THE MAGAZINE THAT FEEDS MINDS

HOW IT WORKS

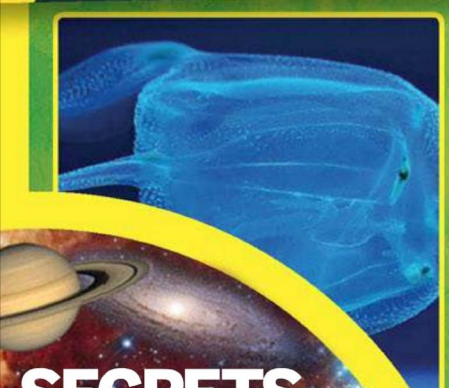
SCIENCE ENVIRONMENT TECHNOLOGY TRANSPORT HISTORY SPACE

INSIDE

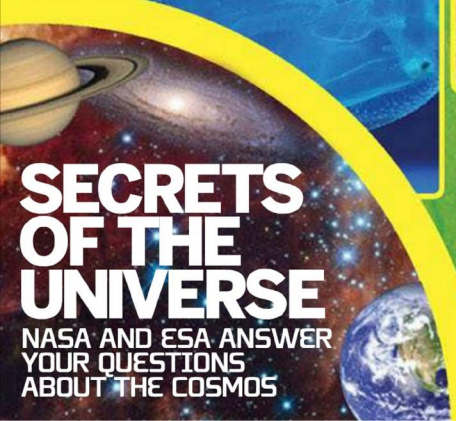
NEXT-GEN PHONE TECH
THE FUTURE OF MOBILES REVEALED

SCIENCE OF FREEZING
How could ultra-cold cryogenic tech help you live forever?

DEADLY VENOM
HOW THE WORLD'S MOST TOXIC ANIMALS KILL



EXTREME MOTORSPORT
Discover the engineering that fuels high-octane race vehicles from NASCAR to Le Mans



SECRETS OF THE UNIVERSE
NASA AND ESA ANSWER YOUR QUESTIONS ABOUT THE COSMOS

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- EMAILS
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- CHAIN FERRIES
- ROCKET FUEL
- GUN TURRETS
- RED SUPERGIANTS

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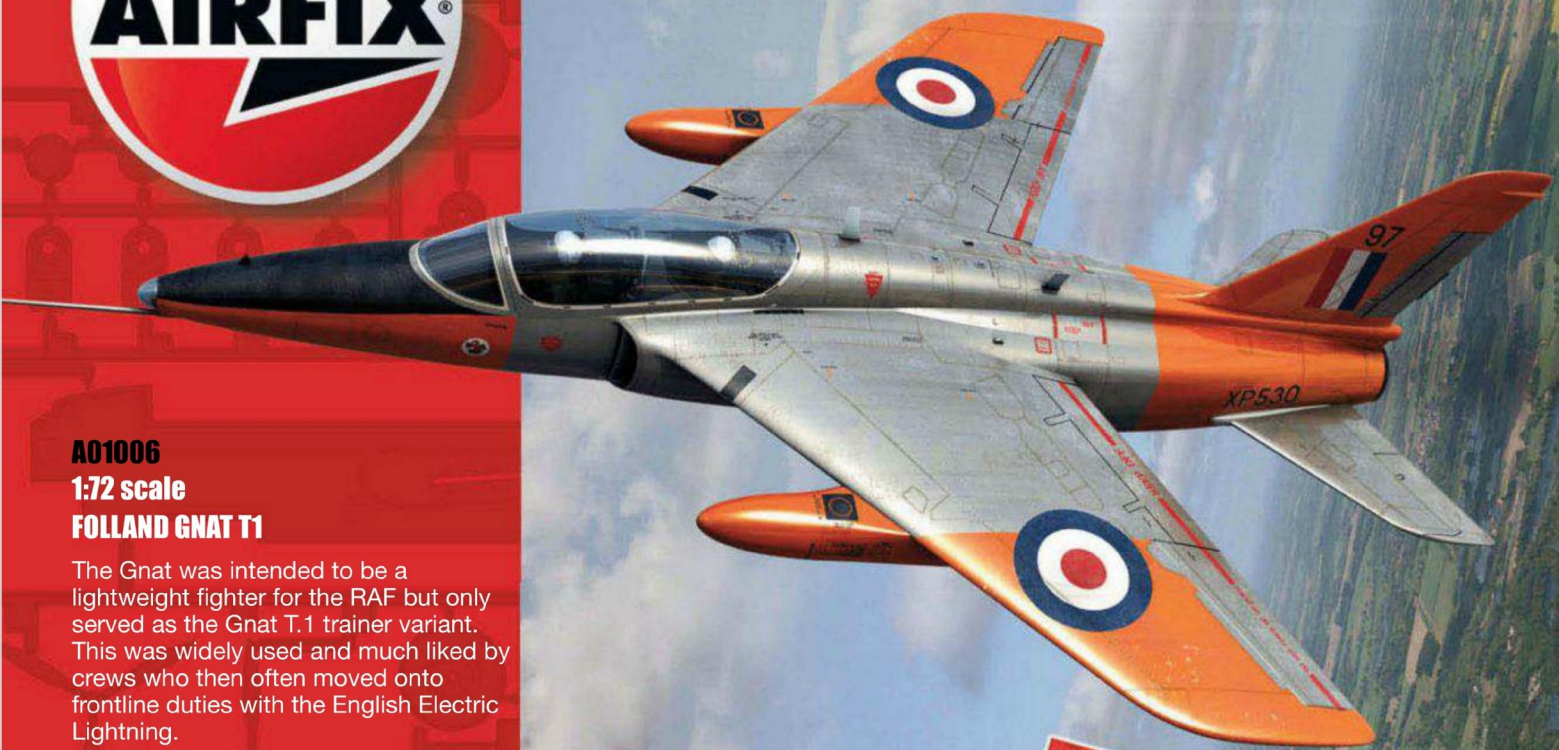
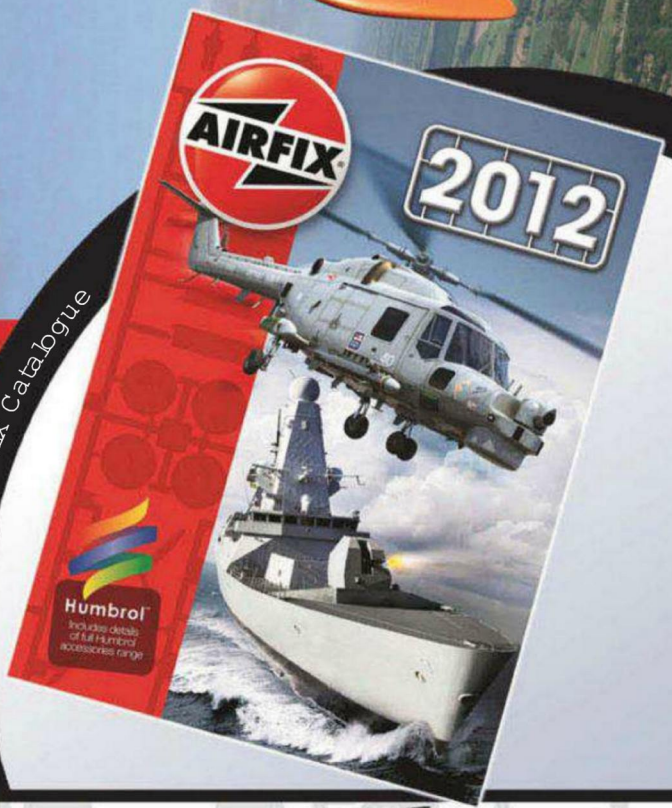


A01006
1:72 scale
FOLLAND GNAT T1

The Gnat was intended to be a lightweight fighter for the RAF but only served as the Gnat T.1 trainer variant. This was widely used and much liked by crews who then often moved onto frontline duties with the English Electric Lightning.

A tiny aircraft in comparison with its contemporaries, the Gnat was used and the mount of a number of aerobatic teams, from the Yellow Jacks to the Red Arrows. Serving until 1979, the Gnat proved to be a capable and much loved trainer.

Number of parts: 49
Length: 155 mm Width: 102 mm



This year's catalogue is even bigger and better than ever!

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HOW IT WORKS
WELCOME
The magazine that feeds minds! ISSUE 31

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MEET THE EXPERTS

Find out more about the experts behind your favourite articles in this issue's edition of **How It Works**...

Dave Roos
Cryogenics

Bringing you the lowdown on the spine-chilling subject of cryogenics and the applications of ultra-cold technologies is one of our longest-serving freelance science writers, Dave Roos.

Luis Villazon
Venomous animals

His knowledge of the natural world knows no bounds, so this issue Luis turns his hand – not literally, of course; that would be foolish – to the planet's most deadly creatures and how they kill with venom.

Rik Sargent
Washing detergent

Rik's experience as an explainer at the Science Museum in London made him the ideal candidate for explaining the chemistry of washing detergents and how they clean your clothes, but making it sound fun.

Shaun McGill
Future of mobile

Communications expert Shaun McGill has written on the subject of smartphones and other mobile devices for many years. His feature reveals the tech we'll be enjoying in the very near future.

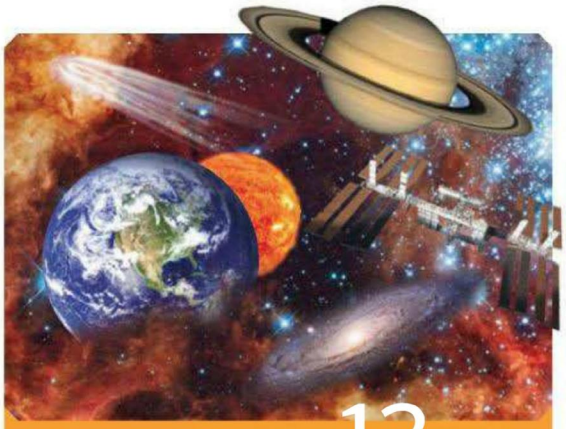
Dave Howell
Quartz clocks

Technology writer Dave authored a number of articles on essential domestic devices in this issue of How It Works, including smart electricity meters, baby monitors, heart-rate machines and quartz clocks.

Alasdair Stuart
Tugboats

Hitting up the How It Works Transport section this issue, Alasdair Stuart reveals how chain ferries and tugboats work as well as how mechanics repair chipped windscreens.

"FEED YOUR MIND!"



EDITOR'S PICK 13

When we asked you to send in your cosmic quandaries for our latest space feature, we were inundated with your curious wonderings. Bringing you those all-important answers this issue are some of astronomy's finest experts – enjoy!

THE SECTIONS EXPLAINED

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 the transport section

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

HISTORY
Your questions about how things worked in the past answered

TECHNOLOGY
The wonders of modern gadgetry and engineering explained

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

HOW TO DECIPHER YOUR QR CODE...

This black and white matrix barcode is what's known as a QR code and in it we've concealed a random – but nonetheless intriguing – fact for you. To decode this message you'll need to download a QR code reader app on to your mobile phone. Then simply view the code through the camera screen and the secret message will appear.

With thanks

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

sciencemuseum
london transport museum
MANCHESTER
National Museums Scotland
DK
NASA

Of all nature's remarkable predators, those with the ability to outsmart and overcome their prey using methods other than sheer size and brute strength are undoubtedly among the most compelling to learn about. Of course, big ferocious bears and sharp-toothed sharks are impressive killers, but that kind of approach to hunting is so, well, obvious. This issue's 'Science of venom' feature looks instead at the variety of species blessed with toxic fangs, stings and even those whose very skin oozes noxious substances.

We've all been warned about the brightly coloured specimens that are not safe to handle – indeed, you can tell from their psychedelic appearance that they're just waiting to pump you full of a lethal cocktail of chemicals – and so we tend to give them a wide berth. But what of those creatures that look harmless – or even cuddly? Turn to page 44 for our guide to the most venomous creatures on the planet. Discover the tactics they use, find out what's in the fatal fluids that they secrete and, ultimately, learn which beasties to avoid at all costs.

Also this issue we are ecstatic to announce the launch of our incredible new How It Works Daily website, which you can learn more about on page 11. Check it out today.

Enjoy the issue.

Helen Laidlaw
Editor

Meet the team...

Dave
Ed in Chief
The max power racers feature packed a mighty punch this issue. I learned so many new things and the machines involved are just incredible. I also enjoyed finding out how Venice was built.

Robert
Senior Staff Writer
Now, I'm an F1 fan but having discovered four other of the world's most insane racing events in the 'Extreme motorsport' feature, I now realise that for pure racing action, we should look elsewhere.

Jonny
Staff Writer
Uncovering the secrets of the universe with a team of astronomy experts was a lot of fun for me this issue. A big thank you to all those involved. And thanks to the readers who sent in their questions.

Adam
Senior Sub Editor
My favourite read this issue was definitely the fascinating field of cryogenics and the secrets of freezing. That said, my dad's a refrigeration engineer, so I might be a bit biased!

HOW IT WORKS

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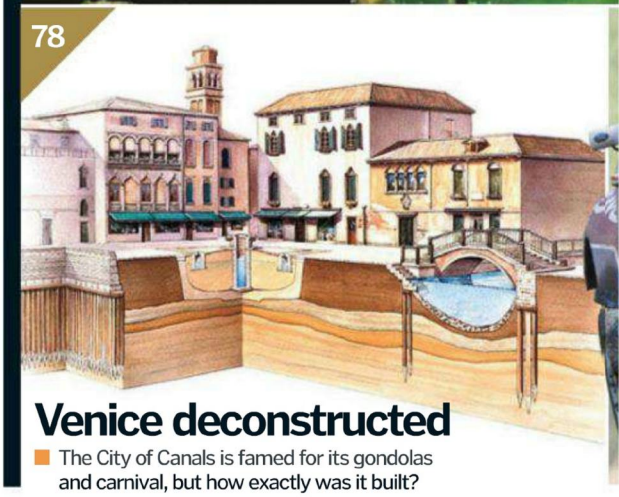
Discover some of Earth's most lethal critters



Venice deconstructed

The City of Canals is famed for its gondolas and carnival, but how exactly was it built?

80 Expert answers

Scientists from the finest museums in the world answer your questions in this issue's jam-packed Brain dump

Caroline Warhurst
London Transport Museum
The information services manager at London Transport Museum, Caroline is here to answer all your transport-related questions this issue.

Andrew Brooks
Science Museum
Andrew loves thinking about all the planets that exist across the universe. When not explaining at the Museum he likes making lots of noise on the drums.

Aidan Dodson
National Museums Scotland
Aidan teaches Egyptology at the University of Bristol. He's the advisor for the Fascinating Mummies exhibition at the National Museum of Scotland now.

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See whether cryogenics is as cool as it's cracked up to be

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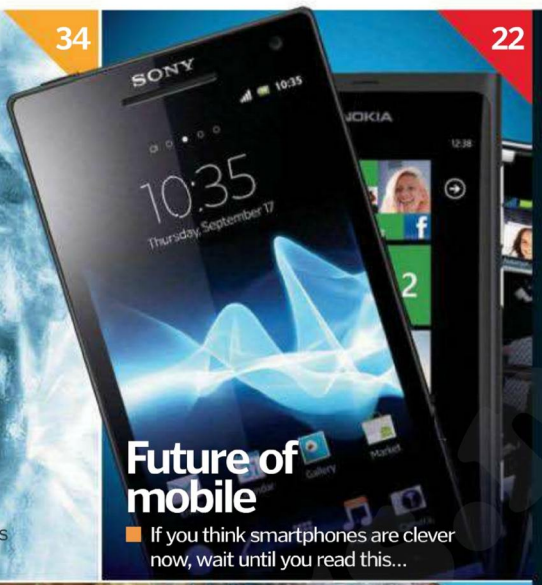

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GLOBAL EYE NEWS

The most sensational news and pictures from around the world

Showcasing the incredible world we live in...

Stunning hi-def image of Earth revealed

NASA celebrates the 40th anniversary of the famous 'Blue Marble' image of our planet by releasing an updated, high-fidelity version

NASA has unveiled a spectacular high-definition version of its famous 'Blue Marble' image of Earth. The stunning shot comes 40 years after the original was taken on board the Apollo 17 spacecraft at a distance of 45,062 kilometres (28,000 miles) from our blue planet. It was taken by NASA's latest Earth observation satellite, Suomi NPP, which launched in October 2011.

The image itself, interestingly, is a composite of many shots which were captured by the Suomi NPP's visible/infrared imager radiometer suite (VIIRS), a scanning telescope that measures the difference between the amount of light coming down to the surface of Earth from the Sun as compared to the amount of light that is reflected back to the telescope. As such, the image you can see here on this page is the result of multiple 3,058-kilometre (1,900-mile)-wide 'smaller' snaps being pieced together to form one seamless picture.

This stitching together of images is possible because the Suomi NPP is currently on a Sun-synchronous orbit; this means that the satellite crosses the equator at the same time each orbit (currently 14 times a day) which allows for an evenly lit and consistent final image.

Despite the awesome fidelity and beauty of the 2012 Blue Marble, the Suomi NPP's work is only just beginning. The satellite, which weighs 2,100kg (4,600lb) and is the size of a small bus, will now spend the next decade observing the Earth and gathering a host of data. This information will include temperature and pressure patterns, ozone levels – especially near the poles, ice and landform movements and emitted thermal radiation.

The satellite was named Suomi NPP on 24 January 2012 in honour of Verner E Suomi, who died in 1995. The American meteorologist is generally considered the father of satellite meteorology.

2x © NASA

The Suomi NPP's VIIRS – as used to create the 2012 Blue Marble – is the largest of five instruments on board the satellite

The 2012 Blue Marble image is a composite of a number of shots of the Earth's surface taken by the Suomi NPP satellite on 4 January

HMS Victory 'to be recovered' from ocean floor

The remains of a predecessor to Admiral Nelson's famous flagship are to be raised from the seabed, along with an estimated £500 million in gold coins

HMS Victory, a 300-year-old warship that was lost in a storm during 1744, is to be hauled up from its resting place after 268 years. The ship, which cost the Royal Navy the lives of over a thousand sailors when it sank, is believed to contain gold coins worth an estimated £500 ($788) million.

The wreckage was found four years ago near the island of Alderney in the English Channel by American company Odyssey Marine Exploration, and was confirmed shortly after by the analysis of an ancient bronze cannon from the site.

According to *The Sunday Times* newspaper, the gun, along with a selection of other surviving artefacts, will go on display throughout Britain in naval museums once they're recovered. However, under the UK laws of salvage, the bulk of any treasure found will be rightfully the possession of Odyssey.

Built in 1737, HMS Victory was the principal ship of the age, constructed by master shipwright Joseph Allin and acting as the flagship for the Royal Navy's Channel Fleet under the command of Sir John Norris. The story of the ship's vast on-board wealth – which was the result of trading and raiding enemy ships – originates from a financial publication released a month after it sank, which stated that 'people will have it that on board of the Victory was a sum of 400,000 pounds sterling that it had brought from Lisbon for our merchants.'

Speaking on the announcement that HMS Victory was to be raised from the seabed, a Ministry of Defence source said that any "efforts to protect key parts of British naval history such as the 1744 wreck of HMS Victory are very welcome."

© Google

The wreckage was found near the Channel Island of Alderney

This depiction of the Victory is from the year it sank

GLOBAL EYE NEWS

A fresh look at the world

WHAT ON EARTH IS IT?

Every month we post weird and wonderful images on the **How It Works** supersite for you to identify. We then print the best suggestions and tell you what they really are right here

Visit the website: www.howitworksdaily.com

Send us a direct message: @HowItWorksmag

Email us: howitworks@imagine-publishing.co.uk

Post on our wall: 'How It Works Magazine'

© Quarto

1

'Surely the eyeball of a fish...' **Owl17**

'It's a blueberry stuck in a Christmas tree' **Dante Weyand**

'It must be a glow-in-the-dark eyeball!' **Ashwin Kumaar**

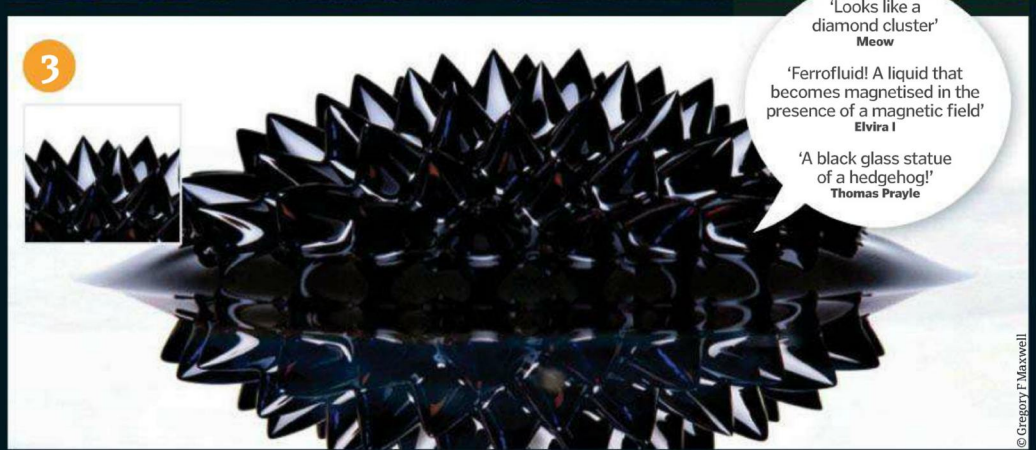
© Nick Hobgood

2

'Sloth hands?' **Jason**

'Lady Gaga's new hat for the next music awards show?' **Rjlabat1**

'It looks like a sea-creature like a starfish or urchin' **Carl Lohse**



© Gregory F Maxwell

3

'Looks like a diamond cluster' **Meow**

'Ferrofluid! A liquid that becomes magnetised in the presence of a magnetic field' **Elvira I**

'A black glass statue of a hedgehog!' **Thomas Prayle**

1. Urchin

This is a fine example of the diadema setosum species of long-spined sea urchin, which belongs to the family diadematidae. Setosum is typical of a sea urchin, sporting long spines filled with a mild venom that, while not fatal to humans, can prove a hazard if stepped on. The orange-ringed sphere at the centre of the image is the urchin's periproctal cone, used for excreting waste.

2. Slate

This is a fantastic shot of the slate pencil urchin – technically known as eucidaris tribuloides – which is a member of the basal echinoid order cidaroida that can be commonly found throughout the Atlantic Ocean. It is primarily a nocturnal creature, spending the day lodged in crevices or on top of rocks, and then feeding on corals and sponges during the night. The slate pencil urchin uses its large primary spines to anchor itself to its surroundings.

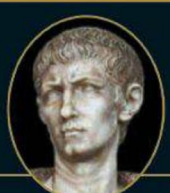
3. Ferrofluid

It may look solid, but this is actually activated ferrofluid, a paramagnetic substance that is composed of nanoscale ferromagnetic particles suspended in a carrier liquid. The fluid, when activated by the positioning of a strong magnet (made of neodymium) under the fluid's carrier plate, causes normal field instability and allows the fluid to overcome gravity, spiking upwards in a magnetically harmonised way.

THIS DAY IN HISTORY

23 FEBRUARY: How It Works issue 31 goes on sale, but what

303 The Roman Emperor Diocletian begins eight years of persecution against Christians by destroying a church in Nicomedia, Turkey.



1455 The Gutenberg Bible is printed for the first time in Germany. It is the first Western book to be printed with movable type.

1739 A retired schoolteacher identifies the notorious highwayman Dick Turpin as John Palmer. The criminal had been a former school pupil of his.

1836 The famous Battle of the Alamo begins in San Antonio, Texas.

1945 One of the most iconic photos of the Second World War is taken as soldiers raise the American flag on the Japanese island of Iwo Jima.

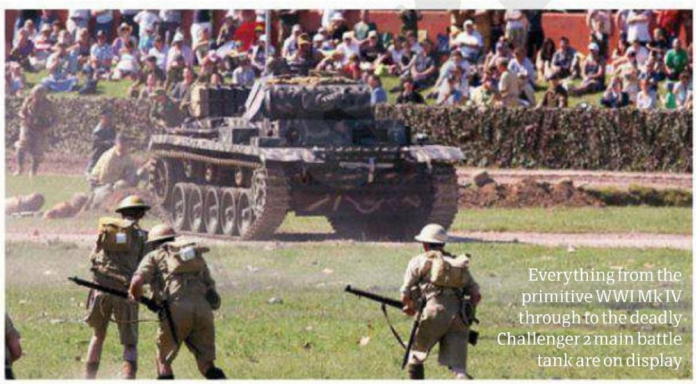
1958 Cuban rebels kidnap five-time world driving champion, Juan Manuel Fangio.

Bovington Tankfest 2012

The tenth anniversary of the world's biggest and best tank festival promises to blow the lid off your expectations with a battalion-load of explosive action over two days

Fancy watching some of mankind's most awesome armoured vehicles delivering demonstrations of their deadly prowess live? Well, if so, the Bovington Tank Museum's annual Tankfest extravaganza in Dorset is one event you should mark in your calendar. With heavy metal operating throughout the weekend of 30 June to 1 July in the Tank Museum Arena, a fantastic selection of trade stalls supplying refreshments and souvenirs, a range of educational living-history encampments to explore, as well as a series of special events in the Museum itself, 2012's festival is set to be the largest yet.

Indeed, this year will see the Museum's World War I Mk IV replica tank – built for the film *War Horse* – in action for the first time, along with the famous World War II Tiger tank and a selection of modern British Army vehicles including the Challenger 2. So, what are you waiting for? For up to 20 hours of non-stop tank mayhem head to **www.tankmuseum.org** for tickets and more information.



Everything from the primitive WWI Mk IV through to the deadly Challenger 2 main battle tank are on display

Mutant flu virus sparks fear of pandemic

US government restricts publication of research detailing creation of mutant strains of the H5N1 avian influenza virus

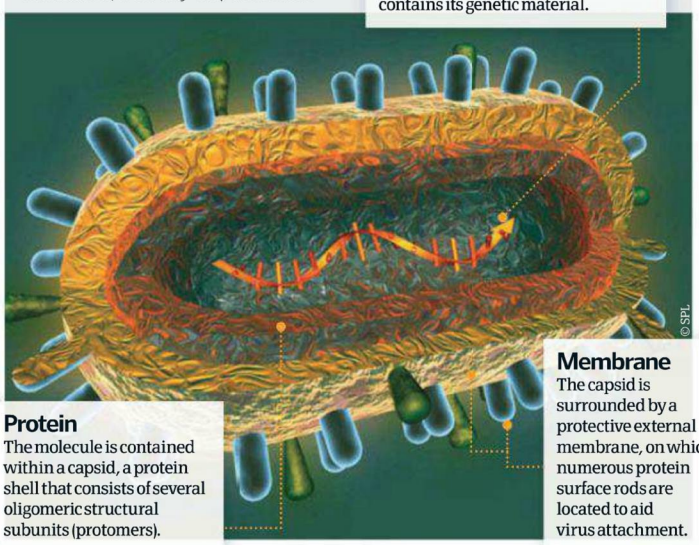
The US government – with co-operation from the revered scientific journals *Nature* and *Science* – has restricted the publication of research detailing the creation of multiple mutant strains of the deadly H5N1 avian influenza virus amid fears of potential outbreaks and bioterrorism.

Currently, the mutant strains are contained within mandatory level 3 (BSL-3) containment facilities, but amid the current controversy engulfing the international bioscience community regarding the projects, many scientists are arguing that due to their extreme danger the strains, as well as research into them, should be kept within level 4 laboratories (BSL-4) that have the highest biosafety rating.

The mutant strains, if released, would spread as quickly as ordinary flu, yet deliver a fatality rate akin to wild-type H5N1, which in 2005 led to nearly 1.2 million birds to be slaughtered in Vietnam to contain an outbreak.

Further, under mounting pressure by international governments and institutions, a 60-day suspension into mutant flu research has been called for. Writing in a statement published on 20 January, many scientists warn that "organisations and governments need time to find the best solutions for opportunities and challenges that stem from the work." However, some scientists believe the research shouldn't continue at all. Richard Ebright, a molecular biologist and biodefence expert at Rutgers University, addressing people's fears, stated: "In the US, there is only voluntary oversight for biosafety, and with the exception of the select agents rule, there is no oversight of biosecurity. What's remarkable [is that for research of this type], which puts at risk not one individual but potentially hundreds, thousands or millions, there is no oversight whatsoever."

It's hoped that the called-for pause in research will provide enough time to weigh up the pros and cons of this research going forward.



Molecule
The virus's core comprises a single-stranded RNA molecule, which contains its genetic material.

Protein
The molecule is contained within a capsid, a protein shell that consists of several oligomeric structural subunits (protomers).

Membrane
The capsid is surrounded by a protective external membrane, on which numerous protein surface rods are located to aid virus attachment.

else happened on this day in history?

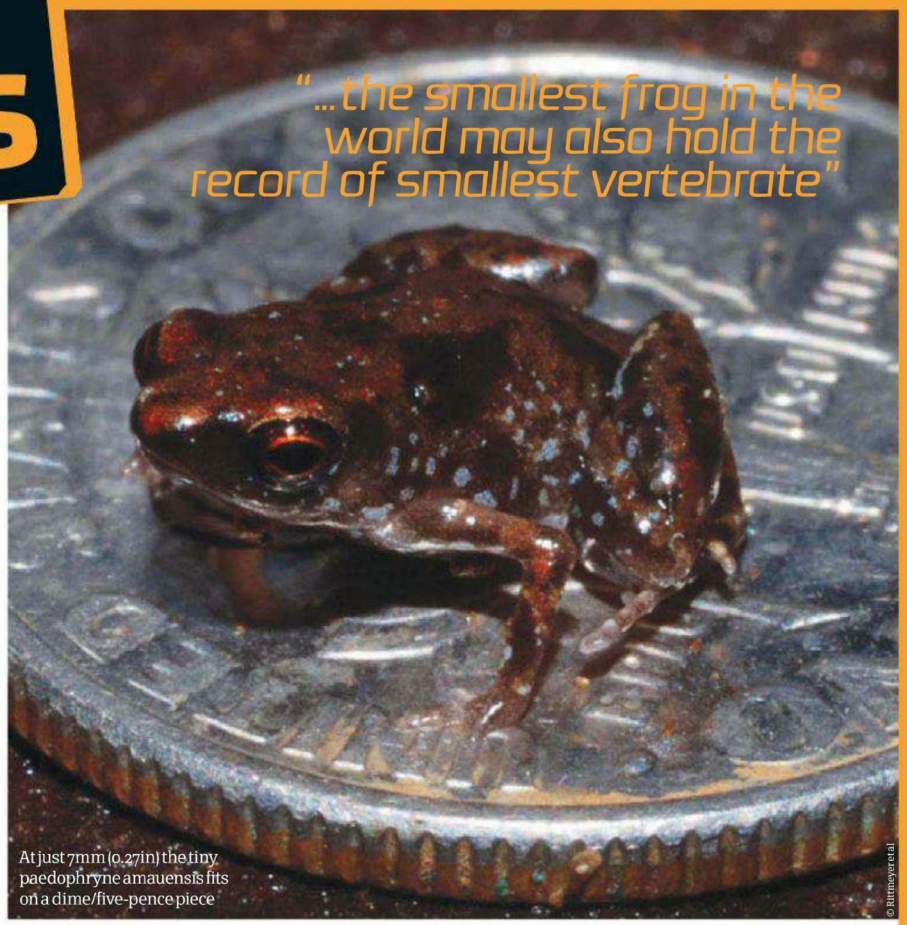
1987 Supernova 1987a is seen in the Large Magellanic Cloud.

1997 A fire breaks out on the Russian space station Mir. No crew-members are harmed.

1999 An avalanche destroys the Austrian village of Galtür located in the southern Tyrol region. 31 people are killed.

2010 Unidentified criminals pour more than 2.5m litres (660,430 gallons) of diesel into the River Lambro, northern Italy, causing an environmental disaster.

10 THINGS WE'VE LEARNED THIS MONTH

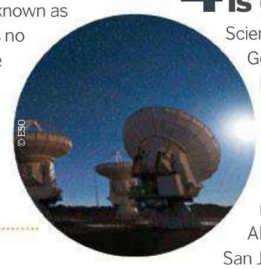


At just 7mm (0.27in) the tiny paedophryne amauensis fits on a dime/five-pence piece

© Rittmeyer et al

1 Smallest frog lives in New Guinea

Researchers in the United States have announced they have discovered the smallest frog in the world, which may also hold the record of smallest vertebrate. Measuring a tiny seven millimetres (0.27 inches) in length, the frog known as paedophryne amauensis is no bigger than a US dime. The frog was found in the forests of New Guinea, Indonesia, although its minute size and calls, imitating that of insects, made it tricky to locate.



2 Every star has planets

A study released at the 219th American Astronomical Society (AAS) meeting suggests that every star in the universe plays host to at least one planet. Using a technique called gravitational microlensing, the researchers studied a variety of exoplanets in orbit around stars and estimated that one or several planets must be in orbit around every star.

3 Rats are friendly creatures

Going against the popular conception that rats are nasty animals, a study in the journal *Science* suggests these oft-maligned mammals are actually rather amiable. The team of researchers placed one rat in a cage, with an external safety release, and left another free to roam outside. Eventually, admittedly after seven days, the free rat found out how to release his trapped companion. If there was no rat inside the cage, or it was replaced with a stuffed animal, the free rat showed little or no desire to free his comrade.

4 Memory storage is getting smaller

Scientists at IBM and the German Center for Free-Electron Laser Science (CFEL) have created the world's smallest magnetic data storage device. Using a scanning tunnelling microscope (STM) at IBM's Almaden Research Center in San Jose, California, the team constructed a nanometre-sized device that fits a whole byte of information into just 96 atoms; that means you could fit an entire gigabyte into a full stop.

5 The longest experiment in the world is... ongoing

In 1930, Professor of Physics at the University of Queensland, Thomas Parnell, began an experiment to show how a material called pitch, which is a derivative of tar, demonstrates signs of viscosity despite being solid and brittle when kept at room temperature. A sample of pitch was placed in a funnel at room temperature inside a container and, ever since, it has been left to slowly move through the funnel. In over 80 years it has dripped just eight times, giving it a viscosity 100 billion times that of water.

6 Monster jet will launch rockets

Planning for the world's largest plane – the Stratolaunch Systems carrier aircraft – has begun, boasting the possibility of firing rockets and satellites into orbit at cut price. Stratolaunch Systems is a new space venture sponsored by Microsoft co-founder Paul Allen. The giant plane, which will be assembled from recycled 747 airliners, aims to take rockets high into the stratosphere and launch them into space, allowing satellites to be taken into orbit at cheaper prices. The massive hangar in California required to build the plane is expected to be finished in late-2012, with the plane scheduled to make its first test flight in 2015.

7 Magnetic soap could clean oil

Details of a new soap that could lessen the environmental impact of oil spills have been published in the chemistry journal *Angewandte Chemie*. The soap is infused with iron, making it magnetic and allowing it to be removed by a magnetic field. As soap naturally sticks to oily substances, the team of researchers at the University of Bristol say this new magnetic detergent could be used to clean up oil spills.

8 Dogs are truly our oldest friends

In the Altai Mountains of Siberia, researchers have found a 33,000-year-old dog skull that shows clear signs of domestication, including a shortened snout and crowded teeth, suggesting dogs have been man's best friend for quite some time. It's believed that dogs would have been useful hunting partners for ancient humans, in addition to providing companionship as they do today. The discovery of similar remains around the world points to an almost-simultaneous domestication of dogs in many areas.

9 Phones could monitor our health

A team of scientists at Korea's Advanced Institute of Science and Technology (KAIST) have suggested the touchscreens on smartphones could be used to detect biomolecular matter, potentially enabling future phones to diagnose us with anything from a common cold to more serious ailments. The research showed that DNA molecules from a person's finger placed on a touchscreen could be recognised by built-in technology, allowing people to perform instant self-diagnoses.

10 Crumpled paper is fascinating

Our most bizarre story this month involves crushed paper. Scientists at the University of Massachusetts have been studying crumpled paper balls to try and ascertain why they are so strong and complex. In their research they found that no matter how hard you squash paper, it's almost impossible to make a structure composed of less than 90 per cent air. Additionally, no computer is powerful enough to create an exact replica of a paper ball; the shapes and folds involved are just too complex.

www.howitworksdaily.com

How It Works launches awesome new supersite

Your favourite magazine's website has just been catapulted into the future with a fantastic redesign and loads of top new content

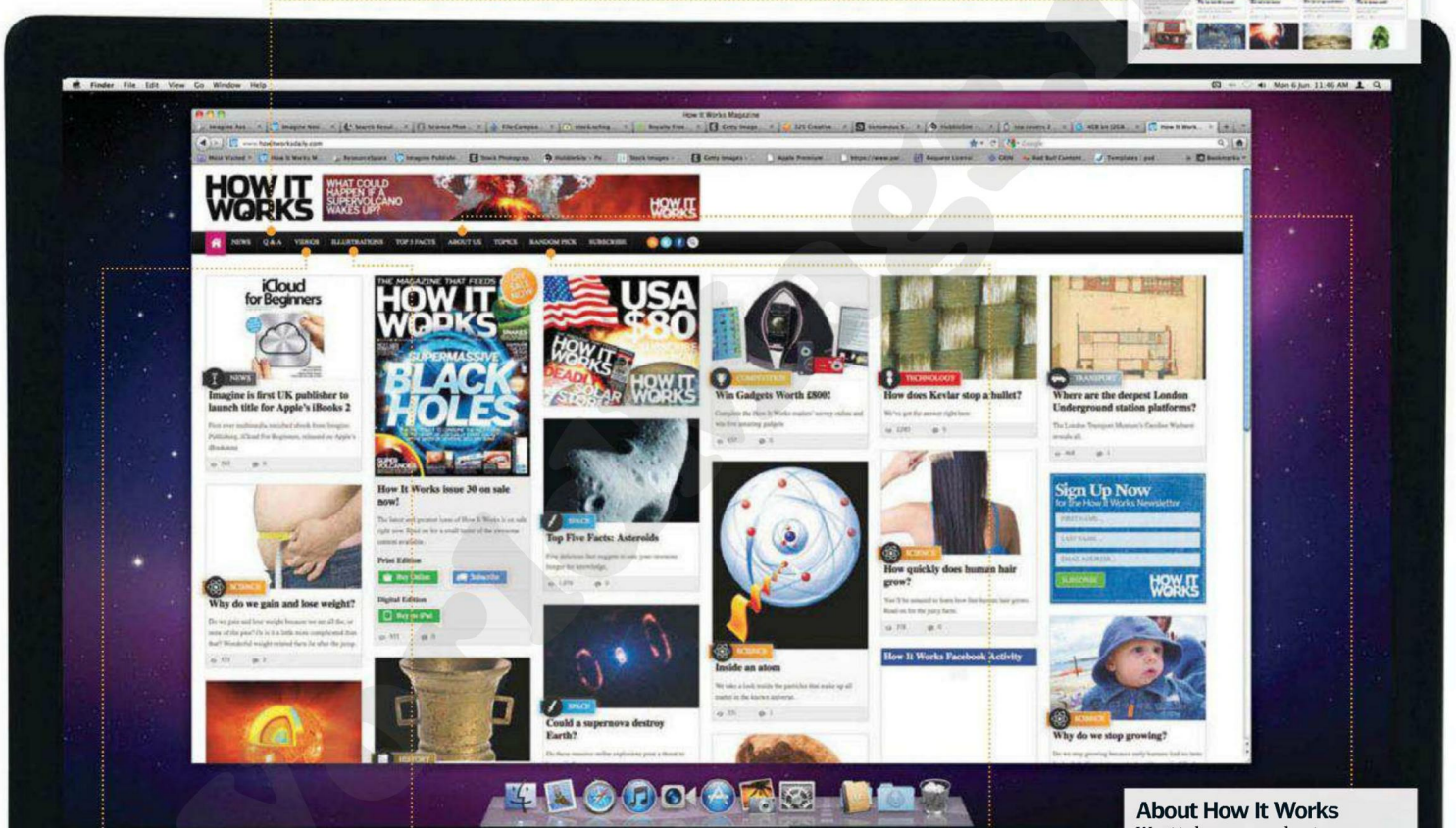
That's right, it's here! **How It Works** is kicking off 2012 with a phenomenal redesign of its website, offering readers a wall of knowledge from which to feed their insatiable hunger for facts.

The site, which is live right now, has been specially created to deliver our vast archive of knowledge in the easiest and most fun way ever, giving you immediate access to all of your magazine favourites such as articles, Q&As, top five facts, reviews, news and interviews. In addition, however, the new site also boasts a host of brand-spanking new material and features such as fully interactive illustrations and cutaways, as well as enhanced social-media integration and interactive quizzes.

So, what are you waiting for? For once put down your copy of **How It Works** and head to **www.howitworksdaily.com** for a little taste of a bright and knowledgeable future.

Readers' questions

For Brain dump lovers, explore our entire archive of juicy facts and answers in the Q&A section.

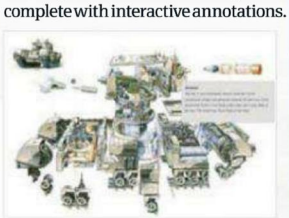


Wall of videos

How It Works TV now has a dedicated media player for embedded videos to see the magazine content come to life.

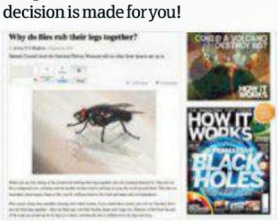
Interactive illustrations

You can access many of our amazing cutaway illustrations on the site, complete with interactive annotations.



Random pick

Overwhelmed by the amazing choice of topics? Well, hit this button and the decision is made for you!



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NASA & ESA *answer your questions about...*

SECRETS OF THE UNIVERSE

ARMED WITH A TEAM OF SPACE EXPERTS FROM AROUND THE GLOBE, WE'VE ANSWERED YOUR MOST BURNING QUESTIONS ABOUT THE COSMOS

The next decade will be the most thrilling era of space exploration and astronomy in the history of mankind – and that's no overstatement. Great advances in technology over the past 50 years have enabled us to study and explore the cosmos like never before, from sending probes into deep space to gazing at distant exoplanets that could potentially harbour life. However, despite making these giant strides in our understanding and knowledge of the wider universe, space largely remains a cosmic mystery with so many questions still unanswered.

With that in mind, we've assembled a team of experts from NASA, the ESA and beyond to answer 75 questions submitted by you, the readers. Over the next eight pages you'll uncover a wide array of fascinating facts, in addition to learning more about some of the most bizarre phenomena that the universe has to offer. Was the first animal in space a dog or a bug? Could you fly a spacecraft through Jupiter? Will space travel for the common man become a reality in our lifetime? Is it certain that we'll find alien life, and will we ever travel to one of the Earth-like planets discovered outside our solar system? Read on to find out the answers to all these questions and many more.

THE EXPERTS

Wesley Traub
Chief scientist for NASA's Exoplanet Exploration Program.

Michael Khan
Spacecraft engineer and mission analyst for the ESA.

Klaas Wiersema
Postdoctoral researcher at the University of Leicester, UK.

Somak Raychaudhury
Astrophysics lecturer at the University of Birmingham, UK.

Harry Cliff
Particle physicist at CERN and the first Science Museum Fellow of Modern Science.

Jonny O'Callaghan
Resident space expert on **How It Works** magazine.

WHICH PLANET HAS THE MOST MOONS?

1 Jupiter has the most moons, with 64 confirmed and possibly more undiscovered. From the inner solar system outwards, Mercury and Venus have no moons, Earth has one, Mars has two, Jupiter has 64, Saturn has 62, Uranus has 27, Neptune has 13 and Pluto has four – the only dwarf planet to have any natural satellites. **HIW**

IS PLANET X REAL?

2 Planet X, or Nibiru, is a hypothetical planet in the solar system that conspiracy theorists suggest will crash into Earth at the end of 2012. However, there is absolutely zero evidence that it exists. A body of this size on a collision course with Earth would be easily detectable from a great distance. **HIW**

HOW WIDE ARE SATURN'S RINGS?

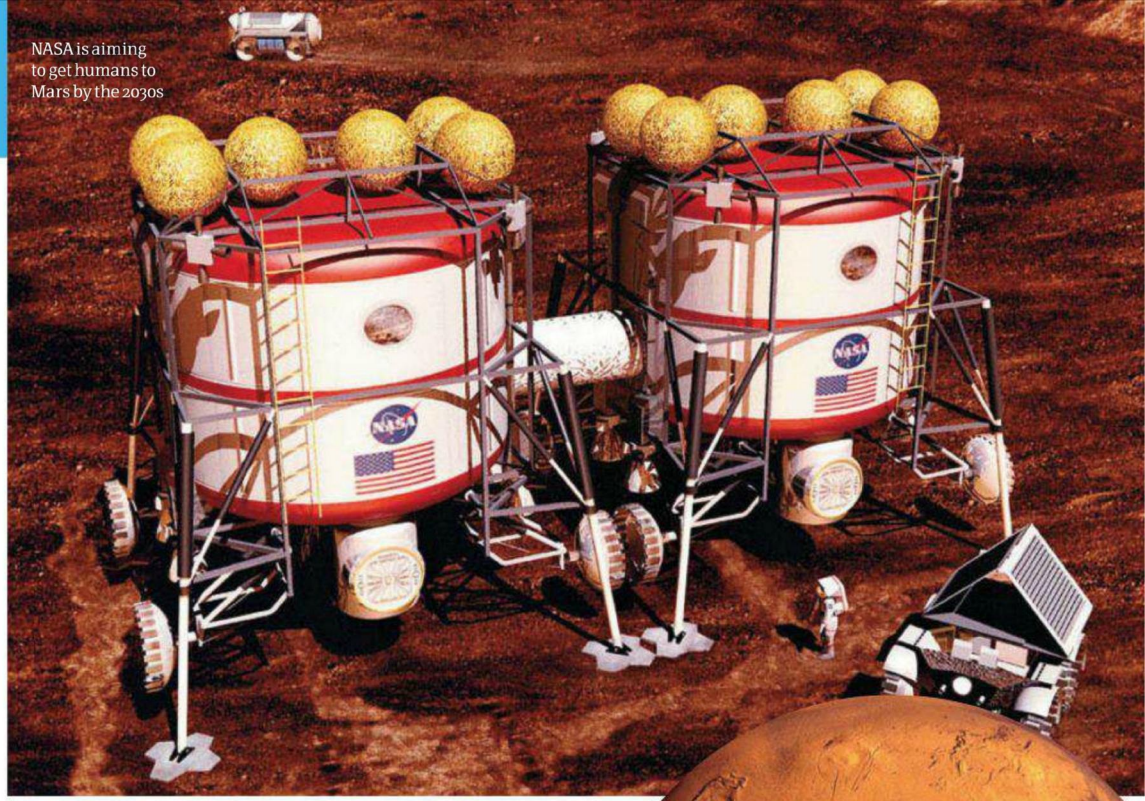
3 First observed by Galileo Galilei back in 1610, the rings of Saturn extend from 7,000 kilometres (4,350 miles) above its surface to 80,000 kilometres (49,710 miles) out into space. **HIW**

WHAT IS THE LONGEST AN ASTRONAUT HAS BEEN IN SPACE?

4 The record for the longest continuous time in space is held by Russian cosmonaut Valeri Polyakov, who spent 437.7 days on board Mir in 1994-95. The record for longest non-continuous time in space belongs to cosmonaut Sergei Krikalev who spent 803 days in space on board Soyuz, the Space Shuttle, Mir and the International Space Station (ISS). **HIW**

WHAT WAS THE TOP SPEED OF THE LUNAR ROVER ON THE MOON?

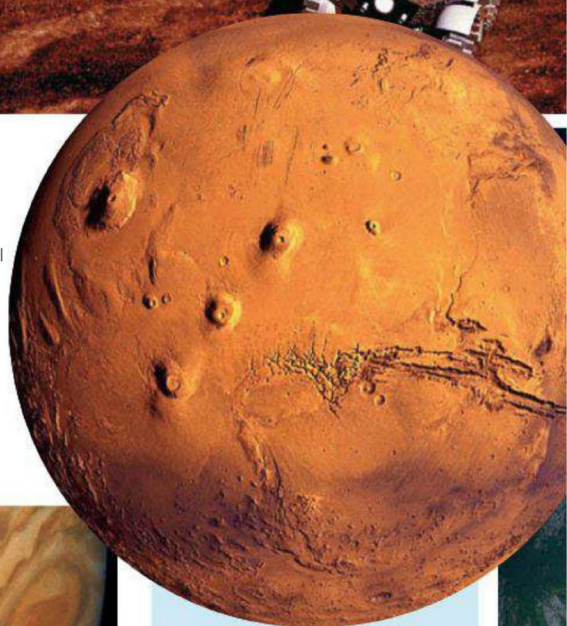
5 Lunar roving vehicles (LRVs) were used on the Apollo 15, 16 and 17 missions. Each of the vehicles had an estimated top speed of 13 kilometres (eight miles) per hour. However, NASA astronaut Eugene Cernan set the unofficial lunar land speed record in 1972 during the Apollo 17 mission, reaching 18 kilometres (11.2 miles) per hour. **HIW**



NASA is aiming to get humans to Mars by the 2030s

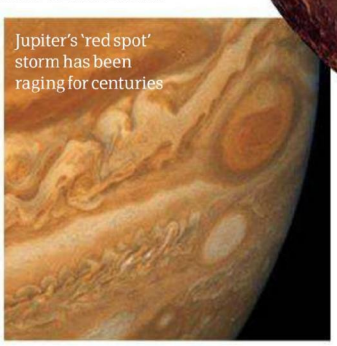
COULD WE LIVE ON MARS?

6 Mars offers a lot of the raw materials that humans need for survival but not all. We would need an airtight habitat that protects its occupants from radiation and meteorites and keeps the thin, unbreathable Mars atmosphere out and maintains Earth-like conditions inside. Much of the habitat and its consumables could be manufactured from materials available on Mars. Mars's gravity is 38 per cent of what we experience on Earth, which would take some getting used to but would still allow humans to live comfortably. However, a manned base on Mars would require constant supply ships from Earth to bring food and other resources that the Red Planet does not have. **MICHAEL KHAN**



WHY IS SPACE BLACK?

