10 ACCIDENTAL DISCOVERIES THAT CHANGED THE WORLD

HOW IT WORKS

SCIENCE ENVIRONMENT

INSIDE

TRAVEL IN 2050

Your ticket to the high-tech holiday of the future

THE 8 FASTEST THINGS ON EARTH

936 FACTS AND ANSWERS INSIDE

WHAT IF...

DINOSAURS DIDN'T DIE OUT?

& 11 MORE ABSURD QUESTIONS ANSWERED WITH SCIENCE

DRONE RACING

How pilots battle it out for sky supremacy

CATS VS DOGS

Who will win the age-old battle? The claws are out

POPCORN

The explosive science behind the cinema snack

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ISSUE 86

GAS GIANTS

The origins of Saturn and Uranus explained

CHAINSAWS

We disassemble this cutting-edge machine

+ LEARN ABOUT ■ ICE CAVES ■ MUSCLE CRAMPS ■ DIABETES ■ CAR WHEELS ■ MAN-MADE WEATHER

ISSUE 86

WELCOME

The magazine that feeds minds!

"Our need for speed goes way beyond a sprint for survival"

The fastest things on Earth, page 16

Meet the team...

Jo
Features Editor
It's not every day that I get to time travel when writing a feature, but for this issue I visited the year 2050 to find out about the future of holidays.

Jackie
Deputy Editor
Not all inventions are deliberate. I like to think that the discoveries in this month's history feature started with someone saying "whoops..."

Katy
Research Editor
Usain Bolt's sprint seems speedy enough, but there are plenty of nimble creatures and incredible inventions that could beat him to the finish line!

Duncan
Senior Art Editor
Maybe I should get out the old science kit, blow my eyebrows off and accidentally discover something amazing to get myself into the history books!

Briony
Assistant Designer
The results are in. It's time to settle the biggest rivalry in the animal kingdom: cat versus dog. I'm cheering on the canines all the way!

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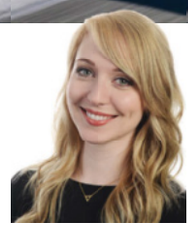

It's fun to ask 'What if?' and fantasise about the life-altering results, but we're all about the facts here. So when we imagine what would happen if dinosaurs still dominated the Earth, or if everyone on the planet jumped at the same time, we apply real science to the answer.

If that weren't enough fuel for your imagination, turn to page 46 where we take you on holiday in 2050. From robot butlers to virtual vacations, the majority of this incredible technology exists or is in development right this second. While I'm definitely not brave enough to take a trip to space, I quite fancy dining with the fishes like Kim Kardashian in Dubai's underwater hotel. Just think of the shark selfies!

Elsewhere in this packed issue, we round up the fastest things in the universe, find out how cats and dogs size up in our head-to-head, and uncover the most amazing discoveries that were made completely by accident. Frankly, it brings hope to us all!

Jodie

Jodie Tyley
Editor

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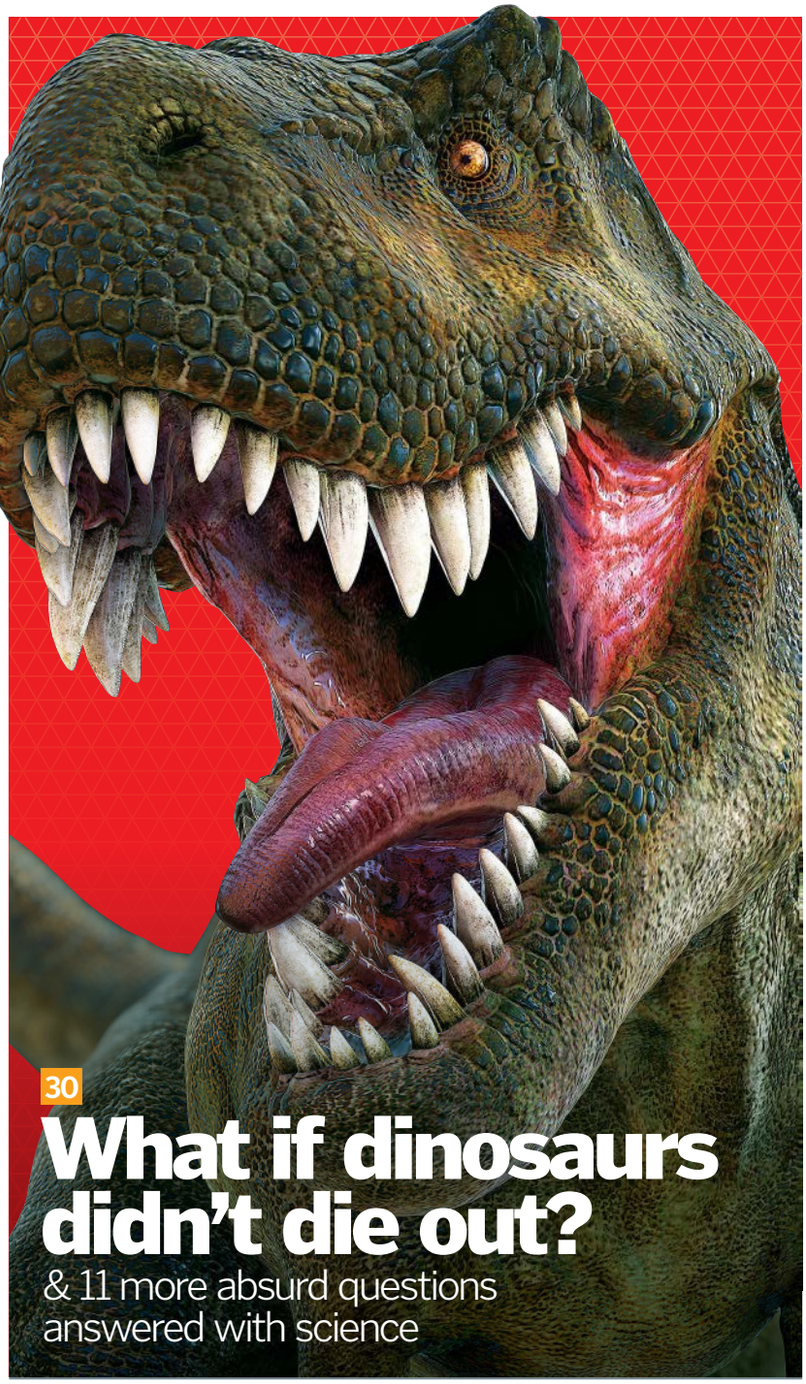

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What if dinosaurs didn't die out?
& 11 more absurd questions answered with science

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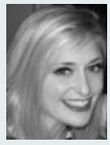
Meet the experts...

Laura Mears
Laura applies serious science to the most absurd What If? questions in this issue's cover feature. We're definitely glad the dinosaurs died out after reading what would have happened!

Luis Villazon
From supercars to sports stars, Luis powers through the fastest things on Earth over on page 16. You'll discover the evolutionary advantages and man-made marvels that break the speed limit.

Laurie Winkless
Laurie is a writer and physicist. After her Master's, she joined the National Physical Laboratory, specialising in materials. Her first book, *Science And The City,* is out in August.



Ella Carter
This month, Ella took an objective look at the age-old debate of cats versus dogs on page 60. She was in no way influenced by the puppy dog eyes of her border collie, Dexter.

Alicea Francis
All About History's Editor reveals some of the most life-changing inventions and discoveries that were made completely by accident!

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REGULARS

The real-life hobbits

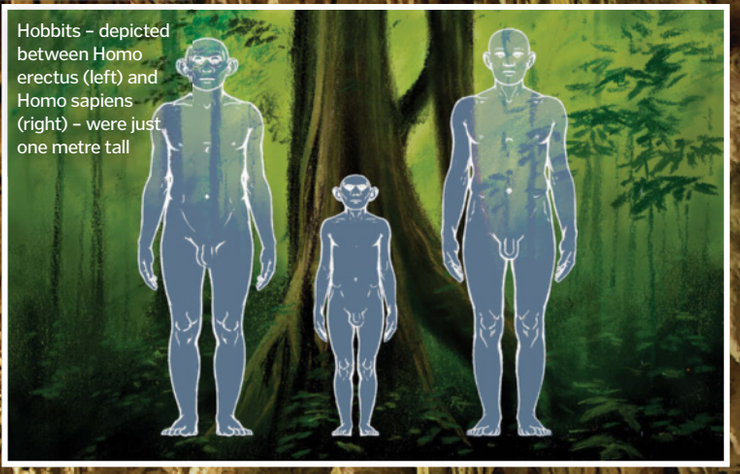
Tiny human species went extinct 50,000 years ago, and we could be to blame

Far from the Shire in Middle-earth, real-life hobbits actually lived in Indonesia, and they were much more interested in stone tools than a magical ring. In 2003, remains of a miniature human species were found six metres below the Liang Bua cave on the island of Flores. Officially named Homo floresiensis, they were nicknamed 'hobbits' due to their size, as a fully-grown adult stood at just over one metre tall.

When the discovery was first made, it was thought that the species had gone extinct 12,000 years ago, meaning that they could have lived alongside modern humans, Homo sapiens. However, scientific dating of the bones, surrounding sediments and the stone tools the hobbits used, has now revealed that they disappeared much earlier, approximately 50,000 years ago.

It is not yet known exactly why they went extinct, but researchers behind the study believe we may have been involved in their downfall. They disappeared around the time Homo sapiens passed through Indonesia, and as we were much larger, it is likely that we would have outcompeted them for food, resources and land. However, there is currently no real evidence that the hobbits ever actually encountered modern humans, so the mystery of why they disappeared remains unsolved.

The hobbit remains were found beneath the Liang Bua cave in Indonesia



Hobbits – depicted between Homo erectus (left) and Homo sapiens (right) – were just one metre tall

The hobbit's skull (left) housed a small brain about the size of a chimpanzee's

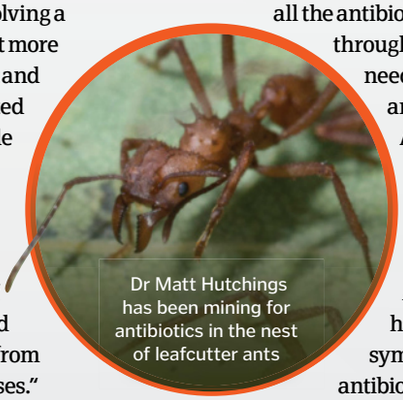
Antibiotics are usually natural products but can be chemically modified to make them more toxic to disease-causing bacteria and less toxic to humans

THE BIG DEBATE

THE THREAT OF ANTIBIOTIC RESISTANCE

The race is on to prevent the biggest healthcare crisis in human history

It's 61 years since the death of Alexander Fleming, the man who discovered the very first antibiotic, and all of his hard work could be about to come undone. Misuse and over-prescription of antibiotics has led to many disease-causing bacteria evolving a resistance to them, making it more and more difficult to prevent and treat infections. "It is estimated that by 2050, 10 million people a year will die from antimicrobial resistant infections," said Dr Matt Hutchings, an antibiotics expert from the University of East Anglia. "This will exceed the number of people dying from cancer and most other diseases."



Dr Matt Hutchings has been mining for antibiotics in the nest of leafcutter ants

This threat has meant that it is more important than ever for scientists to find new antibiotics, but unfortunately, they are very time-consuming, expensive and difficult to design. "Most of the antibiotics we use in human medicine come from soil bacteria and were discovered more than 60 years ago," said Dr Hutchings. "The good news is that we know there are tens if not hundreds or thousands of natural products waiting to be discovered, we just need funding from governments or drug companies to go and find them. Probably one per cent or less of all the antibiotics we discover will make it through clinical trials, so we really do need to discover as many new antibiotic molecules as possible. And fast."

Dr Hutchings is currently leading a pioneering research project to do just that, and has turned to South African leafcutter ants for help. The ants have formed a symbiotic relationship with the antibiotic-producing bacteria they host on the outside of the bodies. "The ants feed the bacteria through special glands and use the bacterial antibiotics to protect against disease. These are antibiotics that are completely new to science and medicine and we hope that some of them will be developed as drugs over the next ten to 15 years."

