352 AMAZING IMAGES & CUTAWAYS INSIDE

THE MAGAZINE THAT FEEDS MINDS

HOW IT WORKS

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INSIDE

BRAIN SCIENCE
BIG BANG THEORY'S MAYIM BIALIK

20 HOME SCIENCE EXPERIMENTS
Magnetic cereal, levitating ice & more

SUPER SPACE DISCOVERIES
The biggest breakthroughs in the galaxy explained

SPY GADGETS

REVEALED: TOPSECRET TECH

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- NEURONES

INCREDIBLE INSECTS & BUGS

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A modern-day lesson in flying a real World War II plane

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ISSUE 63

WELCOME

The magazine that feeds minds!

Page 72
Staff writer Jack has a flying lesson in a plane that was used to train WWII fighter pilots

Time: Monday morning. Location: An undisclosed town in Dorset, Great Britain. Mission: To find the most sophisticated espionage gadgets in existence. Simple? Actually, it turns out that even the most mundane objects can be kitted out with cameras, microphones and tracking devices to dog your every move. The technology is so advanced and inconspicuous that we recruited former CIA agents to lift the lid on their most tried and tested tools.

Listening to their stories, we discovered that real-life spying isn't as explosive as the movies would have us believe, but it's every bit as cool. Today's spies don't need briefcases – they can wear their kit on their wrist, their face or send an insect drone to do the job. It's a far cry from the Cold War-era lipstick pistols and pigeons strapped with cameras, but you'll find all that and more in our feature. We'll be your Q and introduce you to the most mind-blowing gizmos in the spy universe.

Until next month, 007...

Jodie

Jodie Tyley
Deputy Editor

Meet the team...

Moe
Designer
Bzzz... I loved learning about how bees live and work together to protect their hive. Find out more about insects on page 64.

Erlingur
Production Editor
I'm convinced self-driving cars are the future and excited to see they're becoming safer than human-driven ones. Not that that takes a lot...

Jamie
Staff Writer
If you fancy yourself as a budding Albert Einstein, the 20 cool science experiments on page 30 are really fun to try.

Jackie
Research Editor
Go undercover with this month's spy gadgets feature and discover the amazing tech that real-life spooks use.

Hannah
Assistant Designer
See which is the biggest mountain in our universe on page 62. Here's a clue, its not Everest or Mauna Kea on Earth!

Jack
Staff Writer
This month, I went up, up and away in a WWII training plane. Check out my airborne aviation adventures on page 72!

What's in store

Check out just a small selection of the questions answered in this issue of How It Works...

Why do we suffer from hay fever? **Page 41**

How many species of insect are there? **Page 64**

How do roller coasters stay on the tracks? **Page 52**

How do mobile phone calls work? **Page 28**

What are the biggest mountains in space? **Page 62**

What's the story behind St Mark's Basilica? **Page 78**

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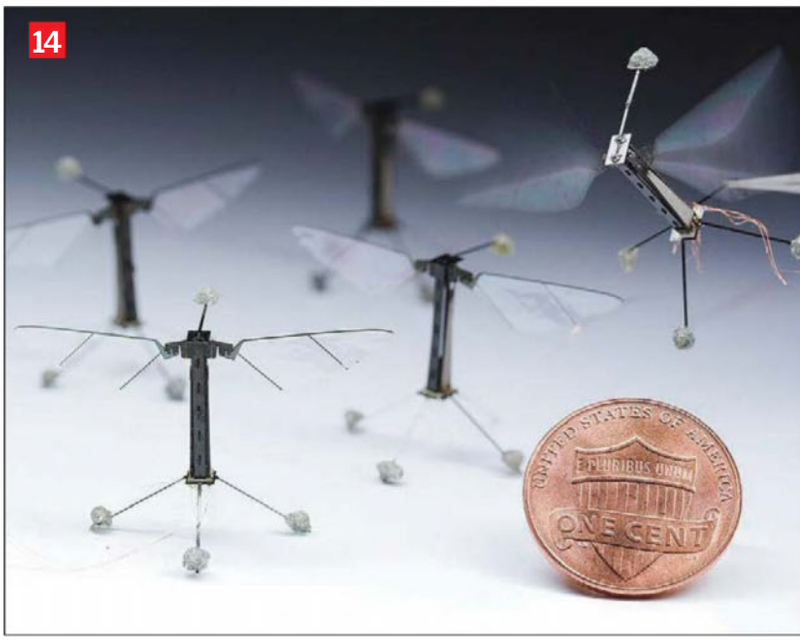
Revealed: The top secret tech in every agent's briefcase



TECHNOLOGY

SCIENCE

TRANSPORT

SPACE

ENVIRONMENT

HISTORY

Meet the experts...

Laura Mears
Amazing insects
Did you know that up to 85 per cent of all species on Earth are insects? This month, Laura wows us with the unbelievable facts behind some of the strangest bugs and shares her tips on how to spot them.

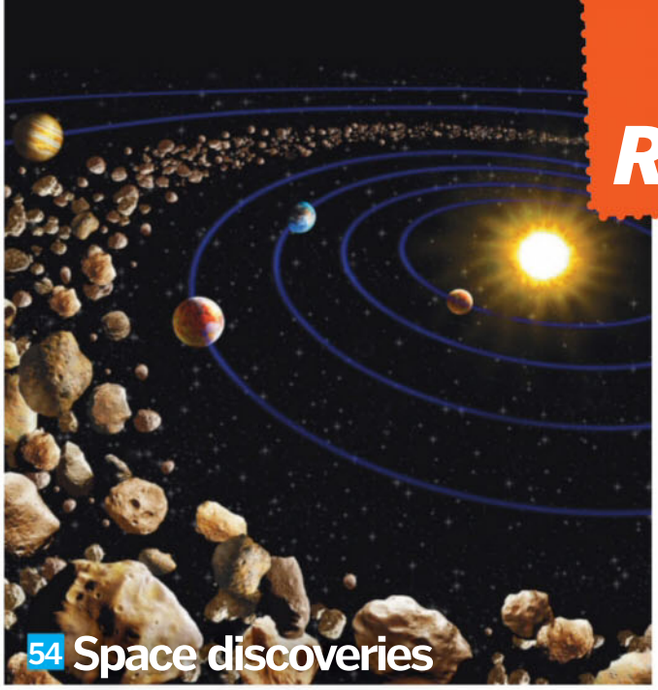
James Hoare
St Mark's Basilica
This month, James reveals the history behind Venice's most famous church, St Mark's Basilica, as well as all you need to know about King Kong's favourite climbing frame, the Empire State Building.

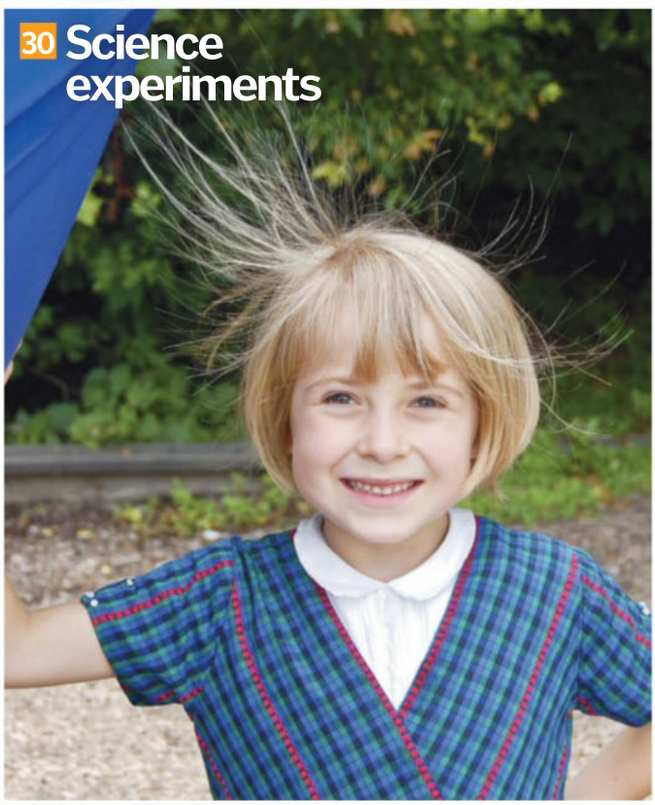
Lee Sibley
Self-drive cars
Lee explores the new tech behind autonomous vehicles and finds they're safer than the regular human-driven kind. As Editor of **Total 911** magazine, he's secretly hoping they don't catch on...

Giles Sparrow
Space discoveries
Space expert Giles counts down the top 50 discoveries in the galaxy. This year marks 50 years of European space exploration, so what better way to celebrate?

Aneel Bhangu
Heart transplants
Aneel takes us through the intricate steps of heart transplants. You'll be amazed at how surgeons perform this life-saving operation. A word of warning, though, it's not for the faint-hearted.

Did ants really help to give humans bigger brains?
Find out on pg 10





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Driving in the sky

A network of sky cars is coming to Tel Aviv

Tired of trams and buses? The SkyTran is set to revolutionise public transport. Using a Personal Rapid Transit (PRT) system, it is quiet and energy efficient and will have no traffic on its high-speed guideway. The proposed system will use magnetic levitation (maglev) technology and will travel between 40 and 160 kilometres (25 and 100 miles) per hour. The two-seater vehicles will be propelled by Linear Synchronous Motors (LSM) and will require virtually no maintenance. Designed to be more affordable and energy efficient than both cars and public transport, the first SkyTran is set to debut in the Israeli city of Tel Aviv by the end of next year.

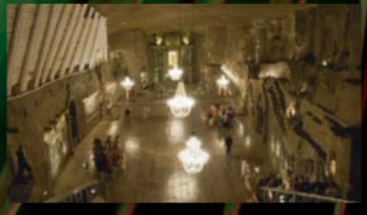
Cave bouncing

A brand-new underground trampoline cavern

Deep down in a Welsh Victorian slate mine, the world's first subterranean playground has been constructed. Known as 'Bounce Below', there are two vast chambers of nets, which are linked by giant walkways and slides one of which is a massive 18 metres (60 feet)! Accessible by a specially built train, a vividly coloured light display illuminates the giant cavern, which is twice the size of St Paul's Cathedral.

Amazing man-made underground structures

Wieliczka Salt Mine, Poland
Located close to the city of Krakow, the mine was originally built in 1290 and produced salt until its closure in 2007. Its caverns are so large, the mine houses an entire cathedral!



Burlington, UK
This 14-hectare (35-acre) 'underground city' is 30m (100ft) below the city of Corsham in Wiltshire and could hold up to 4,000 government personnel in the event of nuclear war.

Derinkuyu, Turkey
60m (196ft) underground, Derinkuyu city could shelter 20,000 people and was first constructed in the 8th century BCE. It was extended in the Byzantine era and is linked by a complex network of tunnels.

ABOVE Dinner service in full flight at the crane-suspended table

Dinner with a view

Fancy having your dinner while suspended from a crane? Incredibly, you can now do just that

If you don't like heights, this particular restaurant will definitely be off the menu for you. Suspended 50 metres (164 feet) in the air, the table can take up to 22 people for a 50-minute meal. Customers are strapped into a safety harness for the entire meal and can see breathtaking elevated views of the surrounding urban jungle at both day and night. Owned by the Four Seasons hotel in the financial district of Shanghai, China, each stomach turning ascent will cost you between 1,888 and 8,888 Yuan (£178-836 / $304-1,432).

Brand-new magazine is now out!

Learn new things every month with How It Works Illustrated

How It Works is delighted to announce that a brand-new magazine hit the shelves on 31 July! **How It Works Illustrated** is a travel-sized 132-page magazine filled to the brim with vivid, colourful illustrations and varied interesting articles for the whole family. Each issue will focus on a particular topic such as planet Earth, space or ancient civilisations. Engaging, educational and simple to follow, **How It Works Illustrated** is ideal for anyone who believes learning can be fun.

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Stephen Hawking headlines Starmus 2014

Science festival has a stellar line-up

It's only the second year for the Starmus conference on the island of Tenerife, but it's rapidly making a name for itself as the Glastonbury of science festivals. Stephen Hawking (pictured) and evolutionist Richard Dawkins have been confirmed as keynote speakers, as well as astrophysicist and Queen guitarist Brian May, Russian cosmonaut Alexei Leonov (the world's first space-walker) plus Apollo 16 astronaut and youngest person to set foot on the Moon, Charles Duke. The six-day festival will take place from 22 to 27 September.

GLOBAL EYE

10 COOL THINGS WE LEARNED THIS MONTH

Aeroplane cabins are getting smarter

Introducing the IntelliCabin, a new type of airline cabin system from BAE Systems. The new development will include wireless tablet entertainment and a control panel to make a journey's temperature and lighting just right. It will aim to create a relaxed and comfortable environment while also providing brand-new technology to passengers and could be seen on flights as early as 2015.

Organs can be supercooled

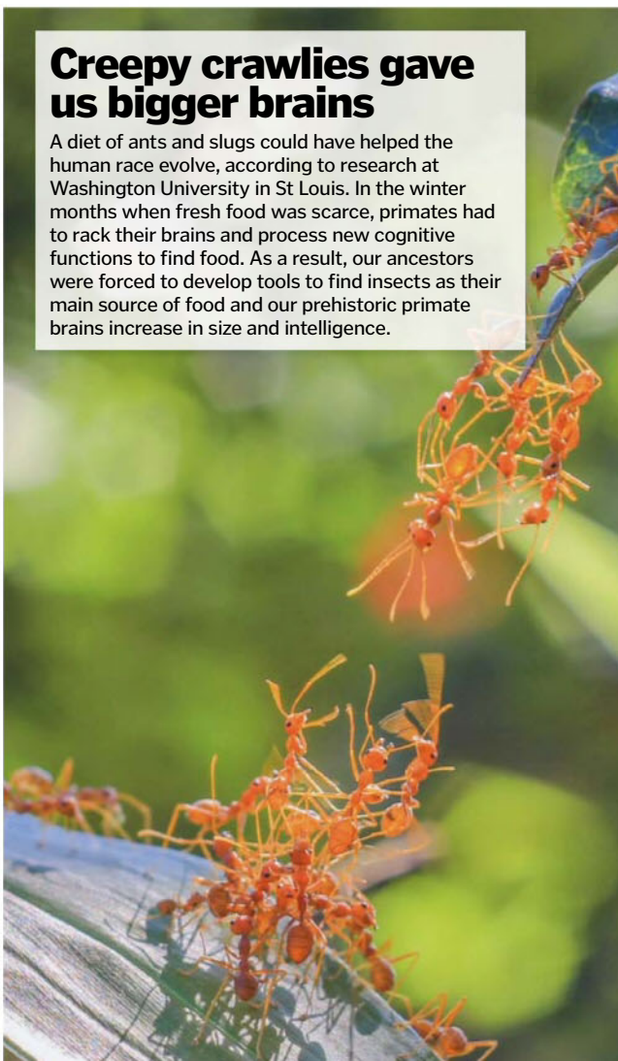
A new development in medicine could transform the world of organ donation. Scientists have discovered that 'supercooling' human organs by chilling cells can slow the deterioration process and give them a better chance of being used in future operations and transplants.

Flying saucers are being made

Looking much like a classic B-movie alien spaceship, NASA's latest vehicle could soon be on its way to Mars. The Low-Density Supersonic Decelerator (LDSD) is the first of three in a project that is designed to improve landing technology for future missions to the Red Planet. This 'saucer' is in fact a parachute that will be deployed from a high-altitude balloon.

There's a cure for garlic breath, at last!

Experts have found a remedy to garlic breath: green tea and apples. The smell of garlic is created by sulphur, but apples and green tea (as well as milk and lemon juice) contain an oxidising enzyme that neutralises the odour through a chemical reaction. So you can have garlic bread, as long as you put the kettle on afterwards.

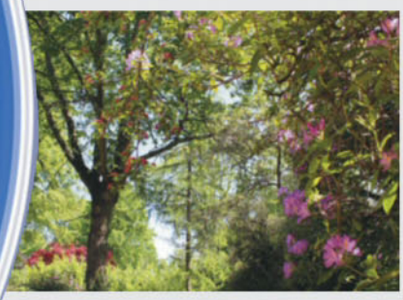


Creepy crawlies gave us bigger brains

A diet of ants and slugs could have helped the human race evolve, according to research at Washington University in St Louis. In the winter months when fresh food was scarce, primates had to rack their brains and process new cognitive functions to find food. As a result, our ancestors were forced to develop tools to find insects as their main source of food and our prehistoric primate brains increase in size and intelligence.

A brighter future for solar cells

A research team from Liverpool University have found a new way of producing solar cells. Current solar panels are made using cadmium chloride, which is toxic to the environment, but they have discovered that magnesium chloride works just as well. This material isn't toxic and is found in bath salts and is plentiful in seawater. The future is looking bright...



Carbs are apparently good for trees

There's good news for the natural world as scientists have found a new and innovative method to help tropical trees survive droughts. It has been found that when exposed to high levels of non-structural carbohydrates (NSCs), the trees could live in spite of severely reduced hydration levels. Experts are still unsure on how NSC benefits the trees but this is an important development against the ongoing problem of deforestation.

Water pistol: version 2.0

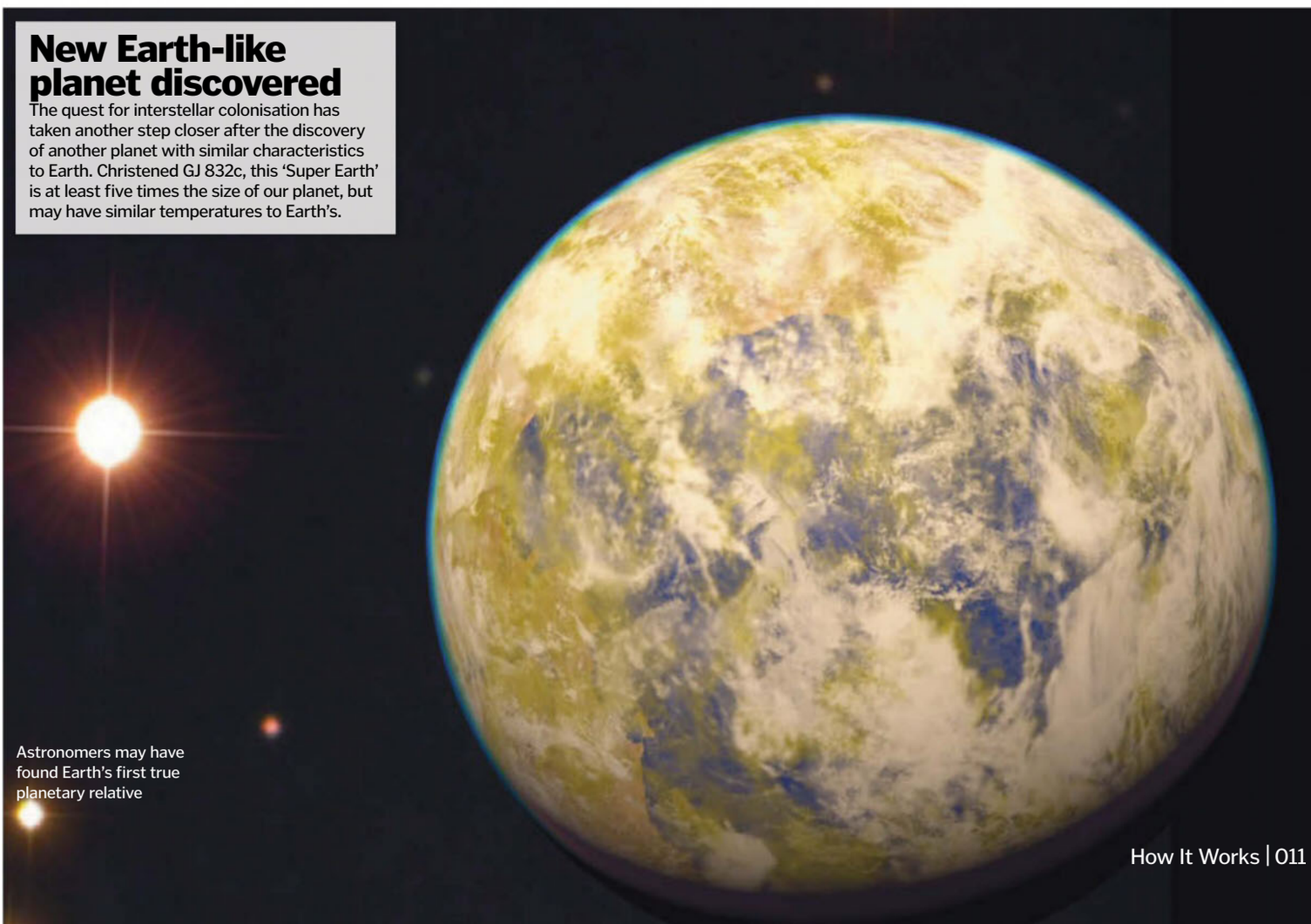
Want to emerge victorious from the neighbourhood water battle this summer? Look no further than this hulking beast. The pistol uses the material sugru, which is the world's first hand-mouldable self-setting rubber. Designed in the style of an action-movie Gatling gun, it is CO_2 powered, has a range of 12 metres (40 feet) and can carry up to ten litres (2.6 gallons) of water to soak the unlucky victim.

Our brains grow and erase old memories

Our infant experiences become hazier as we grow older. Now, scientists from Toronto believe they can explain why that happens. Their theories state that new memories gathered over time effectively erase the old ones. Our brain grows so rapidly in our youth that old memories are just disposed of, especially recollections from before your third birthday. Scientists are delving deeper into the neuroscience of the hippocampus region of the brain to find more answers.

New Earth-like planet discovered

The quest for interstellar colonisation has taken another step closer after the discovery of another planet with similar characteristics to Earth. Christened GJ 832c, this 'Super Earth' is at least five times the size of our planet, but may have similar temperatures to Earth's.



Astronomers may have found Earth's first true planetary relative

Bialik's Big Bang

Star of The Big Bang Theory, Mayim Bialik, reveals her love for neuroscience

Mayim Bialik isn't just a brilliant neuroscientist, she plays one on TV too. Fans of the long-running sitcom *The Big Bang Theory* will know her as Amy Farrah Fowler – Sheldon's squeeze and Penny's 'bestie.' On screen, she's often seen in the lab carving up a brain or two, but that's not really acting. After appearing in the 1990's show *Blossom*, the actress steered away from stardom and earned a PhD in neuroscience – the study of the nervous system. These days she still has a hand in education, working on a campaign that reveals the real science behind the biggest superhero movies. But when the time comes for Amy and Sheldon to walk into the sunset, Bialik tells us that teaching might just be the punchline to this comedy actress' career.

Mayim Bialik as neuroscientist Amy Farrah Fowler

"I believe there's value in teaching and research, so that's why I decided to pursue a doctorate"

Your parents worked in education. Did that fuel your interest in science and education?
They were public school teachers. My mum worked as a nursery school director at our synagogue. It was assumed I was going to be an English major like my parents. I didn't get interested in science until I was about 15. There wasn't a whole lot of technology to be had in the 1970s and '80s, honestly.

Mostly from my parents I learned an appreciation for education, a respect for teachers and a tremendous appreciation for the work they do. My dad was always stressed out and my mum was too. It's a very difficult profession, no matter what you're teaching.

How did you make that left turn into the world of acting?
I was in school plays, like every kid has to be and I liked it a lot. It wasn't a typical 'child actor' story where you start acting aged two because your parents think you're cute and should be in on television. I thought I wanted to be an actress because I really enjoyed it in school. I had no idea what the industry was like. For several years, my parents were really against it. When I was 11 and finishing elementary school, my mum had just finished working as the nursery school director at our synagogue. She said, "If you really want to try this, now that I'm not working, we can try."

***The Big Bang Theory* has been renewed for at least three more seasons, but do you have any long-term goals in the scientific realm once the show is over?**
I could teach or tutor, but I made the decision to be with my children more than being with my students. That's the reason I originally decided not to pursue a postdoctorate and be a research professor. That decision holds, no matter what.

What attracted you to neuroscience?
Originally I wanted to go to medical school, but honestly, I didn't have the grades. I just believe there's value in teaching and in research and so that's why I decided to pursue a doctorate. I've worked with individuals with special needs. That was something I was always interested in. I also studied psychoneuroendocrinology for my thesis, which was a remarkable field.

I've studied oxytocin and vasopressin. I worked with a lot of really interesting parts of the brain and in human behavior. I was trained in genetics and in functional neuroimaging. I've kind of revolved mostly around sort of neuropsychology and neuropsychiatry.

You've been an ambassador for Texas Instruments' STEM Behind Hollywood campaign where they've been teaching kids about the real science of movies and TV. Are you also involved with incorporating actual science into *The Big Bang Theory*?
No, we have a science consultant on the show. His name is David Saltzberg. He does all the physics consulting. Many of our writers have science backgrounds or are married to people that do. My job is really just to be an actor but sometimes they'll ask me questions about things Amy should be doing in her lab so that it looks authentic. We try to stick to good science, but a lot of times, if something has a visual joke, it's not always going to be as accurate as

true science, like the thickness of brain slices I'm working on and things like that.

Do you think *The Big Bang Theory* has become a gateway for people of all ages to get more interested in science?
I don't know if that is what we set out to do. Chuck Lorre and Bill Prady created the show because they wanted to write a show about a bunch of geeks.

I think, for a lot of people, and a lot of teachers, it has become sort of a jumping-off point. I think it has been a great way to dispel some of the myths associated with being a geek or a nerd. Namely that there is no place for you in society, you will never find a girlfriend and you won't have a group of friends or have a social life. Or, that if you are kind of 'spectrum-y' or different that it means your life is not going to be easy. I think it is true that it won't be smooth, but I think we are showing an environment [on *The Big Bang Theory*] where all of these people work together despite all of their differences.

I think it is important to emphasise it is so difficult, socially, to be different and to be the kind of person who wants to do activities that are not deemed normal social activities by most standards. But I don't think *The Big Bang Theory* is changing the course of social history.


Mayim Bialik has a doctorate in neuroscience


A scene from *The Big Bang Theory*

Things Big Bang Theory taught us

Five science lessons in everyday science from *The Big Bang Theory*

Bread doesn't belong in the fridge
When Sheldon pops across the hall to borrow Penny's bread, he can't resist telling her it shouldn't be kept in the fridge. Staleness is caused by crystallisation of starch molecules, which occurs faster at cool temperatures.

Think outside the box
When Penny and Leonard get cold feet before their first date, Sheldon points out that their potential relationship is both good and bad until 'the box' is opened – much like Schrödinger's cat, a thought experiment in 1935 where a cat in a sealed box can be considered both alive and dead.

We need sleep to function
A sleep-deprived Sheldon starts to go mad because he's not spending enough time in REM sleep. This causes neuroreceptors to lose their sensitivity to serotonin (linked to happiness) and norepinephrine (a hormone for alertness), which leads to lack of cognitive function.

Humans mark their scent
Amy gets jealous of Sheldon's new assistant so she marks her territory in his office – by rubbing her armpit on his phone. Humans are often attracted to others because of scent, as we secrete chemicals known as pheromones, just like other mammals.

Queen bees fight to the death
When Penny feels threatened by a new neighbour, Sheldon relates the reaction to usurpation. That's when a swarm of bees invades another hive, kills the queen bee and a new queen is crowned the leader. Penny must therefore either submit or fight for her 'hive.'

SPY GADGETS

REVEALED: TOP SECRET TECH

We've all seen spies on the big screen, but few of us have actually interrogated one. When we spoke to former CIA field operative Melissa Boyle Mahle, she revealed what life as a secret agent is really like. "Western countries have this image of what espionage is by watching James Bond movies", she says. "We have this sense of high intrigue in civilised settings, with car chases and explosions. That's not espionage; espionage is much better than that." As for the super-high-tech gadgets? They're (mostly) true. "We share some of the same tools and technologies but it feels different", adds Mahle. "Espionage is chess. You have to outwit your adversaries without them knowing it. A building blowing up is not sneaky."

It seems a true-to-life Bond or Bourne movie would feature much less heat-of-the-moment action. "Operations are sometimes very risky and you don't want to be caught and [get] your agents killed. Espionage in the media gets a bad reputation because they think that it's too easy. It isn't that way. It takes so much planning to get to the right person who has the information you want and how to convince them to give it up. A lot more strategic planning [is involved], a lot fewer car chases!"

When Mahle was at spy school – yes, it really is called that – the Cold War was still raging. Training was geared toward clandestine film photography and if you made a mistake when the images were developed, agents' lives could easily be on the line. The advent of the digital age transformed espionage forever and these days, spies are trained in how to evade technology as much as they are taught how to operate it.

Using real-life spy stories from former agents, this feature will delve into the realm of espionage and reveal the secrets behind the hottest gadgets on the market today.

5 TOP FACTS
BOND GADGETS

Jet pack
1 Fictional super-agent James Bond uses a jet pack in the 1965 film *Thunderball*. It was based on the Bell Rocket Belt that was designed to be used in the US Army.

Tracking device
2 The Aston Martin cars have always been an integral part of the series and in *Goldfinger* an early version of a modern GPS can be seen as Bond tracks down the baddies.

Q robot
3 In *A View to a Kill*, Q comes up with an advanced surveillance robot known as 'Snooper', which can be seen as a precursor to modern observation devices.

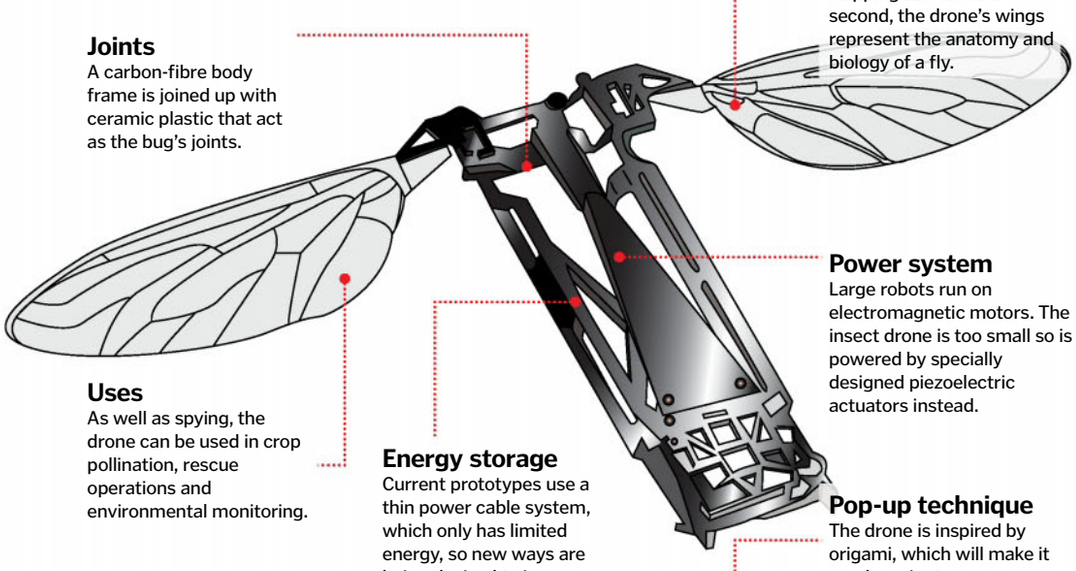
Covert camera
4 In *Moonraker*, a miniature camera, exactly like the ones in real espionage, is used by 007 to take pictures of a villain's nefarious plans.

Wetbike
5 A hybrid of a motorcycle and a jet ski, Bond uses this device in 1977's *The Spy Who Loved Me*, several years before its real-life version hit the market.

DID YOU KNOW? *The highest-grossing spy film ever is 2012's Skyfall, making over $1 billion (£585 million) in cinemas worldwide*

INSECT DRONES

They may look like bugs but they're really highly advanced machines



Joints
A carbon-fibre body frame is joined up with ceramic plastic that act as the bug's joints.

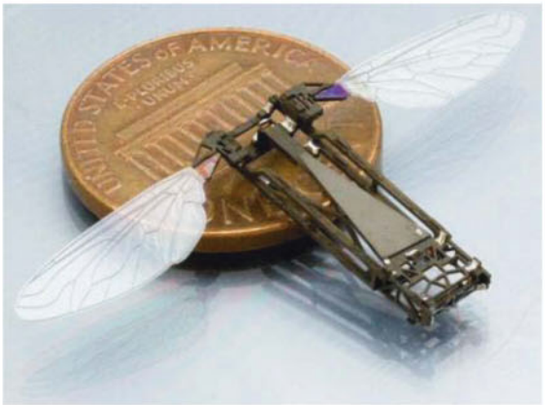
Wings
Flapping 120 times a second, the drone's wings represent the anatomy and biology of a fly.

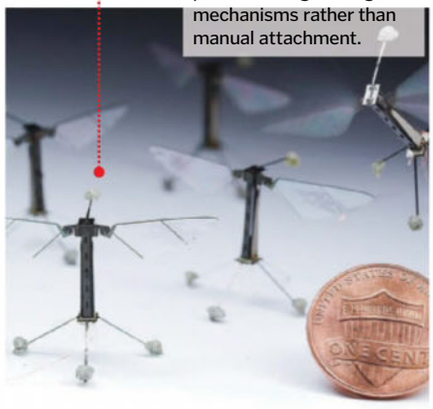
Power system
Large robots run on electromagnetic motors. The insect drone is too small so is powered by specially designed piezoelectric actuators instead.

Uses
As well as spying, the drone can be used in crop pollination, rescue operations and environmental monitoring.

Energy storage
Current prototypes use a thin power cable system, which only has limited energy, so new ways are being devised to increase battery life.

Pop-up technique
The drone is inspired by origami, which will make it much easier to mass-produce using locking mechanisms rather than manual attachment.





With technology progressing so rapidly, it is hardly a surprise that several companies are taking new and innovative approaches to spy gadgetry. One particularly inventive product is the insect drone or 'RoboBee', which is being created with several potential applications in mind, including military surveillance. Disguised as a small insect, one variation of this agile drone has been designed by the Harvard School of Engineering and Applied Sciences. Weighing less than a tenth of a gram and hardly the size of a penny, this tiny robot will be able to access top-secret areas completely undetected. The teeny insect-like flies using wings powered by piezoelectric actuators (deriving the power from pressure) in an electric field. There hasn't been a project similar to this ever before so the majority of the materials used to create the device had to be invented and developed from scratch. The device doesn't travel like conventional human aircraft at all, but instead copies and adopts the flapping of insect wings, adding even further to its bug-like guise. Literally becoming a fly on the wall, swatting pesky insects around with a newspaper could soon literally become integral to your privacy as well as getting rid of the annoying buzz!

Telephone tapping

Learn the secrets of how telephones can be hacked and tracked

Setting up
The first thing a spy will do when wiretapping is to target the main telephone line. They do this by breaking into one of the telephone poles you see on a street. A spy is then free to listen to your calls (or any in the neighbourhood) at will.

Recording the call
Disabling their microphone makes sure they won't give themselves away. They will hook up a recorder to enable repeated listens of the call. Even more sneakily, a bug can be installed in a house to continuously monitor a landline.

Going mobile
Certain software systems can be installed onto a mobile phone. These can monitor calls and text messages. This way if the target has a phone conversation with someone suspicious, you can flick on the device with ease.

"Working under alias is pretty stressful and lonely [...] I spent a lot of time memorising details"

CAN YOU SPY A SPY?

Get to know the many different roles of spies

Spying is said to be one of the world's oldest professions, but it is also one of the most dangerous. There have been many attempts to sum up what drives people to become secret agents, including the theory MICE (Money, Ideology, Compromise or Coercion, and Ego or Extortion). For Lindsay Moran, former CIA operative, it was a childhood dream. "I actually sent an old-fashioned cover letter and CV, via snail mail!" she recalls. A few weeks later, she was drafted in for an interview.

After clearing a gruelling assessment period, Moran began training to jump out of aeroplanes with cargo attached to her body, crash cars into barriers at 97 kilometres (60 miles) per hour and travel under an alias. Surprisingly, it was the latter that caused her the most difficulties: "Working under alias is actually pretty stressful and lonely", she says. "I would use a set of alias documents. This entailed spending a lot of time memorising believable details. I was always worried at border crossings and airports – situations where you might be questioned about who you are and what you're doing."

For Mahle, who spent the majority of her career in the Middle East, a fake name was only the beginning. She worked on many of the key challenges to US national security, including running operations against al-Qaeda terrorists, so disguises were essential. "We have many different kinds. It can be low tech with glasses and a wig or very high tech with facemask technology we basically steal from Hollywood. You have to find out about your environment, what the locals wear and how they act. I would often take on the garb of a traditional Arab woman, with black robes, headscarf and sunglasses. Then I could blend in."

Standing up to scrutiny in high-pressure situations is par for the course. "There are different levels of interrogation", she adds. "One is being able to withstand questions into your cover identity, which happens quite frequently when you're operating under a different name. The other extreme is when you are apprehended and accused of being a spy. It's a very hostile environment and I am grateful I was never caught."

1. SNEAKY

Fritz Kolbe
A German working for the Allies, Kolbe gathered and supplied secret documents to the United States containing plans for V1 and V2 rockets.

2. SNEAKIER

Richard Sorge
A Communist spy who infiltrated the Nazi Party, the 'Hero of the Soviet Union' passed on German battle plans to the Soviets.

3. SNEAKIEST

Elyesa Bazna
Codenamed 'Cicero', he was known as the 'spy of the century.' He revealed D-Day invasion plans to the Germans, but they ignored his warnings.

DID YOU KNOW? *The head of MI6 is known as 'C' after the first-ever chief, Mansfield Cumming*

Spy in the city

Discover the roles of secret agents

1 Field agents

A field agent will be entrusted to gather information that cannot be accessed from HQ. Likely to be a double or even a triple agent, they operate behind enemy lines and blend into their surroundings. A risky strategy, a spy must be completely sure their cover will not be blown.
Trusty gadget: Mobile phone tracker or similar.

2 Whistleblowers

A whistleblower will obtain knowledge they believe should be shared with the public, usually within organisations where illegal activity is happening. The media will be alerted to the news and the activity will be investigated. Whistleblowers put themselves at risk when they reveal their identity.
Trusty gadget: A dictation machine.

3 Surveillance squads

Not always but sometimes located in the 'van with a dish on the roof', surveillance squads work as a team. Keeping a close eye on a group under an inquest, they will gather information that is required for the investigation to go further.
Trusty gadget: Wireless bugging and communication devices.

4 Mole

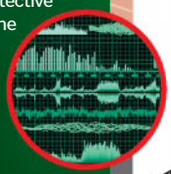
Also known as a sleeper agent, moles are the most long-term of all spies. Tasked with monitoring an organisation or individual, a mole can spend years in the same place, only responding to missions when assigned. They are trained to be visible but to keep their motives unknown.
Trusty gadget: Covert spy camera.

5 Bureau staff

Most of the legwork is done in the field, but a team is still required back at base. They will gather and assess the information collected by a spy and research the case details. They will also provide backup and deal with issues that can only be solved at HQ.
Trusty gadget: Computer surveillance equipment.

6 Detective

A detective performs the classic spy role. Often posing as a bystander, the detective will investigate criminal activity in the field while remaining completely elusive. They are usually deployed by the police as a prelude to using force and to monitor suspected activity more thoroughly.
Trusty gadget: An audio amplifier.