7 This is an old chestnut, first pondered by Thomas Digges in the 16th century. He considered a universe that was infinitely large, infinitely old and filled evenly with stars. If our universe were like that then the night sky would be as bright as the surface of the Sun – everywhere you looked you would see a star. This problem was finally resolved by the discovery that space is expanding, stretching light as it travels, shifting it from high to low energy. The further away a star is, the more the light from it has been stretched and the dimmer it appears, making the sky between nearby stars appear black. **HARRY CLIFF**



Jupiter's 'red spot' storm has been raging for centuries

WHY DOESN'T JUPITER'S 'RED SPOT' STORM EVER DISPERSE?

8 Jupiter's great red spot is a vast storm system. We don't know that it doesn't ever disperse as Jupiter has been observed through telescopes for only 402 years. In that time, the great red spot has fluctuated in size, but not disappeared. We don't know how long it has existed, and we don't know how long it will be there. Currently it appears to be shrinking, but that might well change again. **MICHAEL KHAN**

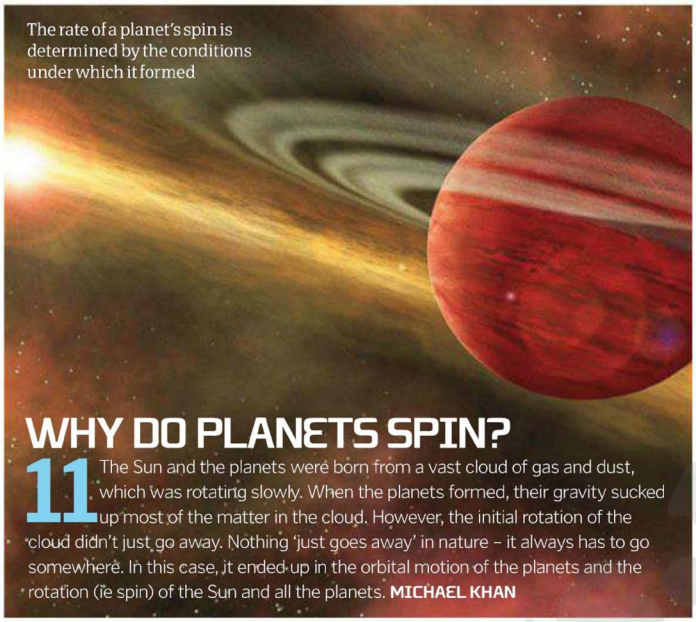
IS THERE WATER ON MARS?

9 There's definitely ice on Mars, which has been directly observed at the poles and elsewhere. However, evidence from NASA's Mars rovers and the Mars Reconnaissance Orbiter (MRO) suggests that beneath Mars's surface is also liquid water, but upon exposure to the air it evaporates. It's estimated that we'll need to drill several metres below the surface to find this liquid water. Gullies on Mars also indicate water once existed here, and may still do today. These may have formed due to a large quantity of ice melting under its own pressure, forming liquid water that could flow briefly before evaporating. **JONNY O'CALLAGHAN**

WHY IS VENUS HOTTER THAN MERCURY?

10 Mercury has no atmosphere. Heat from the Sun reaches the surface and heats up the rocky land, which then radiates heat back into space. It does get very hot on Mercury at the spot where the Sun is directly overhead but at the poles it is much cooler and the 'night' side is very cold. Conversely, Venus has a thick atmosphere made up of carbon dioxide, so there is a strong greenhouse effect.

Though Venus is farther from the Sun and therefore less intense sunshine reaches it, much of the heat gets trapped in the super-dense atmosphere. As a result, Venus is consistently very hot all over its surface. **MICHAEL KHAN**

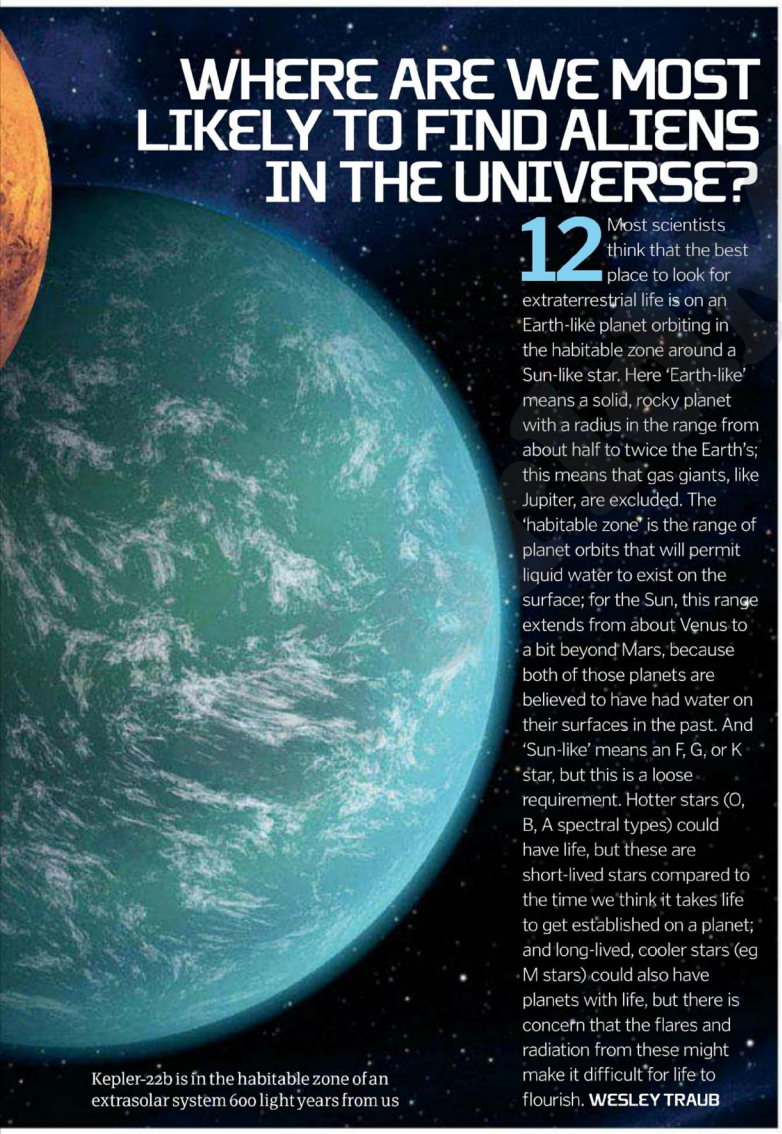


The rate of a planet's spin is determined by the conditions under which it formed

WHY DO PLANETS SPIN?

11 The Sun and the planets were born from a vast cloud of gas and dust, which was rotating slowly. When the planets formed, their gravity sucked up most of the matter in the cloud. However, the initial rotation of the cloud didn't just go away. Nothing 'just goes away' in nature – it always has to go somewhere. In this case, it ended up in the orbital motion of the planets and the rotation (ie spin) of the Sun and all the planets. **MICHAEL KHAN**

WHERE ARE WE MOST LIKELY TO FIND ALIENS IN THE UNIVERSE?



Kepler-22b is in the habitable zone of an extrasolar system 600 light years from us

12 Most scientists think that the best place to look for extraterrestrial life is on an Earth-like planet orbiting in the habitable zone around a Sun-like star. Here 'Earth-like' means a solid, rocky planet with a radius in the range from about half to twice the Earth's; this means that gas giants, like Jupiter, are excluded. The 'habitable zone' is the range of planet orbits that will permit liquid water to exist on the surface; for the Sun, this range extends from about Venus to a bit beyond Mars, because both of those planets are believed to have had water on their surfaces in the past. And 'Sun-like' means an F, G, or K star, but this is a loose requirement. Hotter stars (O, B, A spectral types) could have life, but these are short-lived stars compared to the time we think it takes life to get established on a planet; and long-lived, cooler stars (eg M stars) could also have planets with life, but there is concern that the flares and radiation from these might make it difficult for life to flourish. **WESLEY TRAUB**

IS THE UNIVERSE EXPANDING?

13 When astronomers look deep into space distant galaxies appear to be zooming away from us, and the further away they are the faster they are receding. But in fact, these galaxies aren't moving in the traditional sense. Instead the space itself between them and us is expanding. However, the universe isn't expanding into anything; as far as we know, the expansion is an intrinsic property of space itself. No one knows what the eventual fate of the universe will be. **HARRY CLIFF**

Most of the galaxies in the universe appear to be moving away from one another

HOW DO YOU EXTINGUISH A FIRE ON THE ISS?

14 In the event of a fire on the station, the crew will first shut down power in the affected area and then turn off the ventilation system to starve the fire of oxygen. If it continues to burn they have portable carbon dioxide extinguishers to put it out. **JONNY O'CALLAGHAN**

WHAT IS SPACE SICKNESS?

15 On Earth we analyse our surroundings predominantly with our eyes and ears to balance. However, in space your audio receptors are rendered useless, so you must rely on vision alone. This can be disconcerting during the first few months in space and can often lead to a bout of nasty nausea. **HIW**

WHAT IS THE LARGEST STAR EVER FOUND?

16 The biggest star we know of in the universe is a red supergiant called VY Canis Majoris. Located in the constellation Canis Major 4,900 light years from Earth, it is up to 2,100 times bigger than our Sun. Massive red supergiants like this are commonly called hypergiants. To find out more about these huge stars, head to page 64. **HIW**

WHAT WAS THE FIRST ANIMAL IN SPACE?

17 The first animals to be sent into space were fruit flies on board a US V2 rocket on 20 February 1947. The first mammal in space was the rhesus monkey Albert II on 14 June 1949, while the first animal to orbit Earth was the Russian dog Laika on 3 November 1957. **HIW**

COULD THE MOON EVER BE KNOCKED OUT OF ORBIT?

18 To be stopped the moon would have to be struck by a force at least equal to its kinetic energy (half its mass times its velocity squared). With a mass of 7.3×10^{22} and a velocity of about 1,000 metres (3,280 feet) per second, this is roughly equivalent to 10 trillion megatons of TNT. Nothing on Earth or in the solar system has this necessary force to dislodge the moon. **HIW**

WHY DO SOME PLANETS HAVE RINGS?

19 There are two theories as to why planets have rings. The first suggests that material orbiting too close to a planet like Saturn would be unable to form into a moon early in its life, instead forming rings of debris. The other theory is that an impact that takes place near a planet could create debris which remains trapped in its orbit. **HIW**

WHY DO MOONS FORM?

20 Moons form early in a planet's life cycle when space-faring rocks either crashed into the planet and threw off debris or became ensnared by the planet's gravitational pull. The rocks and dust were gradually squashed into a spherical shape by the host planet's gravity to create moons. **HIW**

WHEN WILL WE GO TO THE RED PLANET?

21 The nation most likely to be the first on Mars is the USA. NASA is now testing its Orion spacecraft, which it plans to use to transport humans to and from Mars along with another vehicle. NASA's provisional schedule will first see humans return to the moon in the 2020s, before landing on an asteroid towards the end of that decade and finally putting humans on Mars in the 2030s. **HIW**

WHERE IS THE OFFICIAL LINE OF SPACE?

22 The official line at which space starts is the Kármán line, 100 kilometres (62 miles) above sea level. Gases in the atmosphere scatter blue wavelengths of visible light to produce a blue glow above Earth. The higher you go the thinner the atmosphere becomes until the glow disappears. This definition is used by space agencies to determine when something has reached space. Theodore von Kármán (1881-1963) calculated this as the point at which a vehicle would have to be in orbit to maintain its altitude. **HIW**

HAS OUR SOLAR SYSTEM EVER HAD MORE PLANETS IN IT?

23 Other than Pluto, which was declassified from a regular planet to a dwarf one in 2006, there have never been additional planets in our solar system. However, some scientists believe there is a planet larger than Jupiter lurking at the edge of the solar system. **HIW**

COULD THE SUN TURN INTO A BLACK HOLE?

24 Put simply, no; the Sun does not have enough mass to collapse and form a black hole. At the end of its life, which will be in a few billion years, it will expand to form a red giant, consuming the four inner planets of the solar system in the process. **HIW**

WHAT HAPPENS WHEN STARS AND BLACK HOLES COLLIDE?

25 The random collision of stars is a very rare event, since in a galaxy like the Milky Way, the distance between stars is large compared to the size of the stars themselves. However, in crowded environments, like in a globular cluster, where millions of stars are packed into a clump that is 50 light years across, stellar collisions frequently occur – maybe once every 10,000 years. When two normal stars collide, they may coalesce to form a new, hot and blue, rejuvenated body (called a 'blue straggler'). In the rare event when the stars colliding are compact objects like neutron stars or black holes, more spectacular things happen. When two black holes, for instance, come very close, they fall towards each other in a spiral motion and, as this happens, their tug on the local fabric of space-time is so strong that ripples are sent out in all directions in the form of gravitational waves. We haven't found these gravitational waves yet, but detectors like LIGO (the Laser Interferometer Gravitational-Wave Observatory) in the USA are soon expected to, and we think the first waves they detect will be from merging black holes. Finally, a small fraction of spinning black holes, as they come close together, don't merge; instead, one gets a strong kick that ejects it from its galaxy. So if you come across a black hole travelling at a breakneck speed, this is almost certainly what happened to it. **SOMAK RAYCHAUDHURY**

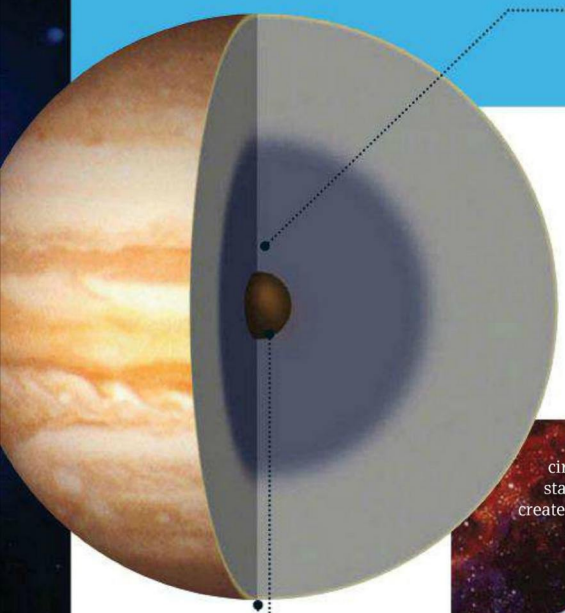
HOW COLD IS SPACE?

26 Cold, but not as cold as it could be. In the Sixties, two US radio astronomers found an unusual microwave signal. They had accidentally discovered an echo from the Big Bang – light that was emitted when the universe had cooled down to about 3,000°C (5,432°F), cool enough for the first atoms to form. Thanks to the expansion of the universe this light has now been stretched to -271°C (-455°F), just 2.7°C (-37°F) above absolute zero, the lowest temperature possible where all motion (apart from quantum wobbling) ceases. **HARRY CLIFF**

> **"...where millions of stars are packed into a clump that is 50 light years across, stellar collisions frequently occur – maybe once every 10,000 years"** *Somak Raychaudhury*

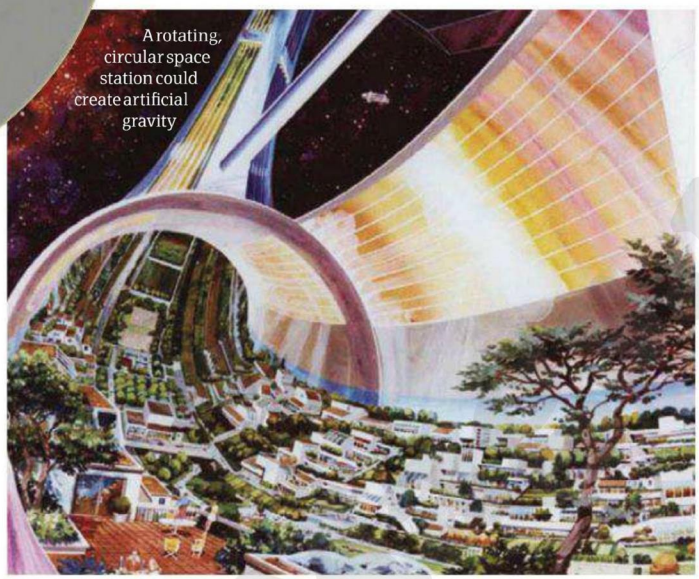
COULD WE TRAVEL TO EXTRASOLAR PLANETS?

27 Yes, it is possible to travel to an exoplanet without breaking the laws of physics. However to do so might mean breaking the bank, because it would be extremely expensive. And it might also mean breaking some laws of biology, because it would take many, many generations of human life – note that nearby stars are typically about ten parsecs, or 30 light years, away from us. So if a spaceship could travel at only one per cent of the speed of light, it would still take 3,000 years to fly there! **WESLEY TRAUB**



HYPOTHETICALLY, COULD A SPACECRAFT FLY THROUGH JUPITER?

29 No. Jupiter has a rocky core as large as the Earth and, around that, many thousands of kilometres of ice. Above that is a thick layer of a strange material known as metallic hydrogen. But even before you get there, the tremendous atmospheric pressure even a few hundreds of kilometres into the Jupiter atmosphere would have squashed you to a gooey pulp! **MICHAEL KHAN**


A rotating, circular space station could create artificial gravity

WHAT'S THE DIFFERENCE BETWEEN A METEOR, METEOROID AND METEORITE?

28 A meteoroid is any kind of small body (mostly rocks that can be smaller than a speck of dust or larger than a house) that enters the Earth's atmosphere. As such a rock always enters at very high speeds. It will get very hot and start glowing, or even trail a cloud of incandescent matter called plasma, but this varies between meteoroids; this visible trail (or 'shooting star') is called a meteor. Mostly, in that intense heat, all of the rock burns to ashes and dust. However, if some of it survives and falls to Earth, it becomes a meteorite, a piece of space rock that has fallen to our planet's surface. **MICHAEL KHAN**

CAN WE CREATE ARTIFICIAL GRAVITY IN SPACE?

30 Artificial gravity is a favourite of science-fiction writers and filmmakers. Perhaps the easiest way to give the illusion of gravity would be to rotate your spaceship. This would produce a feeling of being pulled towards the outside of the ship in the same way you feel pulled sideways whenever you go round a sharp corner quickly in a car. Long-distance space travel would most likely require some form of artificial gravity in order to avoid the negative health effects of weightlessness. **HARRY CLIFF**

ARE THERE SUCH THINGS AS 'WHITE HOLES'?

31 A black hole is a phenomenon from which nothing – not even light – can escape. However, some theories point towards the existence of an 'opposite' black hole, into which nothing can enter. Their existence has never been confirmed, and indeed their very nature is a paradox. If nothing can enter a white hole, and everything leaves it, then surely it should not exist. Stephen Hawking argues that black and white holes are one and the same. For now, the possibility of whether they exist remains a mystery. **JONNY O'CALLAGHAN**

IS IT CERTAIN THAT SOME DAY WE'LL FIND ALIEN LIFE?

32 It would appear so. The Drake equation is one of several that predicts that the probability of finding life elsewhere is 100 per cent certain. If we consider that life on Earth took just several hundred million years to evolve, and the universe has existed for at least 14 billion years, then it is likely that other planets have had a much longer time to support life than ours. With every star now thought to host at least one planet there are billions of potential homes out there and it's highly unlikely that not one of these supports life like Earth. **JONNY O'CALLAGHAN**

WHAT'S THE BRIGHTEST THING YOU CAN FIND IN THE UNIVERSE?

33 Gamma-ray bursts are often said to be the most luminous emitters of electromagnetism in the cosmos. These bursts of energy can last for several minutes and are released when a supermassive star collapses during a supernova. However, quasars (the areas around a black hole) are also among the brightest objects in space. **HIW**

WHY DOESN'T JUPITER EXPLODE?

34 While Jupiter is mostly made up of hydrogen it contains very little oxygen. Fire needs fuel, heat and oxygen in order to ignite. Jupiter has heat in the form of lightning and the fuel is hydrogen, but with such relatively low levels of oxygen no combustion can occur. **HIW**

DO WORMHOLES EXIST?

35 Wormholes have been theorised by many famous physicists, such as Stephen Hawking, but so far they have never been discovered. They act as a 'fold' in space-time, allowing us to traverse long distances in an instant. However, their existence is the cause of much debate in the astrophysics field. **HIW**

WHAT ARE ION DRIVES?

36 Ion drives are a particularly efficient means of spacecraft propulsion. Ions – electrically charged atoms – are accelerated at high speed from the engine and thus provide a weak but steady thrust force that propels the spacecraft in a controlled way. **HIW**

ARE YOU WEIGHTLESS IN ORBIT?

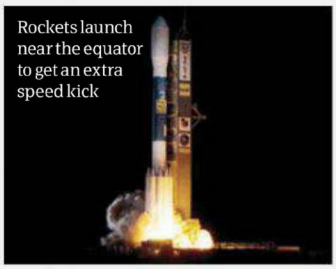
37 The very essence of being in orbit means that you are not weightless. Being in orbit means the gravitational pull of the body you are orbiting is pulling you inwards. This in itself gives you weight, albeit only a small fraction of what you'd experience on the surface of that celestial body. **HIW**

HOW DID THE VAN ALLEN BELTS FORM?

38 The Van Allen belts are areas where electrically charged particles from the Sun are trapped in the Earth's magnetic field. As long as the magnetic field holds up, so will these belts. However, the Earth's magnetic field reverses polarity every 450,000 or so years and such a reversal is long overdue. When it happens, the magnetic field will collapse and the radiation that is now held back will reach Earth's atmosphere or even the surface. **MICHAEL KHAN**

WHAT DEFINES THE BOUNDARY OF THE SOLAR SYSTEM?

39 If you travelled out of the solar system you would eventually reach a point where the Sun's influence reduces to zero and interstellar space begins. This boundary is not clearly defined, but based on information from NASA's Voyager probes it is thought to be roughly up to 4,000 times farther from the Sun than Pluto. **HIW**



Rockets launch near the equator to get an extra speed kick

WHY DO ROCKETS TAKE OFF CLOSE TO THE EQUATOR?

40 The Earth spins on an axis that runs through both poles. This means the poles experience little to no rotational force from the Earth, whereas the equator experiences the maximum possible force. By launching close to the equator, rockets get an extra boost of speed from the rotation of the Earth that helps them reach orbit. **HIW**

HOW MUCH DOES THE EARTH WEIGH AND WHO WEIGHED IT?

41 If you could put it on a theoretically unbreakable scale, the Earth would weigh in at a hefty 6 trillion trillion kilograms (13.2 trillion trillion pounds). It's weighed by adding up the sum of its parts and accounting for its gravitational pull. The Earth is also constantly gaining weight from incoming dust and meteorites – about 45,000 kilograms (99,208 pounds) a year. **HIW**

WHICH PLANET HAS THE LARGEST MOON?

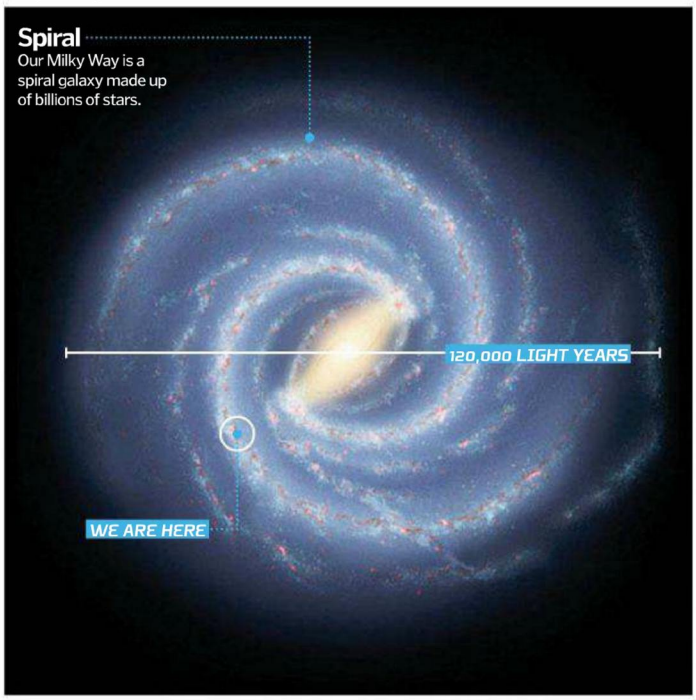
42 Jupiter has the largest moon in our solar system. It is called Ganymede and it is roughly three times the size of our own moon. **HIW**

IS THERE ANY SOUND AT ALL IN SPACE?

43 Audible sound for humans is essentially the vibration of air particles, and as there aren't any of these in the cosmos then there isn't any sound. However, there is 'sound' in the form of different types of electromagnetic radiation, such as light and radio waves, which we can interpret. **HIW**

HOW BIG IS OUR GALAXY?

44 Our galaxy, the Milky Way, is made up of stars and a substantial amount of gas and dust, which can be imaged by optical and radio telescopes. These are spread through a flat disc that's about 120,000 light years across. Our solar system is approximately 25,000 light years away from the centre of this galaxy, orbiting in a circular path around it. However, our galaxy is embedded in a large spherical ball of dark matter, whose mass is at least ten times that of the stars in the galaxy. We cannot see dark matter, but we *can* feel its gravitational pull. We know that this dark matter 'halo' is at least 500,000 light years across, though we don't yet know how large it is precisely. **SOMAK RAYCHAUDHURY**



WHAT WAS THE SPACE RACE?

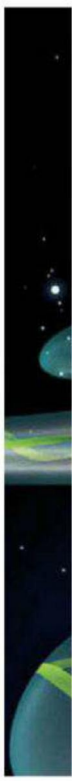
45 The space race started in 1957 when the Soviets launched their first Earth satellite, Sputnik 1. Both Soviets and Americans understood the importance of space; this was the high frontier – whoever dominated space would dominate the Earth. Therefore, both superpowers attempted to be the first to conquer the challenge of space exploration. Initially, the Soviets had some successes, but finally, the USA scored the decisive victory by landing humans on the moon, only 12 years after Sputnik 1. Very rarely has such a massive jump in technology been achieved in peacetime, and rarer still has a scientific venture captured the hearts and minds of the world's youth to this extent. [The world watched the first moon landing on TV], fervently wishing the two brave men who had set out on this epic journey onto the surface of the moon would return safely. Everybody who lived through these years felt he or she was witnessing the most important moment in human history. It is perhaps ironic that the 'space race', which had started out as a quasi-military endeavour, turned out to be something that united all of humanity, if only for a short time. **MICHAEL KHAN**

WHAT'S THE FUTURE OF SPACECRAFT?

46 The first thing we need is a larger rocket than those available now. Several companies are working on those, mostly in the USA. With such a rocket, we can place large elements, eg of a hotel, a lab, but also modules of an interplanetary spaceship in Low Earth Orbit (LEO). The next step would be more efficient propulsion systems. Ion propulsion is a first step but it offers very low thrust and also requires a lot of electrical power in order to operate. Probably, there will be nuclear propulsion units that offer high thrust, high efficiency and still are not too large to be used on a spaceship. **MICHAEL KHAN**

COULD SPACE TRAVEL FOR THE COMMON MAN EVER BE A REALITY IN OUR LIFETIME?

47 Very likely. With the advent of commercial companies investing in space travel, space tourism and space stations, transport capacities will increase, infrastructure will be set up and prices will drop. Although spaceflight will likely be a pastime of the well-heeled for some time to come, at some not-too-far point in the future taking a spaceship to the moon will be as commonplace as taking a jet plane is to us today. **MICHAEL KHAN**



SPACE RACE TIMELINE

4 October 1957
Sputnik 1 is launched by the USSR, the first manmade satellite to enter Earth orbit.

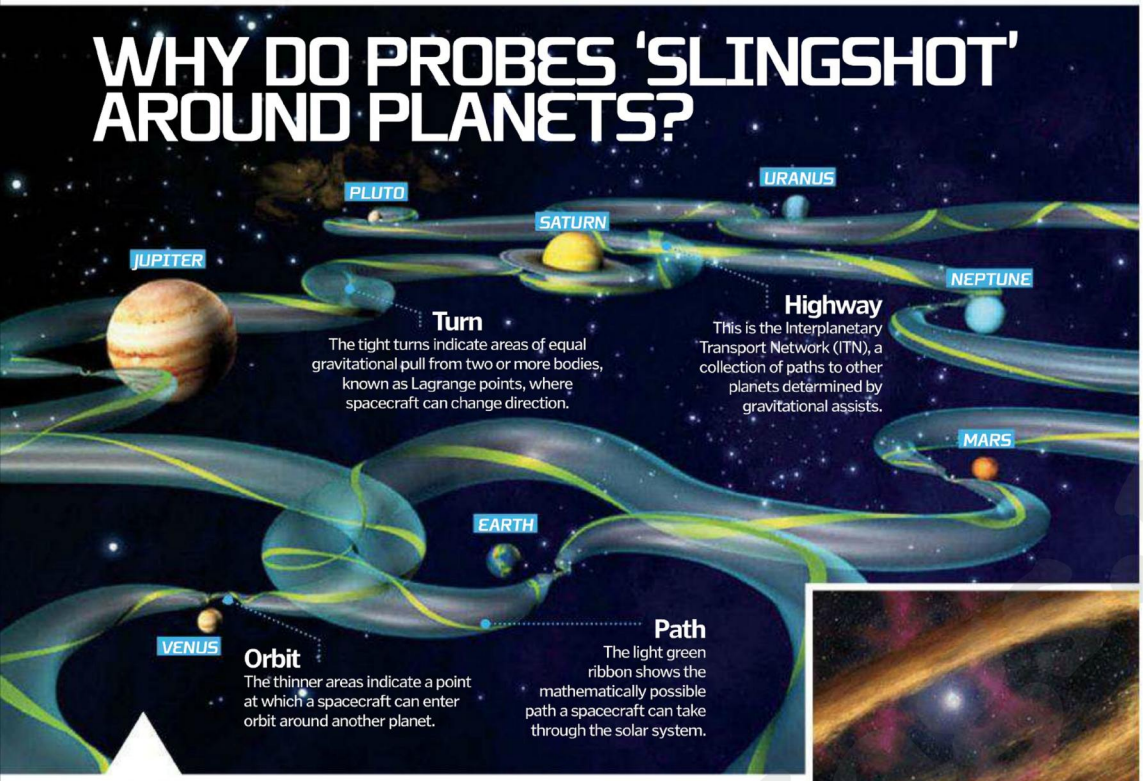
7 August 1959
NASA's Explorer 6 returns the first image of Earth from space.

12 April 1961
Yuri Gagarin becomes the first human to enter space and orbit the Earth on Vostok 1.

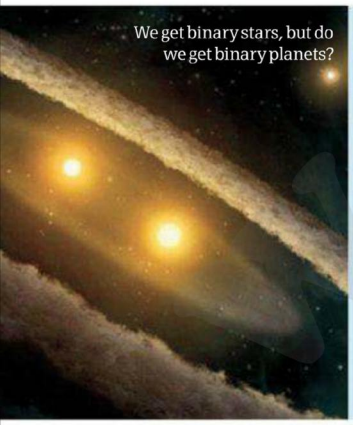
10 July 1962
The USA launches the first active communications satellite, Telstar 1.

18 March 1965
Alexey Leonov becomes the first human in open space on Voskhod 2.

WHY DO PROBES 'SLINGSHOT' AROUND PLANETS?



48 Spaceflight is all about orbital energy. You have to invest a lot of energy to get anywhere in space. If you want to go to Mercury, or out to Jupiter and beyond, then the energy needed for that is so great that even the largest rockets couldn't launch a decent-sized spacecraft capable of the trip. So what is done is passing close to large planets, such as Venus and Earth, as the planet's gravity will change the spacecraft's direction. If you compare the spaceship's velocity with respect to the Sun before and after the encounter, you can see a distinct shift – which is the same as a change in orbital energy. It's like a tennis ball being hit by a racket, although the spacecraft of course does not actually hit the planet! Such 'slingshot' or 'swingby' manoeuvres have opened up the solar system to humanity. We would not be able to explore Mercury or the outer planets without this technique. **MICHAEL KHAN**


We get binary stars, but do we get binary planets?

ARE THERE ANY BINARY PLANETS?

49 Binary planets are certainly possible, but none have yet been found. But if we stretch the meaning of 'binary' to include a really small body around a large one, then the Earth-moon system is a binary planet. If we stretch the meaning in another way, to include very small bodies, then there are examples of asteroids that orbit each other, and the pair orbits the Sun, so these would qualify too. It is quite possible that NASA's Kepler telescope will eventually find a binary planet, and that will certainly make the news! **WESLEY TRAUB**

HOW DO PULSARS FORM?

50 Pulsars are rotating neutron stars with a very high magnetic field, which creates a beam of light that sweeps around like a lighthouse. Neutron stars are created in the violent death of massive stars (ie stars more than eight times more massive than the Sun). When such a star has exhausted its fuel at the end of its life, it can no longer support its own weight and, as a result, collapses in a spectacular explosion called a supernova. The core of the old star gets violently compressed to the densest form of matter that can exist in nature – a ball of matter consisting exclusively of neutrons. How the newly formed neutron star gets the strong magnetic field that pulsars show is not yet understood. **KLAAS WIERSEMA**

1 March 1966
The USSR 'lands' the first probe on another planet – Venera 3 on Venus – but it crashes.

24 December 1968
Frank Borman, James Lovell and William Anders are the first men to orbit the moon.

20 July 1969
NASA astronauts Neil Armstrong and Buzz Aldrin become the first men to walk on the moon.

19 April 1971
The USSR launches the first space station into Earth orbit, Salyut 1.

15 July 1975
The USA and USSR collaborate for the first time, docking Apollo and Soyuz in orbit.

HOW DO ROCKETS MOVE THROUGH SPACE IF THERE'S NOTHING TO PUSH AGAINST?

51 Under Newton's Third Law, every action has an equal and opposite reaction. So, even though there's nothing to push against, the force of the propellant leaving the rocket pushes it forwards with the same amount of power. **HIW**

WHICH COUNTRY SPENDS THE MOST MONEY ON SPACE EXPLORATION?

52 As you'd expect, the USA is leading the way, and by some margin, but other countries like China are beginning to catch up. NASA's budget for 2011 was $19 (£12) billion. **HIW**

IS THE SUN BRIGHTER ON THE INSIDE?

53 According to Stefan's Law, brightness per square foot is proportional to the fourth power of the temperature. As the temperature at the core of the Sun is many thousands times greater than it is on the surface, by this logic it must indeed be trillions of times brighter on the inside. **HIW**

WHAT'S THE FURTHEST POINT IN SPACE THAT WE CAN SEE THROUGH A TELESCOPE?

54 The furthest that we can see from our planet is as far as the limit of the observable universe. This is approximately 14 billion light years away from Earth, where light from the outer reaches of the universe is only now just reaching us. **HIW**

WHAT IS AT THE EDGE OF THE UNIVERSE, IF THERE IS ONE?

55 As discussed in the previous question, there is an observable limit to how far we can see (about 14 billion light years away). At the 'edge' of the universe we can see remnants of the Big Bang in the form of X-ray radiation, but what lies beyond this edge we do not know – at least not yet. **HIW**

WHERE DOES THE MATERIAL THAT GOES IN A BLACK HOLE END UP?

56 Most of the matter that enters a black hole ends up in a singularity, which is an infinitely dense point no bigger than the full stop at the end of this sentence. However, some black holes reach a theoretical mass limit and, when they do, they fire out excess matter in jets of radiation known as Hawking radiation. **JONNY O'CALLAGHAN**

COULD WE MINE THE MOON FOR MINERALS?

57 We could mine minerals from the moon, but we wouldn't have much use for them. The moon is rich in helium-3, which could be a very useful source of energy, but we currently don't possess the technologies to use it. **HIW**

HOW MUCH DOES IT COST TO SEND SOMEONE INTO SPACE?

58 Like aeroplanes on Earth, that depends on whom you fly with. A flight on Virgin Galactic will cost you $200,000 (£125,000) when it launches in the coming years, while a flight on board Russia's Soyuz spacecraft could cost a few million dollars. **HIW**

HOW LONG DOES IT TAKE FOR A MESSAGE TO TRAVEL FROM MARS BACK TO EARTH?

59 Signals sent to spacecraft in orbit and beyond are limited by the speed of light. Sending and receiving a signal from one of the spacecraft around, or on the surface of, Mars takes up to 45 minutes, depending on how far the Red Planet is from Earth in its orbit. **HIW**

COULD THE ISS BE USED TO LAUNCH OTHER SPACECRAFT?

60 No, it's not designed to do so and has no facilities that would support such a function, such as a large propellant reservoir or a launch pad, etc. The ISS would have to be a lot bigger and manned by more people to serve as an orbital launch base. **MICHAEL KHAN**

WHAT IS THE UNIVERSE SHAPED LIKE?

61 No one knows for sure, but there are three main schools of thought. Some think the universe is flat, some think it is more of a cylinder shape and others think it is a sphere. **HIW**

WHAT'S THE MOST COMMON ELEMENT IN THE UNIVERSE?

62 Hydrogen is by far the most abundant. It is found in almost every object in the cosmos, and is also the main component of stars. Helium is the second most common, followed by oxygen and carbon. **HIW**

CAN A STAR ORBIT A PLANET?

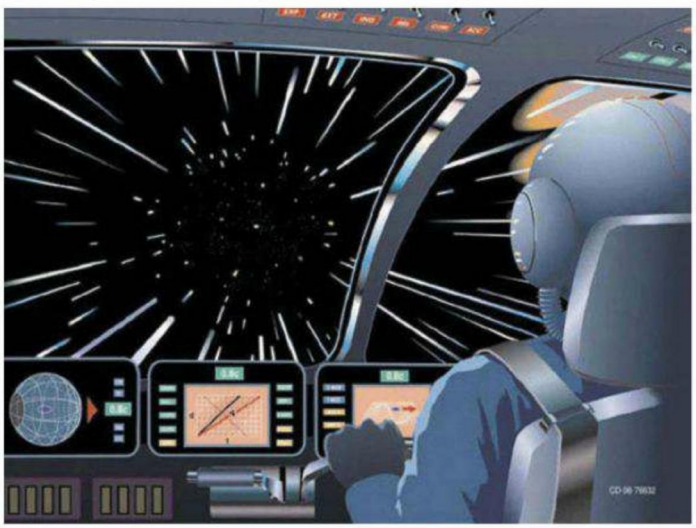
63 Yes, and in fact stars do orbit their planets, just as a planet orbits its star. To be precise, a star and its planet orbit each other, circling around the centre of mass (same as 'centre of gravity' in everyday terms) of the pair. For example, the Earth and Sun are separated by one astronomical unit (AU), or about 150 million kilometres (93.2 million miles). The Sun is about 330,000 times bigger than the Earth. So the centre of mass of the pair is about 1AU divided by 330,001 from the centre of the Sun. This is about 450 kilometres (280 miles) from that centre, so that is the point around which the pair orbits. If we consider all the planets in the solar system, the biggest effect will be from Jupiter, which is at about 5AU. The Sun is roughly 1,000 times the mass of Jupiter, so the centre of mass is about 1AU divided by 1,001. This comes out to about 150,000 kilometres (93,205 miles) from the centre of the Sun. **WESLEY TRAUB**

HOW DO WE CALCULATE THE AGE OF OUR SOLAR SYSTEM?

64 The most widely used technique to find out something's age is radiometric dating. The materials we want to date contain very small amounts of naturally occurring radioactive elements. These elements change into other non-radioactive elements in a process called radioactive decay. We know precisely how long it takes for a given radioactive element to decay, so by measuring the amount of these elements in a rock, we can work out the age. To establish how old the solar system is, we use this technique on meteorites. These were formed at the same time as the Earth but, unlike rocks on our planet, have not been through weathering, volcanic processes and such, and therefore provide us with a clean view of the oldest parts of the solar system. **KLAAS WIERSEMA**

WOULD IT BE DANGEROUS TO TRAVEL AT LIGHT SPEED?

65 No, but getting there might prove hazardous. Galileo taught us that all uniform motion is relative – in other words it's impossible to tell the difference between travelling at constant speed in a straight line and being stationary. Imagine you're flying away from Earth on a spaceship just slower than the speed of light. Without looking out the window there would be absolutely no way of telling you were moving at all. So it really would be quite safe. On the other hand, accelerating up to the speed of light could be a lot more risky. **HARRY CLIFF**

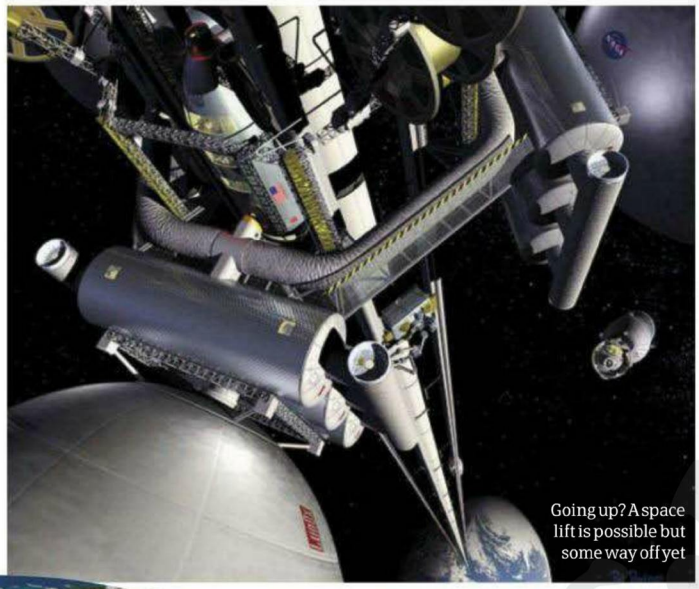


WHO NAMES NEW PLANETS?

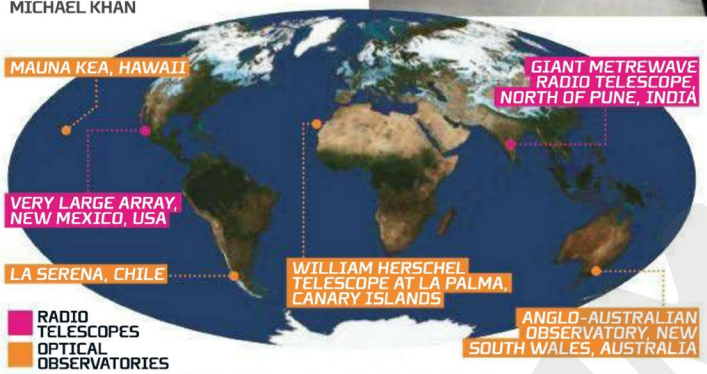
66 There is currently no official naming system in place for planets found outside our solar system other than their scientific classification, which contains information on the star the planet orbits and its order away from the star in relation to other planets. Due to their often lengthy and complex monikers many planets are also christened with unofficial nicknames, although these can vary. For example the oldest planet yet discovered – PSR B1620-26 b – is known unofficially as both Methuselah and the Genesis planet. **JONNY O'CALLAGHAN**

WHY CAN'T WE BUILD A SPACE ELEVATOR YET?

67 We're not too far off. A space elevator would need a cable material that is far stronger and lighter than all materials available to engineers today. A new material called carbon nanotubes might do the job, but we don't have the technology yet to manufacture cables of this material that are longer than a few centimetres. Also, we currently wouldn't be able to launch the large machinery and the amount of raw materials into geostationary orbit (36,000 kilometres/22,369 miles up) that would be required to build the elevator. Space elevators, unlike buildings on Earth, would need to be built starting at the top and working our way down to the foundations. **MICHAEL KHAN**



Going up? A space lift is possible but some way off yet



WHERE'S THE BEST PLACE FOR TELESCOPES ON EARTH?

68 Telescopes that use ordinary (optical) light have to be situated in high and dry places, where the air is clearer. This is why optical telescopes are found on the tops of high mountain ranges in or near deserts, eg in the Andes in northern Chile, the high mountain tops of Hawaii or in eastern Australia. Radio telescopes can see through clouds, but are vulnerable to industrial activity. The biggest radio observatories are in New Mexico in the USA and north of Pune in India. X-ray, gamma-ray, ultraviolet and infrared radiation cannot penetrate the atmosphere, so telescopes for this kind of light are placed in orbit around the Earth. **SOMAK RAYCHAUDHURY**

WHAT ARE THE BEST TYPES OF SPACECRAFT PROPULSION AROUND?

69 The furthest spacecraft from Earth, NASA's Voyager 1, has used radioisotope thermoelectric generators to go about 18 billion kilometres (11 billion miles) in 34 years. Solar sail spacecraft, which use a large and light sail to ride on the solar wind, have a weak rate of acceleration and ion drives are reliable but too weak for deep-space missions. NASA's solar-powered Juno probe, en route to Jupiter, is the furthest spacecraft powered by the Sun alone, but has limited power. The best bets for long-distance propulsion are either nuclear power or the in-development VASIMR (Variable Specific Impulse Magnetoplasma Rocket), which uses electromagnetic thrusters for continued propulsion and may be added to the ISS to keep it in a stable orbit. **JONNY O'CALLAGHAN**

WINNING TWEET!

Congratulations to reader **James (@Cocoa_Pig)** for submitting the winning question in our Twitter competition: "How do rockets move through space if there's nothing to push against?" He wins a **How It Works Book Of Space Extended Edition** for his efforts.

HOW OFTEN DO METEORITES HIT OUR PLANET?

70 Thousands of meteoroids enter Earth's atmosphere every year, and hundreds of these hit the surface of our planet. However, the ones that reach the surface are very small after mostly burning up in the atmosphere. **HIW**

WHAT'S THE BIGGEST KNOWN ASTEROID?

71 Vesta is the largest asteroid. It has a diameter of about 530 kilometres (330 miles) – roughly 1/25th that of Earth's. It is located in the asteroid belt between Mars and Jupiter. **HIW**

IS THERE A CENTRE OF THE UNIVERSE?

72 No, there's no centre. Since the Big Bang, the universe has been expanding; however, everything is expanding away from everything else at an almost equal rate. **HIW**

WILL THE MILKY WAY AND ANDROMEDA HIT?

73 Yes, they probably will. Our neighbouring galaxy Andromeda, which is about 2.5 light years away, appears to be on a collision course with the Milky Way. They are expected to collide in 5 billion or so years. **HIW**

IS OUR SUN ONE OF A PAIR?

74 While another has never been found, some astronomers think our Sun is part of a binary star system, with the second star located far outside the solar system. All evidence points to 'no' at the moment though. **HIW**

Dark matter is believed to be present throughout the universe

WHAT IS DARK MATTER?

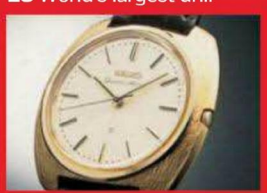
75 Most astrophysicists think dark matter must exist as galaxies appear to be spinning too fast for the gravity created by all the stuff we can see to hold them together. The most widely accepted explanation is that galaxies contain invisible matter that doesn't emit or reflect light, hence 'dark'. **HARRY CLIFF**

categories explained: Computing, Electronics, Gadgets, Engineering, Communication, Domestic, Entertainment, Medical, General

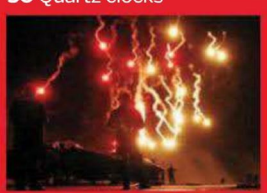
This month in **Technology**

If you think mobile phones are smart now, then you're in for a revelation this issue as we see how they're getting faster and brainier all the time. Other clever machines featured are meters that measure your electricity usage, ECG heart-rate monitors and the biggest drill on Earth that's used to bore tunnels through mountains.

28 World's largest drill



30 Quartz clocks



31 Flare guns

TECHNOLOGY

22 Next-gen mobile tech
26 Emails
28 World's largest drill
30 Baby monitors
30 ECG heart scans
30 Quartz clocks
31 Electric smart meters
31 Flare guns
32 Andy Pad Pro

NEXT-GEN MOBILE TECH

Upgraded hardware, software and networks will come together to offer an amazing smartphone experience

Do you remember a time when you got by with a smartphone packing a tiny amount of memory, a low-resolution screen and a form that was so large it could have been used to anchor a small boat? We laugh about those times now, but in the near future we will be sniggering in exactly the same way about our current phones. Wouldn't it be nice to know what's going to power the smartphones of tomorrow and how future developments will make the smartphones of today look positively archaic? Well, let's find out.

Mobile networks will be 'much' faster. 4G will replace the 3G networks we use now and offer ten times the speeds available today. Future smartphones will have to cope with the power such speeds require and so battery technology will also have to step up. Fortunately, a battery has already been developed that can last for a whole week and, believe it or not, recharge in only 15 minutes. It has been built by addressing two limitations of current battery technology. First, lithium atoms are required to hold a battery charge between an anode and cathode – the two ends of the battery – and they are typically built in layers of one lithium

BIG SCREEN

1. iPhone 4S
The iPhone 4S has an 8.9-centimetre (3.5-inch) screen, but the retina-busting resolution still makes images and movies truly shine.

BIGGER SCREEN

2. Nokia Lumia 800
The Lumia screen, at 9.4 centimetres (3.7 inches), works perfectly with the Windows Phone software to create a lasting impression.

BIGGEST SCREEN

3. Galaxy Nexus
The huge 11.8-centimetre (4.65-inch) display on the Galaxy Nexus is perfect for entertainment and general organisation. It makes every task that bit easier.

DID YOU KNOW? *A new mobile phone is in development that is made from bamboo, which is both durable and incredibly light*

© Apple; Motorola; Sony; Samsung; Nokia

INSIDE NETWORK DEVELOPMENT

The rush to offer complete high-speed coverage continues relentlessly and network providers are using a variety of technologies to give the mobile user all of the speed they desire, whenever they need it. More Wi-Fi hotspots will pop up in businesses and town centres, using the exact same technology as a home router does. They are connected to the fixed telephone network, like your home broadband, and then the bandwidth is available wirelessly via the hotspot. Mobile network operators are increasingly offering bundled Wi-Fi services to help them cope with mobile data demand, plus city-wide schemes to offer free Wi-Fi for all, such as Wi-Fi London which is aiming to have near-complete Wi-Fi access in time for the 2012 Olympic Games.

