supported by a new power unit configuration. The combination of both these technologies grants the train a 0-236 miles per hour time of seven minutes.

Lastly it's worth mentioning braking and noise. The 380A utilises a regenerative braking system that, in optimal conditions, produces a feedback energy rate of 95 per cent. This means that with each stop a trainset makes, a substantial amount of electric power can be fed back into the electric grid to be recycled. Noise from braking procedures and general operation has reduced significantly too with the integration of sound-absorbing and insulating materials. These combine to deliver an average noise level of just 67-69dB in the driver's cabin when travelling at 349 kilometres (217 miles) per hour. While this may seem unremarkable at first glance, it becomes more so when you consider that the CRH2A sported the same noise level when travelling at just 250 kilometres (155 miles) per hour!

Despite the 380A's top speed being limited by a computerised control system, since its mainstream introduction in 2010, the train has had a dramatic impact, reducing commuting times between Shanghai and Hangzhou – which amounts to around 180 kilometres (111 miles) – from 1hr 18min down to just 45 minutes.

A 380A's next-generation driver's cabin

"The 380A utilises a regenerative braking system that, in optimal conditions, produces a feedback energy rate of 95 per cent"



A CRH380A leaving Shanghai's Hongqiao Station

AMAZING VIDEO! SCAN THE QR CODE FOR A QUICK LINK

See an Alstom AGV hit 224mph during a test run

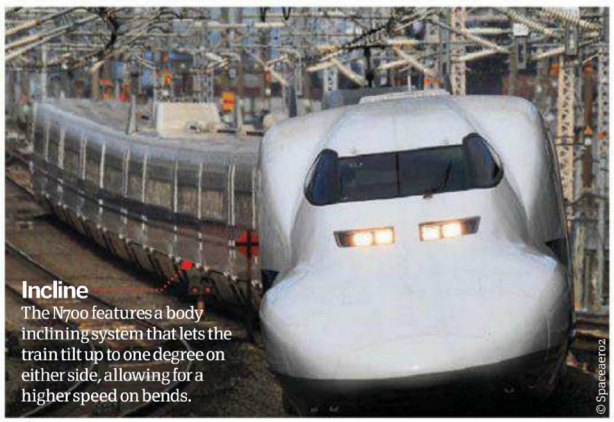
www.howitworksdaily.com

DID YOU KNOW? *The CRH380A has a restricted commercial top speed of 221mph but can reach 319mph*

SHINKANSEN N700: TOP SPEED 205MPH

Acceleration
Thanks to its advanced traction system, the N700 can accelerate at 2.6km (1.6mi)/h/s. This allows it to go from 0-170mph in just three minutes.

Noise
Specially designed low-noise pantographs as well as cover-all hoods for bogies allow the N700 to reduce drag and also noise for passengers.



Incline
The N700 features a body inclining system that lets the train tilt up to one degree on either side, allowing for a higher speed on bends.

© Spareguero2

"Speed comes courtesy of a traction system with 56 305kW units that produces a total power output of over 17,000kW"

JAPANESE BULLET

The Shinkansen N700 is but the latest in a long line of super high-speed trains operated throughout Japan's standard-setting Shinkansen rail network. Delivering commercial speeds north of 290 kilometres (180 miles) per hour, sporting an acceleration rate of 2.6 kilometres (1.6 miles) per hour per second and capable of carrying 1,323 passengers per trainset between Tokyo and Osaka in just 2hrs 25mins, the N700 is, without doubt, one of the best trains on the planet.

Speed comes courtesy of a traction system that consists of 56 305-kilowatt (409 horsepower) units and produces a total power output of over 17,000 kilowatts (22,900 horsepower); that is the equivalent power generation of 19 Bugatti Veyron Super Sports – the world's most powerful road car. This raw power enables the N700 to cruise comfortably at a speed of 300 kilometres (186 miles) per hour, which is artificially limited down from its theoretical top speed of 330 kilometres (205 miles) per hour. The traction system also enables it to accelerate faster than any other trainset in its class on Earth, hitting 274 kilometres (170 miles) per hour in less than three minutes.

Indeed, it's not just the fact that the N700 can reach such high speeds that makes it so cutting edge, but the fact that it does it so efficiently – and can maintain it over long periods of time. The key to the N700's consistent cruise speed is its air spring-powered active tilting system, which allows the train to tilt up to one degree on either side. This body inclination enables the N700 to accelerate continuously at a constant rate even when traversing curves in the rail track. Thanks to this feature, the N700 sports a 0-270 kilometre per hour time of only 180 seconds – precisely 120 seconds faster than stock 700-series trainsets.

What is perhaps most remarkable about the 700 series, though, is its reliability and safety. First, the Shinkansen network runs across train tracks without obstacle (that is, there are no crossings), elevating the track when necessary to avoid things like roads. Second, the average delay of any 700 series across an entire year is staggeringly just 30 seconds. Third, and finally, throw in the fact that since 1964 the Shinkansen series of trains has not had a single fatality due to rail crashes, and it is easy to see why the N700 and the Shinkansen network as a whole is world renowned.

The statistics...

Shinkansen N700

Operator: Japanese Railway Company

Formation: 16 cars per trainset

Capacity: 1,323

Body material: Aluminium

Car length: 25,000mm (984in)

Width: 3,360mm (132in)

Height: 3,600mm (142in)

Doors: 2 per side

Max commercial speed: 300km/h (186mph)

Traction system: 56 x 305kW (409hp)

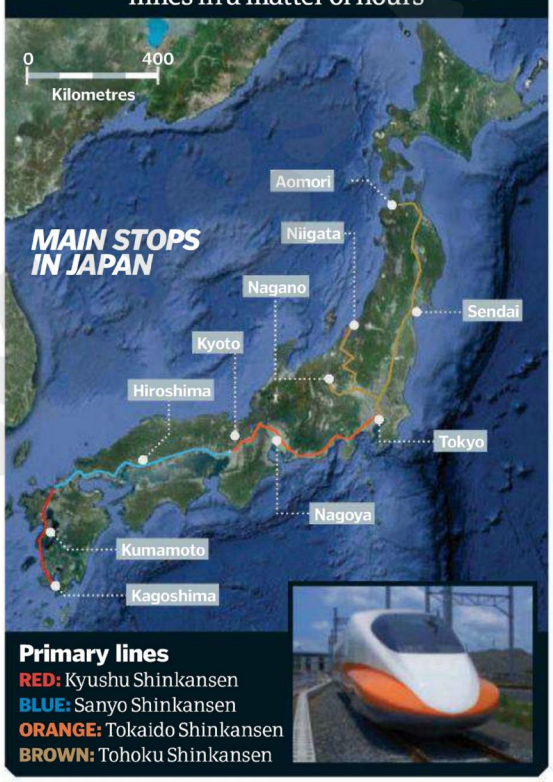
Power output: 17.1MW (22,900hp)

Electric system: 25kV AC, 50Hz overhead catenary

Power delivery: Overhead pantograph

THE ULTIMATE RAIL NETWORK

The Shinkansen network interconnects over 80 per cent of Japan, allowing passengers to travel hundreds of miles in a matter of hours



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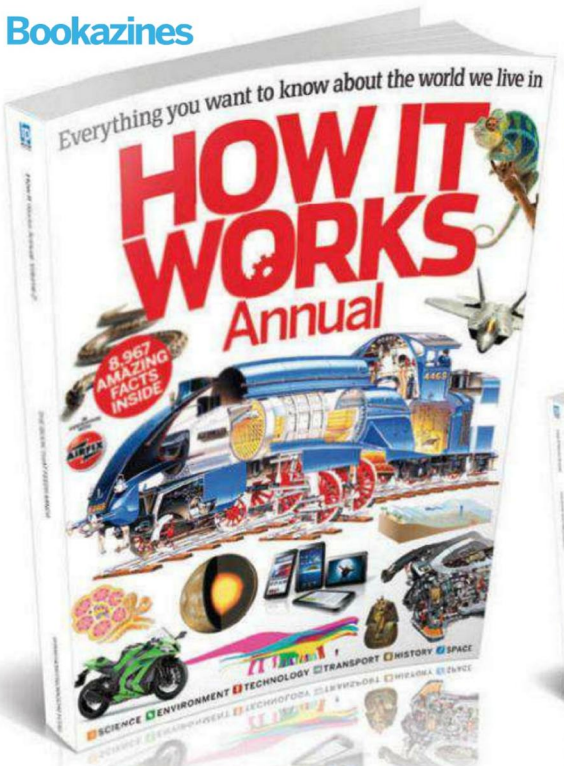

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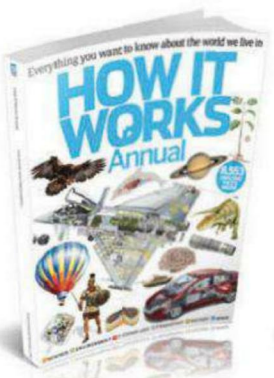

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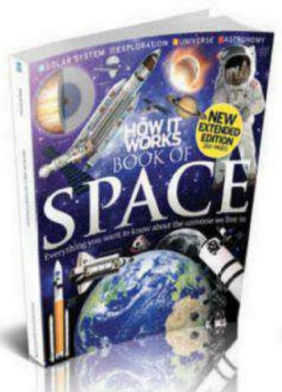

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DID YOU KNOW? *The invention of the oxygen mask is credited to American engineer Lewis P Haslett in 1848*

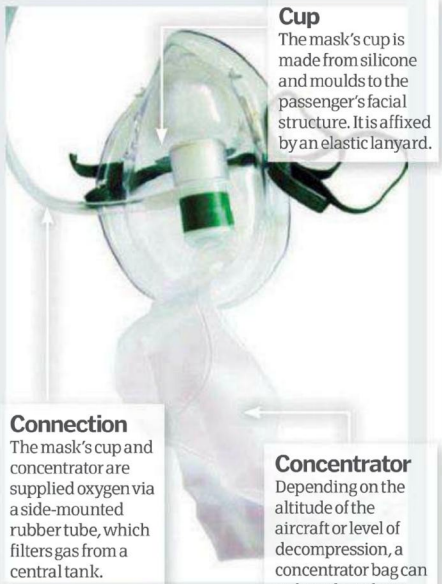
Aircraft oxygen masks explained

How these devices keep us breathing in an emergency

Commercial aircraft are pressurised to a maximum cabin altitude of 2,438 metres (8,000 feet), which is the accepted limit for people to breathe normally. However, if the aircraft's cabin pressure ascends to the equivalent of 4,267 metres (14,000 feet), or if cabin decompression occurs, emergency oxygen masks are required.

Oxygen masks are stored above each passenger's head and can be manually dropped by the pilot or automatically by an on-board electronic system. The mask consists of three main parts: a facial connector, concentrator bag and piping connection.

These masks are fed with oxygen from a central reservoir – usually held in the cargo bay. Importantly, emergency oxygen masks of this type are only intended as a short-term oxygen delivery replacement.



Cup
The mask's cup is made from silicone and moulds to the passenger's facial structure. It is affixed by an elastic lanyard.

Connection
The mask's cup and concentrator are supplied oxygen via a side-mounted rubber tube, which filters gas from a central tank.

Concentrator
Depending on the altitude of the aircraft or level of decompression, a concentrator bag can reduce the volume of pure gas used.

How do HGVs stop?

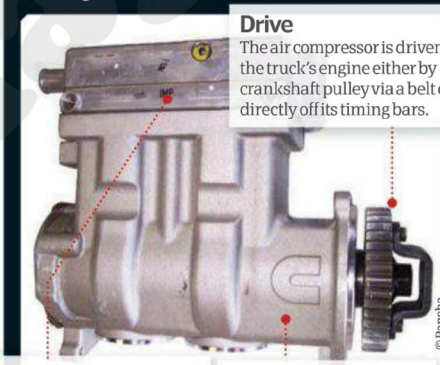
Now a mainstay of heavy-duty road vehicles, air brakes can stop mighty loads quickly and safely

Air brakes were originally designed to stop trains, however today – due to reduction in their component size and cost – they are equipped to many heavy-duty road vehicles too.

Air brakes work differently to those on standard road vehicles, creating a system where the brakes are always on when in a neutral state. As such, rather than using compressed air to activate a vehicle's brakes, it is used instead to deactivate them. This is a design feature very much aimed to maximise safety, as if the air brake system fails (ie the system depressurises), then the vehicle will automatically stop rather than suddenly have no brakes at all.

A compressed air brake array is divided into a supply system and control system. The former draws air into a compressor from the surrounding environment, filters it for impurities, stores it in a reservoir and then distributes it to the control system. The latter consists of a brake circuit and trailer brake circuit, which themselves are split into front and rear wheel circuits. These individual circuits receive air from the supply system's reservoir.

As such, the brakes of heavy-duty road vehicles are essentially engaged on a permanent basis, requiring the driver to disengage them to accelerate – ie the brake circuits' release valves are opened, dropping the contained air pressure and releasing the physical brake components (ie the callipers and brake pads) from the wheels, leaving the vehicle free to move.



Drive
The air compressor is driven off the truck's engine either by crankshaft pulley via a belt or directly off its timing bars.

Distribution
Filtered air is stored in a reservoir from which it is distributed via a four-way protection valve into the front/rear brake circuits.

Filter
Compressed air is drawn in and then routed through a cooling coil and air dryer to remove moisture and any impurities in the oil.

© Panoha

Jet
The F7's means of propulsion, the E-Jet is an electric jetstream system consisting of an electro-motor and encased running impeller within a jet channel.