"We use hidden cameras and listening devices, but it depends on how real-time you need the information"

HIDDEN CAMERAS

These ordinary-looking objects can record your every movement

If there's one modern gadget that has changed the world of espionage in recent years, it's the humble, everyday mobile phone. Today, almost everyone has access to a device that can record high-definition video, capture detailed pictures and track movements, most importantly their own. Mahle reveals that part of every agent's education is learning to spot when you're being watched. "If you're having a clandestine meeting, you need to be very careful that it's done securely", she explains. "Surveillance can come in a variety of different forms, it could be the guy following you as you drive across town or it could be electronic surveillance. Phones are basically GPS [devices]; they are beacons that can track you. We train our officers to be mindful of the physical and technical surveillance they have to defeat in order to keep the operation secure."

This has meant that spy technology has been forced to evolve even further using tiny micro-transmitters and microchips that are almost invisible to the naked eye. Giving whole new meaning to the game 'eye spy' are glasses that contain built-in cameras and microphones that look exactly like the tiny screws that hold the specs together. The advantage to this is that the camera sees everything the wearer can, and the wide-angle lens ensures that it captures as much of the scene as possible. Gizmos like this are available to purchase online but far from a cheap gimmick, Mahle reveals tech such as this really is part of a spy's essential toolkit: "We use hidden cameras and listening devices, but it depends on how real-time you need the information", Mahle reveals. "If you record something, you will want to go back to it and build up an understanding of your adversary."

"Gadgets won't save you in the moment of the act", she warns. "Technology is widespread now but still, in certain places around the world, capturing a communication device like a camera or a phone can cause security services to start asking questions. As spies, we are very careful about what equipment we use and making sure it does not alert anyone. You don't want your spy tools to give you away."

Spy watch

The combination of a long-life lithium battery plus several gigabytes of memory make a spy watch a worthy purchase. On face value, this timepiece looks like any other, but unknown to the spy's target, they are being filmed by a hidden waterproof camera within the watch's clock. Able to record over an hour's worth of HD footage, the watches are compatible with both Mac and Windows through USB 2.0. They can record video and take still images so any spy can have their scoop saved and sent within minutes.

USB port
Hidden away is a tiny USB port that can be used when the mole returns to base to study the footage.

LED
A small LED lights up to show when the device is recording but it is small enough to not be easily noticed.

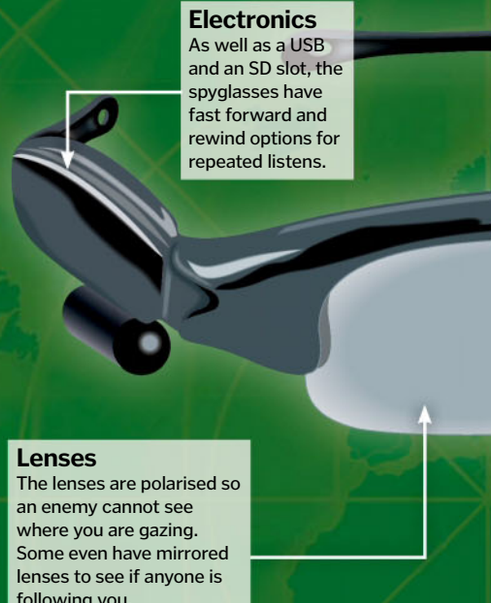
Microphone
Sound is just as important as vision, so a microphone is also fitted for when the key information is revealed.

Camera
On the clock face lies a concealed camera that can record video of an unsuspecting individual.

Stop and start
Looking no different to a standard watch, an on/off switch allows for bitesize recordings.

Glasses

Looking no different from normal specs, the glasses are very useful to a spy. With a small wide-angled camera on the frame just above the nose, there is no need for a fiddly viewfinder as snaps can be taken literally wherever you turn your head. Naturally, the lenses are polarised so a target will not suspect a thing. Like the pen and watch, the device can easily be connected via USB to a computer to allow immediate assessment of your findings.



Electronics
As well as a USB and an SD slot, the spyglasses have fast forward and rewind options for repeated listens.

Lenses
The lenses are polarised so an enemy cannot see where you are gazing. Some even have mirrored lenses to see if anyone is following you.

KEY DATES
BRITISH SPYING HISTORY

1909
The Secret Service Bureau is established but later splits, as the MI5 becomes a separate entity from MI6.

1914-1918
The MI5 is expanded to a staff of 844 and catches 65 German spies during the war.

1942
The MI5 contributed to the war effort; including helping keep Gibraltar an Allied territory.

1984
A counter-terrorism branch is set up in the wake of threats from the IRA and Gaddafi's Libya.

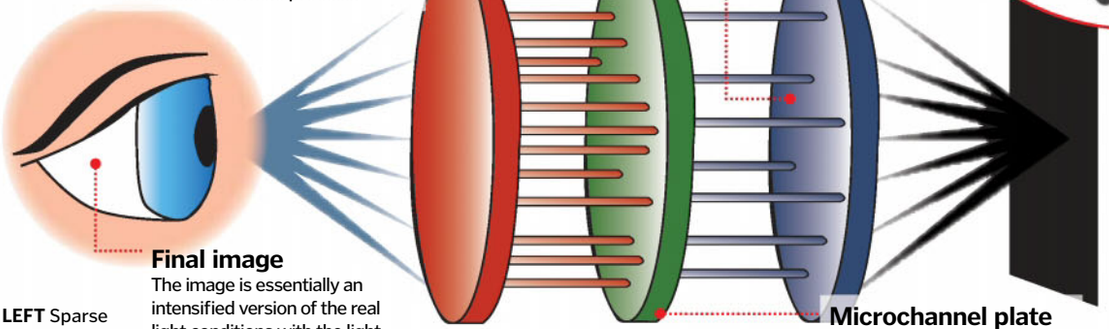
2006
'Operation Overt' is undertaken to defend against al-Qaeda suicide bombers.

DID YOU KNOW? *In the Cold War, the CIA developed 'Acoustic Kitty', a programme to use cats as spies*

Night-vision goggles

Another spy movie classic that works in real espionage, most night vision goggles can work up to 180 metres (590 feet) away on a clear night. The goggles function in two ways: low-light and thermal imaging. The first collects the sparse light from the lower part of infrared spectrum, amplifies it and creates the image. The second does the opposite by using the top part of the infrared spectrum to detect the heat emitted by people, animals and objects.

LEFT Sparse amounts of light are amplified and enhanced



Photocathode
This releases the electrons into the phosphor screen. Older devices used to employ three cathodes but now one made out of gallium arsenide can handle the whole process.

Phosphor screen
The electrons in the goggles hit this screen and change into visible glowing light. Different types of screens are available for a varied performance.

Final image
The image is essentially an intensified version of the real light conditions with the light amplified. Some modern devices send out their own infrared beam to use as a light source.

Microchannel plate
This plate helps increase the gain (power) of the goggles as well as the resolution of the intensified image.

Ninox Armasight night-vision goggles

Microphones
As well as logging what secrets you hear, the microphone is perfectly positioned to record anything the wearer comments on.

Video recorder
If HQ isn't available, the specs can be plugged into a portable body-worn covert video recorder for instant analysis.

Camera
Placed just above the bridge of the nose, a wide-angle lens records exactly what you can see in front of you.

Spy pen

The ultimate tool for office-desk surveillance, the spy pen can find out just who's been stealing your stationary. Able to capture video and audio, the pen can record HD-quality footage. Extremely simple to use, it has a high amount of storage and a long battery life. The pen could prove invaluable for an undercover spy with the inconspicuous nature of a biro, meaning it is a safe option for espionage missions. The pen comes complete with a USB cable and micro-SD card slot so you can review the footage afterward.

Operation and reset button
The camera begins rolling with a press of the switch at the top of the pen and can be halted at any time with another click.

Camera
The camera itself is located here and uses a tiny lens to capture all the activity a spy will need to take back to HQ.

Pen
Perhaps best of all, you can still put pen to paper like a normal biro, further concealing the gadget's true purpose.

MIC
Next to the lens is the microphone, which can record and uncover top-secret information.

USB and card
When you have gathered your recordings, the spy pen uses a card slot or a USB connection so you can review your findings.

"In high-threat and high-risk environments, we communicate using 'dead-drops'"

PROTECTING SECRETS

Is high tech always best?

Spy technology is so advanced that it forces you to question even the most mundane objects. Moran revealed that even her notepad wasn't all it seemed. "I had water-soluble paper for the possibility that we were caught," she tells us. "I also had some nifty secret compartments. Sometimes, going back to basics can work just as well, because the technology can't fail you."

Mahle adds that fake rocks, empty soda cans and even dead rats are relied upon. "In high-threat and high-risk environments, we will communicate using 'dead-drops'", she explains. "This is a trade craft where we will hide communications in a concealment device and put down the item in a predetermined location for an agent to come by at a later time to pick it up. It's slow tech but also very secure."

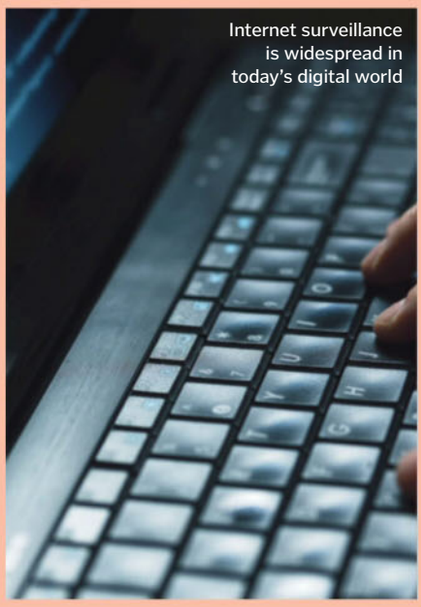
Indeed, the switch to digital has created as many problems as it has solved. Mahle explains: "As technology changes, it presents new challenges to how we operate. It used to be easy to cross international borders but biometrics have made this increasingly difficult. Ultimately, it comes down to the agent and the operator. Whether you use high-tech or low-tech gadgetry, it's people who matter."

Global Positioning Systems

Approximately 30 satellites orbit the Earth to make the GPS system function. Originally a military invention, the GPS is now used in cars and other transportation systems across the globe. The devices work by using a method known as trilateration. The GPS receives a set of signals from three separate satellites and uses this information to plot its coordinates and destination. Spies can use special 'GPS trackers' – like the ones you saw in *Breaking Bad* – to attach to transport and even people to stay on their tail.

Internet encryption

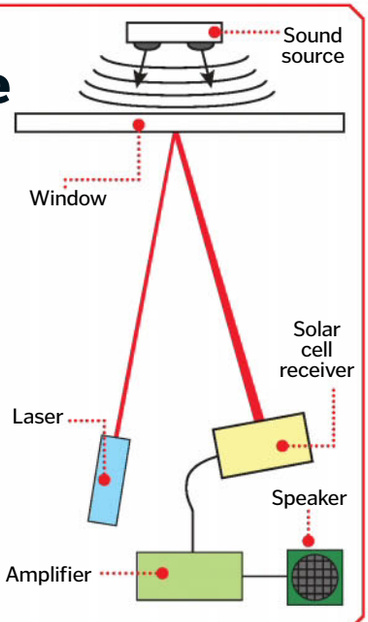
Encryption is the scrambling of data into a code only certain people can read. The system has been used throughout history to send and receive messages and is used today for much the same purpose. Perhaps the most important encryption machine in history was the Enigma used in World War II by Nazi Germany. Encryption is designed to be hard to crack. For example, it is used to hide your card details online. For spies, encryption involves advanced mathematics that jumbles up long and complex passwords and keys, to protect secret and classified information. It uses a digital key that only specific receivers can decipher. Security systems are constantly tightening up their procedures as hackers get ever-more sophisticated in their methods.


Internet surveillance is widespread in today's digital world

Laser microphone

Laser microphones have been a spying revelation. The device uses a laser beam projected into a building to eavesdrop on conversations. It picks up sound waves in the room and bouncing them back to your position. You can even build your own using a laser pointer and some basic audio equipment.

The laser microphone has its roots in a device created by Russian inventor Léon Theremin, who devised a gadget known as 'The Thing' in 1947. It was given to the USA as a gift disguised as the 'Great Seal of the United States' and hung in the US ambassador's office in Moscow. It was only discovered by the US in 1952.



DID YOU KNOW? *Women were involved in espionage during WWI and WWII as they were thought to be less suspicious*

Satellite
Navigation satellites orbit the Earth at 20,000km (12,430mi) and work with the grounded GPS systems using trilateration.

Transport
The microwave signals are transmitted from the satellites into road vehicles to be used as a spy GPS tracking device.

Receiver
Every GPS is part of the GNSS (Global Navigation Satellite System) network and GSM and GPRS towers help support the system.

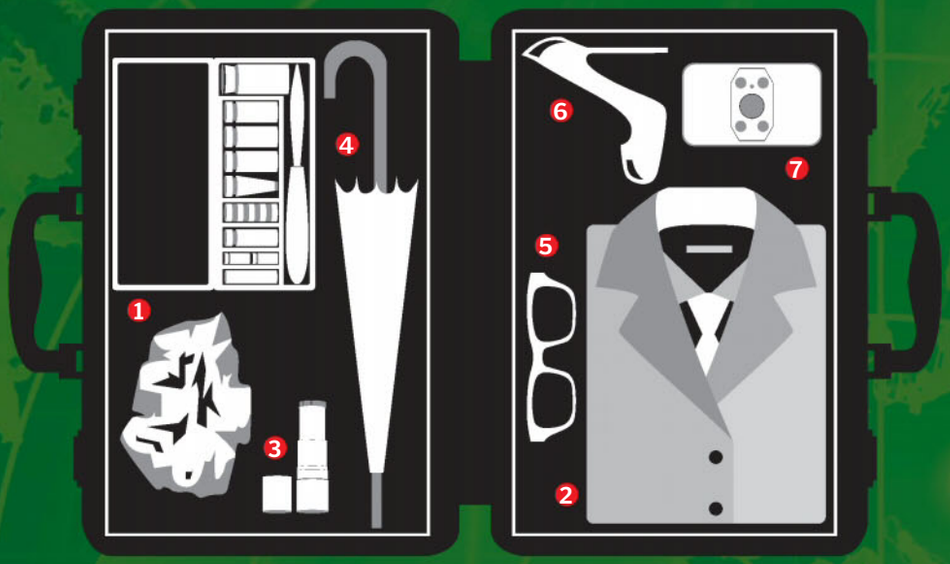
Computer Servers
A computer at HQ receives data from the tracking unit and displays it enabling base to see the target's whereabouts.

Online
The GPS maps are now online and free for the spy service to track at their leisure.

Retro spy gadgets

Dr Vince Houghton, historian and curator at the International Spy Museum, talks How It Works through the gadgets of yesteryear

Spy gadgets aren't solely limited to modern-day, high-tech gizmos. They played a major part in the Second World War as well as the Cold War, as the superpowers and their respective allies desperately tried to gain an advantage over the other. Below is a selection of the various espionage devices that would have been in a typical spy case of years past.



1 Coal camouflage
Era: World War II
The idea was that you could make an explosive look like an everyday item. This was especially useful in an industrial plant or a train track where you wouldn't give coal a second look.

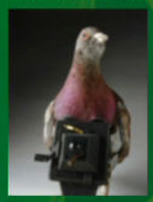
2 Coat camera
Era: World War II
Designed to take pictures secretly with the spy blending into the environment around them. They were difficult to use, as there was no viewfinder so you had to be pretty skilled at working it.

3 Lipstick pistol
Era: 1960s
Designed to get up close and personal with an enemy, the 'kiss of death' was a low-power single-shot pistol. In couldn't penetrate body armour and you literally had to be next to someone for it to work.

4 Bulgarian Umbrella
Era: 1970s
This brilliantly subtle device was used in the late Cold War by the KGB in London. It fired a gas-fed projectile poison dart that could be carried around the city without being noticed.

5 Cyanide pill glasses
Era: 1970s
These were designed for a spy to take his own life so they wouldn't be interrogated and give away important secrets to the enemy should the worst ever happen and they were captured.

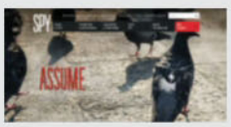
6 Shoe heel transmitter
Era: 1960s
In the era before most everyone had GPS-tracked phones on them, these were attached without the knowledge of the individual wearing them and the person could be tracked wherever they went.



7 Pigeon camera
Era: World War II
Homing pigeons outfitted with tiny cameras were released over military sites to gain information. The photos taken automatically during the flight were developed and interpreted upon the pigeons' return.

Learn more

To discover more exciting spy tech, visit **www.spymuseum.org** where you can also plan a visit!



BEGINNINGS: THE MAKING OF THE MODERN COSMOS

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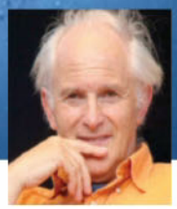
Theoretical Physicist & Cosmologist

Robert Wilson
Nobel Prize Winner



Harold Kroto
Nobel Prize Winner

Richard Dawkins
Ethologist & Evolutionary Biologist

Brian May
Astrophysicist, musician, singer and songwriter

Charles Duke
Apollo Astronaut

Edgar Mitchell
Apollo Astronaut

Harrison Schmitt
Apollo Astronaut

Alexei Leonov
Soviet/Russian Cosmonaut

Viktor Savinykh
Russian Cosmonaut

Sergei Krikalev
Russian Cosmonaut

Yuri Baturin
Russian Cosmonaut

Chris Lintott
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5 TOP FACTS
DETECTION TYPES

Infrared
1 Any object that generates heat produces infrared radiation. These types of alarm are passive so they sound when the area around them is altered in any way.

Ultrasonic
2 These analyse sound waves in their surroundings and send signals out to continuously search the room. If the reflected rays have been changed, the alarm will sound.

Microwave
3 This type is used in presence and absence detection so will help save power by automatically turning off lights when you leave a room and on when you enter.

LED optics
4 Most common in shopping centres, these sensors put escalators into an 'eco mode' that stops when not in use and can even reduce the speed in less busy times.

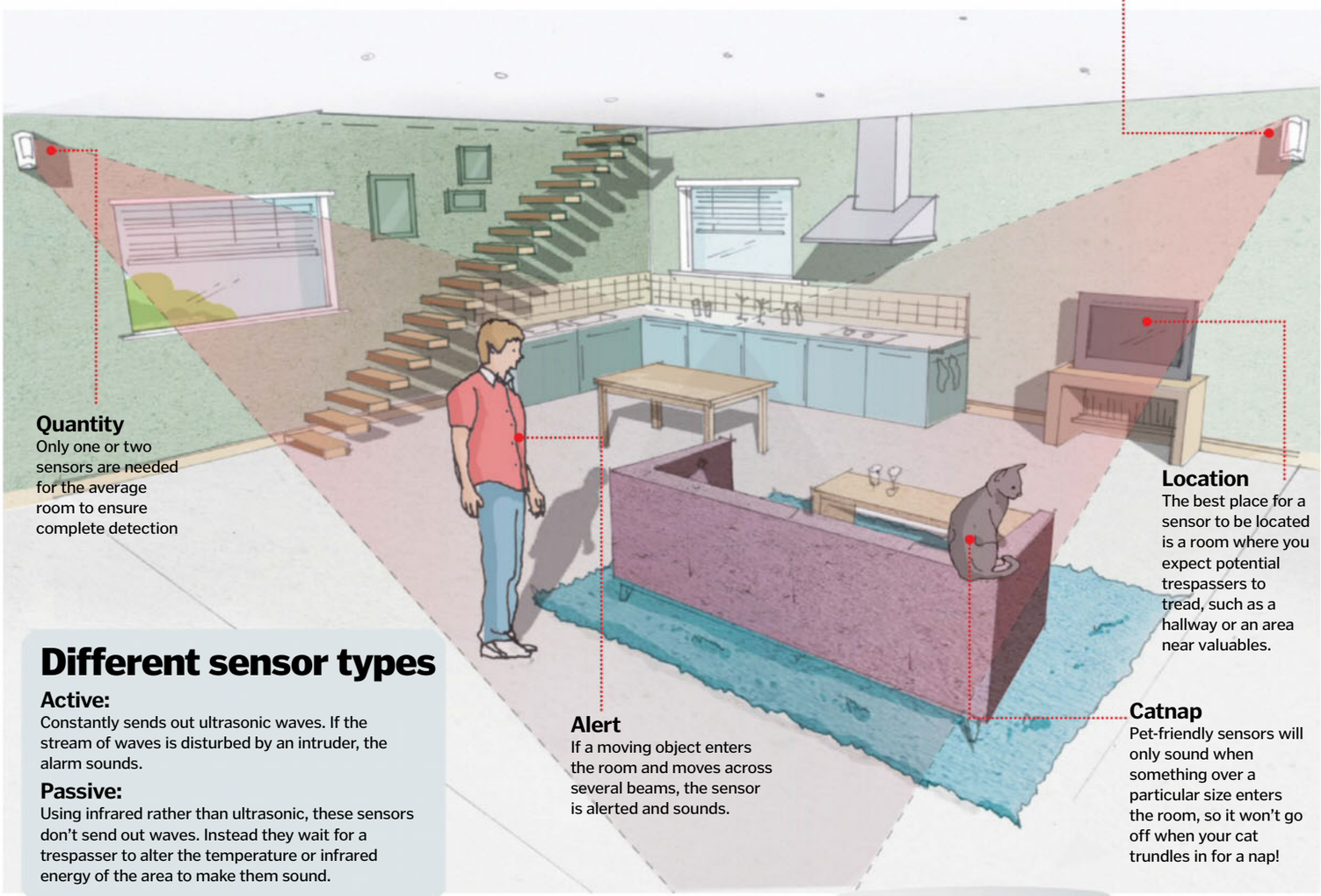
Tomographic
5 Unlike ultrasound and infrared, this new type can go through walls and furniture by using 'anti-masking' technology to scan potential intruders who hide behind objects.

DID YOU KNOW? *A new streetlight LED is expected to last for up to 100,000 hours - that's over 11 years!*

World in motion

The inner workings of motion sensors explained

Active and passive
'Active' detectors use microwaves and ultrasound while infrared is the preferred wavelength in 'passive' devices.



Quantity
Only one or two sensors are needed for the average room to ensure complete detection

Location
The best place for a sensor to be located is a room where you expect potential trespassers to tread, such as a hallway or an area near valuables.

Alert
If a moving object enters the room and moves across several beams, the sensor is alerted and sounds.

Catnap
Pet-friendly sensors will only sound when something over a particular size enters the room, so it won't go off when your cat trundles in for a nap!

Different sensor types

Active:
Constantly sends out ultrasonic waves. If the stream of waves is disturbed by an intruder, the alarm sounds.

Passive:
Using infrared rather than ultrasonic, these sensors don't send out waves. Instead they wait for a trespasser to alter the temperature or infrared energy of the area to make them sound.

Doorbells How they go ding dong

A simple everyday device that we take for granted, the humble doorbell comes in many shapes and sizes. The classic version works by using a basic electrical circuit complete with battery, switch and electric motor. Variations can emit different sounds and chimes by using an electromagnet in the circuit. They use a self interrupting circuit that closes when pressed and opens when the button is released. The chime works slightly differently by using a solenoid electromagnet which hits a set of tone bars in a preset sequence to make the sound. Like many other small gadgets and devices today, doorbells are also going wireless. Similar to a wireless telephone in some ways, this updated invention will allow you to place the actual bell in any room in your house. It uses a short-range radio transmitter that sends signals up to 100 metres (328 feet) away from the trigger (the button by the door). It's especially useful in larger residences, where they will be perfect for when you're stood out in the rain and dad has cranked the classic rock up to max volume.

An example of the wireless system with the unit you can put anywhere in your house

"The invention of steel framing in the late-19th century made it possible for buildings to be taller than ever"

The Empire State Building


The Empire State Building is one of New York's most easily spotted landmarks

How this US icon came to tower over New York City

With 103 floors and a 56-metre (185-foot) spire, the Empire State Building is an incredible 443.2 metres (1,454 feet) high. The world's tallest skyscraper when it was opened on 1 May 1931, it pipped New York's beautiful 319-metre (1,046-foot) Chrysler Building to the record and held onto it until 1970, when New York City saw the World Trade Centre spring from the pavement. They certainly build them big in the Big Apple and for 40 years, the Empire State Building was the biggest of them all.

The invention of steel framing in the late-19th century had made it possible for buildings to be taller than ever. While brick would eventually collapse under its own weight if you piled on too many floors, a honeycomb-like frame of steel beams could take the strain and spread the pressure of the upper floors throughout the building. Another 19th-century development – the elevator – raised the limit on how many storeys you could put on a building, for the simple reason that you can't expect someone to walk up 102 flights of stairs.

Construction began in March 1930. Financed by two former General Motors executives, John J Raskob and Pierre S du Pont, they applied the same revolutionary style of working that they'd used in the factory, with assembly lines of men putting the building together in shifts. However, without the benefit of modern cranes and lifting equipment, materials were hoisted up by pulleys and moved around the inside of the building on narrow railway tracks.

As many as 3,500 workers were on the building at once, many of them (known as 'sky boys') balancing on beams high above the city with no harnesses or helmets. It would be considered incredibly dangerous and reckless today, but those conditions were accepted as part of the job in 1930. After all, only five people died in the 410 days of its construction...


The 'sky boys' put their lives on the line

Behind the walls

Everything you need to know about the Empire State Building

Elevators
Originally there were 64 elevators in the central core of the building, but there are now 73 in total.

Office space
With 1,000 businesses based there, the Empire State Building is the second-largest office space in the US after the Pentagon.

Foundations
The Empire State Building's concrete foundations extend 16.7m (55ft) below ground.

Air conditioning
The air conditioning was installed in 1950. It has since been upgraded to conserve energy.

What was the Empire State's spire built for?

A Signalling UFOs **B** Flagpole **C** Mooring airships

Answer:
The Empire State Building's spire was originally intended for anchoring airships. The updrafts of wind caused by the sheer size of the building meant it was too dangerous to be actually used for this purpose.

DID YOU KNOW? *The Empire State owns the longest survived elevator fall after Betty Lou Oliver plummeted 75 storeys in 1945*

Television mast
The spire is used to broadcast nearly all of New York's TV and FM radio stations.

Observation deck
The 102nd Floor Observation Deck is the highest and smallest lookout point, offering 360-degree views of New York City.

Water supply
While most buildings store water on their roof, the Empire State Building has water tanks spread throughout and connected by 113km (70mi) of pipe.

Steel frame
57,000 tons of steel T-frames and beams allow the Empire State Building to take its own weight. The entire frame was encased in concrete for extra strength.

Limestone panels
The outside of the skyscraper is covered in panels of Indiana Limestone, behind them are 10 million bricks.

Windows
Did you know there are 6,500 windows in the Empire State Building? That's a lot of cleaning!

Entrance
The main entrance has a 9.1m (30ft) high frontage with diamond-shaped frames of glass and two carved eagles on pillars.

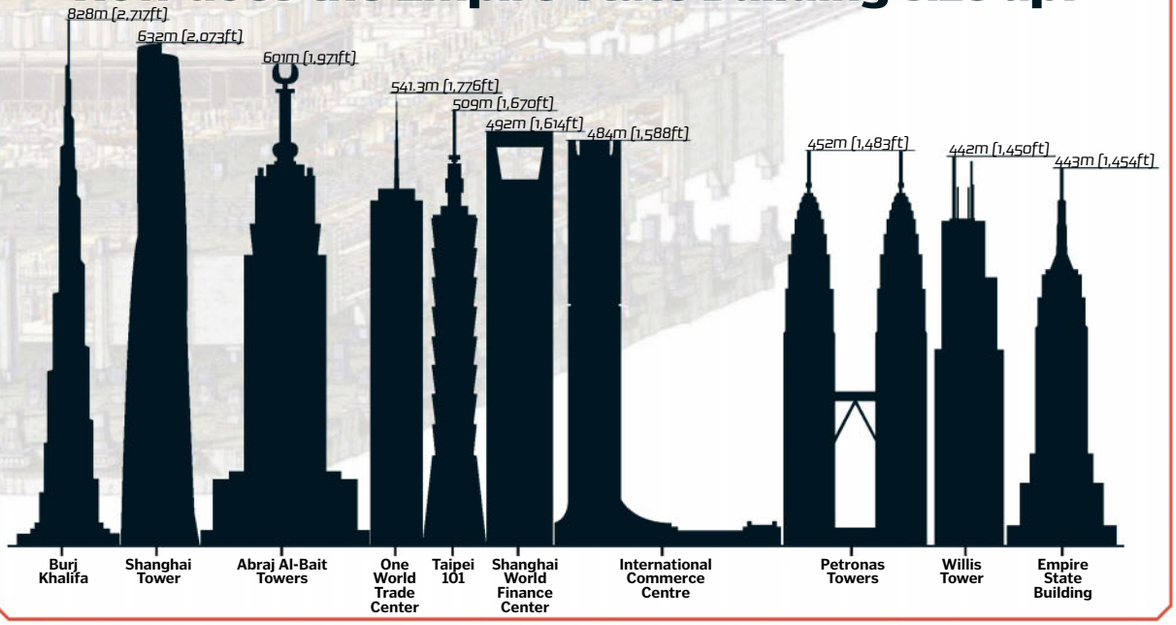
Beautiful shapes

Although not as stylish as the Chrysler Building, the Empire State is an example of the architectural style known as Art Deco. Prominent in the 1920s, '30s and '40s, Art Deco is recognised by its bold geometric shapes, symmetrical design and ornate decorations.

The Empire State Building's most prominent Art Deco features are the 'setbacks', where levels of the building become narrower the higher it goes, with overlaps between the small parts and larger parts. Because they look like steps, they're also called 'stepbacks' and give the Empire State its instantly recognisable shape. Angular sculptures can be found over the entrances, but its inside was where the decorations were at their most impressive with a gold-leaf mural on the lobby ceiling, marble walls and floors, and Art Deco chandeliers.

The Empire State Building is the world's most famous Art Deco building

How does the Empire State Building size up?



"To convert the electronic signals into power, heat is created by kinetic energy"

Electron guns

Far from a weapon, these guns are an important part of everyday electricals

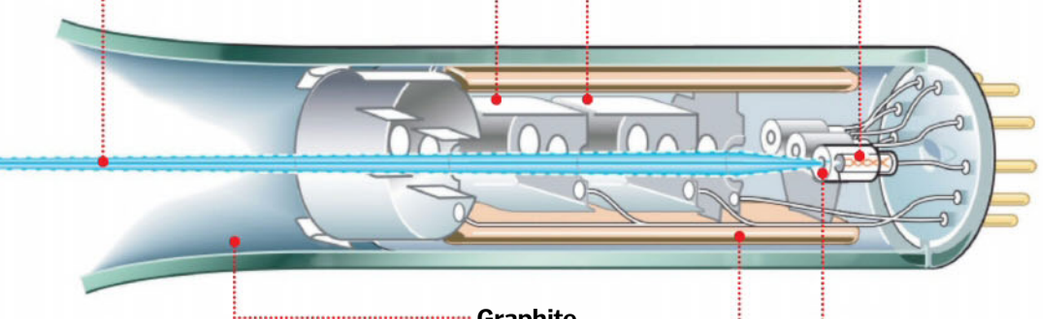
Electron guns are a very versatile electrical component. They are essential to a number of devices, from 3D printers and welders to the large synchrotron at the Diamond Light Source in the UK and the electric systems of Kimball Physics in the US. But how do they work? It's all down to kinetic energy and electrical currents. When installed in an electrical device's vacuum tube, the gun turns electrons and ions into usable beams of energy by releasing them from their metal source (cathode). This process is known as thermionic emission.

Inside the gun there is a small filament that heats the cathode, which makes it release a stream of electrons. The electrons accelerate rapidly and the resulting beam is pulled toward the neighbouring anode, which is positively charged. There are small holes in the anode which allow some electrons to pass through, so a concentrated beam then continues onward within the device. JJ Thomson discovered the electron using this concept in 1897 after conducting experiments with cathode rays and studying their uses.

There are two main types of electron gun: thermionic and field emission. The former are much more common and work at a high temperature. Field emissions have less heat but a higher brightness and electric field. Additionally, 'flood guns' are used to scatter the beam over a wider area.

Naked gun

Inside the inner workings of an electron gun



Electron beam
Now a strong and usable ray of light, the electron beam can exit the gun to work in the rest of the device.

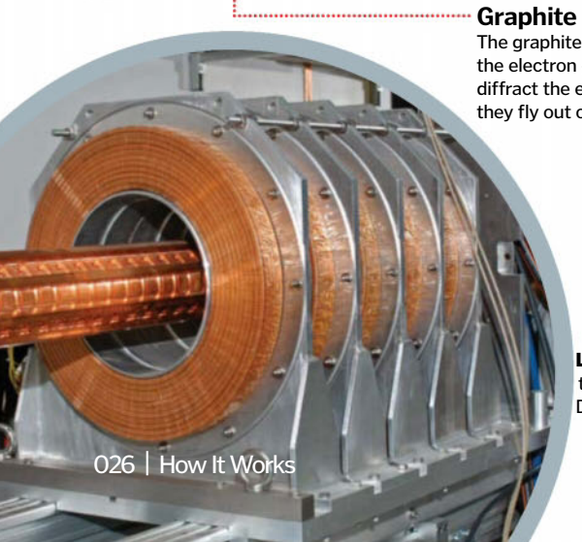
Anode
Made up of two parts, the anodes accelerate and focus the electrons to make a beam.

Heater
Working in unison with the cathode, the heater's hot filament begins the whole electron-gun process.

Graphite
The graphite foil coating of the electron gun helps diffract the electrons as they fly out of the gun.

Cathode
Warmed by the heater, this is where the electrons are heated and emitted.

Insulator
An insulator is provided within the gun to be used as a charge drainage path for excess energy.



LEFT The electron gun at the Diamond Synchrotron in Didcot, Oxfordshire

Learn more

For more on electron guns, check out the Diamond Light Source website at www.diamond.ac.uk

diamond

Chris Christou working on the Diamond Light Accelerator

Electron expert

We chat to Chris Christou, the head of the radio frequency group at Diamond Light Source, who have a supremely powerful electron gun of their own

How is energy turned into a usable product by the gun?

The key is getting the electrons out of the conductor, which the electrons are bound to. The hard part is controlling the electrons once they have escaped. We heat the metal, which gets the electrons out of the cathode and then pulls them away with a high electric field.

How do they work in TVs and the Diamond synchrotron? These are very different things!

Electron guns are very versatile as the physics behind them is relatively simple. It's just giving energy to an electron to take it away from a bound state. The hard part is controlling the beam after it comes out of the cathode of the gun. At Diamond we have a set of electrodes on the gun, which shape the beam to allow it to be extracted and taken into the linac. Old cathode-ray TVs have something like 10,000 volts to accelerate the beam straight into the screen. So the difference between TVs and us is what we do with the beam is after it's been generated.

Where would industry be without the invention of an electron gun?

Until very recently you'd have had no TV sets, but that wouldn't matter, because you'd have nothing to watch, as radio and TV transmitters use an amplifier with an electron gun. It's not just TV, though; old-fashioned electrical valves were based on electron beams and so we would have missed an essential step in the development of electronics.

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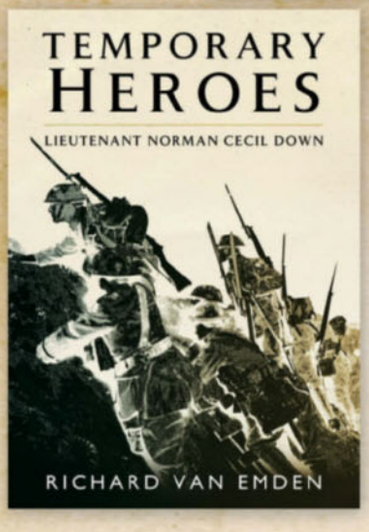

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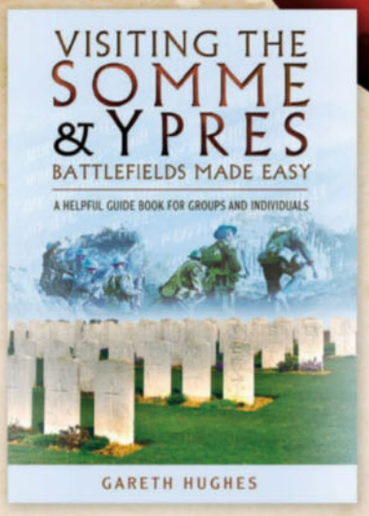

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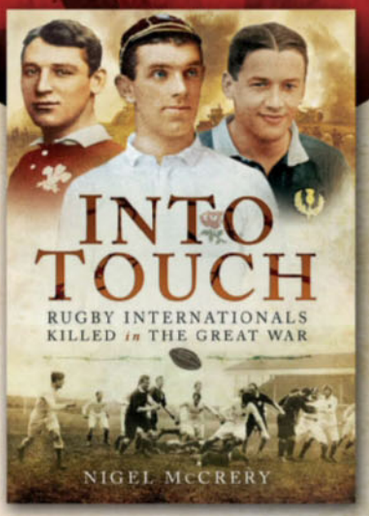

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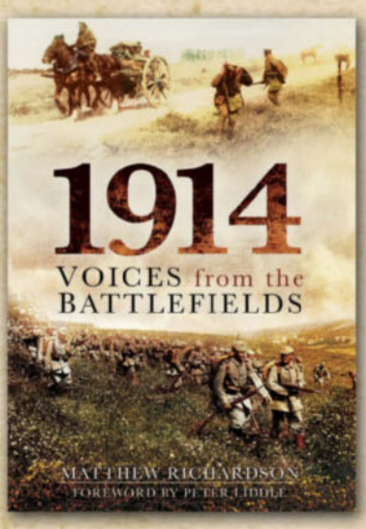

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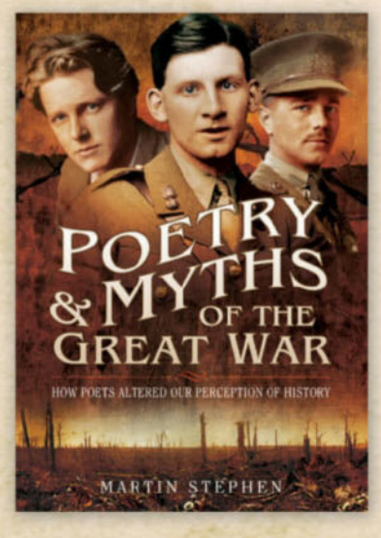

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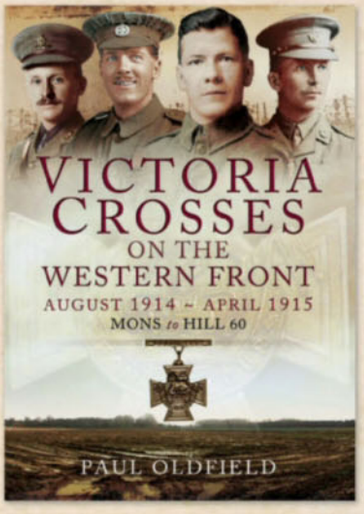

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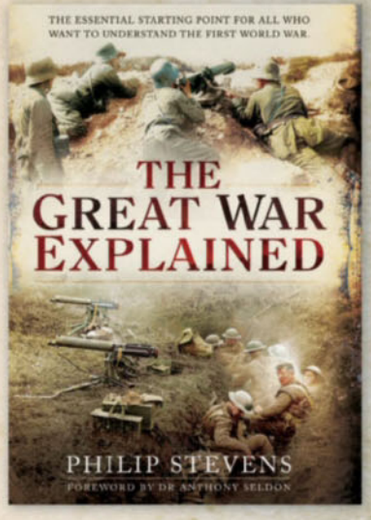

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"There will be one mast per 'cell', which is the maximum area in which the mast can pick up a mobile signal"

How mobile calls work

The tech behind making phone calls

Our mobiles are portable gaming consoles, computers, alarm clocks and personal assistants all in one, but they're still pretty useful for calling someone without being tethered by a cord.