4G will offer the most obvious benefits to smartphone users and is destined to let us all connect to the mobile internet at speeds upwards of 100 megabits per second. This will be achieved by increasing the amount of spectrum available to mobile operators – more spectrum at 800MHz and 2.6GHz, which represents the equivalent of three-quarters of the spectrum available today and took two decades to create. With spectrum secured, operators can then start to build the required infrastructure to enable users to take full advantage of the greater speeds through a host of devices from smartphones, dongles, laptops and possibly even desktop computers. With fewer networks competing for these spectrum bands thanks to network-sharing deals, the process should complete quite quickly. Orange and T-Mobile already utilise each other's networks, via the Everything Everywhere brand, and Vodafone and O2 have been working on jointly building new sites that they can both serve to customers. This is on top of the long-term network-sharing arrangement between 3 and T-Mobile.

Potentially, mobile data will be advanced enough to pose a serious threat to home broadband connections and could eventually signal the end of the land line for many people.

atom to six carbon atoms, but by sandwiching clusters of silicon atoms between the layers and by not using carbon atoms, the number of lithium atoms can be greatly increased, which in turn means more power can be held. Tiny holes have also been created in the layers of silicon to effectively offer a shortcut to the anode which makes the charging process ten times quicker than the batteries we use now; just imagine being able to charge your phone for 15 minutes every Sunday and that's it!

Display technology will also evolve significantly and, because it is the most used part of any smartphone, we can count on greater resolutions, clarity and bright light performance. However, we can also expect them to become flexible. Displays of today are built by attaching organic LEDs to glass, but in the future we can expect LEDs to be 'printed' onto pliable plastic instead which will make them completely flexible. Imagine the possibilities; a smartphone you can roll up and stuff in your pocket, a device that can be used as a phone during the day and then a tablet when you require a bigger screen at night. It sounds impossible because of all the components that need to sit behind the screen, but take yourself back to the future battery technology – if they can hold ten times the charge of today's batteries, they can also be made ten times smaller and thus never impede on the display's flexibility.

> *"This process of miniaturisation will be true for all other smartphone components, such as processors and cameras"*

This ongoing process of miniaturisation will also be true for all other smartphone components, such as processors and cameras, and will complete the ultra-portable setup for future phones.

As the smartphone becomes the compact camera of choice for most, so the camera technology will improve beyond what we can conceive today. Light-field cameras will no doubt be snuck into the latest high-end phones and these will give you the ability to take a shot and focus it when you get home. Such devices are able to do this as microlenses are placed within the focal plane of the camera lens just behind the main image sensor and these allow the parts of a photo that are not in focus to be analysed later and then matched to the corresponding image parts that are in focus. From this data, a perfectly focused photo can be created irrespective of how bad a photographer you are ▶

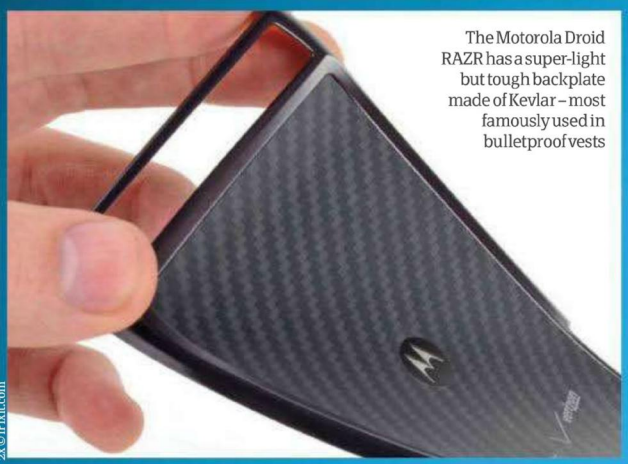
Super-svelte
The Huawei Ascend P1 S is currently the world's thinnest phone at 6.68mm (0.26in).

Snap happy
The camera of the Ascend P1 S packs 8MP, an autofocus setting and a dual-LED flash.

2x © Huawei

"Behind all of the parts you see and touch will sit some hefty processing power"

Cutting-edge smartphones



The Motorola Droid RAZR has a super-light but tough backplate made of Kevlar – most famously used in bulletproof vests

2x © iFixit.com

and this will likely become as important to future smartphone camera technology as lenses, megapixels and everything else put together. You will never take a bad snap again!

Behind all of the parts you see and touch will sit some hefty processing power that will make even the fastest of today's home computers look feeble. Quad-core processors, which spread the load of intensive tasks evenly over each core to reduce power requirements, are already available in mobile form, but the expectation of 16-core processors and above is not unrealistic. With so many powerful cores you will be able to run everything you can on today's smartphones, but many times over. The technology will allow the most resource-hungry tasks to use as many cores as they need and still undertake completely separate operations, thus offering an experience which never slows down. This ties in nicely with the faster network speeds and will offer a super-smooth end-to-end experience that is completely unlike a computer.

Imagine, you will be able to roll up your phone or unfold it into a tablet when you want to. You will charge it only once a week for a few minutes. You will never take a bad photo or even consider hardware and mobile network speeds. Now look at what you use today. There's no doubt that we will all look back to today and wonder at how we survived.

INSIDE A FEATURE-PACKED PHONE

Lightweight
Every major component, including the accelerometer, has been designed to be as small and lightweight as possible.

Memory
There really is 16GB of memory held within this minuscule memory chip.

A bigger camera
The 8MP rear camera is also tiny but can capture an even more impressive 1080p HD video at 30 fps.

Make some noise
The main speaker packs quite a punch when the volume is turned up to the max despite its diminutive form.

Tensile yield strength
The woven Kevlar back cover is incredibly flexible but retains immense strength due to the bonds created in the weaving process.

Diamond standard
The chassis is diamond cut because precise measurements are required for such a thin component. Any deviation and the final product would rattle.

Motorola's Droid RAZR

The Droid RAZR defies the laws of what we expect from a smartphone. Not only does it include a 10.9-centimetre (4.3-inch) Super AMOLED screen, 16GB of internal memory, a microSD slot, every communication feature you could possibly need and an eight-megapixel camera, but it also manages to do all of this in a phone that's only 7.1 millimetres (0.3 inches) thick. Everything from the battery life to the sound quality and speakerphone are at the top of their game and this makes it a marvel of smartphone design.

Mind the water
There are two liquid damage indicators built in to the phone which will change colour permanently if exposed to liquid.

A tiny camera
The 1.3MP front-facing camera is incredibly small but still able to capture video at a very respectable 720p HD.

Minimal components
The RAZR includes surprisingly few components in order to create a very thin and strong device.

Ultra-thin battery
The battery is only 2.79mm (0.1in) thick yet still provides more capacity than many larger examples.

5 TOP FACTS MOBILE PHONES

Apps
1 Each of the most popular mobile operating systems now boasts many thousands of apps that can be used for everything from internet banking through to satellite navigation.

Power
2 The processing power of high-end mobiles is comparable to the internals found on many laptops and netbooks from a couple of years ago and their power is set only to grow.

Voice recognition
3 Voice-recognition apps, like Siri, are fast becoming a preferred method for data input and are expected to challenge touchscreen keyboards in popularity in the future.

Photography
4 Smartphone cameras now rival compact cameras from two or three years ago in terms of megapixels and they are improving quickly in optic and zooming capabilities too.

Storage
5 The amount of memory on modern mobile phones lets the user carry thousands of photos, thousands of songs and as much data as they could possibly need when out and about.

DID YOU KNOW? *Future phones are expected to be built to last with unbreakable screens and full waterproofing*

TOP FEATURES OF THE LATEST MOBILES

iPHONE 4S
Pixel packed
As well as introducing us to voice-recognition feature Siri, the iPhone 4S also boasts the highest-res phone screen ever (the Retina display) and wireless storage with iCloud.

DROID RAZR
Super materials
The Motorola Droid RAZR features 'a force shield of water-repellent nanoparticles' to protect it from splashes, while the screen is reinforced by Gorilla Glass and Kevlar fibre.

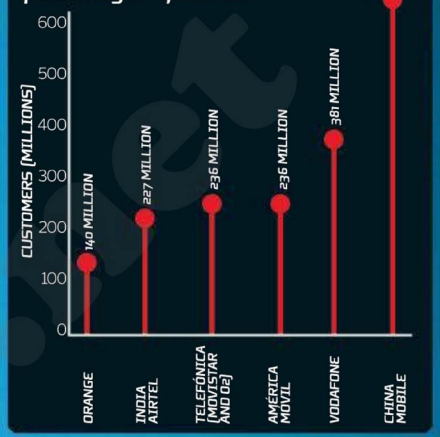
XPERIA S
Hi-def
This phone from Sony Ericsson, which comes to the UK in March, will be the first to include a high-definition 12-megapixel camera, using a CMOS sensor for perfect pictures.

GALAXY NEXUS
Powerful
The first to run the Android 4.0 Ice Cream Sandwich OS, Samsung's Galaxy Nexus packs a speedy 1.2GHz dual-core processor and a Super AMOLED screen.

LUMIA 800
Xbox connected
Nokia's Lumia 800 is regarded as the greatest Windows phone available. The ability to link it to your Xbox 360 is also extremely attractive for gaming fans.

WORLDWIDE MOBILE USER NUMBERS

Even the largest operators still only control relatively small percentages of users...



2X © Motorola

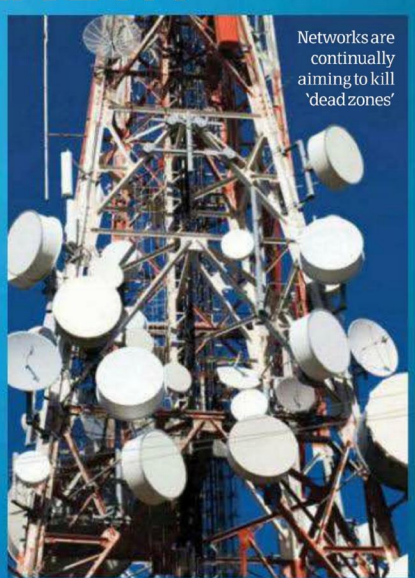
THE TRUTH ABOUT SIGNAL STRENGTH

Signal strength is measured in decibels (dB). The transmissions between mobile device and base station are of a relatively low power, so the figures you see are usually microvolts per metre; simply put, the greater the number of microvolts, the stronger the signal.

Unfortunately, the signal bars on a mobile phone do not accurately represent the true signal. The bars do not account equally for decibel loss – for instance, having two out of four bars does not mean that you are receiving at half power, as the smallest three bars together cover less power loss than the top single bar on its own. As you can see, this makes the system highly inaccurate and you could be classed as having a 'low-strength' signal even with three bars showing.

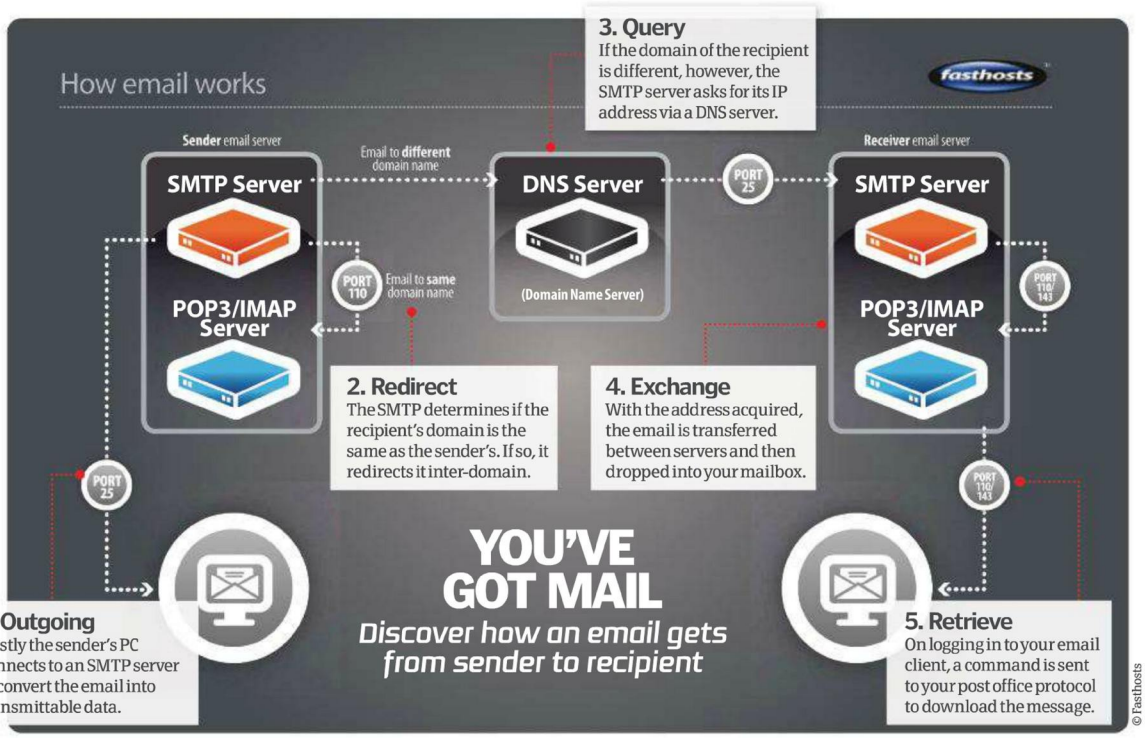
The mobile networks are constantly battling to improve coverage and they still use the same solutions they always have: more base stations, higher power transmissions, taller antenna masts and stronger antennas, and, more recently, femtocells to provide signal in high-traffic but low-coverage areas. As with all radio services, the higher the power, the further the signal will be transmitted – equally, the lower the frequency of the spectrum, the lower the power needed to achieve the same distance. A mobile operator with spectrum at 800MHz will need to broadcast at a lower signal strength than an operator with spectrum at 2.6GHz to achieve the same coverage, assuming an equivalent number and placement of base stations.

Network providers use coverage noticers to spot 'dead zones' – areas with no coverage – and these devices will emit a beep when within one. They can be used alongside tracking software in cars or on foot to build a map of general coverage over wide areas. Population density and dead zone data is used with destructive interference information to create a picture of where coverage is required most urgently. Destructive interference can be caused by large buildings constructed from metal, which can kill off a signal indoors, trees, terrain and many other obstacles. This makes the science behind coverage extremely complex but something networks continually use to improve signal strength for us all.



Networks are continually aiming to kill 'dead zones'

"The SMTP converts the information to a TXT file to send across the web"



© Fasthosts

How do you send and receive emails?

How It Works explains how an email can cross multiple networks and entire continents in just a few seconds

An email is an electronic text message constructed and sent through an email client (such as Microsoft Outlook). Once written, the sending process begins, with the email client connecting to a simple mail transfer protocol (SMTP) server via the internet and through a DSL or line modem. The client then communicates with the SMTP part of your designated email server (for instance, GoogleMail) through a dedicated port.

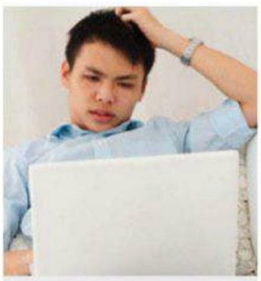
During the transmission between your email client and server, your email client relays the header information of your email – in particular the recipient's address and the contents within the email body. At this point the SMTP converts the information to a TXT file to send across the web.

Based on the header information within your email, the SMTP server then contacts the recipient's correct email server. Using the '@' sign as a divider, the SMTP takes the second part of the address to determine the location of the recipient's server. If the domain name is the same as the sender's, the SMTP simply transfers the email information across. If the domain name is different, the SMTP contacts a DNS (domain name system) server and requests the exact IP address for the relating domain name's hosted email server, such as those provided by Fasthosts.

Once the IP address has been obtained, the sender's SMTP server sends out a signal message to the recipient's SMTP over the web and all its gateways informing them that they have received a message. From then, the two servers converse with each other and the email is transferred.

The TXT file converts back into its original form, dropping the message into the bottom of the addressee's mailbox. Finally, when the recipient logs in to their email client, it connects to the internet and commands the recipient's POP3/IMAP (post office protocol/internet message access protocol) server to download all pending messages for viewing on the local machine.


SMTP servers, like these at Fasthosts, are integral to the email-sending process, converting data and tracking down the recipient's address
© Fasthosts



JARGON BUSTER

Break through the complex lingo with our handy guide

Email client: An application used to view, compose and send emails. Examples include Microsoft Outlook, Microsoft Exchange or web-based ones such as www.mail.com.

Email server: A remote machine hosting your email, perhaps sourced from a freemail provider or a web-hosting company such as Fasthosts. The server is split into an SMTP server and a POP3/IMAP server.

Email address: Your unique online site for emailed material that uses a domain name, either individual to you or shared by a company/institution, etc.

DNS (domain name system): A remote server used to convert domain names to IP addresses (unique 32-bit numbers).

SMTP (simple mail transfer protocol): The part of the email server that starts the process for outgoing mail and receiving mail into the correct server.

POP3 (post office protocol)/IMAP (internet message access protocol): These parts of an email server store and download incoming mail for each user account.

WORK BETTER ONLINE WITH 24/7 SUPPORT

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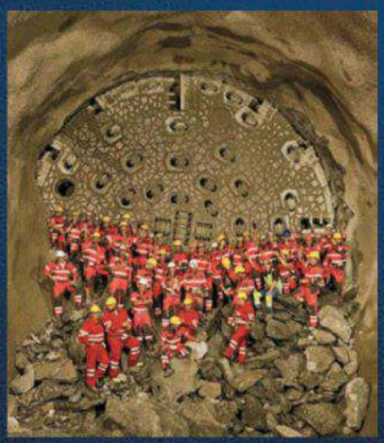
"The largest of these cutterheads is a 15.2-metre (49.8-foot)-across Herrenknecht-brand EPB Shield"

World's largest drill

Our inability to make inroads into some of Earth's most impenetrable terrain was a problem once... then they built tunnel-boring machines!

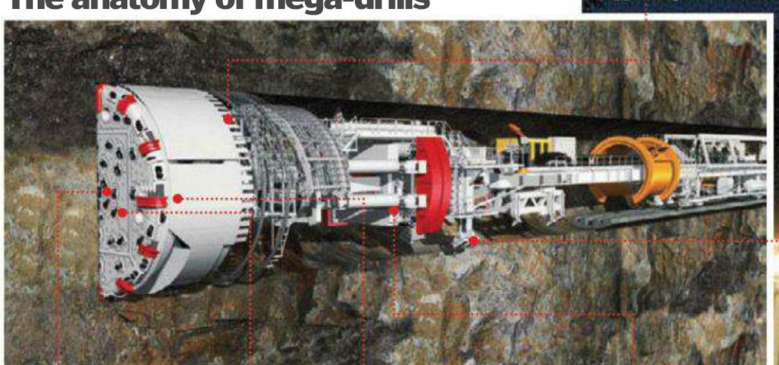
Tunnel-boring machines are designed to drill large-scale excavation holes into terrain that would otherwise be difficult or even impossible to penetrate. They are commonly used in the construction of underground tunnels and bypasses – modern motorway and train tunnels are often built with them – and they are specially designed not just to cut through rock and earth, but crucially to support the tunnel in the process. Additionally, today's most advanced boring machines are engineered to remove debris as it is generated by the drilling process, with rocks and rubble transported to the rear of an assembly on conveyor belts for easy disposal.

Key to any tunnel-boring machine though is its colossal cutterhead, a cylindrical wall of disc cutters and drills that – in partnership with extreme pressure, which is generated by the bore's thrust cylinders – literally crush any material that sits in its path. The largest of these cutterheads currently in operation is a 15.2-metre (49.8-foot)-across Herrenknecht-brand EPB Shield, a record-breaking piece of machinery that was used to carve out chunks of earth in the construction of Madrid's M-30 motorway north tunnel. As you can see on this page, the total assembly is huge and it weighs hundreds of tons.



Engineers, along with a large tunnel-boring machine, celebrate after completing the western tube of the Gotthard Base Tunnel in Amsteg, Switzerland. The tunnel will be a new world record in length once it's completed

The anatomy of mega-drills



Roof bolting unit
This part can rotate around the machine's axis and drills holes into the rock for supporting metal bolts.

Walking device
The rear of the bore and the back-up systems rest on the feet of the walking device. They are lifted as tunnelling progresses and the back-up system follows.

Thrust cylinders
These press the rotating cutterhead against the tunnel face.

Cutterhead
All the excavation tools are mounted in the cutterhead, which also supports the tunnel face.

Disc cutters
These are mounted in the cutterhead and roll in concentric circles over the tunnel face. The contact pressure crushes the rock.

Buckets
The system's buckets transport the excavated rubble behind the cutterhead onto a conveyor belt system.

DID YOU KNOW? *A tunnel-boring machine excavated 10.5 million cubic metres of rubble to carve the Gotthard Base Tunnel*

What is it?

This image shows a record-breaking tunnel-boring machine (15 metres/50 feet across) in the heart of Madrid, Spain. The titanic bore was used in the construction of the city's M-30 motorway north tunnel.

"An ECG machine detects and amplifies the changes in electrical impulses on your skin as your heart contracts"

How do quartz watches work?

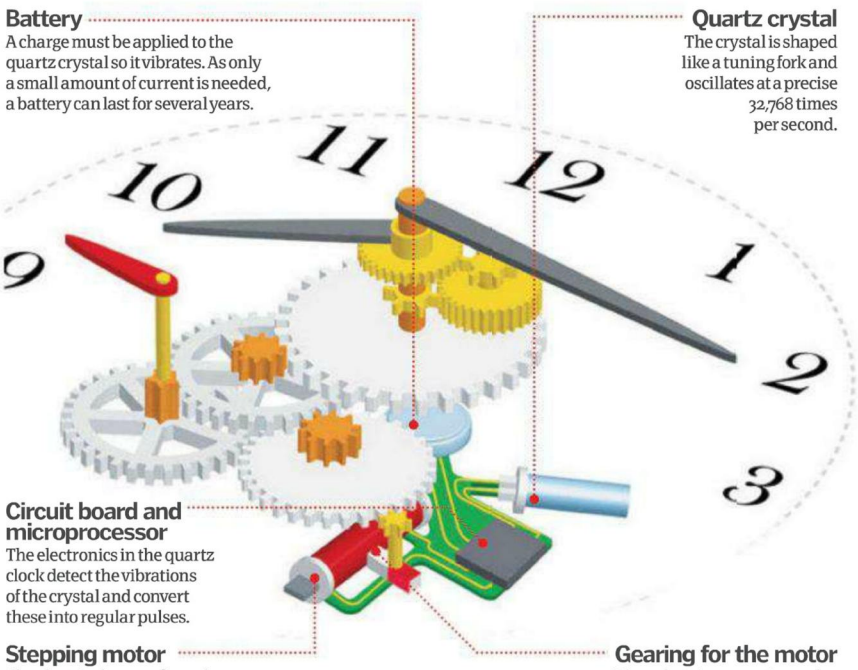
Keep accurate time with nothing more than a lump of rock

The quartz watch uses a special quality of the crystal (actually made of a silicon dioxide compound) that was discovered to vibrate at a very regular 32,768 times per second. Clocks and watches that utilise quartz are generally very accurate but they do lose and gain time; this is because the crystal reacts to changes in the atmosphere such as shifts in temperature and pressure.

Quartz watches work because the crystal itself is piezoelectric, which means it vibrates when you apply an electrical current to it. The circuit that the quartz crystal sits at the heart of also collects the energy that the piezoelectric effect generates to drive the motor that moves the hands or, alternatively, power the LCD display if it's a digital display.

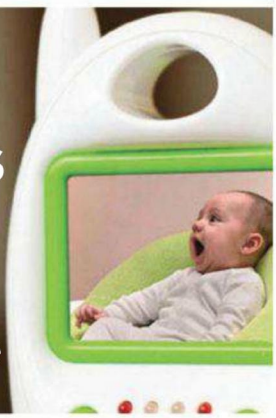
© Seiko

The first quartz wristwatch was the Astron by Seiko in 1969



Wireless baby monitors

How to hear and watch your baby on your phone or tablet PC with the latest surveillance technology



In their most basic form, baby monitors are just a radio transmitter that uses a fixed frequency usually in the 49.300MHz, 900MHz or 2.4GHz ranges. To reduce interference, some systems also employ digital enhanced cordless telecommunications (DECT) technology, similar to that used in cordless phones, while others can be linked to smartphones or tablet computers.

A modern monitor works by detecting any sound – or movement if a video camera is also being used – and transmitting the audio or video wirelessly to a receiver.

The devices work in a similar way to two-way radios with the addition of a sensor attached to the microphone that triggers the transmission of the audio or video. Baby monitors are usually what is called 'half-duplex'; this allows one monitor to transmit its signal to any number of receivers simultaneously.

Digital baby monitors have mostly replaced their analogue counterparts. Using an iPad or smartphone now means baby surveillance can be done anywhere, eg systems like WiFi Baby utilise the 3G network for super-clear pictures and sound.

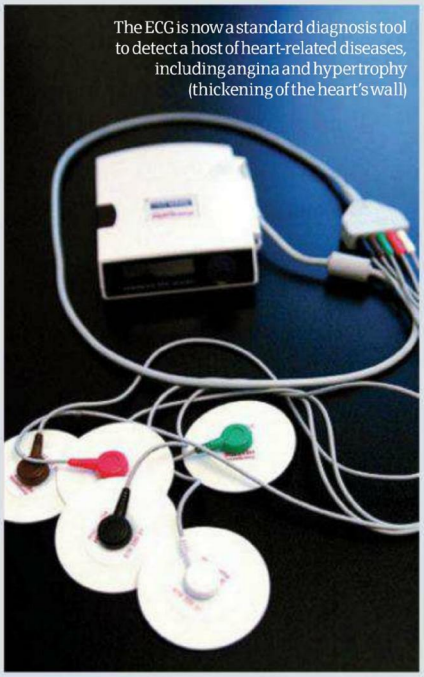
How do ECGs measure your heart rate?

To diagnose a range of illnesses, accurately monitoring your heart rate is essential

Measuring your heart rate is now easier than ever before. Apps can even use a smartphone's camera to measure tiny changes in your finger to study your heart, while sports watches with and without chest straps also do the job. But it's electrocardiography (ECG) that is mostly used in the medical world.

An ECG detects and amplifies the changes in electrical impulses on your skin as your heart contracts. The ECG can record the changes in your heart as each heart cell muscle has a negative charge across its outer wall. When the organ contracts the charge alters; this is called depolarisation. The ECG's electrodes pick up these changes as variations in voltage. Heart conditions alter the conductivity of your heart's tissue in specific ways that the ECG can distinguish. An ECG can have up to 12 electrodes to view your heart from many angles to ensure an accurate result.

The digital or paper tracing that the ECG produces includes waves and peaks that can show if there is any irregular activity that indicates any medical issues.



The ECG is now a standard diagnosis tool to detect a host of heart-related diseases, including angina and hypertrophy (thickening of the heart's wall)

5 TOP FACTS ELECTRICITY GETS SMART

Behavioural change
1 Once you have a meter installed you quickly become sensitive to the amount of electricity you are using. Energy paranoia can reduce energy usage, which in turn can cut carbon emissions.

Business matters
2 After installing smart meters the World Museum in Liverpool saved huge levels of CO_2 and £36,000 per year, giving a payback on the initial stake in just over seven months.

Every home will have one
3 It's thought that every home in the UK should be fitted with a smart meter by 2020. This is estimated will save consumers between £2.5-3.6 billion over the next two decades.

Go mobile
4 In a bid to educate everyone about energy usage, many of the main suppliers now have iPhone and iPad apps that allow you to closely monitor your electricity consumption.

Smart homes
5 These meters are only the first step towards a smart home with systems like AlertMe (**www.alertme.com**) arriving where you'll be able to monitor energy usage no matter where you are.

DID YOU KNOW? *The military uses many types of flare, sometimes as a countermeasure against heat-seeking missiles*

Electricity smart meters explained

Keep an eye on how much power you're using with one of these clever gauges

Electricity meters come in two varieties: the DIY approach or the fixed meter that is installed by your electricity supplier. Using the DIY approach the meter monitors your electricity usage via a sensor that clips onto the main electricity cable usually located in your meter cupboard. This sensor has a wireless transmitter that sends your electricity usage data to the display unit, which can be positioned anywhere in your home.

Meters directly connected to your electricity supply operate in much the same way as the DIY variety, but they are wired directly into your power supply. Most meters use radio frequency (RF) transmitters in the 900MHz ISM (industrial, scientific and medical) band that is reserved for special radio transmissions as well as systems like Bluetooth, though some utilise the 2.4GHz and 5.8GHz bands. The RF enables your reading to be sent to the supplier.

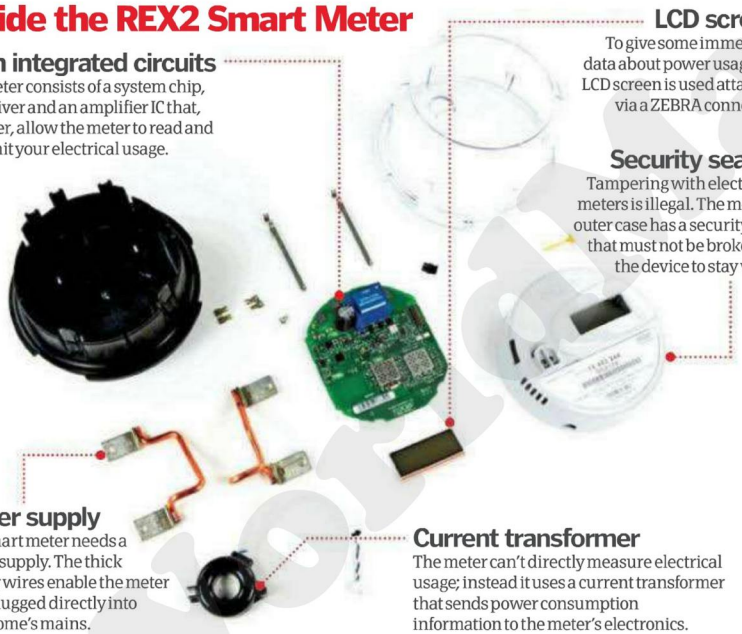
Smart meters send your readings to your electricity company in about 45 seconds, once a day. Some meters can also be read with portable handheld devices, but you no longer have to be home when a reading is due.

Inside the REX2 Smart Meter

Main integrated circuits
The meter consists of a system chip, LCD driver and an amplifier IC that, together, allow the meter to read and transmit your electrical usage.

LCD screen
To give some immediate data about power usage, an LCD screen is used attached via a ZEBRA connector.

Security sealed
Tampering with electricity meters is illegal. The meter's outer case has a security seal that must not be broken for the device to stay valid.



Power supply
The smart meter needs a power supply. The thick copper wires enable the meter to be plugged directly into your home's mains.

Current transformer
The meter can't directly measure electrical usage; instead it uses a current transformer that sends power consumption information to the meter's electronics.

©iFixit.com

The same mechanism that is used in traditional firearms was only slightly adapted for the flare gun

How do flare guns work?

Discover the mechanism that makes this lifesaving device go off

A flare gun works in the same way as any traditional firearm with one key difference: it must ignite its projectile and propel it high into the sky. Generally credited to Edward Very (1847-1910), the first gun that could fire a flare was tested by the American Navy back in 1882.

When the trigger of a flare gun is pulled, a chain of events begins. First, the flare's propellant is ignited as the gun's hammer strikes the detonator cap. The signal is then pushed out of the gun's barrel through deflagration, which is a subsonic combustion process where an intense burning of gases in a small space generates great pressure.

The short time it takes to ignite the propellant is enough for the flare to also be lit. These objects burn so brightly because they contain magnesium, an element also used in fireworks. Other chemical additives can produce varying colours. In some cases, the flare will also have an inbuilt parachute (most commonly for military use) that prolongs its fall to Earth and extends the average 40-second period that a flare will typically burn for.

"The device has a seven-inch capacitive LCD screen with a resolution of 1,024 x 600"

Andy Pad Pro

How does this Android tablet device work?

The Andy Pad Pro is a low-cost Android-powered tablet relatively new to the market. The Andy Pad Pro's unibody, plastic-composite shell is machined with a high-tension threshold and is purposely designed to withstand drops as well as bumps and scrapes – something helped by the sturdy body which is 1.27 centimetres (0.5 inches) thick. The operating system of the Andy Pad Pro is a modified version of Android 2.3 Gingerbread that comes pre-installed with a variety of apps. One of its most innovative features is the auto-typing feature – SwiftKey Tablet X – which is a keyboard replacement app that uses an advanced prediction engine (see 'Typing recognition' boxout). Inside is a Cortex A8 1GHz single-core processor with 512MB of RAM and a 3D-capable GPU. For connectivity purposes the Andy Pad Pro has a 3.5-millimetre (0.1-inch) headphone socket, mini-HDMI port, microSD slot and a charging port, while a built-in Wi-Fi receiver supplies access to the web.

The device has a 17.8-centimetre (seven-inch) capa citive LCD screen with a resolution of 1,024 x 600, which can be used for HD movies and games. The screen supports up to five-point multitouch, allowing for a range of gestures and commands to be used with Gingerbread. The tablet also has an accelerometer that can switch the screen between portrait and landscape modes, in addition to providing an alternative method of control in motion-sensitive games.

A stripped-down base unit Andy Pad is also manufactured. At 374 grams (13 ounces) it is 18 grams (0.6 ounces) heavier than the Andy Pad Pro, has only one camera and a resistive (rather than capacitive) 800 x 480 screen. It also has half the memory of the Andy Pad Pro – 8GB (again, with the option of upgrading to 32GB with an external SD card) as opposed to the Pro's 16GB.

The statistics...

Andy Pad Pro

Display: 17.8cm (7in)
Resolution: 1,024 x 600
Weight: 374g (13.2oz)
Storage: 16GB
Processor: Cortex A8 1GHz
RAM: 512MB
Battery: Six hours
Connectivity: Wi-Fi/Bluetooth
Ports: microSD, microUSB, mini-HDMI, headphone jack
Cameras: 0.3 and 2MP

Camera
The front and rear-facing cameras – 0.3 and 2MP, respectively – allow you to take quick snaps in addition to performing video calls.

microSD
While the device has 16GB of memory, it also supports microSD cards up to 32GB in size.

Typing recognition

How does the Andy Pad tablet learn how you type?

One of this tablet's most advanced features is its typing system. It uses SwiftKey Tablet X, which is a keyboard replacement app that uses a smart prediction engine. From users' Facebook, Twitter and Gmail accounts it learns typing patterns and how they generally construct sentences, ultimately helping users to type much more quickly and efficiently. Software like SwiftKey Tablet X is able to log your writing style in order to more easily predict the words you may type in the future. Aside from its advanced word prediction engine, SwiftKey is also integrated system-wide throughout the Android OS. This means that, despite the application the user types in – be it a stock email client or social-networking tool like Facebook or Twitter – SwiftKey's system tracks and logs text patterns and sentence construction, allowing it to 'learn' their typing style and, as a direct consequence, speed up the writing process. Eventually, users can type full sentences by just tapping words as they appear based on the software's programs.

Head to Head TABLET SHOWDOWN

1. iPad 2
The most famous and current market leader, Apple's powerful iPad 2 remains the king when it comes to tablet computing.

2. Xoom 2
Motorola's second attempt at a tablet computer is considerably better than the disappointing first-generation Xoom released last year.

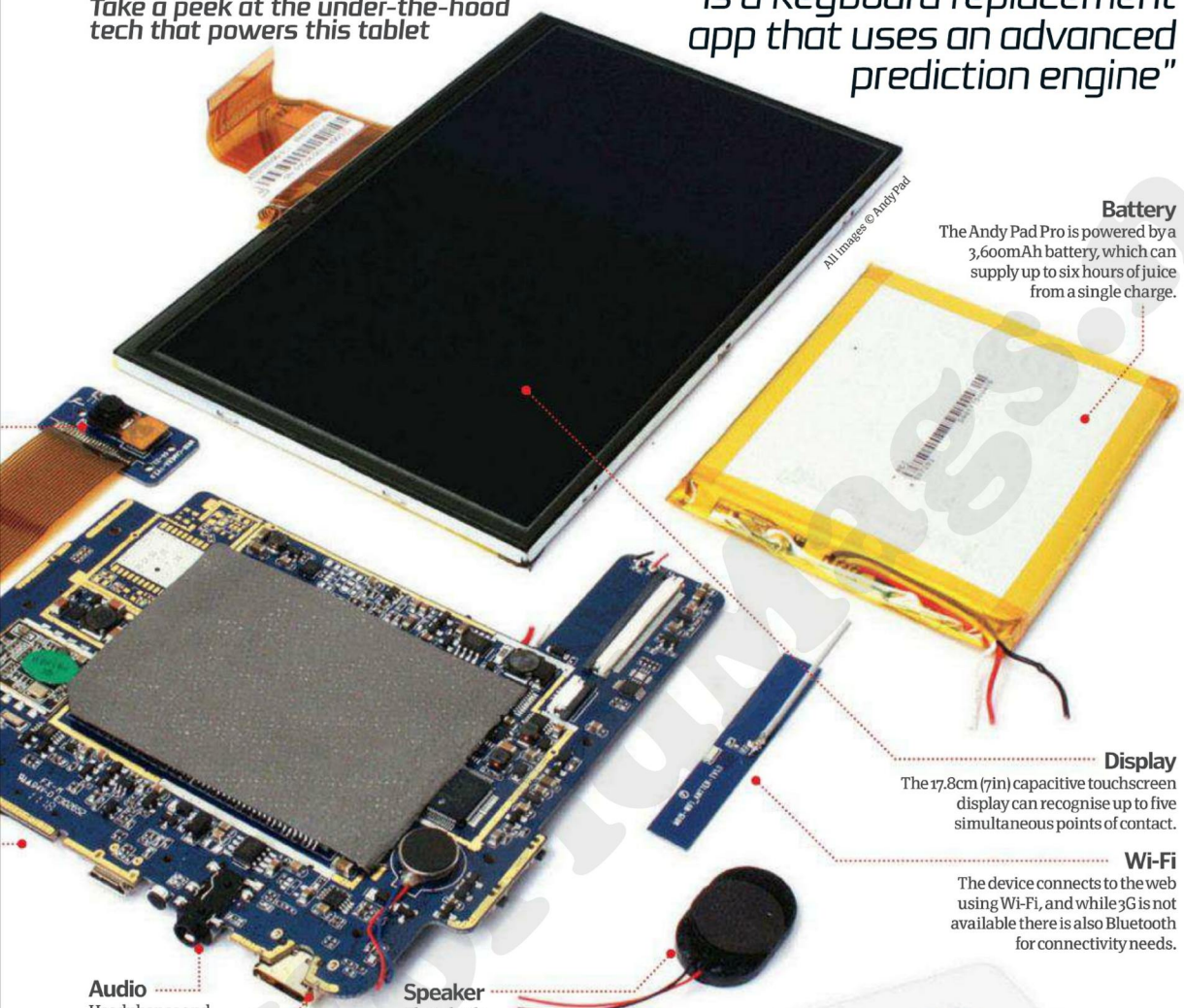
3. Galaxy Tab 10.1
Billed by many as the iPad 2's greatest rival, the 25.6-centimetre (10.1-inch) screen of the Galaxy Tab from Samsung makes for an enjoyable tablet experience with a variety of cutting-edge features.

DID YOU KNOW? *Elisha Gray patented the telautograph in 1888, an electrical tablet designed to record handwriting*

Inside the Andy Pad Pro

Take a peek at the under-the-hood tech that powers this tablet

"One of its most innovative features is its typing system – SwiftKey Tablet X – which is a keyboard replacement app that uses an advanced prediction engine"



All images © Andy Pad

Battery
The Andy Pad Pro is powered by a 3,600mAh battery, which can supply up to six hours of juice from a single charge.

Display
The 17.8cm (7in) capacitive touchscreen display can recognise up to five simultaneous points of contact.

Wi-Fi
The device connects to the web using Wi-Fi, and while 3G is not available there is also Bluetooth for connectivity needs.

Audio
Headphones and speakers can be plugged into the 3.5mm (0.1in) headphone socket.

Speaker
The inbuilt speaker lets you listen to music and videos on the go.

HDMI
The HDMI-out port enables you to connect the Andy Pad Pro to other HD-ready devices to view high-quality video and images.

The Andy Pad is a step towards bringing tablet devices to the masses

TOP APPS

HERE ARE SOME OF THE BEST PRE-INSTALLED APPS ON THE ANDY PAD PRO

Evernote

With Evernote you can write memos and categorise them with tags, in addition to syncing your notes with other devices including your phone and computer. No tablet user should be without this super-handy app.

Dropbox

If you frequently transfer files between devices then you'll definitely want to use Dropbox. You can store files, images and more in 'the cloud' and access them from any device, anywhere, at any time.

Movies

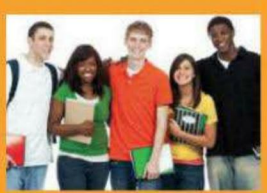
Movies by Flixster brings together film trailers and reviews into one simple application. You can also check out your local cinema listings and see what's new to buy on both DVD and Blu-ray.

TuneIn Radio

This app lets you listen to thousands of online radio stations and over a million on-demand programmes, so you've always got quality audio content to entertain you when you're on the move.

This month in **Science**

Brrr, it's a bit chilly here as we're exploring one of science's coolest fields: cryogenics. In this feature you'll learn how this complex freezing process works on an atomic level plus how it is used to preserve life in many forms. Also we discover the biology that determines skin colour, how pasteurisation is used to extend the shelf life of many everyday products and how gastric bands can help us lose weight. And, you know, all that's just for starters...



38 Skin colour

40 Pasteurisation

41 Mushroom clouds

SCIENCE

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38 Washing detergent
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40 Photons
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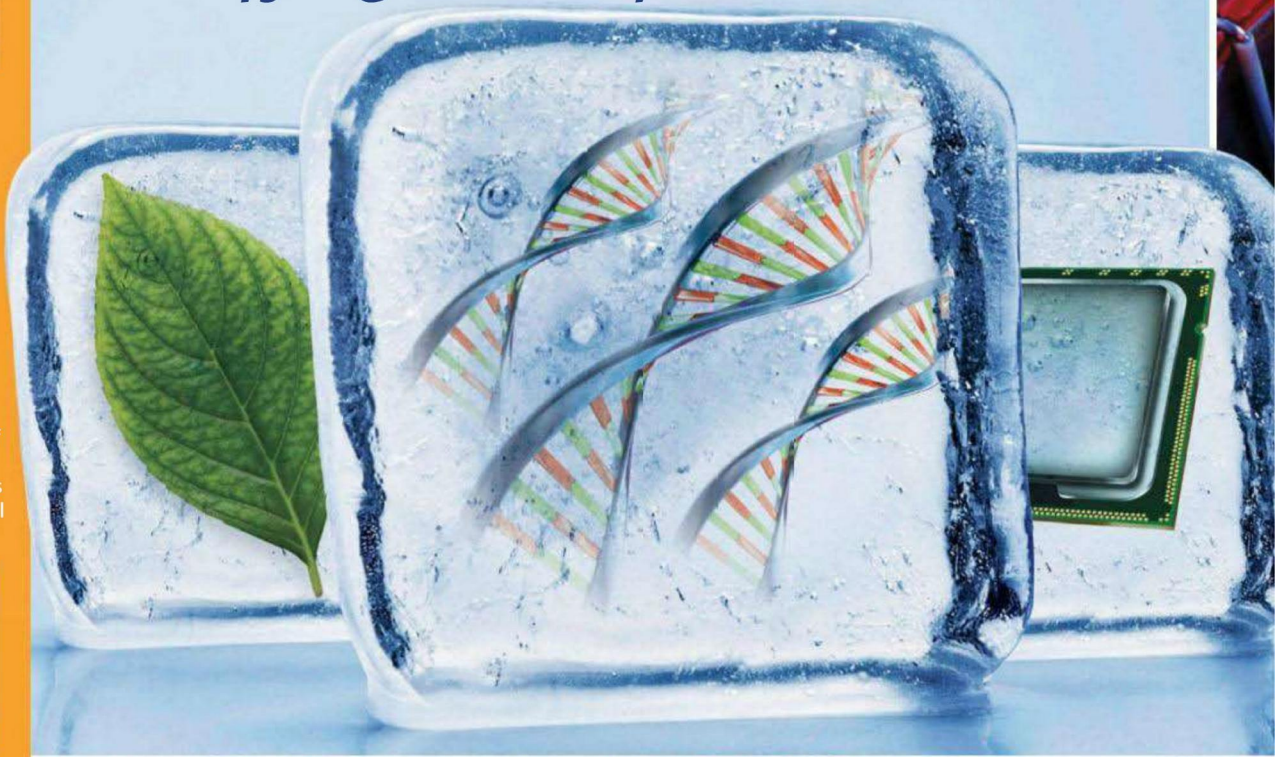
41 Mushroom clouds
42 Gastric bands

Enter the heart-stopping, physics-defying world of the ultra-cold



CRYOGENICS EXPLAINED

Put simply, cryogenics is the science of the extremely cold. This is not about deep-freezing your deceased chihuahua. The freezing of dead people or animals in the hope of future reanimation is called cryonics – not cryogenics – and is less a science than a really expensive alternative to burial. True cryogenics is a field of physics that studies the unique properties and applications of extremely cold liquids, materials and environments.

How cold, exactly, is cryogenics cold? Anything below -150 degrees Celsius (-238 degrees Fahrenheit or 123 Kelvin) and approaching absolute zero (-273 degrees Celsius/-460 degrees Fahrenheit), the coldest theoretical state of matter. To put those temperatures into perspective, the coldest recorded temperature on Earth – at a research station in Antarctica – was -89.2 degrees Celsius (-129 degrees Fahrenheit or 184 Kelvin). To obtain cryogenic temperatures, researchers must alter the natural states of gases like nitrogen and helium, two of the most abundant elements in the universe. Nitrogen is a gas at room temperature, but if you can bring the temperature of nitrogen past its incredibly low boiling point of -196 degrees Celsius (-321 degrees Fahrenheit or 77 Kelvin), it becomes a supercold liquid that's easy to store and transport in vacuum tanks.

But how do you get anything, especially a gas, to become so cold? Physics, of course! We know that higher pressure means higher energy (heat) and lower pressure means lower energy (cold). To create liquid nitrogen or other liquid gases, regular atmospheric air is compressed in stages. With each compression, the air naturally gets hotter, so it must be cooled using heat exchangers. Once the air is both tightly compressed and cold, it is sprayed into a large storage tank, dramatically lowering the pressure on the gas, causing its temperature to drop so quickly as to become liquefied. Through a distillation process, liquid air can be separated into its component elements like liquid nitrogen, oxygen, hydrogen and helium.

Armed with these hyper-cold liquids (also known as refrigerants), researchers are able to test and study the properties

5 TOP FACTS
THE COLD HARD FACTS

Cool and clear
1 Cryogenic cooling drastically reduces signal-to-noise ratio, which is why NASA cools its microwave receivers to cryogenic temperatures for deep-space communications.

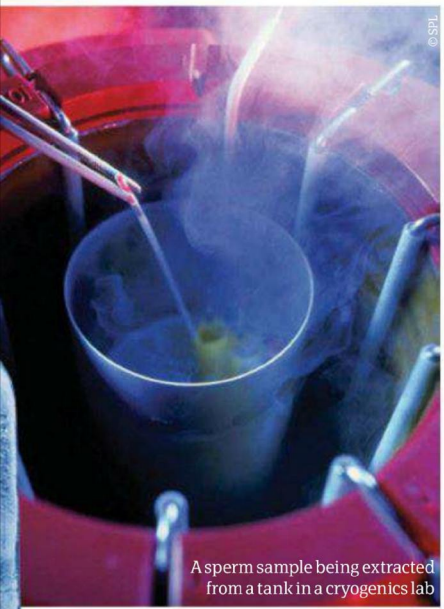
Colder, faster
2 Microprocessors in computers run faster when they're cold. Supercomputers have been built with their processors immersed in liquid nitrogen, doubling processing power.

Dr Freeze
3 Cryosurgery can be used to remove early-stage cancerous and non-cancerous growths. A dab of liquid nitrogen totally kills the tumour without damaging any local tissue.

Cryo foods
4 Your freezer contains many goods that are flash frozen with liquid nitrogen-based processes. Cryogenics also supercools cookies in commercial bakeries.

Iced lice
5 Some pest-control companies are using carbon dioxide 'snow', a kind of foamy dry ice. The blast of snow kills bugs and eggs, and the non-toxic ice dissolves into gas, leaving no water damage.

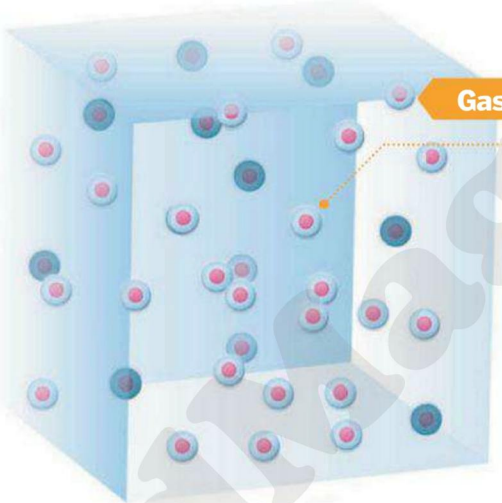
DID YOU KNOW? *Trumpets, saxophones and violin strings exposed to cryogenic temperatures are more resistant to wear*



A sperm sample being extracted from a tank in a cryogenics lab

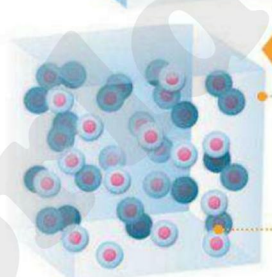
Cryogenics on a molecular level

Molecules are not that attractive. By that we mean that two adjacent molecules of the same element are held together by a weak attraction known in physics as Van der Waals' forces. As you raise the temperature (ie provide more energy), molecules vibrate with greater and greater intensity. When molecules get excited, they easily overcome the Van der Waals' forces trying to keep them together. This is the process that transforms solids into liquids and liquids into gases. But if you make the temperature really, really cold, those previously weak forces become so strong that molecules align themselves in a supertight formation, changing the molecular structure of solids into something much harder and even more stable.