Accumulator
The F7 is installed with a modular-designed accumulator box, which stores the Li-ion battery. The box is easily removed for recharging.

Shell
The F7's shell is formed from hard-integral plastic composites and features a hydrodynamic surface coating to maximise speed and agility in the water.

Cockpit
An LCD display delivers the pilot key data from the motor's electronic system, like remaining operating time.

Grip
The F7's control grips allow the pilot to both accelerate and decelerate smoothly, as well as program the unit's data menu.

Seabob Cayago F7

The ultimate high-performance marine toy explained

The Cayago F7 is Seabob's flagship water and diving scooter. It allows a user to traverse marine environments at high speed and agility, be that either across the surface of the water, or diving through it down to a depth of 40 metres (131 feet).

The F7 is powered by an E-Jet, an electric jetstream system that works on the principle of water displacement. Water is drawn into the E-Jet when the F7 is in use by a powerful rotating impeller and then forced out in a jet channel under high pressure. This method of propulsion allows it to hit 22.5 kilometres (14 miles) per hour across the surface of the water and 15.9 kilometres (ten miles) per hour when diving.

Due to the high power of the F7, pilots can choose to be strapped to it via an integrated belt system, which is top-rear mounted to the unit. This enables users of the marine vehicle to dive at high speeds and perform sharp turns without any fear of losing grip on the Seabob's control handles.

Finally, the device is powered by a lithium-ion battery array, which is installed within the F7's front-centre-slotted accumulated box that, due to its modular design, is easily removed from the unit's main shell for a simple recharging process.

Seabob's top-of-the-range Cayago F7 can propel its user at speeds up to 15.9km/h (10mph) when underwater

2x © Seabob

"[The Hercules C-130 has the] ability to lift the equivalent of seven fully grown African elephants"

C-130 Hercules

One of the longest-lasting and most widespread military transport vehicles of all time, the C-130 Hercules remains to this day an aerial behemoth, capable of flying thousands of miles to deploy troops and vehicles alike

The C-130 Hercules is a military transport aircraft famed for its durability and versatility, having been in active service for over 50 years. Since its introduction in December 1957, over 40 models and variants of the Hercules have been produced and are used today by more than 60 nations worldwide.

The aircraft works by delivering a cavernous central fuselage in which the vast cargo bay can carry a plethora of civilians, soldiers, vehicles, equipment, weapons and supplies over huge distances. This makes the Hercules an ideal tool to aid military operations in the 21st-century battlefield, a global theatre of war where mission parameters often need to adapt fluidly and at high speed.

Indeed, the sheer lifting power of the C-130 cannot be overstated, with a single plane capable of lifting northwards of 33,000 kilograms (72,753 pounds). To put that in context, that is an ability to lift the equivalent of seven fully grown African elephants or 44 Mini Metros! As a heavy-lifting workhorse, the C-130 has few competitors capable of matching it and, as such, has seen off several contenders that were supposed to replace it (such as the C-5 Galaxy) and even spawned a larger but rarer Super Hercules variant.

All that lift comes courtesy of four Allison T56 turboprop jet engines, each capable of generating 3,423 kilowatts (4,590 shaft horsepower). The combined output makes this plane more powerful than 15 Bugatti Veyron Super Sports – the most powerful car on the planet. It also means the Hercules can not just lift more than 33,000 kilograms (72,753 pounds), but it can do so at both high altitude (the C-130 has a service ceiling of 10,000 metres (33,000 feet) and at high speed, with a cruise speed of 541 kilometres (336 miles) per hour. In addition, the titanic turboprops allow the Hercules to climb at a rate of 9.3 metres (31 feet) per second, a fact that allows it to quickly get airborne and out of range of many anti-aircraft armaments.

Interestingly, despite the US Air Force aiming to instigate a programme to produce a replacement for the C-130 in 2014 – for eventual delivery in 2024 – uptake for the programme has not been marked. Further, in December 2011, Lockheed Martin – the manufacturer of the Hercules – announced two new variants of the Hercules: the C-130XJ and C-130NG. As such, despite the aircraft being 57 years old, it is unlikely that it will be retiring in the next decade at least.

Avionics

Later models in the H series of C-130s are installed with ring laser gyros, GPS receivers, an upgraded APN-241 colour weather and navigational radar, improved generator control and bus switching units as well as an integrated radar and missile warning system.

Crew

Due to its tremendous size and flexible capabilities, the C-130H is manned by five crew members. There are two pilots, a navigator, flight engineer and loadmaster. Due to its large carrying capacity, the loadmaster's role is to determine how to most efficiently load huge and diverse cargo.

Global distribution

The C-130's awesome versatility has seen it adopted the world over

5 TOP FACTS
HERCULES C-130

Versatile
1 Despite being introduced in the Fifties, the Hercules C-130 is still a mainstay of militaries worldwide, with over 2,300 built and over 40 different variants in use today.

Elite
2 As of 2012, only five aircraft have been used continuously for over 50 years. The C-130, English Electric Canberra, Boeing B-52 Stratofortress, Tupolev Tu-95 and Boeing KC-135 Stratotanker.

Georgia
3 The original prototype was produced in California, where it took its first flight. Since production began, however, all C-130s have been built in Marietta, Georgia.

Super
4 A larger, more advanced version of the C-130 is currently being produced – the C-130J Super Hercules. As of November 2011, 250 have been built and deployed.

Upgrade
5 In 2010 the Pentagon approved funding for a selection of C-130s to be upgraded with an Avionics Modernization Program (AMP) kit. A total of 198 C-130s will feature the upgrade.

DID YOU KNOW? *The Hercules C-130 was first introduced in December 1957*

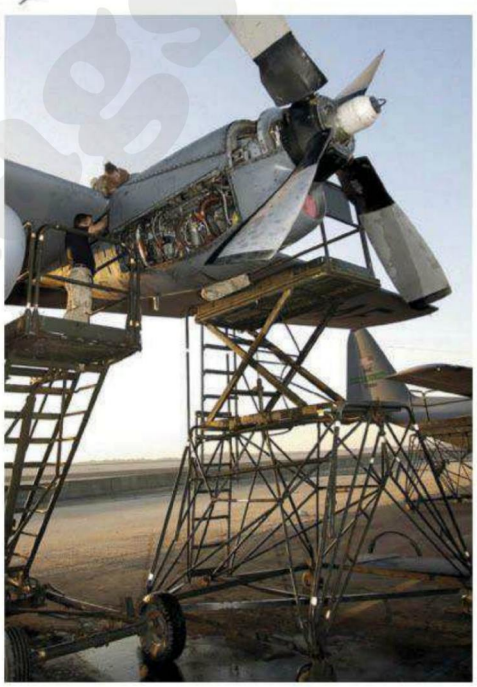
The C-130 is one of a prestigious group of only six aircraft to have been in continuous service for over 50 years

Anatomy of a C-130H Hercules

How It Works breaks down a popular variant of this aerial titan

Powerplant
Due to its immense weight, four Allison T56-A-15 turboprop engines are equipped to each C-130H. These produce a colossal 3,423kW (4,590shp) each and allow the aircraft to reach a respectable top speed of 592km/h (366mph). The T56 is a single-shaft turboprop with a 14-stage axial flow compressor.

Capacity
With a max takeoff weight of over 70,000kg (150,000lb), the C-130H can carry up to 92 passengers, 64 airborne troops, three Humvees or two M113 armoured personnel carriers. If specced out for a medical role, a single aircraft can carry 74 litter patients plus two medics.



Engineers work on the turboprop engines of a Hercules deployed in Iraq

The statistics...

Hercules C-130

Crew: 5

Length: 29.8m (97ft 9in)

Wingspan: 40.4m (132ft 7in)

Height: 11.6m (38ft 3in)

Capacity: 92 passengers; 64 airborne troops; 3 x Humvee; 2 x M113 troop carriers

Payload: 20,000kg (45,000lb)

Powerplant: 4 x Allison T56-A-15 turboprop (3,423kW/4,590shp each)

Max speed: 592km/h (366mph)

Max range: 3,800km (2,360mi)

Max altitude: 10,060m (33,000ft)

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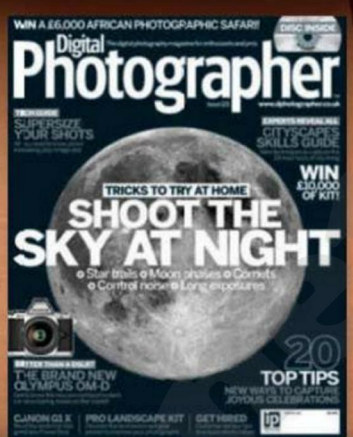

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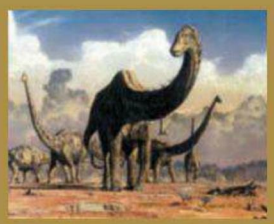
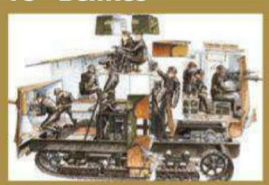


Welcome to... HISTORY

Kick off the History section with a closer look at one of the biggest – and most well-known – dinosaurs to have walked the Earth: the colossal diplodocus. We also discover how wells have provided us with fresh water over the centuries, and why the Sturmpanzer-Kraftwagen, or A7V tank ultimately proved a failure for Germany in WWI.

78 Water pumps

79 Belfries



80 A7V tank

LEARN MORE

Diplodocus

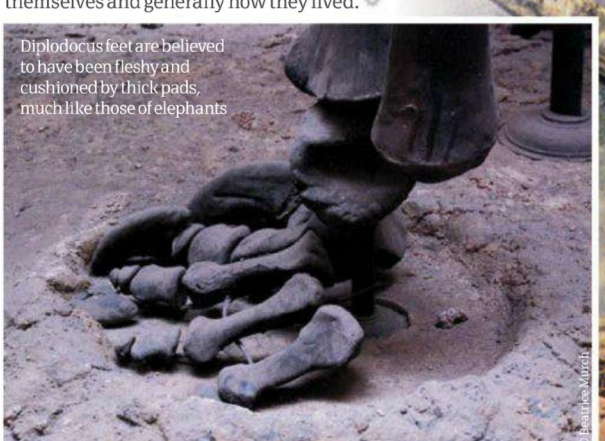
We find out how this mighty dinosaur once lived

Diplodocus is, without doubt, one of the most famous dinosaurs. It belonged to the group known as the sauropodomorphs and was around in the Late Jurassic period – specifically the Kimmeridgian and Tithonian eras roughly 154-150 million years ago. It reached sizes of up to 25 metres (82 feet) in length and was predominantly found in what is now North America. There were four species of diplodocus, with the largest of these being seismosaurus, which essentially translates to 'ground shaker'.

Diplodocus was part of the diplodocid family, sharing the same characteristic of having 15 neck vertebrae, short forelimbs compared to the rest of its body and a whip-like tail. Its giant neck made up a large proportion of its body, but there is still some contention as to whether it held its neck vertically or horizontally. Its rectangular skull contained huge eye sockets and nasal chambers, in addition to a long flat jawline and a small space for its comparatively little brain. Studies of its teeth suggest that diplodocus fed using what is known as branch stripping, where the branch of a tree is grasped in a creature's jaw and then pulled sharply up or down, tearing off foliage as it goes.

For its time, diplodocus was the largest dinosaur around. It was later eclipsed by other sauropods, but it roamed the tallest for at least a few million years. Numerous diplodocus bones have been found and studied by palaeontologists, providing an insight into how these giant dinosaurs were able to support themselves and generally how they lived.