Unlike land lines, mobile phones work by sending electric signals via radio waves to mobile phone towers or masts. These masts pick up the signal, transmitting it along a network of masts until they reach the closest one to the phone receiving the call. Once there, the radio waves are finally beamed to the target phone and converted back into electronic signals and then into sound waves that enter the recipient's ear.

Mobile phone masts are placed several kilometres apart in rural areas but can be just a few hundred metres from each other in cities. There will be one mast per 'cell', which is the maximum area in which the mast can pick up a mobile signal. Hence the further away you are from a mast, the weaker the signal, so if you cannot get a signal at all, that means you aren't within range of a mast. As well as the large main masts, there are also a number of micro and picocells that are much smaller and have less coverage. However, these can pick up the radio waves and transmit them to the larger main masts, increasing the coverage without being an eyesore.

This network allows people to call wherever and whenever they want, only having to be within range of a tower. Even though satellites are required for long-distance calls that can't be transmitted from tower to tower, the process of making a phone call by relay is an amazing technological victory.

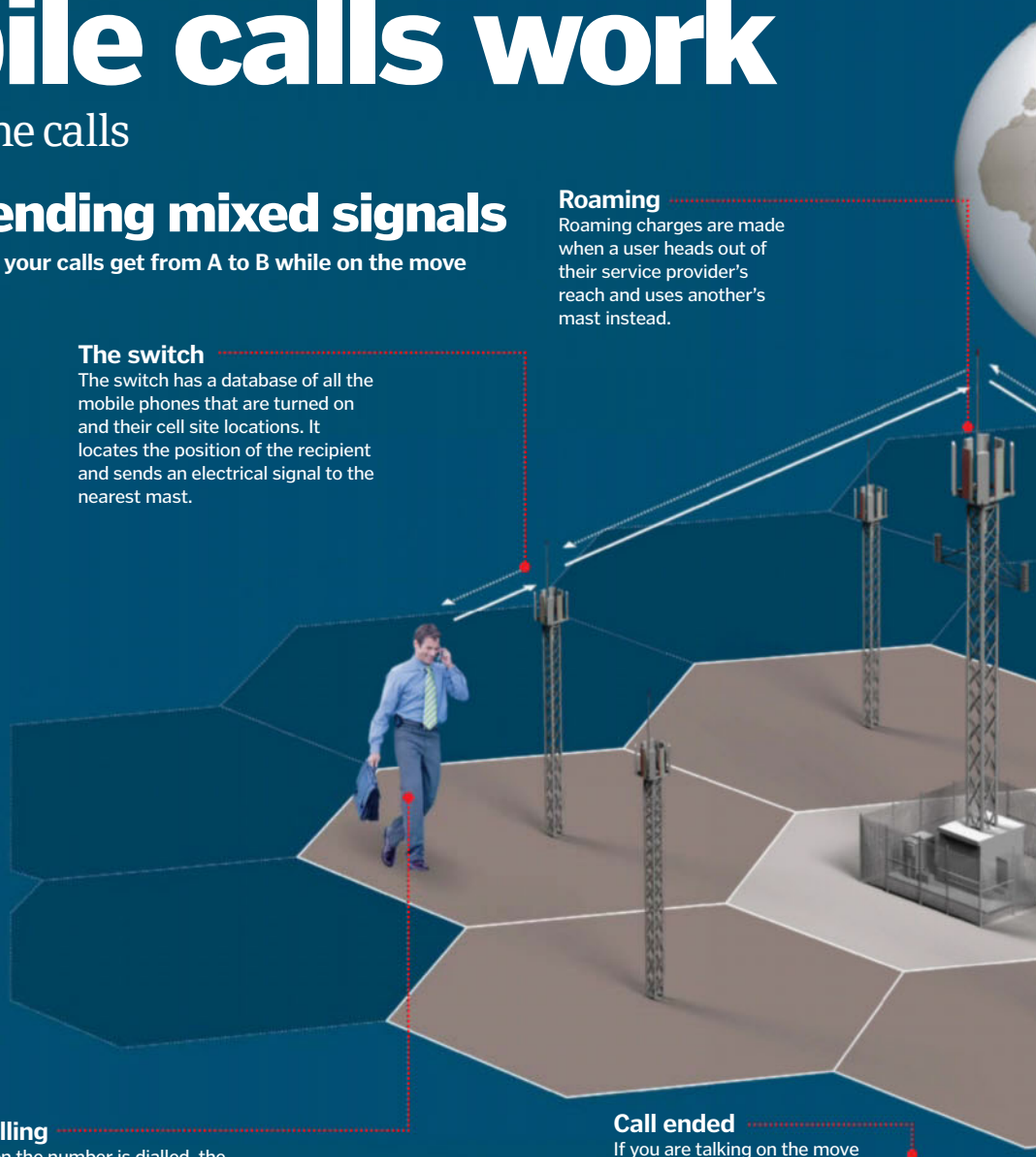
First smartphones

Most of you reading this will have a smartphone in your pocket or within arm's reach. The world's first smartphone is generally considered to be IBM's Simon Personal Communicator from the 1990s. It surpassed any other mobile at the time, as it sent and received emails, had a calculator, calendar, games and even a touchscreen, which was a revolutionary concept back then. It even had a basic predictive text function.

But it was not a commercial success, so the first smartphone to really take off was the Kyocera 6035, launched in 2001. It had an attached modem that wirelessly to the internet to send and receive emails and had 8GB of memory. It made work on the go a real possibility without the need for cables or heavy laptops.

Sending mixed signals

How your calls get from A to B while on the move



Roaming
Roaming charges are made when a user heads out of their service provider's reach and uses another's mast instead.

The switch
The switch has a database of all the mobile phones that are turned on and their cell site locations. It locates the position of the recipient and sends an electrical signal to the nearest mast.

Dialling
When the number is dialled, the antenna at the local cell site identifies the caller and the recipient. A cell site is where antennas and communications equipment are placed inside a mast or tower.

Call ended
If you are talking on the move and travel out of range of a phone mast, the phone call will cut off.

1983 — **Motorola DynaTAC 8000X**
Widely regarded as the first-ever commercial cellular phone.

1994 — **Simon Personal Communicator**
First PDA/cell phone - included applications such as a calculator, calendar, address book, etc.

1996 — **Motorola StarTAC**
First clamshell cell phone – design reaches the cell phone at last.

1999 — **Nokia 7110**
One of the first to use Wireless Application Protocol (WAP).

1999 — **Sharp J-SH04**
One of the first camera phone (released only in Japan).

2000 — **Samsung SPH-M2100**
The first MP3 cell phone.

5 TOP FACTS
MOBILE DATA

Heavy lifting
1 The first-ever commercial mobile phone was the Motorola DynaTAC 8000X, which weighed 790g (28oz), or about the same as seven modern smartphones.

Buy Phone
2 Up until June 2014, 500 million iPhones have been sold worldwide, from the original launch in 2007 to the latest 5S model released in late-2013.

First to phone
3 Motorola engineer Marty Cooper made the first public mobile phone call. When he made it on 3 April 1973 his first words were to mock a rival telecoms engineer.

Price drop
4 The first-ever mobile phones cost over £2,300 ($3,500) but were still hugely popular with people who were on the go, even though coverage was much more limited.

Half the world away
5 There are six billion registered mobile phones across the globe, so there's nearly one for every person on the planet, although multi-mobiled people do skew that statistic.

DID YOU KNOW? *The best-selling mobile phone in history was the Nokia 1100, with over 250 million sold*

Going international
When making a very long-distance call, satellites are used to bridge the gap. This is why there is often a delay as the signal has to travel much farther.

On the move
If you have come into range of another mast before leaving another, it transfers seamlessly.

Connecting
The local cell site antenna establishes communication with the recipient's phone. When you start talking, vibrations are turned into electrical signals.

The recipient
The electrical signal is turned back into vibrations by the target phone, which enter the recipient's ear as sound.

2001 Kyocera QCP6035
The first successful 'smart' phone.

2005 Motorola ROKR
First cell phone with iTunes.

2001 Panasonic P2101V
Among the first third-generation cell phones (with videoconferencing).

2007 iPhone
It has a 8.9-cm (3.5-in) touchscreen and Wi-Fi Web access.

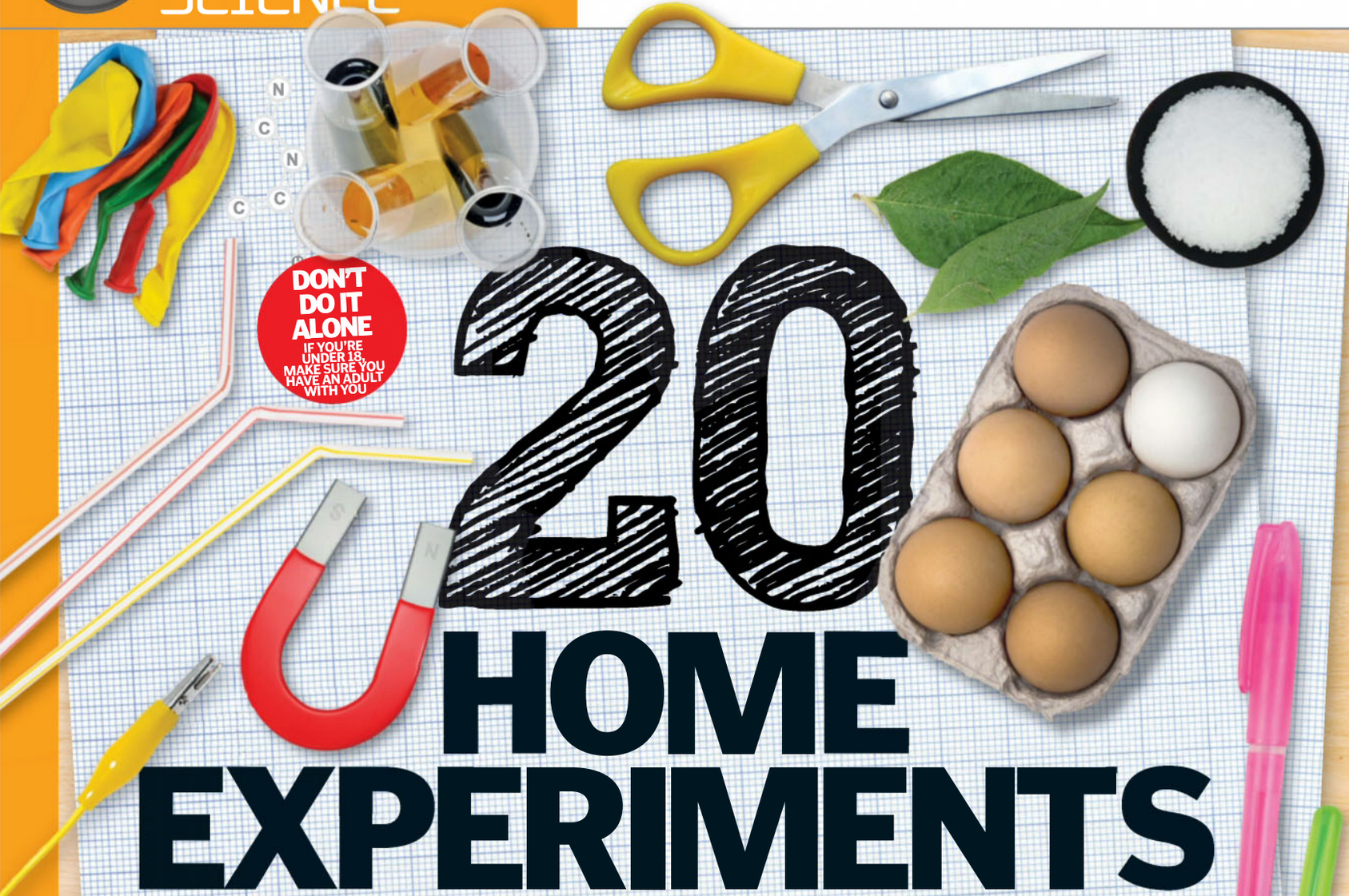
App attack

Apps are a crucial part of the modern mobile phone. It's estimated that the app market is worth a staggering £14.6 billion ($25 billion) worldwide, but which have had the biggest impact on the mobile scene?

Biggest buzz
The simple but insanely difficult *Flappy Bird* was an incredible success, netting independent creator Dong Nguyen £29,200 ($50,000) per day through advertising alone. He eventually took it down after he couldn't deal with the sudden pressure and fame.

Most downloaded
Probably the most famous app of all time, *Angry Birds* has been downloaded more than two billion times since it launched in December 2009. It has since spawned a cartoon series, console games and a planned feature film.

Highest grossing
Strategy and battle app *Clash Of Clans* has been at the top of the most recent charts in terms of revenue, gaining around £700,000 ($1.2 million) per day. However, *WhatsApp* netted its founders £11 billion ($19 billion) when they sold it to Facebook in 2014, dwarfing *Clash Of Clans'* cumulative revenue.



DON'T DO IT ALONE
IF YOU'RE UNDER 18, MAKE SURE YOU HAVE AN ADULT WITH YOU

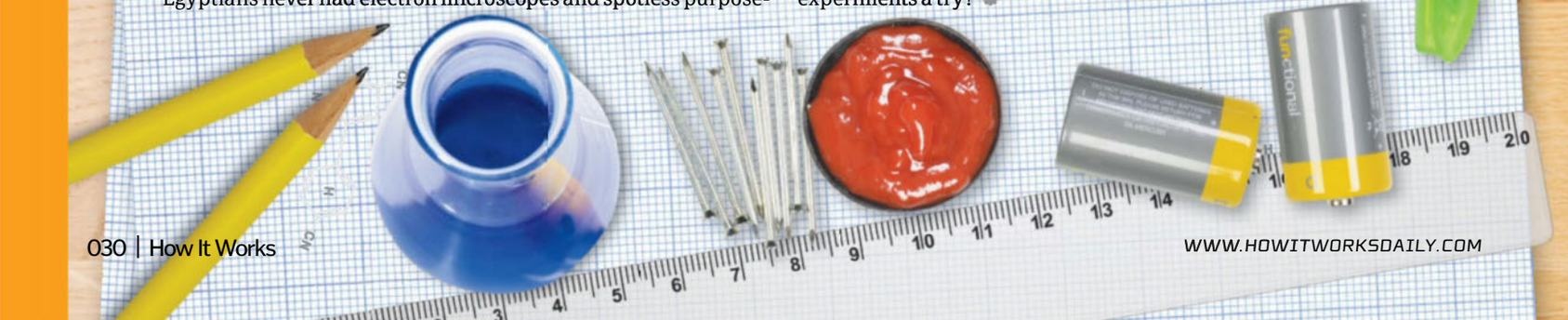
20 HOME EXPERIMENTS

Discover science in the most fun way possible – by doing these awesome experiments in your own home!

If you've ever seen a hovercraft and thought it looks amazing but you'd never be able to have one, think again. You can make one in minutes! It's just one of our 20 experiments you can do at home, no lab coat required. Not only are they fun to do, but they will also explain some of the basic parts of our everyday lives, like how magnets work, the secret to how planes stay airborne and the reason why plants will stop at nothing to reach sunlight.

Using everyday items like combs, rubber bands and string, we will demonstrate real science. After all, the Greeks, Romans and Egyptians never had electron microscopes and spotless purpose-built labs, but they made huge headway with medicine, geology, engineering and maths, to name a few. With nothing but a piece of card and a glass of water you'll discover the true colours of light, and by the end of the article, you'll be standing on egg shells that appear to be made of steel.

Science is fascinating, but it can also be delicious. Skip ahead to the Food And Water section of this feature to discover how to pour an instant soda slushy and make ice cream in a bag in 30 minutes flat. So if you have an enquiring mind and a few things lying around the house, why not leap right in and give these experiments a try?



THE STATS
LIGHTNING STATS

AVERAGE SPEED **360,000km/h**

STRIKES PER SECOND 100

TEMPERATURE 27,700°C

ODDS OF BEING STRUCK IN A LIFETIME 1/3,000

ENERGY PER BOLT 5bn joules

AVERAGE LENGTH **8km**

DID YOU KNOW? *Earth's magnetic fields flip every 500,000 years and one is due in the next few thousand years*

ELECTRICITY & MAGNETS

1 Make a magnet

15 mins

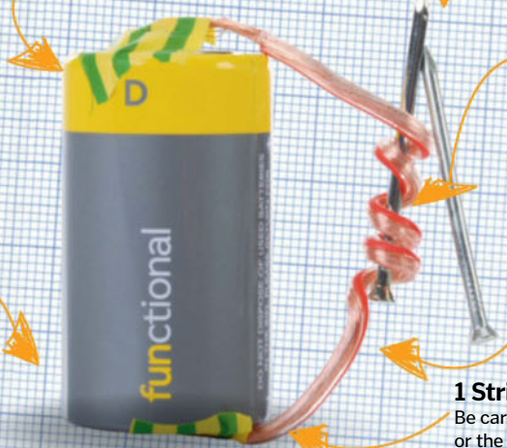
How to create your own electromagnet from the contents of a toolbox

Checklist
- ✔ D battery
- ✔ Iron nail
- ✔ Thin-coated copper wire
- ✔ Magnetic object, eg paperclips

3 Tape it down
Secure one wire end to the positive and one to the negative end of the battery using electrical tape.

4 Make your magnet
Congratulations, you have now made an electromagnet! Test it by picking up your magnetic items.

ALWAYS TAKE APART WHEN FINISHED



2 Wrap the nail
Wrap the wire around the nail, with about 20cm (8in) of wire free at either end.

Once enough atoms point in the same direction, they will pick up other magnetic items.

Electricity flowing through a wire creates a magnetic field. Winding this around an object concentrates the field.

1 Strip it down
Be careful not to cut yourself or the wire and trim 2.5cm (1in) of plastic coating away from each end.

The molecules in the nail are rearranged by the electricity flowing through them. This makes them point in the same direction.

Each atom is magnetic but as they are scattered, they cancel each other out.

What you'll learn
How an electromagnet is created and what it's able to pick up

2 Compass

10 mins

Make a compass from just a needle

Checklist
- ✔ Needle
- ✔ Magnet
- ✔ Leaf
- ✔ Bowl of water

What you'll learn
How magnetising an object can help you find your way around

1 Magnetise your needle
Stroke the needle with the magnet 50 times in the same direction. Put a marker on the end you've stroked toward to help you identify it.

2 Make your compass
Magnetic objects naturally point north. Place the leaf and nail on the water so it can spin unhindered until it finds the direction.

3 The science behind it
Stroking the needle with the magnet aligns the atoms. It points north because that is the direction Earth's magnetic field lines point.

3 Magnetic cereal

Cereals are fortified with so much iron you can actually see it!

Checklist
- ✔ Box of cereal
- ✔ Magnet
- ✔ Blender

10 mins

What you'll learn
How you can find out the amount of iron in your cereal

Empty cereal into a blender, cover with hot water and blend until mushy. Pour it into a plastic ziplock bag and after five minutes, drag a magnet along the bag toward the bottom. Bit by bit, the iron in the cereal should appear, drawn to the edge of the bag. Iron is vital for our bodies, as it helps make red blood cells, so many cereal manufacturers add this to their products.

4 Conjure lightning

Create a small electrical storm in your own kitchen

Checklist
- ✔ Plastic fork
- ✔ Tin foil
- ✔ Balloon
- ✔ Rubber glove

10 mins

What you'll learn
Find out how electricity is created thanks to static charges and a conductor

Wrap the fork in silver foil and rub the balloon all over your hair, giving it a negative charge. Put the balloon down and touch it with the fork, using your gloved hand. This transfers electrons to the fork. Touch the tin foil with your ungloved hand and take it away. A small spark of static electricity should appear as electrons leap from the fork to your hand.

"As the air flows out of the balloon [...] it creates a cushion of air underneath the CD"

FORCES AND MOTION

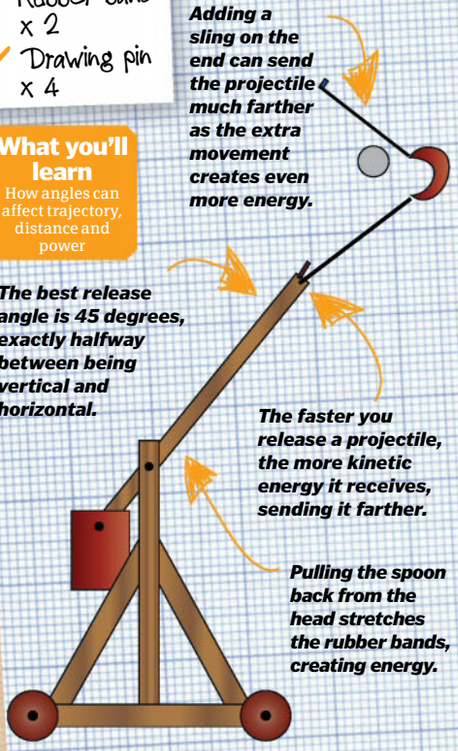
5 DIY catapult

How to defeat your medieval enemies with physics

20 mins

Checklist
- Block of wood
- Spoon
- Rubber band x 2
- Drawing pin x 4

What you'll learn
How angles can affect trajectory, distance and power



1 Make the base
Select a weighty block of wood, about 2.5cm (1in) thick. Wrap two rubber bands around the front, one above the other, secured either side by a drawing pin.

2 Create the catapult
Slip a spoon in between the wood and the rubber bands, with the head pointing up. This will become your catapult arm.

3 The crossbar
Build a crossbar by gluing two pieces of wood to a horizontal one. Use a protractor to see when the spoon's angle is 45 degrees and glue the structure on either side.

6 Hovercraft

Create your own working hovercraft with basic items

10 mins

Checklist
- CD
- Balloon
- Bottle cap

What you'll learn
How a hovercraft stays aloft on air currents alone

You might think a hovercraft is a bit out of your reach, but you can easily make one from a few party leftovers. Either use a pop-open bottle cap or poke a hole in the screw-on kind. Glue it firmly over the CD hole, making sure there's no place for air to escape. Blow up a balloon and pinch it shut, but don't tie it. Fit the balloon mouth over the bottle cap and release. Within seconds you should have a fully operating hovercraft! As the air flows out of the balloon through the small hole in the bottle cap, it creates a cushion of air underneath the CD, lifting it off the ground. The CD can rest on this cushion of air, much like a hovercraft does.

7 Mini-glider

Learn all about lift and airflow with this speedy paper aeroplane

Checklist
- Stiff paper or card
- Straw
- Sticky tape

5 mins

What you'll learn
How lift keeps a plane airborne with little effort

Cut the card into thin strips, one half the length of the other. Loop it around and secure with tape. Attach either end of the straw to each cylinder to create an aeroplane. Air flows faster over the top of the hoops' curves, creating low pressure above the plane and providing lift. The larger hoop at the back creates the required drag to keep the plane level.

8 Eggs of steel

Walk on eggs to discover the hidden strength of your breakfast

Checklist
- Two cartons of eggs
- Newspaper
- Bravery

What you'll learn
How eggs are some of the strongest structures in the world

It is possible for you to stand on top of a carton of eggs without breaking them, if you evenly distribute your weight. This is because the curved ends of the egg form one of the strongest structures in nature – an arch. It's the reason why chickens don't break their eggs when they sit on them. Simply turn the eggs in a carton so the pointy end is facing down and keep your feet flat as you step on them. Alternatively, collect four empty eggshells and snip off any sharp edges around the middle. Arrange them in a rectangle shape and carefully place a book on top. As long as the shells are all the same height, the dome will spread the weight evenly. That's why bridges are often constructed from arches.

AMAZING VIDEO! SCAN THE QR CODE FOR A QUICK LINK

Watch this video of Jon Tickle walking on custard

www.howitworksdaily.com

DID YOU KNOW? *When sea water freezes to form sea ice, a lot of the salt is actually removed from it*

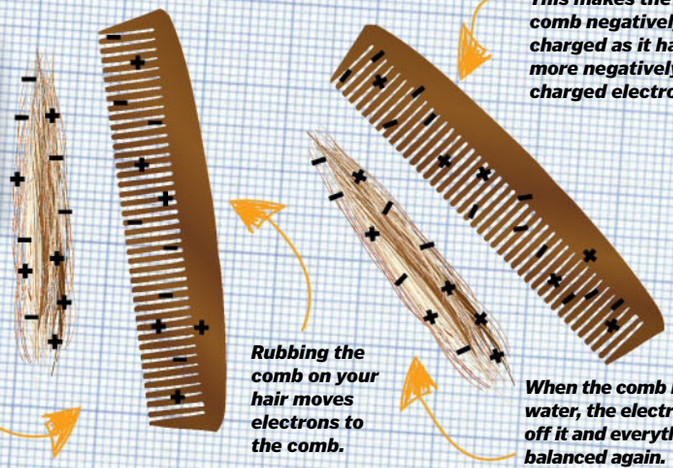
FOOD AND WATER

9 Bending water

5 mins

How to use electron transfer to make water bend before your eyes

Checklist
- ✔ Water tap
- ✔ Comb
- ✔ Hair

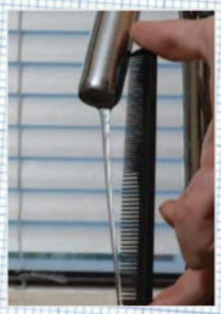


Hair doesn't conduct electricity very well so every time you comb it, you are increasing static charge

What you'll learn
How you can manipulate a stream of water without even touching it

1 Charge the comb
Rub the comb on your hair. This will transfer electrons onto the comb and negatively charge it. As you are grounded, electrons will come from the ground and balance you, but the comb remains full of negative charge.

2 Force of attraction
Start the water running at a very slow stream. The negatively charged comb repels some of the electrons in the water. This creates a positive charge in the stream so it is attracted towards the comb.



3 Coming together
This desire to transfer electrons pulls the positively charged water toward the comb when it's nearby. The force that attracted the two together is called static electricity.

10 Levitating ice cubes

Perform science-inspired magic by sliding a string into a block of ice

Checklist
- ✔ Glass of water
- ✔ Ice cube
- ✔ String
- ✔ Salt

10 mins

What you'll learn
How salt lowers the freezing temperature of water

Drop the ice cube into a glass of water and lower string onto the top of the ice cube. Shake a little salt over it, which melts the ice. This is because salt molecules lower the freezing point of water. After a few minutes, the salt will dissolve which enables the ice to re-freeze around the string, trapping it so you can lift the cube.

11 Instant soda slushy

Turn your ordinary fizzy drink into a delicious brain-freezing slushy

Checklist
- ✔ Bottle of fizzy drink
- ✔ Freezer

2 hours

What you'll learn
How pressure affects freezing points

Shake the bottle and put it in the freezer for three hours and 15 minutes to create a soda slushy. The reason the drink doesn't freeze completely is because all the sugars, flavourings and carbon dioxide bubbles in the soda lower its freezing point. As soon as you open the bottle, the carbon dioxide rushes out and the freezing point rises again, giving you instant soda slush.

12 Ice cream in a bag

30 mins

How to create ice cream

Checklist
- ✔ 250ml milk/cream
- ✔ 2 tablespoons sugar
- ✔ 12 tablespoons salt
- ✔ Half teaspoon vanilla extract
- ✔ 2 ziplock freezer bags

What you'll learn
How an ice pack can rapidly reduce temperature

Mix together the milk or cream, sugar and vanilla extract and pour into a ziplock bag. Pour the ice and salt into another and put the first bag into the second. Leave it to freeze for half an hour, take it out and it should have solidified. The salt slightly lowers the ice temperature so the ice cream becomes cold and solid, rather than completely frozen.

"The pitch lowers with the water level because there's more air vibrating, making a deeper sound"

SOUND AND LIGHT

13 Create a rainbow

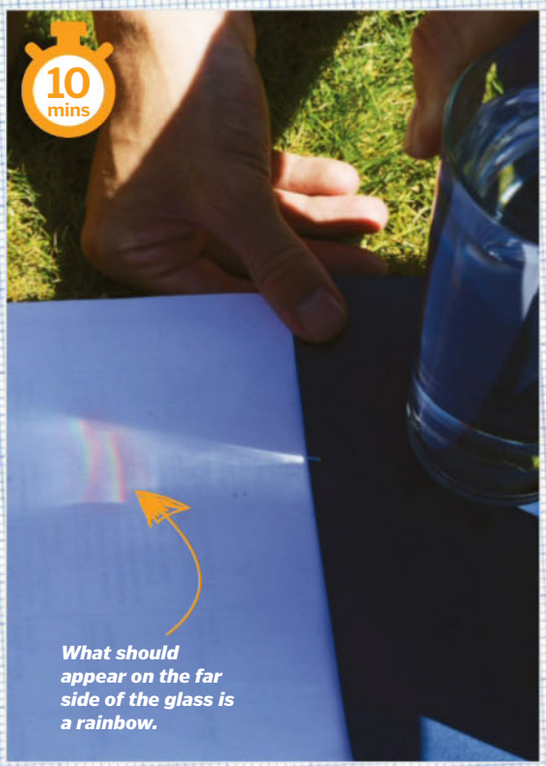
Create a rainbow with nothing but a glass of water

What you'll learn
Properties of light, their different wavelengths and the light spectrum

Checklist
- ✔ Glass of water
- ✔ Cardboard
- ✔ Scissors
- ✔ Sellotape

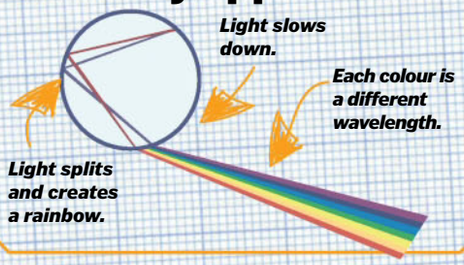
1 Cut the card
Wait for a sunny day. Cut a 2.5cm (1in)-wide slit in the cardboard, slightly longer than the height of your glass.

2 Secure the card
Stand it up with the slit between you and the Sun. Sellotape the bottom to keep it steady.



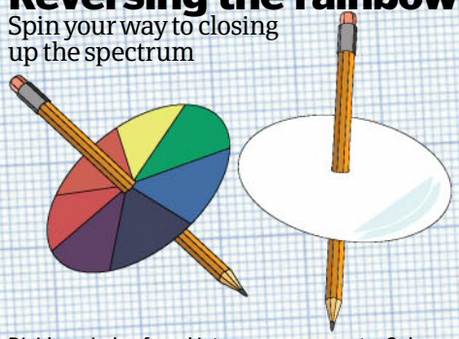
3 Place your glass
Put your glass of water next to the card so that the card is between the glass and the Sun. The light should stream through, hit the glass and split into a rainbow. Move the glass about a bit until it appears.

Why does light suddenly appear?



Reversing the rainbow

Spin your way to closing up the spectrum



Divide a circle of card into seven segments. Colour each one with a different colour of the rainbow, push a pencil through the middle and spin it as fast as you can. The colours should merge, leaving the card nearly white. This is because the colours of the spectrum merge into the white light we usually see.

14 Bottled music

Make music with bottles of different levels of fluid

Checklist
- ✔ Several bottles
- ✔ Water
- ✔ Drumstick

What you'll learn
How vibrations can affect the pitch of sound as it reaches your ear

When blowing across the top of bottles, the air vibrates, sending sound waves to your ears. The pitch lowers with the water level because there's more air vibrating, making a deeper sound.

15 Chasing light

See how plants grow toward the Sun

Checklist
- ✔ Plant in a pot
- ✔ Shoebox
- ✔ Cardboard
- ✔ Scissors
- ✔ Glue
- ✔ Black paint

What you'll learn
How plants grow toward the light, even with obstacles in their way

Paint the inside of a shoebox black and glue pieces of cardboard to the sides. Cut a hole in the top and place it in a sunny spot. The plant will grow to reach the light because it needs light for energy. The plant hormone auxin controls the direction of growth and makes cells more elastic, resulting in a bendy stem.

16 Soundboard

Discover how you can manipulate acoustics

Checklist
- ✔ Guitar
- ✔ Plastic board
- ✔ Metal board
- ✔ Decibel meter

Using a decibel app, play a note while holding a sheet of plastic above the guitar and record how loud it is. Change materials to see how some absorb sound and others deflect it.

What you'll learn
How different materials reflect sound

5 TOP FACTS
RAINBOW FACTS

How many colours?
1 Aristotle believed rainbows were only made up of red, green and violet. Isaac Newton was the first to divide the spectrum into the seven colours of the rainbow.

Follow that path
2 In Ancient Greece, rainbows were believed to be the path the goddess Iris took across the sky, linking the worlds of humans and gods together.

Find the angle
3 Light has to be refracted through water droplets at an angle of around 42 degrees in order to be seen by the human eye, and you must face away from the Sun.

Make mine a double
4 Double rainbows happen due to differently sized water droplets creating the required refraction angle. Triple and even quadruple rainbows are also possible, but very rare.

Working nine to three
5 The people of Sheffield were able to enjoy a rainbow that lasted from 9am until 3pm on 14 March 1994, which holds the record for the longest continuously viewed rainbow.

DID YOU KNOW? *Sunflowers move their heads to follow the Sun across the sky – this is called heliotropism*

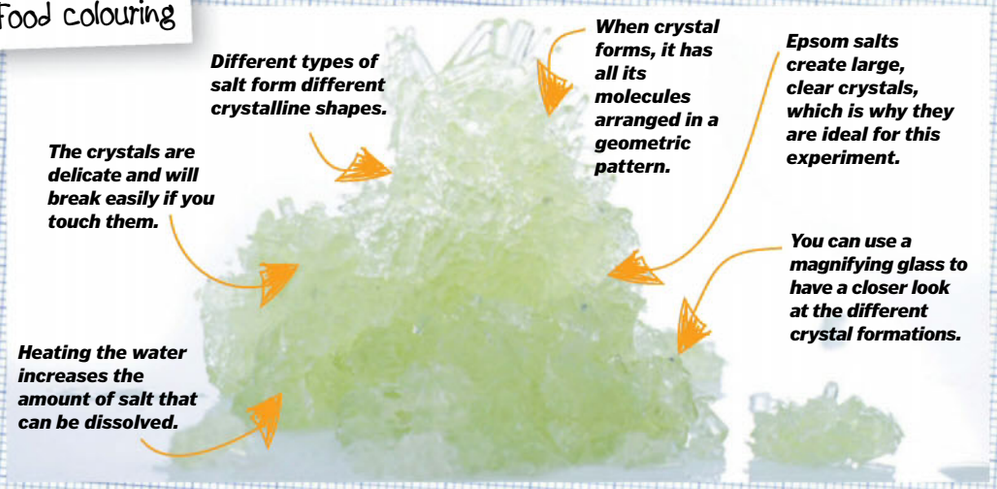
COLOUR AND LIGHT

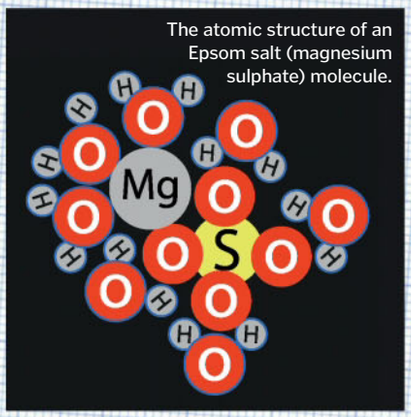
17 DIY crystals
3 hours

Grow your own beautiful gemstones with some salt and water

What you'll learn
The crystalline shapes that Epsom salt molecules form

Checklist
- ✔ 75g of Epsom salts
- ✔ 125g water
- ✔ Dish
- ✔ Food colouring





The atomic structure of an Epsom salt (magnesium sulphate) molecule.

1 Prepare the mixture
Boil some water and pour it into a container. Next, slowly tip the Epsom salts into the container, constantly stirring the mixture. Wait until they have totally dissolved.

2 Make your crystals
If want to see the results more clearly, add in food colouring. Pour the mixture into a bowl, with just enough liquid to cover the base. You could line it with a sponge.

3 Watch them grow
Place your container in a warm, sunny place. The water should begin to evaporate and, bit by bit, your crystals appear. They will be very fragile, but you can see amazing patterns.

18 Create milk art
5 mins

Channel your creative side with chemical reactions

Checklist
- ✔ Milk
- ✔ Plate
- ✔ Food colouring
- ✔ Washing up liquid
- ✔ Cotton bud

What you'll learn
How molecules react to reduce surface tension

Pour some food colouring into the middle of a plate of milk. Dip a cotton bud into washing-up liquid and dab the milk. The colour zooms to the edges of the plate because washing-up liquid contains water-hating micelles that push liquid away and reduce surface tension that is holding the food colouring in place.

19 Turn summer to autumn
2 hours

Change the colour of leaves

Checklist
- ✔ Leaves
- ✔ Rubbing alcohol
- ✔ Bag
- ✔ Jar
- ✔ Coffee filter paper
- ✔ Hot water

What you'll learn
Why leaves turn different colours in autumn and again in spring

In a jar, mash up leaves with rubbing alcohol. Put the jar into a bowl filled with hot water and cover. After 30 minutes, place a coffee filter in the solution. An hour later, the leaf will look autumnal. It's because chlorophyll makes leaves green, covering up other colour pigments. In autumn, chlorophyll levels reduce so the other colours can be seen.

20 Red cabbage pH indicator
20 mins

Acids and alkalis

Checklist
- ✔ Red cabbage
- ✔ Chopping knife
- ✔ Hot water
- ✔ Filter paper
- ✔ Six beakers
- ✔ Baking soda
- ✔ Lemon juice
- ✔ Vinegar
- ✔ Washing soda crystals
- ✔ Coca-Cola
- ✔ Tomato ketchup

Boil the red cabbage and then pour the water into beakers that contain different ingredients. The water contains a pigment that changes with pH. The colour reveals if it's an acid (red) or alkali (blue).

What you'll learn
Which items in your kitchen are acidic or alkaline

"The default eye colour is blue, but in most people, the iris is packed with protective pigment known as melanin"

The truth about eye colour

Discover the science behind the blues, browns, greens and greys of human eyes

It was originally thought that eye colour was based on a single gene, with a dominant brown variant and a recessive blue variant. But that's not the case. The truth is that eye colour is actually determined by more than a dozen genes.

The proteins that make up the iris scatter blue light and the default eye colour is blue, but in most people, the iris is packed with protective pigment known as melanin. It comes in two forms, brown eumelanin, and red pheomelanin, and the ratio of one to the other influences the shade, from light chestnut, to almost black.

The bulk of the melanin production in the eye is controlled by two genes on chromosome 15, and if either one of these is faulty, very little pigment is deposited in the iris. Almost all people with blue eyes have mutations in one or both of these genes.

But what about other eye colours? In some people, the melanin production is not turned off, it is just turned down, and small amounts of pigment are still able to reach the eye. Sometimes the pigment covers the whole iris, resulting in green or hazel eyes, and other times it clumps together to form spots, stripes and rings.

Spot the difference

Not only is there huge variation in eye colour in the human population as a whole, but some people also have amazing variation in their own eyes. People with complete heterochromia have two different-coloured irises. The trait is not inherited and is most often the result of random gene mutations, or sometimes physical injury, causing uneven distribution of melanin. Heterochromia is quite rare in humans, but common in dogs, cats and horses.