Gas molecules

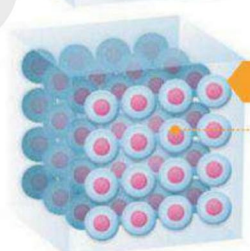
1. Flying free
In a gaseous state, molecules vibrate with such intensity that they easily overcome the weak forces of intermolecular attraction binding them together.



Liquid molecules

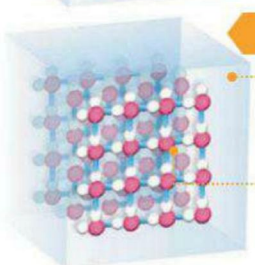
2. High boiling point
As the temperature dips below 100°C (212°F), water molecules slow down enough to be drawn together by relatively strong intermolecular bonds, forming a liquid.

3. Frozen boiling point
Helium has such a weak intermolecular bond that it doesn't become a liquid until the temperature reaches -269°C (-452°F).



Solid molecules

4. No wiggle room
As the temperature descends below the freezing point, molecules are so strongly attracted to one another and become so tightly arranged that they cannot move, forming a solid material.



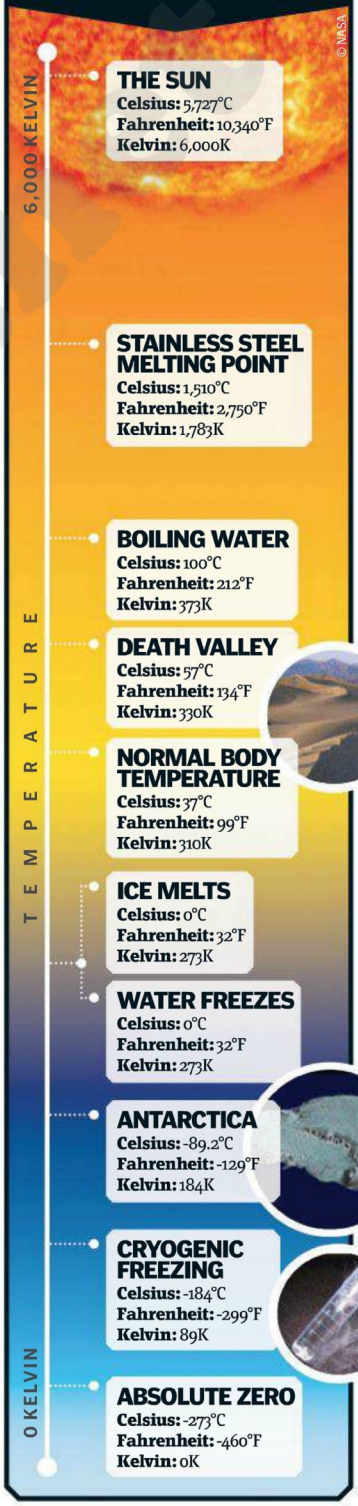
Cryogenically frozen

5. Cold attraction
Exposure to extreme cold will cause molecules to be so highly attracted to one another that it permanently realigns a material's micro-structure.

6. Stronger structure
After forging, steel contains stronger and weaker crystalline structures. Deep-freezing aligns more of the crystals as martensite, an ultra-hard form of steel.

TEMPERATURE SCALE

The hot and cold extremes and everything in between!



THE SUN
Celsius: 5,727°C
Fahrenheit: 10,340°F
Kelvin: 6,000K

STAINLESS STEEL MELTING POINT
Celsius: 1,510°C
Fahrenheit: 2,750°F
Kelvin: 1,783K

BOILING WATER
Celsius: 100°C
Fahrenheit: 212°F
Kelvin: 373K

DEATH VALLEY
Celsius: 57°C
Fahrenheit: 134°F
Kelvin: 330K

NORMAL BODY TEMPERATURE
Celsius: 37°C
Fahrenheit: 99°F
Kelvin: 310K

ICE MELTS
Celsius: 0°C
Fahrenheit: 32°F
Kelvin: 273K

WATER FREEZES
Celsius: 0°C
Fahrenheit: 32°F
Kelvin: 273K

ANTARCTICA
Celsius: -89.2°C
Fahrenheit: -129°F
Kelvin: 184K

CRYOGENIC FREEZING
Celsius: -184°C
Fahrenheit: -299°F
Kelvin: 89K

ABSOLUTE ZERO
Celsius: -273°C
Fahrenheit: -460°F
Kelvin: 0K

of matter at unnaturally low temperatures. The results have been revolutionary. Space flight was first made possible through the advent of liquid-propellant rocket engines powered by cryogenic fuels like liquid hydrogen and liquid oxygen. Not only do cryogenic fuels produce massive amounts of pressure and energy during combustion, but they can also be used in their liquid state to cool overheated rocket components.

Semiconductors are another major cryogenic breakthrough. Certain metals and chemical compounds have been found to conduct electricity with nearly zero resistance or energy loss when cooled to cryogenic temperatures. The result is a hugely more efficient and effective way to generate and transport energy. Superconducting magnets – formed from coiled and cooled superconducting materials – are used to create the world's most powerful magnetic fields, like the one inside an MRI machine or the 1,232 dipole magnets that bend proton beams inside the Large Hadron Collider at CERN.

Cryogenics also provides a safe and effective way for preserving small samples of living tissue indefinitely without any cell damage. In fertility clinics, blood banks, hospitals and research labs, technicians routinely freeze sperm cells, egg cells, fertilised embryos, rare blood types, bacteria, viruses, plus plant seeds and tissue.

When the right precautions are taken, living cells stored at cryogenic temperatures enter a state of suspended animation, safe from cell death or deterioration. The biggest danger is ice ▶

"Computer processors run twice as fast when bathed in liquid nitrogen"

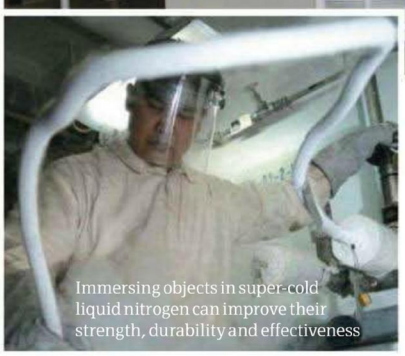
formation inside and outside of cells. To prevent ice formation outside cells, the temperature is lowered slowly at a computer-controlled one degree Celsius (34 degrees Fahrenheit) per minute. To avoid deadly ice formation inside cell walls, meanwhile, technicians use osmosis to replace the water within cells with antifreeze solutions called cryoprotectants.

Sperm samples have been successfully thawed and used for in-vitro fertilisation after more than 20 years in the freezer and some cryobiologists estimate that properly frozen tissue can be stored undamaged for 1,000 years or more. In frozen zoos (see boxout) around the world, biologists are preserving sperm and embryo samples from thousands of endangered animal and plant species to create a 'Noah's Ark on ice' as a precaution against extinction.

Cryogenic temperatures have other unusual effects on electronics. Computer processors run twice as fast when bathed in liquid nitrogen and microwave radio receivers can detect the faintest signals from outer space when their components are super-cooled to cryogenic temperatures.

Devices known as SQUIDs (or superconducting quantum interference devices) are tiny magnetic field detectors with extreme sensitivity that might be used to create the first viable quantum computers. When cooled to near absolute zero, SQUIDs can detect the directional spin of individual electrons (up, down or somewhere in between). Like the 1s and 0s of a silicon transistor, quantum computers will use the relative position of infinite numbers of electrons to make calculations many millions of times faster than today's most powerful computers – all so long as they can keep their cool.

Commercial cryogenic processing company 300 Below's cryo-processors are used across the world


Immersing objects in super-cold liquid nitrogen can improve their strength, durability and effectiveness

"Cryogenic hardening can greatly improve the life span of tools and industrial machine parts"


Deep-freezing can strengthen metal items like sports equipment by altering their micro-structure

Cryogenic hardening

Picture an 18th-century blacksmith pounding a red-hot blade on an anvil, then dunking the metal into a bucket of water with a hiss. That's called quenching, and even before metallurgists knew what molecules were, they understood that rapid cooling makes metal stronger. In the Sixties, scientists discovered that if you lowered the temperature of stainless steel to -185 degrees Celsius (-301 degrees Fahrenheit), its molecules would be drawn together so tightly as to permanently alter the steel's molecular structure. After the steel is exposed to a cryogenic 'soak' for 24 hours, the temperature is slowly raised to 148 degrees Celsius (298 degrees Fahrenheit). As the molecules break free from their tight formation, they settle into a highly stable crystal structure called martensite that is up to 600 per cent more resistant to wear than untreated steel. Cryogenic hardening can greatly improve the life span of tools and industrial machine parts that undergo heavy stress.

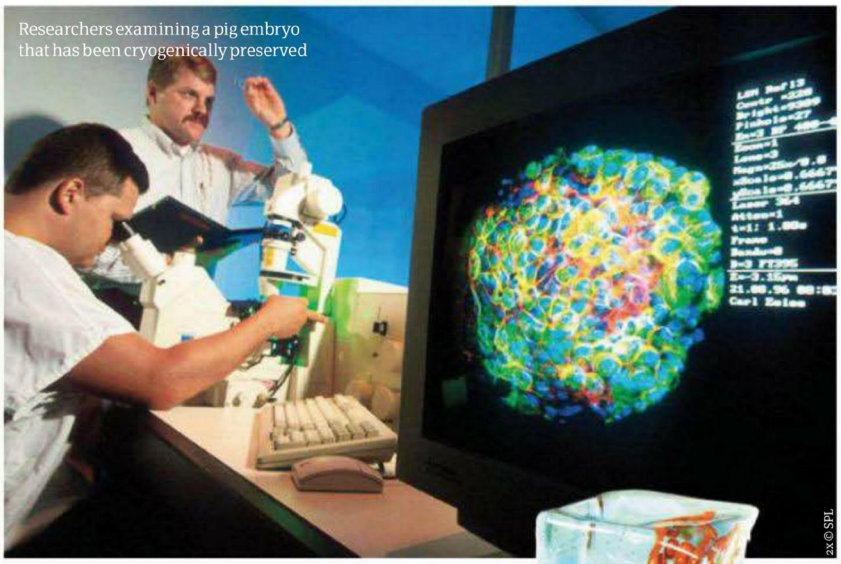
Frozen wood frogs

Could this amphibian on ice provide the answers?

North American wood frogs survive the winter by freezing solid – with no heartbeat or brain activity – and thawing out in the spring unharmed. If humans are frozen, our cells suffer irreparable damage called frostbite. The wood frog protects its cells by injecting them with a glucose solution produced in its liver. The glucose acts as antifreeze, lowering the cells' freezing point.

But any water that exists outside of the cells – eg blood plasma is 90 per cent water – will freeze at its normal temperature (0 degrees Celsius/32 degrees Fahrenheit), leaving the frog in a perfectly safe state of suspended animation. When temperatures rise, the water thaws first, slowly replacing the glucose in the cells, and the frog's heart starts pumping 20 minutes later.

DID YOU KNOW? *In March 1984, Zoe Leyland, Australia, became the first baby to be born from a thawed frozen human embryo*



Researchers examining a pig embryo that has been cryogenically preserved

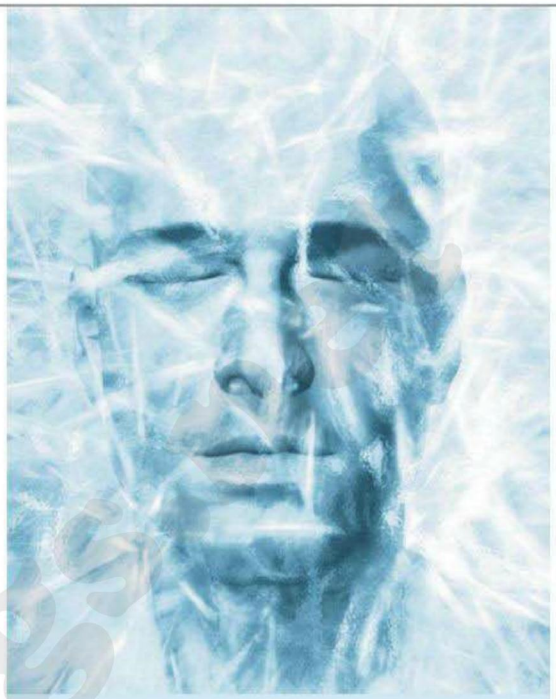
Frozen zoos

Is animal extinction now a thing of the past?

Cryogenic preservation is the closest thing we have to a time machine. Under controlled conditions, living tissue can be frozen in a state of suspended animation and revived undamaged after as many as two decades. Sperm and egg cells, as well as blood, DNA samples, viruses, bacteria and tissue samples are routinely preserved at cryogenic temperatures. The frozen zoo at San Diego Zoo, CA, contains 15,000 frozen sperm samples from 309 endangered species, some of which have been successfully paired with thawed egg cells to create viable test-tube embryos.

Ice is the greatest threat to cryogenic preservation. For living tissue to survive the process, it must be vitrified, meaning frozen without ice formation. Specimens are first treated with a cryoprotectant solution that acts as antifreeze, lowering the freezing point inside the cell and halting ice formation around fragile cellular tissue. Secondly, specimens must be cooled slowly at a precise rate of one degree Celsius (34 degrees Fahrenheit) per minute to control ice formation between cells. Successful thawing and rejuvenation of living tissue has been limited to small samples, because cryoprotectants become toxic at higher doses. This is one of the greatest obstacles to cryonics – the freezing of entire bodies or brains in the hope that future scientists can 'cure' ageing and, perhaps, even death itself. While no living creature has been revived from cryogenic preservation, millions of babies have been born from in-vitro fertilisation (IVF) using frozen sperm, eggs and embryos.

Blood samples inside a cryogenics storage freezer



CRYONICS

The future of freezing humans

Small samples of human tissue and a few hardy organs have been successfully revived from cryogenic temperatures, but what about a whole human brain? Proponents of cryonics – cryogenic life extension – believe it's only a matter of time, and some careful preparation.

The trick is to preserve the brain of a deceased person before it suffers irreversible damage from oxygen deprivation. The instant the heart stops a team of medical attendants lowers the body into an ice-water bath and starts a heart-lung resuscitator. All blood and water is slowly replaced with an increasing concentration of cryoprotectant, which circulates into the brain. Fans blowing nitrogen gas lower the body's temperature to -125 degrees Celsius (-193 degrees Fahrenheit), at which point all cell tissue is vitrified.

The brain is surgically removed and suspended in a storage tank of liquid nitrogen at -196 degrees Celsius (-321 degrees Fahrenheit). The greatest hope for revival lies with innovations in nanotechnology – employing an army of micro-machines to repair damaged tissue. Cryonics has its critics, but it wouldn't be the first time that theories dismissed as science fiction become science fact.

Will we one day be able to cheat death via cryonics?

"By lowering the surface tension, the water can become more 'wet' and permeate clothes better"

Skin colour explained

What is melanin and how does it affect the tone of our skin?

The light-absorbing pigment melanin is a chemical substance that gives your skin its natural colouring. Skin can vary from very dark brown to almost completely white due to a combination of your genes and inherited traits and the amount of sunlight to which you're exposed.

Skin colour differs from person to person depending on the concentration of melanin present in their skin and its distribution throughout the skin's layers. Basically, those with less melanin have lighter skin, while those with more of the pigment have darker skin. Melanin is produced by specialised skin cells called melanocytes in the lower layers of the epidermis and is contained inside a melanosome by a very thin membrane.

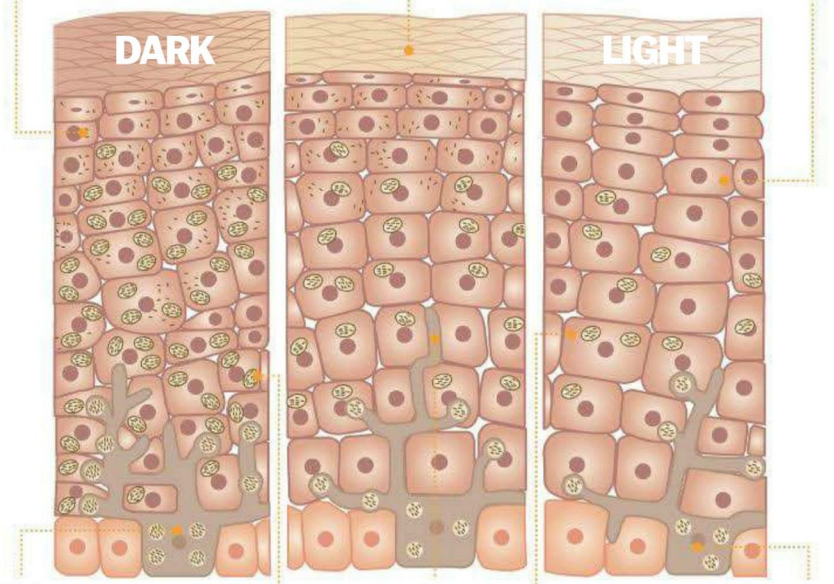
Exposure to sunlight stimulates the production of melanin granules. The melanosomes containing the melanin then move out towards the skin's protective keratinocyte cells along branch cells called dendrites. Melanin is then stored in the nuclei of the keratinocytes where it acts as a natural protector against the effects of the Sun's ultraviolet rays. Keratinocytes make up the bulk – around 95 per cent – of the outer layers of the skin and form the barrier between the body and the outside world. They take up melanin which can absorb cancer-causing UV radiation so it doesn't get into the body's internal tissues.

Melanin and skin colour

Keratinocytes
These protective cells are produced in the lower layers of the epidermis. They take up the melanosomes produced by the melanocytes.

Surface
Basal skin cells manufactured in the lower layers of the epidermis grow through the skin to the surface, where they are eventually sloughed away.

Keratinocytes
The keratinocytes of lighter-skinned people take up fewer melanosomes.



Melanocyte
Melanin is made in the melanocytes. People with darker skin, or those who live in regions with greater sunlight exposure, have more active melanocytes.

Dendrite
These branching cells pass melanin to keratinocytes.

Melanocyte
Those with lighter skin have fewer dendrites in their lower layers and their melanocytes are also less active.

Melanosomes
These packets of melanin release melanin granules into the keratinocytes.

Melanosomes
The melanosomes in lighter skin release far fewer melanin granules.

Washing detergents

Discover the chemistry at work inside your washing machine

Anionic surfactants are the workhorse ingredients of most washing detergents. They are compounds such as sodium alkyl sulphate and are made up of molecules that have opposite charges at different points (polar molecules). Water is also made of polar molecules and, when mixed with washing detergent, the hydrophilic (water-loving) part of the surfactant molecule attracts to the water molecule, while the hydrophobic (water-hating) part of the molecule adheres to the dirt and grease in your clothes. This makes the dirt and grime more soluble in the water, allowing for easier removal from your clothing.

Another cleaning effect surfactants have is to lower the surface tension of water. Surface tension is created by these polar molecules pulling on one another due to their charge. This accounts for how pond skaters walk on water and why beads of water hang suspended on grass. By lowering the surface tension, the water can become more 'wet' and permeate clothes better allowing for a deeper clean.

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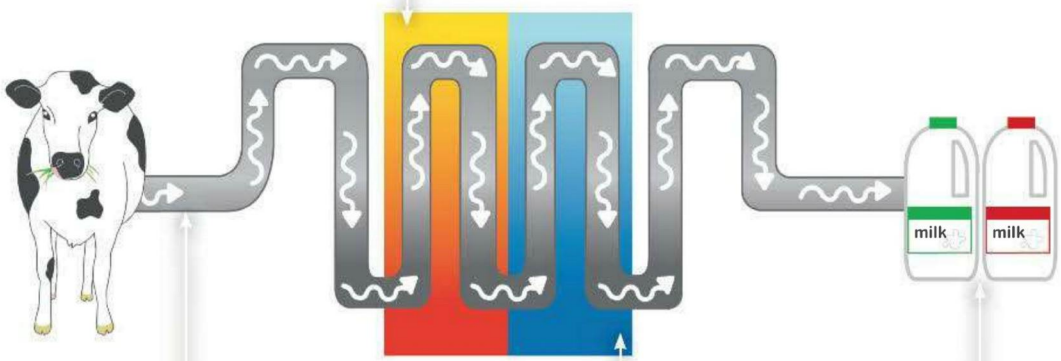
"Photons are responsible for one of the fundamental forces of nature – the electromagnetic force"

How pasteurisation works

Find out how pasteurising food increases the shelf life of many products

The process of pasteurisation



2. Heating section
Hot water on the opposite side of two metal plates heats the milk to 71°C (160°F) denaturing enzymes responsible for bacterial growth.

1. Fresh milk in
Cold raw milk is drawn into the regenerator section of the pasteuriser for heating.

3. Cooling section
Warm milk passes through two plates where a coolant on the opposite side of the metal plates chills the milk to below 4°C (39°F).

4. Pasteurised milk out
The pasteurised milk is then sent to a cooled storage tank for packaging and later distribution.

Pasteurisation is a process of heating food and liquid to a specific temperature in order to slow microbial growth, essentially giving it a longer shelf life. This technique is usually associated with milk where it reduces the number of potentially harmful bacteria such as E coli and salmonella that are present in its raw state.

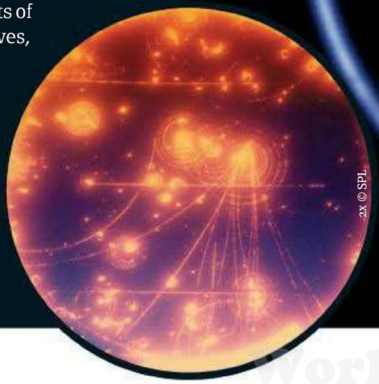
Bacteria produce enzymes which help them to break down and digest a wide range of organic materials allowing them to divide and conquer. Heating milk to 71 degrees Celsius (160 degrees Fahrenheit) for 15 seconds changes the shape of the enzymes in the harmful bacteria, rendering them useless and hindering the bacterial growth and multiplication process. Pasteurisation does not stop all the bacteria, which is why you still need to keep it in the fridge. It does, however, significantly lower the concentration of harmful bacteria, leaving your stomach to do the rest of the work.

What is a photon?

Just how do these tiny packets of light work?

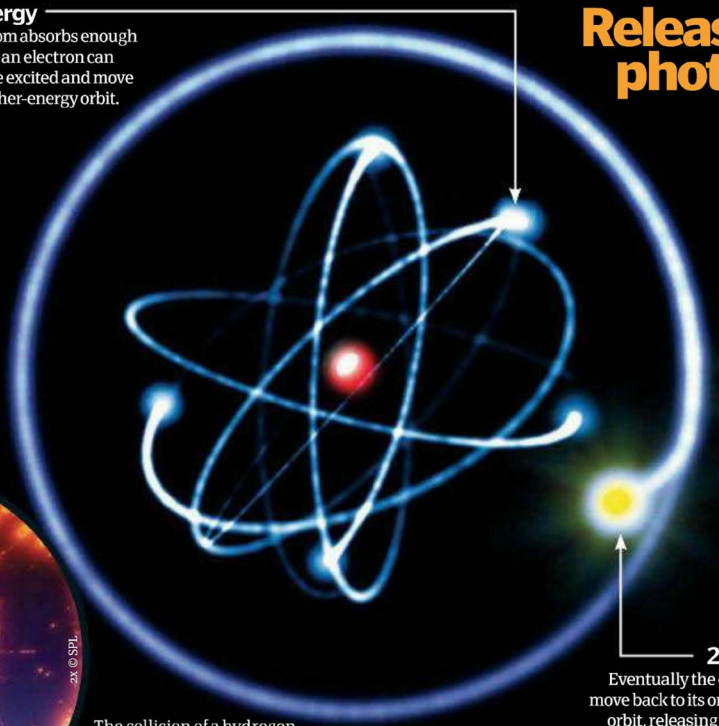
A photon is one of the elementary particles of the universe and is accountable for much of its basic structure. Photons are responsible for one of the fundamental forces of nature – the electromagnetic force – and are often regarded as the basic unit of light. They are also responsible for forces in an electromagnetic field and are the main constituent of light that enables it to travel throughout the cosmos.

Photons are basically packets of energy, or electromagnetic waves, but they contain no mass or electrical charge. They are released from atoms when a change in energy occurs, travel at the speed of light and can exist as both a wave and a particle. When we see light, we are really observing the emission of photons from agitated atoms.



The collision of a hydrogen nucleus (proton) and a high-energy photon

Releasing photons



1. Energy
If an atom absorbs enough energy, an electron can become excited and move to a higher-energy orbit.

2. Release
Eventually the electron will move back to its original lower orbit, releasing the energy it previously gained as a photon, which takes the form of light.

HOW IT WORKS TV

Watch a video of the Tsar Bomba being detonated at How It Works Daily

www.howitworksdaily.com

DID YOU KNOW? *The biggest nuclear weapon ever detonated was the Tsar Bomba in 1961, with a yield of 50 megatons of TNT*

How does a mushroom cloud form?

What's the science behind these oddly shaped clouds?

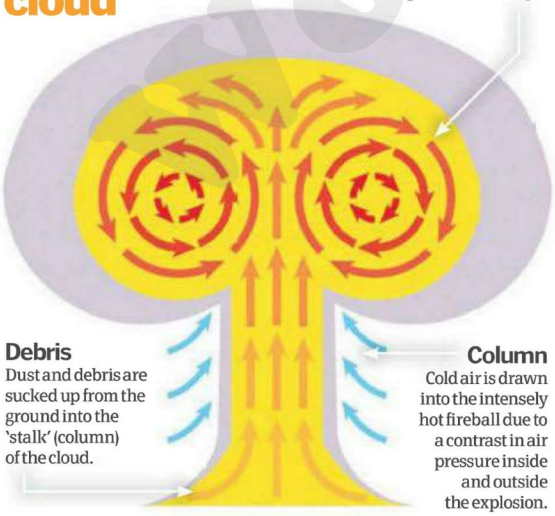
Mushroom clouds are usually the result of a colossal explosion, such as that produced from a nuclear weapon or another type of large explosive device. Mushroom clouds can tower many miles in the sky, but they will flatten out around the stratosphere, hence how they acquired their name.

When an atom bomb is dropped, it doesn't explode on the ground. Instead, it's detonated several hundred metres above land to maximise the blast impact. This creates a fireball of superhot gases in the air within a split second of the explosion that can be several miles wide. This intensely hot ball draws up debris from the ground as the air pressure inside is much lower than that outside. The ball of fire rises upwards as the head of the mushroom cloud, carrying a column of dust and debris in its wake. It eventually reaches a point where the air is thinner – the stratosphere – causing the head to flatten out. The fire spreads out in all directions and convection currents form inside the head. These currents force the edges of the head to curl downwards and rejoin the central column, giving the appearance of a traditional toadstool or mushroom.

Mushroom clouds generally only form as the consequence of a large manmade or natural explosion, such as a volcanic eruption, however they have been recorded to occur in much smaller explosions on Earth too, such as after the firing of a cannon. In the case of a volcanic eruption, the enormous amount of heat created at the peak of the volcano takes the place of the fireball in the atom bomb scenario.

Inside a mushroom cloud

Convection
At the top of the cloud convection currents form, bringing the hot gas round in a circle back into the central column and creating a toadstool shape.



Debris
Dust and debris are sucked up from the ground into the 'stalk' (column) of the cloud.

Column
Cold air is drawn into the intensely hot fireball due to a contrast in air pressure inside and outside the explosion.

A shot of the atomic bomb exploding over Nagasaki, Japan, in 1945

© SPL

"The gastric band is placed in position in its deflated state"

How do gastric bands work?

Gastric bands aren't just for cosmetic purposes – they can help to prevent health problems too

Gastric bands only work in conjunction with a strict diet plan

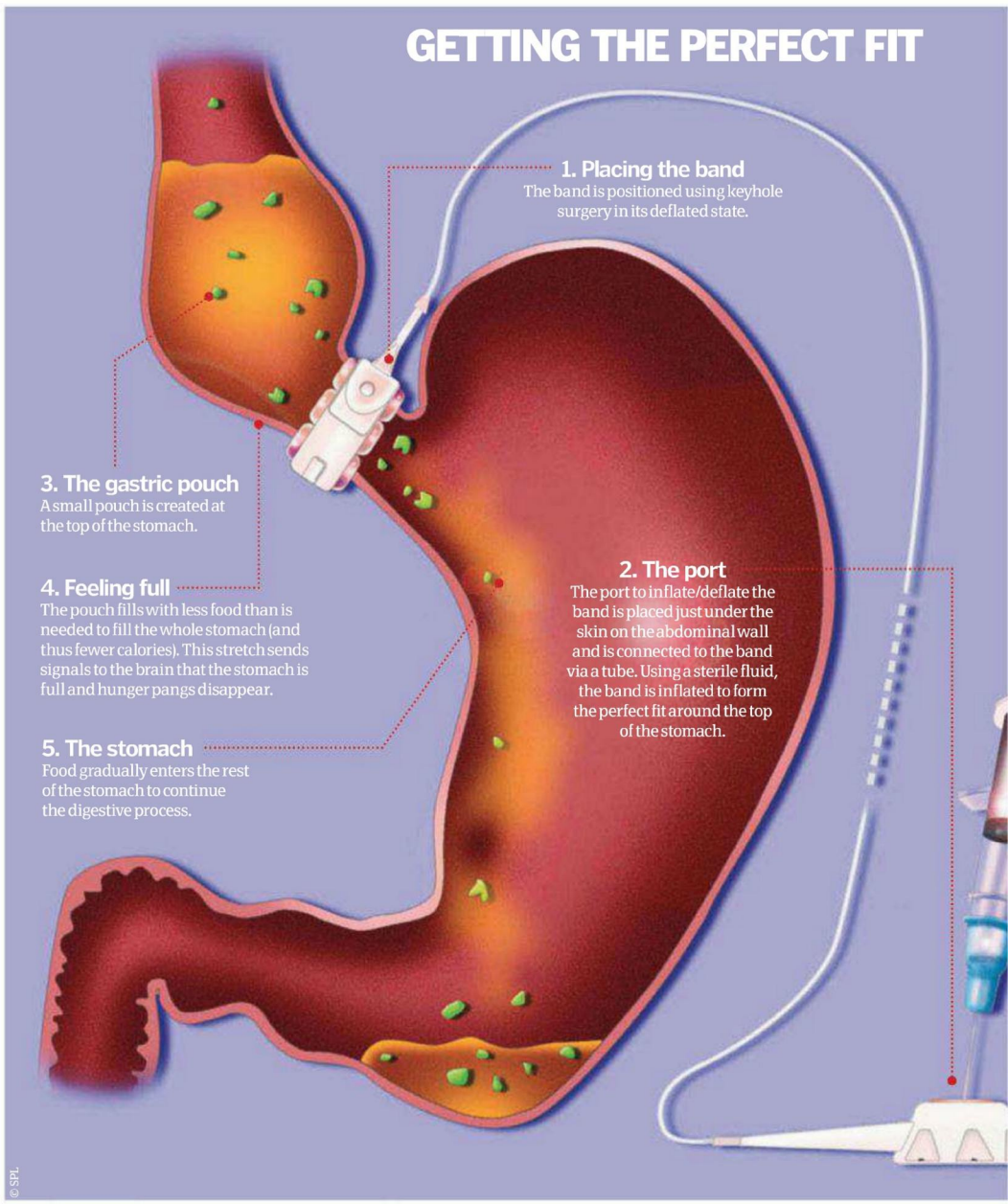
Gastric bands are inflatable circular balloons that are placed around the top of the stomach. They reduce the total capacity of the sack-like organ, so when the patient eats, their stomach wall stretches sooner and tells their brain that they are full, but with a smaller volume of food. This leads to a lower daily calorific intake and, as part of a controlled diet and exercise regime, results in weight loss.

The band is typically placed with keyhole (or laparoscopic) surgery, leading to smaller scars, less pain and a shorter hospital stay. However, patients first need a vigorous workout. They must try and lose weight through conventional methods and medications, which may take up to six months. All patients undergoing weight-loss surgery must see a health psychologist too. The patients should be mentally prepared and positive that a gastric band will help them slim down as part of a holistic approach – for example, it won't work if they continue to eat pizza and chips at every meal!

The band is placed in position in its deflated state. Through a port placed just under the skin, its size can be adjusted incrementally, leading to a controlled rate of weight loss; uncontrolled, over-quick weight loss can be very dangerous.

As with any medical procedure, there are potential risks and complications. The band can slip or become too tight around the stomach, leading to pain and visits to the emergency department. In these circumstances, deflating the band through the port beneath the skin solves most problems in the short term.

"[Patients] must try and lose weight through conventional methods and medications, which may take up to six months"



5 TOP FACTS GASTRIC BANDS

History
1 The first non-adjustable band, made of a permanent mesh, was used in the Seventies. It wasn't until the early-Nineties, with the arrival of keyhole surgery, that adjustable bands became common.

At any rate...
2 Most experts agree that weight loss of approximately 1kg (2.2lb) a week is safe – any faster than this and you can risk dangerous metabolic side-effects.

Extra treatment
3 Although gastric bands are successful in most patients, in some they will have no effect. Around a third of patients will need a further procedure related to the band.

Be a patient patient
4 Gastric band surgery doesn't work immediately and can take up to 12 months to take effect; this is in contrast to a sleeve gastrectomy or bypass operation, which work immediately but are more invasive.

Up in the air
5 Most surgeons recommend deflating the band by half before flying. If it's full, any trapped air bubbles can expand and cause painful excessive restriction.

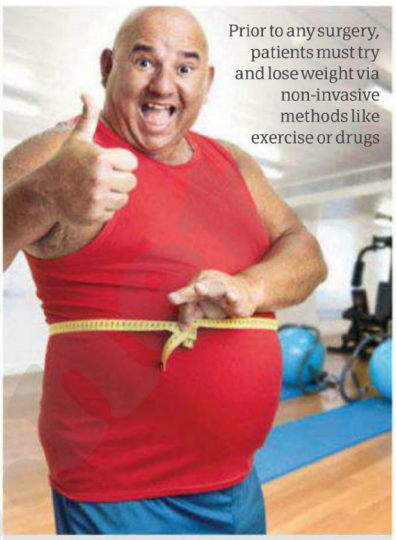
DID YOU KNOW? *The first adjustable gastric band was patented by Dr Dag Hallberg in Sweden in 1985*

How healthy are you?

The body mass index (BMI) is commonly used to estimate a person's body fat. It is utilised around the globe, including by the World Health Organisation. It estimates a person's body size by dividing their weight by their height squared (ie BMI = weight in kilograms/height in metres squared). The advantages are that it is easy to use, is the same for males and females and, in adults, is age independent. In children, it is used slightly differently and correct values vary according to age.

The BMI reading corresponds to categories of underweight, normal, overweight and obese.

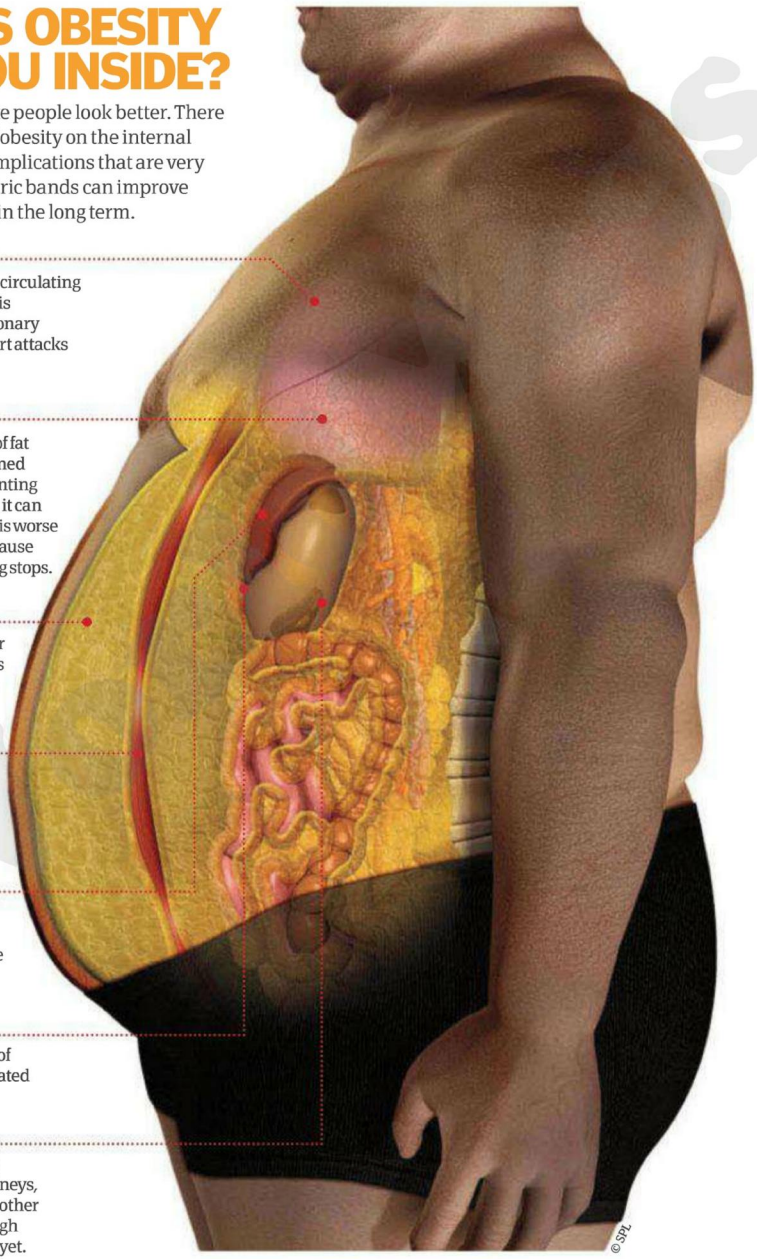
The disadvantage of the BMI system is that it doesn't take into account people's differing body proportions or muscle bulk. Athletes with lots of muscle, for example, would be classified as being overweight and thus unhealthy, although they're probably very fit. Some children who grow at different rates may be classed as outside normal ranges too, whereas they are in fact just in a growth spurt. That's why BMI must be used in conjunction with the person's overall fitness and appearance, and should be measured at several points over time to detect trends.



Prior to any surgery, patients must try and lose weight via non-invasive methods like exercise or drugs

HOW DOES OBESITY AFFECT YOU INSIDE?

Gastric bands don't just make people look better. There are serious consequences of obesity on the internal organs, which have health implications that are very expensive to treat. Thus gastric bands can improve health and be cost-effective in the long term.



The heart
Obesity reflects underlying high-circulating triglycerides and poor health. This 'circulating fat' can block the coronary arteries, leading to angina or heart attacks (myocardial infarctions).

The lungs
When obese people have a layer of fat sitting on their chest wall, combined with fat from the abdomen preventing complete expansion of the lungs, it can lead to breathing problems. This is worse at night when lying flat and can cause sleep apnoea, where all breathing stops.

The abdominal wall
Everyone has a fatty layer on their abdominal wall. In obesity, this is often larger and it reflects what's going on inside too.

The muscles
Everyone has rectus abdominis (six-pack) muscles, even if they're buried between layers of fatty adipose tissue.

The liver
Obesity can lead to fatty liver disease (FLD), which in turn can progress to serious scarring of the organ (known as cirrhosis).

The pancreas
Obese people are at a higher risk of developing diabetes, which is related to changes within the pancreas.

The kidneys
High levels of circulating fats can block the arteries feeding the kidneys, causing hypertension. There are other effects on the kidneys too, although these are not fully understood as yet.

What's the alternative?

All patients should start with a regime of healthy eating and exercise before considering surgery. Medications should be tried next and, combined with the right lifestyle, most people will lose weight and regain their health. However, some people don't manage to lose weight, despite trying hard, so surgery is the only option left.

An alternative to the gastric band is the sleeve gastrectomy. During this procedure, most of the stomach is removed, leaving a sleeve-shaped tube. In a similar way to gastric bands, the patient feels full sooner, reducing the calorific intake. Gastric bands are not permanent and can be removed, but they can also slip out of place. Sleeve gastrectomies are permanent and won't dislodge, but the procedure is more invasive and there are other potential complications that will need to be discussed thoroughly with the surgeon.

During a gastric bypass, on the other hand, a small pouch of the stomach is created which is connected to the small intestine lower down. This has a malabsorption effect, which ultimately means that fewer calories from what is ingested are taken into the body.

There are other forms of intervention, such as intragastric balloons, but not enough evidence exists to assess them properly. Finally, abdominoplasty (a 'tummy tuck') is a quick way to get rid of some excess abdominal fat without changing anything inside; this is purely cosmetic surgery though and has no internal health benefits.

This month in **Environment**

Our big Environment feature this month is looking at some of the most noxious creatures you can find in the animal kingdom. From reptiles to arachnids to mammals, we reveal exactly how lethal they are with our 'deadly rating' and how they put their complex biological weapon to good use. Elsewhere we look in depth at the anatomy of trees and why sometimes we are able to see two rainbows at once. Finally, you can wise up on one of the planet's finest birds of prey, the owl.

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DEADLY VENOM

It's the tiniest bite that does the most damage. Find out how these poisonous predators bring pain and paralysis on their prey

Venom is a force multiplier. It allows small animals to tackle prey that approach or even exceed their own body size. Killing your prey with brute strength alone requires a large body, which in turn means that you need to catch more food to sustain it. Venom enables a predator to make a single strike from ambush and completely incapacitate its victim in less than five seconds. This is much more energy efficient than a prolonged tussle and eliminates the risk of injury to the predator.

Most venom is secreted by modified salivary glands. Ordinary saliva already contains digestive enzymes to begin breaking down food before it reaches the stomach. Venom probably first evolved in animals that killed their prey with a bite and then injected saliva to 'marinade' the meat so that it was easier to consume. After that, natural selection would favour those animals with evermore potent combinations of enzymes until the saliva itself did enough damage to kill the prey. Modern venom is often a cocktail of hundreds of different enzymes and peptides. As well as digestive enzymes, most species also include specific compounds that block the transmission of nerve impulses; this causes paralysis and suffocation.

Of course, while venomous animals are continuously evolving new toxins, their prey are also frantically evolving venom resistance. To counter this, most animals inject vastly more than the minimum lethal dose of venom with each bite. This guarantees the kill and also hastens it, which stops the victim from escaping to die alone, or injuring the predator.

Venom is less effective against large animals because of the time it takes to spread through the body, so larger animals are less likely to be venomous. The main exception to this is snakes, which use venom to compensate for their lack of claws to hold struggling prey in place. There are about 650 venomous species of snake but only a few venomous lizards.

Although related to the Brazilian wandering spider, the venom of the cupiennius getazi (above) is nowhere near as potent

DEADLY FACTOR
Brazilian wandering spider

AGGRESSION: High. Often hides in houses and bites when cornered.

INTELLIGENCE: Limited. A deadly, instinctive assassin.

SPEED: High. A speedy scuttler that jumps when it strikes.

STRENGTH: Low. But the fangs will puncture skin and clothes.

DEADLY RATING:

Mouth
Red chelicerae, or mouthparts, may serve to warn birds and mammals.

Head to Head
NOXIOUS NATURE

1. Yellow-bellied sea snake
This marine serpent has a venom more toxic than any land snake, which causes muscle breakdown, renal failure and cardiac arrest.

2. Lonomia moth caterpillar
The spines of this bug inject a powerful anticoagulant. Brushing past a group of them can cause inner haemorrhaging as well as kidney failure.

3. Box jellyfish
Virtually transparent and carrying around half a million stingers per tentacle, the box jellyfish is one of the deadliest creatures in the sea.

DID YOU KNOW? *Although the inland taipan is the world's most venomous snake, there's no recorded case of a human fatality*

BRAZILIAN WANDERING SPIDER

Wandering spiders do not spin webs. They stalk the forest floor at night and attack anything they come across, from insects to mice. In the day they hide somewhere dark and moist and this can bring them into contact with humans as they are often found near houses or in bunches of bananas. The Brazilian wandering spider has the deadliest venom of any spider – a neurotoxin two to five times more toxic than the black widow's. The relatively low fatality rate of victims is thought to be partly because the spider will often 'dry bite' to conserve venom. Bites cause instant, intense local pain and swelling, followed by irregular heart rhythm, vomiting and internal haemorrhaging.

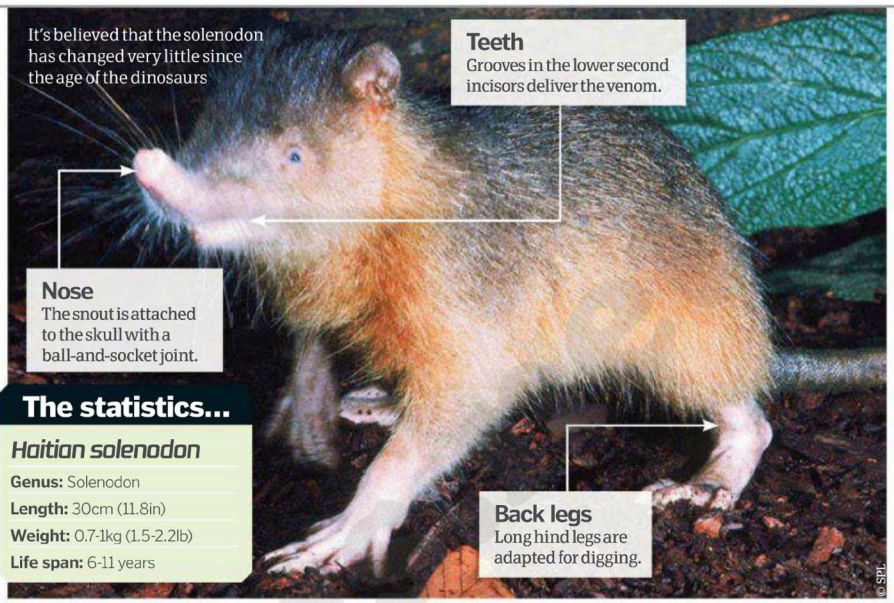
Eyes
Two large and six smaller ones for good all-round vision.

The statistics...

Brazilian wandering spider

Genus: Phoneutria
Length: 14cm (5.5in)
Weight: 10g (0.35oz)
Life span: 1-2 years

Front legs
These are lifted up when threatened to reveal some warning stripes beneath.



It's believed that the solenodon has changed very little since the age of the dinosaurs

Teeth
Grooves in the lower second incisors deliver the venom.

Nose
The snout is attached to the skull with a ball-and-socket joint.

Back legs
Long hind legs are adapted for digging.

© SPL

The statistics...

Haitian solenodon

Genus: Solenodon
Length: 30cm (11.8in)
Weight: 0.7-1kg (1.5-2.2lb)
Life span: 6-11 years

HAITIAN SOLENODON

Solenodons are related to the shrew but much larger – about the size of a hedgehog. The word solenodon means 'slotted tooth' in Greek and these slots, or grooves, are used to inject the venomous saliva into their prey. They evolved on the islands of the Caribbean, without any natural predators. The introduction of cats and dogs has left them extinct everywhere except for Cuba and Hispaniola. The Haitian, or Hispaniolan, solenodon is the more aggressive of the two and will attack without provocation. In the wild they eat earthworms and insects, as well as the occasional frog or lizard. Their venom is not lethal to humans but, in smaller animals, it causes paralysis, convulsions, bulging eyeballs and death. Interestingly, solenodons aren't immune to their own venom.

DEADLY FACTOR
Haitian solenodon

AGGRESSION: High. Evolved without natural predators and shows no fear.
INTELLIGENCE: A mammal's brain makes this one shrewd shrew.
SPEED: Slow. Solenodons run in an awkward zigzag pattern.
STRENGTH: High. Solenodons have been known to tear a chicken to pieces.

DEADLY RATING:

Harpoon
A modified barbed tooth that is made of chitin.

Proboscis
This flexible tentacle contains the harpoon.

DEADLY FACTOR
Geography cone snail

AGGRESSION: High. Cone snails will normally sting anyone that picks them up.
INTELLIGENCE: Low. Molluscs hunt by smell and instinct.
SPEED: Slow-moving but with a lightning-fast sting.
STRENGTH: Low. Relies on immobilising prey before eating it.

DEADLY RATING:

© Getty

The statistics...

Geography cone snail

Genus: Conus
Length: 15cm (5.9in)
Weight: 300g (10.6oz)
Life span: Unknown

Shell
Attractive patterning makes it popular with shell collectors.

GEOGRAPHY CONE SNAIL

There are over 600 species of cone snail and all of them are venomous. Cone snails deliver their venom using a thin harpoon made from a modified tooth. This is fired from a flexible proboscis that enables the snail to fire in any direction, even directly behind it; this means that there is no safe way to pick up this gastropod. The venom of the cone snail contains over 200 different compounds that can paralyse a small fish in less than two seconds. The geography cone is a particularly large and venomous species. It can deliver enough venom to kill 15 humans in a single sting. There is no antidote; medical care consists of just treating the symptoms until the venom is metabolised.

"Blue-ringed octopus venom is 10,000 times more toxic than cyanide"

BLUE-RINGED OCTOPUS

Although one of the smallest octopuses this is easily the most lethal. The main ingredient in its venom is tetrodotoxin, which is 10,000 times more toxic than cyanide. Tetrodotoxin is found in many other venomous animals, including cone snails, but it's present in much higher concentrations in blue-ringed octopus venom. Bites are tiny and almost painless but, within ten minutes, the venom blocks the action of all the nerves that control the muscles. General paralysis and breathing difficulty ensue, but because the venom can't cross the blood-brain barrier, the victim remains aware throughout. The paralysis even results in fixed, dilated pupils and rescuers may give up resuscitation attempts while the victim is still alive and conscious.

DEADLY FACTOR

Blue-ringed octopus

AGGRESSION: Docile. Will only attack if provoked or stepped on.

INTELLIGENCE: High. Can solve mazes and imitate its surroundings.

SPEED: Moderate. Uses jet propulsion for extra speed when making a getaway.

STRENGTH: Moderate. Powerful, muscular tentacles but small overall size.

DEADLY RATING:

The statistics...

Blue-ringed octopus

Genus: Hapalochlaena
Length: 15cm (5.9in)
Weight: 28g (1oz)
Life span: 2 years

The statistics...