"Its giant neck made up a large proportion of its body, but there is still some contention as to whether it held its neck vertically or horizontally"



Diplodocus feet are believed to have been fleshy and cushioned by thick pads, much like those of elephants

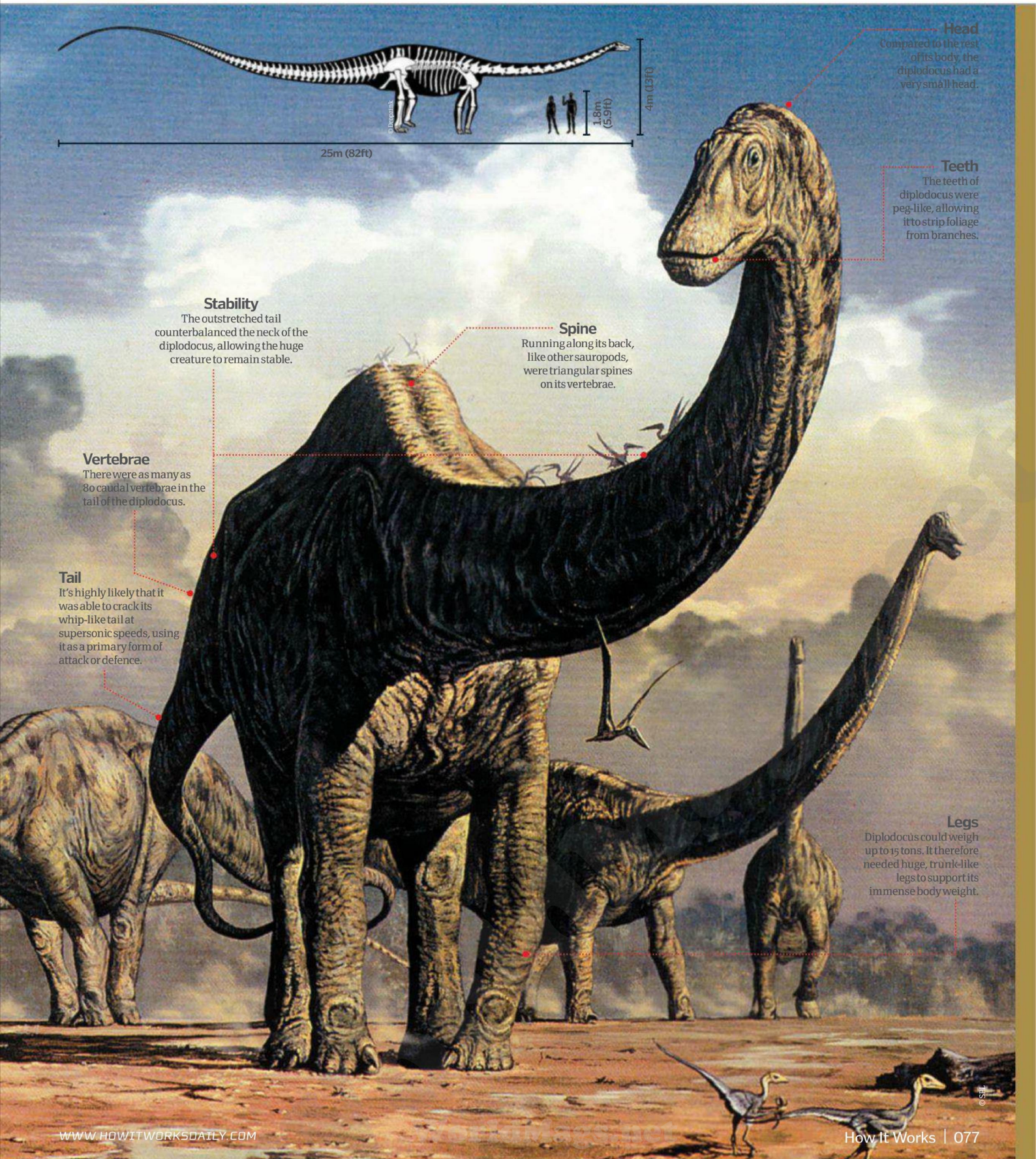
© Beatrice Munch

35m

BIGGEST DINOSAUR

The largest confirmed dinosaur is argentinosaurus, which is estimated to have reached lengths of 35m (115ft). As its name suggests, it roamed across South America, and it was alive approximately 97-94 million years ago.

DID YOU KNOW? *The name diplodocus means 'double beam', a reference to the V-shaped bones in the vertebrae of the tail*



"Historically, water pumps were invented to optimise water retrieval from town wells"

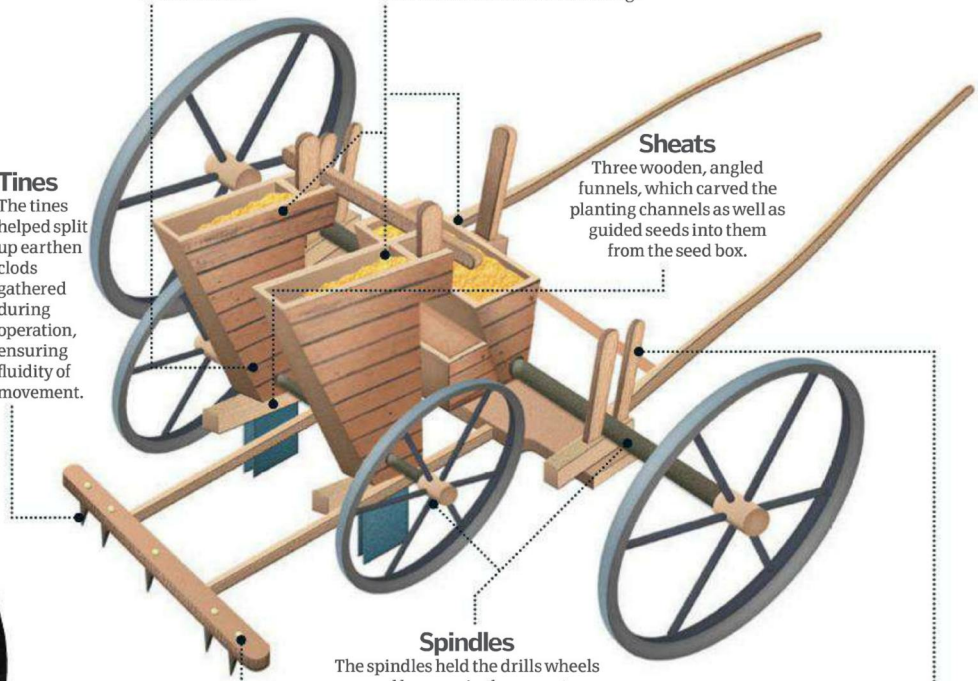
Jethro Tull's seed drill

One of history's greatest agricultural inventions explained

A key invention during the British Agricultural Revolution, the seed drill allowed for a semi-automated, controlled distribution and plantation of wheat seed. Designed by renowned agriculturalist Jethro Tull in 1701, the drill went on to spawn many other mechanised planters and ploughs, which many of today's agricultural tools and vehicles are descendents of.

The drill – which was made from elm wood and consisted of a wheeled wooden frame – worked by carving three channels into the earth into which seeds were dropped from containers at regular intervals. The seeds, once dropped by the horse-drawn drill, were then covered by the harrow (a trailing bar), which gathered soil and evenly deposited it over the channels. For a detailed breakdown of Tull's seed drill, check out the accompanying illustration.

17th and 18th-century agriculturalist and inventor of the seed drill, Jethro Tull



Seed boxes
Sitting at the bottom of the hoppers, these boxes distributed the seeds at set intervals.

Hoppers
The drill's hoppers were chute-like containers that held the seeds en masse. They dropped from here into the seed boxes for scattering.

Tines
The tines helped split up earthen clods gathered during operation, ensuring fluidity of movement.

Sheats
Three wooden, angled funnels, which carved the planting channels as well as guided seeds into them from the seed box.

Spindles
The spindles held the drills wheels and hoppers in the correct positions for even distribution.

Standards
The standards held the spindles – and therefore the drill's wheels – perpendicular to the sheats and level.

Harrow
The harrow covered the seeds with soil once deposited in the cut channels.

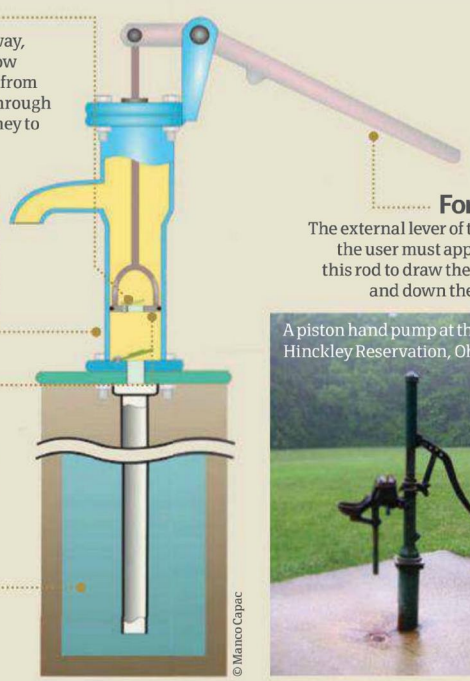
How do water pumps work?

We break down a manual water pump to see how it delivers H_2O

There are many different types of water pump, however the most common are positive displacement varieties, such as the manually operated piston pumps which are often found in parks, as well as developing countries.

Positive displacement pumps work by trapping water from a central reservoir and then forcing its volume upwards into a discharge pipe. This is achieved most commonly through the use of a valved piston and cylinder, which when combined (see illustration), draw water via suction up into a cylinder, before redistributing it through a descending valved piston head into an expanding higher chamber. When the piston begins to rise, its own valve is forced shut by increased pressure within the higher cylinder chamber, while the cylinder's reservoir valve is pulled open by a release of pressure in the lower chamber. This allows pockets of water to be continuously drawn up from an underground source to an outlet on the surface.

Historically, water pumps were invented to optimise the retrieval of water from town wells, which previously had employed simple but labour-intensive bucket-on-rope methods.



© Manco Capac

Check valves
The check valves are one-way, non-return valves, and allow water to pass through first from the reservoir and second through the piston head on its journey to the surface.

Cylinder
The vertical body of the pump, the cylinder provides an enclosed compartment for the pump's piston to move through.

Piston
The piston descends and ascends through the cylinder, with water from the lower chamber forced through its head valve via an increase in pressure.

Reservoir
A mediating tank or chamber where the pump's water is stored ready for extraction.

Force rod
The external lever of the pump, the user must apply force to this rod to draw the piston up and down the cylinder.

A piston hand pump at the Hinckley Reservation, Ohio

© Analogue Kid

5 TOP FACTS
BELFRIES

Heritage
1 Due to their age and craftsmanship, many belfries are now protected structures. In 1999 32 Belgian belfries were added to UNESCO's list of World Heritage Sites.

Calling
2 Belfries serve two main purposes: the first to call people to prayer and the second to announce the time. The latter is done on both religious and civic buildings.

Origin
3 The first bell towers were designed as early warning systems against invasion. This lineage can be seen in the Dutch term 'belfort', which combines 'bell' and 'stronghold'.

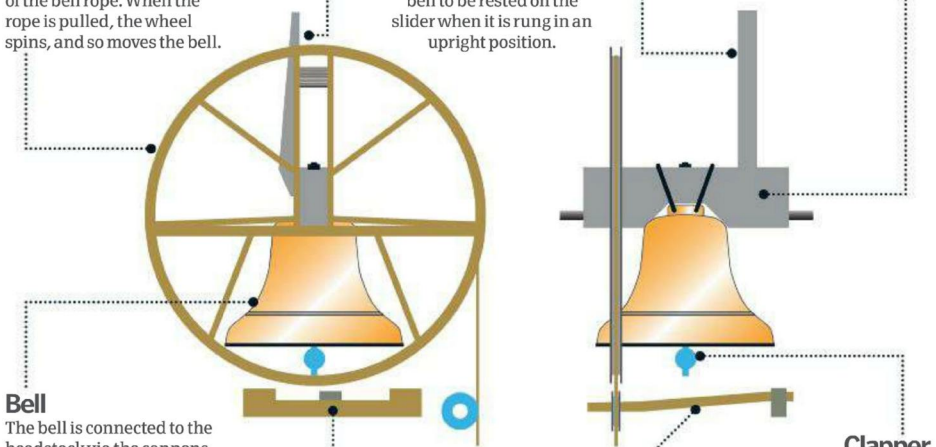
Lucky
4 The heaviest functioning bell in the world is called the Bell of Good Luck, and weighs in at 116 tons. It's located in the Foquan Temple, Henan, China.

Carillon
5 Some larger bell towers are fitted with carillons, a musical instrument consisting of an array of variously sized bronze bells. The bells are played via the striking of an attached keyboard.

DID YOU KNOW? *The word belfry stems from the Old French word berfrei*

Anatomy of a bell mechanism

The operation of any belfry's sound-making apparatus requires a host of mechanical components



Wheel
The wheel is secured to the headstock and holds the end of the bell rope. When the rope is pulled, the wheel spins, and so moves the bell.

Stay
The stay extends from the headstock and allows the bell to be rested on the slider when it is rung in an upright position.

Headstock
Typically a block of wood from which the bell is hung via cannons (metal loops formed at the top of the bell).

Bell
The bell is connected to the headstock via the cannons. Bells are typically made of bell metal, a hard alloy and form of bronze famed for its resistance to oxidation.

Slider
In partnership with the stay, this moving wooden bar allows the bell to be rested when rung in the upright position.

Clapper
The sound produced by the bell is done so by the clapper, which strikes the inside of the bell on either side in opposition to its motion.

The large and ornate Belfort Tower in Bruges, Belgium

A triple bell array within a church tower's belfry. Note how the bell ropes extend down through to a lower floor

Belfries explained

Found throughout the world, belfries are complex structures whose bells have served many uses over the centuries

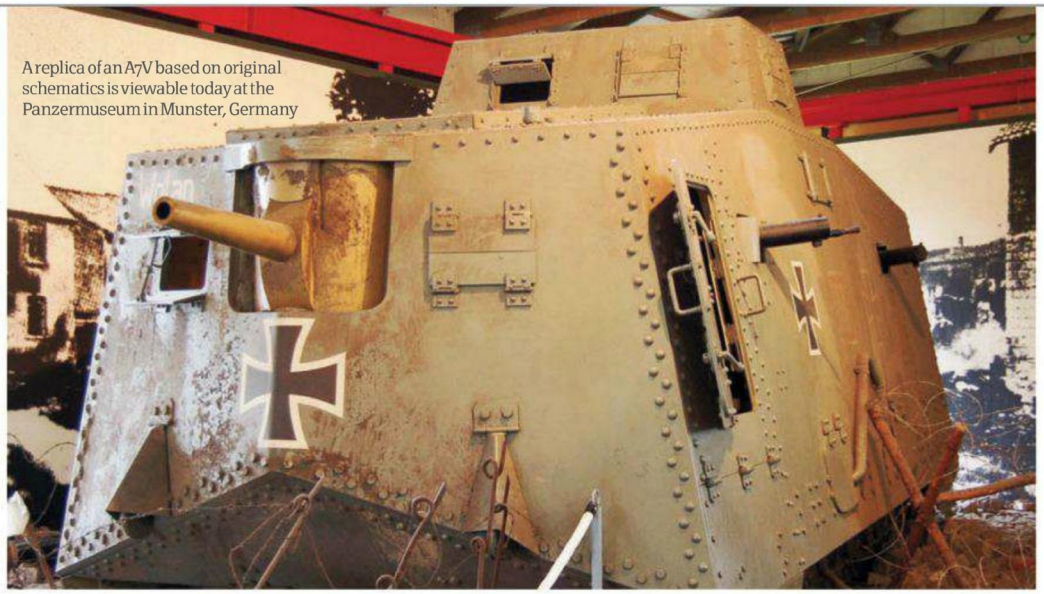
Belfries are common features on both religious and civic buildings alike worldwide. Their purpose is to elevate one or more bells to a height at which they can be rung with most effect – ie where there is little obstacle to the passage of their produced sound.