Nerve cells

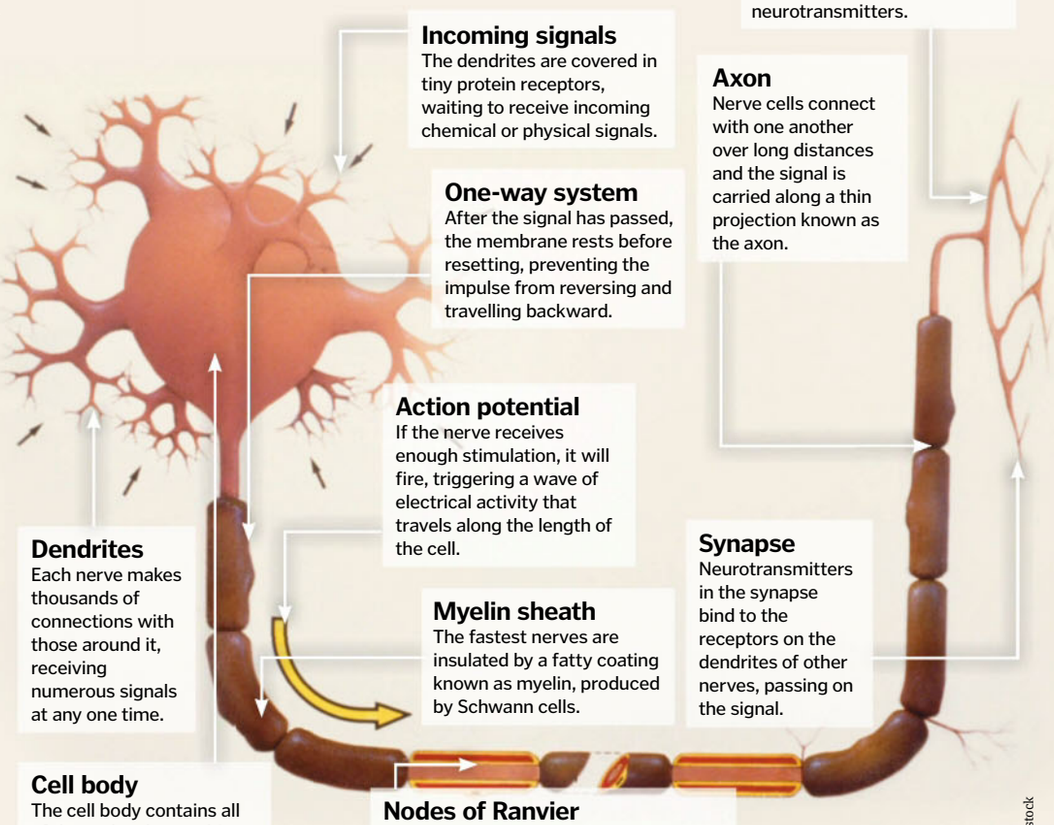
Learn about the network of messenger cells in your body

Neurones are cells in your nervous system that transmit messages around the body. They do this in the form of electrical signals called nerve impulses. At rest, the cells expend huge amounts of energy pumping positively charged sodium ions (Na+) out into the surrounding fluid. This leaves the inside of the cell slightly negatively charged. The sodium ions are attracted to the negative charge, but they are unable to cross the cell membrane and therefore become trapped on the outside, waiting for an opportunity to re-enter the neurone.

The outside of the cell is covered in voltage-activated channels; pores wide enough to fit a sodium ion, but which only open when the membrane voltage is high enough. If the neurone receives activation signals, tiny amounts of sodium are allowed to leak in, causing the voltage across the membrane to rise, opening the channels. As the ions flood the cell, more channels are activated further along the axon, initiating a domino effect. This transmits the signal to the synaptic terminal. Here, prepackaged neurotransmitters are released into synapse, where they deliver the message to other cells.

Inside a nerve cell

Neurones are some of the longest and most highly specialised cells in the human body



Axon terminal
When the signal reaches the end of the axon, it triggers the release of chemical messengers known as neurotransmitters.

Incoming signals
The dendrites are covered in tiny protein receptors, waiting to receive incoming chemical or physical signals.

Axon
Nerve cells connect with one another over long distances and the signal is carried along a thin projection known as the axon.

One-way system
After the signal has passed, the membrane rests before resetting, preventing the impulse from reversing and travelling backward.

Action potential
If the nerve receives enough stimulation, it will fire, triggering a wave of electrical activity that travels along the length of the cell.

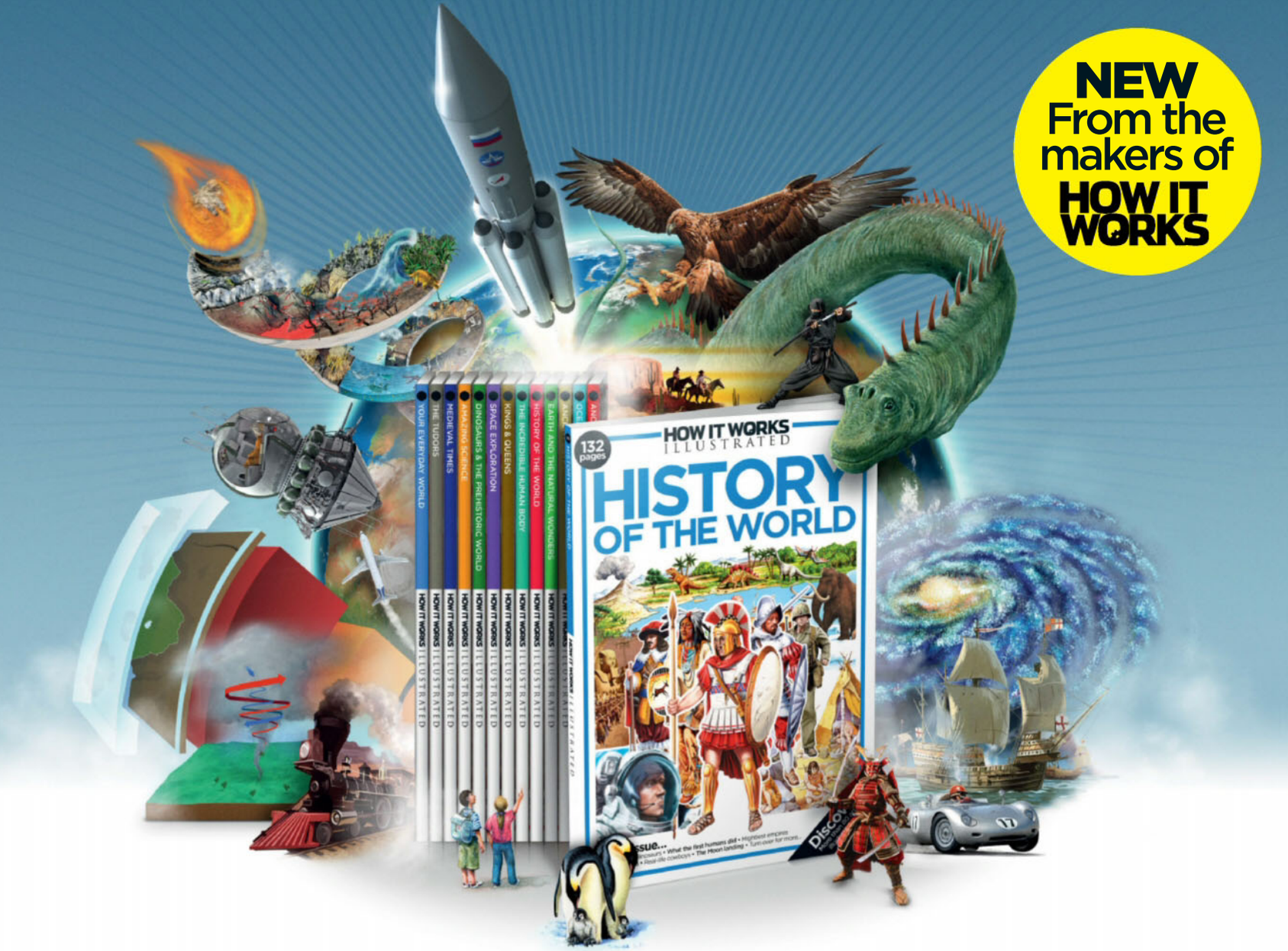
Dendrites
Each nerve makes thousands of connections with those around it, receiving numerous signals at any one time.

Synapse
Neurotransmitters in the synapse bind to the receptors on the dendrites of other nerves, passing on the signal.

Myelin sheath
The fastest nerves are insulated by a fatty coating known as myelin, produced by Schwann cells.

Cell body
The cell body contains all of the molecular machinery required to keep the nerve cell functioning.

Nodes of Ranvier
Gaps in the insulating layer allow the impulse to jump, skipping from one node to the next, speeding their transmission.



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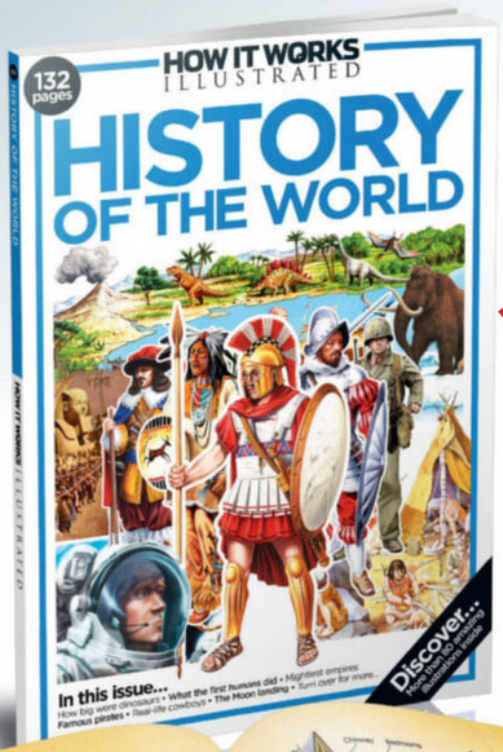
How big were the dinosaurs? Find out in issue one
big
How were the dinosaurs?
Dinosaurs were the largest animals ever to walk the Earth. Some of them were taller than trees, longer than aeroplanes and heavier than a herd of elephants
Diplodocus
Tyrannosaurus rex
Did you know?

HOW IT WORKS ILLUSTRATED

Issue one

HISTORY OF THE WORLD



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STRANGE BUT TRUE

MISLEADING NAME

Where did hay fever get its name?

A Hay allergy **B** Harvesting **C** Doctor's name

Answer:
The term hay fever has nothing to do with hay, and everything to do with trees, grasses and ragweed. The name came about because symptons would strike during hay-harvesting season, when these pollens would be rife.

DID YOU KNOW? *Allergic diseases, including asthma, are the fifth most common chronic disease in all ages*

When hay fever attacks

When summer strikes, why do some of us suffer?

We trample on lawns and mow them down, but eventually grass gets revenge. Its pollen causes many of us to suffer from hay fever, and so do trees, weeds and even some fruit and vegetables.

Despite being smaller than the tip of a pin, pollen is carried by the wind and lodges in the nasal lining tissues and throat, where it can cause an allergic reaction. This is when the body mistakenly thinks it has been invaded by a threat, such as a virus.

To fight back, the body produces a type of antibody known as immunoglobulin E (IgE) in response to the allergen, causing nasal passages to become inflamed, producing more mucus. This is designed to help flush out the allergens but can lead to other symptoms like headaches from blocked sinuses or coughing caused by mucus dripping down the back of the throat from the nose.

People genetically predisposed to hay fever are called atopics. Hay fever usually develops during childhood or teenage years, but adults can get it too. This is likely to follow repeated contact with a substance that your immune system perceives as a threat. No one knows for sure why hay fever starts affecting someone at the point in time it does.

Hay-fever sufferers are in trouble when the pollen count reaches 50 pollen grains per cubic metre of air. You'll experience it worse in the morning when plants release their pollen. Allergens collect in the air on humid days and during storms, but rain clears the pollen.

Pollen forecast

GRASS POLLEN (MAY-JULY)
95 per cent of hay-fever sufferers are allergic to grass pollen. Close windows on dry, windy days.

TREE POLLEN (MARCH-MAY)
Affects 25 per cent of sufferers and instigators include ash, birch, beech, willow and oak. Cut back branches in the garden to reduce pollen.

WEED POLLEN (SUMMER - EARLY AUTUMN)
In the USA, ragweed is the biggest culprit. One plant can spew out millions of pollen grains daily.

Why do we get a runny nose?

An inside look at how pollen can affect us

The statistics...

Allergy in numbers

- **15%:** Of UK population get hay fever
- **40%:** Risk if one parent suffers
- **80%:** Risk if both parents suffer
- **95%:** Of hay-fever sufferers are allergic to grass pollen
- **1 in 5:** Affected by hay fever
- **21 million:** UK adults suffer from one or more type of allergy

Airborne pollen
Fine dusty pollen is carried by the wind and inhaled through the nasal passage. People with a genetic disposition to hay fever, known as atopics, will have an allergic reaction.

Too much histamine
Histamine irritates the upper respiratory passages, making them swell and produce the typical hay fever symptoms. Histamine makes your mucus membranes work over time, producing enough mucus to flush the pollen out.

Antibodies
The pollen protein triggers your immune system, which creates thousands of antibodies. The antibodies attach themselves to mast cells, which release histamine – a substance the body produces to fight infection.

Protein problem
Proteins on the surface of the pollen grain irritate and inflame the cells that line your mouth, nose, eyes and throat. The body's immune system treats the pollen like a virus and takes action to expel it.

"After the operation, lifelong medications are taken to prevent the body rejecting the new heart"

Heart transplants

Discover what happens in one of the most complex surgeries

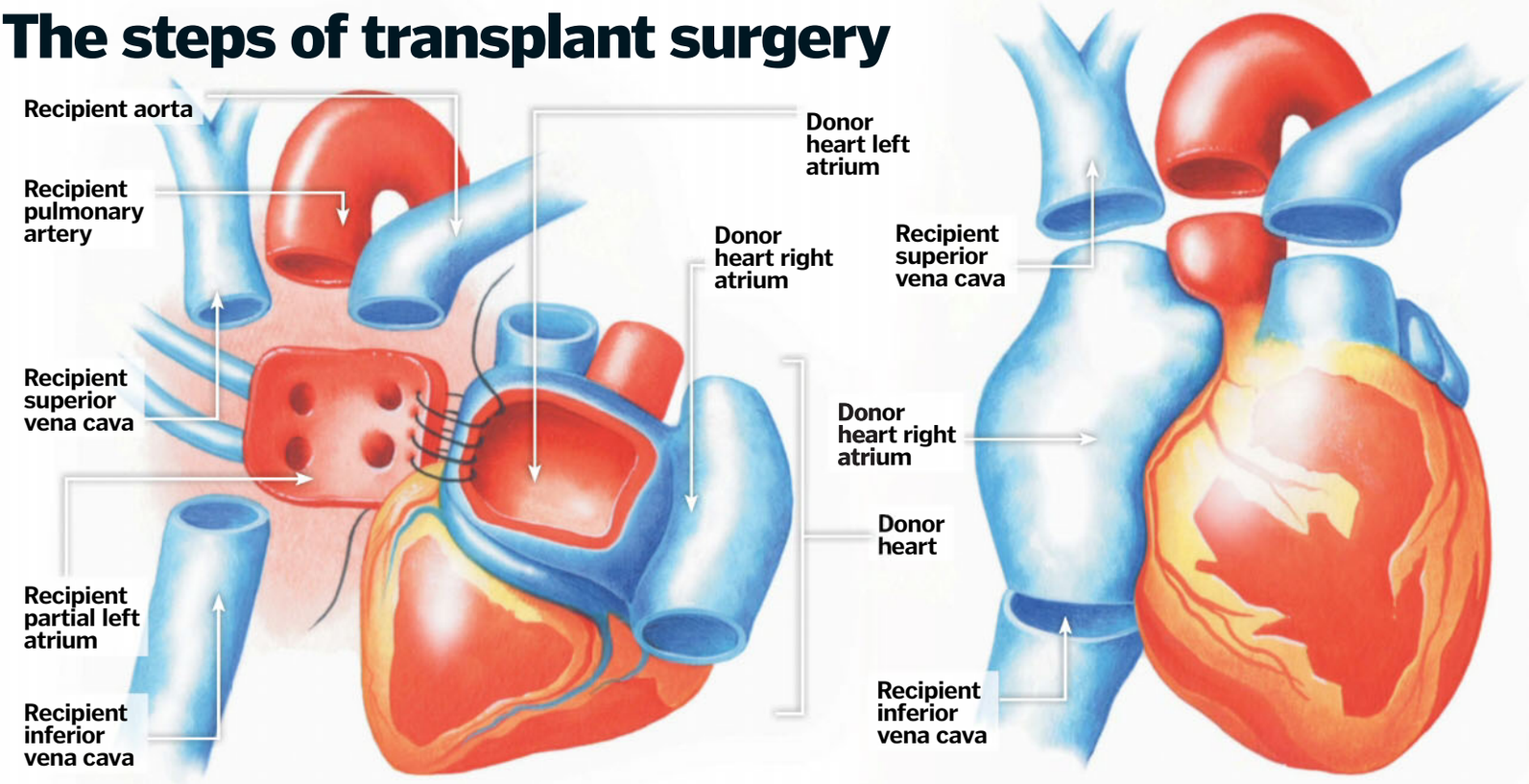
Heart transplants are a life-saving treatment that can restore a patient's quality of life.

Selecting suitable people for a heart transplant is a carefully controlled process. There are strict criteria to ensure maximum possibility of success, preventing wastage of any precious donor hearts. A heart transplant is recommended if a patient has severe heart failure, where not enough blood is being pumped around the body. Causes of this include diseases of heart muscles (cardiomyopathy) and a variety of genetic cardiac diseases. Patients typically have to pass psychological and emotional testing, be willing to take lifelong medications and have a current expected survival time of less than one year without transplant. Sometimes, newborn babies are affected, with ultrasound tests revealing structural problems meaning that the heart cannot pump enough blood. Further blood tests to rule out current infections and confirm tissue compatibility are performed.

The technical process of transplantation is complex and demanding for both patients and cardiac surgeons. The first step involves retrieval of the heart from the donor, at which time other organs might be harvested so that more patients can benefit. The receiving patient is given a general anaesthetic and a cut made through the breastbone (sternum) to access the heart. A heart-lung bypass machine is then started, and the heart transplant takes place. At the end of the operation, the new heart is tested, and if it's pumping blood successfully, the bypass machine is removed, the breastbone closed and the patient is moved to an intensive care unit.

After the operation, lifelong medications are taken to prevent the body rejecting the new heart. These include immunosuppressants, which reduce the patient's natural immunity, so their body does not reject their new heart.

The steps of transplant surgery



First incision

The sternum is cut with a special saw that doesn't damage the softer tissues underneath. The sac containing the heart (pericardium) is cut open and the patient placed on a heart-lung bypass machine. The blood vessels and chambers of the old heart are disconnected, leaving the back wall of the left atrium in place, which acts as the starting point for attaching the new heart.

Attaching the heart

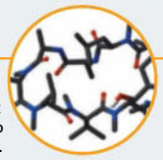
The veins carry blood back toward the heart. The biggest – the inferior and superior vena cava – drain into the right atrium. These are carefully attached to the new heart, which fixes the donor right atrium into place. Tiny stitches are sewn using very sharp needles, special needle holders and a steady hand!

KEY DATES
TRANSPLANT MILESTONES

2000 BCE
Evidence of heart disease has been found in 4,000-year-old Egyptian mummies.

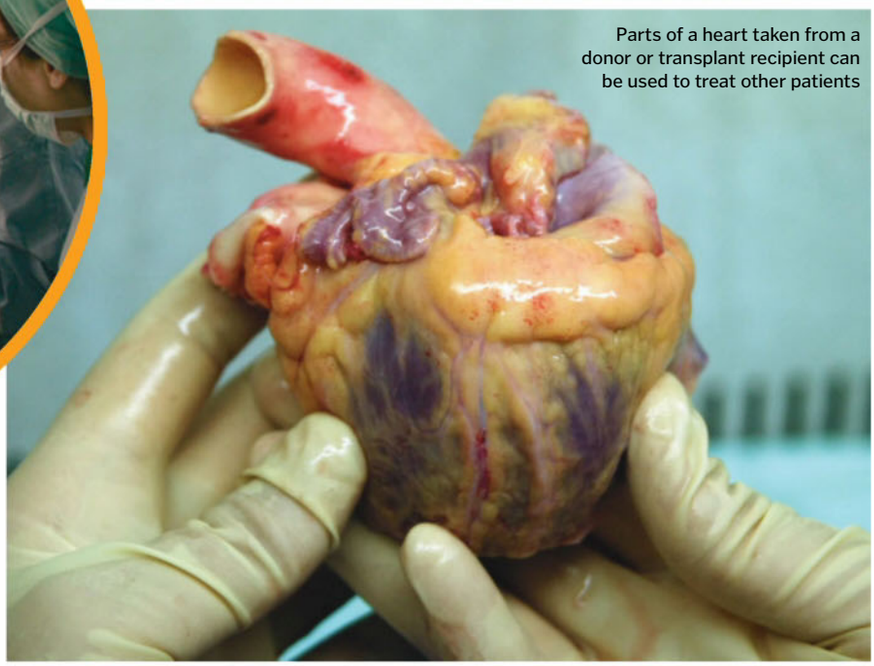
1967
The first human-to-human heart transplant takes place in South Africa, by Christiaan Barnard.

1971
Cyclosporine, an immuno-suppressant that prevents rejection, helps to advance heart transplants.

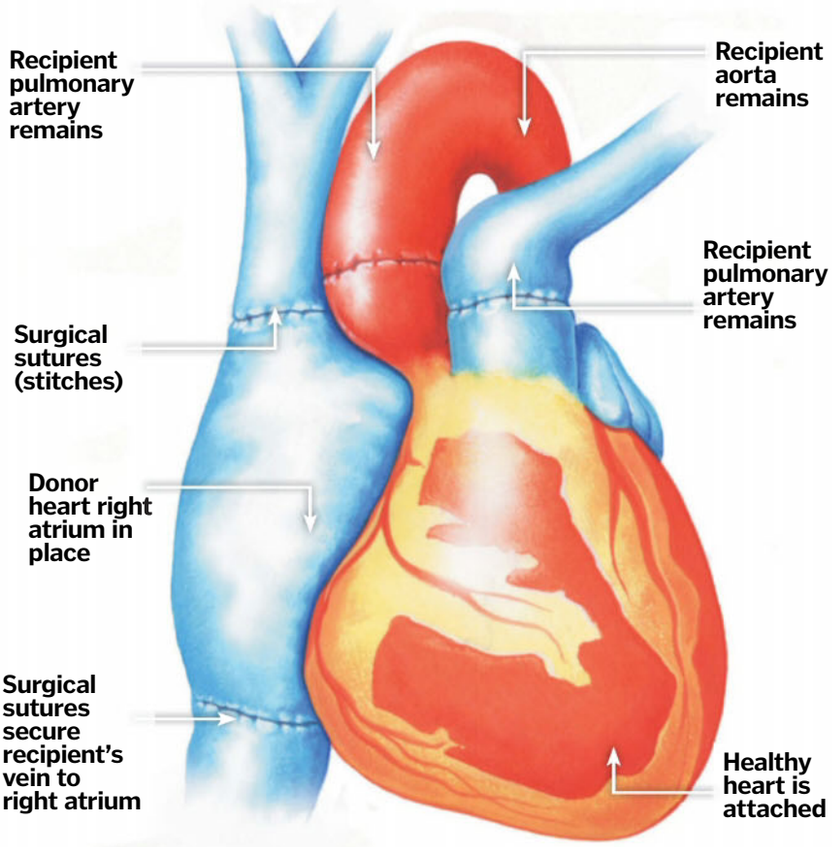


1982
The first successful artificial heart is transplanted into a human being. The patient survives fro 112 days.

DID YOU KNOW? *The human heart is not heart shaped – the popular heart shape was widely used on T-shirts in the 1970s*

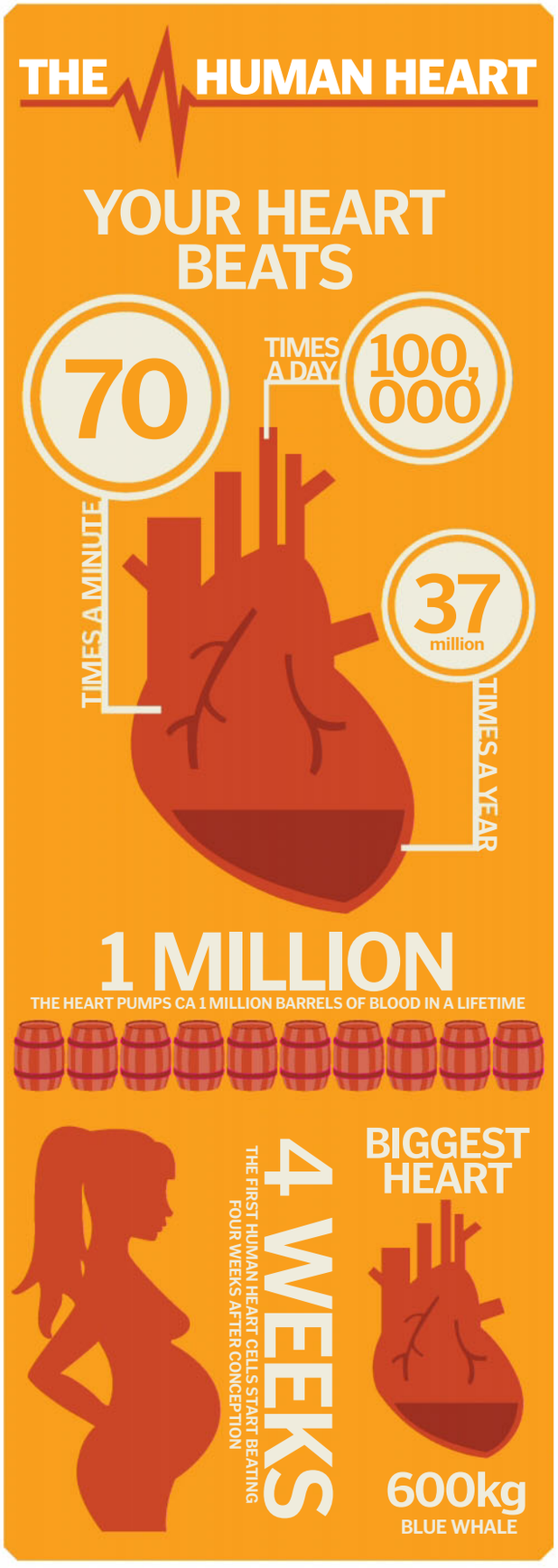


Parts of a heart taken from a donor or transplant recipient can be used to treat other patients



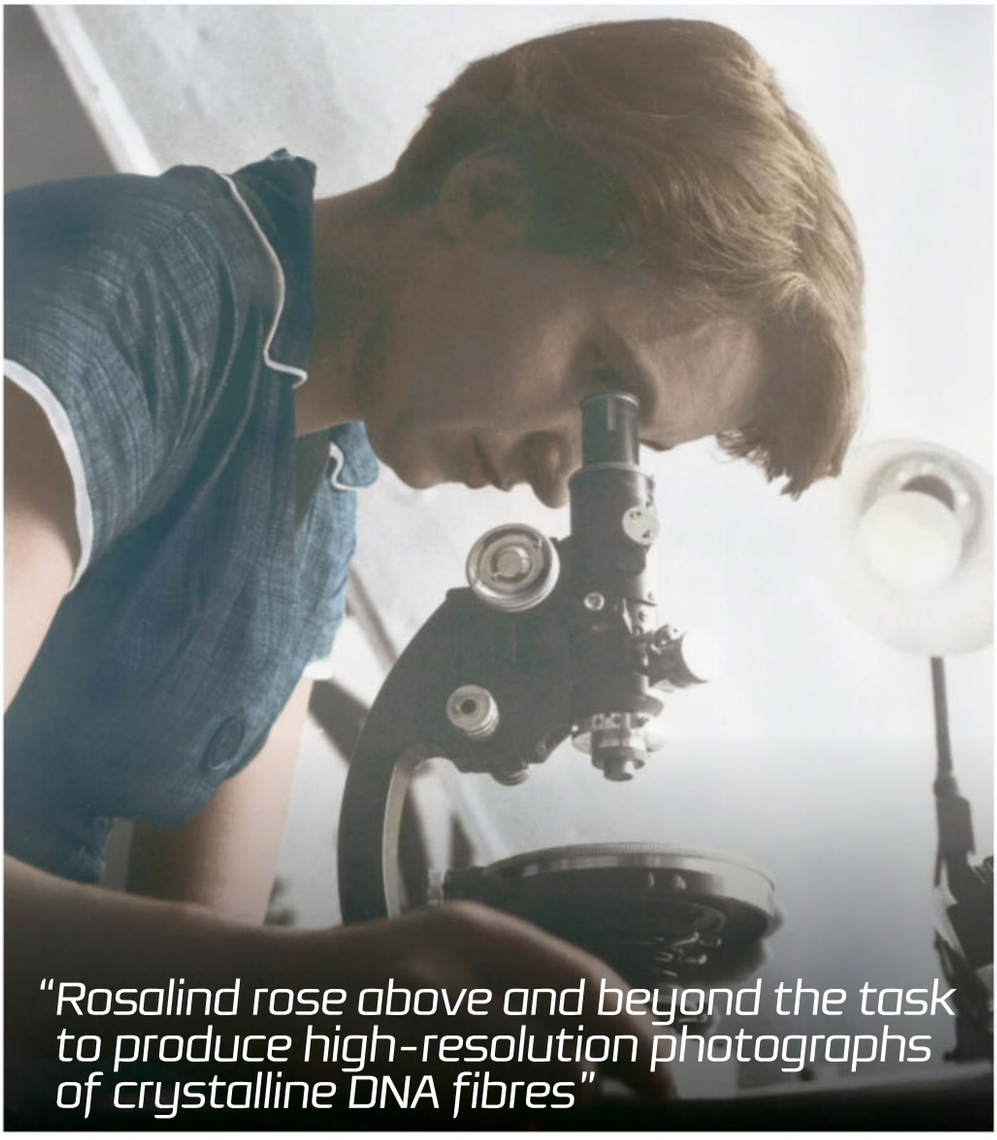
Completing the operation

The final steps include attaching the body's biggest and strongest artery – the aorta. This pumps oxygenated blood to the entire body and is under the highest pressure. The vessel bringing oxygenated blood back from the lungs (the pulmonary vein) is also attached. The clamps controlling the vessels are removed and the new heart started with a small burst of electricity.



Rosalind Franklin

How the work of the 'Dark Lady of Science' helped to solve the mystery of DNA



"Rosalind rose above and beyond the task to produce high-resolution photographs of crystalline DNA fibres"

Rosalind Franklin was not the most popular figure in science. Nicknamed the 'Dark Lady' by her male colleagues for being hostile and troublesome, it's hard to say if this really described her nature or if it was a result of patriarchal prejudice. What is certain, however, is that she lived in the darkness of these men's shadows.

Born in London in 1920, Rosalind attended St Paul's Girls' School – one of the few institutions in the country at the time that taught chemistry and physics to girls. She excelled in these subjects and by the age of 15, she knew she wanted to become a scientist. Her father tried to discourage her, as he knew that the industry did not make things easy for women. But Rosalind was stubborn. In 1938, she was accepted into Cambridge University where she would study chemistry.

On graduating, Rosalind took up a job at the British Coal Utilisation Research Association. By this point the Second World War was in full swing, and Rosalind was determined to do something to help the war effort. Her research into the physical structure of coal was pivotal in developing gas masks that were issued to British soldiers, and it won her a PhD in physical chemistry as well.

In 1946, Rosalind moved to Paris to work as a researcher for Jacques Mering – a crystallographer who used X-ray diffraction to work out the arrangement of atoms in substances. Here she learnt many of the techniques that would aid her later discoveries.

Five years on, she was offered the role of research associate in King's College London's biophysics unit. Rosalind arrived while Maurice Wilkins, another senior scientist, was away. On his return, he made the assumption that this woman had been hired as his assistant. It was a bad start to what would become a very rocky relationship.

Despite the tense environment in the lab, Rosalind rose above and beyond the task,

1920
Rosalind is born in London to an affluent Jewish family.

1938
She begins her studies in chemistry at Newnham College, Cambridge.

1945
Awarded a PhD in physical chemistry for her research into the structure and usage of coal.

1946
Moves to Paris to work as a researcher for crystallographer Jacques Mering.

1951
Joins King's College London as a research associate alongside Maurice Wilkins.

1952
Rosalind and her assistant Raymond Gosling take 'Photo 51', which proves the helical structure of DNA.

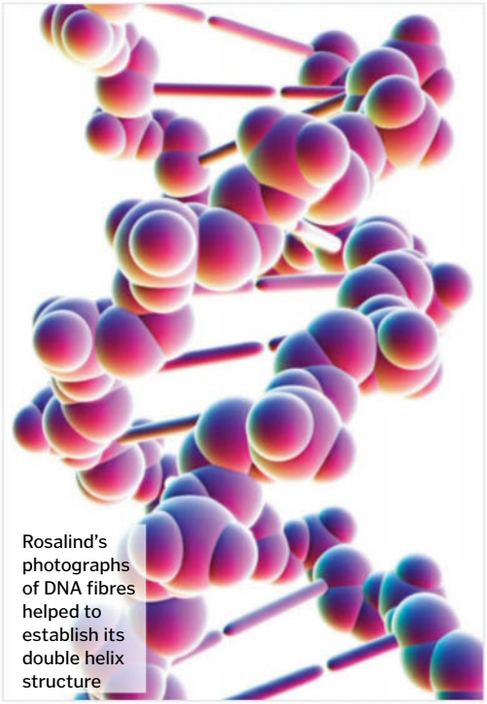
In their footsteps...

Marshall Warren Nirenberg

Nirenberg won the 1968 Nobel Prize in Medicine for cracking the genetic code. He, Har Gobind Khorana and Robert Holley discovered the rules by which genetic information is translated into proteins. They were able to identify the codons, a sequence of three chemical DNA units that determine the amino acid units from which protein molecules are built.

Christiane Nusslein-Volhard

Christiane is a German biologist who has used genetics to study developmental problems. After gaining a PhD in biochemistry, she screened for mutant genes in fruit flies and analysed the mutations. She shared the 1995 Nobel Prize in Medicine with Ed Lewis and Eric Wieschaus. She now studies zebrafish to research vertebrate development.



Rosalind's photographs of DNA fibres helped to establish its double helix structure

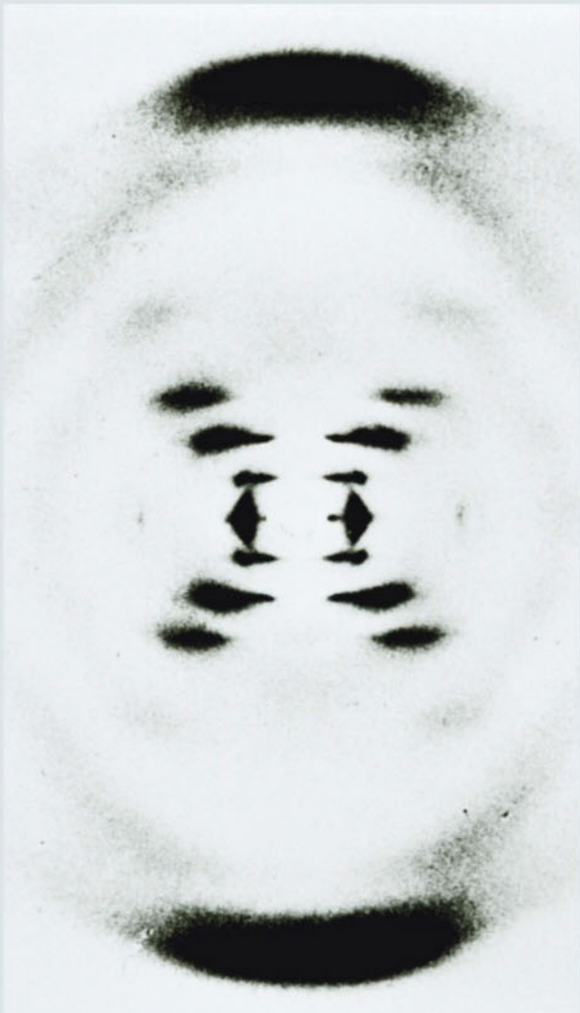
working alongside PhD student Raymond Gosling to produce high-resolution photographs of crystalline DNA fibres. The structure of DNA was a puzzle that Maurice and two of his friends – Francis Crick and James Watson – had been trying to piece together for years. But with a single photograph, simply labelled 'Photo 51', Rosalind and Raymond had cracked it.

Without her permission, Maurice took this photograph and showed it to Watson and Crick. It was the final piece in their puzzle – DNA was indeed a double helix. The trio published their findings, and in 1962 they were awarded the Nobel Prize in Medicine.

By a tragic twist of fate, Rosalind died of ovarian cancer four years previous to that. The doctors at the hospital she was treated at believed that prolonged exposure to X-rays was a possible cause of the disease. She had made the ultimate sacrifice for the sake of science, with no living reward.

The big idea

Rosalind used X-ray diffraction to analyse the physical structure of substances. This involves firing X-rays at them. When the X-ray hits the substance, the beam scatters, or 'diffracts.' Rosalind recorded the pattern created by this diffraction in order to discover how the material's atoms were arranged. The molecular structure of DNA had been puzzling scientists for years. Rosalind found that by wetting DNA fibres, the resulting images were a lot clearer. One photograph, called Photo 51, showed two clear strands. This indicated a double-helical structure, explaining how cells pass on genetic information.



Rosalind Franklin

1 Faking a death
Even during her experiments, Rosalind was unconvinced that DNA was helix-shaped, and even once sent her colleagues a notice commemorating the 'death' of helical DNA.

2 Beyond DNA
In addition to her work with DNA molecules, Rosalind also carried out pioneering research into the tobacco mosaic and polio viruses.

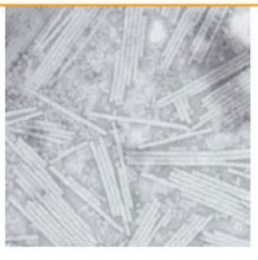
3 Girl power gone sour
Sexism was rife at King's College, where even Rosalind was accused of discriminating against women. In a letter to her parents, she allegedly referred to one lecturer as "very good, though female."

4 Not giving up
Rosalind tirelessly continued to work throughout her cancer treatment and was even given a promotion during the process.

5 No Nobel
Many people argue that the Nobel Prize should also have been awarded to Rosalind. But when the list of nominees was released 50 years later, it was revealed that, remarkably enough, she hadn't even been nominated.

1953
Maurice shows Photo 51 to his friends James Watson and Francis Crick, who then publish the findings.

1955
Rosalind reveals her discovery that tobacco mosaic virus particles are all the same length.



1957
Begins research into the polio virus, despite undergoing treatment for ovarian cancer.

1958
Rosalind dies of cancer, aged only 37, with no recognition for her groundbreaking discovery.

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2. QUICKEST

BMW 5-series

Although not tested under self-drive, a BMW 5-series can sprint to 100km/h (60mph) in five seconds – the fastest current vehicle with self-drive tech fitted.

3. HEAVIEST

Cadillac SRX

This American family wagon weighs a hefty two tons – and that's before it's laden with additional autonomous drive technology.