Deathstalker scorpion

Genus: Leiurus
Length: 3-7.7cm (1.2-3in)
Weight: 10g (0.35oz)
Life span: 5-6 years

Stripes
The scorpion's Latin name leiurus quinquestriatus translates as 'five stripes'.

Thin yellow skin
The deathstalker prefers at least 40 per cent humidity.

Rings
The characteristic blue rings are only displayed when threatened.

Tentacles
Each one has its own mini-brain and is semi-autonomous.

Beak
Made of keratin. The only hard organ in the entire body.

THE ODD ONE OUT

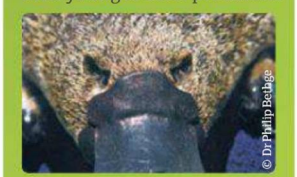
Which of these is venomous?

BLUE POISON ARROW FROG

The bright colours warn of the deadly toxins in its skin. The most toxic species can kill a human after one brief touch.

SLOW LORIS

This sleepy creature has a special gland on each arm that it licks to give itself a toxic bite. Mothers also lick the fur of their young to deter predators.



DUCK-BILLED PLATYPUS

The male platypus has a sharp spur on its hind legs. The venom isn't powerful enough to kill a human but it can cause excruciating pain.

HOODED PITOHUI

Its diet of beetles provides a supply of the neurotoxin homobatrachotoxin. This chemical seeps into the feathers and just touching the bird can cause numbness.

ANSWER: THEY ALL ARE!

DANGER MAP

We pinpoint the home turf of some of the toxic beasties featured in this article

Haitian solenodon
Continent: North America
Countries: Haiti, Dominican Republic
Notable region: Hispaniola

Brazilian wandering spider
Continent: South America
Countries: Costa Rica to Argentina
Notable region: Brazilian Amazon

Deathstalker scorpion
Continent: Africa
Countries: Egypt, Libya, Chad, Niger, Mali
Notable region: Edges of the Sahara Desert

Inland taipan
Continent: Oceania
Countries: Australia
Notable region: Western Queensland

5 TOP FACTS VEN

Different strokes
1 Bees and wasps look similar but strike in different ways. Bee venom is acidic, to cause pain and drive attackers away. Parasitic wasps, meanwhile, use a neurotoxin to paralyse their host.

Small but deadly
2 Baby inland taipans are actually more lethal than adults as they haven't yet learned to regulate their venom dose so will inject their entire supply with a single bite.

Painless stinger
3 Cone shell toxin contains a compound that is 100-1,000 times more effective than morphine as an anaesthetic. This helps to calm prey so they don't struggle too much.

Poisoner by proxy
4 The blue-ringed octopus doesn't even need to bite to poison you; the venom can be absorbed directly through the skin so even swimming near one can result in mild symptoms.

Stiff medicine
5 One unusual side-effect of a bite from the Brazilian wandering spider is that the venom causes acute and painful erections in men that can last for hours.

DID YOU KNOW? *In 2005, a chef in Somerset, UK, bitten by a Brazilian wandering spider only survived after a week in hospital*

Stinger
The penultimate segment is darker due to the venom glands.

DEATHSTALKER SCORPION

The deathstalker is the most venomous scorpion with a lethal dose of around a third of a milligram of venom per kilo of bodyweight. A cocktail of toxins causes heart failure and pulmonary oedema (fluid in the lungs). The deathstalker's normal prey is locusts and crickets but it is a twitchy and aggressive creature that will sting anything that comes too close. Only its small size reduces the danger to humans; a typical sting only delivers 0.225 milligrams of venom and deaths are rare, except in small children and cases of allergic reaction.

Nevertheless, antivenom is not as effective as it is for snakebites and a sting from a deathstalker is regarded as a medical emergency, even with prompt hospitalisation.

DEADLY FACTOR
Deathstalker scorpion

AGGRESSION: High. A twitchy, trigger-happy stinger that attacks anything nearby.

INTELLIGENCE: Low. Simple arachnid cunning designed to hunt down insects.

SPEED: High. The strike from the tail is impossible to dodge.

STRENGTH: Low. The pincers are there to grip small prey only.

DEADLY RATING:

"The lethal dose for a typical adult human is calculated to be around two milligrams"

Teeth
Fangs are short and aren't hinged like those of a viper.

Skin-changer
The skin becomes darker in winter to absorb more sunlight.

Sleek
Streamlined body with no narrowing at the neck.

INLAND TAIPAN

The inland taipan has the deadliest venom of any land animal; in fact, it is one of the most deadly substances of any kind. At least 40 times more powerful than the venom of a cobra, the lethal dose for a typical adult human is calculated to be around two milligrams; that's about as much as the blood you lose from a mosquito bite. A typical bite injects enough venom to kill 25 humans, or a quarter of a million mice! Fortunately, the inland taipan lives in extremely remote parts of central Australia where it very rarely comes into contact with people. For such a deadly creature, it is also very shy and, despite its other name – the fierce snake, it never attacks unprovoked.

DEADLY FACTOR
Inland taipan

AGGRESSION: Shy and reclusive, prefers biting rats and mice to humans.

INTELLIGENCE: A hunter's cunning – traps rats in deep fissures or dead-end burrows.

SPEED: Slow. Relies on cornering victims rather than lightning-strike attacks.

STRENGTH: Its 2m (6.6ft) body is certainly powerful, but bite strength is relatively weak.

DEADLY RATING:

The statistics...
Inland taipan

Genus: Oxyuranus
Length: 1.8-2.5m (5.9-8.2ft)
Weight: 6kg (13.2lb)
Life span: 10-15 years

Blue-ringed octopus
Continents: Oceania/Asia
Countries: Japan, Australia, Indonesia
Notable region: Southern New South Wales

Geography cone snail
Continent: Oceania
Countries: Australia
Notable region: Northern coast of Australia

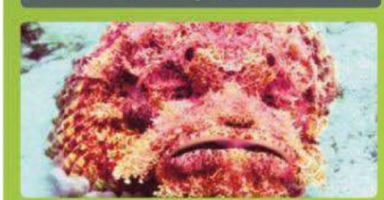
BEST OF THE REST...
Nature has plenty more toxic creatures – here are just a few...

BOX JELLYFISH
Found in the waters of northern Australia, the box jellyfish has one of the most deadly venoms in the world. It attacks both the heart and nervous systems.

MOST PAINFUL VENOM

BLACK MAMBA
A native of eastern Africa, this long, highly venomous snake (actually brown in colour) can inject a whole bunch of nasty neurotoxins and cardiotoxins.

AFRICA'S MOST VENOMOUS SNAKE



STONEFISH
Not to be mistaken for a lump of coral, the stonefish delivers powerful neurotoxins from its dorsal spines; in fact, some think it's the most venomous fish in the world.

MOST VENOMOUS FISH

FUNNEL-WEB SPIDER
Unlike most other venomous spiders, the venom of the male funnel-web is more deadly than that of the female. These arachnids have super-powerful fangs.

AUSTRALIA'S MOST FEARED

HOW IT WORKS TV

Head to our site for an amusing video of someone seeing a double rainbow

www.howitworksdaily.com

DID YOU KNOW? *The dark band between double rainbows is named after Alexander of Aphrodisias who mentions it in 200 CE*

Double, or multiple, rainbows are only visible to the naked eye when the incoming sunlight is unhindered by atmospheric effects, so is very intense

Double rainbows

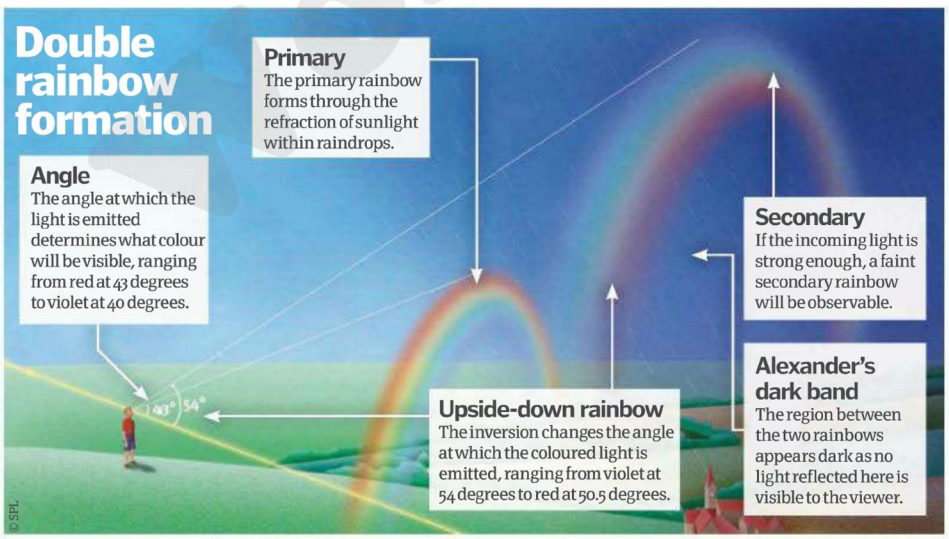
What causes this colourful meteorological phenomenon?

Regular rainbows occur when moisture in the air – commonly rain, but also mist or spray such as that from a waterfall – refracts sunlight in such a way that it is broken up into its constituent colours.

The phenomenon occurs when the Sun is positioned behind you and sunlight passes through the airborne water. The light refracts (bends) inside the droplets and the white light is broken up. Each colour has a different wavelength so, depending on the angle of refraction, a different colour of light will be reflected outwards; the result of this process is what we observe when we see a rainbow.

Every rainbow is accompanied by another, secondary rainbow, but it's usually too dim to see. This double rainbow effect is due to the continued reflection of light inside each water drop. Sunlight is actually reflected twice inside a drop: once to produce the primary rainbow and a second time at the back of the drop. This second reflection inverts the light but undergoes the same refraction, so exits in the same way as before – though upside down.

This second reflection reduces the intensity of the sunlight, but it also produces a second inverted rainbow, creating a double arc of multicoloured light in the sky. Interestingly, sunlight can reflect many more times inside a water drop so many more rainbows (three, four or even more) can be produced, but the incoming light is rarely strong enough for these to be visible by the naked eye.



A double rainbow above the Krimml Waterfalls in Austria

"Every rainbow is accompanied by another secondary one, but it's usually too dim to see"

"Belugas don't have fused neck bones so are the only whales capable of turning their heads"

Hydroponics dates back to at least 600 BCE when chain pull systems were used to carry water to Babylonian gardens

What is hydroponics?

How the natural world can be replicated to grow plants

To grow, plants generally need a combination of water, sunlight, carbon dioxide and nutrients. Through photosynthesis they convert these four basic elements into sugars and oxygen, allowing them to survive, grow and reproduce. Hydroponics is the practice of growing plants by artificially supplying them with these four things in the absence of natural sources. This process means the plants can be grown in an interior environment with neither sunlight nor soil. Artificial lights are often used instead of the Sun to enable the plants to produce chlorophyll, while oxygen, water and minerals are transported to the roots directly through a series of tubes. In this manner the plants are able to grow in exactly the same way as they would if they were outside in their natural habitat.

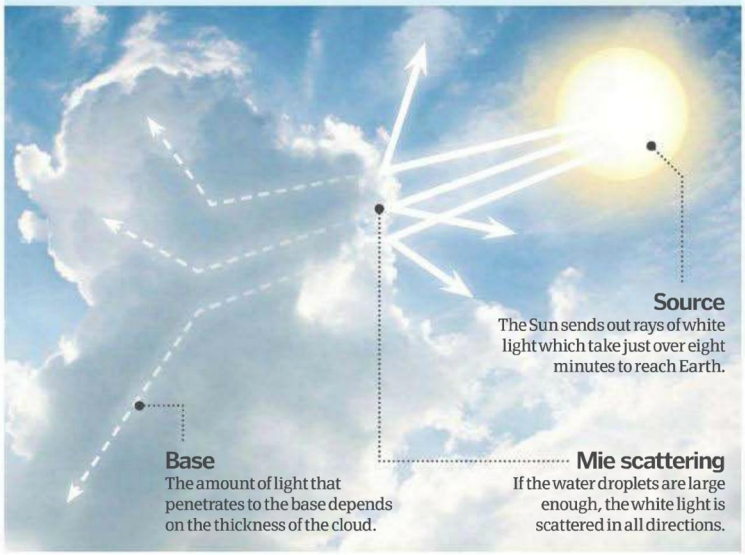
Hydroponics is very useful as it enables different plants to be grown en masse in adverse conditions where they would otherwise perish, such as in hot or cold climates. The absence of soil also largely removes the intrusion of insects and weeds, which can hamper growth. This artificial growing technique has also been considered for use on other planets.

Why are clouds white?

Discover the basic scientific principle that makes clouds white

Clouds are formed when humid air, or water vapour, rises and cools. The vapour expands and becomes tiny droplets. Clouds only get their white appearance if these droplets become large enough to scatter visible light in all directions; this is known as Mie scattering.

Visible light is a form of electromagnetic radiation, with each different colour that we can see having a different wavelength. White light, however, contains equal amounts of all colours of the spectrum. When sunlight hits the individual water droplets in a cloud all wavelengths of light are scattered evenly in all directions. However, very thick clouds, which are made of very densely packed water droplets, will appear darker – like storm clouds – because less of the incoming light from the Sun can penetrate to the base. From above in an aeroplane, though, a storm cloud will still appear white – it only looks dark from the ground because little sunlight is not getting through.



© SPL

Once a year beluga whales head to river estuaries to shed their dead skin

How do beluga whales moult?

What makes these white whales so well adapted to Arctic waters?

Belugas, also known as white whales, are carnivorous mammals that are found in and around the Arctic coastal regions of Europe, Asia and North America. Beluga whale skin is grey at birth (as it serves as better camouflage) and gradually becomes lighter till at around the age of five it becomes creamy white, giving them their unique appearance.

To keep them warm during the freezing Arctic winters, the belugas have extremely thick insulating skin – 100 times thicker than human skin. In the summer months, however, belugas take part in an unusual custom whereby they group together in pods and head for the shallow fresh waters of river estuaries to moult. Once in the shallows, the groups roll around on the mud and rocks to wear away the dead skin.

Unlike other whales, belugas don't have fused neck bones and so they are the only whales capable of turning their heads.

5 TOP FACTS TREES

Broadleaves
1 Most trees are 'broadleaves' with large, flat, veined leaves. These can be simple (growing individually at the end of a single stalk) or compound (consisting of a group of leaflets).

Deciduous
2 Many broadleaves are deciduous, shedding their leaves in the autumn. This enables them to conserve energy throughout winter when sunlight is limited.

Antifreeze resin
3 To survive the winter, evergreen trees produce a sticky resin that acts like antifreeze. This prevents the leaf cells from crystallising, which would otherwise cause cell damage.

Fighting pollution
4 As well as producing oxygen, trees can also rid the soil of certain chemicals by storing them or breaking them down into harmless substances; this is called phytoremediation.

The treeline
5 This imaginary line represents the height above which trees cannot grow due to adverse conditions. The highest treeline is in Bolivia at 5,200m (17,060ft) and the lowest is in Sweden at 650m (2,133ft).

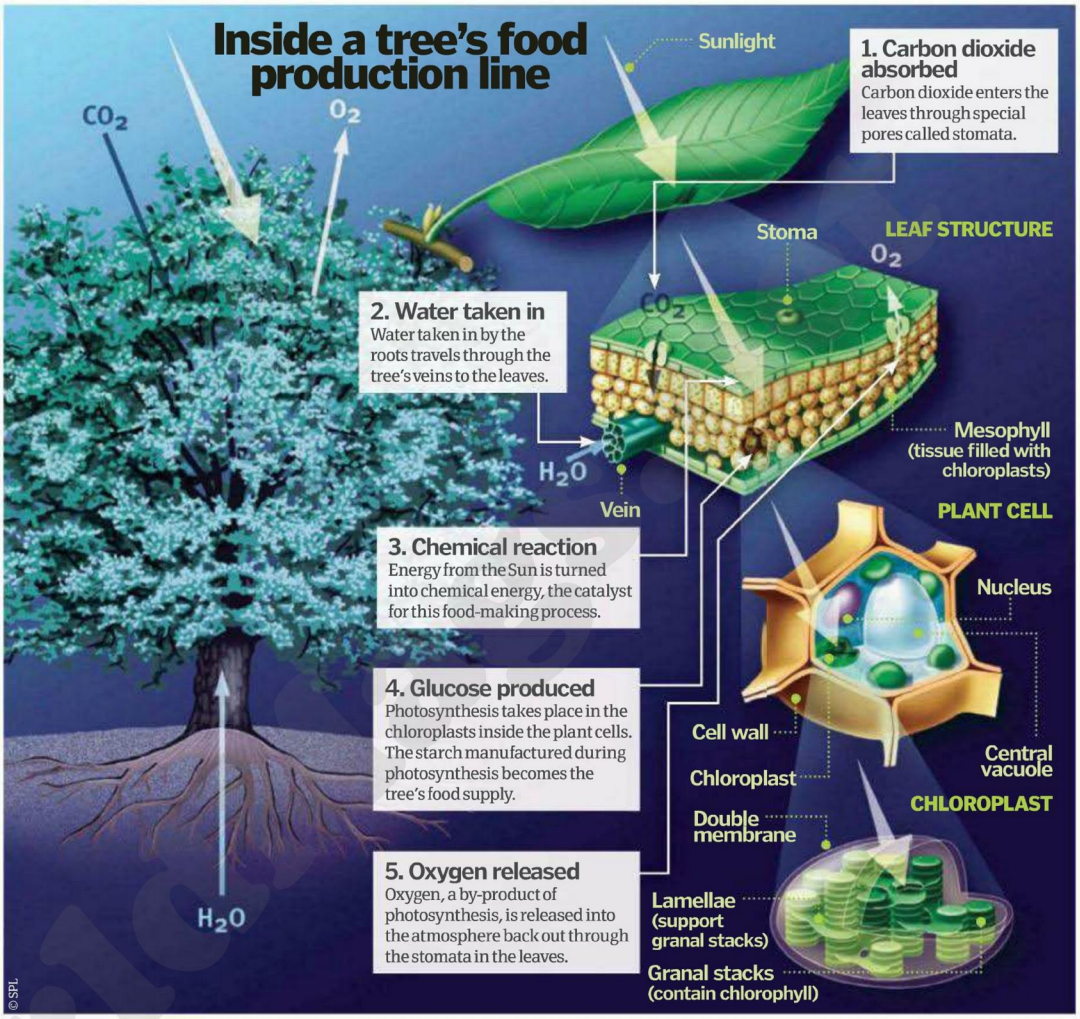
DID YOU KNOW? *Most conifers are evergreen and only replace their needle-like leaves when necessary*

How trees work

How do these large plants grow, nourish themselves and provide oxygen for us?

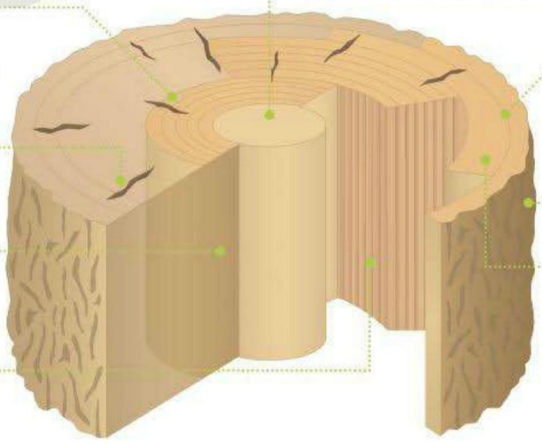
Trees are oversized plants that become so big that they require a woody stem to support their weight. Not only are they attractive to have in your garden, but they're also amazing natural air filters, capable of absorbing harmful carbon dioxide and turning it into oxygen. They also clean the soil, provide habitats for wildlife, muffle noise pollution and prevent soil erosion.

Like all plants, trees harness energy from the Sun to convert carbon dioxide and water into glucose and oxygen. Sunlight is the catalyst for photosynthesis, which takes place within the plant's cells, inside structures called chloroplasts. If you look at a leaf under a microscope it's possible to see the tiny chloroplasts, which are green due to chlorophyll – this green pigment is vital as it traps the energy which powers photosynthesis.



Trunk structure

One of the main differences between flowering plants and trees is the woody stem. You can tell a lot from looking at the cross-section of a tree trunk, including its age and past environmental conditions.



Growth rings
Thick rings indicate excellent growth conditions (eg plenty of water), while thin rings suggest a lack of nutrition. By counting the rings you can calculate the number of seasons (or years) a tree has lived.

Wood ray
This passageway enables nutrients and water to be distributed horizontally through the trunk from pith to phloem.

Heartwood
This darker layer, which surrounds the core of the trunk (the pith), consists of dead sapwood to support the weight of the trunk and branches.

Sapwood
Often paler than the rest of the trunk, the sapwood is the living wood inside a trunk. This layer containing structural xylem is capable of transporting raw sap to the leaves.

Pith
The pith is the relatively soft, nutrient-rich tissue that makes up the core of the trunk and helps promote sapling growth.

Phloem
Just below the bark is the phloem, a tissue that transports sap and glucose produced by photosynthesis up and down the tree.

Bark
This fibrous outer layer consists of hardened dead cells that protect the trunk from harmful external forces.

Cambium layer
This tissue layer contains active cells that constantly divide, enabling outward growth that increases the trunk's diameter. The new cells produced form the ring markings, which tell us more about the tree from season to season.

How do trees manage to stay hydrated?

In order to obtain water for photosynthesis, the tree's root hairs absorb moisture from the soil, entering tubular xylem cells through a process called osmosis. Because water is constantly evaporating from the leaves at the top of the tree (a process called transpiration), negative pressure is created in the xylem, which draws water up into the cells from below. The xylem tissues in the trunk are rigid. A tree's internal transport system enables water, food and other nutrients to be delivered to all parts of the tree, much like arteries and capillaries in the human body.

"Super-sensitive hearing helps the owl pick up on the gentle rustling of small-footed prey"

How owls hunt

Discover what makes this nocturnal bird of prey such a superior predator

The owl has evolved a number of traits that make it a masterful sky hunter. As well as being a keen territorial predator, with an intimate knowledge of the local terrain, the owl also has a number of physical characteristics that make it a formidable aerial assassin. Features include powerful talons, a sharp, hooked beak for rending flesh from bone plus heightened senses for locating and homing in on prey from above.

Super-sensitive hearing helps the owl pick up on the gentle rustling of small-footed prey such as birds, rodents and frogs far below. The extra-large disc-like shape of an owl's face with a ridge of feathers down the middle further improves hearing as sound waves are collected and channelled outwards towards the ears.

While we humans can hear sounds on a horizontal plane – ie we have the ability to tell whether a sound came from the left or right by turning our head in a particular direction to focus on the location of a sound, owls can hear things on a vertical plane. Species like the great horned owl, for example, have lopsided ears – with the left ear positioned slightly higher than the right, enabling them to accurately detect whether a sound originated from above or below.

Unlike the majority of other bird species, whose eyes are positioned on the sides of their heads, owls have front-facing eyes, giving them binocular vision and depth perception. This helps them get a fix on their quarry. They cannot, however, move their eyes in the sockets; instead they have the ability to turn their entire head some 270 degrees. This means they do not have to move the rest of their body to see what's going on behind them, which helps the birds to stay quiet. It's the ability to remain silent that gives an owl its greatest advantage when hunting.

The great grey owl lives in the taiga, a coniferous, snowy zone in the northern half of the planet that stretches from Alaska to Siberia

The statistics...

Owl

Type: Bird

Diet: Carnivore, including rodents, rabbits, snakes, fish, frogs and even other owls

Average life span in the wild: 5-15 years

Weight: 0.9-2.5kg (2-5.5lb)

Size: Body 45-65cm (18-25in), wing span 1-2m (3.2-6.4ft)

1. Surveillance
Many owls scan for their next meal from a concealed perch while others glide high over the ground until they spot a potential victim.

2. Surprise
When the owl has locked on to its prey it either dives down wings folded, opening them at the last second, or glides down keeping the animal in its line of sight.

The silent stalker

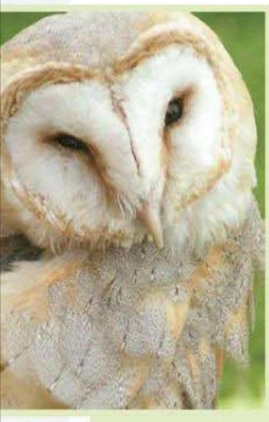
Owls use stealth and the element of surprise to execute deadly strikes from above. An owl can glide silently and swoop down on prey due to the clever engineering and arrangement of the feathers on its wings. An owl's flight feathers feature soft, serrated fringes that disrupt the turbulent flow of air over the wings. This reduces the noise produced as air flows over a smooth surface, making flight almost silent.

DID YOU KNOW?

Dive-bombing owls

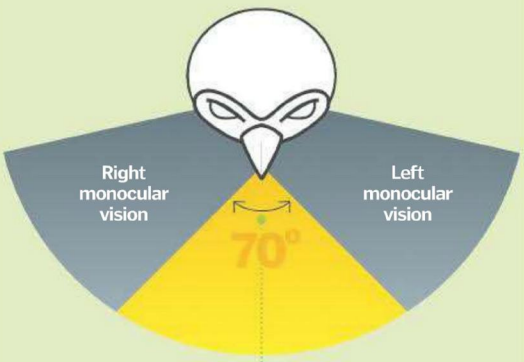
While owls remain generally out of sight during the day, there are occasional reports of them exhibiting aggressive behaviour, attacking or dive-bombing animals many times their size, including domestic dogs and even humans. Rather than attempting to kill and eat said humans, they are in fact defending their territory, mates, nests and/or chicks.

DID YOU KNOW? According to the Guinness World Records, the newest bird of prey is the Socotra buzzard, discovered in 2010



Seeing is believing

Owls have forward-facing eyes, like humans, and so this means they can see an object with both eyes at the same time. That is, their vision is binocular, as opposed to the monocular vision of most other birds whose eyes are located on the sides of their heads. As you can see from this diagram, owls have a wide field of view – around 110 degrees – but only about 70 degrees of this are binocular.



Binocular vision (70 degrees)
Owls have some of the best eyesight in the bird world. To put it into context, humans have an 180-degree field of vision, 140 degrees of which are binocular.

© SPL

Pellets get rid of anything the owl can't digest

What are pellets?

You can discover a lot about what an owl eats from the pellets it spits out. These pellets contain the indigestible parts of an owl's diet. Birds of prey eat rodents and small birds. However, because they don't have teeth and cannot chew their food, they have to swallow things whole – that includes any fur, bones, feathers, claws and teeth. While other birds have a special organ called a crop, which is used for storing food for digestion later, owls do not have one of these. Instead, when an owl consumes food, it passes into the muscular gizzard called the ventriculus, a kind of secondary stomach full of small stones. The stones help to grind up the digestible food (which includes muscle, skin and organs) and digestive enzymes and acids dissolve the food so it can pass into the intestines. The leftover rubbish, which can't be broken down, is squeezed by the muscles of the gizzard and compacted into a soft pellet to be expelled from the body after many hours. The owl cannot eat again until the pellet has been coughed up, or regurgitated.

Learn more

Hunters of the Sky, brought to Longleat Park by the Hawk Conservancy Trust, will be returning in 2012 with a new birds of prey show. This spectacular display of eagles, kites, vultures and owls will fill the skies over Longleat; this is family fun at its very best! Open weekends only: 25 February-18 March. Open daily: 24 March-4 November. For more information on Longleat Safari & Adventure Park visit **www.longleat.co.uk**.

Interview Jimmy Robinson

Hawk Conservancy Trust curator Jimmy runs the 'Hunters of the Sky' bird of prey display at Longleat

How It Works: What do owls like to eat?
Jimmy Robinson: Owls will eat a variety of different prey, normally depending on the size of the owl and where it lives. A barn owl mainly feeds on rodents while eagle owls will take prey like rabbits and even foxes on rare occasions.

HIW: What is the owl's most effective method/ tactic for hunting down this kind of prey?
JR: Many owls have silent flight. This is thanks to a comb-like edge to their flight feathers allowing air to pass through them; this reduces the noise of its flapping wings.

HIW: At what age is a young owl old enough to attempt its first kill?
JR: At about four months old owls are catching prey for themselves. Some small species are fully feathered at ten weeks old. They grow up at an alarming rate and, once feathered, the race is on to be hunting as quickly and successfully as possible. In the wild it's survival of the fittest.

HIW: How and where do owls make their nests?
JR: Owls nest in many different places. Barn owls nest in farm buildings or artificial nest boxes purposely put up to help them. Snowy owls, on the other hand, nest on the ground, while some species take over nests from other birds like crows.

HIW: What do owls do all day? How are they protected from predators?
JR: Many owls are very well camouflaged. During the day the nocturnal owls will roost in a high tree or suitable safe place away from prying eyes.

HIW: What are the owl's main natural predators?
JR: Other birds of prey, carnivorous mammals and reptiles like snakes will all look at owls as a suitable meal.

HIW: Do owls live up to their wise reputation?
JR: Owls have incredibly large eyes; this enables them to see at night very well, but it does mean that the eyes take up much of the skull, leaving little room for the brain. Owls are not dim-witted, by any means, but are certainly not as wise as we're led to believe. There are many links to birds of prey and Greek deities; in fact, the little owl's Latin name links it to Athena, who was known as the goddess of wisdom.

21 © Longleat Safari & Adventure Park, Hunters of the Sky

This month in **Transport**

Formula One might be the first thing that springs to mind when you think of motorsport, but there's a world of racing beyond this. In our six-page feature we explore four of the most exciting alternatives; from the speed-focused NASCAR to the extreme terrains of the World Rally Championship, this article's for all you petrolheads. Those with their heads in the clouds will love reading about the decoy flares used to confuse heat-seeking missiles and finding out how they work.

61 Mending windscreens

61 Tugboats

61 Chain ferries

TRANSPORT

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EXTREME MOTORSPORT

While F1 is considered the king of motorsport, a fleet of other adrenaline-pumping racing series are vying for its crown, offering all manner of high-octane action

Man and machine as one, unbridled by restrictions, whether of the physical, financial or metaphorical variety; in short, racing in its purest form. A free, open and level arena where humans push the boundaries of conventional physics for glory in a battlefield that demands only the highest levels of skill, engineering prowess and cutting-edge tech. Some would argue that, today, this ideal is only partially delivered by the world's top-tier motorsport – Formula One – insisting that all the greedy conglomerates and human politics have detracted from the thrill of the race.

The motorsport king's corruption will be short-lived however if left unchecked, as surrounding it is a host of youthful, experienced and dynamic contenders, delivering purer racing in all its forms. From the supreme speeds of NASCAR, through to the extreme endurance delivered by Le Mans, awesome aerodynamics of Formula Two and on to the off-road insanity of the World Rally Championship, racers and racing fans alike are flocking to their banners, tempted by affordable racing thrills, innovative engineering and the diverse tracks.

Over six pages we scout out these maximum-power motorsports, delivering detailed run-downs of how they work, the state-of-the-art hardware, advanced engineering and spectacular racing circuits, in an attempt to tap into their appeal and understand how now, more than ever before, they should be celebrated. So to learn all you need to know about F1's rivals, put the pedal to the metal and let's go!

5 TOP FACTS NASCAR

Prolific
1 NASCAR sanctions over 1,500 races across 100 tracks in 39 states throughout the USA and Canada. Additional exhibition races are often held in Japan, Mexico and Australia.

Cup
2 The NASCAR Sprint Cup Series is the sport's most prestigious tier of racing and, as a result, is often referred to as NASCAR by fans, ignoring the Nationwide Series among others.

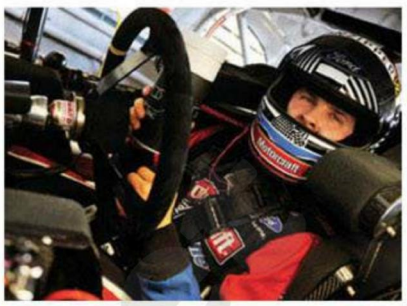
Trucks
3 Interestingly, NASCAR runs the Camping World Truck Series, a contest where racers drive modified pickup trucks. The most recent champion was American Austin Dillon.

Money
4 NASCAR is broadcast in over 150 countries worldwide and has an estimated fan base of 75 million. Each year NASCAR makes over $3 billion from licensed product sales.

Fuel
5 In 2007 NASCAR switched to unleaded fuels for all of its top series amid criticism of excess pollution. In 2011 it began using E15 'green' fuel (15 per cent ethanol and 85 per cent gasoline).

DID YOU KNOW? *The NASCAR Sprint Cup Series trophy was designed by Tiffany & Co and is made of solid silver*

Sprint Cup Series NASCAR

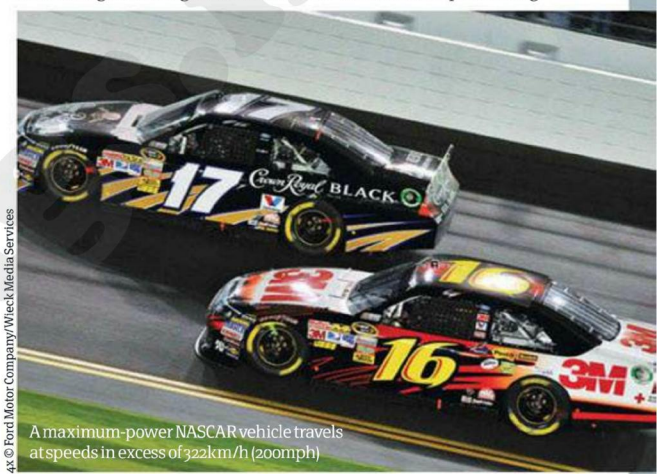


Famed for its insane speed and danger, NASCAR is the second-most-watched motorsport on Earth, delivering frenzied action for racers and fans

Broadcast in over 150 countries, generating $3 billion a year in revenue and holding 17 out of the top 20 attended single-day sporting events in the world, NASCAR is one of the most popular – and intense – motorsports on the planet. While NASCAR sanctions over 1,500 races a year within multiple series, its top-tier event is the Sprint Cup Series, a ferocious melding of high-powered stockcars (see 'NASCAR teardown' for a hardware breakdown) with America, Mexico and Canada's tightest and fastest race circuits.

The competition works in two segments. Throughout the first 26 races – races are held at various circuits, including the prestigious Daytona International Speedway in Florida – 49 drivers from 22 construction teams vie for a place within the top ten, being awarded points ranging from 43 for first place downwards. At the close of the first 26 races the top ten drivers (as well as a further two wildcards) enter into the second stage of the competition, which is referred to as the 'Chase for the Sprint Cup'. From here the 12 drivers have the points equalised to a level playing field once more and then compete over the next ten races for the championship trophy.

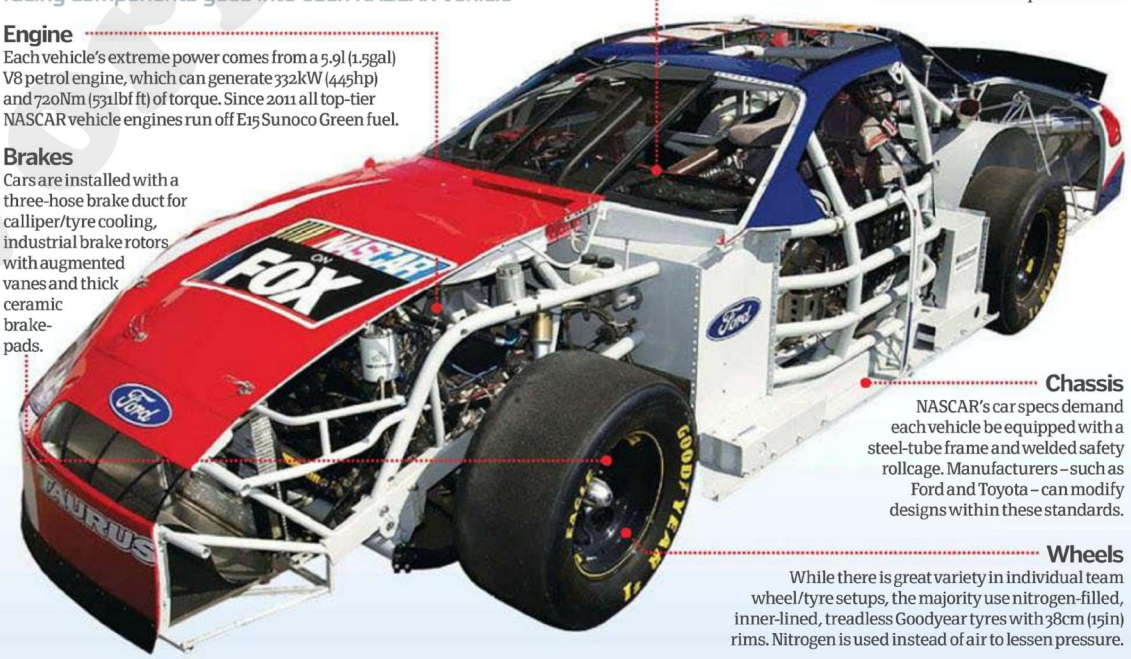
Why split the series in two? To make sure maximum racing skill needs to be employed in every race and that the competition is never wrapped up mid-season – something recently demonstrated in the Formula One 2011 season, where Sebastian Vettel won the F1 Championship over a month and a half before the final race took place. As such, NASCAR delivers nail-biting action right down to the final race's chequered flag.



A maximum-power NASCAR vehicle travels at speeds in excess of 322km/h (200mph)

NASCAR teardown

While plain on the surface, a wide variety of awesome racing components goes into each NASCAR vehicle



Engine
Each vehicle's extreme power comes from a 5.9l (1.5gal) V8 petrol engine, which can generate 332kW (445hp) and 720Nm (531lbf ft) of torque. Since 2011 all top-tier NASCAR vehicle engines run off E15 Sunoco Green fuel.

Brakes
Cars are installed with a three-hose brake duct for calliper/tyre cooling, industrial brake rotors with augmented vanes and thick ceramic brake-pads.

Transmission
Unlike many other motorsports, NASCAR Sprint Cup Series cars are equipped with a Jerico, top-loader, four-speed manual transmission with H-pattern shift.

Chassis
NASCAR's car specs demand each vehicle be equipped with a steel-tube frame and welded safety rollcage. Manufacturers – such as Ford and Toyota – can modify designs within these standards.

Wheels
While there is great variety in individual team wheel/tyre setups, the majority use nitrogen-filled, inner-lined, treadless Goodyear tyres with 38cm (15in) rims. Nitrogen is used instead of air to lessen pressure.

The statistics...

Sprint Cup Series NASCAR

Length: 5,283mm (208in)
Width: 1,943mm (76in)
Wheelbase: 2,794mm (110in)
Weight: 1,451kg (3,199lb)
Engine: 5.9l (1.5gal), 700hp, V8 petrol
Transmission: Four-speed manual

"F2 offers fans an opportunity to get closer to the ideal of the pure race than ever before"

Anatomy of a Formula 2 car

Follow our part-by-part guide to the awesome hardware packed into each F2 car

Engine
A heavily modified Audi 1.8l (0.5gal), four-cylinder petrol engine in partnership with a Garrett GT35 turbocharger allows each car to generate 313kW (420hp). The engine's crankshaft, rods, pistons, valves and cams have all been redesigned for high strength and light weight.

Transmission
A six-speed Hewland TMT sequential semi-automatic transaxle transmission, in partnership with a limited slip differential, delivers superb responsiveness and racing performance. It uses a paddle-shift control system.

The statistics...

Formula 2

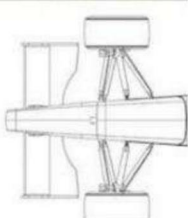
Length: 4,573mm (180in)
Width: 1,875mm (74in)
Wheelbase: 2,885mm (114in)
Weight: 595kg (1,312lb)
Engine: 1.8l (0.5gal), 420hp turbo with Overboost technology
Transmission: Six-speed sequential semi-automatic

Each driver is assigned a dedicated team of race engineers

Wheels
F2 cars use 33cm (13in) front and rear rims combined with Yokohama tyres.

Chassis
Each Formula Two car sports a carbon-fibre composite shell with an aluminium and NOMEX (meta-aramid material) honeycomb. Various other composite materials are used for its brake ducts, nosebox and wings.

FIA Formula Two Championship



Despite Formula One's prestige and higher-powered cars, Formula Two is regarded as one of the purest forms of racing in the world, offering drivers the complete package at a significantly reduced cost

Formula Two is, quite possibly, the hottest motorsport in Europe right now, delivering blisteringly fast single-seater vehicles – read: 373 kilonewtons (500 horsepower) and 450 Newton metres (332 pound-force feet) of torque, mind-bending physics and some of the most talented drivers outside of F1. Surely, though, it is just a smaller, less-powerful and less-glamorous variant of motorsport's top-tier championship? This is a façade that couldn't be further from the truth. The reason? A completely level and fair playing field for all drivers (see the 'Formula One vs Formula Two' boxout), something granted through a single vehicle constructor, dedicated championship organiser and one of the lowest-cost entry points in the world.

Indeed, it's a lot easier for talented drivers to raise £250,000 ($311,000) to race in F2, compared with up to £2 ($3.1) million to do so in GP2 (an F1 feeder series).

The Formula Two season works by pitting a selection of 24 drivers against one another in 16 races on eight of Europe's most famous racing circuits. Circuits for the 2012 season include the legendary Monza racecourse in Italy, prestigious Silverstone in England and terrifying Nürburgring in Germany.

Each course is attacked over a three-day weekend, with drivers hitting the track for a total of 230 minutes. Practice and testing take place on each Friday, with a pair of races following on the Saturday and Sunday. As in Formula One, the top drivers are then attributed championship points – in F2, from 25 for first, down in increments to one point for tenth place. At the end of each season, the points are totted up and ultimately the driver who has accrued the most wins. This earns them not just a trophy, but also a test with the Williams F1 team.

This series is not just the ideal testing ground for ambitious drivers though. Formula Two – largely thanks to the comprehensive all-round package delivered by MotorSport Vision (MSV), the championship's organiser – also offers racing fans an opportunity to get closer to the ideal of the pure race than ever before. Asides from easier financial access to event circuits, Formula Two is broadcast in over 38 countries, into 21 million European homes and for more than 100 hours each season.

Head to Head FORMULA RACING

1. Formula One
The highest tier of single-seater racing sanctioned by the FIA, F1 sees teams and drivers vie for a single World Championship. Cars have upwards of 597kW (800hp).

2. Formula Two
Reborn as the FIA Formula Two Championship in 2009, F2 drivers compete in identical 298kW (400hp) cars. A high-quality but low-cost alternative to F1.

3. Formula Three
A host of series in which racers – usually younger drivers aiming to progress to a higher tier – can demonstrate and improve their ability. Cars have around 149kW (200hp).

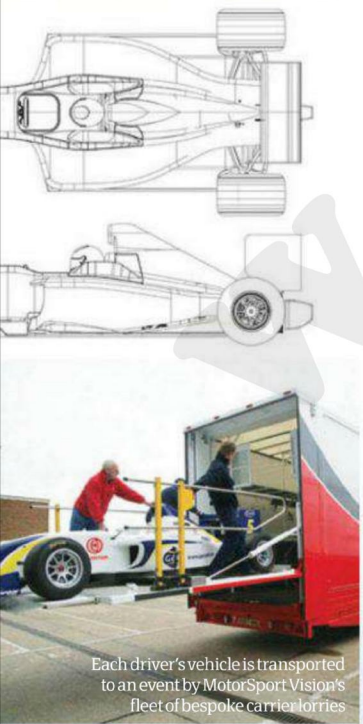
DID YOU KNOW? *The Fédération Internationale de l'Automobile's (FIA's) Formula Two Championship was established in 2009*

Maximum boost

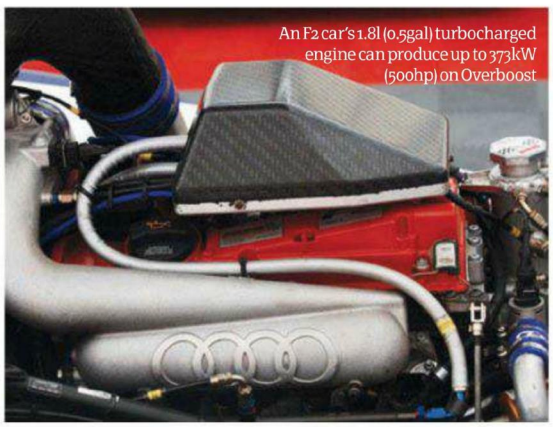
One of the most exciting aspects of Formula Two from a hardware point of view is each vehicle's Overboost button, which when activated increases the vehicle's engine power from 313 to 373kW (420 to 500hp) for six seconds. The boost feature can be deployed by each car a maximum of ten times during a race, granting the driver extra power for overtaking or to defend a position from a rival. The button is located to the centre-left of the steering wheel.

Brakes

The entire brake system for Formula Two is supplied by AP Racing. Both front and rear master cylinders are aluminium push-types, brake discs are made from carbon and grooved, while pads are carbon metallic.



Each driver's vehicle is transported to an event by MotorSport Vision's fleet of bespoke carrier lorries



An F2 car's 1.8l (0.5gal) turbocharged engine can produce up to 373kW (500hp) on Overboost

Formula One vs Formula Two

F2's profile is growing season by season, challenging F1 with its comprehensive racing package and lower costs

The main reason, excluding differences in hardware, why Formula Two is held in such high esteem by race drivers and fans alike is its low entry costs – allowing junior racers a far greater chance of making it onto the track. All cars are made by Williams F1 identically and all drivers have access to the exact same race engineers, race information (performance statistics and video, etc) and hospitality, which is all co-ordinated and managed by MotorSport Vision. In fact, MotorSport Vision takes its dedication to providing an equal and excellent driver package to such an extent that they even rotate each driver's engineers continually throughout the season, ensuring no driver gets preferential treatment.

This contrasts completely with Formula One, whereby individual teams operate private budgets, vehicles, mechanics, designers, race engineers and hospitality – a fact that leads to a mere handful of drivers realistically being able to compete for the championship each year. It also raises the question: where does driver skill end and car performance/value begin in deciding who takes the Formula One title?

Despite each Formula Two vehicle generating colossal downforce, the penalty for losing control is severe

8x © MotorSport Vision

Interview James Goodfield

How It Works speaks to F2's chief engineer about the racing series that's hot on F1's heels

How It Works: Tell us about your role for F2.
James Goodfield: I oversee any development undertaken on the F2 car as well as all the engineering over each race weekend. Between events I'm also involved in talking to drivers to make sure that they're happy. At the moment, I am overseeing development work on this year's vehicle ahead of the start of the season, looking at what we can upgrade and basically how we can make the car faster.

I'm also liaising with all of our race engineers to ensure that they have the same information, understand how the new cars are set up and providing a detailed technical manual for their usage. The manual ensures all engineers completely understand how every part of the car works, while a simplified version delivers relevant information to the drivers themselves.

HIW: All F2 cars are built identically by Williams, but is there room for driver-specific tweaks?
JG: Yes. We list on the set-up sheet everything the driver can and cannot change on the vehicle. Many drivers operate the vehicle with just the stock, baseline setup, however others are more dynamic, requesting changes to ride height and tyre pressure, etc.

HIW: You mentioned you were currently looking into potential upgrades for the 2012 season's vehicle – are there any you can discuss?
JG: Last year a lot of the focus was on reliability, as we aim here for 100 per cent reliability throughout the season. That's always going to be our aim and in 2011 we had a very, very good year; we had a run during the summer of five or six races where we had zero car stoppage issues – which is quite phenomenal at this level. As such, we are in a nice position this year where we can look more at development.

The main thing for 2012 is that we are transitioning to carbon brakes from iron ones. This is exciting as the combined weight of carbon discs and pads will be 12.5 kilograms [27.5 pounds] lighter than the current iron-disc setup, granting the vehicles greater performance.

HIW: You're currently three years in to a five-year tender to run the FIA F2 Championship – what would you say is your goal for the remaining two?
JG: There are all sorts of pulls on us, really. Obviously, reliability is our main goal as we have 24 guys at the start of the season that want to win the championship. If one of them has to stop in a race, especially if they are in a good position, potentially they can lose points that will affect their final result. If no car breaks down, then the result at the end of the year is wholly the result of driver performance.

The other thing we need to achieve in Formula Two – as we are in a competitive environment with Formula Three, GP3 and WSR – is to make sure our performance keeps in step with them. We constantly need to go faster as well as find innovative ways to improve the F2 vehicle.

"Le Mans is a brutal test of driver skill, consistency and concentration"

Peugeot 908 HDi FAP

We take a look inside one of the most notable Le Mans cars of the past five years to see what makes it a winner

Chassis
The 908 HDi's body is a carbon-fibre shell, which delivers enhanced rigidity and a lower weight than a conventional open structure. The chassis is built entirely in-house by Peugeot.

Engine
The vehicle is powered by an industrial 5.5l (1.5gal) V12 diesel engine, the largest permitted in Le Mans racing. The engine produces 544kW (730hp) and 1,200Nm (885lbf ft) of torque. It is twin turbocharged.

© Antonio Pamullo

Wheels
Magnesium-forged, monoblock wheels are supplied by BBS. The wheels are covered with Michelin 53cm (21in) tyres.

The statistics...


© Peugeot Sport

908 HDi FAP LMP1

Length: 4,650mm (183in)
Width: 2,000mm (79in)
Wheelbase: 2,950mm (116in)
Weight: 930kg (2,050lb)
Engine: 5.5l (1.5gal) turbocharged V12 twin-turbo diesel
Transmission: Six-speed sequential manual

Engineers must do all they can to tune the car prior to the race in the WRC, as once the car crosses the starting line, the driver and navigator are on their own

24 Hours of Le Mans

The oldest and arguably greatest test of racing endurance, Le Mans demands composure, skill and elite engineering

Think two hours of racing, as undertaken by F1 drivers, is demanding? Well, think again. Le Mans requires drivers to race continuously for 24 hours, with over 50 high-powered racers clocking in over 4,828 kilometres (3,000 miles) over a weekend. It is a brutal test of driver skill, consistency and concentration, with just one mistake liable to, at best, erase hours of excellent driving or, at worst, potentially lead to a fatal accident.