Mounting bells within a belfry is a complex operation, not least due to their extreme weight, and as such, they are typically placed in a space-saving mechanical array (see 'Anatomy of a bell mechanism' boxout). The array allows both multiple bells to be mounted within an enclosed environment and also for their operation to be handled in another room or compartment further down the bell tower.

Bells in a belfry are rung traditionally by bell ringers, who draw down an individual bell's wheel rope. This has the effect of rotating the wheel and drawing the connected bell upwards, which when released, allows it to swing through a high-degree rotation, forcing its clapper to connect with the inside walls and produce that familiar ringing sound. Today, however, many mechanical systems are also in operation within belfries, either in the form of a carillon (a type of musical instrument in which a selection of smaller bells are rung by an automated keyboard), or by electronic amplification of chimed metal rods through loudspeakers.

Historically, belfries evolved out of early watchtowers, which were common throughout antiquity. Here, rather than calling worshipers to prayer or announcing the time of day, they were used to spot incoming enemies and then broadcast the threat to local soldiers and civilians.

"Many got stuck on difficult off-road terrain and two even toppled over into holes"



A replica of an A7V based on original schematics is viewable today at the Panzermuseum in Munster, Germany

The A7V

One of the earliest tanks to be produced, the A7V was supposed to deliver German soldiers a mobile fortress to break through Allied lines, but wasn't a great success...

Designed specifically to counter the emergence of British tanks on the Western Front during World War I, the A7V was a medium-armoured tank designed by the German General War Department in 1916. The vehicle resembled a mobile pillbox or APC (armoured personnel carrier) and delivered a steel-plated body for 18 soldiers, a 57-millimetre (2.2-inch) cannon and six to eight 7.9-millimetre (0.3-inch) machine guns (for a full hardware breakdown see 'Anatomy of an A7V' diagram). Its role, as hinted at by its German classification – Sturmpanzer-Kraftwagen translates roughly as 'assault armoured motor vehicle' – was to assault and break through fortified Allied lines.

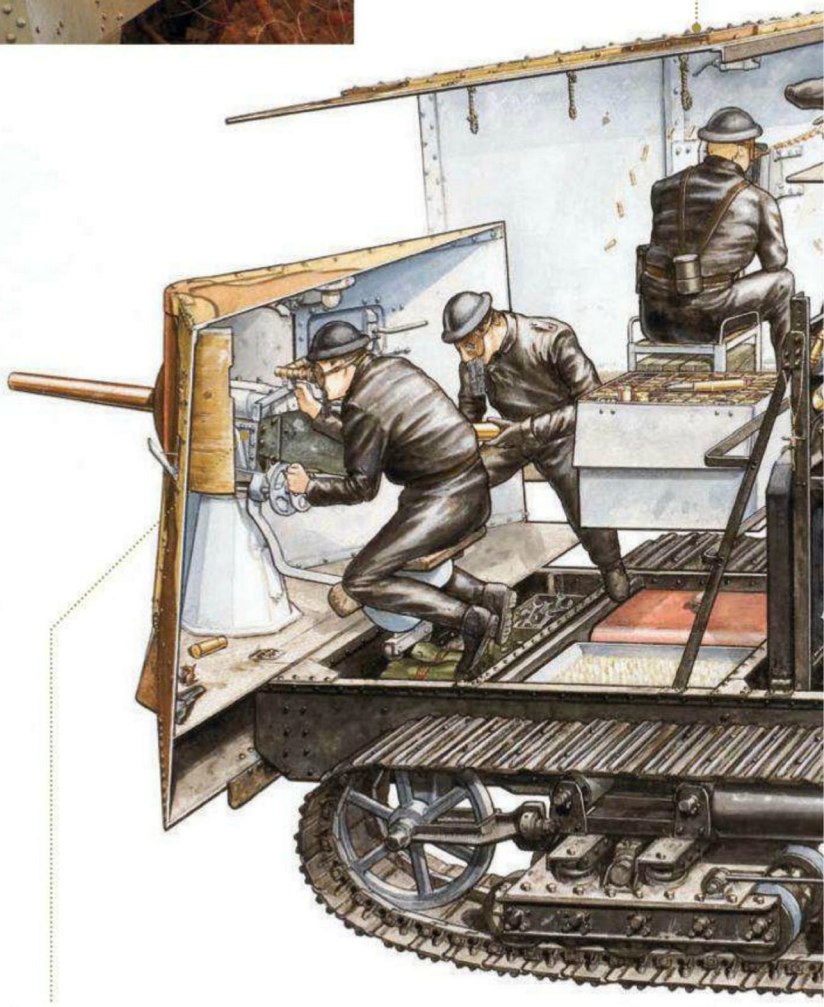
The first preproduction A7V was delivered in September 1917 and was closely followed by the first production model in October of the same year. Despite this, the first deployment of the A7V had to wait until March 1918, where five of the total 20 made were deployed north of the St Quentin Canal in northern France. Unfortunately, this is where the first design flaws of the vehicle were first encountered. Three of the five tanks broke down during operation due to mechanical faults.

Despite these issues, the A7V fleet was then deployed en masse, with 18 vehicles partaking in the Second Battle of Villers-Bretonneux in April 1918. Although reports from Allied soldiers at the time state that the A7V's armour made direct attack from their handheld weapons impossible, the A7V's modest armour was easily breached by the Allied Mark IV's six-pounder cannons. Further, due to the low clearance and crude design of the A7V's suspension and tracks, many got stuck on difficult off-road terrain and two even toppled over into holes. In addition, after a swift counterattack by Allied forces, three of the stranded A7Vs were captured.

As such, even though 100 A7Vs had originally been ordered, their limited impact led to the programme to be scrapped, with many of the remaining vehicles dismantled as early as October 1918. Today, no original A7V has survived, with the majority scrapped after the war. However, a replica based on original designs was built between 1987 and 1990 and can now be viewed by the public at the Panzermuseum in Munster, Germany.

Anatomy of an A7V

How It Works breaks down this World War I tank to see how it was built and operated



Armour
Despite having 20mm (1.2in) steel plate at the sides, 30mm (0.8in) at the front and 10mm (0.4in) on the roof, the A7V was easily penetrated by cannon fire. This was because the steel was not hardened armour plate. As such, it could only stop small arms fire.

Armament
The main weapon of the A7V was a 57mm (2.2in) Maxim-Nordenfelt cannon, which was equipped to all male variants. The secondary armament was a series of six to eight 7.9mm (0.3in) MG08 machine guns. The tank could carry 180 shells for the cannon.

Suspension
The A7V was equipped with helical springs, rear-drive sprockets, front-mounted idlers and 24 roller wheels in bogies. The lack of shock absorbers made the ride incredibly bumpy and the low clearance (ie 190-400mm/ 7.5-15.7in) led to poor off-road capabilities.

5 TOP FACTS
A7V TRIVIA

1 Fortress
British forces nicknamed the A7V the 'Moving Fortress' when it was first deployed on the battlefield. This was due to its large pillbox design and heavy (for the time) armour.

2 Service
Due to its crude design and myriad problems, the A7V was only in operation for a total of seven months, from March to October 1918. Only replicas survive today.

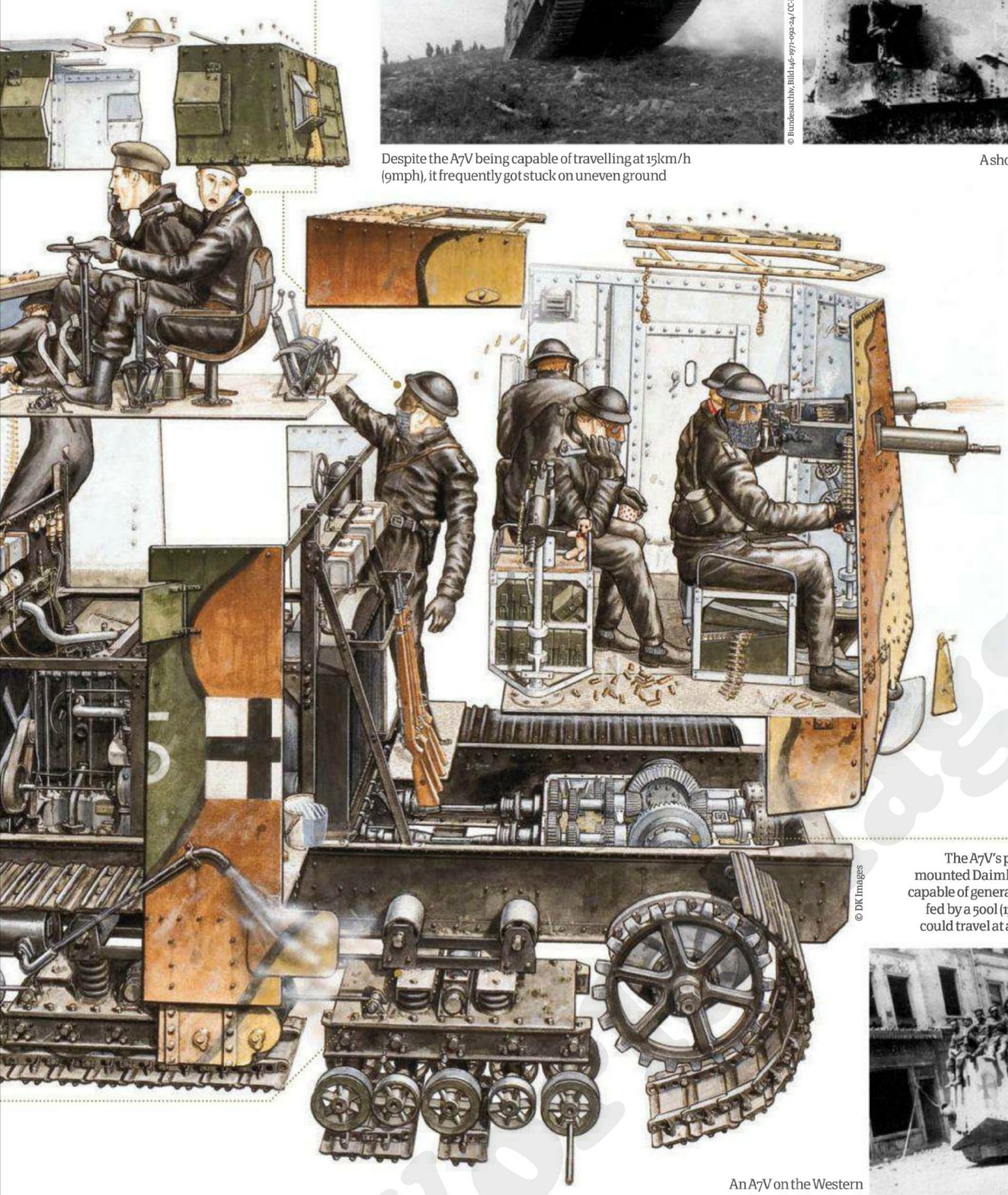
3 Designer
The inventor of the A7V, Joseph Vollmer, was the chief designer for the German War Department. He went on to produce the K-Wagen, LK I and LK II tanks.

4 Female
The A7V had both male and female variants. The male had six machine guns and a 57mm (2.2in) cannon, while the female version replaced the cannon with two extra machine guns.

5 Wotan
One A7V, named Wotan, after being scrapped by the Allies in 1919 was rebuilt in the Eighties based on original designs. The replica now resides in the Panzermuseum, Germany.

DID YOU KNOW? *In German the A7V was called the Sturmpanzer-Kraftwagen [which means assault armoured motor vehicle]*

Crew
An A7V's crew consisted of 17 soldiers and one officer. These were needed for the following roles: commander, driver, mechanic, two artillery men (gunner and loader) and 12 infantry men (six gunners and six loaders).



Despite the A7V being capable of travelling at 15km/h (9mph), it frequently got stuck on uneven ground

A shot of an A7V and its crew from July 1918

The statistics...

A7V

Crew: 18
Height: 3.3m (11ft)
Width: 3.1m (10ft)
Length: 7.3m (24ft)
Weight: 30 tons
Engine: 2 x Daimler four-cylinder petrol (149kW/200hp total)
Suspension: Holt track, vertical springs
Max speed: 15km/h (9mph)
Max range: 80km (50mi)
Armour: Sides: 20mm (0.8in); front: 30mm (1.2in); roof: 10mm (0.4in)
Main armament: 57mm (2.2in) Maxim-Nordenfelt cannon
Secondary armament: 6 x 7.9mm (0.3in) MG08 guns

Engine
The A7V's power came courtesy of two centrally mounted Daimler four-cylinder petrol engines, each capable of generating 75kW (100hp). The engines were fed by a 500l (132ga) fuel tank. At full power, the A7V could travel at a maximum speed of 15km/h (9mph).