DID YOU KNOW? *Mainstream autonomous cars are closer than you think: Volvo wants to release a fully self-driven vehicle by 2017*

All aboard the road train

A further development on the self-drive principle for a single car has already been implemented on a series of vehicles, allowing them to travel autonomously and in tandem as a group. The concept was an idea borne from the 'SARTRE' project, which stands for Safe Road Trains for the Environment. Pioneered by Swedish manufacturer Volvo and a group of technological partners, their system uses an array of radar, camera and laser sensors linked together by wireless technology to allow autonomous vehicles to travel together in a train-like platoon. At the front of the platoon is a dedicated lead vehicle – driven by a professional driver, which is followed autonomously by the trailing vehicles. This is all being done in a bid to reduce the number of accidents caused every year by driver fatigue.

The technology has already proved plausible after tests were carried out over 200 kilometres (124 miles) of road near Barcelona, Spain, in May 2012, with three cars automatically following a truck driven by a human being. The road train successfully melded autonomous technologies with car-to-car 'communication' to ensure the three self-driven vehicles remained in line throughout the whole test – and crucially, with no collisions.

Volvo's SARTRE project in action on a public road

Self-driving trucks

Family cars aren't the only vehicles currently receiving the autonomous treatment. Mercedes is developing the self-drive concept for its fleet of heavy-haulage trucks.

And, different to the realms of pioneering software of a Google car, Mercedes is simply evolving some of the tech already found in their new luxury saloons instead. Cruise control, lane assist, auto braking and stability control – all available on the Stuttgart company's new S-Class – has been synced to a radar on its Mercedes-Benz Future Truck 2025 prototype, which scans the road ahead by up to 250 meters (820 feet) and communicates with the established systems to keep the lorry moving safely, without input from a driver. Developers say the system will drive more economically than a human, saving fuel, while increasing productivity as the vehicle will be able to travel for longer periods than what daily driver limits will currently allow.

Self-drive technology could revolutionise truck transport

The cars of tomorrow won't need steering wheels, an accelerator or a brake pedal; they're autonomous and don't require any human input. What's more is that they are already on the road, with car company Volvo unleashing 100 of them on public roads of Gothenburg, Sweden, in a two-year project.

An autonomous (known as 'self-drive') vehicle works mainly thanks to a wealth of on-board radars, sensors and cameras that continuously 'read' the car's surroundings to build a picture of the road ahead. While radars and sensors monitor everything from the proximity of other cars on the road to the whereabouts of cyclists and pedestrians, a forward-facing camera interprets highway instructions from road signs and traffic lights. All of this information is continuously fed to the vehicle's on-board computer, which uses the data to action appropriate inputs into the car's speed and trajectory within milliseconds. Meanwhile, advanced GPS technology is constantly used to clinically navigate the vehicle along a precise route.

An autonomous vehicle prototype, otherwise known a self-driving car, looks fairly similar to a contemporary human-driven vehicle. Built-in sensors dotted around the car emit frequencies that bounce back off objects – much in the same way parking sensors work on executive saloons now – to provide a rationale of how close things such as curbs, pedestrians and other vehicles are to the self-driving car. The processing computer and GPS system are stored out of sight, leaving the roof-mounted LIDAR (Light Detection and Ranging) as the only discerning differentiation from the norm.

This rotating camera sends out lasers and uses the reflected light to effectively build a 3D picture of the car's position within the current environment. The information received from these 'bounced' light rays is sent to the main on-board computer. In the cabin, an occupant is treated to a screen showing the route, plus there's an emergency stop button that will immediately pull the car over if needed.

Although technology giant Google has led the way in terms of evolving self-drive technology, automotive manufacturers such as BMW and Nissan have placed considerable resources for research and development into the technology of their own autonomous vehicles. These test vehicles tend to be adapted versions of current human-driven vehicles and as soon as a person touches any of the foot pedals or steering ▶

"The unpredictability of hazards when driving is the biggest challenge for an autonomous vehicle to overcome"

wheel, the system immediately cedes control back to the driver.

Although Google began its autonomous vehicle mission by adapting already homologated Toyota and Lexus cars as far back as 2010, its latest prototype is arguably the best yet. So far, it has proved to be markedly safe compared to human-input driving, as driver fatigue or alcohol impairment will play no part in getting from A to B.

To heighten safety even further, Google is experimenting with flexible windscreens and a front made of foam-like material to protect pedestrians on impact, should the worst happen. These cars have also been limited to a relatively tame 40-kilometre (25-mile)-per-hour top speed while the project is still in the development stage.

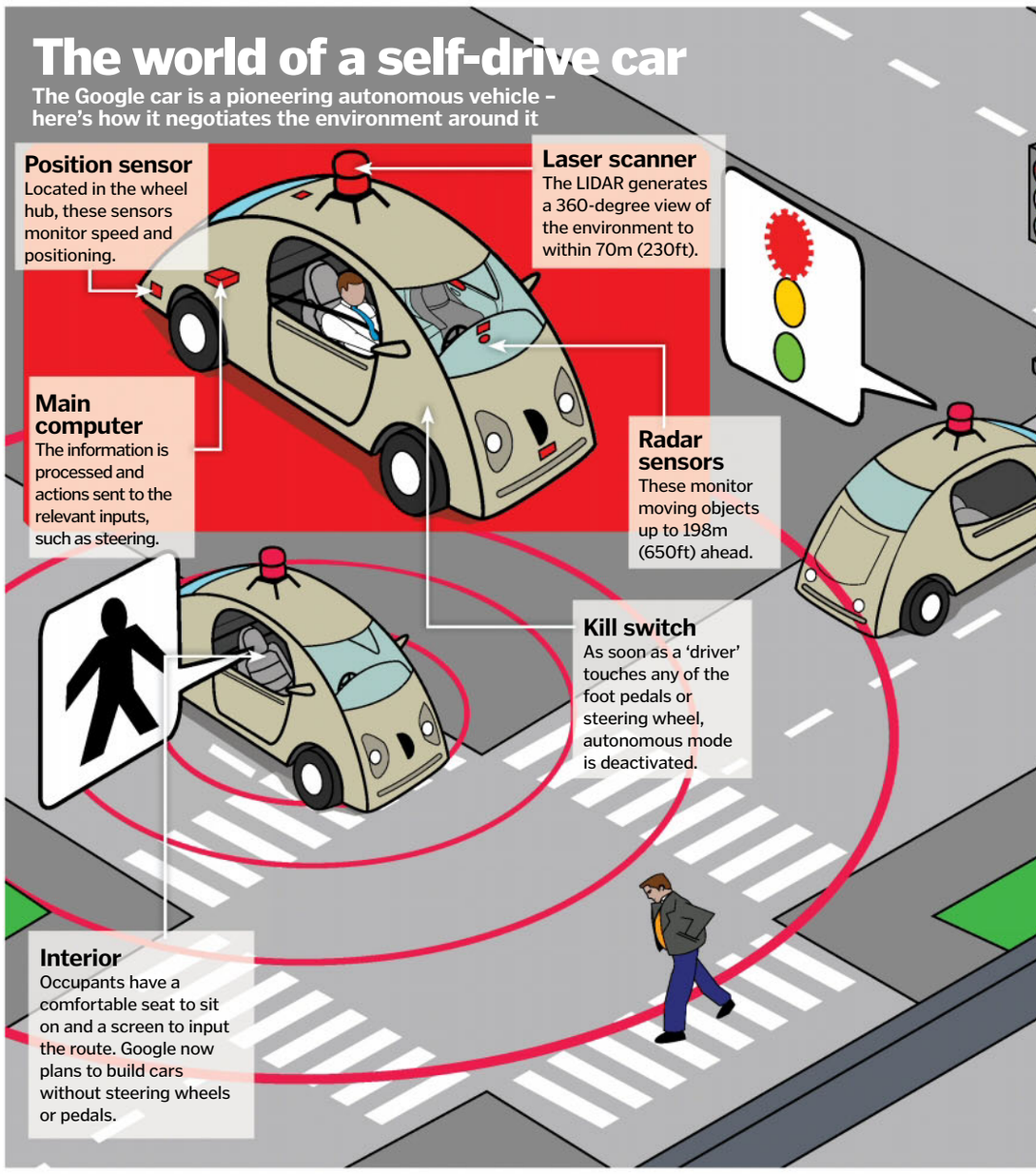
However, while the theory of self-drive cars is relatively straightforward – a computer actions an input for a mechanical device to implement – the unpredictability of hazards when driving is the biggest challenge for an autonomous vehicle to overcome. Much like a human having plenty of practice ahead of their driving test, the process for 'training' self-drive cars is to evaluate every single possible hazard perception scenario that could arise on the road and input them into the car's computer for the best course of action to take.

There are further limitations to the technology. Currently, a Google car cannot drive on a road that hasn't been mapped by the company's Maps system, so taking a self-drive car for a spin around your newly built suburban housing estate could prove somewhat problematic. Also, sensors on the car currently struggle to pick up on lane markings when roads are wet or covered in snow, making autonomous driving in adverse conditions particularly hazardous.

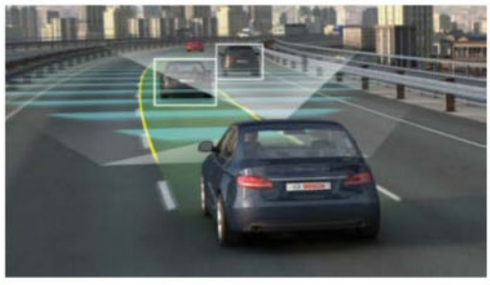
Companies are seeking to address these shortfalls, with safety drivers currently testing their self-drive vehicles in a variety of situations on the road every day and providing feedback on how to further improve the concept. Google even admits that its self-drive prototype is built with learning and development and not luxury in mind, so their own vehicle is currently bereft of any real creature comforts. However, if the blueprint for an autonomous car proves successful, that could well change and we could soon see motorways packed with moving vehicles where every occupant is kicking back and watching a film, checking emails, or reading How It Works.

The world of a self-drive car

The Google car is a pioneering autonomous vehicle – here's how it negotiates the environment around it



Autonomous tech available now



Predictive braking
Available on most modern cars, a radar-controlled Electronic Stability Program (ESP) continuously analyses the traffic ahead and, if the driver fails to react to the proximity of another object, it automatically stops the car.

Lane assist
This stops a vehicle from drifting between lanes. If the front camera detects the vehicle has unintentionally deviated out of a motorway lane, it'll input counter-steer at the wheel to ensure the vehicle returns to its lane.

AMAZING VIDEO!

SCAN THE QR CODE FOR A QUICK LINK

See a Google car self-driving on city streets

www.howitworksdaily.com

DID YOU KNOW? *An autonomous vehicle builds a 360° picture of its environment, better than human field of vision, which is under 180°*

Sensors on all sides

LIDAR
The LIDAR sits on top of the car and continuously spins at a rapid pace while emitting light pulses that bounce back off objects to sense and map the surrounding environment.

Radar sensors
Placed at the front and rear, these relay info to the computer to help determine the proximity of other vehicles and objects.

Engine
Similar in principle to a power unit in a conventional car, an engine control unit controls the engine performance.

GPS
An evolution of sat-nav technology, this helps position the vehicle and maps a route to a destination.

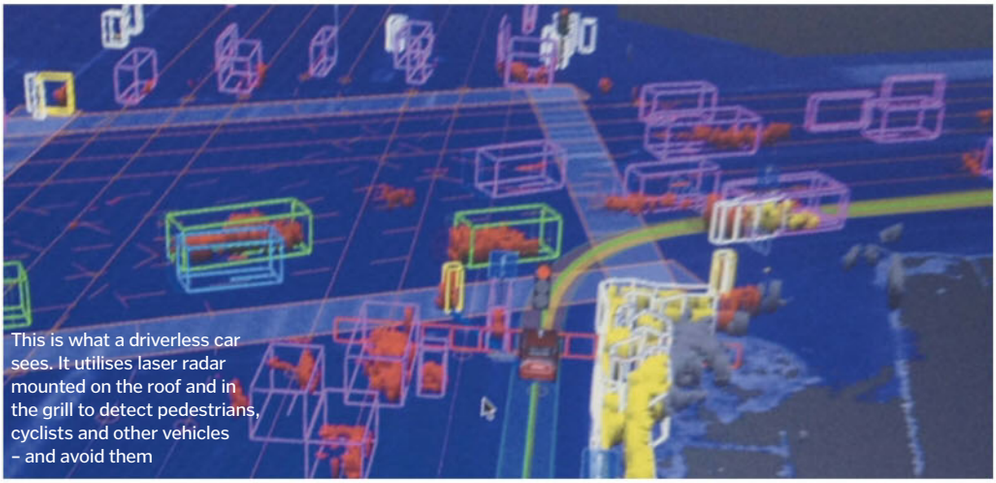
Processor
This ECU continuously reads the info fed to it by the radars, LIDAR and camera, altering the car's speed and direction.

Forward-facing video camera
This detects conventional road signs, traffic lights and other highway instructions the LIDAR and radar sensors cannot 'see.'

Front-facing camera
Mounted at the top of the windscreens, these effectively read road signs and traffic lights, detecting traffic cones and even lanes.

Wheels
Driving technology may be vastly different in a Google car, but vehicles still need lightweight alloy wheels and rubber-compound tyres for practical and efficient motoring over a variety of surfaces.

Active high beam control
Porsche and Volvo have introduced active high beam control, which dips the main headlight beam when sensors detect oncoming traffic at night. This avoids dazzling other road users with glare from the main beam.



This is what a driverless car sees. It utilises laser radar mounted on the roof and in the grill to detect pedestrians, cyclists and other vehicles – and avoid them

"The world's first and only commercial supersonic jet could cross the Atlantic in about three hours"

Supersonic aircraft

The heir to Concorde is getting closer

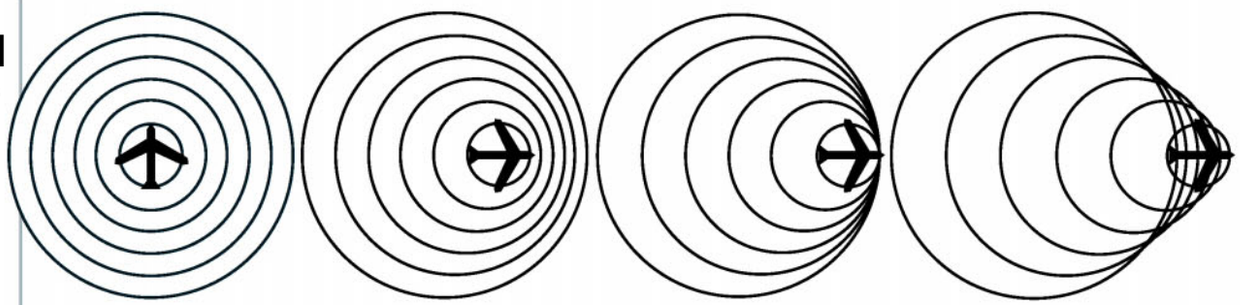
From its debut in 1969 until it touched down for the last time in 2003, Concorde broke all kinds of records, as well as the sound barrier nearly 50,000 times. The world's first and only commercial supersonic jet could cross the Atlantic in about three hours due to its sleek body and revolutionary engines. They used reheat technology that added extra fuel at the final stage of the engine cycle to make it reach speeds of 2,173 kilometres (1,350 miles) per hour, but the downside was the sonic boom created when the jet pushed sound waves to the sound barrier, which then became shock waves that disturbed people living below.

The next generation looks to reduce this noise by making the nose longer and thinner, meaning fewer shock waves are created. It is hoped supersonic aircraft from Boeing and Lockheed Martin could be ready by 2030.

A concept drawing for the Spike S-512, which could become the world's first supersonic business jet

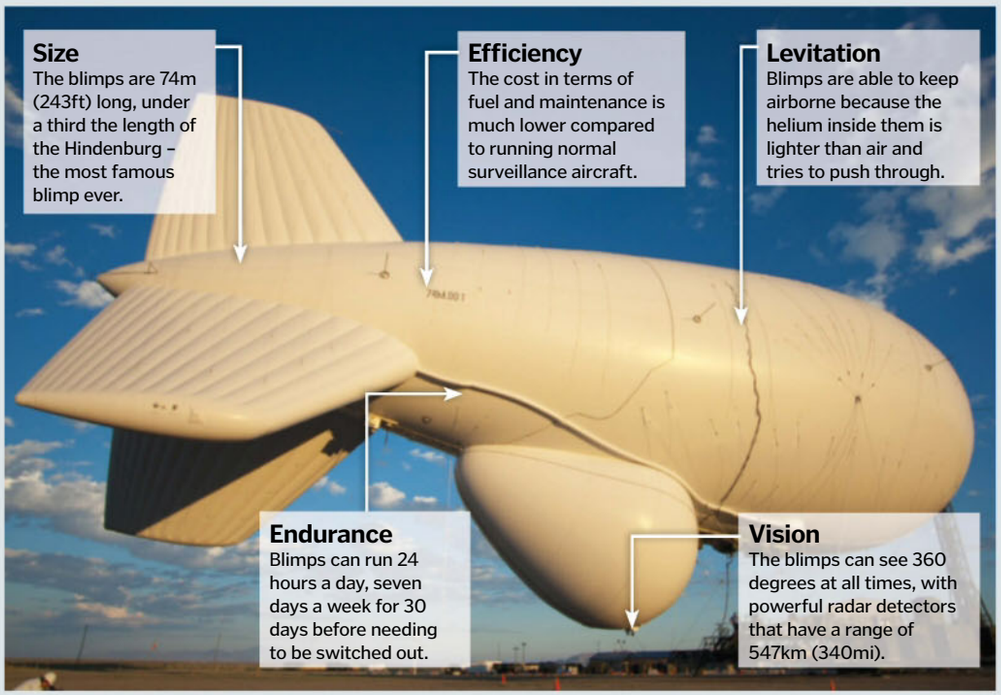
How a sonic boom is created

As an aircraft travels, it compresses the air in front of it. These waves move away from the aircraft at the speed of sound, but the faster the plane flies, the more the waves pile on top of one another. If a plane travels at supersonic speeds, all of the sound waves that would have travelled ahead of the plane get released in one go. This is why we hear such a loud boom when the sound barrier is broken.



What's in a defence blimp?

The new generation of blimps has been modified for modern-day air defence



Blimps

The wartime aerial giants are back to protect our skies

Blimps were originally designed as an aircraft that could take passengers across the Atlantic in style and comfort. Filled with lighter-than-air helium, they became a fixture over the skies in wartime Britain as barrage balloons protected the country from enemy warplanes flying over major cities and bombing them during WWI.

While the Hindenburg disaster of 1937 put an end to their role as commercial aircraft, they have made a return in the pursuit of national defence. A new breed of blimps is being used for relatively cheap 360-degree, 24/7 defence surveillance over a range of military bases in the United States. Raytheon's JLENS system includes 74-metre (243-foot) long aircrafts which float 3,048 metres (10,000 feet) above the ground and can see 547 kilometres (340 miles) away, searching for incoming missiles and aircraft.

THE STATS
JYRO'S SCOPE

14km/h SIMULATED SPEED

1,550rpm MAX FLYWHEEL SPEED

10,000 UNITS SOLD

2006 DESIGNED

2010 LAUNCHED

BATTERY LIFE Three hours

DID YOU KNOW? *The Jyrobike, funded through crowd-funding site Kickstarter, is the highest-funded kids product ever on the site*

The gyroscopic bike

Never graze your knees again with the self-balancing bicycle

CEO of Jyrobike Rob Bodill

The gyroscopic effect is the force that keeps an object rotating as long as nothing obstructs it. Essentially, it makes use of Newton's first law of motion, which states that a body will keep moving until another force changes it. Just as gravity pulls objects toward a more massive object, the gyroscopic effect pulls the disc back to its original position, even after a force has been applied to it. That's why even when you push a spinning top, it keeps on spinning despite moving sideways.

The Jyrobike uses this technology in a bid to revolutionise the way children learn to ride. CEO Rob Bodill explains how it works: "When a bike reaches 14 to 20 kilometres (8.7 to 12.4 miles) per hour, it becomes more stable because at that speed the wheels become natural gyroscopes," he says. "A Jyrobike has a flywheel inside the front wheel of the bike with most of its weight at its outer rim, simulating the movement of a bike wheel. Putting this flywheel inside the front wheel and spinning it very quickly simulates the bike travelling at 14 to 20 kilometres (8.7 to 12.4 miles) per hour, providing high-speed stability at low speeds."

This is very helpful in teaching, especially since a child's natural instinct is to pedal slowly. "Their parents are telling them to go faster because a bike needs speed to become stable, but the Jyrobike doesn't have to do that," Bodill adds. "You can go with the child's instinct because the bike provides the stability." Jyrobikes will be available to buy in shops in 2015, so until then you'll just have to stick with kneepads and a steadying hand.

Inside a Jyrobike

Does the self-stabilising bike stand up to scrutiny?

Helping hand
To make it easy for adults to help, there is a handle on the saddle.

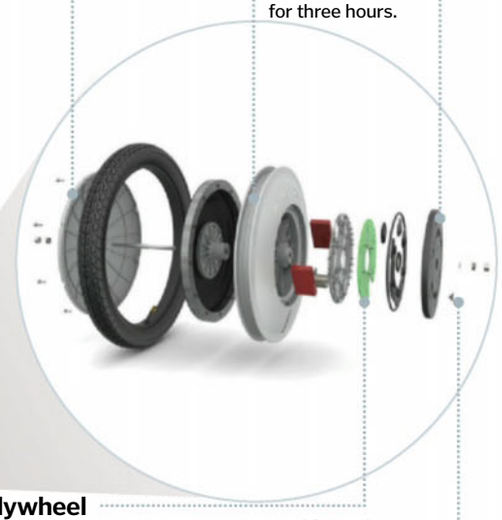
Tyre
The wheels are wide-profile tyres, making the bike more stable even without the gyroscopic assistance.

Frame
The frame is made from a lightweight alloy so it is easy for children to push off from a standing start.

Speaker
The wheel can also play sound effects like bells, trumpets and barking.

Weight
The flywheel can be removed, reducing the weight of the control hub by 60 per cent, removing the need for assistance.

Settings
The flywheel can spin at three different speeds, providing different levels of stabilisation as the rider improves.



Motor
A motor powers the flywheel's rotations, fuelled by a battery.

Battery
The battery takes two to three hours to charge and on full power will last for three hours.

Flywheel
The flywheel spins at up to 1,550rpm to provide a stabilising effect on the bike. It's heavily weighted around the rim.

Charging
There is a micro-USB port in the wheel to allow you to charge the battery.

5 things that use gyroscopic tech

Spinning top
When you spin a top, it is desperate to keep on rotating. Even if you push it, it doesn't topple over but uses its spinning motion to right itself. It will only fall when it slows down and loses that force that has been keeping it upright.

Frisbee
A Frisbee is basically a flat spinning top. A flick of the wrist will give it the initial force to spin and keep a flat trajectory, whereas if you throw it without a wrist flick, it won't be spinning fast enough to stay stable in the air.

Ice skater
If an ice skater tries a slow spin, they'll fall over or wobble. If they spin themselves quickly, they can stay upright due to the gyroscopic effect. If their body is off-centre, they'll still spin but would move like an out-of-control spinning top.

Compass
When you allow a gyroscope to move freely, it will continue pointing in the same direction, so if you spin the gyroscope toward north no matter which way you turn the rest of the device, it should continue pointing north.

Aeroplanes
Spinning a gyroscope horizontally will allow a pilot to know to what degree they're tilting. If they angle themselves upward, the gauge will move but the gyroscope won't, so the pilot will know the plane has gone upward.

"The idea behind this super-ride is to get Formula One fans as close to the real thing as possible"

The world's fastest roller coaster

Experience the thrill of an F1 car from over 50 metres in the air

Most of us will never know what it's like to hit top speed in a Formula One car, but you can have something even better – by experiencing that thrill while rising and falling on the world's fastest roller coaster.

It's called Formula Rossa and can be found at Ferrari World in Abu Dhabi. Not only does it go from zero to 100 kilometres (62 miles) per hour in a face-flattening two seconds, it also reaches a dizzying 240 kilometres (149 miles) per hour in under five seconds, topping the world's second-fastest 'coaster by 34 kilometres (21 miles) per hour.

The idea behind this super-ride is to get Formula One fans as close to the real thing as possible. Those brave enough to try the ride will experience forces of 1.7 g when accelerating and an incredible 4.8 g around the corners, which is similar to the forces a driver will confront in a Grand Prix race at Silverstone or Monaco. Dedicated Formula One fans may recognise a few of the corners too, as they've been inspired by some of the real-life circuits' most famous turns and chicanes.

It is able to reach its mind-boggling speed due to the wealth of technology underneath the track. 48 hydraulic motors generate an immense amount of power before transferring it to the catch car, which is hurled along the track, carrying the train with it. Eventually the catch car stops, catapulting thrill seekers to those immense speeds.

The world-record-breaking Formula Rossa ride's highest peak is at about 52 metres (171 feet) in the air, before dropping worryingly close to the ground to just 1.5 metres (4.9 feet). Only the brave need apply.

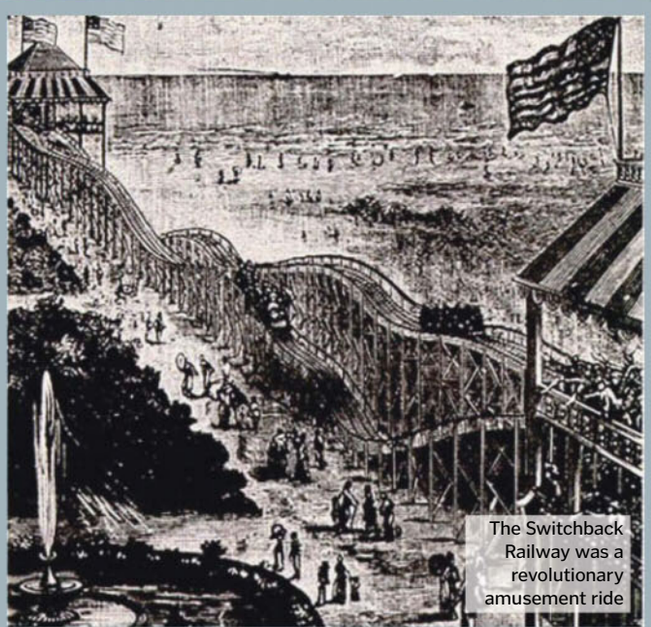
The ups and downs of the roller coaster

The roller coaster dates back over 350 years as 17th-century Russians whiled away the winter on ice slides. These were big wooden slides covered in ice that people threw themselves down before flying back up as it curved, much like a half-pipe.

The roller coaster we know and love today begun to take shape in the 19th century as an undulating track was built and patrons rode on a wheeled cart. Safety then became a concern and 1817 saw a French construction with wheels that locked onto the track. France was also the location for the first-ever loop-the-loop coaster, as people could experience the thrill of a four-metre (13-foot) loop.

As with many things, the news spread to the United States and became a massively popular tourist attraction as La Marcus Adna Thompson took the model of a railroad and made it extreme! Opened in 1884, the Switchback Railway made Thompson hundreds of dollars every day, leading to an explosion of interest in the area. Coney Island in New York got in on the act with its own spectacular thrill ride and from there, the race to become the biggest and best took off.

Today, most of the best roller coasters are in the USA or Japan with the likes of The Incredible Hulk, Dodonpa and Superman regularly on lists of must-visit coasters.



The Switchback Railway was a revolutionary amusement ride

THE STATS
ROSSA SPECS

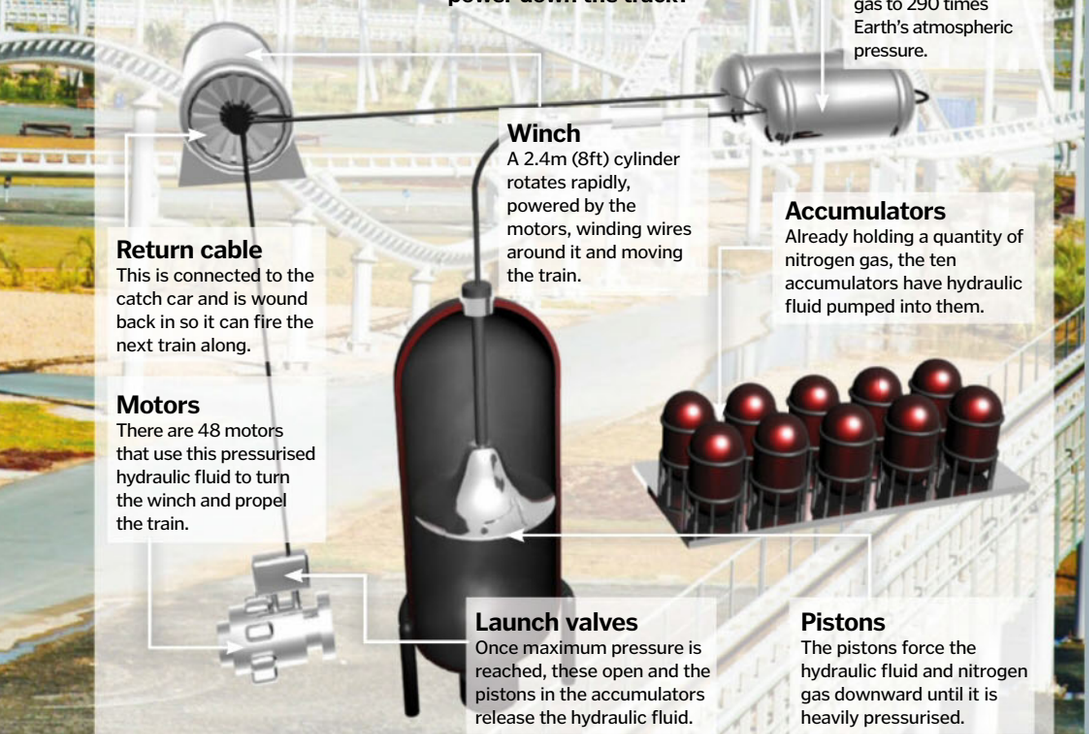
SPEED 240km/h | MAX G-FORCE **4.8 g** | TRAIN WEIGHT **8.8 tons**
LENGTH **2.1km** | RIDE LENGTH 1min 32s | HEIGHT 52m

DID YOU KNOW? *The Formula Rossa is so fast that anyone who goes on it has to wear goggles to protect their eyes*

Ferrari World in Abu Dhabi is the world's largest indoor theme park

Under the hood

What makes the Formula Rossa power down the track?



Pumps
Cylinders push hydraulic fluid into the accumulators, compressing nitrogen gas to 290 times Earth's atmospheric pressure.

Winch
A 2.4m (8ft) cylinder rotates rapidly, powered by the motors, winding wires around it and moving the train.

Accumulators
Already holding a quantity of nitrogen gas, the ten accumulators have hydraulic fluid pumped into them.

Return cable
This is connected to the catch car and is wound back in so it can fire the next train along.

Motors
There are 48 motors that use this pressurised hydraulic fluid to turn the winch and propel the train.

Launch valves
Once maximum pressure is reached, these open and the pistons in the accumulators release the hydraulic fluid.

Pistons
The pistons force the hydraulic fluid and nitrogen gas downward until it is heavily pressurised.

HEAD TO HEAD

	Formula One	Formula Rossa
SPEED	370 km/h	240 km/h
0-100KM/H	1.7 seconds	2 seconds
WEIGHT	691 kilograms	8.8 tons
SEATS	1	16
STEERING WHEEL	20+ controls	None required

50 SPACE DISCOVERIES

The biggest breakthroughs in the galaxy explained

Exactly 50 years ago, Europe's major nations came together for the first time to turn their attention to the exploration of space. ESRO, the European Space Research Organisation, was originally founded by France, Germany, Britain, Italy, Belgium, the Netherlands, Switzerland, Sweden, Denmark and Spain. Four years later, the organisation launched its first successful satellite, called Isis, which studied X-rays and solar particles. ESRO transformed into the European Space Agency (ESA) in 1975 and never looked back. Since the 1980s, Europe has been a major player in the scientific exploration of space.

ESA's projects read like an astronomical checklist for some of the most exciting areas of space research: satellites such as EXOSAT, looking at the violent universe of black holes and quasars, and Herschel, peering into the cool cosmos of the far infrared. There are missions like Hipparcos, whose precise measurements of shifting stellar positions have built up the first accurate map of the distance to over 1 million stars, and Planck, which maps the tiny fluctuations in radiation left over from the Big Bang. Interplanetary probes ranging from Giotto sent back the first pictures from the heart of a comet in 1986, to the Mars Express' 3D images that have transformed our understanding of the Red Planet.

Yet the breakthroughs made by these amazing spacecraft are building on a long tradition of astronomical discovery stretching back over more than 2,000 years. Each new revelation has brought us a little closer to our current understanding of the universe – some by adding key pieces to the cosmic jigsaw puzzle, a few by smashing the whole thing up and forcing us to start again. After five decades of European discovery in space, it's never been a better time to look back at the 50 biggest astronomical breakthroughs.

5 TOP FACTS
SPACE RESEARCH

1 Heliocentrism
Nicolaus Copernicus' 1543 theory that the Sun was at the centre of the universe paved the way for understanding the motion of planets, and led to Newton's theory of gravity.

2 The distance to stars
In 1838, Friedrich Bessel measured the distance to a nearby star called 61 Cygni. Confirmation that stars are suns in their own right helped understand their properties.

3 Cosmic chemistry
19th-century breakthroughs in the analysis of light from stars and nebulas helped to find out their chemical composition and ultimately the power source that makes them shine.

4 General relativity
Einstein's 1915 theory saw space and time as a four-dimensional whole that can be manipulated by large masses, with implications such as black holes.

5 Dark energy
Late-1990s discoveries overturned seven decades of assumptions about the behaviour of the universe after the Big Bang, and showed that cosmic expansion is speeding up.

DID YOU KNOW? *A total of four exploration rovers have successfully landed on Mars*

1 The Big Bang

Edwin Hubble's 1929 discovery that our universe is rapidly expanding led to the realisation that it must have once been smaller, denser and therefore much hotter. A theory was formed that it ultimately originated in a huge explosion called the Big Bang, now estimated to have taken place about 13.8 billion years ago.

2 Star formation

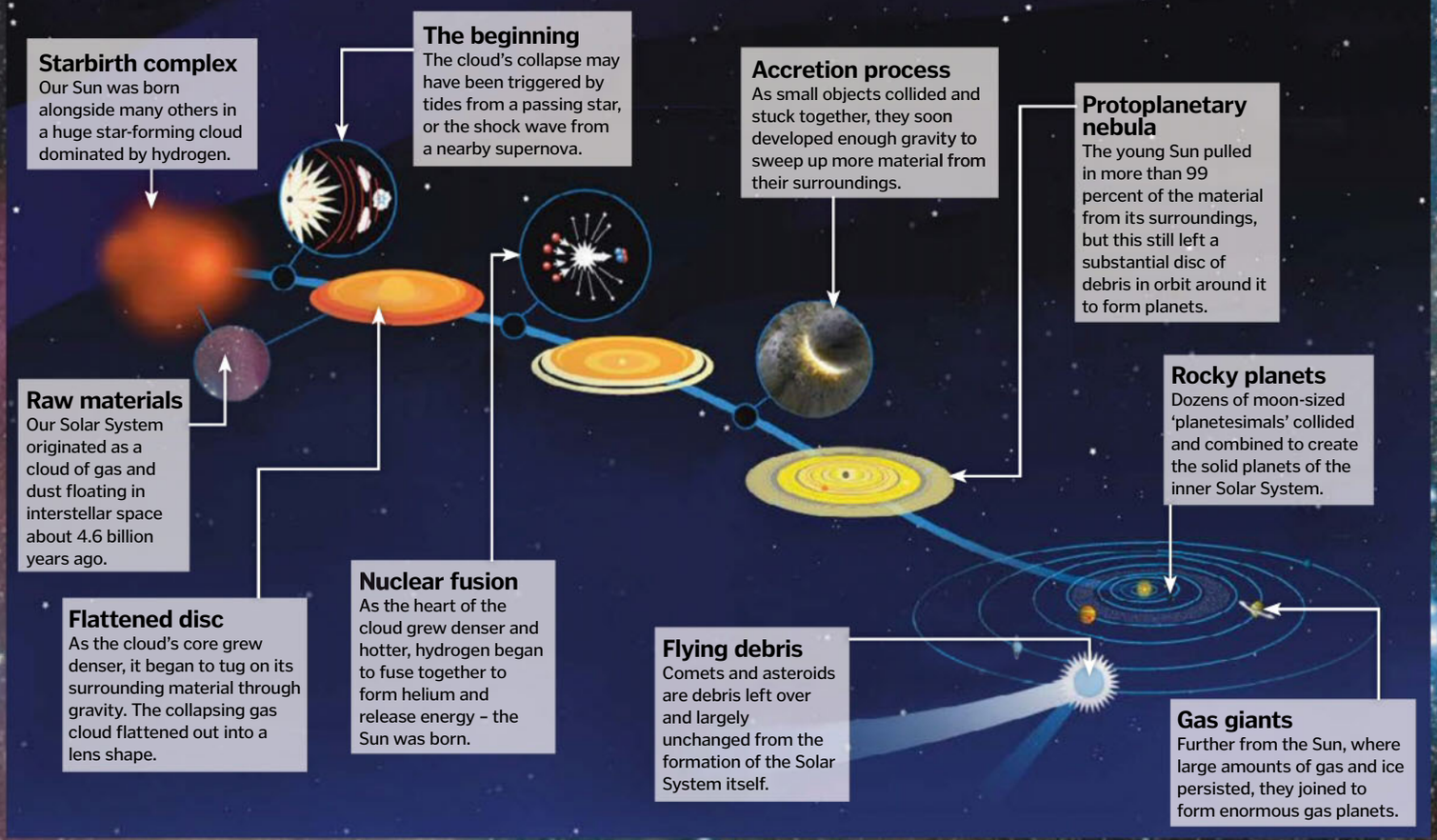
The idea that stars form from collapsing clouds of gas was suggested as early as the 18th century by the philosopher Emanuel Swedenborg, but it was not until the mid-20th century that discoveries in the field of nuclear physics led to the discovery of how compressed and heated gas generates energy through nuclear fusion.

3 How planets form

The idea that planets are born from debris after star formation stemmed from Swedenborg's 'nebular hypothesis', developed by Immanuel Kant and Pierre-Simon Laplace, but it was only in the 20th century that Soviet astronomer Viktor Safronov explained how small, low-mass objects could coalesce to form planet-sized objects through the process of 'accretion.'

4 Regularity of comets

In 1705 Edmond Halley used his friend Isaac Newton's laws of gravity and motion to show that comets seen in 1531, 1607 and 1682 were manifestations of the same object on a long elliptical path around the Sun. This comet now bears Halley's name and is the first of many periodic comets to have been discovered.



5 Elliptical orbits and gravity

In 1609, German mathematician Johannes Kepler published the first two of his three laws of planetary motion. Based on careful measurements of the way planets moved through the sky, he showed their motion was best described by elliptical orbits around the Sun, with the planets moving faster close to the Sun, and slower when further away. Kepler's laws led to Isaac Newton's more general discovery of 'universal gravitation', first published in 1687.

6 Uranus and Neptune spotted

No one suspected that there might be planets beyond Saturn until German-British astronomer William Herschel discovered Uranus while searching for comets in 1781. His discovery triggered a wave of interest in searching for new planets and led directly to the discovery of the Asteroid Belt. By 1846, however, unexplained discrepancies in Uranus's orbit led French mathematician Urbain Le Verrier to predict the position of an eighth planet, Neptune, discovered by German astronomer Johann Galle.