How do antibiotics fight infections? Dr Matt Hutchings explains

Antibiotics work by targeting essential structures in bacteria cells that do not exist, or which are different, in human cells. We call this selective toxicity because it makes it possible to kill living cells inside a body without harming the human.

Many successful antibiotics target the bacterial cell wall, which is made up of a material called peptidoglycan that is unique to bacteria. Others target DNA and RNA, which are essential to all life forms but are made by different machinery in humans to bacteria. This means it's possible to block DNA in bacteria without harming the human. Natural antibiotics have evolved to do this in nature over 3 billion years and are impossible to replicate in a test tube.

The search is on

Discover the strange places scientists are looking for new infection-fighting drugs

Beards

University College London's Swab and Send project has led to interesting microbial species being found on banknotes, men's beards and even a cat's nose.

The desert

The Atacama Desert is perhaps the driest place on Earth and is home to a new species of bacteria that may have potent antibacterial properties.

Golf courses

A drug used to treat parasitic worm infections – which has saved millions of lives – was found on the fringes of a golf course near Tokyo.

The ocean

Conditions in deep sea trenches are unlike anywhere else on Earth, so scientists are hoping to find unique bacteria in the sediment.

Sponges

Not the ones you use to wash up, but marine sponges, which are some of the oldest animals on Earth. They lack immune systems so may use antibiotic-producing bacteria to protect themselves.

Soil

The first new antibiotic to be found in 30 years was discovered in 2015 in a grassy field, suggesting there could be many more close to home.

NEWS BY NUMBERS

99%

The percentage of oxygen in the atmosphere of the newly discovered Dox star

100.5 km

The height reached by the Blue Origin rocket before it successfully landed back on Earth

£15,600

The crowdfunding target for Russia's Mayak satellite, which will become the brightest object in the night sky

32°

The steepest slope the Opportunity rover has ever attempted, and failed, to climb on Mars

The Roborace will take place alongside the 2016/2017 Formula E races

The world's first driverless race car

The artificially intelligent Robocar will take to the track very soon

With autonomous vehicles already starting to invade our roads, it was only a matter of time before they began to appear on our racetracks too. Roborace is a competition that will see electric cars tear round the course using the power of self-driving technology. The first competitor to be revealed is the futuristic-looking Robocar, which has been produced by designer Daniel Simon, who has worked on films such as *TRON: Legacy* and *Oblivion*. The vehicle's low profile improves aerodynamic performance, allowing it to reach speeds of over 300 kilometres per hour.

Apollo 11 astronaut Buzz Aldrin will take you to some exciting and important destinations on Mars

Walk on Mars with Buzz Aldrin

Augmented reality allows you to take a guided tour of the Red Planet

Holidays to Mars may be a long way off, but you can already explore the planet while keeping your feet on Earth. NASA's Destination: Mars exhibit, opening at the Kennedy Space Centre this summer, will give members of the public the chance to visit the Red Planet using the Microsoft HoloLens augmented reality headset. It will display a virtual Mars environment created using real imagery taken by the Curiosity rover, and Buzz Aldrin will serve as a holographic tour guide.

Emitting a continuous 30-megawatt laser for about ten hours once a year could be enough to hide us from aliens

How to hide from aliens

Lasers could cloak our planet from unfriendly extra-terrestrials

If countless sci-fi films have taught us anything, it's that a visit from aliens could be bad news, and so two astronomers at New York's Columbia University have come up with a way to hide our planet from any hostile invaders. They have suggested that we shine powerful lasers into space to compensate for the dip in light created when the Earth passes in front of the Sun, a common signal that astronomers use to identify other planets.

10 COOL THINGS WE LEARNED THIS MONTH

Termites are nature's top engineers

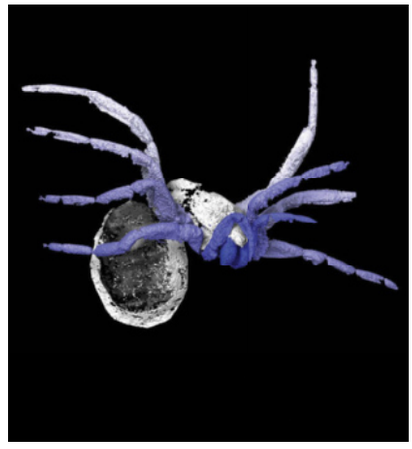
A new study into the building techniques of termites has led researchers to crown the insects the top engineers of the natural world. It was already known that they build their enormous mounds from grains of soil that they fuse together with moisture to form 'bricks'. However, the Indian Institute of Science in Bangalore has found that when building, they purposefully opt for finer grains that can be packed together more tightly to form super strong structures.

Virgin plans low-cost supersonic flights

13 years after Concorde was retired, Richard Branson is teaming up with aerospace start-up Boom to build a new fleet of supersonic jets. The 40-seat plane will be able to travel at more than twice the speed of sound and is expected to take off from 2017. A flight from London to New York will take under 3.5 hours and cost £3,520 ($5,000) for a return ticket.

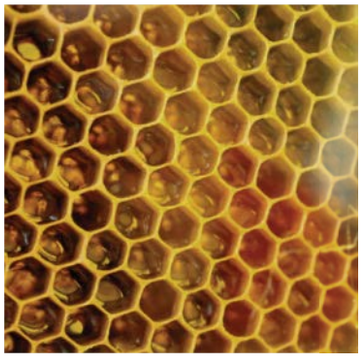
Spiders have been around for 305 million years

An international team of researchers has discovered the fossil of a 305 million-year-old arachnid, revealing fascinating details about how spiders have evolved. The fossil, which has been preserved in 3D, has a tail-like structure, which it used to lay down silk in sheets, but as the species evolved this was replaced with appendages for spinning it into thread.



Google's AI is a Go champion

Google's DeepMind artificial intelligence programme AlphaGo has won four out of five games of Go against one of the world's top players, Lee Se-dol. Go is thought to be more challenging for computers than chess, but the programme still managed to beat the human to the $1 million prize.



Trypophobia is a fear of holes

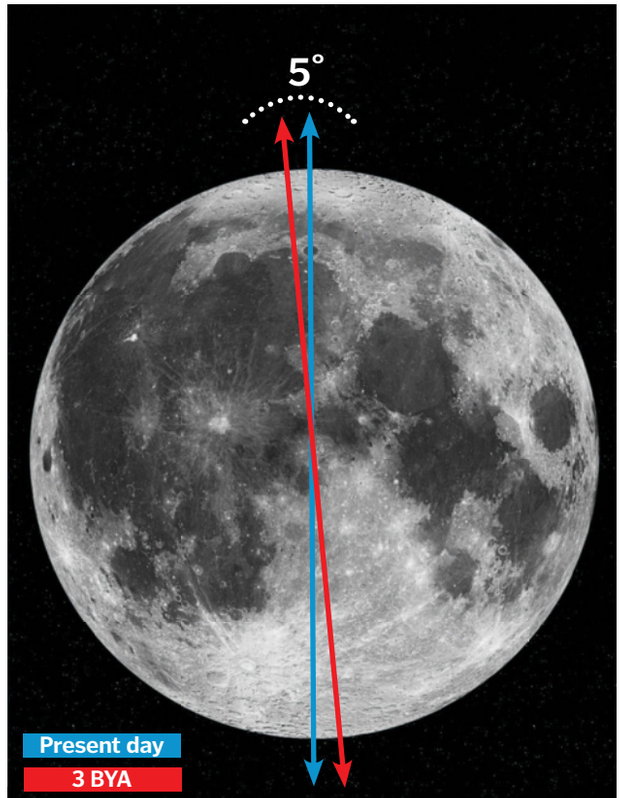
Looking at a cluster of tightly packed holes, such as those in honeycomb, has been found to trigger symptoms such as anxiety, itchiness, nausea and shortness of breath in some people. It is thought the phobia arises from the discomfort of looking at such objects, as they require more brain oxygenation to process, provoking eyestrain and headaches.

Watching sport can make you a better athlete

An experiment by researchers at the University of Montreal has proved that observing a demonstration of a motor skill, such as swinging a golf club, can help you to master it, particularly if you know the demonstrator's skill level beforehand. They believe this prior knowledge helps the brain to know whether to pick up technical errors from an unskilled demonstrator or imitate the movement of the professionals.

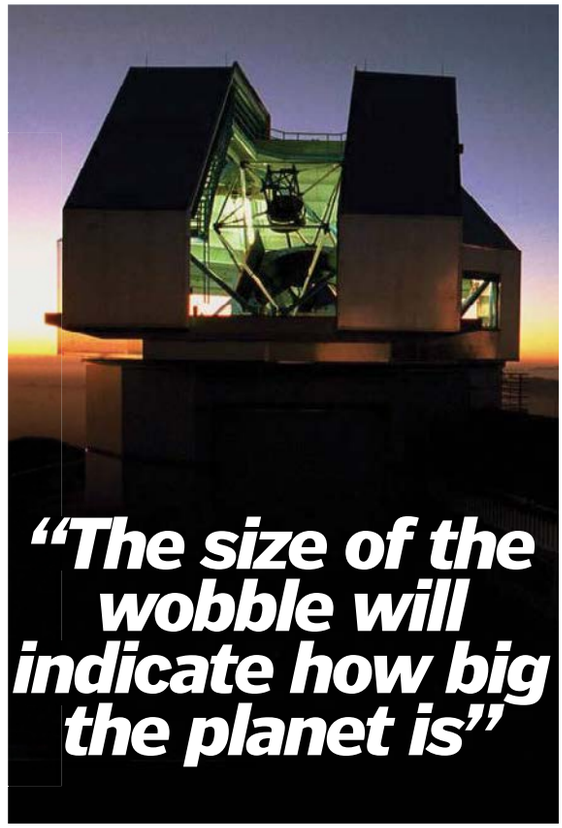
There's a two-faced super Earth covered in lava

The most detailed examination of a rocky planet outside of our Solar System has revealed a planet of two halves. Planet 55 Cancri e is almost completely covered by lava, but one side is molten and the other is solid. The 'hot' molten side can reach temperatures of 2,500 degrees Celsius, while the 'cool' side is about 1,100 degrees.



The Moon used to spin on a different axis

The view of the Moon from Earth looked a little different until around three billion years ago (BYA). New research funded by NASA has found that the Moon's axis shifted by about five degrees, leaving a slightly different face pointing towards Earth. The evidence of this shift was recorded in the distribution of ancient lunar ice, which changed as new areas became exposed to direct sunlight.