An A7V on the Western Front in March 1918

BRAIN DUMP

Because enquiring minds want to know...

Ask your questions

Send us your queries using one of the methods opposite and we'll get them answered

MEET THE EXPERTS

Who's answering your questions this month?

Bridget McDermott

Bridget is an expert Egyptologist who is passionate about all things pharaohs, pyramids and hieroglyphs. She has written several books including *Warfare In Ancient Egypt* and *Death In Ancient Egypt*.

Luis Villazon

Luis has a degree in Zoology from Oxford University and another in Real-time Computing. He has been writing about science and technology since before the internet was invented.

Rik Sargent

Rik is an outreach officer at the Institute of Physics where he works on a variety of projects aimed at bringing physics into the public realm. His favourite part of the job is travelling to outdoor events and demonstrating 'physics busking'.

Shanna Freeman

Shanna has been bugging her parents with questions since she could speak. As a generalist freelance writer she can now research beyond just satisfying her own curiosity. The subject of space has held a special place in her heart since she caught her first *Star Trek* rerun.

Aneel Bhangu

A top surgeon by day and the **How It Works** biology guru by night, Aneel is on hand to answer all your burning questions about the human body, its most bizarre functions, and the weird and wonderful things it can do.

What determines the speed of your internet connection?

Hayley Paterson

Broadband data is sent down telephone lines as lots of oscillating electrical signals layered on top of one another. Your modem divides the total available frequency range into channels of 4.3125kHz each and analyses the level of interference in each one. The more interference in a given channel, the less data per second that can be sent at that frequency, without introducing errors. Living more than four kilometres (2.5 miles) from your telephone exchange, old telephone wires in your house, having more than five phones connected to the same landline and long telephone extension cords will all introduce electrical interference. Fibre-optic broadband is much faster because it uses light pulses in special glass wires that don't suffer from interference in the same way.

Luis Villazon

Which is the most radioactive element?

Helen Parker

Radioactive elements are those made up of atoms with unstable nuclei. Unstable nuclei emit ionising radiation in the form of alpha particles, beta particles or gamma rays in a process called radioactive decay. Polonium is thought to be one of the most radioactive naturally occurring elements, due to the high intensity of alpha particles that it emits. Just one gram (0.04 ounces) of polonium can self-heat to temperatures of 500 degrees Celsius (932 degrees Fahrenheit). However, there are elements with a higher radioactivity that have been synthesised in a lab, such as ununpentium, which is so unstable it can only last a few fractions of a second before decaying.

Rik Sargent

Does snow dehydrate you?

Nicholas Fenn

Not directly, but eating snow in a survival situation isn't the best strategy. As it's so cold, it will decrease your core temperature, forcing your body to increase its metabolic rate to keep you warm. In these cases, you trade high levels of energy for relatively little gain. Melting the ice to water is a far better option. If you can't do that, sucking on ice is still better as it has more water for the same volume compared to snow. The other problem is that, like drinking from a stream, you don't know exactly what pollutants may be in the snow.

Aneel Bhangu

Could we terraform Mars?

Neil Field

Many scientists believe that it's possible to make Mars habitable, but there's a lot of work to do. First, we need a new atmosphere. That of Mars is about 95 per cent carbon dioxide, and very thin in comparison to Earth's. We also need liquid water. Mars is currently a desert planet. Since it's further from the Sun, on average Mars has a temperature measuring about -60 degrees Celsius (-76 degrees Fahrenheit), so we'd definitely need more heat. Finally, Mars would need a magnetic field to hold in that atmosphere, heat and water, as well as protect us from solar radiation.

We could help along some of these issues by creating a greenhouse effect on Mars – it's how Earth is warmed, as sunlight is reflected off the planet's surface and is absorbed by gases in the atmosphere. This would require importing or creating those gases on Mars, and there are lots of proposals for how to make that happen... some of which are either not possible with our current technology or are too cost-prohibitive. So the answer to whether we could actually live on Mars one day is, for now, a decided 'maybe'.

Shanna Freeman

Why do bees buzz?

Mikey Saunders

Bees, like most insects, don't have muscles directly connected to their wings. Instead the flight muscles are attached to the roof wall of the thorax. When it is pulled down, the thorax suddenly pops inward, like the dent that appears when you squash a ping pong ball. This flips the wings upward. A second set of muscles squashes the thorax lengthwise and the roof pops up again. This happens about 190 times a second in honeybees and the rapid clicking of the thorax wall sounds like a buzz to our ears. Bumblebees also use this feature to shake pollen out of flowers.

Luis Villazon

Bumblebees make use of their 'buzz' to dislodge pollen in certain blooms

Who invented pizzas? Find out on page 85

BRAIN DUMP

Because enquiring minds want to know...

How big is the Milky Way?
Find out on page 87

Want answers?

Send us your questions using one of the methods opposite and we'll get them answered

How come babies can swim underwater until a certain age?

Emma Squire

This is one of the primitive reflexes which all newborn infants have, but which are lost as they grow past six months old. Many of these reflexes are to protect the baby and carry a survival advantage, but some have no benefit. In the swimming reflex, placing a baby facedown in water will cause them to kick and paddle. The aim is to buy enough time until someone can come and help. It carries risks, however, since the baby may swallow large quantities of water or aspirate it into their lungs. Another example is the palmar grasp, where placing an object (such as a finger or toy) into a baby's palm will cause a strong grip.

Aneel Bhangu

Can scissors cut glass?

Eira Davies

Glass is a very brittle material and likes to crack and shatter under pressure. It would not be possible to cleanly cut glass using scissors without cracks appearing, and a high risk of the glass shattering. Glass is an amorphous solid which means, unlike most solids, it has no repeating arrangement of molecules within its structure. The glass used to make drinking vessels and windows is composed of around 75 per cent silica mixed with sodium oxide and calcium oxide; this is known as soda-lime glass. The best way to cut this type of glass is by scoring the line you want to cut with a glass cutter, then applying some pressure to both sides of this line to achieve a clean break.

Rik Sargent

Why are bubbles spheres?

Charlie Stubbings

The skin of a bubble is composed of a thin layer of water molecules sandwiched between two layers of soap molecules. Water on its own has a high surface tension due to intermolecular forces causing molecules to pull on one another, trying to minimise the surface area and be as flat as possible. Soap reduces this surface tension, however the effect of surface tension is still present in a bubble which causes the bubble 'film' to be stretched. A sphere is formed as it is the shape with the least amount of surface area for its volume.

Rik Sargent

When and where did the pizza originate?

Paul French

The pizza as a flat bread can be linked to ancient times. The Ancient Egyptians were expert bread makers and remains of this type of bread can still be found in many tombs. Flat bread was also popular with the Ancient Greeks and the Romans. However, the modern pizza is inextricably linked to Italy where it first became popular in the 18th century. Naples is thought to be the home of the pizza – a description of this type of dish is given by the French writer Alexandre Dumas in 1830. Its popularity continued to flourish as Italian immigrants brought the recipe to America along with the rest of the world.

Bridget McDermott

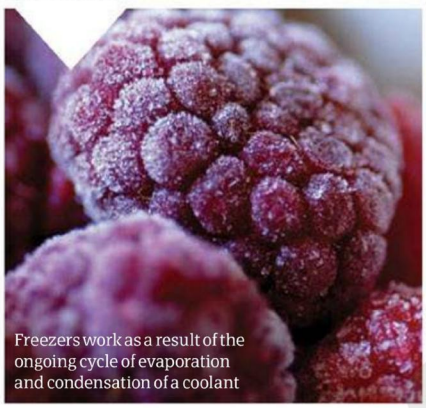
How do electric freezers get so cold?

Iain McWhinnie

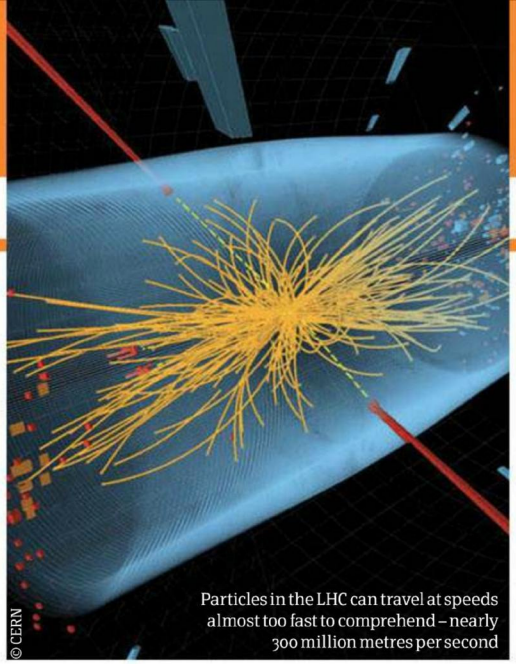
The freezer in your kitchen is at about -22 degrees Celsius (-7.6 degrees Fahrenheit) despite the fact the outside temperature is more like 20 degrees Celsius (68 degrees Fahrenheit). It achieves this using a gas, such as tetrafluoroethane, that has a boiling point not too far below 0 degrees Celsius (32 degrees Fahrenheit). The freezer compresses the coolant, which heats it, and then passes the hot vapour around the coils at the back. Heat radiates from the coils to the kitchen, and the coolant temperature drops. As the coolant is under pressure, it condenses, even though it is above its normal boiling point. Then it is pumped to the interior of the freezer and a pressure valve lets about half the coolant boil off. This drops the temperature of the rest of the coolant, which allows heat to flow from the freezer compartment to the coolant. Once boiled off, it returns to the compressor in order to restart the cycle.

Vapour compression cycling using different gases can achieve much lower temperatures – as low as liquid helium (around -269 degrees Celsius/-452 degrees Fahrenheit). Below that you can use a laser to reach temperatures a fraction of a degree above absolute zero. This uses the momentum from the photons themselves to slow down individual atoms.

Luis Villazon



Freezers work as a result of the ongoing cycle of evaporation and condensation of a coolant



© CERN

Particles in the LHC can travel at speeds almost too fast to comprehend – nearly 300 million metres per second

At what speed does the LHC smash particles together?

Bill Porter

The Large Hadron Collider (LHC) uses an array of 9,300 supercooled electromagnets to guide and accelerate particles – namely protons – around the 27-kilometre (17-mile) underground ring at CERN in Geneva, up to speeds extremely close to that of light. At their fastest, these particles travel at around 299.8 million metres (983.6 million feet) per second completing 11,245 laps of this ring every second. This is equivalent to travelling around the circumference of the Earth seven and a half times in one second. The LHC has two rings with beams of trillions of particles zooming around in opposite directions. Detectors are placed at certain points where the pipes intersect causing collisions to occur. As both the particles are travelling in opposite directions at nearly the speed of light, you might expect their combined collision speed to be almost twice the speed of light. However both particles would measure their collision speed to be less than the speed of light. This seems counter-intuitive but is accounted for by the slowing down of time and warping of space as explained by Einstein's special theory of relativity. This explains why no particle with mass should be able to travel faster than light, as it would require an infinite amount of energy to get there.

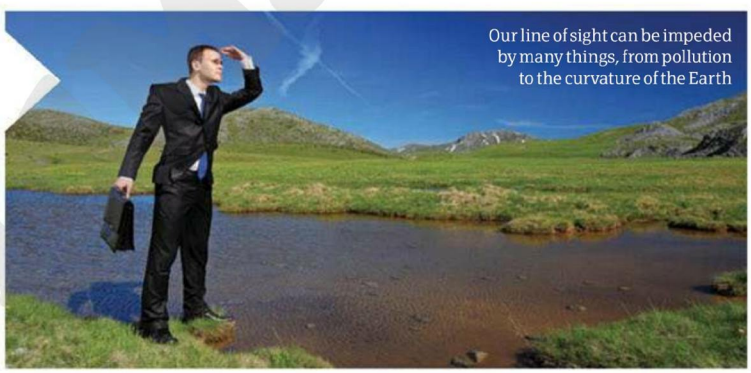
Rik Sargent

What is the maximum distance the human eye can see if unobstructed?

Sue Shrimpton

Dust, water vapour and pollution in the air will rarely let you see more than 20 kilometres (12 miles), even on a clear day. Often, the curvature of the Earth gets in the way first – eg at sea level, the horizon is only 4.8 kilometres (2.9 miles) away. On the top of Mt Everest, you could theoretically see for 339 kilometres (211 miles), but in practice cloud gets in the way. For a truly unobstructed view though, look up. On a clear night, you can see the Andromeda galaxy with the naked eye, which is 2.25 million light years away.