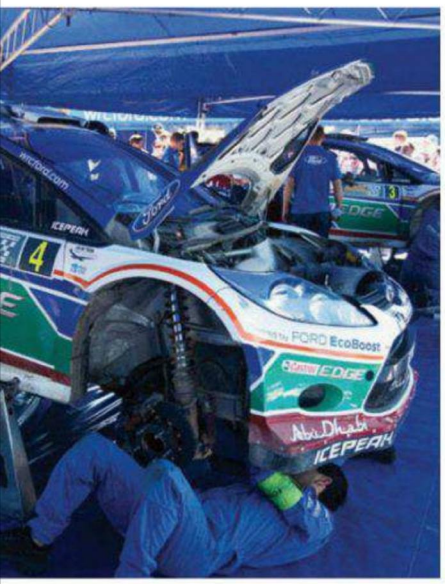
There are four classes to Le Mans: LMP1, LMP2, GTE Pro and GTE Am, which divide vehicles on power, budget and car-type. LMP1 is the most prestigious class, with its custom-built prototype-level vehicles usually leading each race. While all cars compete at the same time during the race, each class has its own trophy, and despite vast differences in power, it is not unheard of for a lower-tier vehicle to win the overall event as endurance is just as important – if not more so – than power output.

Speed, however, obviously plays an essential role in Le Mans – with drivers rarely dropping below 161 kilometres (100 miles) per hour – and as such, it is not only considered the most gruelling of motorsports but also one of the most dangerous. Since the competition's conception in 1923, 21 drivers have died on the Circuit de la Sarthe (one of the world's longest). There have been numerous high-speed accidents – the most recent being in last year's race, with two Audi-designed LMP1-class vehicles spectacularly colliding at over 274 kilometres (170 miles) per hour.

Brakes
Both front and rear wheels are supported by carbon-fibre ceramic disc brakes, allowing for superb stopping speeds.

Watch professional rally driver Ken Block go flat out on snow and ice

DID YOU KNOW? The average World Rally Championship car accelerates from 0-60mph in just three seconds



World Rally Championship

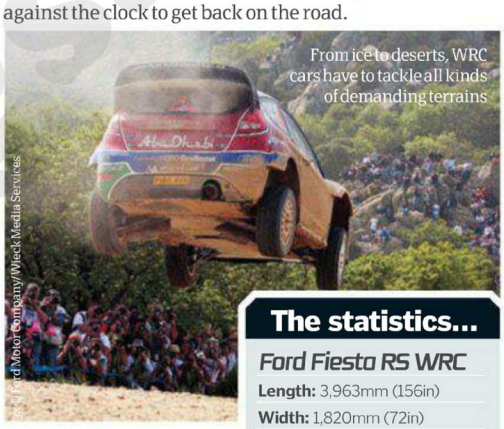
The WRC series delivers some of the most spectacular and demanding racing in the world, pitting drivers against ice, snow and boulder-strewn cross-country tracks at intense speeds

From the desert scrubland of Jordan, through the alpine forests of Sweden and on to the snow and ice of Finland, World Rally Championship (WRC) drivers must take on some of the most demanding and technically challenging terrains in all of motorsport. It's a sport where £650,000 ($1-million) vehicles are pitted against 13 of the toughest courses in the world and where drivers need to constantly adjust race after race to remain at the front of the pack. As such, the WRC is broadcast in over 180 countries and has a worldwide audience of more than 800 million.

The WRC works by splitting each course into between 15 and 25 special stages, which are short (2.4-kilometre/1.3-mile) to long (50-kilometre/31-mile) stretches of closed roads that the driver – along with a navigator – attempt to complete in the shortest possible time.

Each vehicle, when driving to and from each special stage does so on public roads, adhering to regular traffic regulations. The special stages are often tailored to test specific aspects of a driver's skill and vehicle's prowess, ranging from steep downhill sprints, through tight, winding mountain roads and on to rough off-road canyons and scrubland. The racing goes on over a three-day period, with reconnaissance and 'shakedown' testing runs taking place on the first day.

Interestingly – and perhaps another reason why the World Rally Championship has such a substantial fan base – is that as soon as vehicles leave any course's starting point, the driver and navigator can receive no support from the rest of their team; they have to deal with any breakdowns solely by themselves. This adds an extra dimension to each race, with teams racing around and against the clock to get back on the road.



From ice to deserts, WRC cars have to tackle all kinds of demanding terrains

© Ford Motor Company/Wieck Media Services

Transmission

It uses a six-speed sequential manual transmission, combined with an electro-pneumatic controlled gearbox – positioned lengthways and with a maximum of six gear ratios.

Ford Fiesta RS WRC

The anatomy of one of the World Rally Championship's most advanced cars laid bare

Chassis

A unitary construction bodyshell with unique composite side panels and aerodynamic rear wing grant the RS WRC a light and streamlined chassis. A welded T45 rollcage is installed for driver safety and extra rigidity.

Engine

Ford's 1.6l (0.4gal) EcoBoost engine, in partnership with a high-powered Garrett turbocharger, delivers a restricted (by regulation) 224kW (300hp). The engine is managed by a Cosworth-designed electronic system.

The statistics...

Ford Fiesta RS WRC

Length: 3,963mm (156in)

Width: 1,820mm (72in)

Wheelbase: 2,480mm (98in)

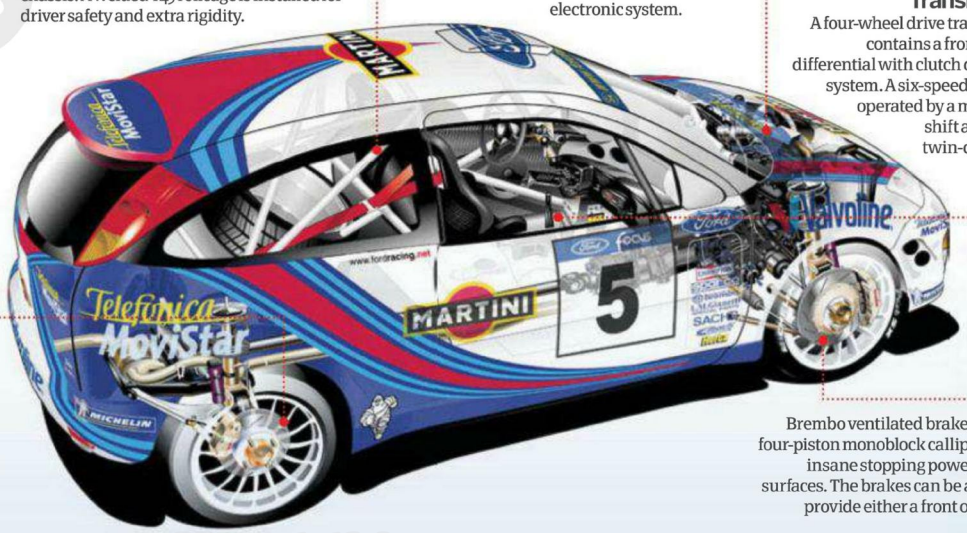
Weight: 1,200kg (2,646lb)

Engine: 1.6l (0.4gal), four-cylinder, 16-valve turbocharged Ford EcoBoost engine

Transmission: Six-speed sequential manual

Transmission

A four-wheel drive transmission contains a front and rear differential with clutch disconnect system. A six-speed gearbox is operated by a mechanical shift and using a twin-disc clutch.



Wheels

The Fiesta RS can be equipped with either 20x46cm (8x18in) wheels for asphalt surfaces or 18x38cm (7x15in) aluminium wheels for gravel and snow. All tyres are from Michelin.

Brakes

Brembo ventilated brake discs with four-piston monoblock callipers deliver insane stopping power across all surfaces. The brakes can be adjusted to provide either a front or rear bias.

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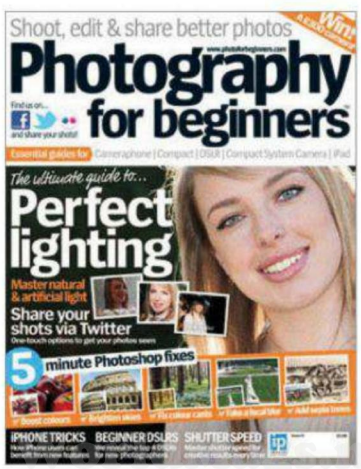

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Head to Head
THE ULTIMATE TUG OF WAR

© Linda Shanklett

1. Horse
Originally horsepower was designed to compare the power of draught horses and steam engines. One horsepower equals about 736 watts.

© Terex

2. TA300
The TA300 articulated dump truck has a 287-kilowatt (385-horsepower) engine and can carry up to a 30-ton load.

© Greg Walsh

3. The Edward J Moran
One of a very powerful series of tugboats, with a 4,848-kilowatt (6,500-horsepower) twin engine, it can haul up to 94,000-ton vessels.

DID YOU KNOW? *40mm windscreen cracks can be repaired, but in the 'A- zone' in front of the driver, only 10mm faults can be fixed*

The chain anchored at both shores is slack so it drops to the riverbed once the ferry passes.

©Andrew Macpherson

Chain ferry platforms
The mechanisms guiding cable ferries

There are three primary types of cable ferry: reaction ferries, hand-operated ferries and powered-chain ferries. Reaction ferries use the power of the river itself to 'tack' across the current while the other two both operate off the same basic apparatus of powered cogs or drums. These run along either side of the ferry and act as guides for the chains, drawing them in and around their circumference before letting them fall back to the riverbed or seabed.

The chains themselves have a tremendous amount of slack built in to protect other boats. Otherwise, instead of sinking back to the bed of the channel/river once the ferry has passed by, the chains would remain on the water's surface, or just beneath, where they could cause serious damage to other vessels.

2x © Autoglass

The worst place you can get a crack on your windscreen is the 'A-zone' in front of the steering wheel

Cracking repair jobs
The secret to fixing cracked windscreens

The vast majority of modern car windscreens are constructed of two layers of laminated safety glass and often have a layer of plastic laminate between them. As a result, repairing small cracks is a relatively easy operation as they tend to only affect the outer layer of glass.

Repairing cracks involves using a drill to break through the damaged glass and get down to the lamination layer. Once the drill has reached the lamination layer the next step is to inject an adhesive resin. This resin is often based on polyurethane, a polymer that's flexible like rubber but at the same time retains rigidity like plastic, which is ideal for fitting into the already-established shape of the windscreen. Once in place, the resin is cured with ultraviolet light, causing it to harden. This not only seals the crack but in a lot of cases reduces the prominence of the crack, restoring near-complete visibility as well as much of the windscreen's original strength.

A tugboat pulls a massive freighter into Hamburg Port, Germany

Engines
Tugboat engines are extremely powerful – up to 2,535 kilowatts (3,400 horsepower).

Kort nozzle
One of several types of tug propulsion, Kort nozzles focus the thrust of the propeller.

Propulsion
Tug propellers can rotate up to 360 degrees, allowing the tug to manoeuvre easily.

Tugboat power explained
Discover why the smallest ships are also often the strongest

Tugboats have a 507-2,535-kilowatt (680-3,400-horsepower) engine, which can grant them a power-to-weight ratio of up to 4.50. This is a measure of the sheer brute force of an engine, worked out by dividing the engine's power by the weight of the vehicle. It's also a mark of how extraordinarily strong tugboats are, relative to their size, given that the power-to-weight ratio of the much bigger ships they tow varies between 0.30 and 1.20.

The key to a tugboat's success lies in how it utilises this strength. Z-drive propellers are designed to rotate 360 degrees so that the tug can change direction on the spot. Similarly, the Voith Schneider Propeller (VSP) system often employed uses a series of blades whose angle can be altered so they can provide thrust in any direction, once again allowing the tug to haul or push its charge into any position.

"There are two main types of countermeasure flare – pyrophoric and pyrotechnic"

The CH-46 Sea Knight is designed to provide all-weather, 24-hour assault transport for US Marine Corps combat troops. As such, it is equipped with a wide variety of countermeasure devices

Decoy flares

One of the most widely used aerial countermeasures in the world, decoy flares offer a simple but robust last line of defence against incoming missiles

Decoy flares, as commonly used by military aircraft, work by generating a heat signature in excess of the launch vehicle's jet engines. This has the effect of confusing any incoming heat-seeking missile's homing system into locking on to the flares' signatures instead of the aircraft's, causing it to explode at a safe distance and saving the pilot's life.

There are two main types of countermeasure flare – pyrophoric and pyrotechnic. The former is activated automatically on contact with air and the latter by the mechanical removal of a friction cap prior to firing. Pyrotechnic flares use slow-burning fuel-oxydiser mixtures to generate heat, such as MTV (magnesium/Teflon/Viton), while pyrophoric variants use either ultra-fine, aluminium-coated iron platelets or liquid compounds such as triethylaluminium. The composition of either type of flare is often tailored to counter specific missile systems or to mimic the launch jet's heat signature.

All military aircraft being built today are fitted with automatic flare dispensing systems, which actively track incoming missiles and launch flares accordingly at optimal range to avert damage, while older or civilian aircraft usually require the pilot to activate the flare launches manually. Systems are fairly flexible and flares can be dispensed one at a time, over long or short intervals and even, if desired, in large clusters – as demonstrated by the CH-46E Sea Knight in this stunning image.

DID YOU KNOW? *Modern military aircraft launch flares automatically when missiles are detected in close proximity*

What is it?

This image shows a Boeing CH-46 Sea Knight helicopter dumping a cluster of decoy flares into the atmosphere. Flares are a form of aerial infrared countermeasure employed to trick heat-seeking surface-to-air or air-to-air homing missiles.

This month in **Space**

To kick off the Space section this issue, bask in the glory of this spectacular artist's interpretation of Betelgeuse, one of the closest supergiant stars to Earth. Next we find out exactly how the Magellanic Clouds were pulled into the Local Group of galaxies of which we are a part before looking at the next generation of space stations that are inflatable – anyone got a foot pump? Finish with a roundup of Russia's Venera missions to Venus, which broke lots of new ground in their day.

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SPACE

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Supergiant stars

We take a look at the biggest stellar bodies in the universe

Put the Sun next to a supergiant star and you'll have a hard time finding it. Supergiant stars, as the name suggests, are the largest kind in the universe. They can be thousands of times bigger than our Sun and have a mass up to 100 times greater. The largest-known supergiant star, VY Canis Majoris, is up to 2,100 times the size of the Sun (based on upper estimates). If it were put in the position of our Sun, it would extend out to the orbit of Saturn.

Supergiants come in a variety of sizes and temperatures, but they are typically classed as being either red or blue. Red supergiants have a mass of at least eight solar masses and are generally old stars that were once similar in size to the Sun. They form when a star more than ten times the mass of our Sun runs out of hydrogen fuel in its core, preventing any further fusion.

It subsequently starts to collapse but, as it does so, the hydrogen in its outer shells begins its own process of fusion. At this point the entire star experiences fusion and begins to burn through the rest of its fuel supply at an astounding rate. In fact, they can burn all of their remaining hydrogen in just a few million years, compared to the several-billion-year lifetime of stars like our Sun. During this period they will shine at least 100,000 times brighter than our galaxy's star. At the end of their life, red supergiant stars often explode as a supernova, producing either a neutron star or a black hole as a result. The nearby red supergiant Betelgeuse, which is around 1,000 times the mass of the Sun, is only 8.5 million years old but is expected to go supernova within the next millennium.

Blue supergiants are considerably hotter than red supergiants, but generally much smaller – only about 25 times the size of the Sun. Like red supergiants they have very short lifetimes of only a few million years. They usually form when a star more than ten times the mass of the Sun heading towards its own demise enters a slow-burning phase. However, red supergiants can also turn blue if their own rate of nuclear fusion begins to decline; in fact, a star can continually switch between red and blue supergiant over the course of its life. Between the two extremes it can also become a yellow supergiant, such as the North Star (Polaris). However, stars of this nature tend to spend the majority of their existence as red supergiants rather than in their blue or yellow forms.

Supergiant
Betelgeuse, shown here, is a supergiant star 640 light years from Earth in the Orion constellation. It has 20 times the mass of the Sun.

Head to Head STELLAR GIANTS

1. Betelgeuse
This star, which is located in the Orion constellation (his shoulder), is 10,000 times more luminous than the Sun and about 370 times its size.

2. Eta Carinae
7,500 light years away, this star is about 400 times the size of our Sun, but due to its scale it loses a large amount of its mass every year.

3. VY Canis Majoris
This star 5,000 light years from Earth is up to 2,100 times the size of the Sun. It takes light over eight hours to travel its circumference.

DID YOU KNOW? *Supergiant stars larger than 100 solar masses are sometimes referred to as hypergiants*

How big is a supergiant?

Supergiant stars dwarf all others in the cosmos. Here's a look at how the various types stack up

Orbit
If Betelgeuse were placed at the centre of our solar system, it would reach beyond the orbit of Mars and possibly even out to Jupiter.

Rigel
Type: Blue supergiant
Mass: 24 solar masses
Size: 71 solar radii
Temperature: 12,130K (11,860°C/21,380°F)
Distance from Earth: 860 light years

Antares
Type: Red supergiant
Mass: 12.4 solar masses
Size: 883 solar radii
Temperature: 3,400K (3,130°C/5,660°F)
Distance from Earth: 550 light years

Sirius A
Type: White star
Mass: 2.02 solar masses
Size: 1.711 solar radii
Temperature: 9,940K (9,670°C/17,430°F)
Distance from Earth: 8.6 light years

Sun
Type: Yellow dwarf
Mass: 1 solar mass
Size: 1 solar radius
Temperature: 5,778K (5,500°C/9,940°F)
Distance from Earth: 0.000016 light years

© SPL

Inside a red supergiant

Core
The dense core of a red supergiant contains layers of heavy elements, ranging from iron at the very centre to hydrogen at the edges.

Exterior
The outer layer of a red supergiant is blown off when hydrogen fusion ceases in its core and the star goes supernova. This distributes heavy elements which are key to forming new planets.

Interior
Around the core is an area consisting of a substantial amount of hydrogen and other elements which may undergo fusion.

© DK Images

What's the limit?

The colder a supergiant star, the larger it can become. Currently the biggest star we know of is VY Canis Majoris, at 2,100 times the size of the Sun. Canis has a temperature of 3,500 Kelvin (3,227 degrees Celsius/5,840 degrees Fahrenheit). Estimates suggest a supergiant star at 3,000 Kelvin (2,727 degrees Celsius/4,940 degrees Fahrenheit) would be 2,600 times the size of our Sun; this is believed to be the upper limit before a star collapses in on itself.

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DID YOU KNOW? When solar tsunamis were first observed, scientists thought they were merely the shadows of solar flares

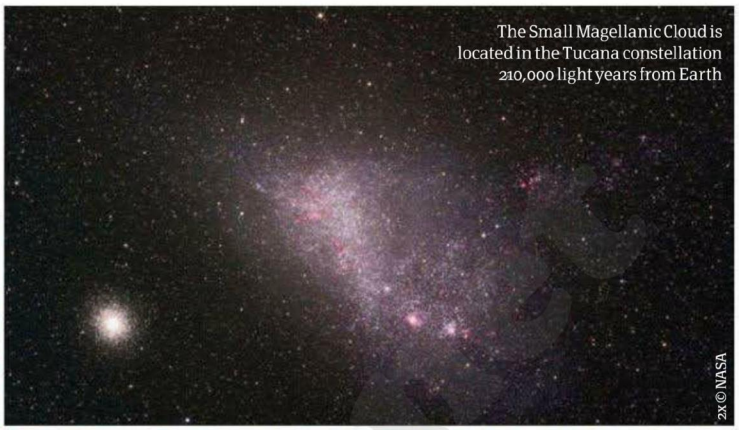
Inside the Magellanic Clouds

Where did these galaxies come from?

The Magellanic Clouds consist of two irregular dwarf galaxies, both of which are found in the Local Group of galaxies that includes our own Milky Way.

The Large Magellanic Cloud (LMC) is the biggest of several galaxies in our vicinity, spanning 30,000 light years across and located 160,000 light years from us. It's packed full of young star-forming nebulas and is home to mainly blue-white hot stars. The Small Magellanic Cloud (SMC) is somewhat more miniature, measuring in at 15,000 light years wide, and is 210,000 light years from us. The SMC has a mass around 7 billion times that of our Sun.

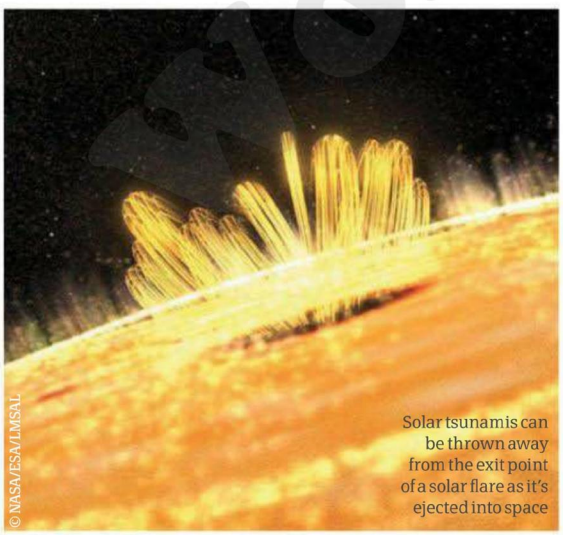
Perhaps the most interesting thing about the two galaxies is their origin. Both of them are moving rapidly – roughly equal to the velocity needed to escape from the Milky Way, suggesting that rather than forming in our own galaxy as was first thought, they were 'snared' by the Milky Way as they travelled past. Their movement and speed suggest that they were thrown out of the nearby Andromeda galaxy no more than 8 billion years ago, hurtling through space before entering the orbit of the Milky Way.



The Small Magellanic Cloud is located in the Tucana constellation 210,000 light years from Earth

2x © NASA

The Large Magellanic Cloud plays host to thousands of newborn heavyweight stars



© NASA/ESA/LMSAL

Solar tsunamis can be thrown away from the exit point of a solar flare as it's ejected into space

Solar tsunamis

The mega-waves of energy that tear across the Sun

Solar tsunamis, also known as Moreton waves or fast-mode magnetohydrodynamic (MHD) waves, are surges of material sent crashing across the Sun as the result of a solar flare being launched into space. They can travel up to an incredible 1.6 million kilometres (1 million miles) per hour.

Solar tsunamis are made of hot plasma and magnetic energy. The first was observed by Gail Moreton in 1959, and since then several more studies have been conducted on the phenomenon by the Solar and Heliospheric Observatory (SOHO) and the Solar Terrestrial Relations Observatory (STEREO) spacecraft.

The tsunamis are formed when the Sun emits a coronal mass ejection (CME), a massive burst of solar wind commonly associated with solar flares. Around the ejection point a circular wave extends outwards in all directions travelling at a super-fast rate.

In February 2009, the two STEREO spacecraft watched as a billion-ton cloud of gas was hurled off the surface of the Sun from a CME. The result was a solar tsunami that towered 100,000 kilometres (60,000 miles) high speeding across the star's surface at about 900,000 kilometres (560,000 miles) per hour. Estimates indicate it contained the same energy as 2.4 million megatons of TNT.

"Kevlar fabric modules were more resilient to micrometeoroid impacts than the casings of the ISS modules"

Modules
Pictured here are mock-up models of how Bigelow Aerospace's proposed inflatable modules will look.

Airlock
Each of the inflatable modules will be able to join together in order to create a complete space station.

Inflatable space stations

Could this new type of module revolutionise space living?

Inflatable space modules are a proposed way to set up sizable space habitats in Earth orbit at a much lower cost than currently possible. Unlike the existing modules on the International Space Station (ISS), which must be constructed and launched in their finished state, inflatable modules would be folded up on the rocket. Once they reach orbit they would be pumped full of a gas, such as nitrogen, to expand to their full size. It is estimated that just one inflatable module packed into a rocket could one day have the potential to expand to the size of the entire ISS, roughly equivalent to an American football field, which is about 100 metres (328 feet) in width.

At the forefront of inflatable space technology is Bigelow Aerospace. This company has launched and tested two modules in space – Genesis I and II (in 2006 and 2007, respectively) – which have proved that inflatable modules are just as reliable, if not more so, than their metallic counterparts. In one test, Bigelow found that its Kevlar fabric modules were more resilient to micrometeoroid impacts than the casings of the ISS modules. Bigelow's next inflatable spacecraft will be the Sundancer module, due to launch by 2014 at the earliest. It will be the first inflatable module in orbit around Earth capable of supporting humans on board.

Layers
The inflatable shell, which is 30cm (one foot) thick, is made of multiple layers to provide insulation and protection from orbiting debris.

Docking
At the top of the module is an airlock, allowing it to be attached to other similar modules or even to other space stations like the ISS.

Shape
Superstrong woven Kevlar is used on the interior of the shell to ensure the module keeps its shape when it is inflated.

Interior
The spacious interior is about 8.2m (27 feet) in diameter and can house different areas including exercise rooms and eating quarters.

Structure
Most of the external shell is made of a material called Nextel, an insulating material found under the hoods of cars, placed between sheets of foam.

DID YOU KNOW? NASA has looked into filling stations, or propellant depots, orbiting Earth for rockets on deep-space missions

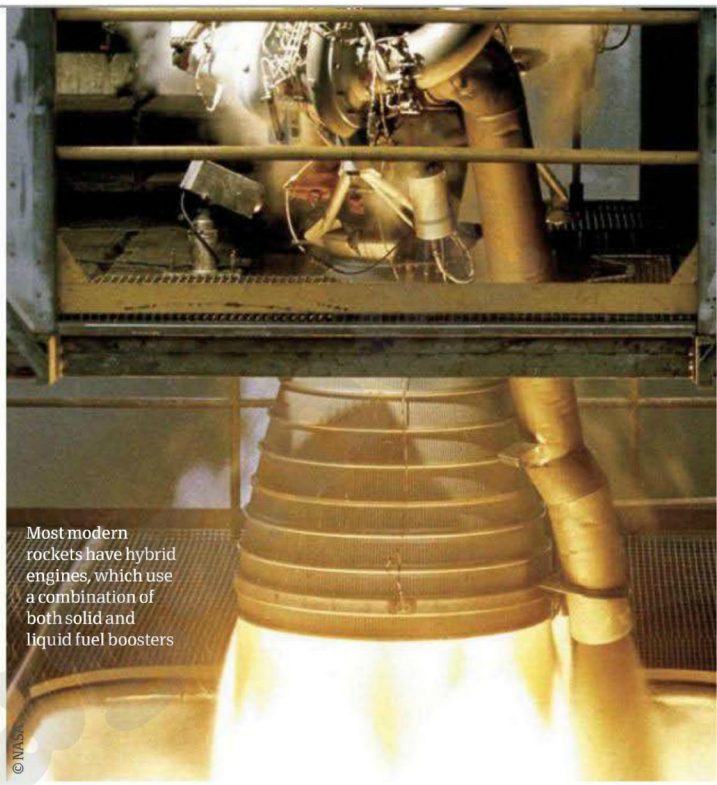
Rocket fuel

How does this powerful propellant take spacecraft into the cosmos?

Rocket fuel works on the basis of Newton's Third Law of Motion, which states that 'every action is accompanied by an equal and opposite reaction'. By firing fuel out the back of a rocket, the force propels it upwards with acceleration equal to the force at which the fuel is expelled. It is almost identical to how a jet plane is able to fly in the atmosphere. However, one difference is that jet planes use oxygen in the atmosphere to ignite their fuel, while a rocket must carry its own oxidiser.

There are two main types of rocket fuel used on modern rockets: liquid and solid. Liquid propellants separate fuel and oxidisers and the two are combined in a combustion chamber where they burn and are fired out from the base of the rocket. While more complex than solid fuel, the ability to control the flow of propellant means the engine can be throttled to a particular speed. Liquid fuels are further subcategorised into either petroleum, cryogens or hypergols. Petroleum is fuel derived from crude oil and hydrocarbons, cryogens are those stored at very low temperatures (such as liquid hydrogen), while hypergols are able to self-ignite on contact between the fuel and the oxidiser.

Solid rocket fuels are those in which the fuel and oxidiser compounds are already combined. Most use an aluminium powder as the fuel and an ammonium perchlorate as the oxidiser, while an iron powder is used as a catalyst for the reaction. All that's required is a spark to start them burning. While they are much simpler than their liquid counterparts, they cannot be stopped once they have been ignited. For that reason, solid fuels are generally used more for the initial launch sequence, when the speed needs to be at its maximum, whereas liquid fuels are used later so the speed can be adjusted to get the rocket's payload on to the right trajectory.



Most modern rockets have hybrid engines, which use a combination of both solid and liquid fuel boosters

© NASA

"Despite many technical hitches, the Venera spacecraft are regarded as a success"

Venera probes

The highs and the lows of these groundbreaking Russian missions to Venus

Venera 10 returned this image from Venus on 25 October 1975 during its 65 minutes of operation

This 170-degree panoramic image of Venus's surface was taken by Venera 13 on 1 March 1982

The Venera probes were a series of spacecraft designed by the USSR to glean unprecedented data on the hottest planet in our solar system: Venus. Venera 1 was the first to launch in 1961, followed by 15 more missions through to 1984. The spacecraft encountered numerous problems and glitches in almost every launch, but there was more than enough data returned to label the overall mission a success. The spacecraft were launched in batches across the 23-year period, with each group possessing new and upgraded features based on the experiences from the previous missions.

The first two spacecraft – Venera 1 and 2 – were designed as spherical probes intended to merely perform a flyby of the planet and provide information about the density of its atmosphere and temperature. Unfortunately, both probes suffered a communications failure after leaving Earth orbit so couldn't send any data back, although Venera 1 is thought to have come within 100,000 kilometres (62,137 miles) of Venus, thus becoming the first manmade object to pass the planet.

The next four spacecraft – Venera 3 to 6 – employed a similar spherical design but were somewhat heavier, weighing about a ton. Although Venera 3 was unsuccessful, earning itself the unwanted accolade of becoming the first spacecraft to crash-land on another planet on 1 March 1966, Venera 4 finally returned positive results and became the first spacecraft in history to measure the atmosphere of another planet. Each of the spacecraft carried a probe to attempt an atmospheric entry, but the Soviets grossly underestimated Venus's surface pressure, believing it to be just 25 times more than Earth's when in fact it is closer to 100 times, and thus the first two probes were instantly destroyed once they entered the atmosphere. Realising their design error, the USSR's space agency decided to jettison the majority of the instruments on Venera 5 and 6 mid-flight and instead use them solely as atmospheric entry probes; each managed to survive for over 50 minutes in the harsh atmosphere.

The remaining missions were designed to land and operate on the surface of Venus, taking into account the intense pressure measured in previous missions. Venera 7 was the first spacecraft in the programme specifically tailored to survive the intense pressure and heat on Venus's surface (see the 'Landing on Venus' boxout for more detail). It became the first spacecraft to transmit data from the surface of Venus on 15 December 1970 despite a

1. Venera 3
This Russian probe was the first spacecraft to impact another planet – Venus – in 1966. Due to equipment damage, no data was returned.

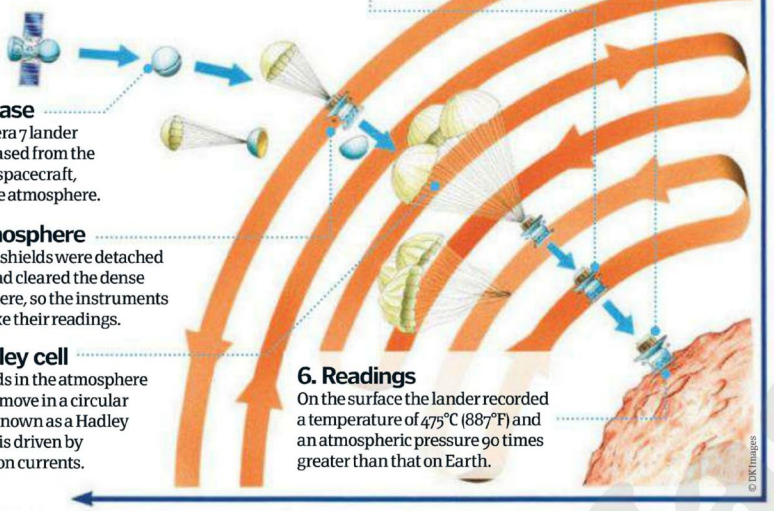
2. Mars 2
This Soviet-built unmanned probe, with a fairly unoriginal name, crash-landed on Mars in 1971, becoming the first spacecraft to 'touch down' on the Red Planet.

3. Huygens
On 14 January 2005 the Huygens probe performed the first and only landing in the outer solar system, successfully touching down on Saturn's moon Titan.

DID YOU KNOW? *Russia and the USA are the only two countries to successfully land spacecraft on another planet*

Landing on Venus

How did Venera 7 make it to the surface?



1. Release
The Venera 7 lander was released from the orbiting spacecraft, above the atmosphere.

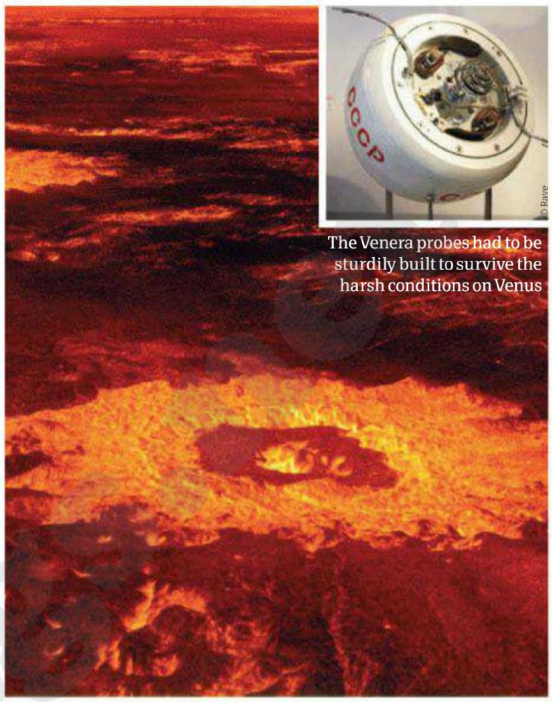
2. Atmosphere
The heat shields were detached after it had cleared the dense atmosphere, so the instruments could take their readings.

3. Hadley cell
The winds in the atmosphere of Venus move in a circular motion known as a Hadley cell; this is driven by convection currents.

4. Descent
The probe was meant to take 60 minutes to descend, but damage to its parachute meant it reached the surface in just 35 minutes.

5. Crash-landing
Venera 7 impacted the surface at 17 metres (56 feet) per second, but it still managed to survive for 23 more minutes.

6. Readings
On the surface the lander recorded a temperature of 475°C (887°F) and an atmospheric pressure 90 times greater than that on Earth.



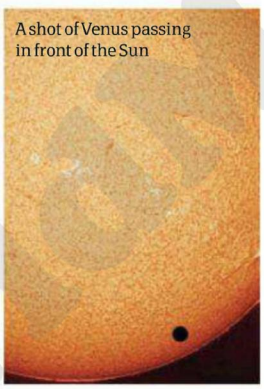
The Venera probes had to be sturdily built to survive the harsh conditions on Venus

parachute failure shortly before landing, which saw it impact the surface at almost 65 kilometres (40 miles) per hour. It survived for 23 minutes, as planned, and despite possessing very few experiments, it was still able to return information on the temperature and pressure, which were calculated at 475 degrees Celsius (887 degrees Fahrenheit) and 90 atmospheres (190,460 pounds per square foot), respectively. Venera 8 was nearly identical to Venera 7 save for a few additional instruments, and it was able to survive on the surface for almost an hour.

Venera 9 to 12 were much larger than their predecessors, weighing close to five tons. They included an orbital craft that relayed data from each spacecraft's landing probe, designed to operate for 30 minutes. For the first time each lander also included two cameras, but unfortunately all of the landers suffered a camera malfunction. Venera 9 and 10 lasted about an hour on the surface and managed to return some images, with the former becoming the first to do so from another planet, but the camera lenses on both Venera 11 and 12 failed.

Venera 13 through to 16 were similar in design but contained more instruments including a drill, compressibility arm (to determine the rigidity of Venus's surface) and a seismometer. They both returned images and data from the planet, but unfortunately for Venera 14 its lens cap was ejected directly beneath its compressibility arm, so it was unable to analyse the surface.

Despite their many technical hitches, the Venera spacecraft are generally regarded as a success for the Soviet space programme, providing a substantial amount of data on Venus. They paved the way for the two Russian Vega spacecraft in 1985, which released atmospheric balloons on Venus that stayed active for two days.

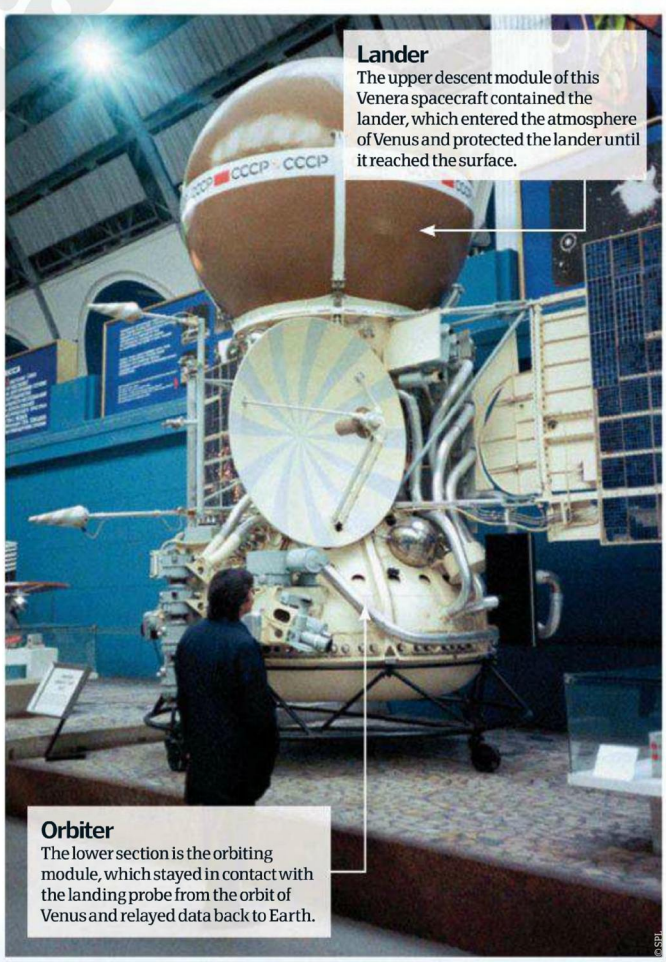


A shot of Venus passing in front of the Sun

VENERA LAUNCHES

A roundup of when all the Veneras took off...

- **Venera 1:** 12 Feb 1961
- **Venera 2:** 12 Nov 1965
- **Venera 3:** 16 Nov 1965
- **Venera 4:** 12 June 1967
- **Venera 5:** 5 Jan 1969
- **Venera 6:** 10 Jan 1969
- **Venera 7:** 17 Aug 1970
- **Venera 8:** 27 Mar 1972
- **Venera 9:** 8 June 1975
- **Venera 10:** 14 June 1975
- **Venera 11:** 9 Sept 1978
- **Venera 12:** 14 Sept 1978
- **Venera 13:** 30 Oct 1981
- **Venera 14:** 14 Nov 1981
- **Venera 15:** 2 June 1983
- **Venera 16:** 7 June 1983



Lander
The upper descent module of this Venera spacecraft contained the lander, which entered the atmosphere of Venus and protected the lander until it reached the surface.

Orbiter
The lower section is the orbiting module, which stayed in contact with the landing probe from the orbit of Venus and relayed data back to Earth.

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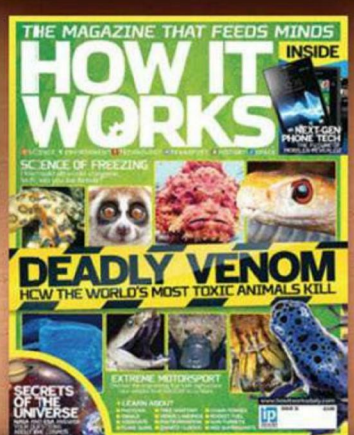
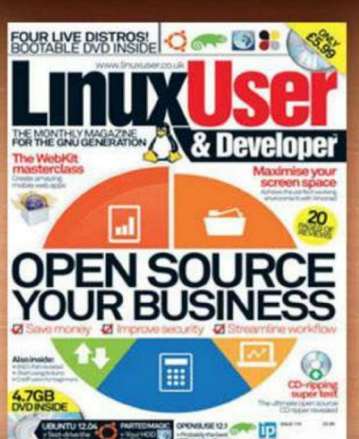


How It Works



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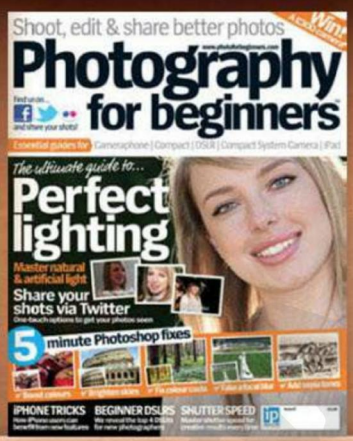

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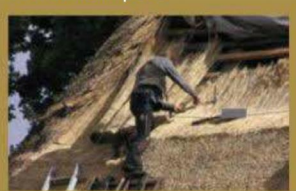
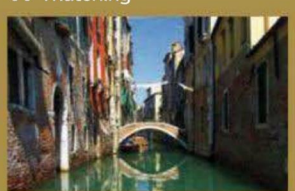
This month in History

This month we are diving straight into history, with an in-depth look at one of the most successful submersibles of all time – the Bathyscaphe Trieste. This two-manned vessel broke a record for travelling to the deepest known area in Earth's oceans – the Challenger Deep near Guam – back in 1960 and it retains its title to this day. Another watery marvel explored is how the City of Canals was built over a lagoon, while firmly on dry land we consider how thatchers have gone about their craft for centuries. Also revealed are the inner workings of fountain pens and gun turrets.

76 Fountain pens



77 Thatching



78 Venice deconstructed

HISTORY

74 Bathyscaphe Trieste
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Bathyscaphe Trieste

A real-life Nautilus, the Bathyscaphe Trieste explored the deepest parts of Earth's oceans, remaining to this day the only manned vehicle to have reached the bottom of the Mariana Trench in the Pacific

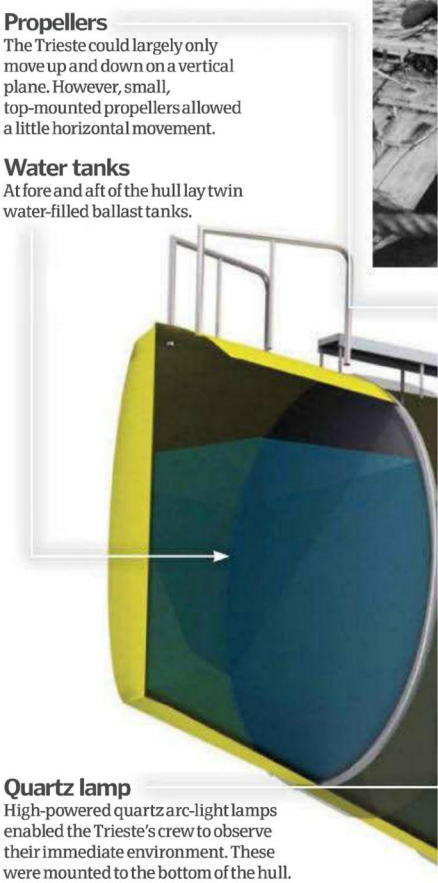
After passing 9,000 metres (30,000 feet), one of the Plexiglas windows cracked. Over 1,000 atmospheres – a pressure over six tons per square inch – relentlessly bore down upon the Bathyscaphe Trieste. The hull shook violently, threatening to collapse under the mighty strain. If fractured on even a microscopic scale, the weight of the Earth's deepest ocean would rip the vessel in two, triggering explosive decompression and instantly killing both oceanographer Jacques Piccard and pilot Lieutenant Don Walsh of the US Navy. 23 January 1960, however, was not their day to die. The men had still not reached the bottom of the Mariana Trench's Challenger Deep; the structure *had* to hold – there was no plan B.

Descending further into the black void, completely cut off from the outside world – the sonar/hydrophone communications system had packed up hours ago – the Trieste continued to dump iron pellets into its ballast system. After all, you don't descend vertically nine kilometres (nearly six miles) beneath the surface of the ocean only to quit so close to your goal. Then finally, out of nowhere and after four hours and 48 minutes within a two-metre (seven-foot) pressurised sphere, Piccard, Walsh and the Trieste touched down. Clouds of diatomaceous ooze (made of the skeletons of dead sea-creatures) diffused from the seabed on contact, filling the surrounding water with a liquidated organic haze.

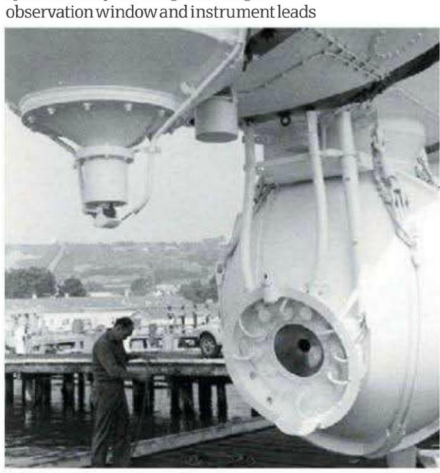
Half an hour later, after periodically observing this alien environment with high-powered quartz arc-light lamps – periodically as when activated they caused the water to violently boil – and discovering a multitude of life including a white flatfish, several shrimp and jellyfish, Piccard initiated the Trieste's ascent. The vessel had held, but at a depth of 10,916 metres (35,814 feet) the temperature of the pressure sphere was dropping continuously (the minimum recorded was just seven degrees Celsius/45 degrees Fahrenheit); if they were not careful, there would be no return. Three hours and 15 minutes later, the Trieste re-emerged into the daylight and human civilisation. The vessel and its crew had been to a world only envisioned in fiction and returned with field-changing information.

Key to the data gathered was establishing the existence of life at the bottom of Earth's deepest ocean. This revealed that not only were there creatures impervious to extreme atmospheric pressures, but also that water at this depth wasn't stagnant. This was a clear indication that ocean currents even penetrated these extreme depths, so they should not be used as a dumping ground for radioactive waste. Unfortunately, despite this first-hand evidence, dumping of this kind still continues throughout large parts of the world to this day.

Today the legacy of the Trieste is being built upon, with numerous programmes currently underway focused on designing new vehicles to return to this uncharted territory. The most high profile of these is Richard Branson's Virgin Oceanic, which intends to return to the bottom of the Mariana Trench in the latter part of this year.



A close-up view of the Trieste's pressure sphere, clearly showing the Plexiglas observation window and instrument leads



5 TOP FACTS TRIESTE TRIVIA

Launch
1 The Trieste was launched on 26 August 1953 into the Mediterranean Sea near Capri. It proceeded to operate in the vicinity for five years under the command of the French Navy.

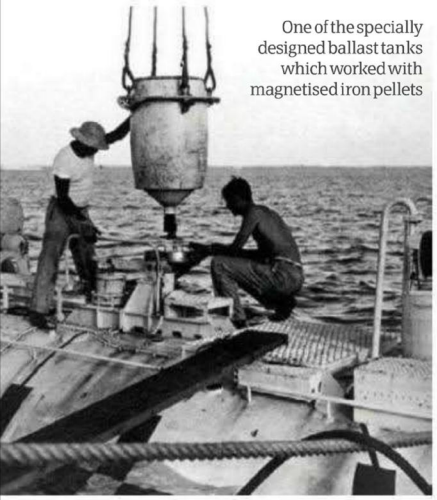
Purchase
2 In 1958 the Trieste was bought by the US Navy. It was used in Project Nekton, a series of dives in the Pacific Ocean near Guam, where it first entered the Challenger Deep.

Sphere
3 During the USA's ownership the Trieste was fitted with a new pressure sphere. This was produced by Krupp Steel Works of Essen, Germany, and weighed in at 13 tons.

Robots
4 No other manned vessel has returned from the Challenger Deep. In 1995 a Japanese robotic craft reached the bottom, as did a remotely operated vehicle in 2009.

Retirement
5 In 1980 the Trieste, which had been continuously redesigned for three decades, was retired and taken to the Washington Navy Yard. It's now housed in the US Navy's museum.