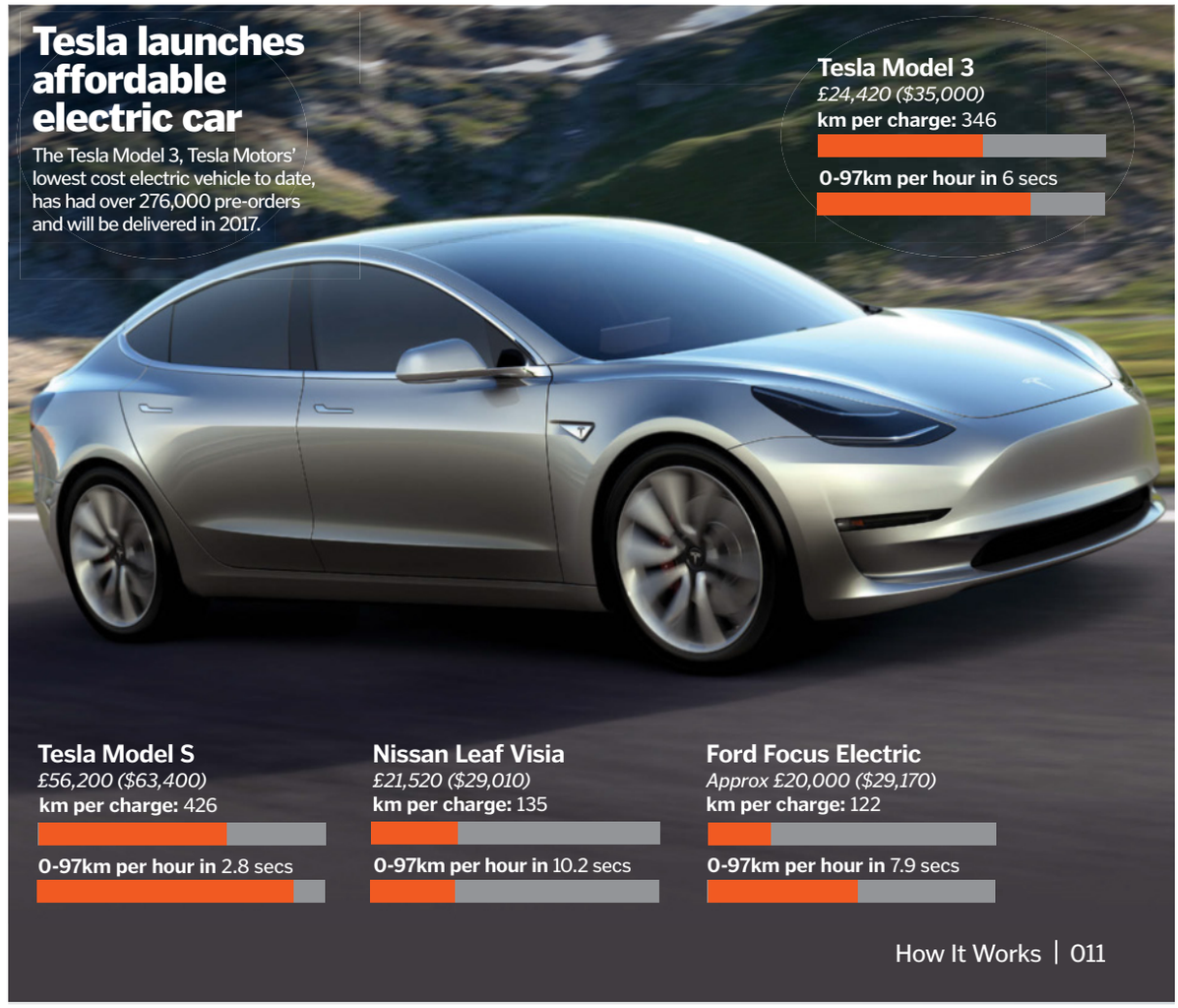
"The size of the wobble will indicate how big the planet is"

NASA is building a next-gen planet hunter

The cutting-edge NN-EXPLORE Exoplanet Investigations with Doppler Spectroscopy (NEID) instrument will measure the tiny back-and-forth wobble of stars caused by the gravitational tug of planets in orbit around them. This wobble will indicate that there is a planet orbiting the star, and the size of the wobble will indicate how big the planet is.

Tesla launches affordable electric car

The Tesla Model 3, Tesla Motors' lowest cost electric vehicle to date, has had over 276,000 pre-orders and will be delivered in 2017.



Tesla Model 3
£24,420 ($35,000)
km per charge: 346
0-97km per hour in 6 secs

Tesla Model S
£56,200 ($63,400)
km per charge: 426
0-97km per hour in 2.8 secs

Nissan Leaf Visia
£21,520 ($29,010)
km per charge: 135
0-97km per hour in 10.2 secs

Ford Focus Electric
Approx £20,000 ($29,170)
km per charge: 122
0-97km per hour in 7.9 secs

A synchrotron scientist

Using giant microscopes to make ground-breaking discoveries

A synchrotron is an enormous machine used to study objects that are too small for traditional microscopes to see. It works by accelerating electrons to near light speed so that they give off an intense light 10 billion times brighter than the Sun. This light is used by scientists to study the molecules and atoms that make up everything, from fossils and jet engines, to viruses and vaccines.

Diamond Light Source in Oxfordshire, UK, is a government-funded synchrotron, which is available for scientists from all over the world to use. Visiting scientists are assisted by Diamond's 500-strong team of staff.

PREPARE THE BEAMLINE
8:30am

Before the visiting users arrive, the resident scientists must calibrate the instruments and check that the computers, robots and optical instrumentation are working properly, in order to ensure that the data collected is reliable. They then collect the users' samples, which have been sent ahead by courier, and tidy up the control cabin.

TRAINING NEW USERS
9:00am

Once the visiting users arrive, the scientists train them to use the equipment and assist them in preparing their experiments. This involves using mirrors to focus X-rays from the storage ring onto the sample, which is kept at a low temperature of -173 degrees Celsius using liquid nitrogen. Sensitive X-ray detectors then produce up to 100 images of the sample per second for analysis.

FINAL CHECKS
9:30am

When everything is set up, the scientists check that the samples, which can be just one millimetre in size, are accurately hit by the X-rays. They also

The Diamond Light Source synchrotron is half a kilometre in circumference

make sure that the software and archiving tools used to analyse the data are working correctly, allowing 3D structures of the sample's molecules and atoms to be produced.

SAFETY FIRST
10:00am

The high energy X-rays that enter the experimental hutch are harmful to humans, so the scientists must make sure the users are aware of the safety procedures. Prior to the experiment, the operators search the hutch and sound an alarm.

IN THE OFFICE
11am

When the users are confident enough to carry out their experiments by themselves, the scientists hand over control of the beamline and return to their office. If any problems arise, they can be contacted to help solve the issue. In the meantime, they liaise with other users to plan and prepare for their future visits.

THE NEXT SHIFT
1pm

On some days, there may be three or four different users with time scheduled on the beamline. It's the scientists' job to make sure the handover runs smoothly, and as their projects are often highly confidential, that no information leaks to the next user, who may be a competitor.

MEETING WITH OTHER SCIENTISTS
3pm

While experiments are being carried out in the beamline, the resident scientists may also meet with each other to design and test new scientific techniques and perform their own experiments for in-house research projects. They are also involved in training, workshops and science conferences, which may require travelling abroad.

ON CALL
11:30pm

As the synchrotron operates for 24 hours a day, experiments are sometimes conducted at night. If the user has a problem, there are scientists on call who can see what is going on inside the experimental station via a webcam and control the computers remotely. If their physical presence is needed, they will come back to the synchrotron.

JOBS AT THE SYNCHROTRON

Scientist
The resident scientists help to develop the instruments available at the synchrotron and work with visiting users. They're a crucial part of the 500-strong team at Diamond Light Source.

Engineer
A team of engineers design and build the experimental stations that use the synchrotron beam and keep developing them to ensure they remain at the cutting-edge of science.

Technician
The technicians ensure that the complex machinery at the synchrotron is operating to the best possible, and safest, standards, allowing the scientists to produce accurate results quickly.

How a synchrotron works

Discover how this giant microscope shines a light on the latest studies

Traditional optical microscopes use visible light to highlight the details of things that are too small for the naked eye to see, such as cells. However, to study even smaller objects, like molecules and atoms, invisible wavelengths of light, such as X-rays, infrared and ultraviolet, are needed. A synchrotron is a circular particle accelerator that produces intense beams of this light, so that scientists can study in greater detail.

First, an electron gun – which operates in a similar way to cathode ray tubes in old television sets – fires electrons into the machine, where they are sped up by a series of particle accelerators. By the time they reach the storage ring, which is half a kilometre in circumference, they are travelling fast enough to circle the Earth's equator 7.5 times every second. The storage ring is an enormous vacuum chamber, meaning it contains no air, to avoid the electrons colliding with air molecules and being lost.

As magnets steer the electrons around the ring, they begin to lose light energy spanning the electromagnetic spectrum. This light is made brighter by arrays of magnets, which wiggle the electron beam, and then it is channelled into beamlines – rooms where scientific experiments can be carried out.

What is a synchrotron used for?

Developing cleaner energy

Scientists have used the synchrotron to develop a porous material capable of refining crude oil by using lower pressures and high temperatures that are much less energy-intensive and better for the environment.

Fighting bacteria

Researchers have found a new method that bacteria use to cling onto their host's biological tissue during infection. They hope to find a way to prevent this chemical process from taking place and use it to develop alternatives to traditional antibiotics.

Exploring ancient life

Palaeontologists, geochemists and physicists have used advanced chemical mapping to study the structure of 50 million-year-old fossil foliage at an atomic level, enabling them to identify its original biochemical composition without damaging the artefact.

Preventing tooth decay

Researchers have identified natural compounds that prevent oral bacteria from creating a protective layer – known as 'biofilm' – around their cells. They hope to identify similar compounds that can be incorporated into products to combat tooth decay.

Unlocking brain chemistry

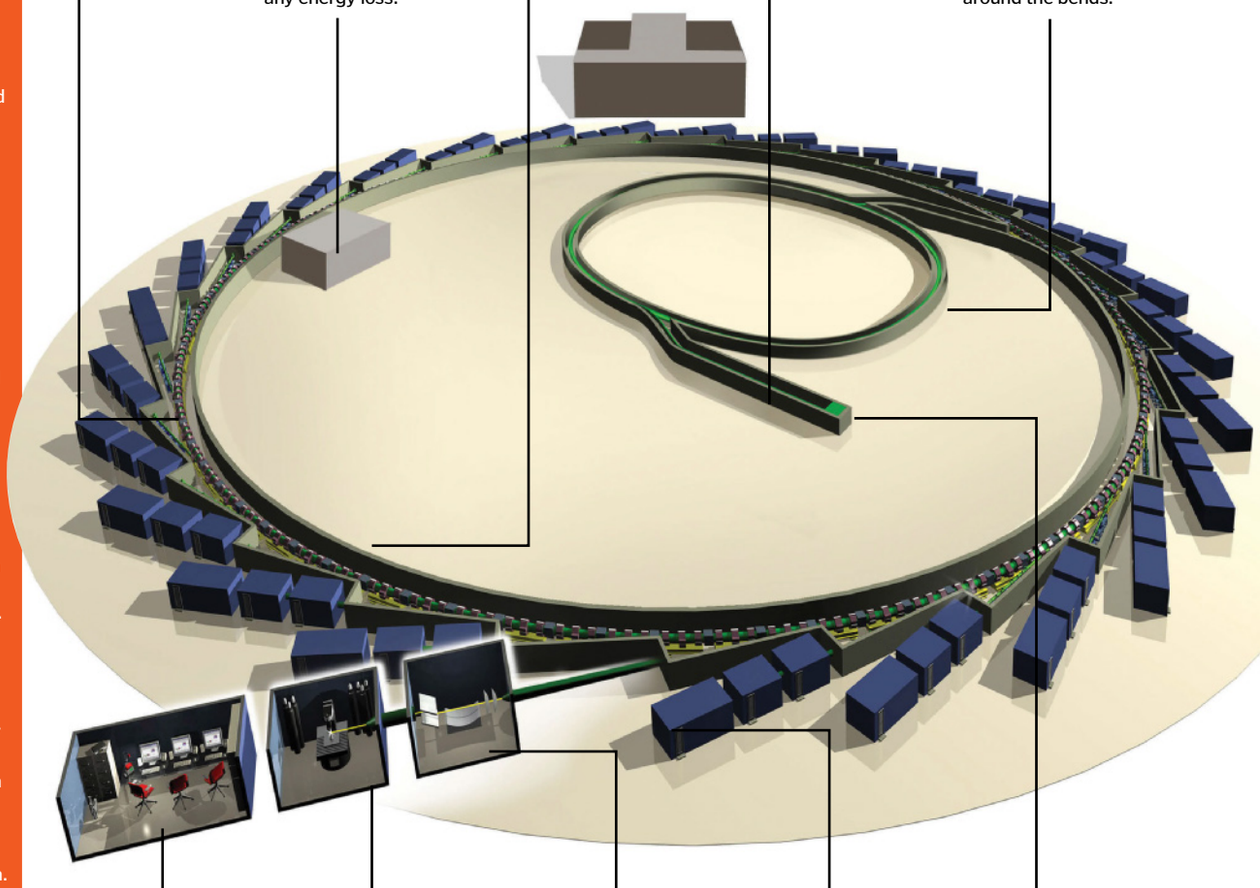
X-rays can be used to study the chemical distribution of metal ions in the brains of Parkinson's sufferers, helping to develop a better understanding. This could help to improve diagnoses for early detection.

Protecting priceless art

At Diamond Light Source, researchers from the Tate Britain used the synchrotron to study how paint pigment molecules change under different atmospheric conditions. This helped them find new methods of preventing paint from fading.

Inside the synchrotron

How are speedy electrons used to produce bright beams of light?