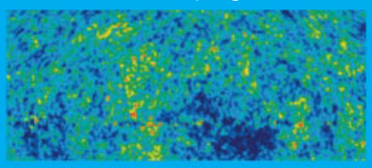
7 The distance to the stars

The realisation that Earth moves around the Sun offered a way to measure the distance of stars for the first time, through the effects of 'parallax', the slight difference in an object's position when viewed from two different locations – in this case, opposite sides of Earth's orbit). The difficulty of measuring stellar parallax showed that all stars were incredibly far away, but Friedrich Bessel finally succeeded in 1838. Parallax-based distances provide the backbone of our understanding of stellar physics.

"His ideas were not widely accepted until a major shower of meteorites fell over northern France in 1803"

8 Cosmic Microwave Background Radiation

The presence of microwave radiation permeating the universe is evidence that the Big Bang theory is broadly correct. The background radiation was discovered in 1964 as a persistent background 'noise' on an antenna being tested by Arno Penzias and Robert Wilson. This vestigial 'afterglow' of the Big Bang heats the entire universe to 2.7 degrees Kelvin.

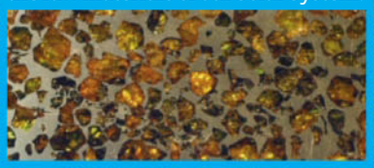


9 Extrasolar planets

After decades of searching for planets around other stars, a breakthrough came in 1995 with the discovery of 51 Pegasi b, or 'Bellerophon.' The detection method used by Michel Mayor and Didier (replicated many times since) involved measuring tiny changes in the spectrum of the star's light as its planet's gravity caused it to wobble slightly in space.

10 Meteorites

For a long time, meteorites were assumed to be volcanic. German physicist Ernst Chladni produced the first detailed argument for an extraterrestrial origin in 1794, but his ideas were not widely accepted until a major shower of meteorites fell over northern France in 1803. Meteorites are now widely studied for the insight they offer into the raw materials of our Solar System.



11 Galaxies beyond our own

In 1925, Edwin Hubble proved that star-filled 'nebulas' such as the famous spiral in Andromeda are independent galaxies many millions of light years away. He did this by measuring the light fluctuations of Cepheid variable stars – a class of bright supergiants that pulsate with a period that reveals their intrinsic luminosity and therefore their distance.

12 Asteroid Belt

In 1766, German astronomer Johann Titius pointed out an apparent mathematical distribution of the planets that left an obvious 'gap' in the region between Mars and Jupiter

Jupiter's orbit

The Asteroid Belt is thought to be the remnants of material that never formed a larger planet thanks to the influence of Jupiter's gravity.

First discovery

Italian astronomer Giuseppe Piazzi discovered the first asteroid in the Belt, Ceres, in 1801.

Vesta

The brightest asteroid visible from Earth, and the third largest, Vesta is a near-spherical world with complex geology, investigated by Dawn from 2011 to 2012.

Comets in the belt

In 2006, astronomers confirmed the presence of a family of icy comets orbiting within the Asteroid Belt.

Kirkwood gaps

Repeated close approaches to Jupiter kick asteroids out of orbit, sending them toward the Sun as near-Earth asteroids.

Near-Earth asteroids

In 1898, astronomers discovered the asteroid 433 Eros, the first in a new class of objects whose orbits take them close to, or even across, that of Earth.

Ceres

The largest object in the Asteroid Belt, Ceres is now classed as a dwarf planet, with a radius of 476km (296mi). NASA's Dawn probe will explore it in detail in 2015.

Gap in the Solar System?

In 1766, German astronomer Johann Titius pointed out an apparent mathematical distribution of the planets that left an obvious 'gap' in the region between Mars and Jupiter.

Orbit of Mars

Mars and Jupiter limit the spread of the main belt and confine it to 300-600mn km (186-373mn mi).

Millions and millions

The Belt contains huge numbers of asteroids (over a million bigger than 1km (0.6mi) across), but is so large that it is mostly empty.

19bn km

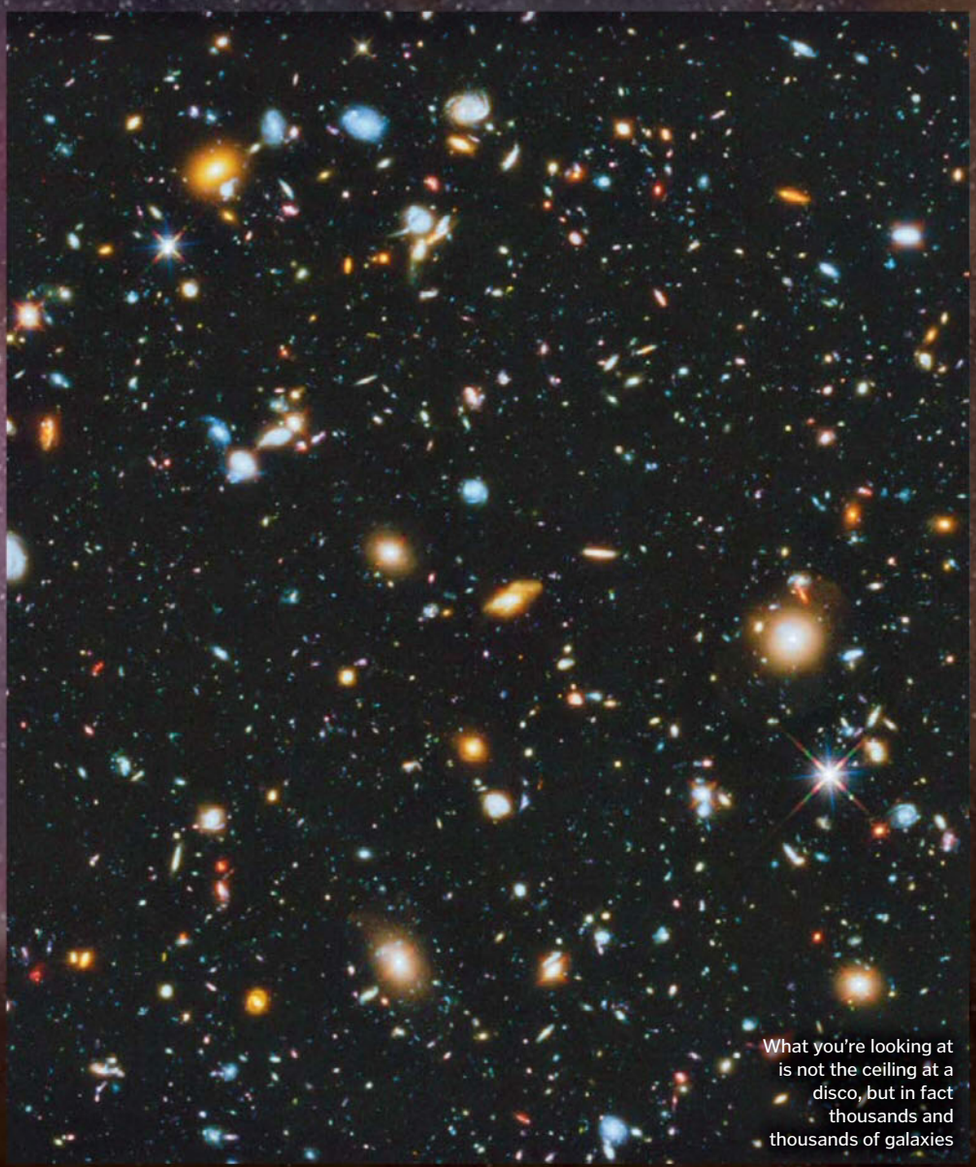
FARTHEST MAN-MADE OBJECT

NASA's Voyager 1 spacecraft is currently zooming through interstellar space almost 20bn km (12bn mi) away. It takes over 17 hours for sunlight to reach the spacecraft.

DID YOU KNOW? *Both Voyager crafts have a 'golden record' with a message to any possible civilisation they may come across*

13 The Hubble Deep Fields

In December 1995, astronomers working with the Hubble Space Telescope performed an unusual experiment, turning the orbiting observatory's powerful gaze onto an apparently empty patch of sky in the constellation of Ursa Major and taking 342 exposures over ten days. As Hubble's cameras swept up faint traces of light from the depths of the universe, it built up an image capturing more than 3,000 galaxies at distances ranging from hundreds of millions to billions of light years away. The experiment has since been repeated several times, imaging different parts of the sky for even longer periods and with ever-more sensitive cameras. Because the light from these galaxies has taken so long to reach Earth, we are seeing them as they were in their youth – the Hubble Deep Fields often reveal the chaotic, shapeless star clouds and countless galaxy mergers that gave rise to today's more orderly universe.



What you're looking at is not the ceiling at a disco, but in fact thousands and thousands of galaxies

14 Dark matter

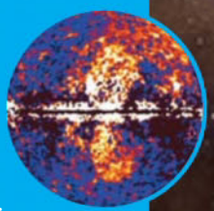
Suspicions of something big missing from our picture of the universe were raised by Swiss astronomer Fritz Zwicky in the 1930s, when he studied the motion of galaxies in distant clusters and found they were behaving under the influence of a lot more mass than could be accounted for by their visible or 'normal' matter. He named the mysterious cause of this behaviour 'dark matter', but it was only given widespread attention in the 1970s when astronomer Vera Rubin showed that stars in our own galaxy orbit under the influence of similar invisible material. Dark matter is now thought to account for almost 85 percent of mass in the universe, but its true nature remains unknown – it simply does not interact with electromagnetic radiations such as light, so it is not only dark, but also transparent – astronomers can, however, map its presence through the effects of its gravity, such as gravitational lensing.

15 Geysers of Enceladus

Shortly after its arrival at Saturn in 2005, NASA's Cassini spacecraft confirmed the presence of huge plumes of water erupting near this moon's south pole. Tidal forces exerted by Saturn raise temperatures beneath the icy crust and make it a potential habitat for extraterrestrial life.

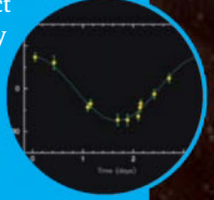
16 Fermi bubbles

In 2010, the Fermi Gamma-ray Space Telescope discovered two huge bubbles of energetic gas extending 25,000 light years above and below the centre of the Milky Way. They are thought to be a remnant of the last time our galaxy's central supermassive black hole was active.



17 Multiple stars

At the start of the 19th century, William Herschel confirmed that most close groups and pairings of stars in the sky are in fact systems physically bound by gravity rather than mere line-of-sight effects. The way these stars orbit each other can reveal valuable information about them, such as their relative masses.



"Finding planets in other solar systems has led to the recent discovery of new classes of planet"

18 Habitable exoplanets

Key
- Too hot for liquid water to exist
- Possible habitable zone
- Too cold for liquid water to exist

Another Earth?
In 2012, astronomers from the European Southern Observatory announced the discovery of a planet with the best prospects so far for a habitable environment.

Red dwarf
Gliese 667 C is the system's least massive star, with 31 percent of the Sun's mass and just 1.4 percent of its luminosity.

Planetary system
Since 2009, astronomers have confirmed the existence of two planets orbiting Gliese 667 C, but observations suggest it could have up to seven.

Miniature solar system
Gliese 667 C's low mass means that planets orbit very close to it.

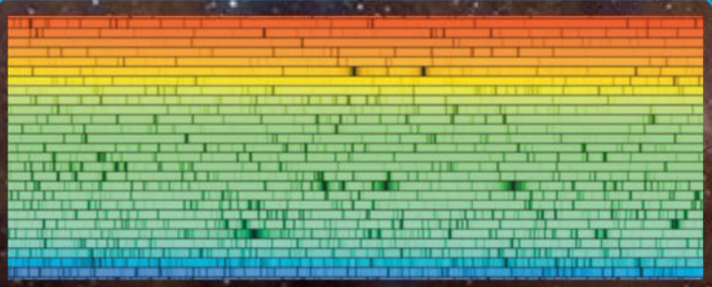
Triple star
Gliese 667 is a triple-star system in the constellation of Scorpius, some 22 light years from Earth.

Super-Earth
Gliese 667 Cc has approximately 4.5 times the mass of Earth, which should enable it to hold on to a substantial amount of atmosphere.

Goldilocks world
Gliese 667 Cc receives about 90 per cent of the energy from its star that Earth does from the Sun, warming it enough for liquid water to exist and survive on the surface.

Planet in the zone
The confirmed planet Gliese 667 Cc orbits its star at an eighth of the average Earth-Sun distance – close enough to be warmed substantially by its weak star.

The habitable zone in the Gliese 667 C system



19 The chemistry of the universe revealed

Joseph von Fraunhofer's discovery and subsequent mapping of dark lines in the rainbow-like spectrum of the Sun in around 1814 turned out to be the key to understanding the composition of objects across the entire universe as we know it. In the 1850s, German chemists Kirchoff and Bunsen showed how these lines could be created by atoms and molecules in a star's outer atmosphere absorbing energy corresponding to very specific wavelengths and colours, effectively creating a chemical 'fingerprint' that could identify elements within the star. Material within interstellar clouds known as nebulas can create absorption effects and, when energised, can also produce so-called 'emission spectra' of light with very specific wavelengths.

20 Black holes

Their existence was first suggested in 1783, but it was not until the 1970s that the first black hole 'candidate' was discovered. Cygnus X-1 is a binary system where a black hole pulls gas away from its more normal neighbour and heating it to emit X-rays.

21 The first planets

Five planets – Mercury, Venus, Mars, Jupiter and Saturn, have been known since ancient times. Efforts to understand their nature and motion were hampered by belief in an Earth-centred universe until Kepler's 17th-century research.

22 Hot Jupiters

Finding planets in other solar systems has led to the recent discovery of new classes of planet. Among the most intriguing of these are 'hot Jupiters' – gas giants that formed far from their stars but have since spiralled into tight orbits with searing temperatures.

23 Quasars

In the early-1960s, radio astronomers discovered rapidly varying radio sources. These proved to be the luminous cores of galaxies billions of light years away, generated as supermassive black holes at their centres feed on gas, dust and stars.

KEY DATES
COSMIC BREAKTHROUGHS

1543 Nicolaus Copernicus publishes *On The Revolutions Of The Heavenly Spheres*, suggesting the Sun is at the centre of the universe.

1608 Dutch lensmakers invent the telescope, leading to discoveries that revolutionise astronomy.

1781 William Herschel discovers Uranus, the first new planet to be discovered since ancient times.

1925 Edwin Hubble proves that 'spiral nebulas' are distant galaxies millions of light years from our own.

1990 The Hubble Space Telescope launch leads a transformation in our view of the universe.

DID YOU KNOW? *The Hubble Space Telescope orbits Earth every 96 to 97 minutes*

24 Jupiter's Galilean moons

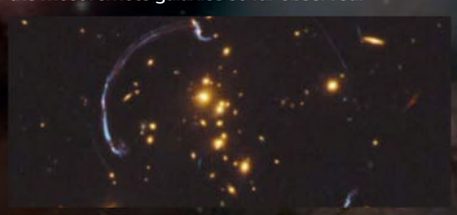
When Italian astronomer Galileo Galilei turned his primitive telescope on the planet Jupiter over 400 years ago, he discovered four points of light moving back and forth around it in periods ranging from hours to days. These were the first satellites discovered around any object other than Earth. More recently, space probes have shown these moons – Io, Europa, Ganymede and Callisto – to be fascinating worlds in their own right.

25 Sagittarius A*

Since the 1970s, studies of remote, violent objects such as quasars have persuaded many astronomers that these 'active galaxies' had enormous black holes at their centres – but what about more sedate galaxies like our own? In 2002, astronomers measured a star very close to the galactic centre in orbit around Sagittarius A* – a massive but almost undetectable radio source that contain over 4 million Suns' worth of mass in a region roughly 40 million kilometres (25 million miles) across – smaller than the radius of Mercury's orbit.

26 Gravitational lensing found

Einstein's 1915 theory of general relativity predicted how large masses bend space and deflect light that passes nearby. This was demonstrated in 1919 when astronomers measured a shift in the apparent position of stars near the Sun during a solar eclipse. Today, astronomers use this 'gravitational lensing' effect to measure the mass of distant galaxy clusters and also as a natural magnifier to detect the most remote galaxies so far observed.



27 Heliocentricity

For much of history, people believed the Earth was at the centre of the universe, with the Moon, Sun, planets and stars orbiting around it. Using this model of the universe, however, astronomers found it hard to predict the motions of planets. The idea of a heliocentric or 'Sun-centred' system, with Earth relegated to a planet and the stars at far greater distances, finally took hold through the theories of Polish astronomer Nicolaus Copernicus, published in 1543. Over the next 60 years, careful planetary measurements by Tycho Brahe, telescopic observations by Galileo and the orbital theories of Johannes Kepler combined to build an unassailable case.

28 Supernovas

Huge stellar eruptions or 'novae' have been observed for centuries, but it was only in the 1930s that astronomers Walter Baade and Fritz Zwicky identified supernovas as stellar cataclysms associated with the deaths of giant stars. We now know they leave behind neutron stars and black holes, and also generate most of the heavy elements in the universe.

29 Kuiper Belt

The 1930 discovery of Pluto, a tiny, icy world in an eccentric orbit beyond Neptune, led Dutch astronomer Gerard Kuiper and others to speculate that it might be the first of many such objects in a belt around the outer Solar System. After a long gap between discoveries, many others have been found since the 1990s.

30 Martian ice caps

Bright regions around the Red Planet's north and south poles were identified as ice caps as early as 1666 by the Italian astronomer Cassini. While their surface frost of carbon dioxide comes and goes with the seasons, orbiting space probes have confirmed the presence of huge water ice reserves beneath the surface.

31 Water on the Moon

Astronomers have long hoped to find water in shadowed craters at the Moon's north and south poles, left there by colliding comets. Impacting spacecraft produced plumes that contain traces of crystalline ice, and a NASA instrument aboard India's Chandrayaan-1 satellite confirmed large amounts of hydrogen (and probably water) in the lunar soil.

32 Mapping the universe

Advances in technology have now made it possible to gather the locations and spectra of huge numbers of galaxies simultaneously, allowing astronomers to build up the first large-scale maps of the universe. These reveal a cosmos in which galaxy clusters and superclusters form filaments and sheets around seemingly empty voids.

33 Our place in the Milky Way

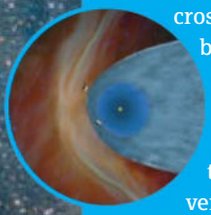
Dutch astronomer Jacobus Kapteyn carried out a detailed photographic survey of stars, concluding in 1922 that the Milky Way is a lens-shaped disc and that we are somewhere close to the centre. Better observations and equipment allowed for more accurate research. These reveal we are about halfway across the disc, some 26,000 light years from the centre.

"NASA's Voyager 1 space probe became the first man-made object to venture into interstellar space"

34 Supergiant stars

In the 1920s, astronomers measured the apparent diameter of the bright and relatively nearby red star Betelgeuse, showing it has a diameter far larger than Earth's orbit around the Sun. Such massive, bloated stars, which end their lives as supernovas, are now called supergiants.

35 Interstellar space

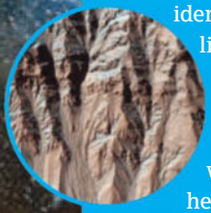


Around 2013, after a 36-year journey, NASA's Voyager 1 space probe crossed the heliopause, the boundary where the solar wind of particles streaming out from the Sun is pushed back by interstellar winds. It became the first man-made object to venture into interstellar space.

36 Moons of the outer planets

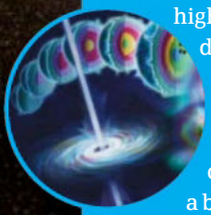
Growth in power of telescopes led to the discovery of several moons around Saturn in the 17th and 18th centuries, and satellites of Uranus and Neptune soon after those planets were discovered. Modern instruments and interplanetary space probes have added many more.

37 Water on Mars



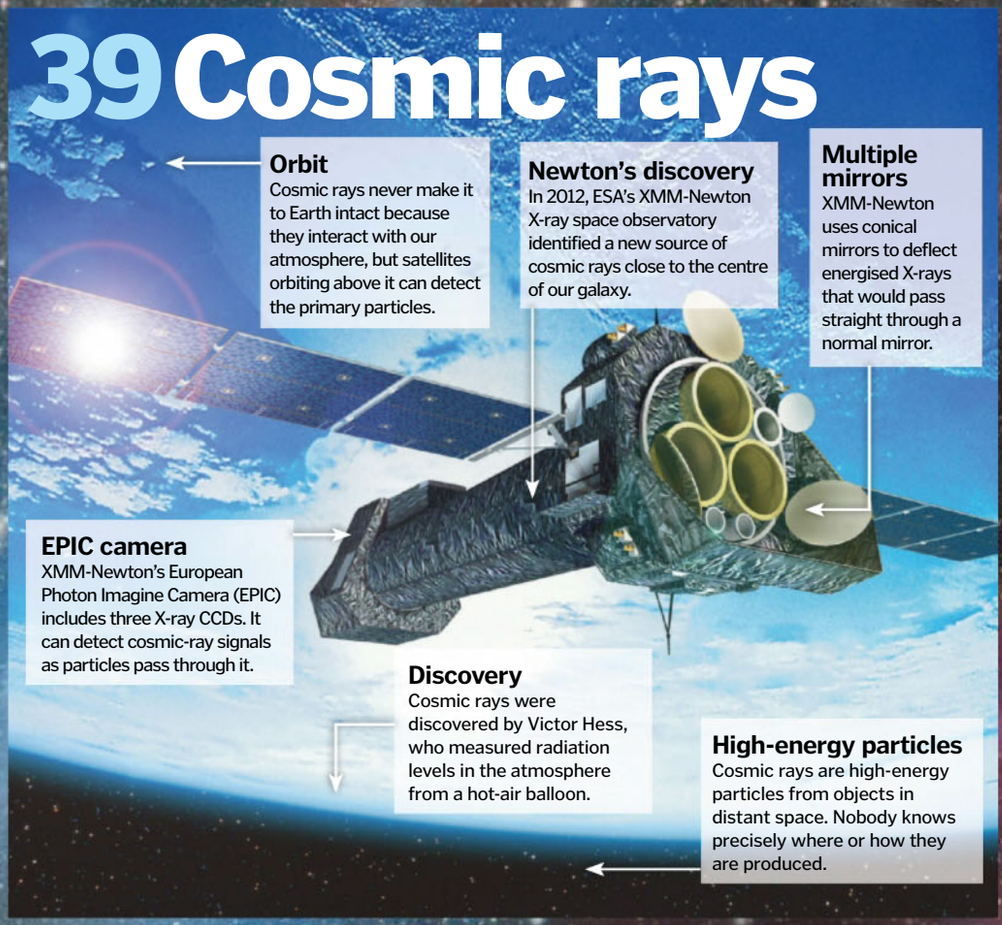
After decades of speculation, in 2011 NASA's Mars Reconnaissance Orbiter identified conclusive evidence for liquid water flowing briefly on the surface of Mars, in the form of seasonal flows – streaks of briny water seeping from the walls of some southern-hemisphere slopes.

38 Gamma-ray bursts



Discovered in 1967 by satellites designed to monitor nuclear tests, blasts of high-energy gamma rays from distant space probably have a number of causes. The most energetic and short-lived events are probably generated as a collapsing high-mass star creates a black hole or neutron star.

39 Cosmic rays



Orbit
Cosmic rays never make it to Earth intact because they interact with our atmosphere, but satellites orbiting above it can detect the primary particles.

Newton's discovery
In 2012, ESA's XMM-Newton X-ray space observatory identified a new source of cosmic rays close to the centre of our galaxy.

Multiple mirrors
XMM-Newton uses conical mirrors to deflect energised X-rays that would pass straight through a normal mirror.

EPIC camera
XMM-Newton's European Photon Imagine Camera (EPIC) includes three X-ray CCDs. It can detect cosmic-ray signals as particles pass through it.

Discovery
Cosmic rays were discovered by Victor Hess, who measured radiation levels in the atmosphere from a hot-air balloon.

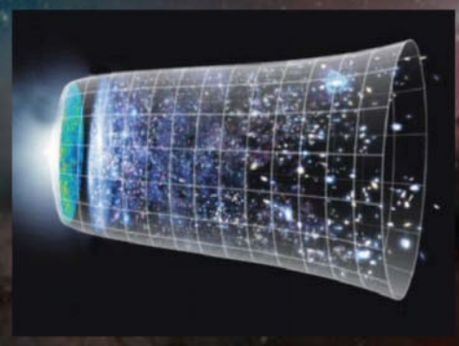
High-energy particles
Cosmic rays are high-energy particles from objects in distant space. Nobody knows precisely where or how they are produced.

40 North Star navigation

As Earth spins on its axis once every day, all the stars in the sky seem to rotate around two fixed points in the sky – the north and south celestial poles directly above Earth's own. In the northern hemisphere, the moderately bright star Polaris lies close to the North Pole and so remains a more-or-less fixed feature of the sky, showing the direction of due north and even revealing your latitude on Earth's surface from its altitude above the horizon. Sailors and travellers understood and made use of this fixed point in the sky since ancient times until the arrival of radio and satellite navigation.

41 The universe is accelerating

In the 1990s, astronomers attempting to measure the rate at which the universe's expansion was slowing down (due to the gravity of matter within it) made a remarkable discovery – cosmic expansion is actually accelerating. This unexpected surprise has been blamed on a phenomenon called 'dark energy' that is now one of the most exciting areas of cosmological research: it seems that something is driving space itself to stretch apart, and dark energy is thought to account for more than 68 percent of all the energy in the universe, even though no one knows exactly what it is yet.



AMAZING VIDEO! SCAN THE QR CODE FOR A QUICK LINK

Celebrate 50 years of Europe in space

www.howitworksdaily.com

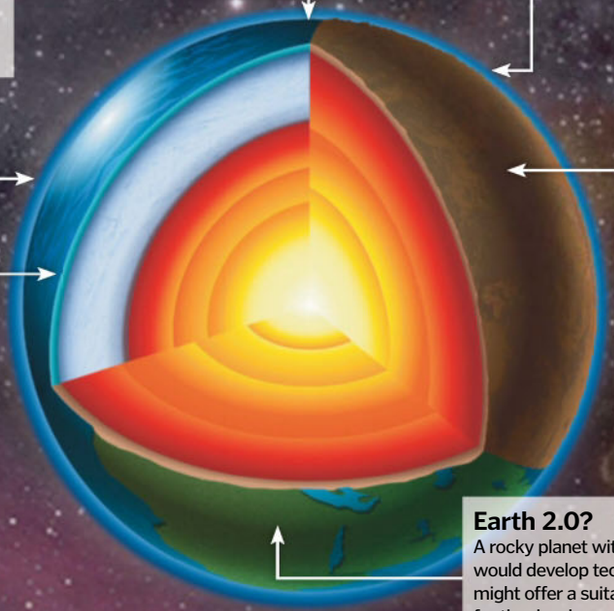
DID YOU KNOW? *Our Solar System contains 36 known objects that are over 400km (250mi) in diameter*

42 Super-Earths

Different types
Theoretical studies suggest there could be several distinct types of super-Earth, depending on the conditions in which they form.

A new breed
Super-Earths are a new class of extrasolar planet with masses between that of Earth and the small gas giants like Uranus and Neptune.

Discovery
The first super-Earths were found in orbit around a pulsar as early as 1992 – not until 2005 did astronomers discover super-Earths in orbit around normal stars.



Rock and metal
High-density super-Earths would be dominated by layers of rock around a molten metallic core, similar to Earth.

Water world
Ocean planets have a density lower than Earth and would have deep layers of liquid water surrounding a mantle and a rocky planetary core.

Earth 2.0?
A rocky planet with large oceans would develop tectonic activity and might offer a suitable environment for the development of life.

43 Invisible radiations

In 1800, while trying to measure the temperature of different colours of solar radiation, William Herschel discovered that large amounts of energy emitted from the Sun as invisible radiation with wavelengths longer than the reddest visible light. This 'infrared' light was the first of several invisible radiations to be discovered – ultraviolet (with wavelengths shorter than visible light) soon followed, and later in the 19th century came radio waves and microwaves (longer than infrared), along with X-rays and gamma rays (shorter than ultraviolet). Since the type of radiation emitted by any object depends on its energy, these new radiations open the way to observing many otherwise invisible cool, hot or violent objects.

44 Expansion of the universe

Edwin Hubble's 1925 measurement of galactic distances (see discovery 11) allowed him to compare distance with the speed of a galaxy's motion relative to Earth, registered in changes to the wavelength of its light. He found that the galaxies that are farthest away are moving away at the greatest speeds. This observation indicates that the universe is expanding and galaxies are moving apart from each other like raisins in a rising cake.

45 Asteroid minerals

Using the method of spectroscopy to study the faint reflected light from asteroids and comets, astronomers are able to work out various aspects of their composition and even link them to specific types of meteorite that have fallen on Earth before. Confirmation that some asteroids are rich in valuable metal reserves has inspired many commercial plans for asteroid mining, with several companies already planning their mining missions.

46 Great Red Spot

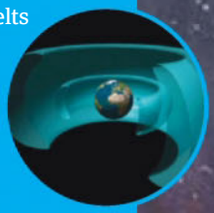
This long-lived feature of Jupiter may have been seen as early as 1664 by English scientist Robert Hooke. It has been observed continuously since 1830 and is now known to be an enormous anticyclonic storm in the planet's atmosphere, bigger than planet Earth.

47 Pulsars

When a repeating radio signal from space was discovered by Cambridge radio astronomers in 1967, they briefly wondered whether it could be a signal from aliens. It turned out to be a cosmic lighthouse beam generated by a collapsed stellar remnant with an intense magnetic field.

48 Van Allen Belts

When the USA launched its first satellite in early 1958, its instruments discovered doughnut-shaped belts of intense radiation high above the Earth, caused by high-energy particles trapped in Earth's magnetic field. They're named after the mission's lead scientist, James Van Allen.



49 Saturn's rings

The true shape of Saturn's rings was first described by Dutch astronomer Christiaan Huygens in the 1650s, but it was not until 1859 that Scots physicist James Clerk Maxwell showed how a series of discs could be created by countless small particles in individual orbits.

50 Oort Cloud

In 1950, Dutch astronomer Jan Oort proposed the existence of a huge spherical halo of comets surrounding the Solar System. Though we cannot observe it directly, we can be sure it is there from the orbits of the long-period comets that originate within it.

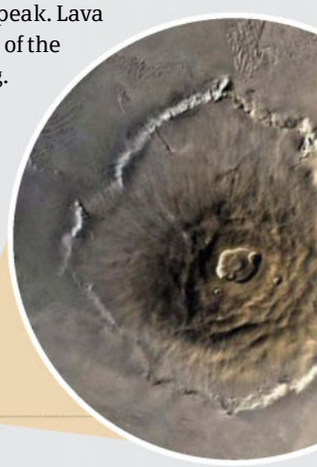
"Shock waves of increased temperature and pressure spread over the planet's surface"

Space mountains

How are the biggest peaks in the galaxy formed?

We may think of planets and moons as round spheres floating in the sky, maybe pockmarked with a crater or two, but it turns out they actually can contain some of the biggest mountains in the galaxy. Top of the pile is the Olympus Mons on Mars, which stands an incredible 25 kilometres (15.5 miles) high, nearly three times higher than the tallest mountain on Earth.

Mountains in space can form in two different ways. On hot, rocky planets like Venus and Mars, most mountains are shield volcanoes. These develop much like volcanoes do on Earth, with extreme pressure under the crust building and pushing up to form a peak. Lava then flows down the sides of the volcano before solidifying. The thin layers of lava gradually form the characteristically low and wide profile of a



Sizing up the tallest mountains in the Solar System

Of all the mountains in the Solar System, which one is the largest? Here we have a side by side comparison of the highest mountains on the rocky planets and their satellites – some of them may surprise you!

Doom Mons, Titan

Scientists are particularly excited about Doom Mons because the combination of the peak, huge craters and evidence of something having flowed down the sides suggests an ice volcano.

Mauna Kea, Earth

Topping Everest because so much of it is underwater, Mauna Kea is a dormant volcano in Hawaii that houses many NASA telescopes.

Maat Mons, Venus

This mountain has lava stretching for hundreds of kilometres down the shallow slopes, typical of a shield volcano, made up of solidified lava.

Olympus Mons, Mars

The tallest mountain in the galaxy is a potentially active shield volcano. Part of it formed over billions of years while some parts may only be a few million years old.

Caloris Montes, Mercury

This mountain ring is made up of bedrock disturbed by a huge impact that created the Caloris Basin. The rocks settled and became mountains.

What inspired Doom Mons' name?

A A fantasy novel location B A sci-fi villain
C An astronomer's pet

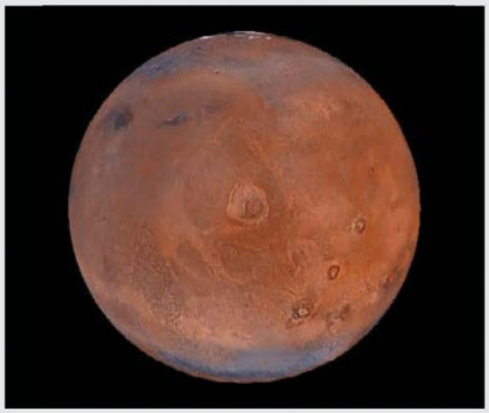
Answer:
Doom Mons is directly translated as Mount Doom, which is the place in JRR Tolkien's fantasy novel *Lord Of The Rings*. It is where the One Ring was forged and where Frodo Baggins needs to take it to destroy it.

DID YOU KNOW? *Most of the mountain ranges on the Moon are named after those on Earth, like the Alps and Apennines*

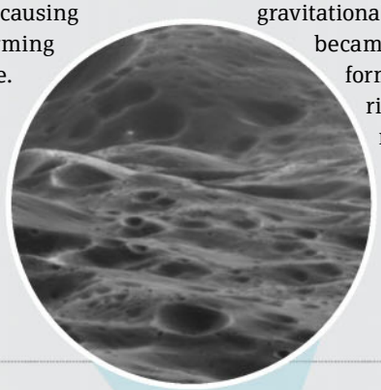
shield volcano. As these are 'self-growing' mountains, they will continue to expand as long as lava flows from them.

This is not the case for other common types of space mountains, which are formed due to high impact. When a meteor or asteroid collides with a moon or planet, a crater is formed. Shock waves of increased temperature and pressure spread over the planet's surface, causing rocks to crack and rebound, forming a peak around the crater edge. An example of a crater mountain is the Herschel Crater on the Saturn moon Mimas. We're able to see these mountains thanks to incredibly sharp telescopes on Earth, while those farther afield are captured on cameras mounted on spacecraft as they fly by their targets.

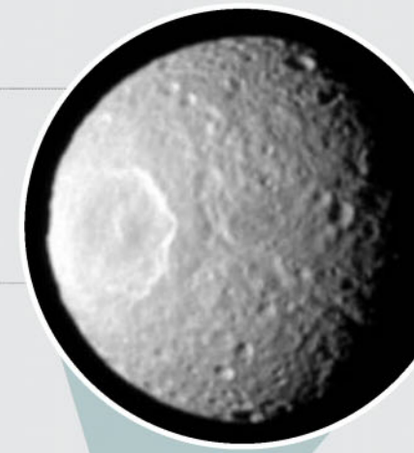
Finally, there is the equatorial ridge on Saturn's moon Iapetus. The theory is that rocks and space debris were trapped in the moon's gravitational field, pulled towards it and became stuck to the planet, forming this ever-expanding ridge and creating a vast mountain range.



The colossal Olympus Mons can be easily seen in this photo of Mars



Rheasilvia crater, Asteroid Vesta
The second-highest known mountain in the galaxy is on an asteroid, strangely enough. It's thought the whole range was created in a single impact, a billion years ago.



22km
20km
18km
5.5km
6km

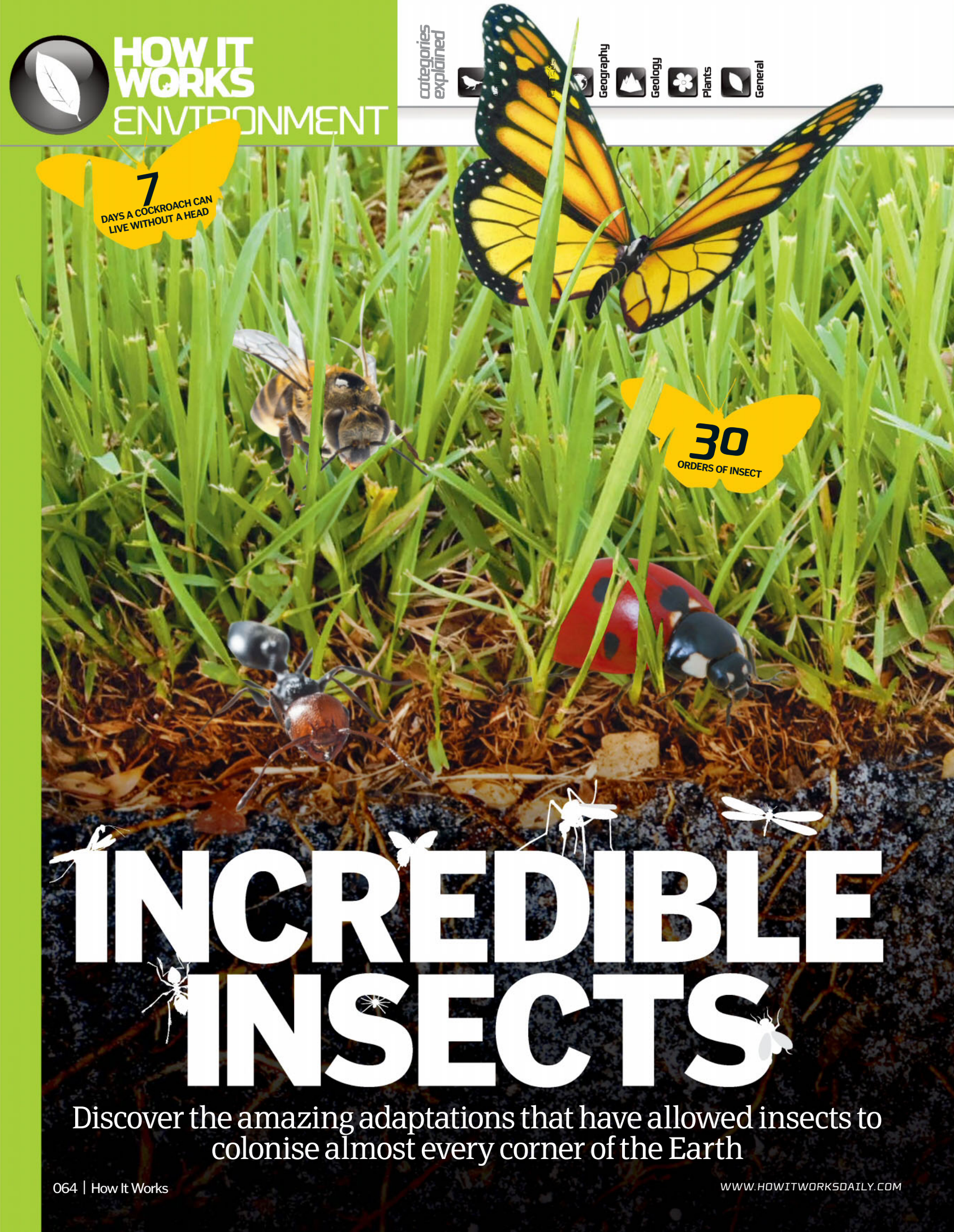
Boosaule Montes, Io
Jupiter's third-largest moon is home to this vast mountain, created by pressure built up under the moon's crust that pushed their way upward.