DID YOU KNOW? *The Trieste was designed by Swiss scientist Auguste Piccard – the father of Jacques who co-piloted it*



One of the specially designed ballast tanks which worked with magnetised iron pellets

Inside the Bathyscaphe Trieste

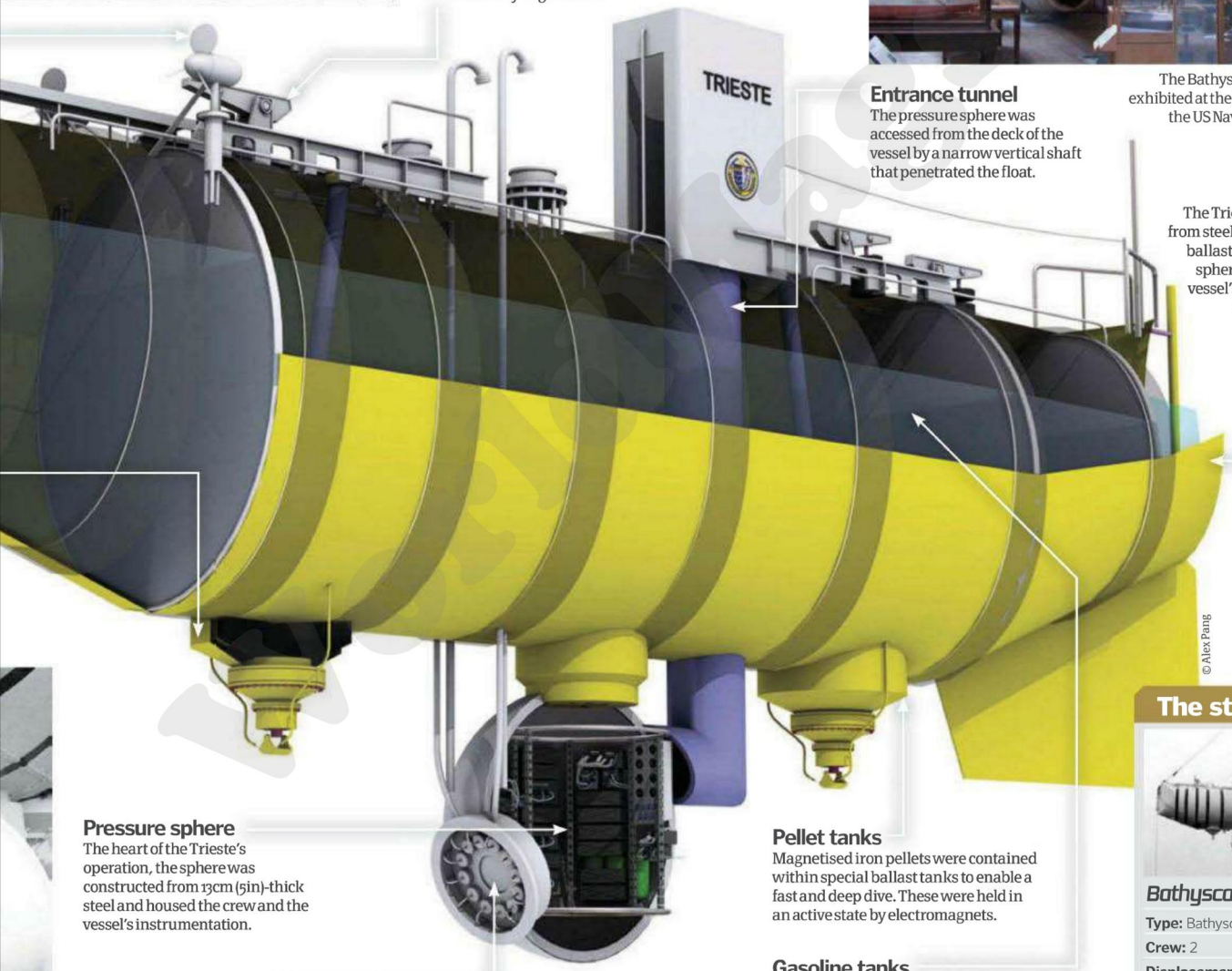
How It Works takes a look at the machinery and technology that enabled this record-breaking dive

The Bathyscaphe Trieste is now exhibited at the National Museum of the US Navy in Washington DC

Electromagnets
The magnetic iron pellets that allowed the Trieste to descend so deep were held in place actively by large electromagnets. As such, if there was an electrical failure, the vessel would automatically begin to rise.

Entrance tunnel
The pressure sphere was accessed from the deck of the vessel by a narrow vertical shaft that penetrated the float.

Hull
The Trieste's hull was made from steel and held numerous ballast tanks. The pressure sphere that contained the vessel's crew was mounted centrally to its belly.



© Alex Pang

Pressure sphere
The heart of the Trieste's operation, the sphere was constructed from 13cm (5in)-thick steel and housed the crew and the vessel's instrumentation.

Observation window
The only transparent material on the entire craft, the observation window was made from a cone-shaped block of shatterproof Plexiglas (acrylic glass).

Pellet tanks
Magnetised iron pellets were contained within special ballast tanks to enable a fast and deep dive. These were held in an active state by electromagnets.

Gasoline tanks
Due to the extreme weight of the pressure sphere, large gasoline-filled tanks were used to ensure neutral buoyancy. Gasoline was chosen as it is relatively incompressible at extreme pressures.

The statistics...

Bathyscaphe Trieste

Type: Bathyscaphe
Crew: 2
Displacement: 51 tons
Length: 18.1m (59.6ft)
Beam: 3.5m (11.6ft)
Draft: 5.6m (18.6ft)

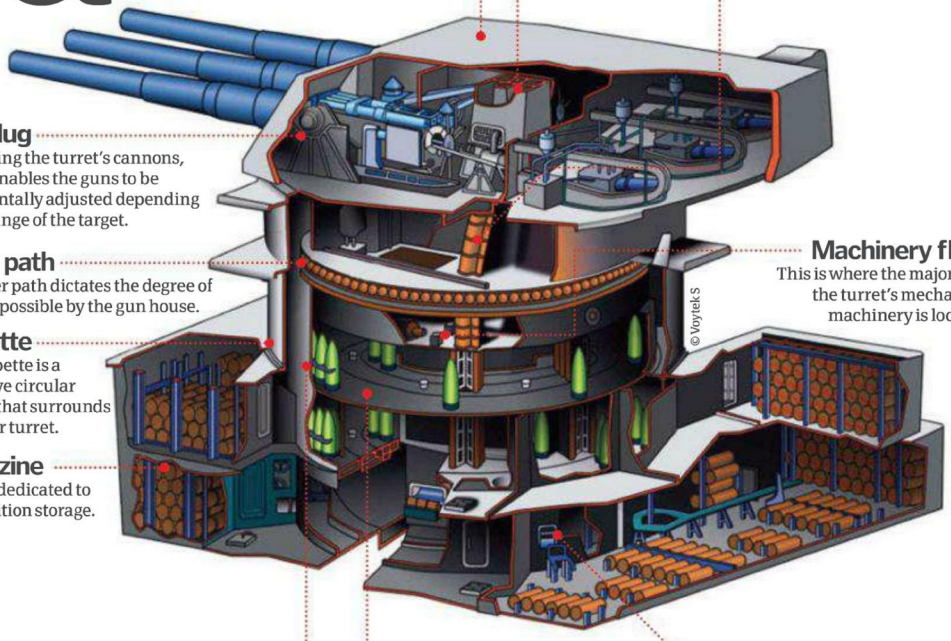
"One of the best modern-day examples of gun turrets can be seen on battleships"

Inside a gun turret

These armoured structures can soak up hefty damage while dealing out awesome firepower

A gun turret works by protecting the crew or computer mechanism of a projectile firing weapon, allowing it to operate with greatest freedom and safety. Gun turrets are often mounted on fortified buildings – such as anti-naval land batteries – or on military-grade vehicles such as APCs and aircraft carriers.

The turret itself can house a wide variety of armaments, often consisting of machine guns, automatic cannons, large-calibre guns or missile launchers, and is either controlled manually by its human crew or remotely by computer systems. One of the best modern-day examples of gun turrets can be seen on battleships, which have the largest cannons and the most sophisticated loading mechanisms.



Armoured gun house
The part of the turret that features its weaponry. This is the most exposed and therefore heavily armoured section of the structure.

Powder hoist
The element dedicated to lifting and loading the explosive substance into the cannon.

Projectile hoist
The ammunition of choice – often large-scale explosive shells – is hauled up from the projectile handling floor by this lift mechanism.

Deck lug
Supporting the turret's cannons, the lug enables the guns to be incrementally adjusted depending on the range of the target.

Roller path
The roller path dictates the degree of rotation possible by the gun house.

Barbette
The barbette is a protective circular armour that surrounds the lower turret.

Magazine
An area dedicated to ammunition storage.

Machinery floor
This is where the majority of the turret's mechanical machinery is located.

Turret foundation
This is the stationary part of the turret that provides it with a platform from which to rotate and absorb its blast shocks.

Projectile handling floor
A gun this size is mostly automatic, however crew-members are still required in most cases to transfer the ammunition from the magazine to the projectile hoist manually.

Powder handling floor
As with the projectile floor, the explosive substance used to propel the missiles must be manually loaded and this occurs here.

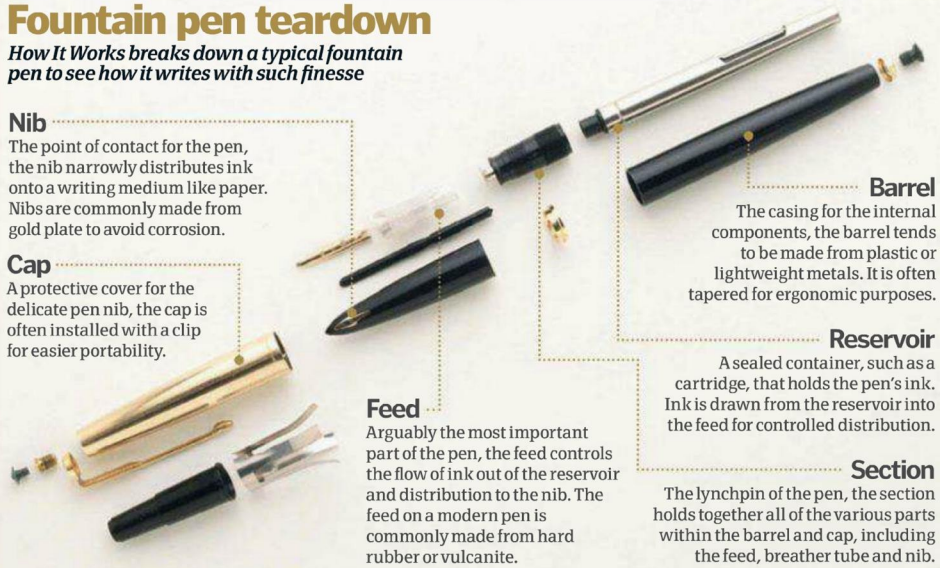
How do fountain pens work?

Considered the king of all writing instruments, this pen has a complex design and structure

Fountain pens work, in general, by transporting ink from a sealed container (usually a cartridge) through a hole, into a finned feed and down to the tip of the nib. As the nib comes into contact with a surface, such as a sheet of paper, the ink is drawn out of the nib through capillary action, causing more ink to be drawn through the feed from the sealed container. Importantly, as the container is sealed, a vacuum is created within as the ink is removed and this – in partnership with the ink's surface tension as well as its molecular attraction to the pen's metal nib – causes it to flow in a controlled and consistent way. It also means the ink ceases to flow when the nib is lifted.

Fountain pen teardown

How It Works breaks down a typical fountain pen to see how it writes with such finesse



Nib
The point of contact for the pen, the nib narrowly distributes ink onto a writing medium like paper. Nibs are commonly made from gold plate to avoid corrosion.

Cap
A protective cover for the delicate pen nib, the cap is often installed with a clip for easier portability.

Feed
Arguably the most important part of the pen, the feed controls the flow of ink out of the reservoir and distribution to the nib. The feed on a modern pen is commonly made from hard rubber or vulcanite.

Barrel
The casing for the internal components, the barrel tends to be made from plastic or lightweight metals. It is often tapered for ergonomic purposes.

Reservoir
A sealed container, such as a cartridge, that holds the pen's ink. Ink is drawn from the reservoir into the feed for controlled distribution.

Section
The lynchpin of the pen, the section holds together all of the various parts within the barrel and cap, including the feed, breather tube and nib.

5 TOP FACTS THATCHING TRIVIA

Guidebook
1 To this day the thatchers' bible is considered to be *The Thatcher's Craft* (1960) that details the complete history of the trade, as well as building techniques and tools.

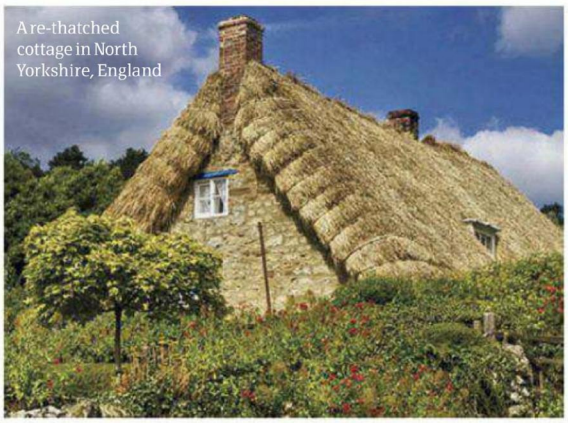
Premium
2 Due to their flammable materials, thatched roofs lead to a significantly higher insurance premium; the rate is higher still if the house has a working chimney.

Rose
3 Shakespeare's Rose Theatre was burnt to the ground due to its thatched roof. A burning wad of cloth ejected from a special-effects cannon is believed to have started the blaze.

Life span
4 Different thatching materials have varying life spans; water reed lasts 40-60 years, wheat reed 25-40 years, long straw 20-35 years and a new ridge (a top-up straw layer) 10-15 years.

Pitch
5 Not all roofs can be thatched. In order to thatch a roof it must have a pitch no less than 45 degrees, as otherwise rainwater can backwards penetrate the material and quickly ruin it.

DID YOU KNOW? *On average, 93 square metres (1,000 square feet) of roof space takes three to five weeks to thatch*


A re-thatched cottage in North Yorkshire, England


A professional thatcher re-thatching a 16th-century cottage with wheat straw

Thatching explained

This traditional – and now very pricey – craft requires a host of speciality tools and techniques

Thatching is the craft of building a roof with a variety of dry vegetation, ranging from wheat and water reed through to long straw and heather. The basic principle is to layer the thatch material in such a way that rainwater is shed away from the inner roof and off the side of the building, providing a waterproof barrier much the same as that granted by typical slate/tile-based roofs.

Any thatching operation starts with the preparation of the thatching material, with straws/reeds bundled together into a loose sheaf. The sheaf is then levelled off by first knocking it against the ground to force all strands to descend to the bottom, then secondly removing any remaining anomalies, and finally shearing off the bottom inch. This last step ensures that the sheaf has a neat, uniform finish. Once the sheaves (many are required) have been prepared, they can then be positioned on the roof.

The layering of the thatch begins at the bottom of the roof, where it is secured to the framework – or a turf substrate (foundation) running over the framework – with wooden or metal rods called sways. Once this base is in place, layering of the thatch begins proper, with hazel rods, referred to as spars, used to peg sheaves into position up the roof. The positioning of the spars and layering of the thatch ultimately determines the quality of waterproofing and the roof's life span.

The type of thatching material varies in both price and longevity too, with straw roofs typically lasting between 20 and 30 years, and reed lasting 30-60 dependent on type. Long straw is cut in the field with a binder and then threshed in a drum, and when applied to a house, typically requires a thickness of 40 centimetres (16 inches) to be effective. Reeds, on the other hand, are more robust and so are layered onto a building with a thickness of around 30 centimetres (12 inches).

Historically thatched roofs were associated with working-class housing, due to the abundance of wheat and free natural materials in rural areas. Today, however, thatched properties are typically far more expensive than slate-based equivalents due to the great drop in professional thatchers available, the limited quantities of cheap thatching materials and the higher-than-average maintenance costs.

"Hazel rods, referred to as spars, are used to peg sheaves into position"

Thatching step-by-step

Take a look inside a traditional 19th-century Irish thatched cottage to see how its roof was built

"Venice's canals, which run for a total of 42km (26mi), are built and maintained in a multi-stage process"

How Venice was built

How was the much-loved Italian city constructed on top of marshland?

Despite Venice being frequently voted the world's most beautiful city, on paper it appears to be a logistical and constructional nightmare. It is built, largely, on marshland – a lagoon which is just 8 per cent land, and one that contains some of the largest and heaviest religious and administrative buildings in Italy. And that's not even accounting for the dwellings of an estimated 60,000 residents and the risk (a very real risk as shown by history) of cataclysmic flooding. This, of course, raises the question: how does Venice keep above the water?

Key to its construction is an ancient method of using raised foundations, which effectively elevate ground zero to a height where buildings can be safeguarded from tidal waters. This involves the hammering of thousands of pilings – large wooden stakes commonly made from alder – through the water and into the underlying sand and clay. Each piling is positioned very closely to its neighbouring stake, one after the other, ultimately forming a raised wooden platform. Once a certain number of pilings has been driven into the earth, the tops are evened off and a substrate (or foundation layer) of wood and marble laid over the top. It is upon this which Venice's buildings are constructed.

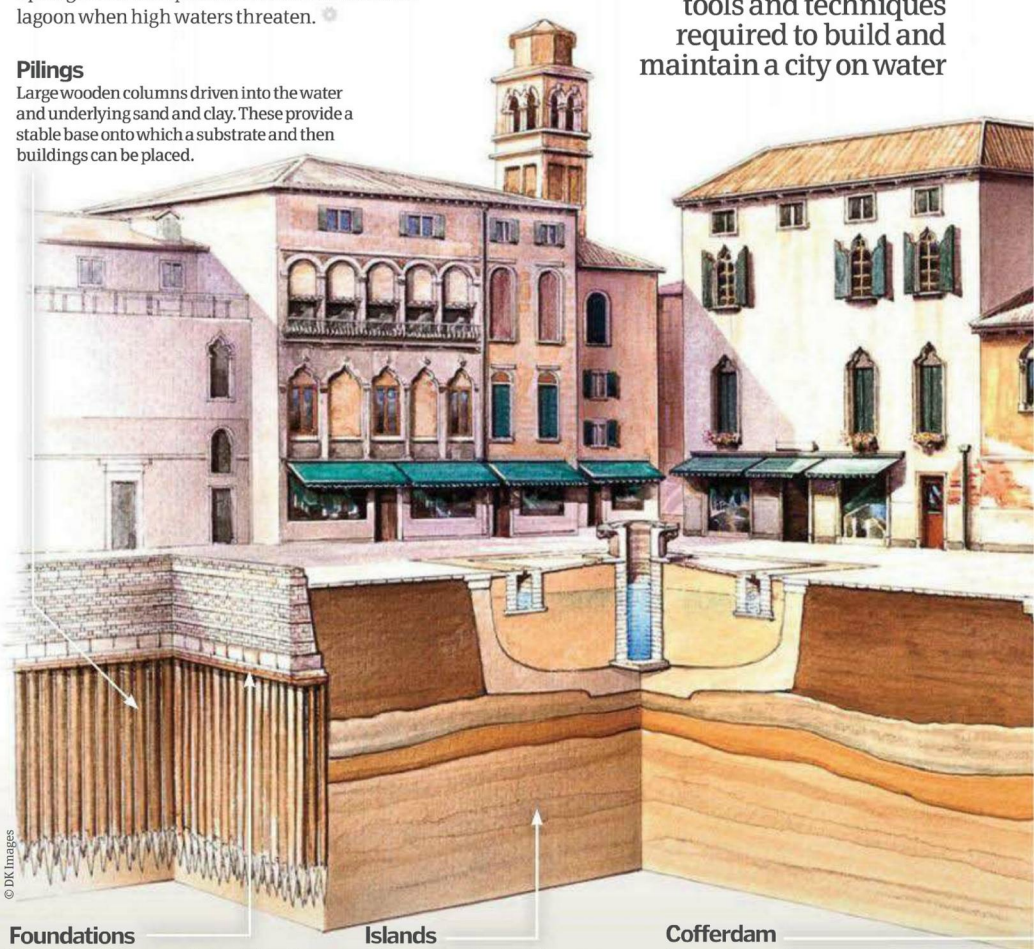
Of course, raising buildings out of the water is but one half of building in Venice – the other being to successfully channel the lagoon's waters into commutable highways. Venice's canals, which run for a total of 42 kilometres (26 miles), are built and maintained in a multi-stage – and never-ending – process that begins with the construction of a cofferdam. A cofferdam is a temporary barricade that, once erected, allows a portion of the lagoon's waters to be blocked and redirected, which is necessary for any building work to take place. Once the damming structure is in place, the draining of the area can start, with industrial pumps removing any remaining water held in the channel. Next, large-scale dredging takes place, with huge diggers and cranes excavating the channel.

Once the channel is clear, engineers can begin fortification of the canal, utilising pilings, bricks, clay and – more frequently in recent years – cement to line and strengthen its core structure. Wooden pilings are still used today because, when submerged, the almost zero-oxygen environment of the canal preserves them incredibly well, as well as bolstering their strength further through petrification – an effect caused by the flow of mineral-rich waters in their immediate vicinity.

Finally, and most topically, Venice's construction is protected by a series of flood-prevention mechanisms. These range from the installation of conventional concrete dams around the city, through to a project initiated in 2003 (MOSE) to set up huge inflatable pontoons at the mouth of the lagoon when high waters threaten.

The floating city explained

How It Works breaks down the materials, tools and techniques required to build and maintain a city on water



Pilings
Large wooden columns driven into the water and underlying sand and clay. These provide a stable base onto which a substrate and then buildings can be placed.

Foundations
Venice's buildings are not placed directly onto pilings but rather a dual-layer substrate made from, firstly, planks of wood and, secondly, thick sheets of marble – the latter being water resistant.

Islands
Of course, very few buildings are built solely on pilings alone, with the Venetian Lagoon containing 117 small islands atop, or off of, which the majority of structures are assembled.

Cofferdam
To properly install or maintain existing pilings, as well as the canal walls themselves, engineers erect temporary dams called cofferdams in order to cut off/divert water flow.

5 TOP FACTS VENICE

Islands
1 Venice spans across 117 small islands in the marshy Venetian Lagoon of the Adriatic Sea. The lagoon itself stretches between the mouths of the Po and Piave rivers.

Plague
2 Between the mid-14th and early-17th centuries, Venice was hit by the plague no less than three times, with the 'black death' claiming more than 200,000 lives.

Sinking feeling
3 In the 20th century Venice began to sink, caused largely by the digging of many artesian wells in the vicinity. As a result, artesian wells were banned in the Sixties.

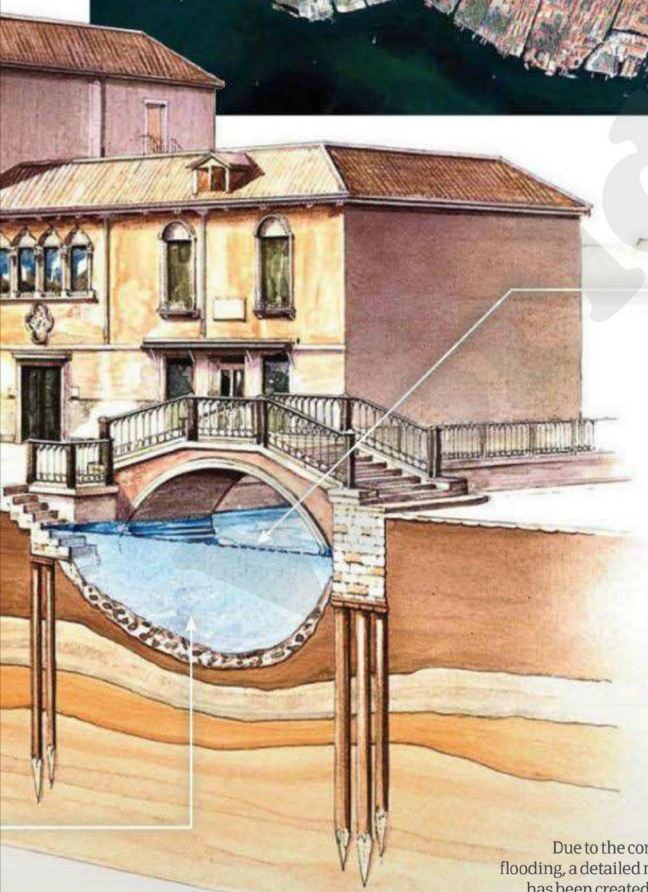
MOSE
4 In 2003 the Italian government initiated the MOSE project, which involves the creation of 79 inflatable pontoons across the entrance to the lagoon to reduce the risk of flooding.

Tourist hotspot
5 Venice is one of the most visited cities in the world, with a recent estimate stating over 50,000 tourists arrive daily. This number increases further during the famous carnival.

DID YOU KNOW? *Venice's name is derived from the ancient Veneti people of the 10th century BCE*

A satellite view of Venice showing its complex network of canals

© ESA



A floating excavator dredges debris from one of Venice's canals

© Nino Barbieri

Dredging

Dredging is an ongoing activity in Venice due to the buildup of debris in and around its canals. Floating diggers are used to haul the flotsam and jetsam into mobile skips.

© SPL

Due to the continual threat of flooding, a detailed model of the city has been created through which scientists can test certain scenarios to ensure better flood defences

BRAIN DUMP

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HOW IT WORKS EXPERTS

sciencemuseum

David Houston
Science Museum explainer

David has worked at the Science Museum for nine years. When he's not talking about science, he enjoys writing and recording music, hanging out in art galleries and watching foreign films.

Kate Mulcahy
Science Museum explainer

Before working as an explainer Kate was a teacher of maths, English and physics. In her spare time she plays rugby and likes making things such as clothes and cakes.

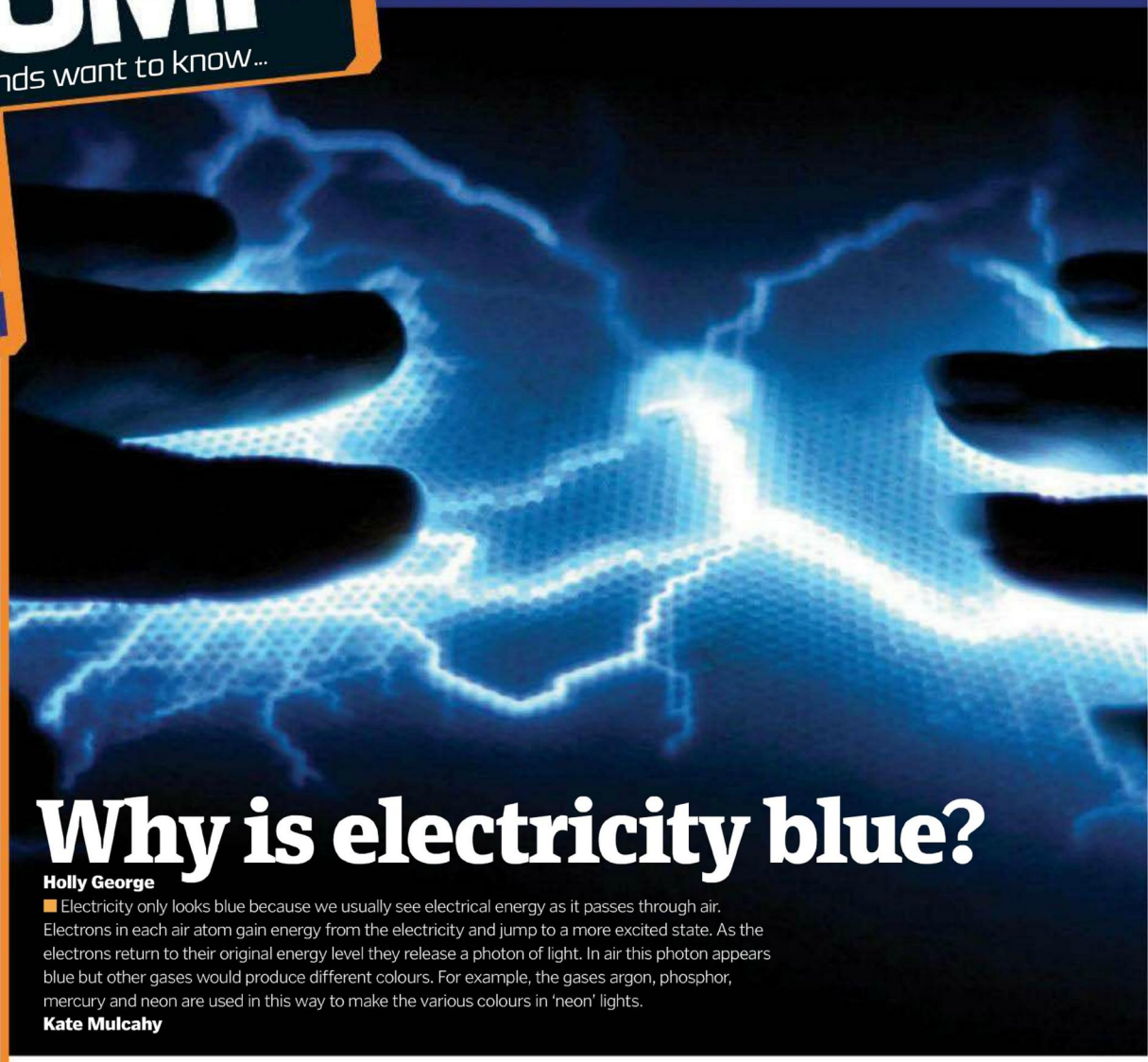
Andrew Brooks
Science Museum explainer

Andrew is an explainer at the Science Museum. He loves drawing robots and thinking about all the cool planets that exist across the massive universe. When not explaining he likes making as much noise as possible playing the drums.

Louise Thomas
Science Museum explainer

Louise previously worked as a freelance museum educator. She has an MA in Museum Studies, enjoys spaghetti bolognese and loves to play the not-so-talked-about sport of ten-pin bowling.

Who built the Sphinx?
Find out on page 82



Why is electricity blue?

Holly George

Electricity only looks blue because we usually see electrical energy as it passes through air. Electrons in each air atom gain energy from the electricity and jump to a more excited state. As the electrons return to their original energy level they release a photon of light. In air this photon appears blue but other gases would produce different colours. For example, the gases argon, phosphor, mercury and neon are used in this way to make the various colours in 'neon' lights.

Kate Mulcahy

There's an absolute zero, but is there an absolute hot?

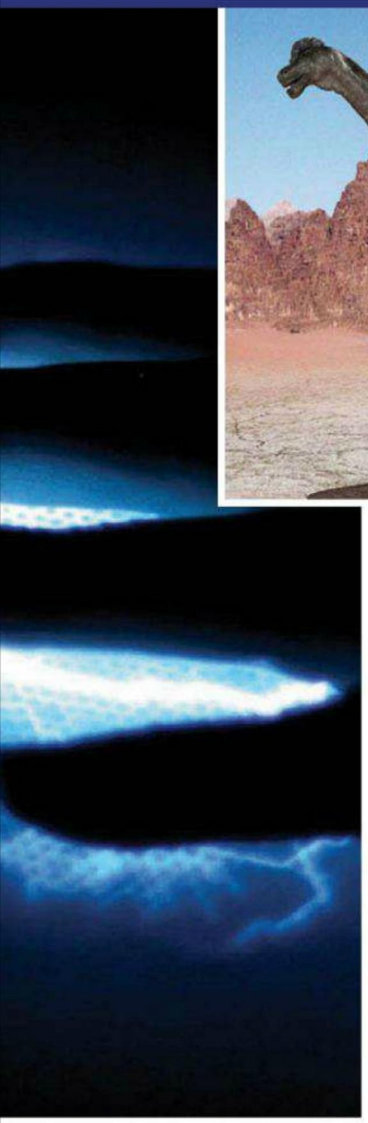
Is there a maximum temperature?

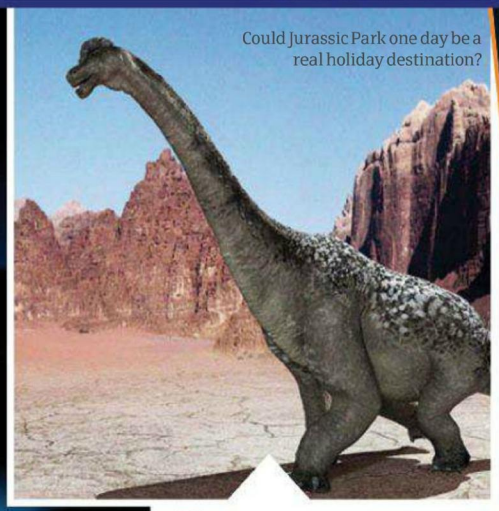
Mia McCarthy

All particles vibrate – and the more energy they have, the more they vibrate. We experience this as heat, which we measure with temperature scales. Nobody really knows if there is a maximum temperature, as it has never been reached. Some scientists suggest the Planck temperature of 1.41679×10^{32} Kelvin may be the hottest possible temperature as, according to Max Planck, above that the laws of physics stop working. However, in theory, there could be no limit to how hot something can get.

Andrew Brooks

Generally, only large objects in the universe have a spherical shape





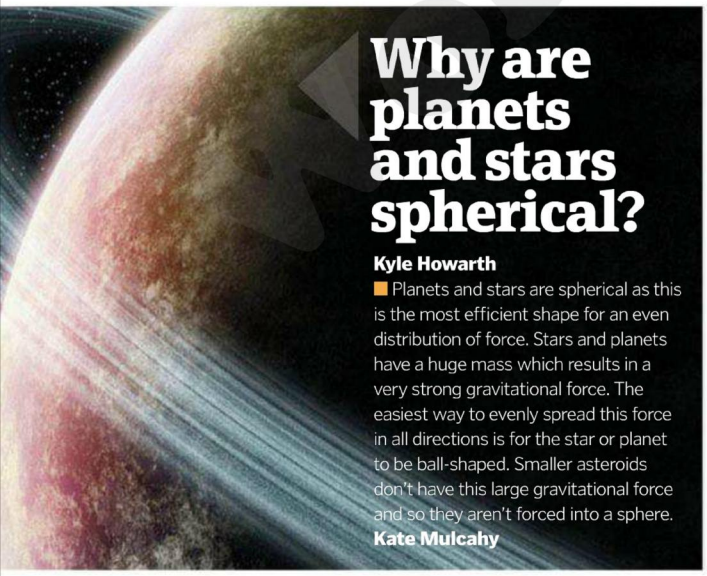
Could Jurassic Park one day be a real holiday destination?

Can we clone extinct animals?

Kai Burton

To clone an animal you must extract its DNA (genetic material) to form a cloned egg; this is then implanted in a surrogate mother. Extracting DNA from long-extinct animals, like dinosaurs, is hard as it's often damaged and incomplete. For more recently extinct animals it may be possible to find well-preserved DNA and use it to clone the animal. Scientists are now preserving DNA of endangered species, so although we have not been able to resurrect any creatures yet, one day in the future it may be possible.

Andrew Brooks



Why are planets and stars spherical?

Kyle Howarth

Planets and stars are spherical as this is the most efficient shape for an even distribution of force. Stars and planets have a huge mass which results in a very strong gravitational force. The easiest way to evenly spread this force in all directions is for the star or planet to be ball-shaped. Smaller asteroids don't have this large gravitational force and so they aren't forced into a sphere.

Kate Mulcahy

INSTANT GENIUS

Brush up on your physics with the help of a Science Museum expert

Throwing yourself out of a plane can be a real drag...

THE EXPERT

WHO: David Houston

David has been an explainer at the Science Museum for nearly a decade. Away from science, some of his biggest hobbies are writing, art, films and music.

What is terminal velocity?

Reece Hill

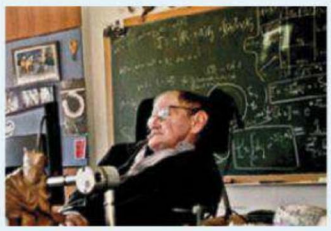
If a skydiver jumped from a plane then the pull of gravity would cause them to go faster and faster as they fall. At the same time, air resistance would create a slowing force called drag. The faster the skydiver fell, the more drag they would experience. At some point their speeding-up force (gravity) and their resistance force (drag) would be exactly equal and balance each other out. This would mean that they cannot gain any more speed and this is known as terminal velocity.

Terminal velocity also applies to vehicles such as aircraft, trains and cars. There is no point having a really powerful engine if the drag is going to stop it from propelling the vehicle, hence why aerodynamics is a major design consideration.

What's on?

Hidden Heroes

WHAT: Could you be bothered to brew leaf tea five times a day or fish the beans out of your morning coffee? Hidden Heroes shines the spotlight on the overlooked inventions we couldn't live without. The inventions are presented alongside original sketches and drawings by their inventors, patent specifications and original adverts. The exhibition reveals the efforts made to establish each product, as well as sharing quirky titbits of information.
WHERE: First floor
WHEN: Until 5 June 2012
PRICE: Adults: £6, Concessions: £3.50, Family: £16



Stephen Hawking: A 70th birthday celebration

WHAT: The world's most famous physicist, Stephen Hawking, is in his 70th year and, to commemorate this, the Science Museum has raided its archive to produce a display that offers an insight into his life. Objects include everything from academic notes, personal photographs, the script from the episode of *The Simpsons* in which he appeared, the suit he wore for his zero-gravity flight in 2007 and even a recorded message from the great man himself.
WHERE: Ground floor
WHEN: Until 9 April 2012
PRICE: Free

Further information

For further information, visit the What's On section at www.sciencemuseum.org.uk.

Visit the Museum

Exhibition Road, South Kensington, London, SW7 2DD. Open 10am-6pm every day. Entry is free, but charges apply for the IMAX 3D cinema, simulators and special exhibitions.

BRAIN DUMP

Because enquiring minds want to know...

HOW IT WORKS EXPERTS

MANCHESTER 1824
The University of Manchester
The Manchester Museum

Kate Sherburn
Curatorial assistant of Natural Sciences at The Manchester Museum

Kate works with the Zoology and Palaeontology collections at the Museum. She is particularly interested in aquatic biology, especially sharks. She travels all over the world to see animals in their natural environment.

Bryan Sitch
Curator of Archaeology at The Manchester Museum

Bryan has been curator of Archaeology at The Manchester Museum for five years. Before he has worked for museums in Hull and Leeds. At the moment he's working on the Ancient Worlds display.

Campbell Price
Curator of Egypt and Sudan at The Manchester Museum

Campbell is currently busy redeveloping the Ancient Worlds galleries, opening in October. He travels to Egypt a lot to work on archaeological projects. Follow him at **http://egyptmanchester.wordpress.com**.

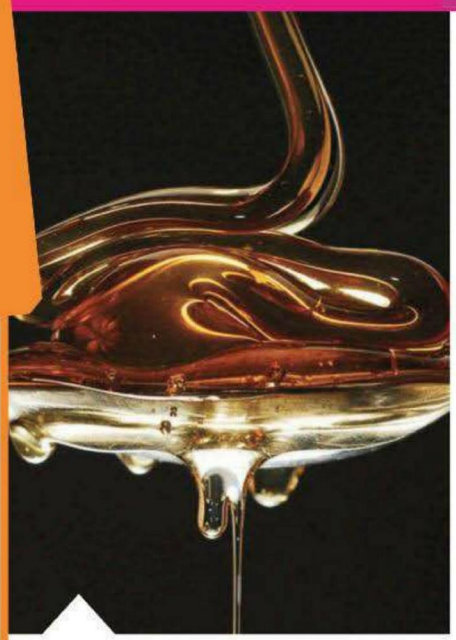
Andrea Winn
Curator of Community Exhibitions at The Manchester Museum

Andrea has been working at The Manchester Museum for four years in outreach and engagement. She has a background in social and economic history.

Who invented the barometer?
Find out on page 84

Want answers?

Send us your questions using one of the methods opposite and we'll get them answered



Can honey go bad?

Eve Lynch

Honey is the only food that does not go off – indeed, honey found in King Tutankhamun's tomb was still edible. It has a high sugar content and antibiotic properties that act as preservatives. Over time honey becomes cloudy as the sugar crystallises, but this does not spoil it and you can dissolve the sugar by heating it gently. If moisture gets into the honey, though, yeast can grow, ferment and spoil the foodstuff, but so long as it is kept tightly sealed honey can keep indefinitely.

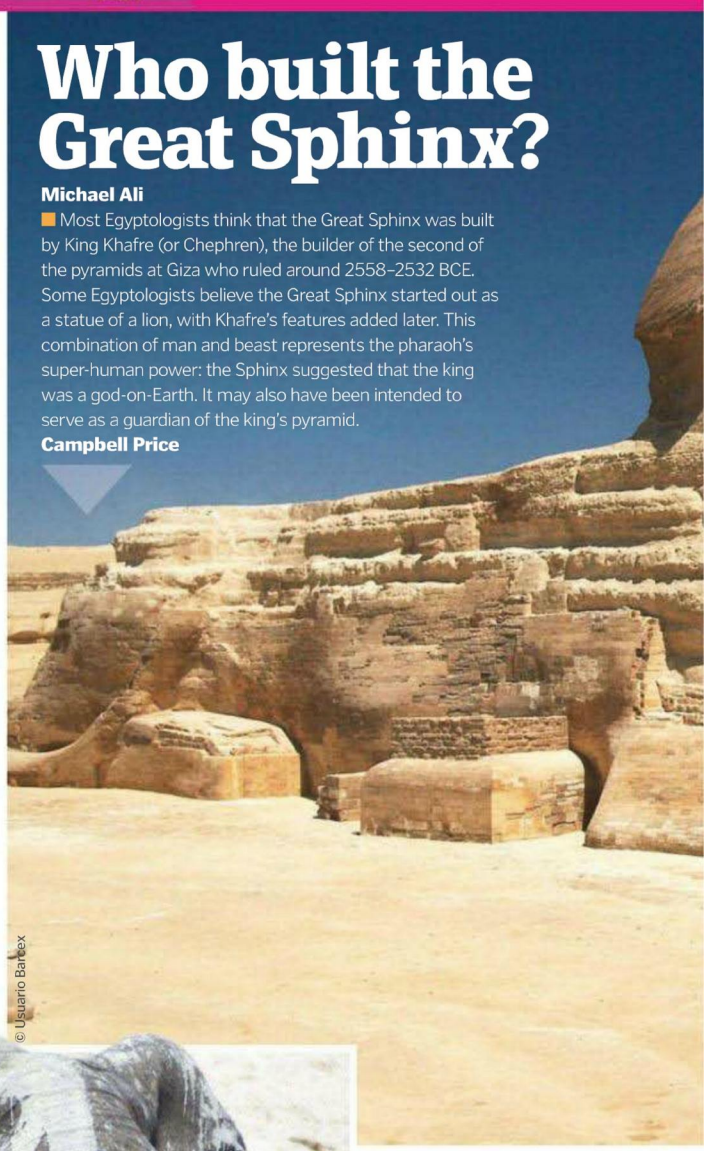
Kate Sherburn

Who built the Great Sphinx?

Michael Ali

Most Egyptologists think that the Great Sphinx was built by King Khafre (or Chephren), the builder of the second of the pyramids at Giza who ruled around 2558–2532 BCE. Some Egyptologists believe the Great Sphinx started out as a statue of a lion, with Khafre's features added later. This combination of man and beast represents the pharaoh's super-human power: the Sphinx suggested that the king was a god-on-Earth. It may also have been intended to serve as a guardian of the king's pyramid.

Campbell Price



Watch out, he's getting ready to jump... or not

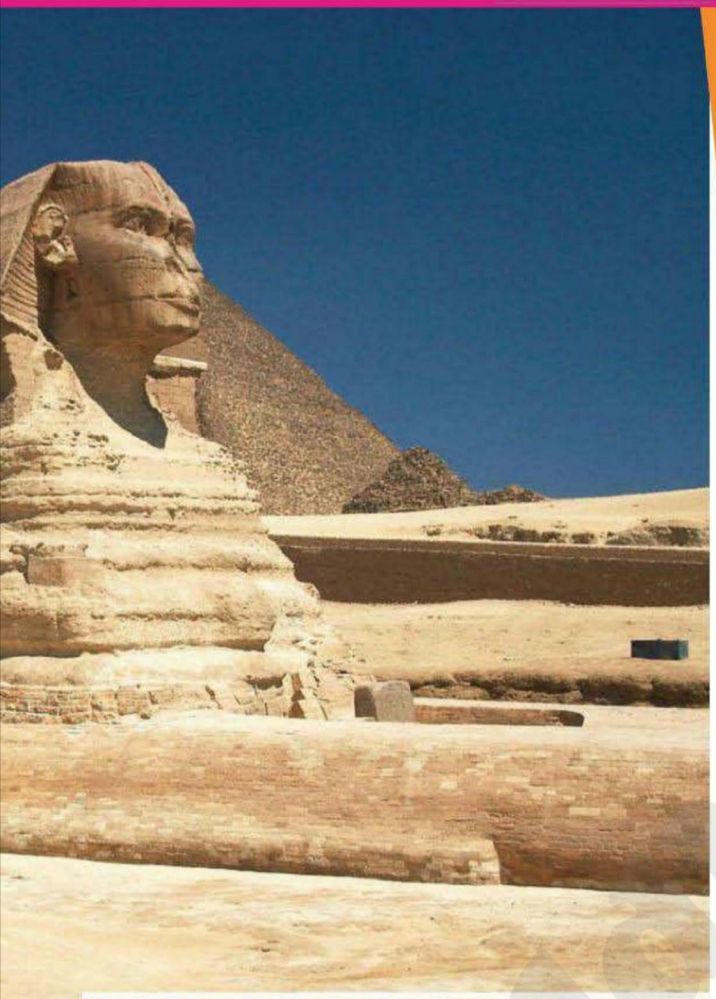
Can an elephant jump?

Laura Turner

As the world's largest land animal, weighing several tons, elephants are simply too heavy to jump. Their bone structure prevents them from bending their legs enough to push themselves off the ground. Elephants do not have natural predators so they did not need to be able to jump to improve their chances of survival. Elephants do not even like standing on two legs, although they can be trained to do so.

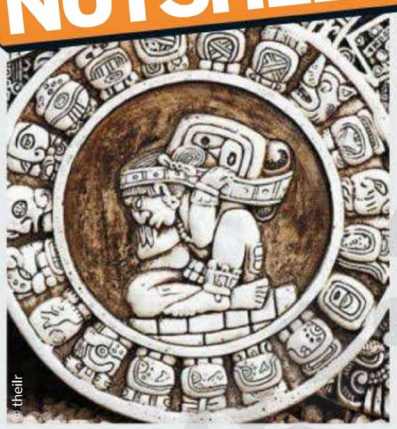
Kate Sherburn

How long do mummies last?
Find out on page 85



EXPLAINING COMPLEX TOPICS SIMPLY

IN A NUTSHELL



THE MAYAN CALENDAR

Katherine Cooke

Did you ever have a spirograph? The toy had different plastic wheels that meshed with one another and revolved like a clock mechanism. You had to insert a pen and move it round the wheel to create a series of increasingly complicated circular designs on a sheet of paper beneath. The Mayan calendar worked in a similar way.

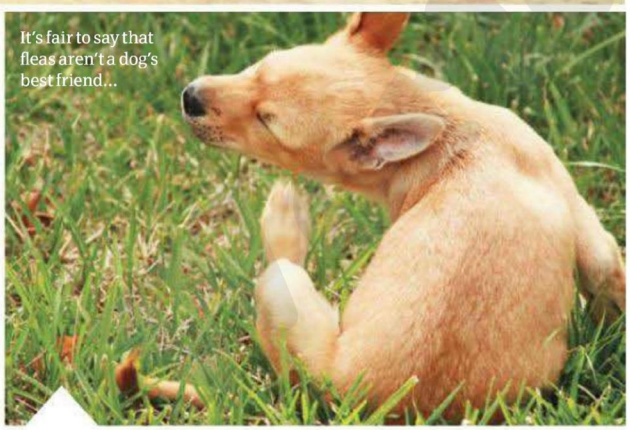
The first cycle in the Mayan calendar had 13 numerals and the second wheel had 20 named days. The two wheels revolved like a cogged mechanism, so it would be 260 days before the same point was reached again as the two circles rotated. This was then meshed with a third wheel of 365 days (known as the 'vague year'), but of 18 months instead of our 12. Each month lasted 20 days with a 'filler' month of five days.

The Mayans appear not to have worried about the extra quarter day (that's why it was a 'vague year'). We do allow for this and that is why every four years we have a leap year (2012 is one), in order to keep our calendar in sync with the movement of the Earth around the Sun.

The Mayan cycles would give a calendar of 18,980 days, or 52 years. For longer time spans there was the 'long count' with a unit of measurement called the bak'tun of 144,000 days. 13 of these bak'tun have passed since the cycle started in 3114 BCE and it ends later this year on 23 December – 1,872,000 days later!

People have speculated the end of this period of time will be marked by a terrible cataclysm that will wipe out the human race. As the Mayan calendar projects dates of anniversaries well into the future (long after 2012), I for one intend to sit back, not do anything rash and see what happens.

Bryan Sitch



It's fair to say that fleas aren't a dog's best friend...

What are fleas?

Toby Connor

Fleas are small (2-3 millimetre/0.08-0.1-inch) red-brown wingless insects that feed on the blood of mammals and birds. They are compressed side to side so that they can move through fur and feathers easily and have long legs that let them jump 100 times their height. They can survive for months without food and their young can live in our carpets and bedding. Flea bites are itchy and can cause allergic reactions. Fleas can also carry diseases such as bubonic plague and myxomatosis.

Kate Sherburn

What's on?

Unearthed: Ancient Egypt

WHAT: 100 years ago, many archaeologists carried out huge digs in Egypt, unearthing ancient objects such as toys, farming tools, stone carvings and burial goods. These discoveries give us an idea of what life was like for the Ancient Egyptians, from their home life and work to their language and beliefs. Travel back to the Twenties and enter the storeroom of our period Egyptologist, played on film by Terry Deary, author of *Horrible Histories* and *Egyptian Tales*.
WHERE: The Manchester Museum, Floor G Temp Exhibitions space
WHEN: Until 6 September 2012
PRICE: Free

The Museum Allotment

WHAT: See what's growing on our allotment. The allotment has been inspired by the Museum's new Living Worlds gallery which explores the connections between all living things, including us, and shows how we can all shape the future by the choices we make (such as growing our own food).
WHERE: Located outside The Manchester Museum
WHEN: Until autumn 2012
PRICE: Free

Tours of the Vivarium (live animals)

WHAT: Zoology students from The University of Manchester will share their knowledge of the animals and highlight the conservation and education work that both the Museum and University do. Monthly tours run in Spanish and French.
WHERE: The Manchester Museum
WHEN: Every Tuesday and Thursday, 12-1pm
PRICE: Free, but you must call beforehand to book a place

Further information

For further information, visit the What's On section at www.manchester.ac.uk/museum.

Visit the Museum
The Manchester Museum, The University of Manchester, Oxford Road, Manchester, M13 9PL
0161 275 2648
museum@manchester.ac.uk

What's the busiest Tube station?
Find out on page 86

Want answers?

Send us your questions using one of the methods opposite and we'll get them answered

HOW IT WORKS EXPERTS

National Museums Scotland

Alison Morrison-Low
Principal curator of Science

Alison is responsible for the collections of historic scientific instruments and photography. Her research interests include the evolution of scientific instruments, the history of the collections and Scottish photography.

Sarah Stewart
Assistant curator of Palaeobiology

Sarah is responsible for the curation of the invertebrate fossil and plant collections – particularly the molluscs and more problematic fossils. Her research focuses on fauna from the Silurian and Ordovician periods.