Electron beam

As the path of the electron beam is bent around the storage ring by powerful magnets, the electrons lose energy in the form of light.

Radio frequency (RF) cavity

On each circuit of the storage ring, the electrons pass through an electromagnetic field, providing an energy boost to compensate for any energy loss.

Storage ring

The electrons speed around the storage ring made from 48 straight sections angled together to form a closed loop.

Linear accelerator (linac)

After being fired into the machine, the electrons are accelerated to high speeds by a particle accelerator called a linac.

Booster

The electrons travel around an athletics track-shaped ring, where radio frequency voltage accelerates them along the straights and magnets curve them around the bends.

Control cabin

Using powerful computers the scientific team control the beam alignment and sample position, and monitor the data obtained by the detectors.

Experimental hutch

The sample that needs to be studied sits on a rotating arm, and as the beam of light hits it, detectors register the data collected.

Optics hutch

In the first section of the beamline, certain wavelengths of light are filtered and focused using mirrors.

Beamlines

The light from the electrons is channelled out of the storage ring and into experimental stations called beamlines.

Electron gun

A high voltage cathode is heated under a vacuum, giving the electrons in the material sufficient thermal energy to escape.

The head of the operation

How Diamond Light Source's CEO keeps the future of science looking bright

Andrew Harrison has been CEO of Diamond Light Source since January 2014

After 20 years teaching chemistry at the University of Edinburgh and conducting scientific research on the structure of inorganic materials, Andrew Harrison took a step back from lab work to run some of the world's leading scientific facilities. He is now the CEO of Diamond Light Source, the UK's government-funded synchrotron, tasked with developing the facility in order to tackle the latest scientific problems and ensuring scientists from all over the world can make the most of the cutting-edge equipment on offer.

The synchrotron has been called Britain's answer to the Large Hadron Collider, but how is Diamond different from CERN?
At their heart, both of them have synchrotrons that accelerate particles. In the LHC it's to collide and make other objects. But I would actually say we are utterly different. The LHC is supporting one or two experiments, albeit things that have momentous outcomes, while we're supporting around 8,000 user visits a year. We currently have 25 beamlines – each of which run many, many experiments per year. So you could say we're comparable in the significance of the science we support, but the operating principle is very different.

What are some of the most exciting experiments conducted here?
One thing that we've started recently is a drug screening service. If you want to develop a new drug, you have to see whether the tiny new drug molecule binds to the biological molecule that you want it to affect. It's like looking for a needle in a haystack. In the past it would take days or weeks but instead of a human putting a sample in the beam, we now have an army of robots that change the sample every two or three minutes, increasing the rate at which we can look at them.

What are your plans for the future?
When Diamond was first switched on it was the brightest facility of its sort in the world. In fact it was the brightest continuous source of light in the Solar System. We've already slipped to about third place because the technology to produce X-rays has increased so much in just the last few years. We currently have a plan to change the way in which we produce light so that we're going to be at least ten times brighter. That will mean we can look at structures in greater detail. We're moving from looking at the structure of DNA to looking at how the structure changes, for example during a chemical reaction, and ultimately making movies of processes as they're happening rather than just static photographs.

What advice would you have for someone wanting to work at Diamond Light Source?
To begin with, just come and see if it inspires you. Of course, it depends on what type of role you want. If you are already at university studying science then we would encourage you to study for a PhD, and because the science we serve is so broad, it could be in any area of physical or life sciences. The most normal route is to come in as a junior member of a beamline team and eventually become a team leader who works to get the most out of that beamline. Then, because synchrotrons are international, you could come and work for Diamond but you can also travel between various synchrotrons all over the world.

"Diamond was the brightest continuous source of light in the Solar System"

Robotic arms controlled by scientists move the samples into the path of the beam

THE FASTEST THINGS ON EARTH

From supercars to sports stars, we reveal the fastest things on Earth

We can't directly sense speed, which is just as well; otherwise we would all be dizzy as Earth hurtled through space. So how do we know what is fast? The fastest sprinter can run at about 38 kilometres per hour – that's close to half the speed of the fastest land animal and almost 4,000 times faster than the banana slug, which is one of the slowest animals. But it's still about 28 million times slower than the fastest speed in the universe – the speed of light – so on the scale of things, we're pretty sluggish ourselves.

Comparing our own speed to other things is deeply ingrained into our DNA, because being fast has a direct survival value. Nature has been looking for faster ways to get around since life first evolved, but the human need for speed now goes way beyond a simple sprint for survival. Our innate curiosity has shifted this race into overdrive. Everything you'll see on the next few pages is the fastest of its kind, but records are made to be broken and the fastest thing *ever* is always the next one.

Built to run

Sprinters are optimised for ten seconds of explosive performance

Arms
Powerful, pumping arms keep the runner balanced and provide momentum, by opposing the forces of the legs.

Chest
Strong core muscles keep the body at the optimum angle throughout the race.

Hamstring
The hamstrings oppose the force of the quadriceps and pull the leg back so that it can push off the ground from the calf.

Quadriceps
The quadriceps pull the legs forward with each step, propelling the runner forward.

Lower leg length
Long shins and shorter thighs give better leverage for the same stride length.

Shoes
High-tech polymers in the sole provide grip and rebound while adding the least possible weight.

Patellar reflex
Sprinters have a faster knee-jerk mechanism that helps to pull their leg forwards.

DID YOU KNOW?

The London Olympic Stadium has a track with a rhombus-patterned underlay that increases the bounce of each stride

The fastest human

Are some athletes built to run fast?

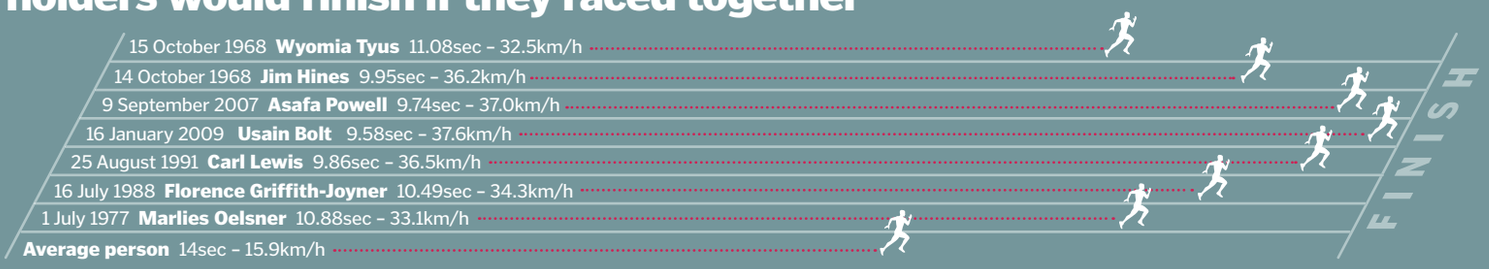
The height of world record sprinters has increased by 16.3 centimetres since 1900, while the average height increase for non-athletes has been only 4.8 centimetres. This may seem surprising, since a taller runner encounters more air resistance, but they also take fewer steps.

Muscle fibres come in two forms; slow fibres use oxygen efficiently and are best for marathon running, while fast fibres need a lot more energy but contract much quicker. A gene called ACTN3 is associated with a higher proportion of fast fibres in the muscles and this gene is common in sprinters, though the exact link is still unclear.

Breaking the speed limit

Since the advent of electronic timing in 1968, the world record for the men's 100-metre sprint has dropped by less than half a second – mostly due to improvements in track and running shoe technology. At one time it was thought that the upper limit for human running speed was determined by the amount of force that the quadriceps tendon could absorb on each stride without rupturing. This would translate to a top speed of 43.06 kilometres per hour but in the 2009 Berlin Olympics, Usain Bolt exceeded that with a top speed of 44.17. The limiting factor is now believed to be how fast the muscle fibres can contract, to impart forward force during the fraction of a second that each foot is in contact with the ground. We still don't know whether training or genetics can increase muscle twitch speeds, but calculations show that human tendons could theoretically withstand speeds of up to 64 kilometres per hour!

How current and former world record holders would finish if they raced together



The fastest animals

How do nature's wildest sprinters compare with Olympic athletes?

The speed of life has steadily increased for two billion years. The first bacteria were helpless passengers in the ocean currents. Then simple cells with swimming tails evolved, followed by multicellular worms, then fish and so on. Evolution is a race to find enough food, and a race to avoid becoming food.

The fastest animals alive today are likely to also be the fastest animals that have ever lived – but not by much. The fastest dinosaur was probably Dromiceiomimus, which lived 70 million years ago. Its name means 'emu mimic' because it looked quite similar to the large bird. Scientists are able to estimate how fast it could move because muscles haven't changed their basic design in the last 200 million years; computer models suggest that Dromiceiomimus could run at 60 kilometres per hour.

Speed comes at a price, though. Running takes a lot of energy and flying takes even more. Cheetahs and lions already have to spend most of their day resting to conserve energy. To minimise the energy used, most animals are fast only for extremely brief periods. Rapid acceleration is even more important than top speed. A squirrel runs slower than a dog but squirrels are rarely caught because they only need to outrun the dog to the nearest tree, where it can climb to safety.

Fast and furriest

Just three strides take the cheetah from a standstill to 64 kilometres per hour, making its acceleration faster than a Ferrari Enzo supercar. A small head and flat ribcage cause minimal air resistance, and footpads that are harder and flatter than other cats give increased traction. Unlike lions and leopards, a cheetah's claws don't retract completely when running, so they act like spikes in a running shoe. At top speed a cheetah takes more than three strides every second and each stride can be eight metres long thanks to its hugely flexible spine and floating shoulder blades.

For the last 10 million years, the cheetah has held the animal land speed record

Evolutionary advantages

On land, underwater or in the air, this is survival of the fastest

Frigatebird
Top speed: 153 km/h
A 2.2m-wingspan gives these aerial giants the largest wing area to body weight ratio of any bird.

Blue wildebeest
Top speed: 80 km/h
Tall, thin legs give a long stride that is powerfully accelerated by the thigh and shoulder muscles.

Southern bluefin tuna
Top speed: 70 km/h
Bluefin tuna don't need to pump water over their gills to breathe because they swim non-stop, with their mouths open.

Springbok
Top speed: 88 km/h
Highly elastic leg tendons recover most of the energy of each stride and allow vertical leaps of up to 2m.

Striped marlin
Top speed: 81 km/h
Partly warm-blooded, the striped marlin can maintain its top speed to hunt squid, even in cold, deep waters.

Springboks are the third fastest animal on land

Sailfish can swim faster than a cheetah can run!

Speedy sailing

Water is almost 800 times denser than air, which means fish have to work even harder than land animals to hit fast speeds. A sailfish has large amounts of red myoglobin in its muscles, which supplies oxygen for sustained, powerful contractions. The sail, or dorsal fin, of the sailfish is used to shepherd schools of smaller fish into dense clusters when hunting. But at speed, it folds the fin down into grooves that run along the body, which dramatically reduces the sailfish's drag.

Eurasian hobby
Top speed: 160 km/h
Thin, tapered wings allow this falcon to fly fast enough to hunt swallows and swifts in the air!

White-throated needletail
Top speed: 171 km/h
These birds can change their wing profile to double their flying speed when attracting a mate.

Peregrine falcon
Top speed: 320 km/h

Pronghorn
Top speed: 89 km/h
The windpipe, heart and lungs are very large relative to its body, which also enable endurance runs of 6km at 56km/h.

Cheetah
Top speed: 95 km/h

Sailfish
Top speed: 109 km/h

Swordfish
Top speed: 97 km/h
Swordfish have lost their pelvic fins, which helps to reduce their drag as they power through the water.

DID YOU KNOW?

Sailfish grow fast too; transforming from an egg to a 1.5m long fish in just one year! A fully grown adult can be over 3m long

Stoop to conquer

The peregrine falcon is the fastest bird in the world, but only in one direction: down. For a human, terminal velocity when falling is around 190 kilometres per hour. After that, the wind resistance balances out the force of gravity and you stop accelerating.