Mons Huygens, Moon
The highest mountain on the Moon is named after Dutch astronomer Christiaan Huygens and is found in the Montes Apenninus mountains.

Equatorial Ridge, Iapetus
It is thought the equatorial ridge around Saturn's third-largest moon isn't actually from the planet but was dragged there by gravity and became part of the moon.

Herschel Crater, Mimas
Rising up from the centre of one of the largest craters in the Solar System is a mountain created by the force of an impact on this Saturnian moon.

Mountain name and location



INCREDIBLE INSECTS

Discover the amazing adaptations that have allowed insects to colonise almost every corner of the Earth

100g

THE WORLD'S HEAVIEST INSECT

Goliath beetles are the world's heaviest insects, the biggest weighing in at a colossal 100g (3.5oz), and measuring up to 11cm (4.3in) in length.

DID YOU KNOW? *The combined mass of all the ants inhabiting the Amazon is more than all of the other mammals there combined*

Insects outnumber humans 1.4 billion to one, and make up an estimated 85 per cent of all animal species. They might look similar to other arthropods, like spiders, centipedes and scorpions, with their segmented bodies, jointed legs and tough armour plating, but what sets them apart is their unique body plan.

All insects share the same basic parts: a head, a thorax and an abdomen, three pairs of jointed legs, compound eyes, and a pair of antennae. For the last 400 million years, insects have been constantly evolving and adapting these simple components, and there are now an estimated five million different species, each slightly different from the next.

There are over 30 orders of insect, divided up according to their evolutionary relationships, each have their own unique anatomy and their own specialities.

On the ground, insects have adapted their six jointed limbs for a variety of tasks. Mole crickets use legs as shovels, grasshoppers have enlarged hind limbs specifically adapted for jumping, and water boatmen use theirs as oars. Many insects also have wings, and in the air, the diversity is just as evident. True flies are the most accomplished aerial acrobats, while other insects, such as beetles, have sacrificed their top set of wings for a tough armour shell, allowing them to spend more time on the ground. Butterflies and moths often use their wings as colourful billboards for mating, or cryptic camouflage for evading predators.

Their incredible ability to travel by land, air and water has allowed insects to take advantage of almost every imaginable habitat and food source on the planet. Their mouthparts are also highly specialised. Grasshoppers have two large, scissor-like mandibles adept at cutting stems, while ants use similar structures as fearsome weapons.

Other species cannot bite at all, having instead adapted to a liquid diet; moths and butterflies have long straw-like mouths used for drinking nectar, while mosquitoes have a hypodermic needle capable of piercing flesh and drawing blood.

Insects are scavengers, parasites, farmers, hunters, builders and masters of chemical warfare. They have a built-in suit of armour, reproduce quickly, adapt rapidly to changes in their environment and are by far the most successful animals on the planet.

"Ants, termites, bees and some wasps live and work together in colonies that can number in the thousands"

SAFETY IN NUMBERS

Raising young is a time-consuming business, and most insects do not tend to their offspring, preferring to lay their eggs on a suitable food source and leave the next generation to fend for themselves. However, this strategy results in a lot of casualties.

Some insect species, including certain types of bees and wasps, dig burrows for their developing offspring and bring food back for the larvae as they grow, but the most successful insects of all are those that work as a team to get things done.

Ants, termites, bees and even some wasps live and work together in colonies that can number in the thousands of individuals. They are accomplished architects and build intricate structures within which to live, segregating special areas for storage and for raising young. They often incorporate natural defences, waterproofing and even air conditioning into their elaborate homes.

The female workers take responsibility for the maintenance of the colony. Some take on the role of builder, others are nurses and tend to the brood, some are guards, while yet others are cleaners. Older workers leave the nest site in search of food, scouting out the best locations and relaying their location to the foragers, either using a pheromone trail (ants and termites), or with an intricate waggle dance (bees). Any food collected is stored and shared among the colony and their resources are fiercely defended; among some species, workers even form living doors at the entrances, blocking the passage of intruders.

In order for this system to work, all of the individuals in the colony need to collaborate; if each worker were trying to raise her own eggs at the same time, the society would quickly fall apart as the insects fought over food and nesting sites. Honeybee queens produce a cocktail of chemical signals that switch off the reproductive systems of their sisters, so instead of wasting time mating and laying their own eggs, with all the foraging, feeding and fighting that entails, the workers divert all their attention to caring for the offspring of their queen.

Life in the hive

Worker bees take on many different jobs during their lifetime

3–5 YEARS A QUEEN BEE LIVES

Drone
Male bees are only present in the hive during the breeding season, and leave each day in search of a mate. They are tended to by the workers on return.

Guard
Before the worker bees become foragers, they spend time as a hive guard, checking the scent of all returning foragers to make sure they belong.

Porter
When the foragers return to the hive, young workers take the nectar and pollen that they have collected and transfer it into storage cells.

Builder
When worker bees are almost two weeks old, they begin producing wax and start to contribute to the building and maintenance of the hive.

Forager
When the worker bees are three weeks old, they start to leave the hive in search of food. They store nectar in a crop near their mouth and pollen in balls on their back legs.

BELOW Worker bees visit about 2 million flowers to make 450g (1lb) of honey

Which are the deadliest insects?

A Fruit flies **B** Africanised honeybees **C** Mosquitoes

Answer:
Honeybees have a painful sting, but mosquitoes are easily the deadliest insects on the planet, if not the deadliest animals. The female anopheles mosquito carries the parasite that causes malaria, responsible for over a million of deaths every year.

DID YOU KNOW? *There are an estimated 10 quintillion (10,000,000,000,000,000,000) insects alive at any one time*

Chambermaid
The queen is too large to care for herself, so the young workers feed and clean her, taking responsibility for her eggs.

Nurse
Young worker bees carefully tend to the larvae, checking on each one over 1,000 times a day.

Housekeeper
When a new worker bee emerges from her cell, her first job is to clean it and prepare it for a new egg.

Queen
If new eggs are needed, the workers escort the queen to the right location and encourage her to lay.

New queen
Worker bees are responsible for raising new queens, feeding selected larvae a rich diet of royal jelly.

RIGHT There are 50,000 or more bees in a hive

TOP 5 Industrious insect teams

1 Paper wasps
Paper wasps build delicate nests out of wood pulp and saliva. Their social structure is particularly advanced and each wasp individual looks different, allowing them to recognise one another by face.

2 Argentine ants
These aggressive little ants have built a global megacolony. This vast family of related insects spans three continents and includes the three largest ant supercolonies in the world in Japan, the USA and Europe.

3 European honeybees
Honeybees colonies are responsible for the pollination of 80 per cent of the flowering plants that we rely on for food. Without them, around a third of the groceries on your table would disappear.

4 Macrotermes bellicosus
These are the largest termites in the world; the queens measure over 10cm (4in) in length. Their enormous mounds can dwarf an adult human, measuring several metres in height.

5 Leaf-cutter ants
These industrious insects spend hours every day gathering grass, but they do not eat it themselves. They are farmers and feed the grass to enormous underground fungus.

"Over time, some species developed more advanced wings that could be folded neatly backward"

INSECT HABITATS

5,000 SPECIES OF LADYBUG

The ancestors of modern insects came from the sea. Around 475 million years ago, plants started to creep across the landscape and within 100 million years, the first insects were scuttling among them. These were similar to modern-day silverfish; small, wingless invertebrates, with a tough exoskeleton and a waxy layer that helped keep them damp. However, as primitive insects started to colonise the land, so too did other arthropods, including spiders, centipedes, millipedes and scorpions, and some of these invertebrates were predators.

Needing to escape these new dangers, insects were the first animals to take to the skies. The first wings were simple, like those of a dragonfly; large, delicate membranes held out from the insect's body. They were good for flying, but their bulky shape made walking on the ground challenging and they were easily damaged. Over time, some species developed more advanced wings that could be folded neatly backward.

The evolution of flight did not just benefit insects, as plants were quick to take advantage. They spend their lives rooted to the floor, so transferring genetic information to other plants can be challenging. Insects are the perfect couriers for genetic material and for millions of years, flowers and insects have evolved side-by side, in a mutual agreement that has allowed both to spread across the globe.

With the arrival of reptiles and mammals and the emergence of flying predators, the world became increasingly inhospitable. But insects are small, reproduce quickly and have had a head start of millions of years, giving them time to adapt to every ecological niche.

Dominating the environment

Insects are adaptable and diverse, and you don't have to look far to find them

Inside their homes

Social insects build large homes that are often easy to spot, but they are fiercely defended and should not be disturbed

In the trees

Several insect species have developed adaptations that allow them to make use of the trees. Wasps chew wood, using the pulp to build vast structures, and moths can sometimes be seen drinking the sticky sap.

Recycling waste

Insects are important natural recyclers and can often be spotted feasting on dead and decaying material.

On other animals

Some insects, like fleas and mosquitoes, specialised as parasites, and can be found feeding on the blood of other animals.

How to build an insect hotel

01: Find twigs
Insects like dark, damp crevices, so all you need are some natural materials with lots of nooks and crannies. Twigs, bamboo canes, pine cones and bark are great. You'll also need string and scissors.

02: Tie together
Collect your materials together into a bundle and tie them firmly with the string. Don't worry about being too neat, strange holes and bits sticking out will make great hiding places for the insects.

03: Hang it up
Choose a spot out of direct sunlight to make the most of the dark and damp that insects prefer. Brace it against something so the wind won't blow it about, and use a loop of string to tie it in place.

AMAZING VIDEO!

SCAN THE QR CODE FOR A QUICK LINK

An amazing slow-motion video of a bee in flight

www.howitworksdaily.com

DID YOU KNOW? *To date, 950,000 species of insect have been identified and classified, but millions remain undiscovered*

In the air

Some species of insect, like the monarch butterfly, travel vast distances by air, migrating to warmer climates during the winter.

Near the flowers

Several insects evolved alongside flowering plants and are attracted to the sweet nectar. Butterflies and bees can often be found flitting between the flowers.

Hidden in the foliage

Many insects, like mantises and stick insects, use mimicry and camouflage to blend in with their surroundings, making them difficult to spot.

Patrolling the ground

Larger insects, like beetles can sometimes be spotted clambering over plants and rocks, and even wandering across the pavement.

In the leaf litter

Many insects like damp, dark places and hundreds of species can be found lurking under rocks, leaves and fallen trees.

Hiding underground

Burrowing insects, like ants and beetles, make their homes below the ground, where the temperature remains relatively constant, the air is moist.

12,000 SPECIES OF ANT

How to make an ant farm

01: Two jam jars

To make this simple ant farm, all you need are two jam jars, one smaller than the other. The small jar sits inside the bigger one, and the ants live in-between, making visible tunnels around the edge.

02: Add soil

Put the small jar inside the big one and carefully tip some soil into the gap between the two. The soil needs to be nice and loose so the ants can dig tunnels, so it may be good to sieve it first.

03: Collect ants

Ants are attracted to sugar and water. Leave some on a cotton ball in the garden and you'll soon have inhabitants for your new farm. Pierce tiny holes in the lid before fastening it on so the ants get some air.

"Once the fungus has latched onto a grass root, it usually means the grass will die"

Fairy rings or frightening fungus?

It may sound otherworldly but this garden phenomenon is very real

Every now and again, a perfectly normal lawn or patch of grass will begin to grow a strange circle of toadstools. Unfortunately, this is not a community of fairies setting up camp in your back garden, but an outbreak of the fungus Marasmius oreades.

This fungus is attached to the roots of turf, having been carried by the wind from other toadstools. They form rings because the mycelium – the tubes that form the underground body of a fungus – grows in an outward direction. After the fungus has spread, the centre of the mycelium dies off, so by the time they are ready to grow above ground, the remaining toadstools will have formed a ring shape on the surface.

They are very unpopular among gardeners because, once the fungus has latched onto a grass root, it usually means the grass will die, forming an ugly patch of dead grass. Removing the toadstools will do little to stop the problem as the fungus has already taken hold. The best way to combat fairy rings is to remove the turf and soil and replace them.

Alternatively, you could try spiking the ground and watering the area heavily. The fungus will have dried out the lawn and made it water repellent, so heavy watering will give the grass enough water to grow and resist the drying effect of the fungus. Fairy rings tend to occur around late summer and early autumn, so if you are a gardener or fairy spotter, this is the time to keep your eyes peeled.

This is not a magical gathering in your garden, but an immediate problem

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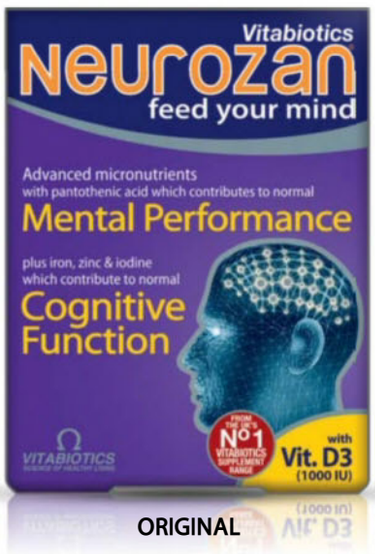

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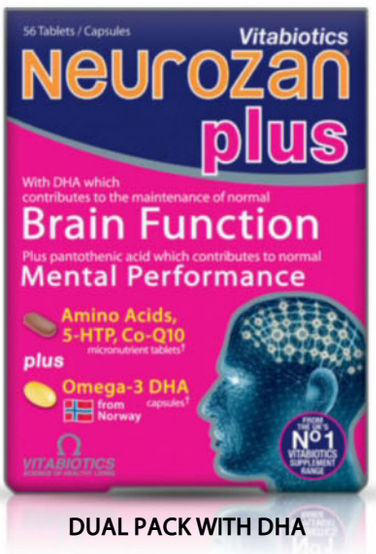

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VITABIOTICS
SCIENCE OF HEALTHY LIVING

ADNEUCONP 27-06-14E

Flying a WWII plane

We get into the aircraft that trained pilots for World War II

It's the summer of 1940 and the German Luftwaffe is preparing to launch a mass air attack on Southern England. If they are victorious, Britain will be open to a land invasion and Blitzkrieg will be upon the British Isles. Luckily, brave and skilled RAF pilots take down the Messerschmitts in their Spitfires and Hurricanes, so the German Operation Sea Lion never materialises. But how were our pilots so skilled at air-to-air combat? How It Works went down to Goodwood Flying School in West Sussex for a lesson way up in the sky almost exactly 74 years after the battle.

On a glorious day on the south coast, we will be over 1,200 metres (4,000 feet) in the air learning to fly like it's 1940. The plane taking flight today is not a Spitfire or a Hurricane; in fact it's not even a fighter at all. Instead it's the official World War II training plane for the RAF, the Harvard T-6, a Canadian-built Noorduyn model. Before we go skyward, we meet pilot Matt Hill who shows us the aviation ropes.

"The Harvard was used for advanced training, gunnery practice and blind flying, it had less speed and power than the Spitfire and the Hurricane as it was a trainer, not a fighter", Matt says, shortly after delivering a crash course on how to fly a plane. How It Works isn't going to be just a passenger on this flight – when we're in the air, we will actually have control of the plane.

Before we take to the skies it is important to know the history behind the aircraft. The Harvard was the second step in a RAF fighter pilot's training. Prior to this, a budding pilot would take to the skies in a Tiger Moth biplane. This aircraft would be used for a four-and-a-half-hour training session to hone the skills and art of flying before ramping up the power in the Harvard. Matt explains: "This plane (the Harvard) has a hydraulic system, brakes, a tail wheel and flaps, which the Tiger Moth doesn't. People who have flown the Mustang (US WWII fighter plane) say it is very, very similar." The ▶

The statistics...

Harvard T-6/North American T-6 Texan

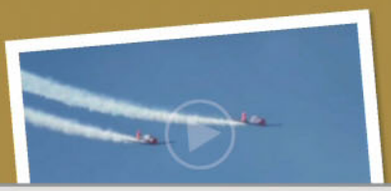
- **Length:** 8.5m (28ft)
- **Wingspan:** 12.8m (42ft)
- **Seating:** Tandem
- **Power:** 450kW (600hp)
- **Engine:** Pratt & Whitney R-1340 Wasp
- **Propeller:** Hamilton Standard Two-Blade 12D40 Propeller
- **Top speed:** 338km/h (210mph)

A fleet of T-6s in 1941 ready for training drills at Randolph Field, Texas

AMAZING VIDEO! SCAN THE QR CODE FOR A QUICK LINK

Watch some stunning Harvard T-6 aerobatics!

www.howitworksdaily.com



DID YOU KNOW? *Despite the Spitfire's popularity, the Hawker Hurricane shot down more German fighters in the Battle of Britain*

RAF fighter aces during the Battle of Britain

NAME	AIRCRAFT	KILLS
Pilot Officer Eric Lock	Spitfire	21
Flight Lieutenant Archie McKellar	Hurricane	19
Sergeant James Lacey	Hurricane	18
Sergeant Josef František	Hurricane	17
Flying Officer Witold Urbanowicz	Spitfire	15

Our Staff Writer Jack being shown the ropes by a Goodwood Flying School pilot

Jack all dressed up and ready to go

"We began with a full loop, which gave the experience of around 3g's worth of force"

Harvard was used by 30 countries as part of their respective air forces and the last military usage was as recent as 1995 in the South African armed forces.

On inspection of the Harvard, it is obvious this striking machine is almost entirely unchanged since the 1940s. In fact, a fresh coat of paint is literally the only difference. The first production model flew in 1938 and its successful test flight convinced the British to order over 300 for training purposes. Far from a relic, the original instruments are all still in complete working condition and the dual cockpits are exactly how they would have been in the war. With that, Matt calls an end to the chitchat as the runway beckons. The *Top Gun*-esque suit is donned and into the skies we go.

The flight itself lasted 40 minutes. First, we undertook a circuit of the airfield and witnessed some breathtaking views of the nearby towns of Chichester and Bognor Regis. There wasn't much time to take in the sights, however, as it was now our turn to take the reins. Matt prepared the plane for a change in control by maintaining a steady speed and making the plane level. With a slight shunting motion, the craft was now in our hands. The Harvard is controlled by a central stick which you move in the direction you want the plane to go. The stick was incredibly sensitive and a slight movement to either side would alter the plane's flight path considerably. It felt very tense being in a tiny vehicle in a huge expanse of sky.

After the short solo journey, it was time to relinquish control and hand over to Matt, who would now do some extreme aerobatic manoeuvres. We began with a full loop, which gave the experience of around 3g's worth of force. Next up was the barrel roll, which was followed by twists and dives that resulted in a similar amount of g-force. The only way to describe the feeling is to imagine the biggest and fastest roller coaster you've been on and then multiply it by ten.

Leaving Goodwood, you couldn't help but wonder how the RAF performed these amazing moves, all while engaging in warfare with the mighty Luftwaffe. It boggles the mind that these brave men did this just a touch over 70 years ago. The Harvard T-6 is a wonderful machine and undoubtedly a key component in the RAF having the skill to win the Battle of Britain and halt the German advance.

To try your hand at flying a World War II plane for yourself, visit www.goodwood.co.uk/aviation for more information.

The Harvard's modern cousin

On the day, we also had the chance to test out another plane, the Cessna 172S Skyhawk, which is one of the planes used currently to train new pilots. However, the one most like the Harvard is the Swiss-built Pilatus PC-21. Used to train modern-day fighter pilots, the PC-21 provides an ideal introduction to flying jet-based fighters. It can be used for both beginner and advanced training, using a turboprop engine that uses a propeller flown by a turbine. It can reach speeds of up to 685 kilometres (425 miles) per hour and current customers include the air forces of Singapore, United Arab Emirates and the Royal Saudi Air Force.

The Cessna 172S Skyhawk, a new training plane

The Harvard: inside and out

A trip around the T-6 and its main features

Cockpits
The Harvard contains two cockpits; one for the pilot and one for the learner. Both have very similar instrument panels and the learner solo control can be engaged at any time.

Cruising speed
Although the top speed is slightly higher, the Harvard generally cruised at around 230km/h (145mph) at an ideal altitude of 2,440m (8,000ft).

LEFT The front propeller gives it an imposing appearance

THE STATS
BATTLE OF BRITAIN

1,012 RAF LOSSES

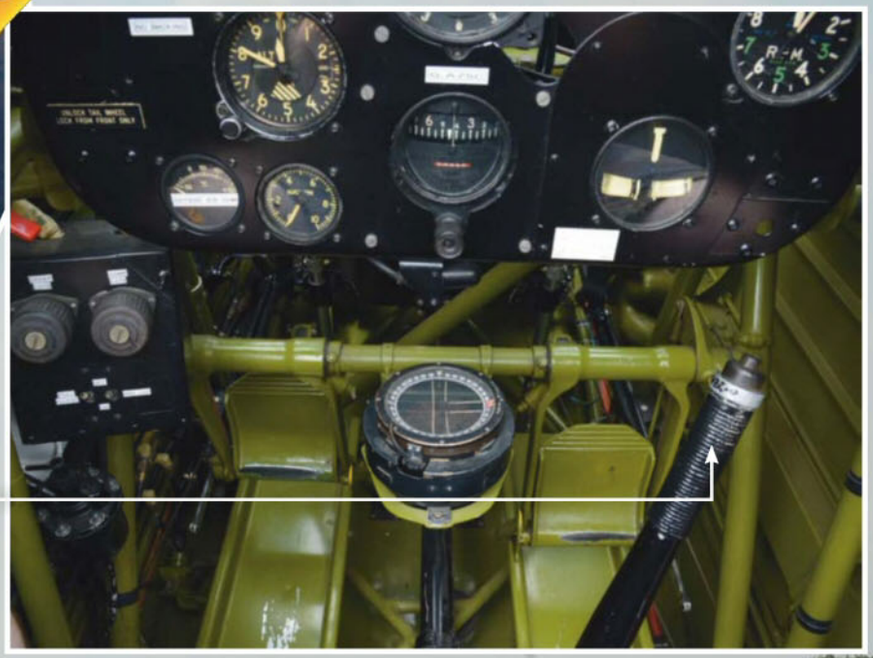
1,918 LUFTWAFFE LOSSES

2,927 ALLIED PILOTS

601 HURRICANES SHOT DOWN

357 SPITFIRES SHOT DOWN

DID YOU KNOW? *The Harvard is used to portray Japanese Mitsubishi Zeros in several war films, such as 1987's Empire of the Sun*



In action
In the war the T-6 could also function as a FAC (forward air controller) to support frontline troops by surveying the local area.

Control
Steering is done using the centre stick, although differential braking in the tailwheel can be used as well.

Armament
Although strictly a training plane, the Harvard could hold light machine guns on its wings and could even include bomb racks.

Altitude
The Harvard can be stretched to a service ceiling of 7,376m (24,200ft) before the elevation is too high for its instruments and mechanisms to cope.

Range
On a full tank and in good conditions, the plane can fly up to 1,175km (730mi). That's further than from John o' Groats to Land's End!

Hydraulic system
Activated by a push of a button, the system allows you to use the gears and flaps on the plane.

On the Tiger Moth biplane

A trip on a Tiger Moth is very different to a Harvard flight. As it's a biplane, flights are completed at a much lower altitude and at considerably slower speeds. This is ideal for the beginner pilot to understand the controls before ramping the difficulty up to the Harvard. The controls in the biplane are less responsive than most, so piloting it is actually pretty tricky. The RAF liked this quality as it quickly separated the talented pilots from the rest. The 'Moth' is a semi-aerobatic plane, so it can still loop and barrel roll, which made it an ideal starter plane for RAF training.

The Tiger Moth served as a preliminary training plane

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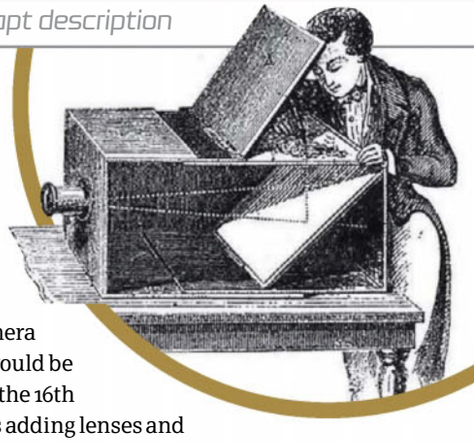
DID YOU KNOW? *Camera obscura is a Latin term that translates as 'dark room', which is an apt description*

Camera obscura

How a pinhole lens brings light to darkness and illuminates our world



RIGHT A camera obscura box from the 18th century

Arguably one of the single most important predecessors to photography, the science behind the camera obscura dates back to Ancient China, perfected over centuries by such luminaries as Aristotle and Leonardo da Vinci.

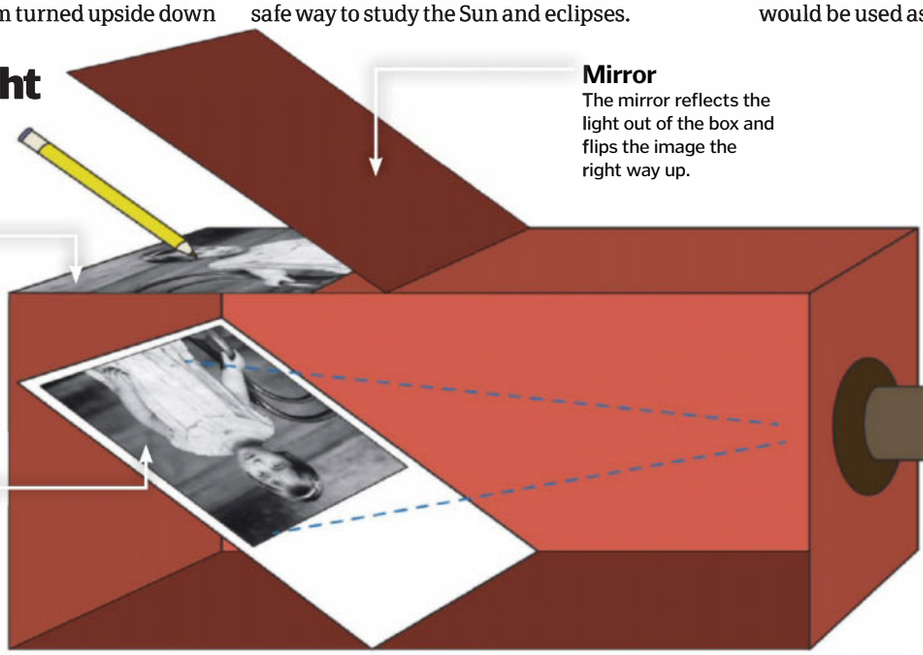
Chinese philosopher Mozi (470-390 BCE) first recorded the fact that light channelled through a small hole into a dark room turned upside down because it travels in a straight line. Aristotle made similar observations while studying the passage of sunlight through leaves, but it was Arabian genius Alhazen who defined the camera obscura when he realised that the light was in fact creating a reflection.

Da Vinci further developed the technology and the camera obscura was used by scientists as a safe way to study the Sun and eclipses.

The camera obscura would be refined in the 16th century as adding lenses and mirrors allowed the user to create a sharper reflection. Artists used it to bring greater detail to their renderings, as the reflected image allowed them to trace their subjects, and it would be used as the basis for the first camera.

Travelling light

How the camera obscura produces the perfect reflection



Mirror
The mirror reflects the light out of the box and flips the image the right way up.

Pinhole and lens
Light passes through this small hole and the lens ensures the image will be focused.

Artist's hand
The image is reflected onto the paper, at which point the artist can trace it.

Light inverted
As light passes through the hole into the darkened space, the rays cross, rather than scatter, producing an upside-down reflection.

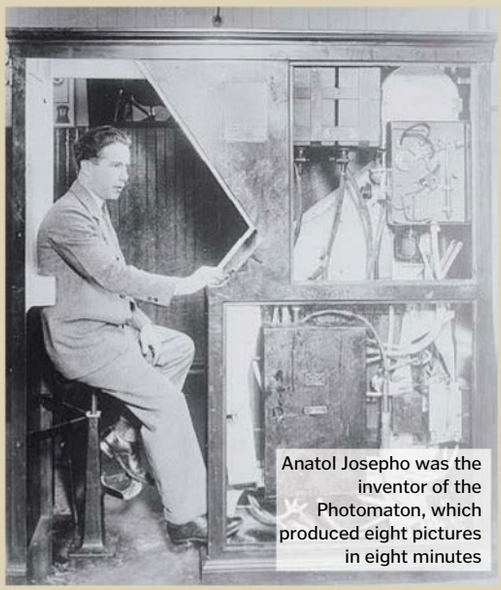
Subject (not shown)
The object you want to reflect is placed directly in front of the pinhole camera.

The first photo booth

How the photo portrait was democratised

The first modern photo booth wasn't perfected until 1925, when Russian Anatol Josepho built the Photomaton, inspired by the penny camera's long strips of cheap photos. It was the culmination of years spent researching the best paper to print on; the chemicals to develop it, and a machine that could print consistently.

Having borrowed $11,000, Josepho built his masterpiece, which would produce eight pictures for 25 cents in eight minutes. They were printed directly onto paper, with the mechanism performing a wet development, 'dip-n-dunk' process. The film would be dunked into water before being submerged in developer fluid, which converts the silver halides into silver metal. Then it would be dipped into the stop bath (water or a diluted solution of acetic or citric acid), which halts the development. It is then dunked into a fixer fluid, which dissolves the silver halide to make the photo light-resistant and fixed, and finally toner, to improve the image quality. Between each stage the film is dunked in a water bath. The finished strip would then be printed. Up to 7,500 customers a day lined around the bloc and Josepho would sell the rights to his machine for $1 million, half of which he donated to charity.



Anatol Josepho was the inventor of the Photomaton, which produced eight pictures in eight minutes

"After the original church was damaged in a fire in 976, it was rebuilt some time before 1094"

Saint Mark's Basilica

Why does Venice's most storied and famous church have so much treasure within its walls?

An eye-catching mix of Eastern Byzantine, Western Gothic and even Islamic styles of architecture and art, Saint Mark's Basilica in Venice, Italy is testament not just to the wealth and power of the Medieval Republic of Venice in northeastern Italy, but to its swashbuckling adventures in the Mediterranean – not just as traders, but as conquerors.

In 828, two rather unscrupulous Venetian merchants stole what they believed were the remains of Saint Mark the Evangelist from Alexandria in Egypt. Declaring Saint Mark their home city's patron saint, they then built a church to house the body. Instead of hiding its origin, one mosaic in Saint Mark's Basilica even boasts of the theft – showing the Venetians in question hiding the stolen saint in barrels of pork, which the Muslim Egyptians were forbidden from touching, so that the customs officials wouldn't inspect their cargo too closely.

After the original church was damaged in a fire in 976, it was restored and then rebuilt some time before 1094 around the striking central dome that still stands there today. With Venice at the height of its powers in the 11th to 14th centuries, the city provided naval support to European armies in the Crusades and actually led the Fourth Crusade against Constantinople (now Istanbul in Turkey, but then the Greek Orthodox Christian capital of the Byzantine Empire) and took the opportunity to loot its many religious relics, gold and chalices, as well as four bronze horse statues, to further embellish their Basilica. The Venetians even stole mosaics, columns and carvings from various churches and houses of worship across the Middle East to pile onto their own back in Venice.

Not everything that found its way into the Basilica was taken by force, though, for it was also a tradition for Venetian merchants to bring back gifts from their travels, making Saint Mark's Basilica – or to give it its 11th-century nickname, Chiesa d'Oro, or 'Church of Gold' – one of the most beautiful cathedrals in not only Italy, but all of Europe.

Inside the Church of Gold

The many origins of St Mark's interior

Winged lion
The winged lion with an open book is the symbol of Saint Mark and of Venice itself.

Horses of Saint Mark
Replicas of the bronze horses that were stolen from Constantinople in 1204. The originals can now be seen in the church museum.

Confession
The 17th-century mosaic over the southernmost door shows the theft of Saint Mark's body from Alexandria, Egypt.

Proclamation stone (not shown)
Important announcements were made from the red Pietra del Bando, or 'proclamation stone', which was stolen from Syria during the Crusades.

KEY DATES
ST MARK'S STORY

832
The original Saint Mark's Basilica is constructed to house the saint's pilfered remains.

976
The Basilica is damaged by a fire during a revolution against Venice's ruler Pietro IV Candiano.

1094
The new church is consecrated. It will be modified many times over the coming centuries.

1202
Venice leads the Fourth Crusade against Constantinople; Saint Mark's is showered in booty.

1797
Napoleon Bonaparte steals many treasures from Saint Mark's. Most are later returned.

DID YOU KNOW? *Saint Mark's Basilica only became Venice's cathedral in 1807 – prior to that it was a chapel*

False dome
The original domes were extended with lead-covered wood in the 13th century to match the style of the palace next door.

Altar screen
The beautiful Pala d'Oro, or 'golden pall', altar screen was bought from Constantinople in 1102, rather than being stolen.

Mosaics
There are 8,000m² (86,100ft²) of mosaics, many in gold. That's more than enough to cover a football pitch.

Doge's platform
To the left of the altar is a platform where Venice's ruler, the doge, would appear after his election.

Columns
There are more than 500 columns, many stolen from the Byzantine Empire and dating from the 6th to 11th centuries.

Syrian columns
Two Byzantine columns stolen from Syria in the crusades – they date from the 5th or 6th century.

The falling tower

Italian churches often have bell towers, or 'campaniles', separate from the main building and Saint Mark's Campanile, which stands 50m (164ft) high, was built in the 9th century.
The tower is so iconic that not only does it adorn postcards, magnets and T-shirts, but replicas – most often used as clock towers – can be found around the world.
But even Saint Mark's Campanile itself is something of a replica. In the early hours of 14 July 1902 a crack appeared in the wall, which continued to grow. Then at 9.45am, the tower completely collapsed. It was rebuilt with stronger foundations and finally opened on 25 April 1912. The reconstruction cost 2.2mn lire (£88,000), a vast amount at the time.

RIGHT View of the Basilica from Saint Mark's Campanile

BRAIN DUMP

Because enquiring minds need to know...

Want answers?

Send your questions to...

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howitworks@imagine-publishing.co.uk

MEET THE EXPERTS

Who's answering your questions this month?

Luis Villazon

Luis has a degree in zoology and another in real-time computing. He's been writing about science and technology since before the web. His science-fiction novel, *A Jar Of Wasps*, is published by Anarchy Books.

Crispin Andrews

Crispin is a freelance writer and history graduate. He likes cricket, Sherlock Holmes, Carl von Clausewitz and pine martens. He has never watched reality TV and has no interest in Cheryl Cole's handbag.

Alexandra Cheung

Having earned degrees from the University of Nottingham as well as Imperial College, Alex has worked at many a prestigious institution around the world, including CERN, London's Science Museum and the Institute of Physics.

Laura Mears

Laura studied biomedical science at King's College London and has a masters from the University of Cambridge. She escaped the lab to pursue a career in science communication. She spends her spare time developing educational video games.

Shanna Freeman

Shanna describes herself as somebody who knows a little bit about a lot of different things. That's what comes of writing about everything from space travel to how cheese is made. She finds her job comes in very handy for quizzes!

Could we ever visit the multiverse through travel to other dimensions or wormholes?

Jeffrey Weir

■ Models of the universe's inflation predict that other universes may exist alongside our own, but visiting one of our neighbours is hard to imagine. It is likely the physics governing a parallel universe would be incompatible with our own. For instance, other universes could have more or fewer dimensions, filled with different types of matter and constrained by different forces, meaning we simply could not exist there. Some forces such as gravity, could be shared across the multiverse, perhaps making it possible to communicate via gravitational effects. Wormholes, forming 'shortcuts' connecting two separate points in space-time, are predicted by the theory of relativity, but they would be microscopic in size and very unstable, unless we could find a way to modify them. But the first step for anyone planning a trip to another universe would be to find evidence for their existence. **AC**

What's the world's biggest non-cathedral church?

Ralph Dalby

The biggest church is St Peter's Basilica in Vatican City, which is 1.2 million cubic metres (42.4 million cubic feet) gross volume. The interior covers 15,160 square metres (163,180 square feet), and the exterior is over 20,000 square metres (215,278 square feet). It was built by Michelangelo, Carlo Maderno, Donato Bramante and Gian Lorenzo Bernini and others between 1506 and 1626. St Peter is said to be buried there, along with 91 popes. Michelangelo's Pieta – the statue of Mary holding Jesus's body and the only work he ever signed – is there, too. It's not a cathedral because it doesn't contain the seat of a bishop. The tallest church is Ulm Minster in Germany, at 161.5 metres (530 feet). **CA**

What is salmonella and why is it dangerous?

Tracy Vaughan

Salmonella is a bacterium that causes food-borne illness (also known as food poisoning). You've probably had salmonellosis and not realised it. In most people, it causes stomach cramps, vomiting, diarrhoea and fever for a couple of days. However, in the elderly, small children, and those with compromised immune systems, salmonellosis can lead to serious illness or death. Salmonella is often present in raw or undercooked eggs, ground beef and poultry. To help prevent it, store and cook these foods to the appropriate temperature and avoid cross-contamination. This means keeping uncooked foods away from cooked and ready-to-eat foods, and washing cooking tools (that includes your hands) well and often. **SF**

Why does bread go hard when it's toasted?

Freya East

When you toast bread, the toaster's dry heat expels moisture from the bread, reducing its elasticity and resulting in a crispy, hard exterior. Temperatures of 120 to 160 degrees Celsius (250 to 320 degrees Fahrenheit) spark a number of other chemical reactions which contribute to altering bread's texture, colour and taste. The flour in bread contains carbohydrates and proteins. The Maillard reaction causes the outer layer of carbohydrates and amino acids to combine, producing a caramelised brown colour and giving toast its signature flavour. The Maillard reaction also occurs when you brown meat and is even used in self-tanning products. **AC**

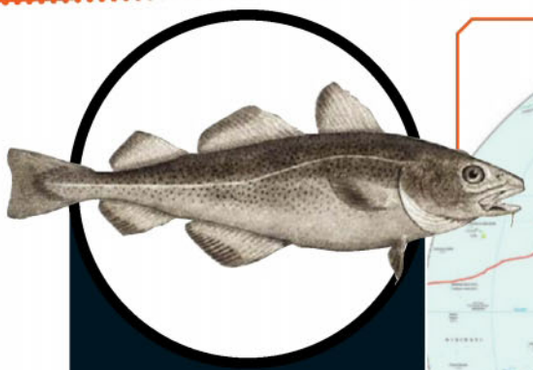
COOL FACTS

The largest vessel

At 488 metres (1,601 feet) long and 74 metres (243 feet) wide, Shell's Prelude is the world's largest floating vessel. It's a floating liquefied natural gas facility (FLNG) and weighs 600,000 tonnes when fully laden. **AC**

Is life dependent on water? Find out on page 82

BRAIN DUMP



What makes cod liver oil so good for you?

Allan Upton

Traditionally, cod liver oil was taken because it has vitamins A and D. During the Industrial Revolution, many people switched from farming to working long hours in factories. This made it difficult for them to get enough sunlight for their bodies to make vitamin D, and children would often develop rickets as a result. But cod liver oil actually contains too much vitamin A – a tablespoon has about 4.5 times the recommended daily intake and a full third more than the maximum safe dose. Vitamin A builds up in the body and can eventually cause liver failure if its level becomes too high. Fortunately, cod liver oil capsules contain a safe daily dose, though. **LV**

What is the fastest anyone has ever travelled around the world without a vehicle?