Luis Villazon



Our line of sight can be impeded by many things, from pollution to the curvature of the Earth

What is the Terracotta Army? Find out on page 86

BRAIN DUMP

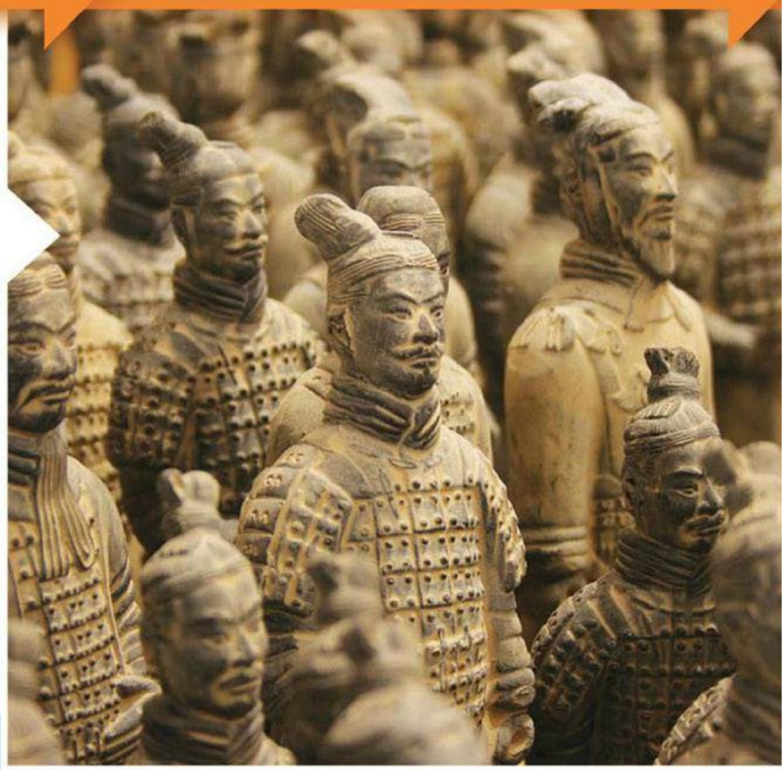
Because enquiring minds want to know...

Is Earth's spin slowing down?

Find out on page 87

Want answers?

Send us your questions using one of the methods opposite and we'll get them answered



What is the Terracotta Army?

Simon Peacock

The Terracotta Army, unearthed in 1974, is one of the most exciting archaeological finds in recent history. The figures represent the soldiers of Qin Shi Huang, the first emperor of China. They had been placed in his tomb, an earthen pyramid mound, which was excavated beneath Mount Li. Construction had begun when the emperor was a child – it took many years to build. The tomb represents the royal palace, and the figures inside, court residents. Beside the warriors, archaeologists found models of officials and entertainers. There are 8,000 soldiers, each depicted with weapons such as spears, bows and arrows. There are also models of horses and chariots. Made out of yellow clay, the Terracotta Warriors were meant to protect the emperor in the afterlife. Artisans first made the limbs and heads which were then fired in a kiln. Once assembled, the models were painted and coated with a preservative, but only some colours are still visible. Each figure was given individual features, with details added to the hair and clothes; artists even added muscle tone to the arms and legs. The height of the soldier depended on his rank – ie the military generals are the tallest figures in the group.

Bridget McDermott

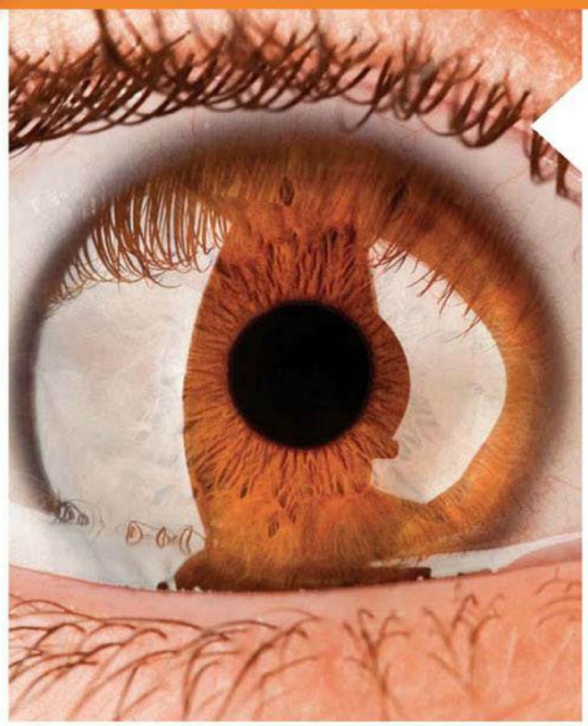
Recent research has raised questions about current thinking on the speed of light, though further tests are needed before anything is confirmed

In space, is there a maximum speed at which an object can travel?

Penny McWalters

The theory of special relativity, proposed by Einstein in 1905, includes the universal constant that nothing can travel faster than light in the vacuum of space. It took several decades to pin down the exact speed of light, but in 1983 it was tied to the definition of the metre by the International System of Units at 299,792,458 metres (983,571,056 feet) per second. Theoretically, then, that's the fastest speed that anything can travel in space. Recently workers at CERN (the world's largest particle physics laboratory) announced they had recorded a type of subatomic particle called a neutrino going faster than the speed of light, but this has yet to be confirmed.

Shanna Freeman

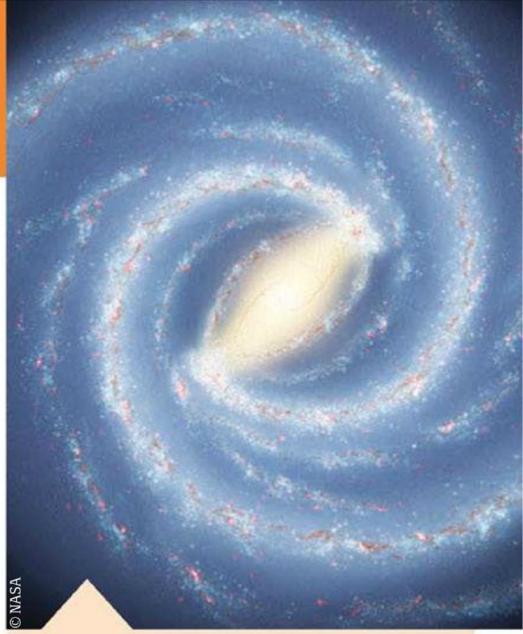


Why do eyes take a while to adjust between darkness and light?

Don Scott

At the back of the eye on the retina, there are two types of photoreceptors (cells which detect light). Cones deal with colour and fine detail and act in bright light, while rods deal with vision in low-light situations. In the first few minutes of moving into a dark room, cones are responsible for vision but provide a poor picture. Once the rods become more active (they are initially slow to react), they take over and create a much better picture in poor light. Once you move back into light, the rods are reset and so dark-adaption will take a few moments again. Soldiers are trained to close or cover one eye at night when moving in and out of a bright room, or when using a torch, to protect their night vision. Once back in the dark, they reopen the closed eye with the rods still working and, as a result, maintain good vision. Give it a try next time you get up in the middle of the night.

Aneel Bhangu



How big is the Milky Way?

Mark Warne

The Milky Way has a diameter of approximately 100,000 light years, meaning that it would take that long to travel from one end to the next. However, our solar system – comprising the Sun, its orbiting planets, comets, asteroids and all kinds of other space bodies – doesn't have a clear boundary. But if you use the orbit of the furthest known objects – the cloud of comets called the Oort Cloud (much farther from the Sun than Pluto) – it's about two light years. That gives you an idea of how small our solar system is in comparison to the Milky Way as a whole.

Shanna Freeman

Does Earth spin slower now than it used to?

Morwenna Williams

Thanks to thousands of years' worth of observations recorded by astronomers, we know that the Earth's rotation has slowed down over the years. The rotation – or the length of a day – can vary by as much as a millionth of a second. It hasn't been a steady decline, but over that period of time the decline has been up to 25 millionths of a second per year. This is all due to the way that the moon interacts with the tidal bulges on our planet, but there's also a relationship between the weather and the Earth's rotation.

Shanna Freeman

Who was the first ever king/queen of England?

Elena Walker

Some historians think the beautiful, but wicked, Aelfthryth (c.945-1000) was the first queen of England, while others believe Matilda (c.1102-1167), the daughter of King Henry I, was the first female monarch. Queen Mary I (1516-1558), aka Bloody Mary after burning many religious opponents at the stake, was officially anointed and crowned, so is generally recognised as the first woman to rule. Early kings of England include Athelstan (c.895-939) whose victories over the Vikings and the Scots meant he was crowned first king of a united England. However, to complicate matters, his grandfather, Alfred the Great (c.849–899; pictured above), was the first to be crowned King of the English.

Bridget McDermott

What is China's Forbidden City?

Charles Morgan

Situated in Beijing, China, the Forbidden City was known as Zijin Cheng – it was named for the North Star which was thought to be the celestial home of the emperor. Built between 1406-1420, its role as an imperial palace continued for 500 years. Covering 73 hectares (180 acres), it was surrounded by a moat and high walls and played home to many magnificent dynasties. The city could house 9,000 people who served the emperor and his many hundreds of wives. Inside the city, ceremony was carefully observed, and all members of the royal family were revered as gods.

Bridget McDermott

THE KNOWLEDGE

GAMES / BOOKS / GADGETS / TOYS

FOR CONNOISSEURS OF KIT AND SAVANTS OF STUFF

SunnyCam video glasses

Price: £75/$120

Get it from: www.sunnycamglasses.com

At first glance we were a bit wary of these video-recording glasses as we've been let down by similar products. It was a pleasant surprise, therefore, to find these specs perform excellently. If you're into extreme sports, from snowboarding to skateboarding, and you'd like to record your sessions, these are for you. Embedded in the centre is a three-megapixel camera that records on to 4GB of internal memory or the 2GB memory card in AVI format. The picture quality is surprisingly good, even if it's not HD (though an HD model is planned), and a microphone captures audio too. The glasses handled sudden movements fine, all the while staying firmly in place. Getting the videos on to your computer is a snap; just plug the glasses in via the included USB cable and you're good to go.

modu Photo Frame

Price: £39.99

Get it from: www.purelygadgets.com

This photo frame provides an intuitive way to display snaps in addition to playing music from your phone. If you have a modu phone or device you can dock it into the top and output any saved shots to the screen, allowing you to create a slideshow of your favourite snaps. This frame also supports input from a USB and SD card port, so if you haven't got a modu device you can still link up to it. It was very easy to get to grips with, especially with the included remote control that lets you control your pictures from afar. In-built speakers also enable you to play music and, while these weren't the best quality, the addition of hands-free calling thanks to the speakerphone and microphone was a bonus. Overall a well-rounded product that will help make your snaps shine.

HOW IT WORKS

BLUETOOTH

To create a connection between the photo frame and an external device, Bluetooth communicates on a frequency of 2.45GHz and sends out a weak one-milliwatt signal; this enables the data to be transferred without interfering with other systems.

HOW IT WORKS

SUPER AMOLED

Super AMOLED devices integrate touch-sensitive technology into the screen rather than laying it on top. This allows the screen to be brighter and more detailed, although it has been known to increase battery consumption.

HOW IT WORKS EDITOR'S CHOICE AWARD

Samsung Galaxy Nexus

Price: £462/$799.99

Get it from: www.google.com/nexus

This smartphone boasts an 11.8-centimetre (4.65-inch) screen that displays in 720p. Despite this, the phone is very light and super-thin, so certainly doesn't feel clunky. There are two cameras (one five-megapixel and one 1.3-megapixel), and it also comes with Wi-Fi, Bluetooth, accelerometers, gyroscopes, a headphone jack, GPS, a microUSB port and 16 or 32GB of memory, which is all pretty standard. It also packs a built-in NFC chip, though this has limited use at the moment. Probably its most distinctive feature is its use of Android 4.0 (Ice Cream Sandwich); in fact, it's the first phone to run ICS. If you've used Honeycomb on an Android tablet you'll be right at home, with ICS bringing a host of new features. There are new apps like People, which brings together all your contacts from social networks and your address books, while the software itself runs fast, loading image-heavy websites in seconds. While the build feels a little plasticky, this is undoubtedly one of the best smartphones currently on the market.

Sony Tablet P

Price: £399/$549.99

Get it from: http://store.sony.com

This tablet is immediately noticeable for its foldable screen, which you'll quickly discover is both a blessing and a curse. First off, though, the tablet is great; it boasts a sharp 1,024 x 480px screen, has a snappy five-megapixel camera, and there's also a headphone socket and USB port on the side. However, its main USP is its dual screens. Offering an 18 x 15.8-centimetre (7.1 x 6.2-inch) display when fully unfolded, the screens both use capacitive touch technology. However, you'll notice that in the middle there is about a quarter of an inch of dead black space where one screen ends and the other begins. This can be very annoying on apps and sites not designed to accommodate a dual-screen device. The tablet excels in portability though, and of course the screens are always protected. It's a bit of a 'love it or hate it' design, but we definitely found ourselves leaning more towards the former. If you can be patient until more native apps are released, you too will love the Tablet P.

HOW IT WORKS

CONTROL

The entire device is controlled by two simple buttons on the side: power and record. This ensures that the glasses are easy and quick to turn on and use, making sure that you don't miss a moment's footage of extreme sport action.

HOW IT WORKS

STAR TYPES

One little taster from the book: 'Astronomers use a standard reference system, the Hertzsprung-Russell diagram, to categorise individual stars. The diagram plots the surface temperatures of certain classes of star against their brightness.'

Rough Guides: The Search For Aliens

Price: £11.99/$18.99

Get it from: www.roughguides.com

If you still have a thirst for extraterrestrial life after reading our feature on planet hunting this month then you'd be well advised to pick up this book from Rough Guides. In typical fashion for the publisher it contains a whole host of sourced information and images that give you a deep insight into the topic at hand: namely the search for ET. Starting with the composition of life on Earth, the book delves into planet-hunting methods, where we stand today and even covers controversial UFO sightings. With over 200 pages of alien goodness on offer, we'd definitely recommend this for those who are certain, or perhaps looking to be convinced, that we are not alone in the universe.

HOW IT WORKS

MEMORY FOAM

Also known as visco-elastic polyurethane foam, memory foam has an open cellular structure. Each cell has an air hole and, when the foam is pressed, the pressure spreads between the cells and distributes the force to provide an added level of comfort.