Peregrines are much lighter than humans so you would expect them to have a lower terminal velocity, but they are masters at reducing wind resistance. With their wings pulled in, they present a tiny cross section to the wind and rotating their shoulders asymmetrically reduces it even further, like squeezing through a narrow hole. The trailing edges of their feathers also have a jagged shape to reduce turbulence.

When it pulls out of its dive a peregrine can experience 27 g of deceleration!

"Evolution is a race to find food and avoid becoming food"

Extreme machines

Pushing rubber, metal and carbon fibre to their limits

Imagine being limited to just 415km/h in the Veyron

Bugatti Chiron

Bugatti reclaim the crown for the world's fastest production car

The Bugatti Chiron weighs 45 kilograms more than the Veyron, its predecessor, but it accelerates harder and has a higher top speed because its eight-litre engine produces 25 per cent more power. The W16 engine is essentially two V8 engines side by side and burns petrol so fast that at top speed, its 100-litre fuel tank would be empty in eight minutes. The air to burn this fuel is supplied by a two-stage turbo compressor that consumes 60,000 litres of air every minute. That's as much air as you breathe in five days!

Only 500 Chirons will be produced, so reserve yours soon!

Supercar showdown

How does the Bugatti Chiron compare to the Veyron Super Sport?

CHIRON	ENGINE POWER	VEYRON
1,103kW		882kW

CHIRON	ACCELERATION 0-300KM/H	VEYRON
13.6s		14.6s

CHIRON	TOP SPEED	VEYRON
420km/h		415km/h

CHIRON	MAX FUEL CONSUMPTION	VEYRON
190l/100km		78l/100km

Beyond the record

The successor to the Thrust SSC is the Bloodhound SSC. Developed by the same British team led by Richard Noble, Bloodhound is currently in testing and in 2017 will attempt to smash the World Land Speed Record by the largest ever margin. To do this it will use a two-stage engine design. A jet engine from a Eurofighter Typhoon will power it to 480 kilometres per hour but then a hybrid rocket engine will boost it to over 1,600 kilometres per hour.

The fastest car

Don't race this at the lights!

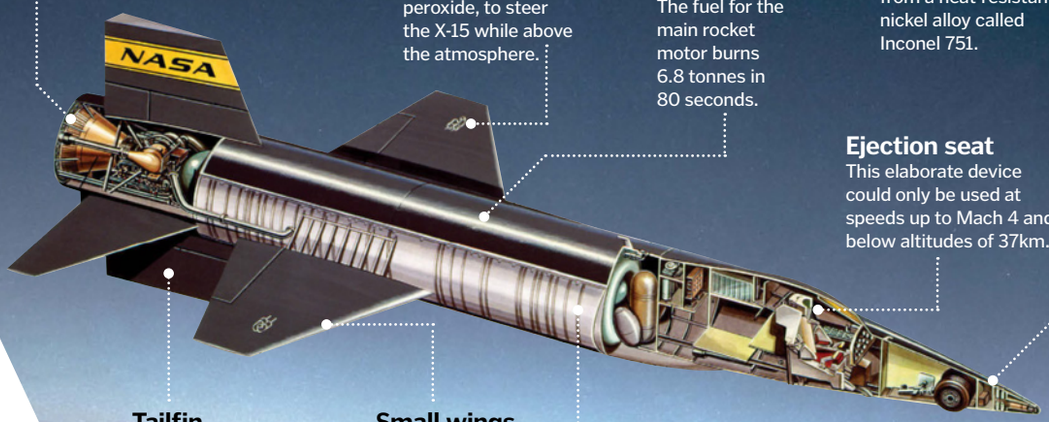
The World Land Speed Record currently belongs to the Thrust SSC. In 1997, this car achieved 1,228 kilometres per hour in the Black Rock Desert, Nevada. It was also the first car to break the sound barrier – but calling it a car is something of a stretch. It is 16.5 metres long, weighs 10.6 tonnes and is powered by two jet engines from an F4 Phantom II fighter plane.

Thrust SSC accelerates from 0-1000km/h in 16 seconds

Bloodhound SSC will travel a mile in 3.6 seconds – faster than a bullet!

At the edge of space

The X-15 is the evolutionary link between a plane and a rocket



XLR-99 rocket engine
Produces 250kN of thrust – about as much as a Boeing 747 engine.

Altitude rockets
This high-altitude control system is powered by hydrogen peroxide, to steer the X-15 while above the atmosphere.

Anhydrous ammonia
The fuel for the main rocket motor burns 6.8 tonnes in 80 seconds.

High-tech alloys
Key parts of the airframe were made from a heat-resistant nickel alloy called Inconel 751.

Ejection seat
This elaborate device could only be used at speeds up to Mach 4 and below altitudes of 37km.

Tailfin
The lower fin extended below the landing skids and had to be jettisoned prior to landing.

Small wings
Stability at hypersonic speeds required wings barely larger than the tail.

Liquid oxygen
The X-15 flew too high to use air-breathing engines, so it brought its own supply.

The X-15 had a top speed of Mach 6.72 (7,273km/h)

The X-15 rocket plane

It can reach Mach 6.7 in two minutes

The X-15 hypersonic test plane, built by North American Aviation for NASA, has held the record for the fastest manned aircraft since 1967, when it reached almost seven times the speed of sound – 7,273 kilometres per hour. Eight X-15 pilots flew high enough to be awarded astronaut's wings and two of the 199 test flights actually crossed the 100-kilometre altitude that is today recognised as the point where space begins. The X-15 carried enough fuel for just 80 seconds of powered flight and had to be carried under the wing of a B-52 airplane to a height of 13.7 kilometres before it could be launched. It flew for no more than 12 minutes, briefly powering to hypersonic speeds, before making a 320-kilometres-per-hour landing on a dry lake bed.

DID YOU KNOW?

In 199 flights, the X-15 test program racked up a total flight time of almost six hours above speeds of Mach 4

Fastest unmanned aircraft

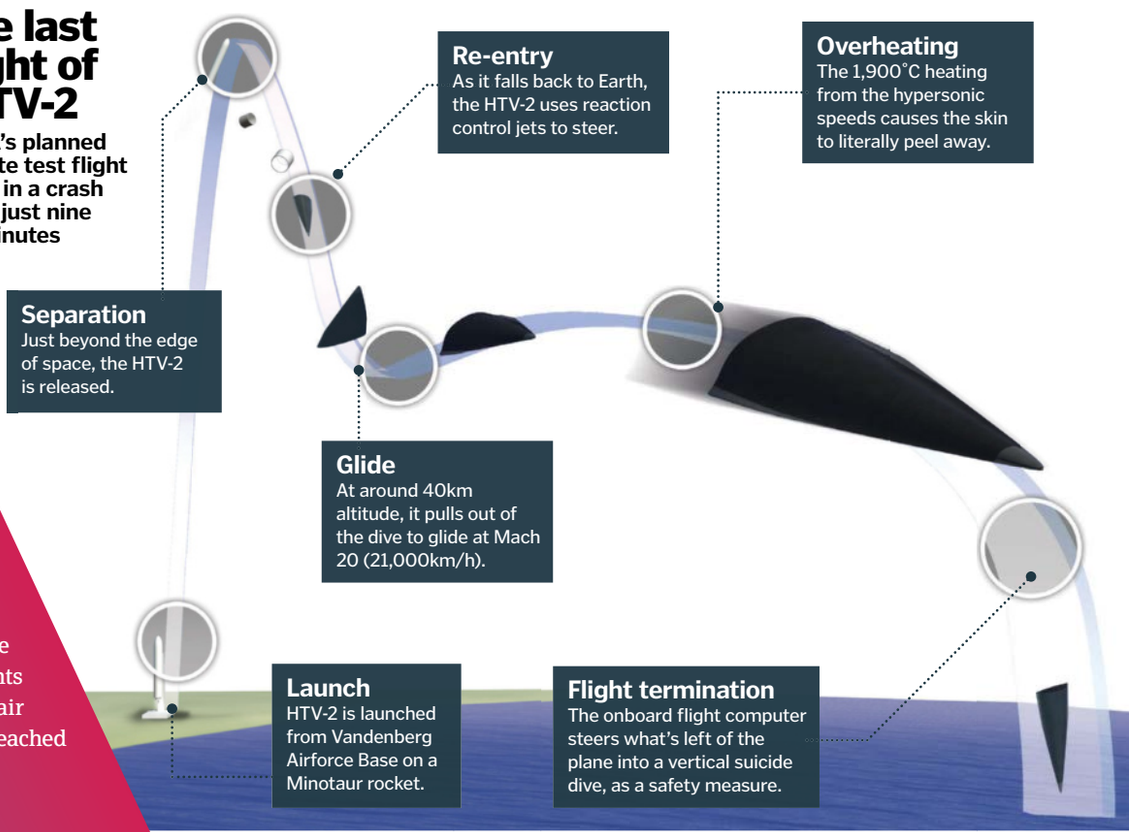
This vehicle flew so fast it melted

The Hypersonic Technology Vehicle 2 (HTV-2) was built by the US Defense Advanced Research Projects Agency (DARPA) as part of a project to develop a reusable unmanned drone capable of striking anywhere in the world within an hour.

HTV-2 was always supposed to crash into the ocean at the end of its flight, but both test flights ended after just nine minutes, with the mid-air destruction of the aircraft. But not before it reached a scorching 21,000 kilometres per hour!

The last flight of HTV-2

DARPA's planned 30-minute test flight ended in a crash after just nine minutes



Re-entry
As it falls back to Earth, the HTV-2 uses reaction control jets to steer.

Overheating
The 1,900˚C heating from the hypersonic speeds causes the skin to literally peel away.

Separation
Just beyond the edge of space, the HTV-2 is released.

Glide
At around 40km altitude, it pulls out of the dive to glide at Mach 20 (21,000km/h).

Launch
HTV-2 is launched from Vandenberg Airforce Base on a Minotaur rocket.

Flight termination
The onboard flight computer steers what's left of the plane into a vertical suicide dive, as a safety measure.

The fastest object ever launched

Pluto is a really long way away. If Earth was the size of a grape, the Moon would be at arm's length, but Pluto would be eight kilometres away. To send a probe there, it needs to be travelling incredibly fast, so New Horizons was the lightest possible probe, strapped to the most powerful rocket available. This was the first time the 551 configuration of the Atlas V had ever been flown. New Horizons was launched from Earth at almost 58,000 kilometres per hour, setting off on a trajectory that would take it to Pluto, more than 3 billion miles away.

New Horizons took nine years to reach Pluto and just nine minutes to pass it

Light payload
Riding on top of all this power is a probe payload that weighs just 478kg – a little more than a grand piano.

Third stage
Hidden inside the fairing with the Centaur is an ATK Star 48, third stage rocket engine.

Blast off!
New Horizons was sent to space on top of the most powerful Atlas rocket ever

Centaur
The Centaur upper stage uses liquid hydrogen and liquid oxygen for propulsion and produces 99.2kN of thrust.

Strap-on boosters
The five Aerojet solid rocket boosters burn for around 90 seconds to give the vehicle extra thrust, and then separate from the main rocket.

DID YOU KNOW?
It took Apollo 11 three days to reach the Moon in 1969, but New Horizons passed it after just 8.5 hours of flight time

Atlas V
The 551 configuration is the largest version of the Atlas V rocket, capable of delivering 18.5 tonnes to orbit.

Launch window
New Horizons' launch was timed so it could swing past Jupiter a year later for an extra boost.