Aidan Dodson
Advisor for Fascinating Mummies

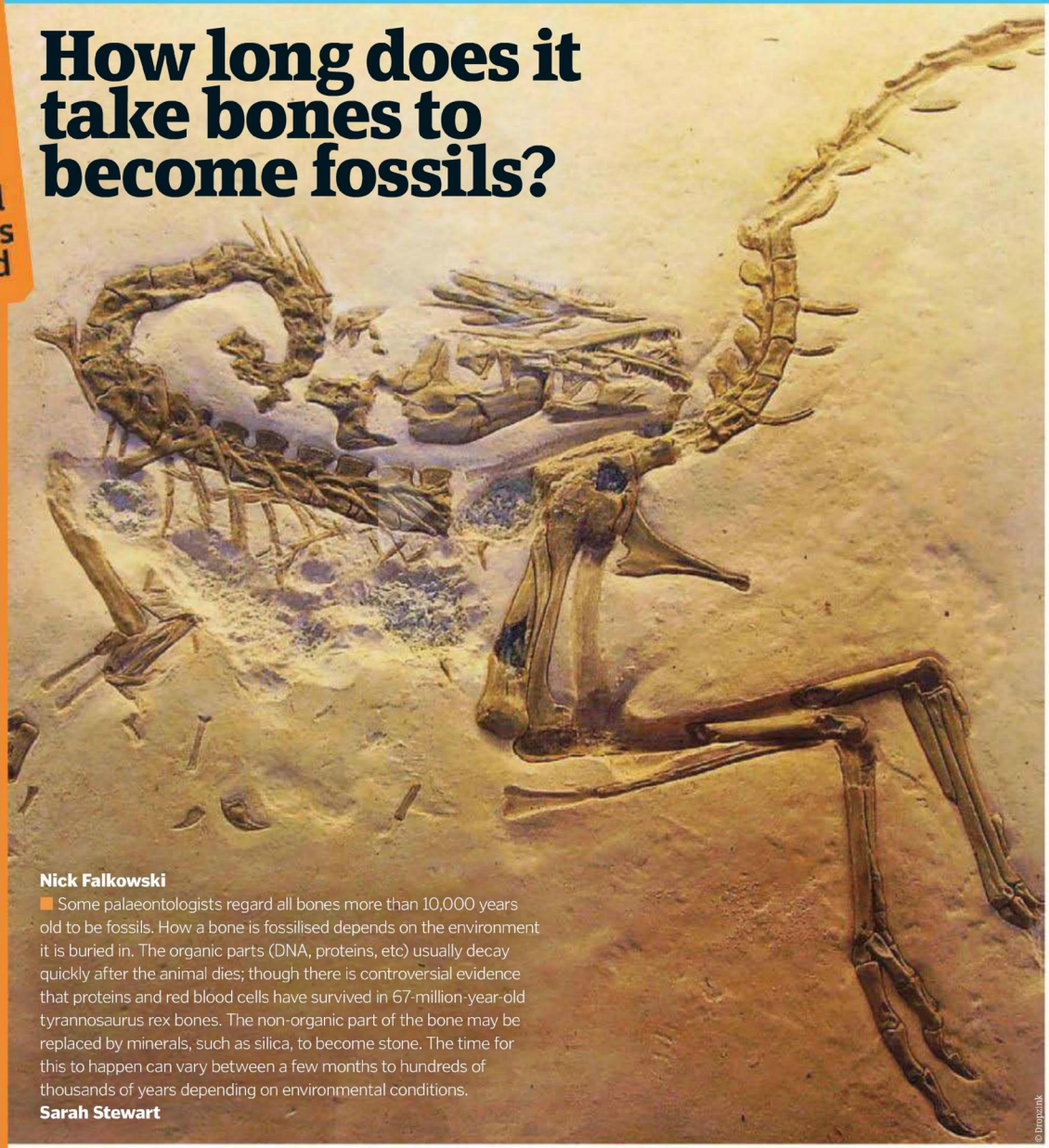
Aidan teaches Egyptology at the University of Bristol and is the advisor for the Fascinating Mummies exhibition, which is running at the National Museum of Scotland until 27 May 2012.

Tacye Phillipson
Senior curator of Modern Science

Tacye has a PhD in Physics and is now senior curator of Modern Science at NMS. Her job involves everything from artificial arms and astronomy to space rockets and zoetropes.

What is a hybrid bus?
Find out on page 87

How long does it take bones to become fossils?



Nick Falkowski

Some palaeontologists regard all bones more than 10,000 years old to be fossils. How a bone is fossilised depends on the environment it is buried in. The organic parts (DNA, proteins, etc) usually decay quickly after the animal dies; though there is controversial evidence that proteins and red blood cells have survived in 67-million-year-old tyrannosaurus rex bones. The non-organic part of the bone may be replaced by minerals, such as silica, to become stone. The time for this to happen can vary between a few months to hundreds of thousands of years depending on environmental conditions.

Sarah Stewart

Who invented the barometer?

Stuart Thomas

Evangelista Torricelli became court scientist to the Duke of Tuscany in 1642. He experimented with fountains in Florence and a long tube over ten metres (33 feet) high filled with water that was in his house. In 1644 Torricelli described how he took a glass tube about one metre (3.3 feet) long, sealed at one end, and completely filled it with mercury, which is much denser than water. Then, holding his finger over the open end of the tube, he inverted it under the mercury contained in a large bowl and removed his finger. The mercury fell to a height of about 76 centimetres (30 inches) above the mercury level in the bowl and stayed there. This is still called Torricelli's experiment and the space at the top of the tube above the mercury in barometers is known as the Torricellian vacuum.

Alison Morrison-Low

How many years can mummies last?

Mike Murphy

A mummy is a body from which most of the moisture has been removed by the use of a mixture of salts known as natron, after the valley in Egypt where it is found, and then wrapped in linen bandages. If kept dry, it can then last for ever – many have been found in perfect condition after up to 4,000 years. However, if they get damp, they can rot down to bare bones – which happened to the pharaoh Psusennes I, in spite of his tomb never having been touched by robbers.

Aidan Dodson

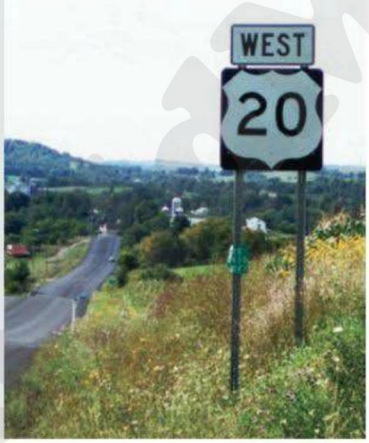
Mummies have lasted for several millennia

What's the USA's biggest road?

William Horan

Spanning a whopping 5,415 kilometres (3,365 miles), the US Route 20 is the longest road in America. The US 20 runs east to west from Boston, Massachusetts, at Kenmore Square, right through to Newport, Oregon, where it merges at an intersection with US Route 101 just a mile from the Pacific Ocean. Interestingly, the route passes by the famous Yellowstone National Park and, up until 1940, this is where the road terminated.

HIW



Who was the longest-serving pharaoh of Egypt?

Alan Pooley

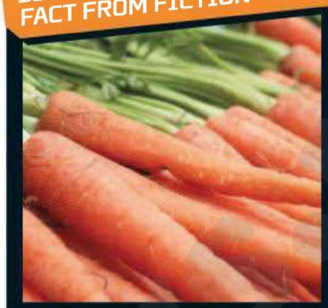
According to later king lists, Pepi II ruled for 94 years around 2200 BCE. However, contemporary documents only go up to the seventh decade of his reign, and it is not certain that he really ruled for that long. The longest fully documented reign is the 67 years of Rameses II, who came to the throne in 1279 BCE and built more temples than any other pharaoh. The next place is a tie between Thutmose III (1479 BCE) and Psamtik I (664 BCE), both of whom ruled for 54 years.

Aidan Dodson

TRUE FALSE

MYTH BUSTER

SIFTING HISTORICAL FACT FROM FICTION



Do carrots help you see in the dark?

Leanne Attwill

This myth isn't quite true, but the story of how it came about is quite interesting. First of all, carrots are rich in vitamin A, which itself has been linked with many health benefits. However, various tests and studies have conclusively proved that eating carrots will not improve your eyesight if it is already good. That being said, if you have a vitamin-A deficiency then it is likely that eating carrots *will* improve your night vision.

The origin of this myth stems from WWII. During the war Britain developed a new way to determine the location of Nazi bombers before they reached England, known as airborne interception (AI) radar. However, not wanting to alert the enemy to their new technology, the British government released various pieces of propaganda through the Ministry of Food stating that the new detection method was the result of pilots eating more carrots and being able to see the bombers more clearly in the dark. As well as fooling the Nazis, this story also encouraged British people to grow and eat more vegetables at a time when other goods such as meat were scarce due to rationing.

Verdict:

☐ True ☑ False

National Museums Scotland

What's on?

Reconstructing Lives

WHAT: Many have lost limbs as a result of war and it takes a lot of strength to get back on track. The medical field has strived to ease this process with prosthetic limbs – the focus of this evocative exhibition. See how they have developed over the centuries from metal hands to cutting-edge bionic limbs.
WHERE: National War Museum, Edinburgh Castle
WHEN: 9 March 2012-February 2013
PRICE: Free, with admission to the Castle

See Scotland by Train

WHAT: Over 30 striking posters give a flavour of what it meant to travel by rail over the past century. The posters depict some of the most scenic locations in Scotland and are works of art in their own right. See Scotland by Train will follow the changes in styles of railway art over the last 120 years, also showing how rail travel in the country has evolved.
WHERE: Exhibition Gallery 2, Level 3, National Museum of Scotland, Edinburgh
WHEN: 16 March-24 June 2012
PRICE: Free

Fascinating Mummies

WHAT: Ancient Egypt is a common theme at British museums and perennially popular, which just goes to prove one thing: we can't get enough of mummies! As well as the super-preserved stars, a host of tech helps bring the Egypt of yore to life.
WHERE: Exhibition Gallery 1, Level 3, National Museum of Scotland, Edinburgh
WHEN: Until 27 May 2012
PRICE: Adults: £9, Concs: £7.50, Children: £6, Members: Free

Further information

For further information, visit the What's On section at www.nms.ac.uk

Visit the Museum

National Museum of Scotland, Chambers Street, Edinburgh, EH1 1JF. Open daily 10am-5pm, including Sundays and bank holidays, but closed 25-26 December and hours are 12-5pm 1-2 January. Entry is free.

BRAIN DUMP

Because enquiring minds want to know...

Horse buses and trams explained
On page 87

Want answers?

Send us your questions using one of the methods opposite and we'll get them answered

Proudly associated with **London Transport Museum** www.ltmuseum.co.uk

HOW IT WORKS EXPERTS

london transport museum

Caroline Warhurst
Information services manager, London Transport Museum

Caroline is responsible for ensuring that the Library collection at the Museum is looked after and that all enquiries sent to the LTM are answered accurately. She also helps colleagues from Transport for London, designers and students with historical research.

What's on?

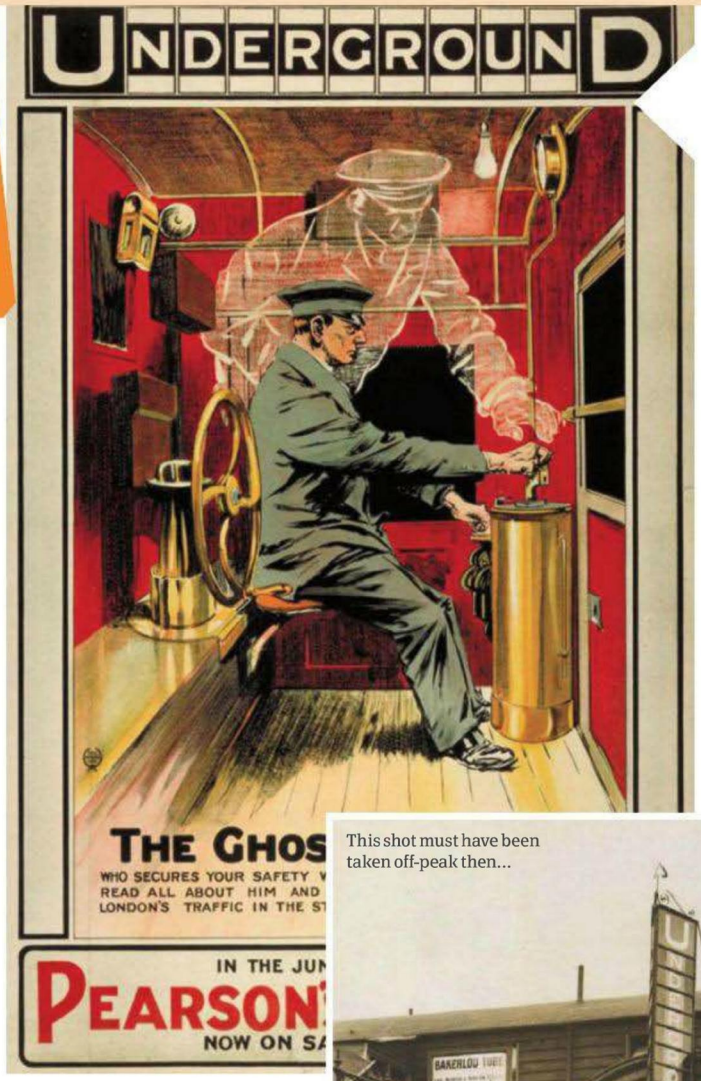
Sense and the City

WHAT: Love it or hate it, emerging technologies are transforming the way we live, work and play in our cities. London Transport Museum's special exhibition, Sense and the City, unravels the digital future and compares this with past visions of the future. Plus a new poster display – Painting by Numbers – complements the exhibition by showing historical versions of data visualisation – infographic posters at their best.
WHERE: London Transport Museum
WHEN: The exhibition and the poster display close on 18 March 2012
PRICE: Adults: £13.50, Concessions: £10 – allows unlimited entry for a whole year, Children: Free

Depot Open Weekend

WHAT: A rare opportunity to visit London Transport Museum's store in Acton, West London. It houses over 370,000 objects including road and rail vehicles, engineering drawings, signs, ephemera, posters and artwork. Highlights include curator-led tours of

When did taxis first get meters?
Find out on page 87



What is the dead man's handle?

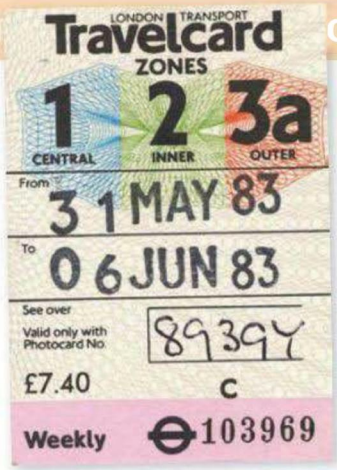
Simon Andrews

The 'dead man's handle' was designed to act in the event of a driver falling ill while on duty. With the introduction of electricity on the railways at the end of the 19th century the fireman was no longer needed, so the driver worked alone in the cab. The Ghostly Driver poster (1912, pictured) highlighted the alerting device, which consisted of a flat knob on top of the controller handle. This was supported by a spring weak enough to be held down without effort by the driver's hand when operating the controller handle. As long as the driver kept the knob down, the controller operated normally. If pressure was released for any reason (ie if the driver became unwell and lifted his hand) the current was immediately cut off and the brakes were applied. The device is still used today, but is more commonly called a vigilance device.
Caroline Warhurst

Which is the busiest Tube station on the London Underground?

James Rafferty

During the three-hour morning peak, London's busiest Tube station is Waterloo, with 57,000 people entering. The busiest station in terms of passengers each year is also Waterloo with 82 million. The original Tube station was opened in 1898 by the Waterloo & City Railway, which was not at that time part of the Underground. The Baker Street & Waterloo Railway operated its services there from 1906. It soon adopted its popular nickname, the 'Bakerloo' line, which persists to this day.
Caroline Warhurst



When were travelcards first introduced in London?

Denise Hall

Travelcards were introduced in 1983 and transformed attitudes to public transport in London. Passengers no longer had to have separate tickets for each part of the journey and, for the first time, the same ticket could be used on buses and the Underground across three zones (Central, Inner and Outer). By 1985 some 800,000 were in use. Today there are nine zones and Oyster cards account for millions of journeys. When Oyster pay-as-you-go was extended to all 350 National Rail stations in Greater London in 2010 it doubled the number of stations where Oyster was accepted, allowing it to be used on all National Rail, Tube, DLR, London Overground, London Buses, Tramlink services and Thames Clipper river services. By 2011, Oyster customers had made over 80 million rail journeys in 13 months.

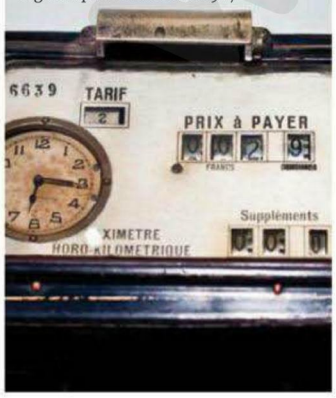
Caroline Warhurst

When did taxis first run on meters?

Tim Early

Taxi meters were made compulsory in motor cabs in July 1907 although a simple device to measure distance was used experimentally as early as 1847. Before meters became obligatory, resistance to any kind of regulation was fierce and overcharging was common. Once they became compulsory in motor cabs though, many horse-cab owners adopted them in order to compete for customers, even though they weren't required to have them. There were only 723 motor cabs on the streets of London in 1907 – hugely outnumbered by 9,789 horse cabs. However, by 1910 the position had reversed with a total of 6,397 motor cabs on the road compared to only 4,724 horse cabs.

Caroline Warhurst



Taxi meters have been a legal requirement since 1907

What is a hybrid bus?

Kimberley Bexon

Hybrid buses are an eco-friendly form of public transport. They are quieter, cleaner and more fuel-efficient than standard diesel buses. Hybrid buses reduce emissions of local pollutants and carbon dioxide by at least 30 per cent compared to conventional buses. The main thing that differentiates hybrid buses is that they combine a standard engine and an electric motor so that, overall, they consume less fuel. The hybrid buses in London also have regenerative braking, which means they produce electrical energy whenever the brakes are engaged. This energy is stored in a battery pack and used to power the motor, making them highly efficient.

Caroline Warhurst

What were horse trams and buses?

Fiona Ryan

Horse buses were pulled by two horses and carried up to 26 passengers. Horse trams were bigger and had metal wheels, which ran on smooth tracks in the road making them much easier to pull. Two horses could pull a tram carrying 50 passengers – twice as many as buses. Being able to carry more passengers than a bus with the same number of horses made trams cheaper to run, helping to bring public transport within the reach of ordinary working people for the first time.

Caroline Warhurst

Horse trams, introduced in the 1870s, were a lot more efficient than buses

London Transport Museum www.ltmuseum.co.uk

the small object store, rides on the Depot's miniature railway and trips on heritage vehicles. This year, the theme of the weekend is London's Transport in Miniature, which will feature working transport model layouts displayed in various sizes.
WHERE: The Museum Depot, 2 Museum Way, 118-120 Gunnersbury Lane, London, W3 9BQ
WHEN: Saturday and Sunday 10-11 March 2012, 10am-5pm
PRICE: Tickets valid for both days. Adults: £10, Senior citizens: £8, Concessions: £6.50, Under 16s: Free

Mind the Map: Inspiring art, design and cartography

WHAT: With everything from early hand-drawn maps to brand-new digital examples, this major exhibition will reveal how the field of cartography has evolved over the centuries. One of its main aims is to show how maps are not just a means of navigation but an excellent way to express creativity and artistic flair.
WHERE: London Transport Museum
WHEN: 18 May-28 October 2012
PRICE: Free

Artists' showcase: Play and the City

WHAT: Mobile devices and social media are having a dramatic impact on the way we use our city. Technology designed for navigation and communication purposes is being subverted by artists and gamers who seek alternative urban adventures. During the evening artists will share how mobile and social-networking tools can transform a city into an interactive playground. Produced in partnership with digital arts group onedotzero.
WHERE: London Transport Museum
WHEN: Friday 16 March 2012, 6.30-8.30pm
PRICE: Adults: £9, Concessions: £7 (includes a complimentary drink)

Further information

Further information about events and exhibitions at www.ltmuseum.co.uk. To book in advance call 020 7565 7298.

Visit the Museum

London Transport Museum, Covent Garden Piazza, London, WC2E 7BB. Open daily. Adult admission charged and allows entry for a whole year.

THE KNOWLEDGE

GAMES · BOOKS · GADGETS · TOYS

For connoisseurs of kit and savants of stuff

Archos 35 Home Connect Internet Radio

Price: £120/$130

Get it from: www.archos.com

The 35 Home Connect is both an impressive internet radio and an alarm clock. It comes with a program called TuneIn Pro, which will find all the stations you want to listen to. The speakers are great for such a small device and setting up is a breeze. However, we did have a couple of issues. For one, it's very bright, and if you plan to use it as a bedside alarm clock then you might have some trouble sleeping. The touchscreen controls are also pretty poor, with scrolling motions especially hard to execute. As far as basic web radios go, however, it's more than adequate, and with a low price to boot you won't be disappointed.

Pros:
- ✓ Simple setup
- ✓ Good speakers

Cons:
- ✗ Screen is too bright
- ✗ Poor touchscreen

Pros:
- ✓ Easy to use
- ✓ Excellent audio

Cons:
- ✗ Pricey

Pros:
- ✓ Colourful diagrams
- ✓ Accurate information

Cons:
- ✗ For younger readers only

Samsung MV800

Price: £200/$280

Get it from: www.samsung.com

While it might not boast some of the advanced features of similarly priced cameras, the MV800 is a great fun compact that has enough on offer to warrant serious consideration. The standout design feature is the 7.6-centimetre (three-inch) touchscreen that can be flipped 180 degrees; this allows you to stand the camera at an angle or easily take self-portrait or group shots. The smartphone-like software uses a tiled app UI to keep the menus clean and simple to navigate, making the camera incredibly easy to use. The 16.1MP sensor and 5x optical zoom also ensure you'll get high-quality images whether you're shooting in low or high light. The camera boasts a ton of both silly and serious shooting modes, from a funny face option to standard panoramic shots. Overall it's a nifty little camera and its small size ensures you'll be able to carry it about in your pocket without hardly noticing it's there.

Pros:
- ✓ Fun to use
- ✓ Simple menus

Cons:
- ✗ Limited features

HOW IT WORKS EDITOR'S CHOICE AWARD

Sony SRS-BTV25

Price: £149/$235

Get it from: www.sony.co.uk

This Bluetooth speaker oozes style, boasting both a super-sleek exterior and a hardy technical interior. Inside are two audio sources: a standard 20-millimetre (0.8-inch) speaker and a 56-millimetre (2.2-inch) woofer. The unique design projects sound in 360 degrees, ensuring that the whole room hears the rich sound. And rich it is, as the addition of a bass boost button raises the meatiness of the audio, giving an excellent listening experience. Any external music device can be connected to the speaker by either the Audio-In jack or Bluetooth, provided the device has it. An additional USB socket lets you charge your device while it plays music. This is an excellent product, and while it's a bit on the pricey side, it's perfect for all your portable audio needs.

My Tourist Guide To The Solar System And Beyond

Price: £9/$15

Get it from: www.dk.co.uk

This book from DK is an excellent beginners' guide to astronomy, providing detailed illustrations and information on a whole host of cosmic phenomena. From the surface of Mars to black holes, the text and images convey the wonders of space in a manner that young children will be able to understand and enjoy. By the same token, most of the information on offer, while accurate, is rather simplistic. You won't find in-depth analyses on any of the topics, but you will find basic facts that will at the very least give you a hunger for more. With that in mind this book is probably only suitable for younger readers but, nevertheless, it's still an excellent account of our solar system and beyond.

Pros:
- Ultra-powerful
- Lightweight design

Cons:
- Speakers not great

ASUS N55SF

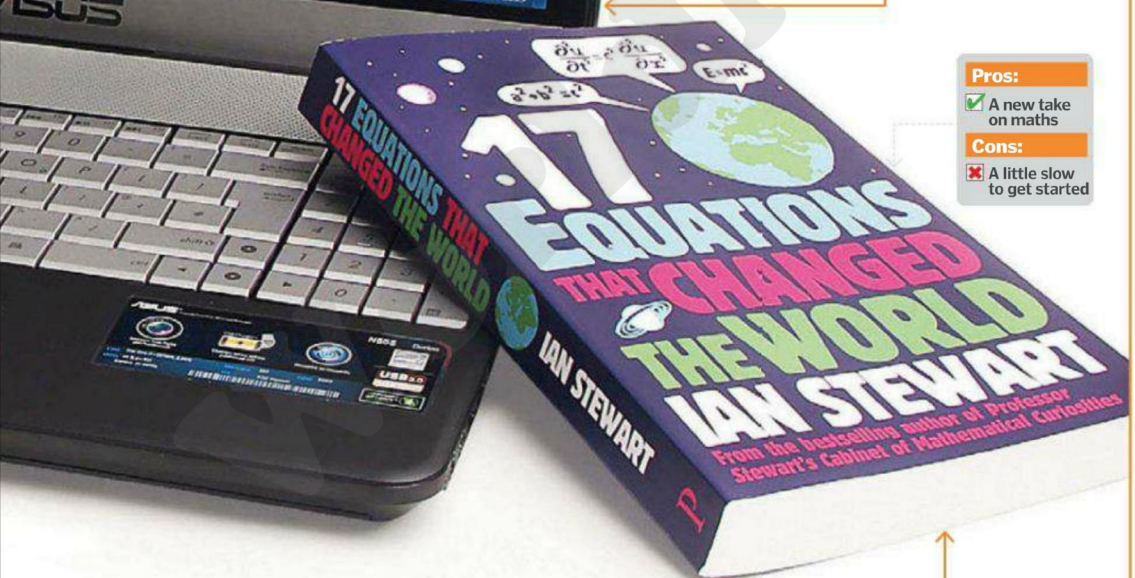
Price: £750/$1,300

Get it from: www.asus.com

This powerful laptop is the ideal desktop replacement on the inside, while its lightweight and minimal exterior also rivals most laptops around right now. Its price is aimed at the mid-range market but what's inside is anything but average as the powerful Core i7-2570QM processor makes this a very fast and impressive bit of kit. Included is also a Blu-ray drive and a top-of-the-range NVIDIA GeForce GT 555M graphics card, making this the ultimate entertainment laptop for gamers and movie-watchers alike. The chassis of the N55SF itself also looks great, with a deliciously sleek style ensuring this won't look out of place in any home or office. Our only grievance was the inbuilt speakers, which are a little weak when it comes to pumping out louder audio. However, this powerhouse of a laptop comes with a reasonable price tag and we'd be hard pressed not to recommend it.

Pros:
- A new take on maths

Cons:
- A little slow to get started



17 Equations That Changed The World

Price: £16/$25

Get it from: www.profilebooks.com

The title might not be the most appealing, but if you've ever wondered how maths is integrated into our everyday lives you'd be well worth checking this book out. Although text heavy and devoid of many diagrams, it makes for a fascinating insight that even those with just a basic understanding of arithmetic will enjoy. In addition to explaining complex topics, Professor Stewart successfully integrates just the right amount of history and modern-day exploits, giving the reader an overview of how important various equations are to us today. Once you get through the initial chapters, you'll unearth a brilliant read.

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

Smoovie

HOW IT WORKS EDITOR'S CHOICE AWARD

Price: £2.99/$4.99

Developer: Open Planet Software

Version: 1.0 / Size: 11.4MB / Rated: 4+

Smoovie makes stop-motion films easy. While you still need to take individual photos with an iPad 2, doing so is made simpler thanks to the huge number of stands that fit the tablet. Scenes can be reordered so you don't have to shoot everything in sequence and you can also add music from your library.

Verdict: ✪✪✪✪✪

Skeleton System Pro III

Price: £10.49/$14.99

Developer: 3D4Medical.com

Version: 3.0 / Size: 509MB / Rated: 4+

Using a host of multitouch gestures Skeleton System Pro III guides you through the intricate design of the human skeleton. If this app is a glimpse at the tech medical professionals will be using in years to come then it will make any visit to a hospital or medical centre a very interesting experience!

Verdict: ✪✪✪✪✪

iPhone

Hailo – The Black Cab App

Price: Free

Developer: Hailo Network Ltd

Version: 1.4.1 / Size: 6MB / Rated: 4+

If you've ever stood in the middle of a London street trying to grab a taxi, you'll know how difficult it can be, but Hailo is here to help. Your location will be pinned to a map and Hailo will display the nearest cabs, as well as an approximate wait time. To call a taxi, simply tap the 'Pick me up here' button.

Verdict: ✪✪✪✪✪

You can get daily app feeds by checking out **www.knowyourapps.com**

Action cameras

We put three all-purpose video recorders to the test

Pros:
- Simple interface
- Excellent video quality

Cons:
- At times can oversaturate
- In-built mic struggles with wind

Pros:
- Sturdy design
- Wide field of vision

Cons:
- Slightly loose outer case
- Tough to operate when moving

HOW IT WORKS EDITOR'S CHOICE AWARD

Pros:
- Low price
- Adjustability

Cons:
- Sound quality
- Average at high-speed

Replay XD1080

Price: £300/$450

Get it from: www.purelygadgets.com

If you're looking for a small and easy-to-use camera that can record HD video in a variety of situations, then the Replay XD1080 is a great choice. The camera itself is a cylindrical design that can attach onto a bike, helmet or other objects with either the included mounting device or the sticky pad. The camera records in 1080p through 115 degrees, making video quality excellent, although the microphone does pick up a bit too much wind at times. As you move from low to high light the camera does also slightly oversaturate, but for the most part you won't have a problem. The stand included with the set is adequate, if a tad small, allowing the camera to be rotated up and down and side to side but not by a huge amount. However, the simple interface is where this camera excels. On the top are two buttons and these are used to power the device and start/stop video recording, with a vibration that can be felt through a helmet letting you know your button-press has been registered, making it very practical when your hands are occupied. This is a light and well-constructed all-purpose camera for biking, skiing and any other times where you could do with a functional snap-on camera.

Verdict: ★★★★

GoPro HD Motorsports HERO

Price: £240/$375

Get it from: www.purelygadgets.com

In the world of versatility, the GoPro HD is king. Boasting a variety of mounts, a waterproof casing and exceptional image quality, the Motorsports HERO edition will handle almost any high-octane situation that you throw at it. Unlike the Replay the camera uses a basic display to sift through menus, which can at times be hard to read but otherwise does its job. You've got the option of recording in 1080p and 30 or 60 frames per second, while the wide-angle lens does a great job of capturing the action, ranging from 170 degrees for standard video to 127 degrees for 1080p. The mounting options are varied with chest, head, bike and handlebar mounts all available. The built-in microphone handles sound better than the Replay XD1080, although we found the camera in general a little trickier to use while out and about. The protective casing is a well-conceived addition for keeping the GoPro safe but it's not the best fit, so you might get a bit of wobbling. Overall, though, this is an excellent recorder that will enable you to capture high-quality video in all kinds of action-packed scenarios.

Verdict: ★★★★★

ContourHD 1080p Full HD Helmet Camera

Price: £140/$220

Get it from: www.purelygadgets.com

For rugged outdoor activities like paintballing, the ContourHD is the perfect companion. This small camera is incredibly tough, meaning it'll handle bumps and scrapes and still provide exceptional 1080p video. It boasts all the bells and whistles of the other cameras in our test including a microSD slot, LED activation lights and a USB port. The camera itself is very simple to use, and when wearing gloves it's easier to get stopped and started than the Replay or GoPro – just move the sliding bar at the top of the device to begin and stop recording. The wide-angle 135-degree lens can be rotated through 180 degrees, allowing you to get the optimal viewing angle. The image quality is good, if just surpassed by the other two products, but unfortunately the out-of-the-box sound quality isn't the best, so it won't handle high-speed excursions too well. However, this is an incredibly easy-to-operate camera designed for fast and jerky movements, so if you're planning to use it for on-foot outdoor activities it's probably the best pick. It also has a nice low price tag, so bargain hunters should be happy!

Verdict: ★★★★

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HOME EXPERIMENT

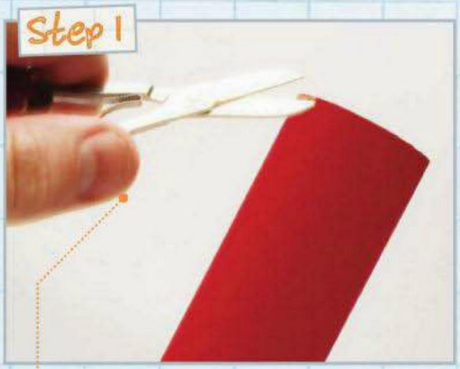
Make an elastic band racer

RUBBER BAND RACING CAR

Create your own DIY racing car from just a few everyday household items

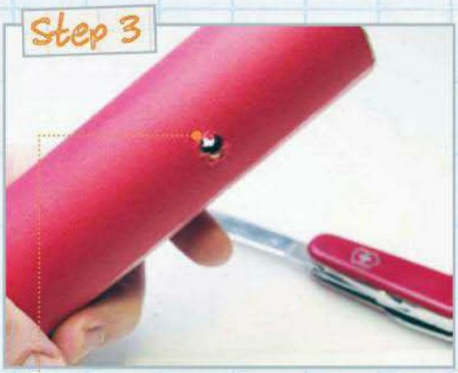
Equipment:

- 1 x cardboard tube
- 1 x sheet of coloured card/paper
- 1 x rubber band
- 1 x sticky tape
- 2 x pencil
- 1 x glue
- 1 x craft knife/scissors
- 1 x paperclip
- 4 x bottle top (identical)
- 1 x ruler



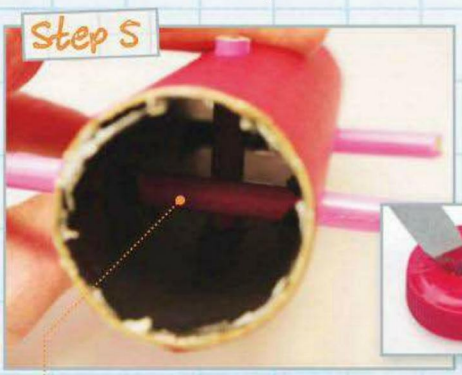
STEP 1. Take your cardboard tube and cut it to your desired length. Your racer can be any size, but the longer its body the stronger the elastic band you'll need; a length of 15-20 centimetres (six to eight inches) is ideal, unless you have some industrial-strength elastic in your house! Carefully cut the tube either with scissors or a craft knife on a stable, protected surface.

STEP 2. With your cut-down tube in hand, mark two pairs of level points about five centimetres (two inches) from each end. We'll use these as a guide to place our wheel rod slots. The rods are your pencils, so any hole will need to be slightly larger than their width. Once the points are drawn, take your cutting instrument and, with care, puncture the tube.



STEP 3. Put aside the tube and measure a pencil, scoring it at a length where it will extrude from either side of the tube. This will ensure there is plenty of clearance for the wheels, which will go on the ends later. Cut the pencil down and then repeat this step with the other. Once both pencils have been trimmed, slot them through the holes in the toilet roll.

STEP 4. Now we need to create another hole running vertically through the tube two centimetres (0.8 inches) behind the forward axle; this is for a fixed rod to attach our elastic band. Follow the steps used to create the wheel axles, except this pair of holes must not leave any room for the rod to move, so make sure the rod (a remaining piece of pencil) fits snugly.



STEP 5. Take your elastic band, slot the fixed vertical rod through it within the tube and then glue the rod in place so the band is stuck. Now unwind your paperclip and use it to hook the band towards the rear of the racer. As with the fixed rod, thread the rear rod through the band and replace it into its holes. The band should now be taut between the two rods.

STEP 6. Finally, puncture the lids and snap them in place on the axles. Then place the racer on an even surface, pull it back and release. If you have constructed it correctly the car should shoot off. Make a few and race them!

WHY NOT TRY...
Decorate your racer with coloured card, paper or paints – or why not increase the number of rubber bands to boost the power output?

GET IN TOUCH! If you have a go at our experiment either at home or at school, remember to send us some pics to **howitworks@imagine-publishing.co.uk** so we can see how you got on.

TEST YOUR KNOWLEDGE

ENJOYED THIS ISSUE? WELL, WHY NOT TEST YOUR WELL-FED MIND WITH THIS QUICK QUIZ BASED ON THIS MONTH'S CONTENT?

ENTER ONLINE

You'll find this How It Works Quiz on our new super-site. Enter online at **www.howitworksdaily.com** and five lucky readers will win a Muc-Off Screen Cleaning Rescue Kit.

1. COSMIC

Q: What is the largest moon in our solar system?

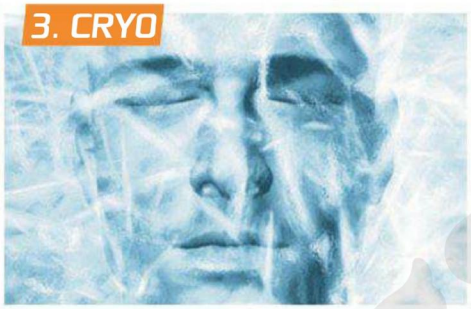
A:

2. 4G

Q: Which unit is a mobile phone's signal strength measured in?

A:

3. CRYO



Q: What is the coldest recorded temperature on Earth?

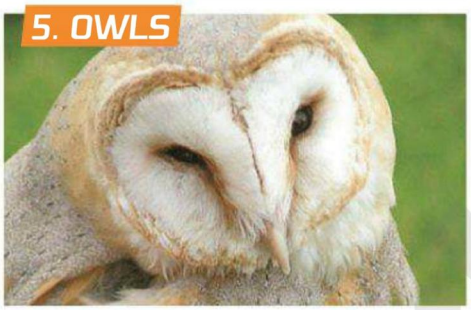
A:

4. VENOM

Q: Roughly how many species of venomous snake are there?

A:

5. OWLS



Q: What is the maximum degree that an owl can rotate its head?

A:

6. FLARE

Q: Which type of decoy flare is activated upon contact with air?

A:

7. VENUS

Q: Which was the first spacecraft to 'touch down' on another planet?

A:

8. THATCH

Q: What is the longest-lasting type of thatching material?

A:

9. VENICE

Q: Which ancient people is the city of Venice named after?

A:

10. RALLY

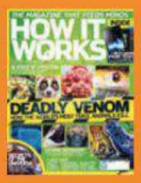
Q: How much horsepower can a Ford Fiesta RS WRC car produce?

A:

> *Answers to this month's quiz will be printed in the next issue of* ***How It Works***

HOW IT WORKS INBOX

Feed your mind. Speak your mind



Get in touch!

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, any science-related news you want to share, or just say hello...

Getting your five a day has never been more complicated...

© Rainer Zenz

Win! Annual Pass to INTECH Science Centre

Letter of the Month

Thyme for answers

I was very interested to read your article on the differences between fruit and vegetables in issue 30. However, it got me thinking as to what exactly herbs are. Is a herb a vegetable or a fruit – or neither? I was under the impression that herbs can be considered as either herbs or vegetables, but that all vegetables are considered as herbs. Is this true?
Alan Pooley

HIW: It all gets a bit complicated to be honest, Alan, but you're pretty much correct. It is often said that everything can basically be classified as an animal, mineral or vegetable, so under this classification herbs are considered vegetables.

However, to be more specific, in horticultural terms herbs are said to be herbaceous plants that have some kind of purpose (whether that's medicinal, edible or otherwise), while vegetables are those that are solely suitable for consumption.

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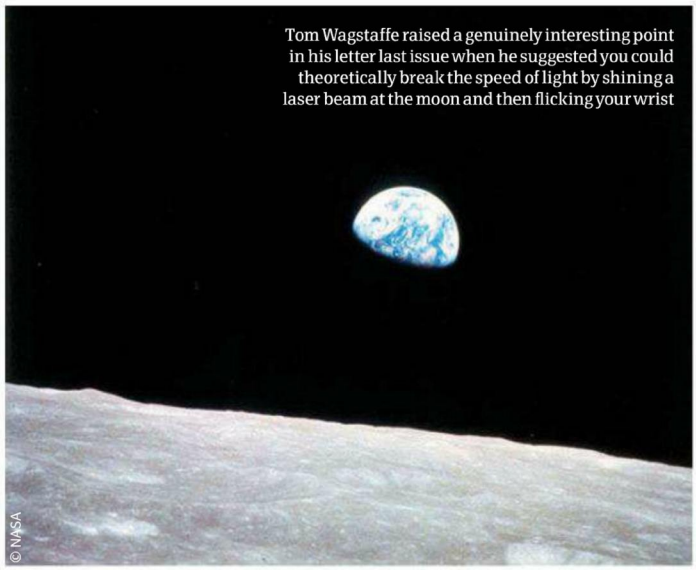


Tom Wagstaffe raised a genuinely interesting point in his letter last issue when he suggested you could theoretically break the speed of light by shining a laser beam at the moon and then flicking your wrist

© NASA

Apologies to Tom

HIW: We'd like to apologise to Tom Wagstaffe. Last issue (30), in an attempt to respond to his letter 'Laser speed' in a humorous manner, we misunderstood the question and were a bit abrupt in our reply. Tom, you are indeed correct in suggesting that shining a laser on the moon from Earth and moving it on the ground would appear to make it move a great distance on the moon in a short space of time – seemingly faster than light. Unfortunately, though, this is merely an illusion. It's not the same dot travelling across the moon, but rather different photons at each point reaching your eye. This 'faster than light' illusion is also prevalent in pulsars, which fire out jets of energy in vertical directions that can appear to travel above light speed due to the distances involved as they sweep around. We're very sorry for getting the wrong end of the stick, but we hope that we've now helped to explain this phenomenon sufficiently.

Make your own spectroscope

Good afternoon, I am trying to make a spectroscope as outlined in your recent magazine. Please can you tell me where I can obtain transparent CDs. All the ones I have are printed on one side.
Mrs C Watson (physics technician)

HIW: A few people have asked the same question. Our transparent CD came from a stack of regular discs. There is usually a transparent disc either on the top or bottom of the set. While this means you'll need to purchase a stack of CDs, you can get a box of ten for just a few pounds.

Oh, man!

I bought the first issue of HIW two years ago when I was abroad, living in Oman, and I absolutely loved it as I love, well, how things work! I was so happy that someone had brought out a magazine that is almost tailored to my passion. I downloaded the app for iPhone and thought I'd wait until I got an iPad to read the rest, since I thought an iPad would be better for viewing a mag like this. However, two years later, guess what I got? An iPad 2. I am now racing my way through the series, catching up on what I missed. Thanks for publishing such a brilliant magazine.
Edd Hulston

Is anyone there?

I have no doubt that there is life out there. There are billions of stars in our galaxy and there are billions of galaxies beyond ours in the universe – the closest being Andromeda, which you can actually see close to the Cassiopeia constellation. But I think ET is most definitely out there. The conditions for life are so specific that the chances of it are extremely minute, like looking for an orange and yellow-tinged grain of sand on a beach. But, if it happened here, why not anywhere else? Whether it is intelligent or not is the real question. As you may or may not know, we have been sending signals (I believe in the form of music and speeches) into space for years. What's funny is that if those signals have reached a planet with life that's not intelligent, it would go unheard. But if it is intelligent, then there

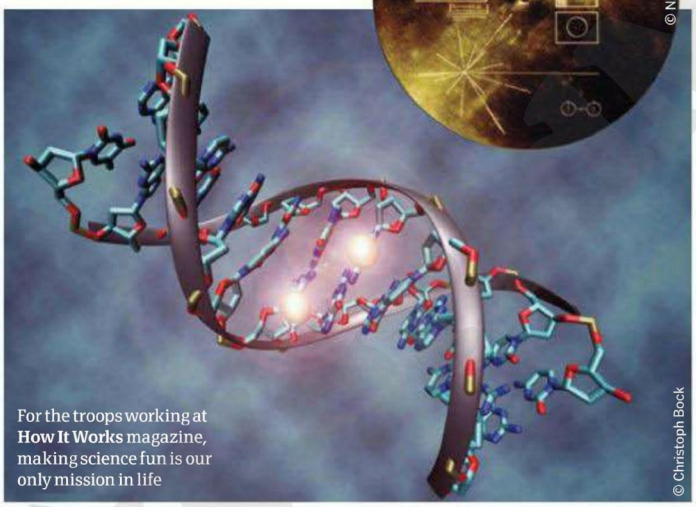
could be a reply on the way. This is very unlikely though. What's more likely is that when our signal reaches a planet with intelligence, they send one back. And the time it takes for all this to happen, we have destroyed ourselves or something else has. But we can dream...
BoothyLad

HIW: We'd be surprised if microbial life, or signs of past life, are not one day discovered on Mars, Titan, Europa or one of the other potentially life-harbouring planets and moons in the solar system. We've long been sending out signals and messages to potential alien races. For example, the Voyager and Pioneer probes both carry plaques (see photo right) with information like our position relative to nearby pulsars plus images and sounds from Earth. In addition, an intense radio beam known as the Arecibo message containing data about Earth was sent out in the direction of a globular star cluster 25,000 light years away, while any intelligent aliens listening in the direction of Earth might have heard one of the many other radio signals emitted from our planet. Whether we'll hear anything back in our lifetime is another matter.

Those who can...

I'm 15 and in my GCSE years. I've noticed that a lot of the Science section is relevant to my biology course and I find it a very useful revision tool. I hate biology mainly because of my teacher, but I found your article on DNA structure in issue 28 very interesting – I finally understand it. I don't suppose you could do an article on the central nervous system and the reflex arc? My teacher really is hopeless!
Edward

HIW: We didn't print your full name, Edward, in case you get in trouble! Glad we could help with your studies.



For the troops working at **How It Works** magazine, making science fun is our only mission in life

What's happening on... Twitter?

This month we asked you guys to submit your own queries for our 'Secrets of the universe' feature (over on page 13). However, not all of your questions made the cut, so here's the best of the rest. Do you know any of the answers?

vespr11 @HowItWorksmag Has the order of the planets in the solar system always been the same?

MRLOFT @HowItWorksmag My nine-year-old son wants to know how long it would take to get from Earth to Pluto

PnkShrtPlatypus @HowItWorksmag Why are there no dodecahedron-shaped planets? #howspaceworks #comp

mst3kuk @HowItWorksmag Do they celebrate Christmas on Mars? #howspaceworks #comp

Tasslehoff62 @HowItWorksmag How do we know how old space is, ie when the Big Bang took place?

EAgamer @HowItWorksmag Is dark matter really an alien interstellar civilisation's cloaking device?

No_youshouted @HowItWorksmag #comp Would it be possible to hear your own echo on any of the planets? If so, which ones?

TheHubbard @HowItWorksmag How does the variable specific impulse magnetoplasma rocket work? #howspaceworks #competition

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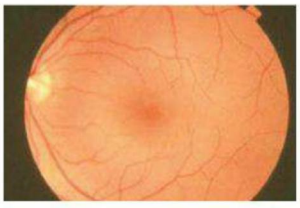

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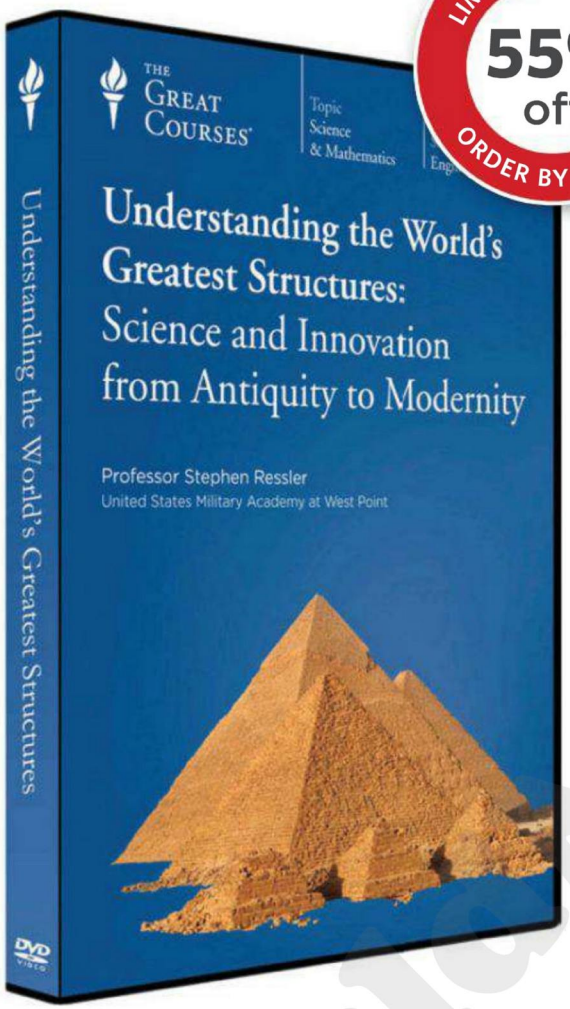

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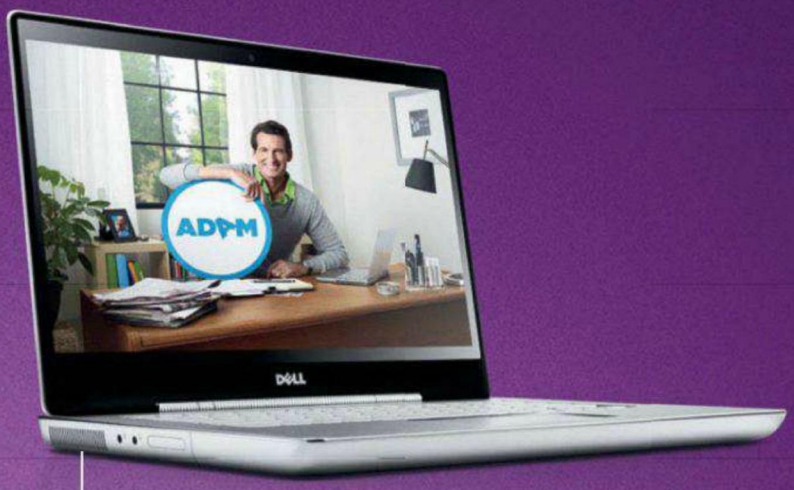

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