Corsair Vengeance 1300 gaming headset

Price: £69.99/$79.99

Get it from: www.corsair.com

These headphones from PC expert Corsair are the perfect companion for gamers looking for comfort, style and quality. The memory foam earpads mould snugly to your lugs, providing an immersive experience that blocks out pretty much all external noise. The sound quality is also excellent, so no matter which game you're playing you'll be getting the full experience. The lengthy wire has a separate headphone and microphone pin at the end, while you'll also find a volume adjustment and a microphone switch on the wire. The microphone itself captures your voice well and limits any external interference, so that whoever you're talking to will hear you clearly. Our only slight grievance was that at times it felt that volume couldn't go high enough, especially for those intense moments where we wanted to bump it up to 11. However, this is still an excellent gaming headset for a reasonable price that's well worth picking up.

HOW IT WORKS

TRUBLACK

Sony's trademarked TruBlack tech controls the refraction of light between the LCD and the screen on the Tablet P. This allows for more detailed and vibrant images to be displayed, which is instantly noticeable on activation.

APPS OF THE MONTH

Brought to you by **Apps Magazine**, your essential guide to the best iPhone and iPad apps available on the Apple App Store

iPad: iPhoto

HOW IT WORKS EDITOR'S CHOICE AWARD

Price: £2.99/$4.99

Developer: iTunes S.a.r.l.

Version: 1.0 **Size:** 106MB **Rated:** 4+

The latest iPad has brought with it the birth of iPhoto for iOS; as you'd expect, it's full of eyecatching features. There are in-depth editing options that can be applied with a single touch or by manipulating one of the many scroll bars. This gives complete control for fine-tuning, otherwise there's oodles of auto settings. Interface wise it has been completely overhauled, with a sleek new glass shelf containing all your albums. There are some impressive new additions for navigating and finding photos too. There is so much to this app that makes it an incredibly immersive editing suite and the updated UI makes sure all the options are always to hand.

Verdict: ★★★★★

iPhone: Chopsticks Novel

Price: £4.99/$6.99

Developer: Pearson PLC

Version: 1.0 **Size:** 143MB

Rated: 12+

Chopsticks has completely rewritten the formula for eBooks and how the user engages with them. In this story of young love, there is in fact no narrative text. Instead the story is slowly unveiled through a mix of ticket stubs, handwritten notes and photographs, making you use your imagination.

Verdict: ★★★★★

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Ultrabooks

We put three of the most powerful laptops to the test

Acer Aspire S3

Price: £699/$849.99

Get it from: www.shopacer.co.uk

With the Aspire S3, one of the first ultrabooks to hit the market, Acer aimed to provide a cheaper alternative to more expensive machines like the MacBook Air. Indeed, it's one of the most affordable ultrabooks but retains a very thin and light feel with a thickness of 1.3-1.7 centimetres (0.5-0.7 inches) and a weight of 1.4 kilograms (three pounds). While the top has a sleek aluminium finish, the rest of the device is a bit plasticky. Inside the machine you'll find an Intel Core i5 processor, 4GB of RAM and a 320GB HDD in addition to a disappointingly small 20GB SSD, while the absence of a USB 3.0 port is also a shame. The device runs Windows 7 and operates reasonably well, with minimal slowdown during regular operation, while the 33.8-centimetre (13.3-inch) screen looks great. The multitouch scroll pad is incredibly effective – easily the best in this test – and using multitouch gestures is a pleasure. You'll get about five hours of battery out of the Aspire S3, which is good but not great. Overall it's a well-rounded product that is more than adequate for the price.

Verdict: ★★★★☆

ASUS UX21E

Price: £849.99/$999

Get it from: shop.asus.com

The UX21E is the smaller and cheaper of two similar Zenbooks from ASUS (the other will be covered next issue). The device has an Intel Core i5 processor in addition to a USB 3.0 port, with all ports neatly on one side of the laptop. The top of the UX21E has a delicious spun metal finish, while the whole device is ultra-thin at just three millimetres (0.12 inches) at the front. The keyboard is decent, if not the best, and its large size is comfortable for work or gaming. The 29.5-centimetre (11.6-inch) display is bright enough for all light conditions and it has about five hours of battery life, which is good considering its portability. The UX21E's 128GB SSD is also a welcome bonus, but the laptop is let down by its trackpad; in fact, using multitouch gestures on the trackpad can be pretty tricky and at times it feels unresponsive. However, plug in an external mouse and you'll find playing games at medium to high specs a breeze. Minor flaws aside, of our three ultrabooks, this is definitely the one that both looks and feels the best, and despite the higher price tag we'd recommend it over its competitors.

Verdict: ★★★★☆

Toshiba Satellite Z830

Price: £799

Get it from: www.toshibadirect.co.uk

The Z830 is the joint-lightest of our three ultrabooks at 1.1 kilograms (2.4 pounds). This is thanks to a magnesium alloy chassis rather than aluminium, but the Z830 won't be winning any beauty contests, with its rather ugly grey finish. There are two USB 2.0 ports, an HDMI port, VGA output and a USB 3.0 port, which should get you by. One top feature is the backlit keyboard, which is excellent in low-light conditions. Unfortunately, the keyboard and touchpad aren't so great, with the former suffering from mushy keys and the latter being a bit clunky, especially with multitouch controls. Indeed, this trackpad is the only one of our three ultrabooks to use physical mouse buttons, which you'll either love or hate. Performance is good with the Intel Core i5 processor, while the battery life of over seven hours easily eclipses the S3 and UX21E. However, the Z830 also suffers from some terrible viewing angles and disappointing audio. The low price of this ultrabook does almost redeem its defects, but if you have a bit more cash to splash then we'd suggest looking at the UX21E instead.

Verdict: ★★★☆☆

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CHANGE A FUSE

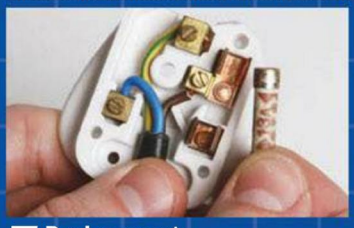
If an appliance won't turn on, there's a chance you might need to replace the fuse in its plug. Find out how here

1 Type
First off, you need to determine which type of plug it is. Older plugs tend to have a screwed faceplate, while more modern variants have a moulded, one-piece design.

2 Faceplate
For older plugs, remove the screws with a flat-head screwdriver and then the plate. If it's a one-piece plug, remove the coloured plastic rectangle from the faceplate by prising it out.

3 Extract the fuse (a)
In screwed faceplate plugs you need to remove the fuse from its holder – part of the internal structure. Take your screwdriver and carefully lever one end of the fuse upwards.

4 Extract the fuse (b)
For one-piece plugs, the fuse holder is part of the rectangular plastic strip removed in step 2. Here, to extract the fuse, simply lift one end of it with your finger until it clicks free.



5 Replacement
Now to install the replacement. Making sure the new fuse is of the same rating as the old one – typically plugs use 3, 5 or 13 amp variants – simply push it back into its holder and then reconnect the faceplate/plastic strip.

CONSTRUCT A GAMING PC

Putting together a powerful gaming computer might look quite daunting, but is actually a relatively straightforward process

NEXT ISSUE
Fly a plane
Change a tyre
Juggle

1. PREP

First, take your components (see page 34 for our suggested kit) and lay them out on a stable surface. A large dining table is ideal, as during the build you want to be handling components at a comfortable level. Cloth or carpet surfaces should be avoided, as static buildup can potentially damage parts. On this topic, if you have a grounding band put it on now; if not, touch a radiator to achieve the same effect.

2. CASE

Your case will come with its side door attached; remove it by taking out the rear thumbscrews for a clear view of the internals. You'll see a small brace of wires, as well as the hard drive and optical disc drive bays. Ignore the wires for the moment, as we'll come back to these later. Notice how the wires extrude through holes in the back of the case; these lead us to our final job for this step: taking off the back panel. Do this as you did with the side door, by simply removing the thumbscrews.

3. MOTHERBOARD

Once the case is prepared, put it to one side. Now take your motherboard and remove the plastic protective cover from the CPU bay (rest the motherboard on top of its conductive grid bag to prevent damage to its underside). In addition, remove any protective plastic caps on the motherboard's VGA and DVI ports, as otherwise you will not be able to slot them through the case's port plate.

4. CPU

Now you can add your CPU. At this stage it's vital to ensure you establish the correct alignment of the CPU before attempting to insert it. This is because the CPU's pin arrangement will only be accepted in one alignment; failure to line it up properly will lead to some of the pins being bent, severely damaging its connection to the motherboard. You can tell which way to insert the CPU by matching up a tiny triangular mark on one of its corners, with an identical mark on the CPU bay. In addition, to prime the bay, you should lift its tiny lever into a vertical position. Once the CPU is in place, lower the lever once more to secure it.

5. RAM

The motherboard's RAM slots can be found to the side of the CPU bay. Inserting the RAM sticks is extremely easy; just prise down the plastic tabs at either end of each slot and then clip the sticks in place. If the RAM sticks have been installed correctly, the plastic tabs should automatically clip back into position.

6. CPU COOLING

Before we insert the motherboard into the case, we need to attach the CPU's cooler. If you followed our kit guide on pages 34-35, you will have an integrated liquid cooling loop. This requires two processes to attach correctly: first the cooling block on top of the CPU bay and secondly the dual fan array. Start with the cooling block, attaching its feet extensions to the motherboard and fixing it in place within its frame. Next, screw the dual fan array to the ceiling exhaust vent of the case.

7. PSU

Inserting the power supply is fairly simple. Ensuring you correctly align it – modern PSUs tend to have rubberised feet to separate them from the case – screw it in place via the backplate. Do not remove the cable ties from the bundle of wires, as chances are you will not need to use them all and, by freeing them, you create more mess that will then need to be tidied away later.

8. SSD

As we're making a high-end gaming PC, we've opted for a solid-state drive (SSD) rather than a slower but bigger-capacity hard disk drive (HDD). Luckily, however, thanks to the case's easily accessible drive bays, we can simply insert the drive into a caddy and slot it in (remember, you want to put it in face first, as power and data cables need to be attached later). The caddy should securely hold the drive in the bay if inserted properly.

STEP 9

9. GPU

Now we can slot the last part into the motherboard: the rather large GPU. It's important to ensure the case you buy is large enough to accommodate the GPU, otherwise the gaming heart is rendered useless. Start by taking out one of the PCIE slots' rear panel covers – ideally the highest one in the array (this is because you want more room beneath the card for cooling purposes). These can be removed by unscrewing their single holder screw and carefully prising the metal strip away. Next, with great care, install the card into its slot and screw it in place at the inside-rear of the case.

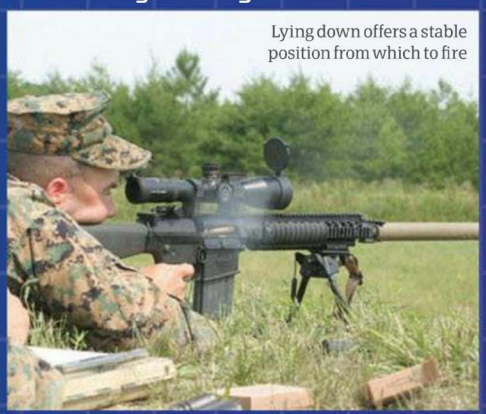
STEP 10

10. WIRING

Before you start connecting anything, remember the goal is to leave as much of the case's internals unobstructed by trailing wires. To help with this, there are rubberised holes in the motherboard panel, enabling you to route unwanted cable between the motherboard panel and the case's back panel. Start with the power cables for each component (specified in their manual), before progressing on to data cables (such as the SSD's SATA connection), and then on to function-related cabling such as the power and reset connections, as well as fan, USB and audio jack wiring.

FIRE A SNIPER RIFLE

Sniper rifles are precision weapons, requiring great skill and technique to successfully take any shot



Lying down offers a stable position from which to fire

1 High maintenance

Before any sniper can make a shot, they must ensure that their rifle is in tip-top condition. Cleaning and servicing is critical therefore, with each imperfection greatly affecting the efficiency of the weapon – for example, any powder buildup in the barrel can have an impact on the spin, and so the trajectory, of a round.

2 The perfect position

Once the rifle is assembled and ready for use, the sniper must then acquire a stable foundation from which to fire. Elevated positions are ideal, however a stable platform on which to rest the rifle is vital. Tripods and attached bipods can help with this, as can a seated or prone firing position.

3 Spotting

Snipers rarely work alone. Instead, they operate as a team of two, with a sniper and spotter working together. A spotter detects, observes and assigns targets for the sniper, and then reports back on each shot fired. This is because the narrow view a sniper is afforded leads to a severe reduction in situational awareness.

4 Zeroing

Depending on information received from the spotter, the sniper will then zero the rifle. Zeroing is the adjustment of the rifle's sights to account for distance and elevation.

5 Variables

In addition to zeroing, the sniper must then adjust their aim for wind speed, wind direction, obstacles (such as shooting through glass), temperature, humidity, target movement and the curvature of the Earth. Each of these can affect the trajectory of a fired round, throwing off a shot by several metres if not accounted for.

6 Pull the trigger

Finally, the shot can be taken. This involves the sniper steadying the picture sights, controlling their breathing pattern and adjusting the point of aim before squeezing the trigger. The target reticle commonly moves in a figure-of-eight pattern in sync with the sniper's breathing, with a sniper commonly taking the shot at the top-centre of the figure of eight.