Teresa Ferry

On 21 July 2012, Erden Eruc of Around-n-Over became the first person to travel around the world solo under his own power, setting the record at five years and 11 days. He used a bicycle, rowboat and kayak to cover a total distance of 66,299 kilometres (41,196 miles), crisscrossing over the equator and passing every line of longitude.

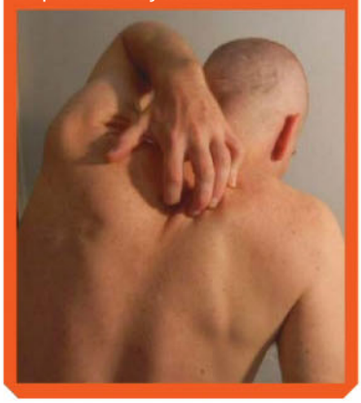
Eruc broke many records during his trip, becoming the first person to row across three different oceans and spending an incredible 312 days rowing solo across the Pacific. By the time he returned in 2012, he was the most experienced ocean rower in the world.

He took breaks on the way, so his total travel time was 1,026 days, approximately two years and ten months, but a British man thinks that he can beat that time. In September of 2014, Sam Greatrex of Lap the World begins his journey to break Eruc's record, aiming to travel 51,500 kilometres (32,000 miles) by bicycle and rowboat in just 18 months. **LM**

COOL FACTS

Itching for insects

Itching evolved as a way of encouraging us to swat away biting insects. Birds also itch but most reptiles have skin that is too thick to be punctured by insects.



Is it possible life on other worlds doesn't need water to survive?

Leyla Timms

It's possible that life originating on other planets might be based on other liquids, with methane being a strong contender. Some speculate that 'methanogens' arising in methane-rich worlds could take in hydrogen, acetylene and ethane, exhaling methane instead of carbon dioxide. However, no other liquid possesses the extraordinary properties of water, imposing many constraints on potential life forms. Methane, for example, is liquid around -170 degrees Celsius (-274 degrees Fahrenheit), but at such temperatures, chemical reactions occur incredibly slowly. Compared to water, methane is a very poor solvent, making it difficult for compounds such as amino acids and DNA to react together. Life would therefore face a steep uphill struggle to take hold without water. **AC**

Why did the Romans have brushes on the top of their hats?

Isha Gamble

Brushes? Proud Roman soldiers wore plumes! They showed both rank and unit, as well as making commanders look taller and more imposing. Centurions' plumes ran from ear to ear, while other soldiers' started from the forehead and ran backward. They were mainly worn in ceremonies after the 2nd century CE. **CA**

How do birds stay on their perch when they sleep?

Leanne Stamp

Passerines (which include sparrows and other songbirds) have their toes arranged with three facing forward and one facing back. The tendon that pulls these toes into a claw is called the flexor and it runs up the back of the leg over the ankle joint. When the bird squats down to perch, the flexor tendon is pulled tight, simply by the pulley action of the tendon over the tarsus (lower leg) bone. The weight of the bird alone is enough to force its claws shut around a twig or telephone wire, without any muscular effort. **LV**

Why do my legs look weird under the water?

Roan Hampton

If you sit on the edge of a pool and hang your legs straight over the side, they can sometimes look like they're bent. You might remember a school science experiment that required you to put a pencil in a glass of water – that straight pencil appeared to bend halfway down if you let it lean and looked at it from the side. Both phenomena have to do with a certain property of light called refraction. When light enters the water, it slows down. When it enters at an angle, the change in speed is great enough to make the light's path bend, so to your eyes your legs appear to be bent. **SF**

What is this silica gel in small packets?

Alina Robin

Silica gel is a desiccant, that is, it dries things out. The beads are made from a form of silicon dioxide (SiO_2) and are structured in such a way that they have lots of tiny pores, creating an extremely high surface area onto which water molecules can cling on to.

Each bead of silica gel can adsorb 40 per cent of its own weight in water before becoming saturated, and once full, the gel can even be reused. Heating the beads to 150 degrees Celsius (302 degrees Fahrenheit) turns the trapped water into vapour, which can then escape through the pores. **LM**

Who first said 'bless you' when someone sneezed? Find out on page 84

BRAIN DUMP

Why are dolphins ranked among the smartest animals?

Pia Ashman

Dolphins have much larger brains than most other animals their size, with a lot of the same structural complexity we see in the brains of other intelligent animals, including elephants and chimpanzees. They engage in sophisticated play, such as swimming in tight circles to create a whirlpool and blowing bubbles into the vortex to create rings, which they will then bite. They can also be taught complex tricks, use signature calls to identify themselves to other dolphins and even use sponges to protect their noses as they forage.

But dolphins don't actually seem to be as intelligent as we once thought they were. There's no convincing evidence that they have a true language, capable of abstract expression, for example. The more we look, the more we find that many animals can do things that were previously thought to be unique to dolphins, whales and the great apes. **LV**

Why does chocolate make you thirsty?

Fatma Zaoui

Chocolate can make you very thirsty because of the way your body processes sugar. Sugar is absorbed very quickly into the bloodstream and it depletes your cells of water. They send the chemical message to your brain that it's time to drink. Your brain can also sense when the sugar is getting too concentrated in your blood and tells you that you need to rehydrate. This isn't limited to chocolate, though – any sugary food can have the same effect. So do salty foods, for that matter. That's why many sweet foods are eaten with a glass of milk and many salty ones washed down with a beer. **SF**

Which WWII plane destroyed the most enemies?

Sandy Burrows

The United States said it was their P-51 Mustang, but the Supermarine Spitfire, famous for London dogfights with German Messerschmitt Bf-109s, also downed many enemy planes over Europe, Southeast Asia and the Pacific.

The most destructive World War II plane was probably a German bomber. Luftwaffe ace Hans-Ulrich Rudel is said to have destroyed an estimated 800 vehicles and over 500 tanks in his Junkers 87 Stuka. But in amongst all the death and destruction, was anyone really keeping score? **CA**

COOL FACTS

Gesundheit!

There's no way of knowing for sure who came up with the phrase 'bless you' when someone sneezes. Some have credited Pope Gregory I with first using the phrase "God bless you" during a bubonic plague epidemic during the 6th century, but the origins are still debated.

Why are horses' tails different from all other animals' tails?

Bradley Yates

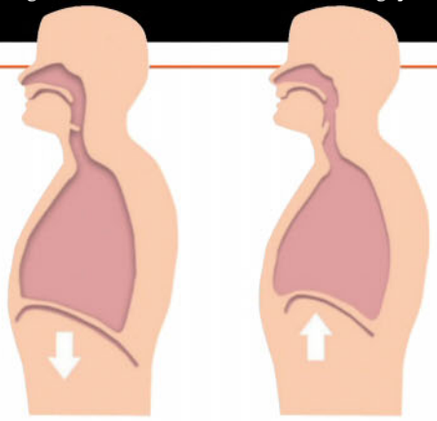
Horses evolved on the North American plains and later moved across the Bering Strait land bridge to Asia. Both places are very cold, so to keep warm, horses evolved large, long furry tails and shaggy manes. Close relations, like donkeys from the desert and zebras from the tropics, have shorter, thinner tails with a small tuft at the end. These tails are good for swatting flies, but not much else.

The central part of the horse's tail, the dock, comes down only to just below the buttocks. It's a natural extension of the horse's spine, made of both muscle and skin and is covered by long hair. Horses are said to communicate their mood with their tails, which has been found to be partly true. A high tail means high spirits or excitement, while if it's tucked between the legs it signals discomfort or fear. **CA**

Are there any advantages to cars like the Reliant Robin that have three wheels?

Aiesha Childs

In the 1970s, three-wheeled cars mostly owed their popularity to low prices, but now their efficiency is earning them a newfound respect among hybrid vehicle engineers. Light and aerodynamic, it takes little energy to get a three-wheeled car on the move. Their engines are smaller and less fuel-hungry than those in their four-wheel counterparts, making them economical both to purchase and to run. Three-wheelers' small size also makes them extremely manoeuvrable. Modern versions usually have two wheels at the front and one at the back, making them just as stable as conventional cars. **AC**



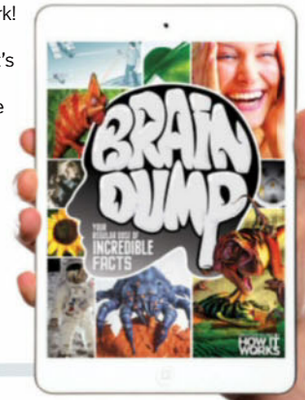
What is a hiccup?

Andy Woolley

Hiccups are involuntary spasms of the diaphragm. As the muscle contracts, air quickly moves into your lungs, forcing the opening between your vocal cords to close, producing that characteristic sound. **LM**

New Brain Dump is here!

Don't miss issue 15 of **Brain Dump**, the digital sister magazine to **How It Works**, which landed on the virtual newsstand on 1 August. Ever wondered why there are innie and outie belly buttons, or how owls turn their heads all the way around? You'll find all this and more inside. This issue is packed with amazing imagery from the natural world, including the formidable great white shark! We also reveal how why glass is transparent when it's a solid and why fleas can jump so high. Download the new issue of **Brain Dump** on the first day of every month from iTunes or Google Play. If you have a burning question, you can ask at **www.facebook.com/BraindumpMag** or Twitter – the handle is @BrainDumpMag.



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Home cinema essentials

Check out the products that will bring Hollywood right to your own living room

You can get dressed up, head out to the cinema, spend a bundle of cash on tickets, popcorn and drinks, only to be thoroughly let down by a rubbish film. It's happened to us all, so why not take the danger out of the date and set up your own home cinema with these amazing gadgets and gizmos? You can get everything from the movie and popcorn, right down to the ambient lighting, all without leaving your home.

1 Set the mood

Remote Control Candle Set
£14.95/ $N/A
www.gizoo.co.uk
If you fancy a bit of ambient lighting with your cinema experience, then you can't go far wrong with these electronic candles. Pop in the batteries and click on with the remote control, which has a range of at least five metres (16 feet). They even smell really nice, with a vanilla scent!
Verdict: ★★★★☆

2 Slushie maker

Smart 2 in 1 Slushie & Soft Ice Cream Maker
£69.99/ $N/A
www.menkind.co.uk
Along with popcorn, a slushie or ice cream is another essential cinema staple. Step forward, slushie/ice cream maker. Throw in ice, salt, water and whatever drink you want and away you go! Or, for an ice cream, drop down the water content and add in some flavouring for the custom touch.
Verdict: ★★★★☆

3 We're jamming

Jam Classic speakers
£39.99/ $N/A
www.menkind.co.uk
These wireless speakers are some of the coolest gadgets we've seen for a while. Bluetooth-enabled, these jam jar-shaped speakers deliver sound in every direction, not just the way they face, allowing everyone to experience the big-screen excitement. Coming in at a lightweight 1.1 kilograms (2.5 pounds), this could sit anywhere.
Verdict: ★★★☆☆

4 The big project

BenQ W1400
£950/ $N/A
www.benq.co.uk
If you want an all-in-one home cinema, then the Benq W1400 is hard to beat. Simply plug in your laptop and it will throw out brilliant pictures on any flat surface and deliver great audio quality as well from its two ten-watt speakers. It is also fully HD and 3D enabled, for the full blockbuster experience.
Verdict: ★★★★★

EXTRAS All you need for your home cinema

BOOK

Beyond The Multiplex

Price: £21.95
Get it from: amazon.com
If you are a fan of home cinema, you should read this fascinating look at how movie-going habits have changed with VHS, DVD and the internet.

APP

THX tune-up

Price: Free
Get it from: iTunes / Google Play
This incredible free app just needs your phone to be hooked up to the TV or sound system and it will make sure that everything from the sound to aspect ratio is set up just right.

WEBSITE

rottentomatoes.com

Not quite sure which movie to plump for tonight? This review-aggregating website will show you what rating films have received. There are reviews as well as audience scores so you can find out what to expect.

Checklist

- ✔ Popcorn maker
- ✔ Remote control candles
- ✔ Boompods
- ✔ Bluetooth speakers x2
- ✔ Slushie maker

5 Movie munchies

Popcorn Machine
£39.95/ $31.95
www.gizoo.co.uk
One of the biggest expenses, but essential for a cinema trip, is the popcorn. This brilliant, retro popcorn stand arrives fully assembled, will make your popcorn in only a couple of minutes and doesn't even need any oil. Just pop and go! It looks cool and it makes great popcorn. What more can you ask?
Verdict: ★★★★½

6 Portable sound

Boompods
£29.99/ $50.94
www.boompods.com
If you are heading over to a mate's house for a night of cinema experience, this nifty but powerful portable speaker will be a handy travel accessory. This three-watt speaker gives superb, clear sound and it can work via Bluetooth v3.0 up to ten metres (33 feet) away or via a cable.
Verdict: ★★★★★

GROUP TEST

Putting products through their paces

Coffee makers

The best machines to give you that early pick-me-up

1 Dualit Xpress 3-in-1

Price: £99 / $N/A

Get it from: www.lakeland.co.uk

If you are looking for options, the Dualit Xpress 3-in-1 is the one to consider. It allows you to use grounds, pods or capsules, so you are really not restricted at all in what kind of coffee you use. About 45 seconds pass between turning the machine on and it being ready, so it's perfect for your morning drink. The espresso shot it produces is designed to create a 35-millilitre (1.2-fluid ounce) shot. It is slightly frustrating that, for a double shot, you need to open up the lid, empty out the grounds or capsule and load in another, but that is only a minor quibble.

You also have to clean it out after every use, which does take a little more of the convenience out of it. A self-cleaning version would make this a superb little machine as it creates a good espresso shot quickly, it looks good and isn't too big. The crema on top of the espresso is just the right thickness to create a smooth shot, so in terms of quality, it can't be criticised.

It does lose a few points because it isn't self-cleaning and is rather loud, but the option to use pods, capsules or grounds is a great benefit.

Verdict: ★★★★★

Keeping things clean
The Eletta has a self-cleaning function, which means you don't have to worry about scrubbing it out every morning.

One-by-one
Make sure you remember to empty the container after each coffee, otherwise the capsules will get stuck.

HOW IT WORKS EDITOR'S CHOICE AWARD ★★★★★

2 Eletta Cappuccino Top Ecam

Price: £899/ $N/A
Get it from: www.delonghi.com
This coffee maker is not exactly slimline. Measuring 26 x 36 x 46 centimetres (10 x 14 x 18 inches) you will need to make a fair bit of room for it on your kitchen counter. Having said that, it is a very effective machine, perfect if you want a bit of variety in your coffee-slurping life. It can make you the classic cappuccino, latte or the up-and-coming flat white. Even though it is a bit of an ordeal setting it up for the first time, once that's done it's very straightforward. There are a lot of options available, like strength, volume, bean or ground and which type of coffee you'd like, which is a bit boggling, especially if you just need a morning hit of caffeine, but the 'My Coffee' setting is a masterstroke, letting you preset the volume of coffee for your favourite mug, ensuring you never over or under-fill again. The milk frother also gives it that barista-style finish.

The machine is hefty, pricey and quite loud, but the range of choices available and the automatic cleaning function makes it a great buy for a household that likes variety. The fact you can use your own beans or grounds will save money too.
Verdict:

3 Nespresso Inissia

Price: £89 / $99
Get it from: www.nespresso.com
Beautifully designed, the Inissia looks gorgeous and takes up barely any space. It is spectacularly easy to set up, as you just fill the water container, pop a capsule in the front and away you go in seconds. The only downside is that its actual delivery is a bit weak and erratic. The espresso seems to dribble out of the spout and the volume of liquid each time not only varies between presses, but it sometimes seems like you get more from the Espresso button than the Lungo button. Having said that, the drink it produces tastes very nice and the capsules are easy to insert and remove. Obviously, you are limited to the company capsules, which makes each cup a little more expensive than buying ground coffee or beans, but much cheaper than buying a coffee from a shop every morning. You can buy a milk frother from the same company if you want to add that to the mix, but this really is a quick shot machine, rather than a maker for a big cup of java.

It looks good and the coffee is nice, but it needs to differentiate more clearly between the Espresso and Lungo settings for it to reach its potential.
Verdict:

Speedy delivery
The water gets heated in just 25 seconds, so it's very handy for getting that quick shot of espresso.

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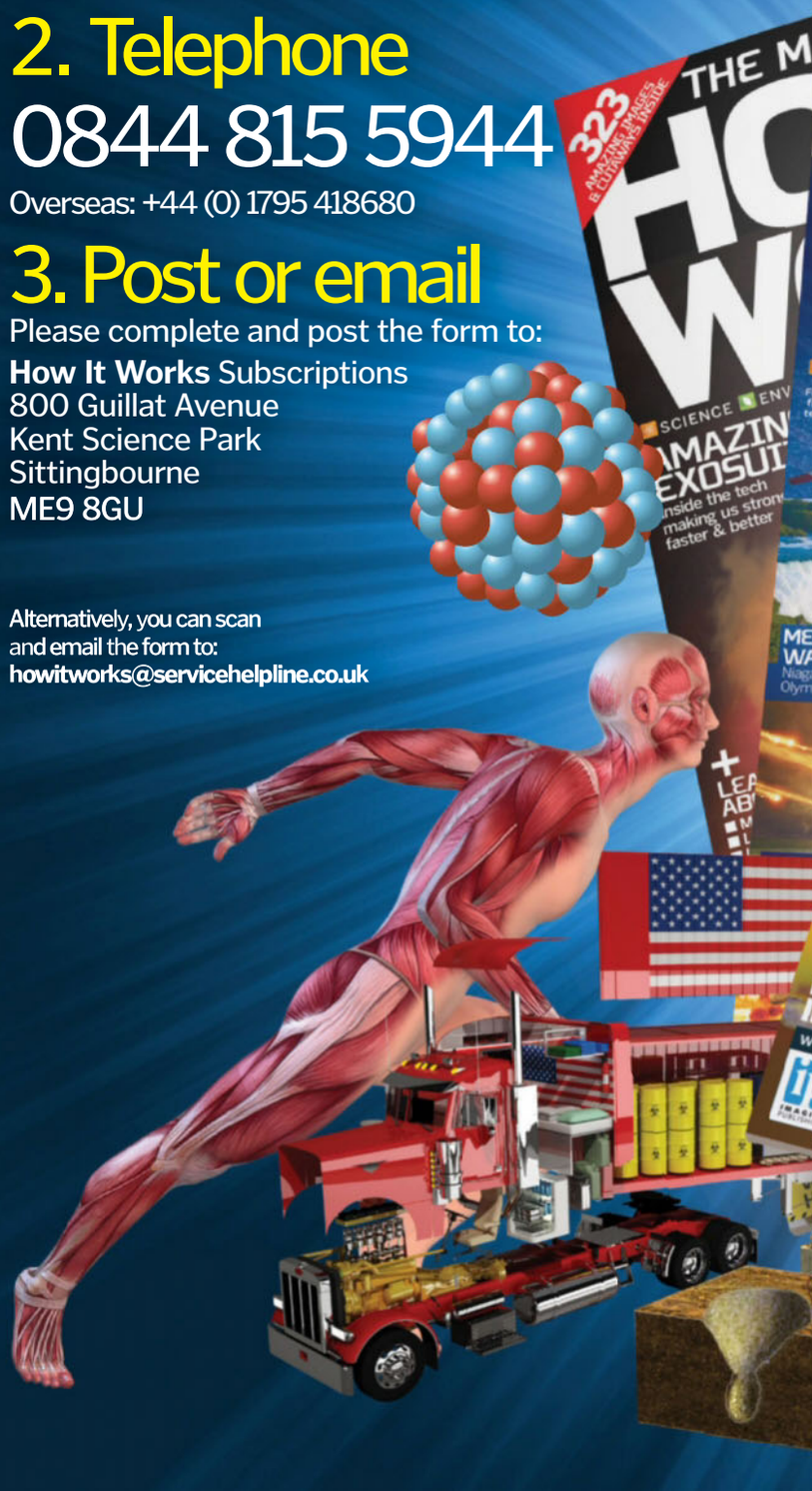

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howitworks@imagine-publishing.co.uk

Cast a fishing line

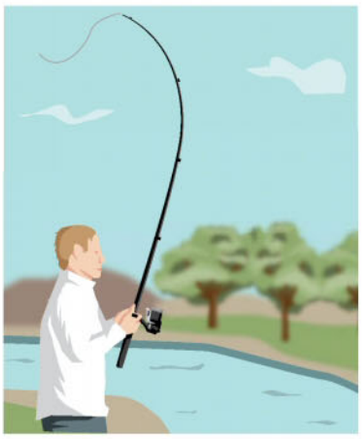
Master the ancient art of catching your own grub

1 Get equipped

Height doesn't matter when buying a rod so make sure you've got one long enough for the environment in which you'll be fishing. Ocean fishing will require a different rod to stream fishing. Ask someone at the tackle shop to set up your reel and take a spare in case. Bear in mind that trout sit low in the water so allow more line than for a bass. The type of bait also depends on the fish you're trying to attract.

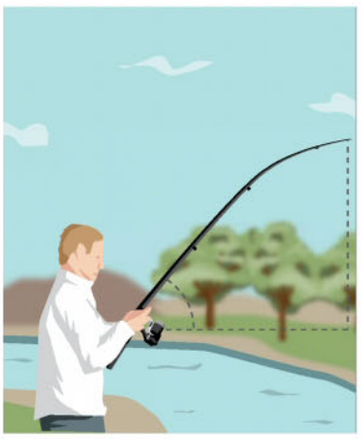
2 Hold it correctly

The best way to hold the rod is with your dominant hand gripping the shaft with the reel directly below the rod and being secured between your middle and fourth fingers. This will provide stability and security when you are casting off. Allow a small amount of line to play out and use your index finger to press it against the rod's shaft. This will ensure it stays secured when swinging back, but will also unreel when you need it to.



3 The pull back

Once you've set your rod up, it's time to cast. Keeping your arms to your side as much as possible, raise the rod by lifting your forearms. It will need to be raised until it is almost completely vertical. As the rod tapers toward the tip it becomes less solid and more bendy. The swift motion of raising it from a horizontal position to vertical will cause the tip to flick back, a bit like the end of a whip.



4 The release

Once the rod is perpendicular to the ground, push it forward, again using just your forearms and wrists, still holding onto the line with your index finger. Once it is at a 45-degree angle to the water, release the line. The tip whipping forward will hurl the suddenly freed line a fair distance away. Releasing too early will send the line and bait high, but not far, while a release after 45 degrees will reduce the distance dramatically.

5 Securing the line

Once you've cast off and the line and bait has landed in the water, use your weaker hand to close the bail. This will keep the line untangled and therefore able to be easily wound in and out. If your line has been cast either too far or not far enough, reel it in again using the handle and begin the casting process anew. It may have to take some practice before you are able to judge how quickly you need to push your rod through, but repetition helps you become consistent.

In summary...

Casting a rod takes time and practice. The process is fairly easy to remember but it is quite an art to get a feel for the distance you are casting and to time it just right. Have a number of goes with a dummy bait because you don't want to waste valuable bait on practice attempts that either go too far or hit the bank.

NEXT ISSUE
- Shoot a basketball
- Create a density tower

How to create latte art

Turn your cup of coffee into a masterpiece with barista techniques

1 Thicken the milk

Place a steam wand into the milk, just below the surface. Once it is visibly heating, but not bubbling, begin to rotate the pitcher so the milk heats evenly. The milk should never reach more than 71 degrees Celsius (160 degrees Fahrenheit) or it can scald. Once it's a few degrees below that, take it off the heat, let it sit and swirl the thickened milk in the pitcher. Alternatively, heat it in a pan, stirring constantly so it doesn't scald.

2 Pull your espresso

A shot of espresso contains about seven to eight grams of espresso grounds, which can be any coffee bean, but in very concentrated form. Pop them into your coffee machine and fill it with water. Push down firmly on the grounds and your espresso shot should pour out. You want to take 20 to 25 seconds to pull your shot. Don't pull too quickly by pushing too hard because this will result in a weak brew, as the coffee will not have been mixed in with the water.

3 Make your design

Now it's time to create your pattern. The trick to creating espresso art is to keep the milk pouring at a consistent rate. If needed, practise a few times first. In order to create the classic fern shape, begin near the bottom of the cup. Once it's been half-filled, start shaking the pitcher with quick wrist movements while moving the pitcher away from you. This, if done correctly, should create a pattern with wide fern-like leaves.

In summary...

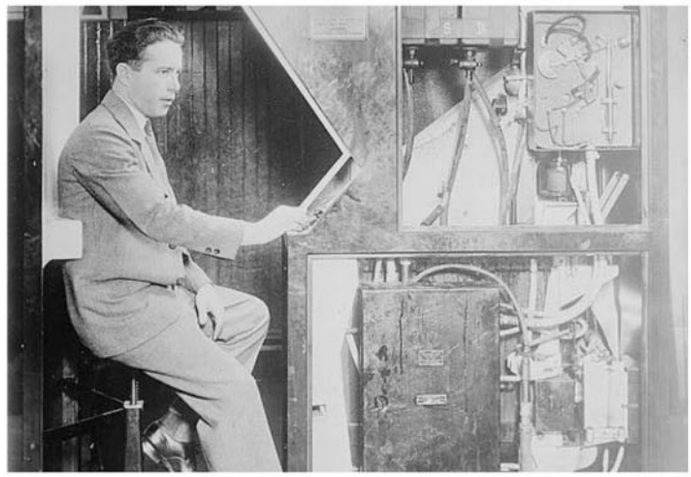
The best cups of coffee are ones in which time has been taken to make them. Milk heated to the right temperature, shot poured slowly and artwork carefully done will make a delicious and satisfying experience. Practice makes perfect, so if one goes wrong, try, try and try again.

QUICK QUIZ

Test your mind with ten questions based on this month's content to win an Airfix model of a Supermarine Spitfire PR.XIX aeroplane.

Answer the questions below and then enter online at **www.howitworksdaily.com**

1. What is the name of Mayim Bialik's character in *The Big Bang Theory*?
2. What is the scientific term for having two different-coloured irises?
3. How many pollen grains per cubic metre begins to affect hay-fever sufferers?
4. When was Rosalind Franklin born?
5. In what year did British physicist JJ Thomson discover the electron?
6. Which app has been downloaded more often than any other?
7. What nationality was Anatol Josepho, inventor of the Photomaton?
8. When was Concorde's first-ever flight?
9. After what scientist was the highest mountain on the Moon named?
10. How fast does the fastest roller coaster in the world travel (in km/h)?



ISSUE 62 ANSWERS

1. 16 years **2.** The T-34 **3.** 1,250°C **4.** Eukaryotes **5.** Approximately 149.6mn km **6.** Up to 75kg/m^2 **7.** 82,944 **8.** Oscar Deutsch Entertains Our Nation **9.** Tianhe-2 **10.** 800 BCE - 43 CE

INBOX
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Next issue's letter of the month will win a Sony PRS-T3 Reader a touchscreen digital book reader. Lighter than a paperback book, it can store 1,200 books and charges in just three minutes!

Letter of the Month

Diamonds are forever?

Hello,
Love your magazine! I read each issue cover-to-cover and then pass it along to others or keep it on the bookshelf to read again. It never goes in the trash! In the Science section of Issue 58, there's an info block about making your own diamond and a statement that says, "diamonds are becoming increasingly rare." The statement puzzles me. Is it referring to industrial grade diamonds only or especially large diamonds? My observation and experience with diamonds and other real gems (at the retail level) is that they hardly depreciate in value, which I've assumed is due to declining demand. Please fill me in between the lines why diamonds might be "rare."
Holly

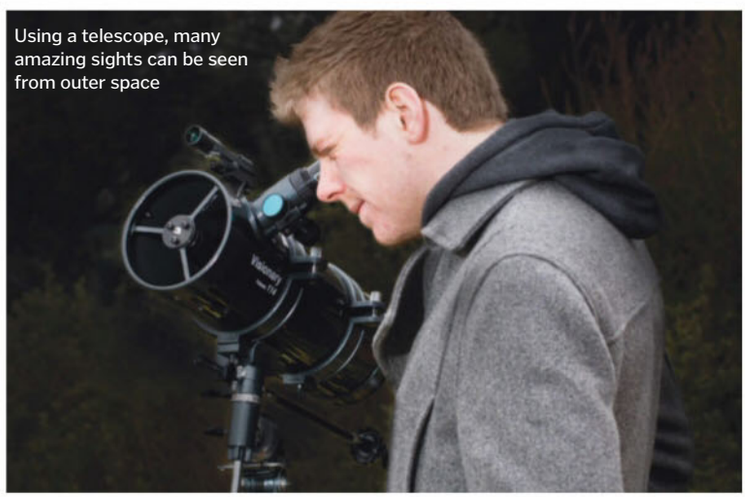
Why thank you very much Holly! For your question, we got in touch with Lynette Gould from the major diamond mining company De Beers, and she had this to say: "Diamonds are a rare and finite treasure of nature. With worldwide reserves at an all-time low – diamonds are rare and getting rarer. There have been no new major diamond discoveries in more than a decade and no major sources of new supply are scheduled to come into production in the near term. Of the acknowledged tier-1 diamond mines (Jwaneng, Orapa, Udachnaya, Mirny, Catoca, Venetia and Cullinan) Venetia was the most recent discovery in 1982."

Are we running out of diamonds?

Stargazing for new worlds

Dear **HIW**,
I have been getting your mag now for six months and I have never missed an issue. I am also an avid stargazer and during the winter I had my Celestron 70AZ telescope out almost every night. I tried to find the Andromeda galaxy but it was too close to the horizon to get a good view. Another evening I saw a satellite from my bedroom and I think it was the ISS. But the greatest thing was when I found a new planet from my back garden. I named it Pandora after James Cameron's famous *Avatar* world. It looked green and blue. I found it in the Belt of Orion. Since you have connections to some observatories, I was wondering if you could find it and give me some facts about it. Also my favourite bit about your mag is either transport or space. My brother Finn is learning about Apollo 11 so I wondered if you could do an issue on it. Thanks a lot.
Luke Scott (age 11)

We've had a little look at Orion's Belt ourselves and what you're seeing could be a star, either Alnitak (two blue stars combined in a binary), Alnilam (a blue and white supergiant), Mintaka (blue and white binary star) or Betelgeuse (a red supergiant). You see blue and green colours due to the Earth's atmosphere distorting the light of the stars. As for Apollo 11, we may have a feature on astronauts coming up in the near future...



Using a telescope, many amazing sights can be seen from outer space

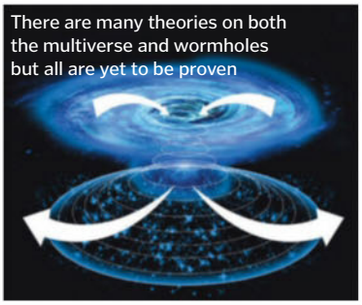
"There have been no new major diamond discoveries in more than a decade"

Hybrid theory

■ Dear **HIW,**
I have recently been reading the *Maximum Ride* series and after reading Brain Dump from Issue 61 about cloning humans it mentioned a human-cow embryo. This got me thinking about if human-animal hybrids such as the ones featured in the fantasy books would ever be possible.
Thanks
Oliver Walker (11)

Many ideas in current science talk about the mutation of human and animal genes. However, making a hybrid as complex as the ones you see in *Maximum Ride* is most likely out of reach, both technically and ethically. Still, as our Brain Dump answer correctly said, there have been minor experiments in this field that insert human genes into animals to help advance our understanding of the potential links between human and animal DNA.

Could we ever mix our DNA with the animal kingdom?


There are many theories on both the multiverse and wormholes but all are yet to be proven

Into another dimension

■ Dear HIW,
I have been wondering for some time if we could ever visit the multiverse through either a wormhole or through other dimensions? Many thanks and can't wait until next issue.
Ryan Doster

Space travel is something the human race is looking to progress upon whether it is missions to Mars or expeditions to distant exoplanets. We are still unsure whether we can visit the multiverse because we still don't know whether it actually exists yet! There is no concrete proof that there is more than one universe, but several theories state that there could well be two or more. The same goes for wormholes. As we keep exploring and mapping out our galaxy, more clues may arise so keep your eyes peeled on the latest updates in our space section as well as our friends at All About Space magazine.

What's happening on... Twitter?

We love to hear from **How It Works'** dedicated followers. Here we pick a few tweets that caught our eye this month...

Sarah
@SarahClarke45
@HowItWorksmag received today looks very interesting will have a read and sure my son will love it too! Thank you!

Harriet
@HarrietLovesMJ
@HowItWorksMag this month is excellent. I mean it always is, but this article on fireworks has got my mind blown.

Tien Do
@tienonsoftware
HMS Queen Elizabeth: the latest and largest ship of the Royal Navy http://www.howitworksdaily.com/news/hms-queen-elizabeth/ ... @**HowItWorksmag**

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@verulamGeogHoD
10000YAG 45% of earth was covered in trees. Today its 31%. Took 8000yrs to cut 1st billion just 160yrs for 2nd!! Great stat **@HowItWorksmag**

Nite Watches
@NiteWatches
@HowItWorksmag Our fave word? Oh tricky... so many!! but I quite like exacerbate ... :) Oooh! scrap that... mechatronic I think... :)

Rankin Clarkson
@Trooperoonie
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Vachie
@skyxsky27
@HowItWorksmag thank you for the giveaway chance! #winthink... :)

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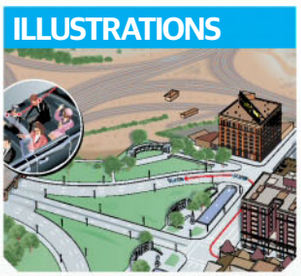

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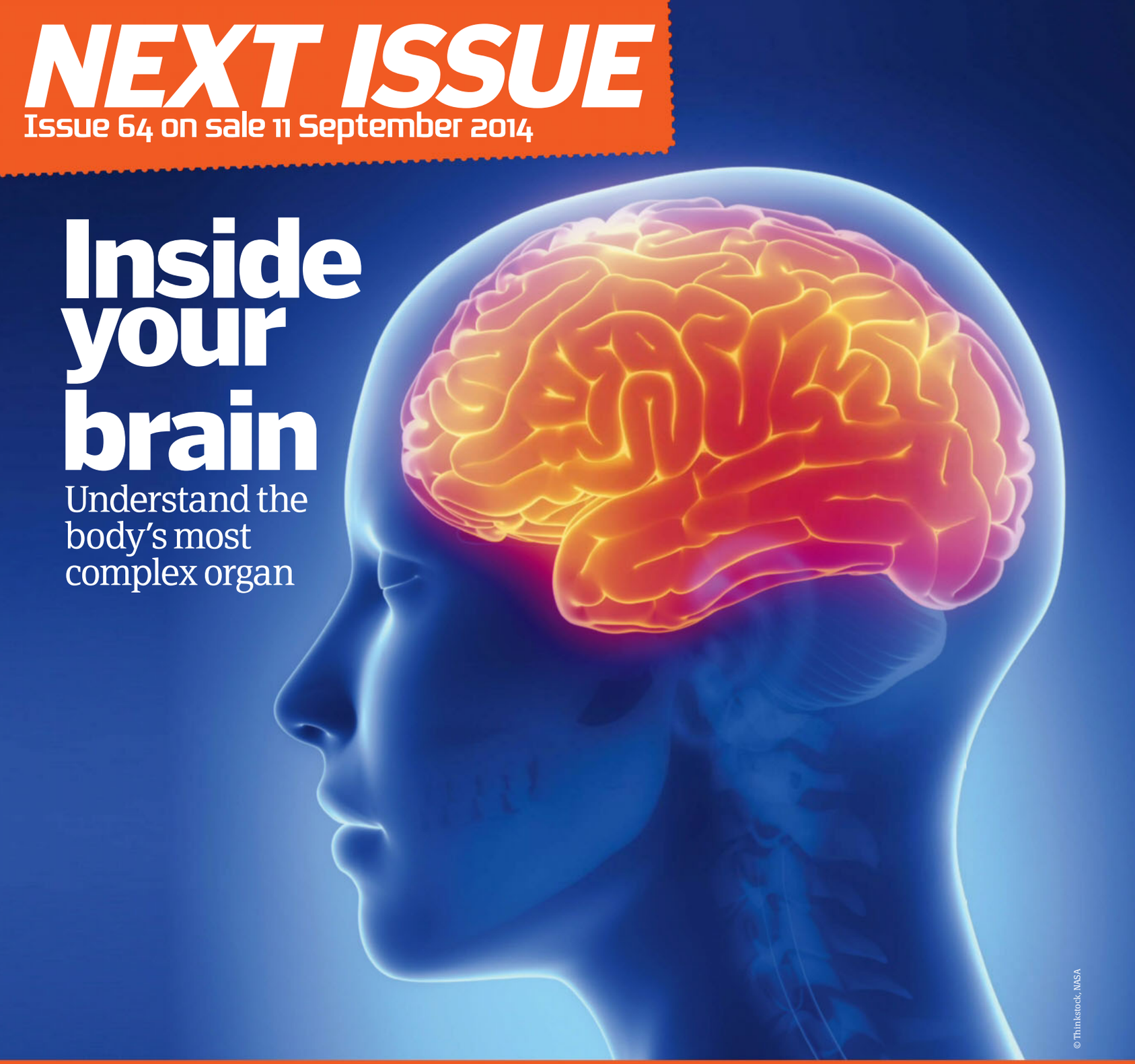
Inside your brain

Understand the body's most complex organ



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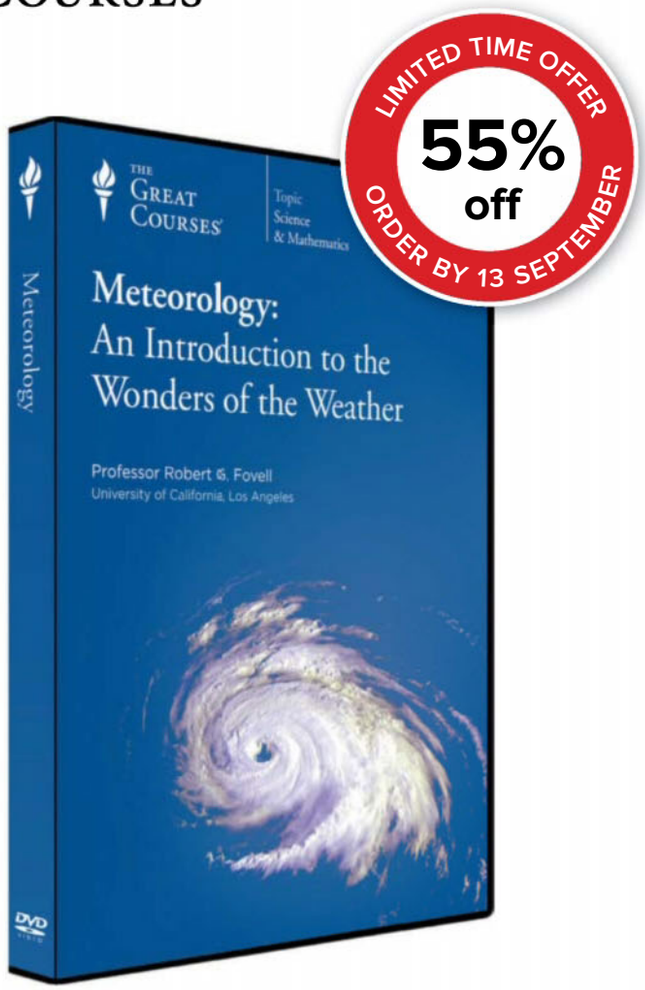

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