Out-of-this-world records

Not even the sky is the limit in space

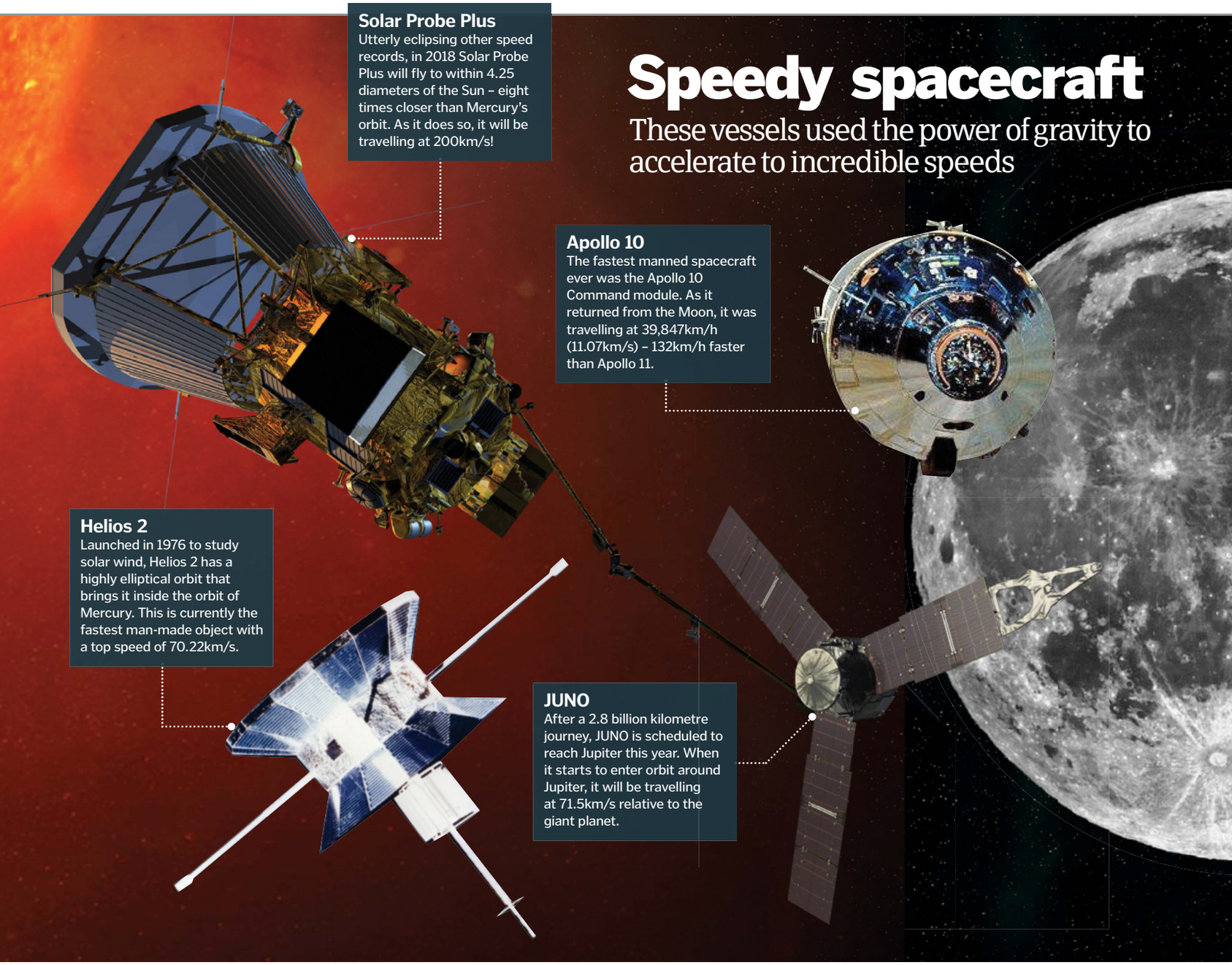
Space is only 100 kilometres above our heads, but to stay in orbit you need to be travelling at over 27,000 kilometres per hour. Imagine if you travelled from London to Oxford and had to reach 22 times the speed of sound down the M40, otherwise you would eventually fall back to London.

Compared to the speeds we know, everything in space is fast. Our own planet travels around the Sun at almost 30 kilometres per second and our Solar System rotates around the centre of the Milky Way galaxy almost eight times faster than that. These tremendous speeds are powered by the unstoppable force of gravity operating over immense scales, and yet puny humans are challenging the universe to a race.

Rocket scientists have already flung space probes fast enough to launch them out of the Solar System, and the next generation of spacecraft will be the swiftest yet. But however fast we go, there's always something quicker. The fastest particle ever detected was a proton from deep space, picked up by a cosmic ray detector at the University of Utah in 1991. It was travelling at 99.99999999999999999999951 per cent of the speed of light!

Speedy spacecraft

These vessels used the power of gravity to accelerate to incredible speeds



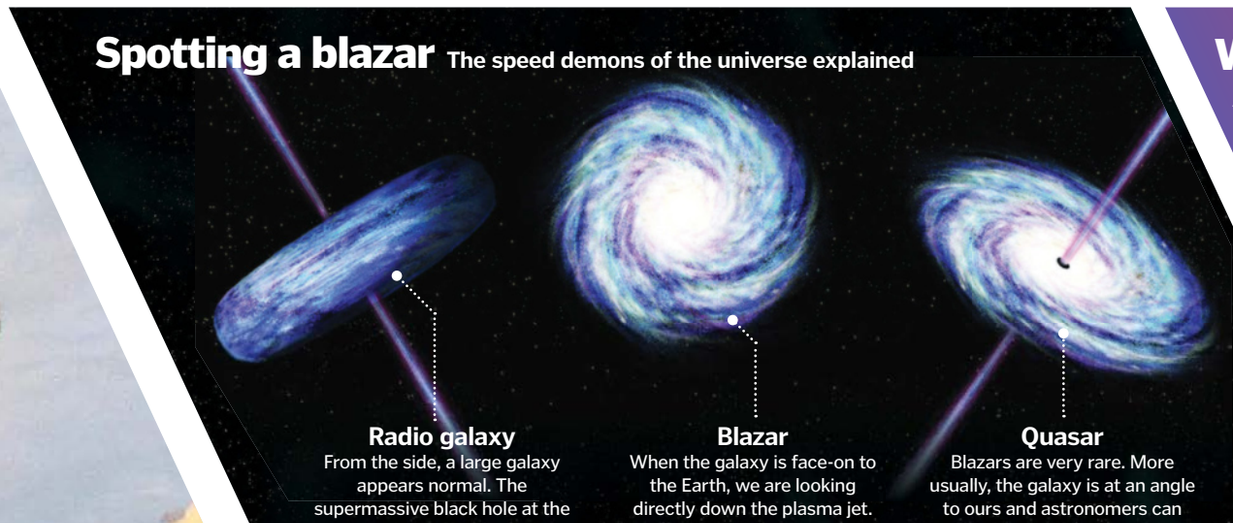
Solar Probe Plus
Utterly eclipsing other speed records, in 2018 Solar Probe Plus will fly to within 4.25 diameters of the Sun – eight times closer than Mercury's orbit. As it does so, it will be travelling at 200km/s!

Apollo 10
The fastest manned spacecraft ever was the Apollo 10 Command module. As it returned from the Moon, it was travelling at 39,847km/h (11.07km/s) – 132km/h faster than Apollo 11.

Helios 2
Launched in 1976 to study solar wind, Helios 2 has a highly elliptical orbit that brings it inside the orbit of Mercury. This is currently the fastest man-made object with a top speed of 70.22km/s.

JUNO
After a 2.8 billion kilometre journey, JUNO is scheduled to reach Jupiter this year. When it starts to enter orbit around Jupiter, it will be travelling at 71.5km/s relative to the giant planet.

Spotting a blazar The speed demons of the universe explained



Radio galaxy
From the side, a large galaxy appears normal. The supermassive black hole at the centre gives off radio waves that astronomers can detect, but the jets from the poles are invisible to us on Earth.

Blazar
When the galaxy is face-on to the Earth, we are looking directly down the plasma jet. The radio waves are so powerful in this direction that the blazar outshines stars in our own galaxy.

Quasar
Blazars are very rare. More usually, the galaxy is at an angle to ours and astronomers can only detect a fraction of the plasma jet's emissions. They are still very bright though and are called 'quasars'.

What is a blazar?

At the centre of every large galaxy is an enormous black hole, millions or even billions of times more massive than our Sun. As dust, gas and stars are pulled into its clutches, the intense gravitational heating creates jets of particles that spew from the north and south poles of the galaxy. These jets are focused into narrow beams by the magnetic field of the black hole and are accelerated to more than 99 per cent of the speed of light. A blazar is a galaxy orientated so that we are staring right down the nozzle of this cosmic firehose.

How wheels move and stop your car

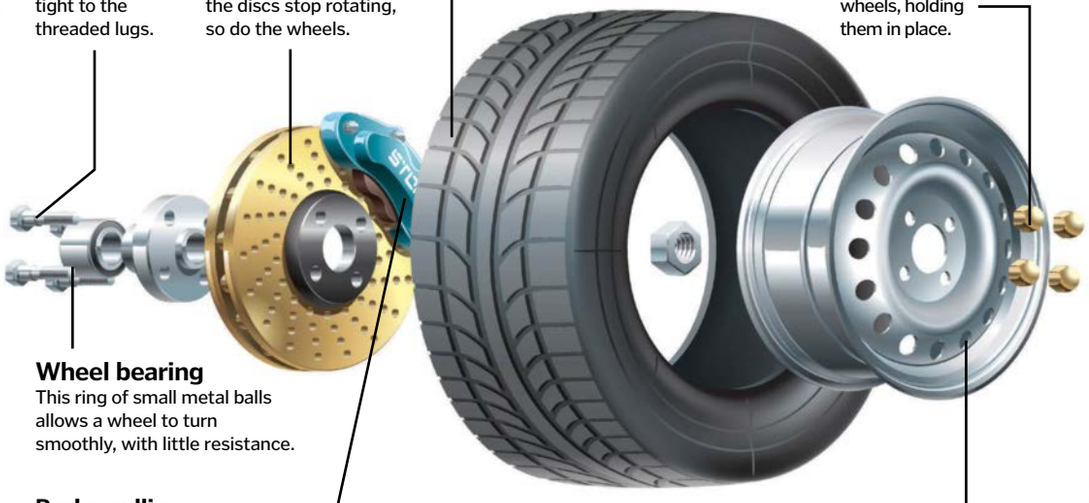
How much do you really know about the rubber-wrapped alloys connecting your car to the road?

Alloy wheels are forged to ensure a strong product, while brake discs are drilled to aid heat dissipation on sports cars

Though often overlooked by the discerning enthusiast, wheels are one of the most important parts of a car. The engine may be the driving force of a vehicle's power but wheels are the only parts that connect it to the road, thereby allowing power generated from the engine to propel it along a highway. This is achieved by each wheel being connected to an axle (via a wheel hub), which rotates on power from the engine. As the axle rotates, so does the wheel, providing motion for a vehicle.

However, wheels do more than allow a car to move – they also stop it, too, thanks to a brake system that consists of a brake disc and a calliper on each wheel. The brake disc is attached to the wheel and turns with it, while the calliper acts as a clamp. When the driver hits the brake pedal, a piston closes the clamp, slowing the rotation of the brake disc and stopping the wheel from turning, bringing the vehicle to a halt.

A car's wheels also provide grip and direction. Tyres wrapped around the circumference of the wheels provide grip, and the front wheels determine the car's direction by moving from left to right with the turning of the steering column.



Hub studs
These hold the brake disc and alloy wheel to the wheel hub by screwing on tight to the threaded lugs.

Brake disc
These rotate at the same pace as the alloy wheel and provide the friction surface for the brake pads to clamp onto. As the discs stop rotating, so do the wheels.

Tyre
Sealed to a wheel using pressurised air, tyres provide a car with grip. Grooves in the tyres help to disperse standing water, increasing the car's contact with the road surface.

Lug nuts
Four or five of these are embedded into the wheel hub and thread through the brake discs and alloy wheels, holding them in place.

Wheel bearing
This ring of small metal balls allows a wheel to turn smoothly, with little resistance.

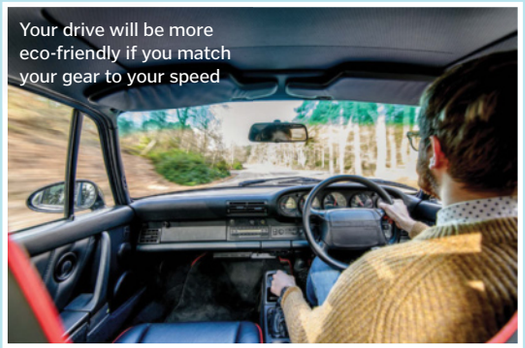
Brake calliper
These static structures house the brake pads, which bite hard onto the brake discs when the driver presses the brake pedal, halting their rotation and thereby stopping the car.