TEST YOUR KNOWLEDGE

ENJOYED THIS ISSUE? WELL, WHY NOT TEST YOUR WELL-FED MIND WITH THIS QUICK QUIZ BASED ON THIS MONTH'S CONTENT?

1 What is the average number of planets that orbit a star?
A:

2 What resolution does the new iPad's screen have?
A:

3 Which calibre of bullet does the AX338 PSR fire?
A:

4 What's the capacity of the Sony Xperia S's battery (in mAh)?
A:

5 Roughly how many domestic cats are there in the world?
A:

6 How many types of cell does the human body contain?
A:

7 What is the commercial top speed of the CRH380A high-speed train?
A:

8 How many years has the C-130 Hercules been in operation?
A:

9 Who invented the seed drill?
A:

10 Which month and year did the A7V tank get deployed?
A:

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> ISSUE 32 ANSWERS

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We enjoy reading your comments every month. So keep us entertained by sending in your questions for the mag, comments on what you like/don't like, or any science-related news you want to share.

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© NASA

Could old light be the key to looking into the past?

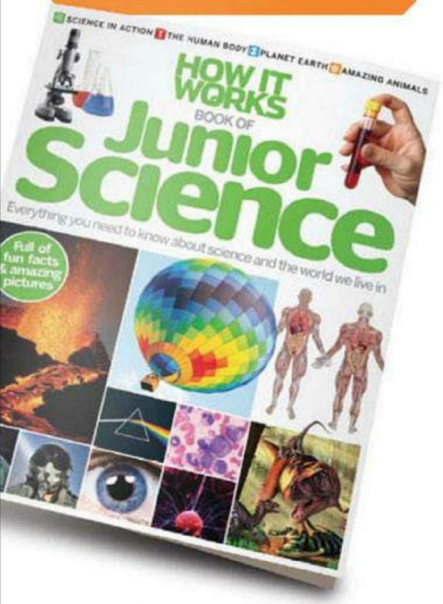
Letter of the Month

Old light

Hi, I was wondering if you could mention a thought I had in your next issue. It would be really interesting to see people's thoughts and yours! Given that light travels at a certain speed through space and that the light we receive on Earth is 'old', this means obviously that what we see is in fact history, like seeing the past. Well, if that is the case, then surely if we could get a device far enough into space at sufficient distance, we could look into the past and see, for example, medieval Earth! I hope this makes sense – it just seems fascinating.
Dan Wood (26, Gloucester)

Win! Annual Pass to INTECH Science Centre

HIW: A very interesting question, Dan, thanks for getting in touch! Your theory would depend on whether you could fly a super-powerful telescope faster than the speed of light. If you could place one, say, 100 light years from Earth at this very instant, then the light you'd be seeing from Earth would indeed be from 100 years ago, so you would technically be looking into the past! Now, the only problem is figuring out how to build this faster-than-light, super-powerful telescope... We'll leave that up to you! Congratulations though, your interesting theory has earned you this issue's Letter of the Month.



Junior science

Your magazine is fantastic in the classroom. I often hand it out to my higher-level pupils to look through. They love it. After reading your magazine a couple of times I thought it would make excellent reading for some of my older pupils, however a children's version of this magazine would also work incredibly well, I think (and there's a bit of a gap in the 'science for children' literature out there).
Stuart Owens

HIW: Thanks for writing in, Stuart; you'll probably want to check out the new How It Works Book Of Junior Science, which is on sale now. It's a compendium of all our school-level articles, a perfect companion for pupils studying physics, chemistry, biology, geography and more.

Sibling rivalry

I've had a subscription to HIW since issue 1 and have loved almost every word. The only bit I didn't like is when my sis wrote in and complained I haven't let her read it. This is untrue; she has never once asked to read HIW. Also one thing I'd like to see is something like a boffin's corner, because in several topics you have explained the basics well but left out anything complicated, like facts, figures and general clever stuff. For example, when you did a bit on Einstein's theories I felt you hadn't really explained in enough detail the things like massive speed plus more energy equals extra mass or that gravity bends light and therefore time. But anyway, I absolutely adore HIW and think it's the best thing to ever hit the newsstand. Keep up the good work.
Henry Cole (Cheltenham)

HIW: Thanks for your kind words, Henry. We do try to go into as much depth as possible but we don't always have enough space in the magazine to cover everything in as much detail as we'd like. We'll keep trying our best though, and hopefully you and your sister can share How It Works from now on.

Three's a crowd

In your article on the Apollo spacecraft (which appeared in issue 25), there were three main sections not two. The Command module, the Lunar Excursion module and the Service module that was connected to the Command module. The Service module contained the support system of fuel, guidance, oxygen, etc, for the Command module.
Michael Bussey

Venice was only built on marshland as a last resort

HIW: Technically you're right, Michael, but the Command and Service modules are usually regarded as one entity – that is, the Command/Service module – while the other is the Lunar Excursion module. So, occasionally Apollo is referred to as having two modules rather than three. Apologies for the confusion.

When in Rome...

I was a bit confused in issue 31 about Venice. Now here's a question for you: why was Venice built on a lake? That's the only city on a lake that I know of. Also why did people want to live there? I wouldn't live there because it's got no parks, and I'd have to go on a boat just to go to school. But I was fascinated about how they built Venice all the same.
Sam Holt

HIW: The Venetians were driven out by the Romans, and found themselves with few places to settle. The only place they could go is what is now Venice, which at the time was a horrible marshy land that nobody else wanted to colonise. Eventually they built it up into the fantastic city we know today that, thanks to its coastal position, became an important port. This, in turn, attracted new settlers to Venice.

Feel the speed

I was reading the article about dwarf planets (issue 30) and got sidetracked into a debate about the speed the Earth is travelling at. Hopefully I'm right in saying it's approximately 1,609 kilometres (1,000 miles) per hour spinning on its axis and 103,803 kilometres (64,500 miles) per hour around the Sun. The query then occurred to me that if we are moving at that speed and we don't feel it and, setting aside any catastrophic impact it would have, how fast would the Earth need to spin or rotate around the Sun before we did feel movement?
Don Kinghan

HIW: The law of inertia states that if you are travelling at a constant speed, it feels the same as if you were stationary. This means that, no matter how fast the Earth was moving, as long as its speed was constant you wouldn't feel any movement. You'd only feel something if it started drastically slowing down or speeding up, in which case the effects would be catastrophic!

As cold as ice

I was reading about cryogenics in last month's edition of How It Works and it said that -89.2°C (-129°F) was the coldest temperature ever to be recorded on Earth. Why couldn't electronic freezers make a cooler temperature?
Iain McWhinnie, 9

HIW: Electric freezers have indeed reached cooler temperatures; we were referring to the coldest natural temperature. For a more in-depth explanation of how electric freezers get so cold, head to page 85.

What's happening on... Twitter?

We really love to hear from **How It Works'** dedicated readers and followers, with all of your queries and comments about the magazine. Here we pull together a varied selection of the latest things you've been tweeting over the last month.

HopscotchFoundr **@HowItWorksmag** Discovered your magazine! Perfect for my inquisitive scientist daughter, who gets little to no real 'science' at school

IslayGaz **@HowItWorksmag** Just waiting for the bus and want to know: why does cold weather make your nose run?

StarryEyedTrut **@HowItWorksmag** Does a cat's colouring affect his/her personality?

AbsWarokar **@HowItWorksmag** It is the best magazine I've ever read so far. I would recommend to buy the mag to those people who love to read :) Impressed

mst3kuk **@HowItWorksmag** The biggest number ever used in maths is called Graham's number; all we know is that it ends ...2464195387 #didyouknow

DaisyCCheung **@HowItWorksmag** Thanks to some dude on the subway with his iPad, I found an interesting publication to read @HowItWorksmag #tech

snapshotscience **@HowItWorksmag** If the molecules in a litre of water were the size of sand grains they would cover the surface of the Earth [48 kilometres] 30 miles deep...

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AMAZING ATOM POWER

Next issue, discover all you need to know about the science of atoms. They may be only tiny particles, but their significance can be felt in everything we do as they make up all matter in the universe. Find out what goes on at CERN, and how atoms can be used to run computers, power energy plants, as well as how the atom is split

ANSWERED NEXT ISSUE

Which is the hottest desert in the world?

How is a rocket booster recovered from the sea?

What are the weapons on aircraft attached to?

How do laptops fit in so much powerful tech?

How does a chick develop inside an egg?

+ LEARN ABOUT

- BAZOOKAS
- KILLER WHALES
- MOSQUITO REPELLENT
- ARTIFICIAL BLOOD
- WHIPLASH
- INCUBATORS
- SNOWMOBILES
- RECORD PLAYERS
- WATER TOWERS
- CARINA NEBULA
- HUMAN BLADDER

5 TOP FACTS: HARRIER

Old Boy
The Sea Harrier was in service for a total of 28 years, from August 1978 to March 2006. The second-generation Sea Harrier FA2 was introduced in April 1993.

Post-colonial
The only other international operator of the Sea Harrier is actually India, who use their own FRS51 variant armed with R550 Magic air-to-air missiles.

Invincible
The first ever Sea Harrier confirmed as operational launched off the Invincible class aircraft carrier HMS Invincible in 1981, a purpose-designed VTOL/STOL carrier.

Vixen
The second-generation Sea Harrier, the FA2, featured the Blue Vixen radar, the predecessor that formed the basis of the system used in the Eurofighter Typhoon.

Forgetful
The second-generation Sea Harrier was also the first British aircraft to be armed with the US AIM-120 AMRAM, a fire and forget high-explosive air-to-air missile.

AIRFIX®

How it worked

In order to supplement its short range, many Harriers were fitted with the aerial refuelling probe seen here.

Retractable 'eye lids' protected the laser ranger and target seeker during take-off and landing, thus protecting the Harriers weapons capability.

In addition to the primary nozzles, were four "puffer jets" housed in the tail, nose and wing tips that used air bled from the high pressure compressor to give added stability.

Seen here armed with two sidewinders and the 30mm gun pods, the GR3s primary role in the Falklands was one of ground attack, armed with bombs and rockets.

The two front nozzles discharged cool air from the front fan of the Pegasus engine, the rear nozzles hot air that had passed through the compressor. All the nozzles could rotate through a full arc of 98.5 degrees in one second.

HAWKER SIDDELEY HARRIER GR.3

Developed in the 1960s, the Hawker Siddley Harrier was the first close support and reconnaissance fighter aircraft capable of V/STOL (Vertical/Short Take-Off Or Landing). After it entered service the RAF positioned the majority of its early Harriers in Western Germany, so as to be as close to the frontline as possible should the Cold War have turned hot and the Soviets launched an invasion. The Harriers trump card in this situation would have been its ability to operate from rough strips and even roads, thus hopefully evading the Soviet Air Force.

It was not until the Falklands in 1982 that the Harrier saw combat however, here the GR3 variant operated as a ground attack fighter with great success. Updated throughout its service life before its retirement in 2011 the Harrier was a capable and dependable warplane. Equally at home delivering guided ammunitions over Afghanistan, or wowing airshow goers with its ability to hover and 'bow' to its audience.

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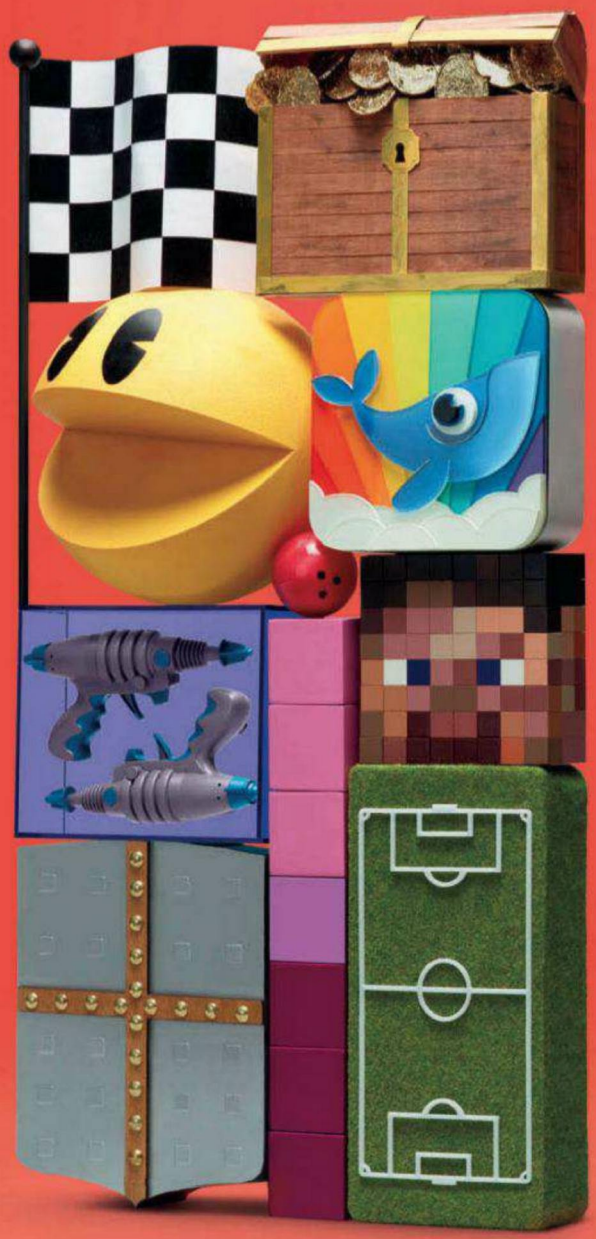

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Stuff ★★★★★

XPERIA