Alloy wheel
Today, car wheels are usually made of aluminium alloy, which is stronger and more lightweight than the more traditional steel.

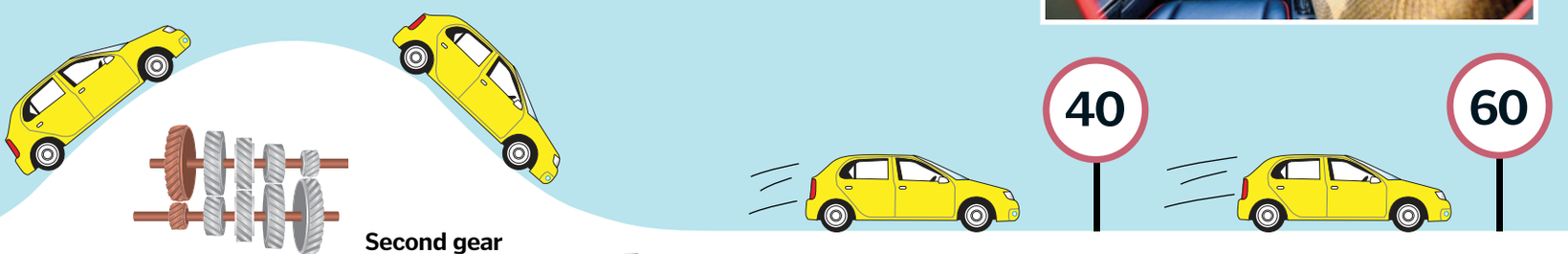
Get into gear

How a gearbox transfers power from the engine to the wheels

A gearbox is attached to a car's engine, and power generated from the engine flows through it before being passed on to a car's wheels. The pistons in the engine have to pump constantly – with a minimum speed of 1,000RPM – to stop the engine cutting out. To stop the car flying off at top speeds, the gearbox controls how much of this power gets to the wheels. Cogs and shafts inside the gearbox create different ratios of speed and torque, which are known as gears. Each gear works best in a different situation, depending on the speed of the car and the incline of the road.



Your drive will be more eco-friendly if you match your gear to your speed



First gear
First gear uses lots of torque and is commonly used to get the mass of a vehicle moving from standstill, or to propel a car slowly up a very steep slope.

Second gear
Second gear is commonly used when traveling down hills with steep inclines. This is because gravity is pulling the car down the hill, so no or little torque is needed from the engine to move the car.

Third gear
Accelerating on a flat surface is likely to require third gear, which sends more torque to the wheels to get them – and the car – moving faster.

Fourth gear
The fourth or 'top gear' is used for high speeds where low amounts of torque are needed. It is usually more fuel-efficient to be in a higher gear at high speeds.

Supersonic without the boom

NASA has revealed plans for a quieter successor to the Concorde passenger jet

In order to reach New York from London in less than three and a half hours, Concorde cruised at speeds of over 2,180 kilometres per hour – twice the speed of sound. At half that speed, it would break the sound barrier, generating an enormous double sonic boom that could be heard for miles.

This incredibly loud noise led to a worldwide ban on continental supersonic flights, restricting the routes that Concorde could fly. It wasn't particularly efficient either, as it burnt two per cent of its fuel just taxiing to the runway. These factors ultimately contributed to the aircraft's downfall, leading to it being retired in 2003.

Now, NASA hopes to bring back supersonic passenger air travel by making flights greener, safer and quieter. To achieve this it has announced plans to develop a 'low boom' aircraft, which generates a soft thump as it breaks the sound barrier, rather than a disruptive boom.

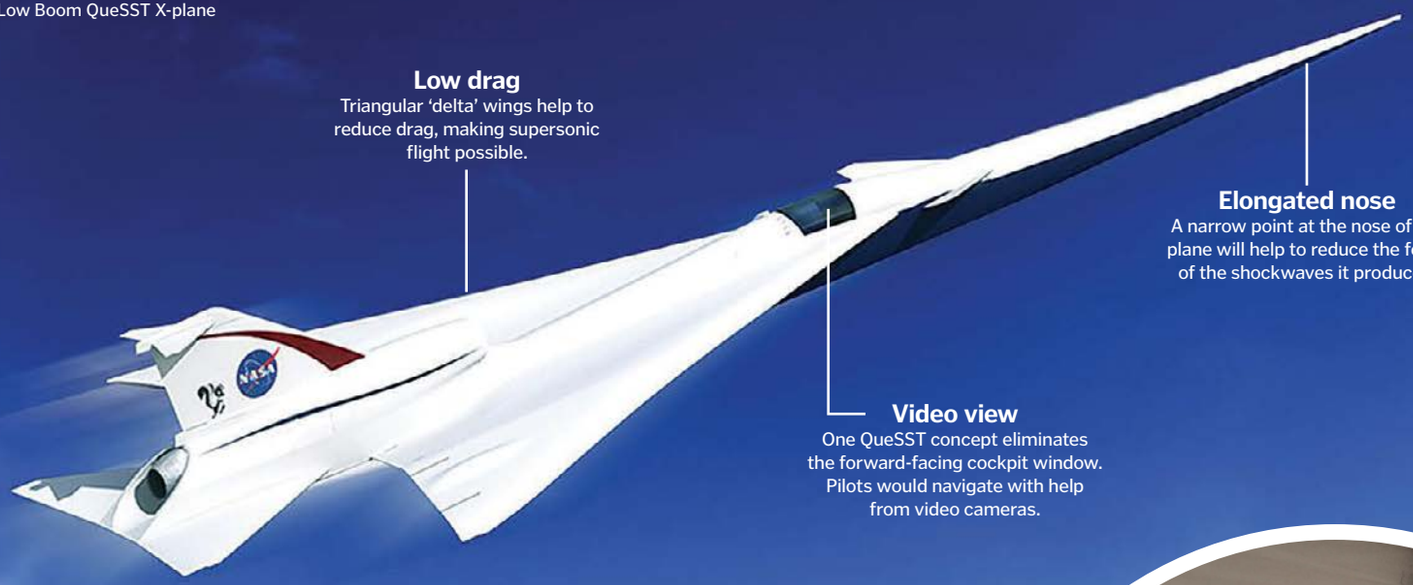
The $20 million contract to design the Quiet Supersonic Technology (QueSST) X-plane has been awarded to Lockheed Martin Aeronautics, and NASA hopes a working prototype will take flight in 2020. To help build this next-generation supersonic jet, NASA has been busy conducting research into sonic booms. It has recently been testing an air data probe that may one day be used to measure the shockwaves generated by supersonic aircraft, providing information that could help improve their design.

What is a sonic boom?

As an aircraft flies, it compresses the air in front of it, producing compression waves a bit like the ripples created ahead of a moving boat. These waves move away from the aircraft in all directions and travel at the speed of sound. When the aircraft itself reaches the speed of sound, the compression waves combine together to create a shockwave, and when this shockwave reaches our ears, we hear it as a loud boom. If the aircraft is travelling faster than the speed of sound, the shockwaves form a cone shape that trails off behind the aircraft, creating a continuous sonic boom.

When an aircraft flies at supersonic speeds, the decrease in temperature and pressure forms a cloud

An artist's concept of a possible design for the Low Boom QueSST X-plane

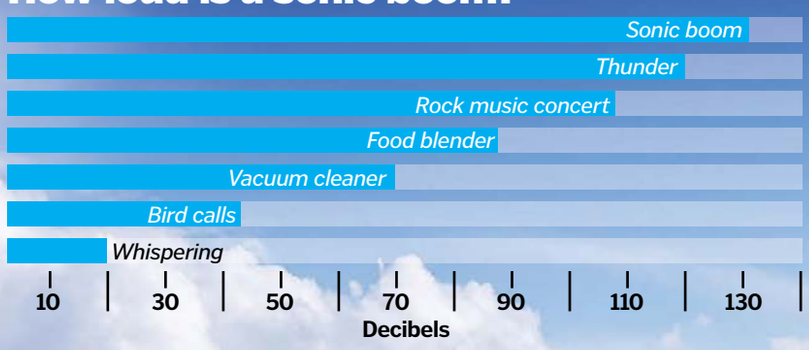


Low drag
Triangular 'delta' wings help to reduce drag, making supersonic flight possible.

Elongated nose
A narrow point at the nose of the plane will help to reduce the force of the shockwaves it produces.

Video view
One QueSST concept eliminates the forward-facing cockpit window. Pilots would navigate with help from video cameras.

How loud is a sonic boom?



NASA's supersonic air data probe affixed to an F-15B aircraft for testing

The Falkirk Wheel

The ingenious engineering behind the world's only rotating boat lift

Despite appearances, the Falkirk Wheel is actually a lift. It can transport six canal boats 25 metres, between Scotland's Forth and Clyde Canal and the Union Canal below it. Up until the 1930s, boats would have to pass through a staircase of 11 locks. Navigating this passage took nearly an entire day, as travellers had to open and close 44 different heavy gates before they could reach the other side. Nowadays, the trip can be done in just 15 minutes, thanks to the futuristic-looking Falkirk Wheel.

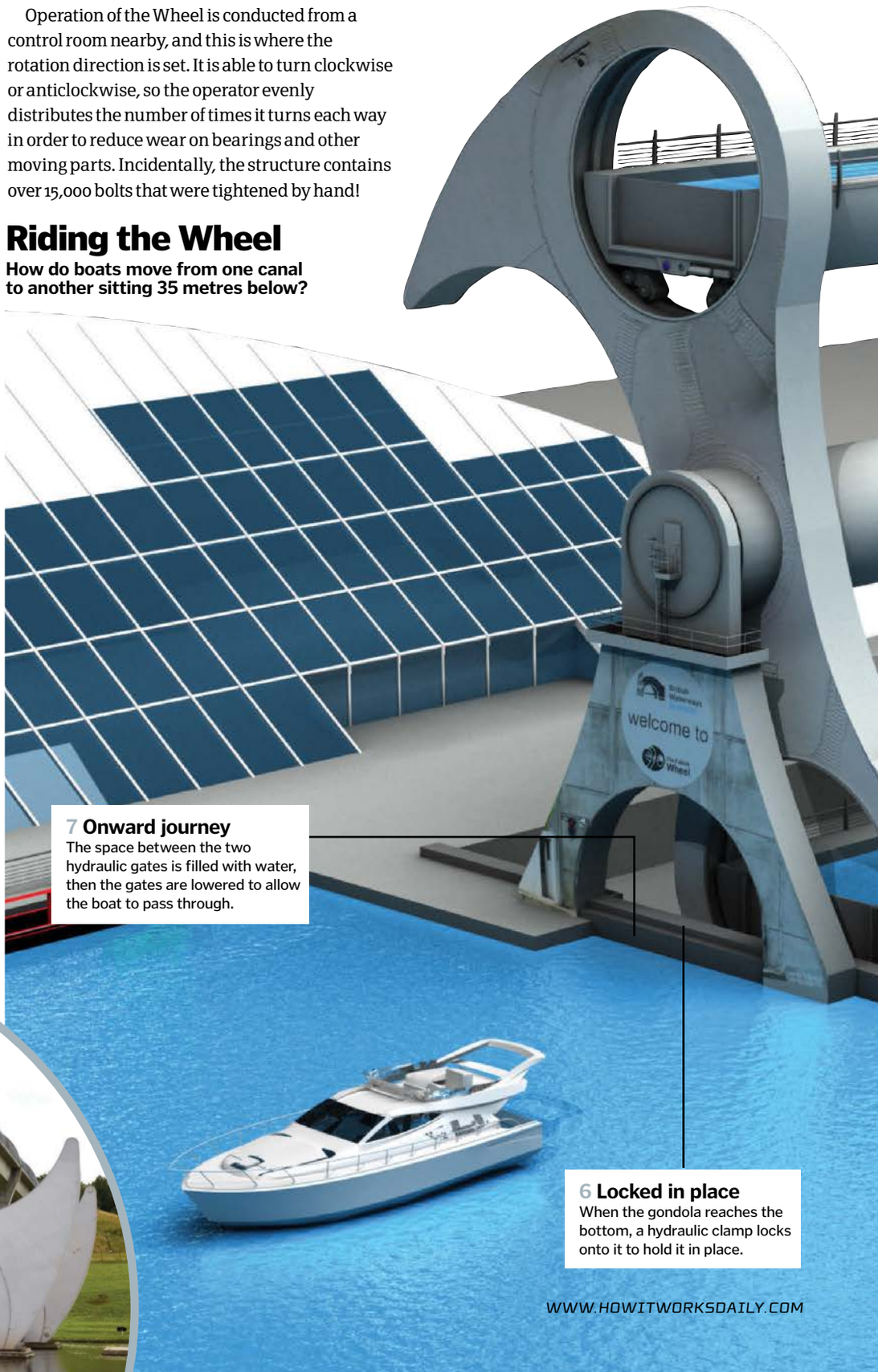
Opened by Queen Elizabeth II in 2002, the world's first rotating boat lift features two large tanks of water called gondolas, which carry the boats up and down between the two canals. Each end of the gondolas sits inside a ring, which rotates to keep them level as the wheel turns. Without this system, the inertia – created by the 80,000 gallons of water sloshing around inside the gondolas – would tip them over.

The wheel's clever lifting system works because of Archimedes' principle: objects displace their own weight in water. So when a boat enters the gondola, it displaces the same volume of water and enables the gondolas to remain balanced. To be on the safe side, a system of electronic sensors monitors the water levels to ensure they remain constant. The Wheel is so balanced that a half-turn requires just 1.5-kilowatt hours of energy – the equivalent of boiling eight electric kettles.

Operation of the Wheel is conducted from a control room nearby, and this is where the rotation direction is set. It is able to turn clockwise or anticlockwise, so the operator evenly distributes the number of times it turns each way in order to reduce wear on bearings and other moving parts. Incidentally, the structure contains over 15,000 bolts that were tightened by hand!

Riding the Wheel

How do boats move from one canal to another sitting 35 metres below?



7 Onward journey
The space between the two hydraulic gates is filled with water, then the gates are lowered to allow the boat to pass through.

6 Locked in place
When the gondola reaches the bottom, a hydraulic clamp locks onto it to hold it in place.

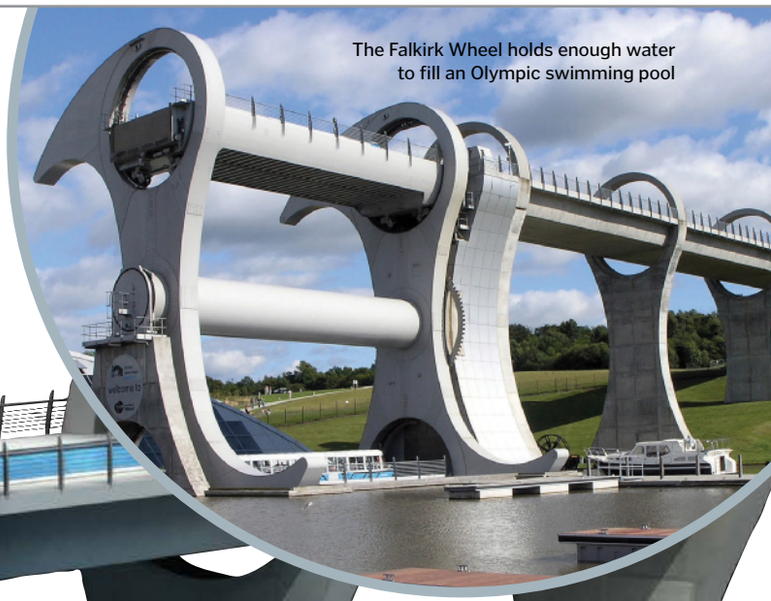
Constructing the Wheel

The unusual design of the Falkirk Wheel is said to have been inspired by the shape of a Celtic two-headed axe. Made from 1,200 tonnes of steel, all of the individual parts were first constructed and assembled in Derbyshire, around 440 kilometres away. They were then dismantled and transported up to Falkirk in 35 lorry loads. The entire structure cost £84.5 million ($122 million) to build and has become a local landmark, attracting over 5.5 million visitors since it first opened.

The Falkirk Wheel is 35 metres tall and weighs 1,800 tonnes in total

"The Wheel is able to turn clockwise or anticlockwise"

The Falkirk Wheel holds enough water to fill an Olympic swimming pool



1 Watertight seal
Once the boat is inside the gondola, two hydraulic steel gates are raised to seal it off from the water in the canal.

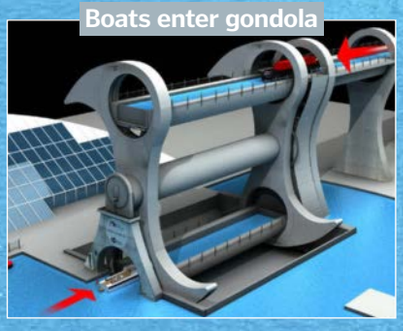
2 Free to move
The water between the gates is pumped out and a series of hydraulic clamps, which prevent the wheel from moving, are removed.

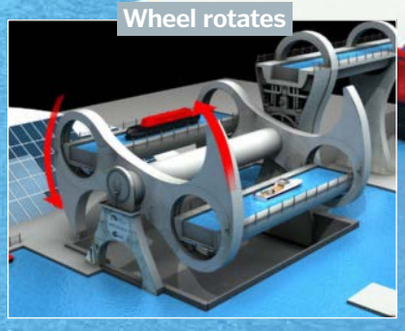
The weight of the water displaced by an object is equal to the weight of the object

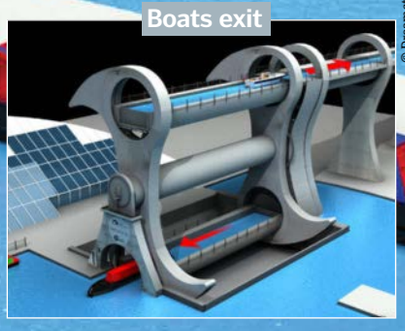
3 Central axle
An array of ten hydraulic motors begins to rotate a central axle, which is carried on bearings at both ends.

4 Spinning gears
A fixed central cog turns the outer rings attached to the gondolas, via two smaller cogs situated between them.

5 Perfectly level
The two smaller cogs rotate in the opposite direction to the outer rings, ensuring that the two gondolas remain level as they move.

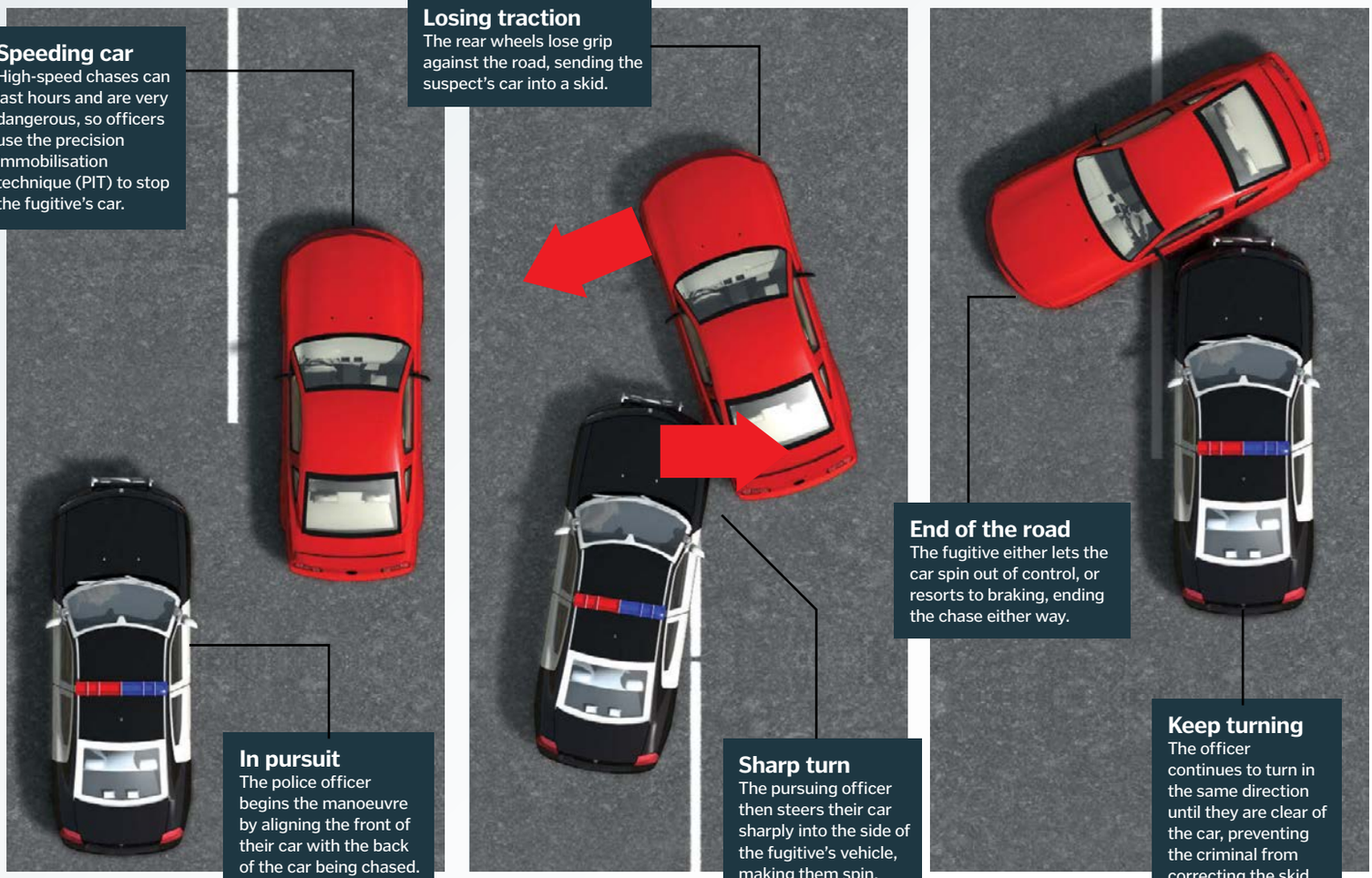






HOW TO STOP A SPEEDING CAR

Police use the precision immobilisation technique



GHOST ships

The next-gen stealth ship that flies through the waves

Minimising drag is an important consideration when designing ships, as friction between the vessel and water greatly reduces efficiency. Juliet Marine Systems (JMS) Inc has tackled this problem by incorporating innovative technology into its demonstration ship called GHOST.

This twin-hull ship is similar to a catamaran, with two wing-like struts attached to the main cabin. The end of each strut features a submerged tubular hull containing the propulsion system. Instead of being pushed along, front-mounted propellers on each hull pull GHOST through the water. Whereas a conventional propeller vessel leaves a trail of foam in its wake, GHOST's unique design redirects the bubbles to surround the twin hulls with pockets of gas. This effect is known as supercavitation, allowing the boat to glide through air rather than water, which JMS claims can reduce drag by a factor of 900.

GHOST's wings can also be repositioned to lift the main cabin above the water. Rising above the bumpy waves ensures a smooth ride, protecting the crew from impact injuries and sea sickness, while also improving the stability and accuracy of onboard sensors and weapon targeting.

GHOST is designed for military use, but can be adapted for commercial and recreational purposes

How do road sweepers work?

Meet the machines that keep our streets clean

Mechanised road sweepers are like huge vacuum cleaners that suck up much more than household dust. Everything from leaves and dirt to paper and cans finds its way into these vehicles, leaving the roads behind them squeaky clean.

They achieve this by using a number of different systems. First, high-pressure water jets at the front of the vehicle break up any caked-in dirt. Rotating 'gutter brooms' sweep this dirt, and any other litter, from the edges of the road into the middle. The sweeper then sprays out a fine mist of water – this helps to hold the dust down, rather than just letting it blow into the air. Next up is the vacuum system itself, which is powered by the vehicle's engine. It is connected to a hose that sits under the centre of the sweeper, and litter is sucked from the road and up into the vehicle's collection bin.

Once it's in there, the litter is shaken and dried, to break it up into smaller particles, and passed through filters. The dirt is trapped, while the cleaned air is either recycled back into the vacuum system, or released into the environment.

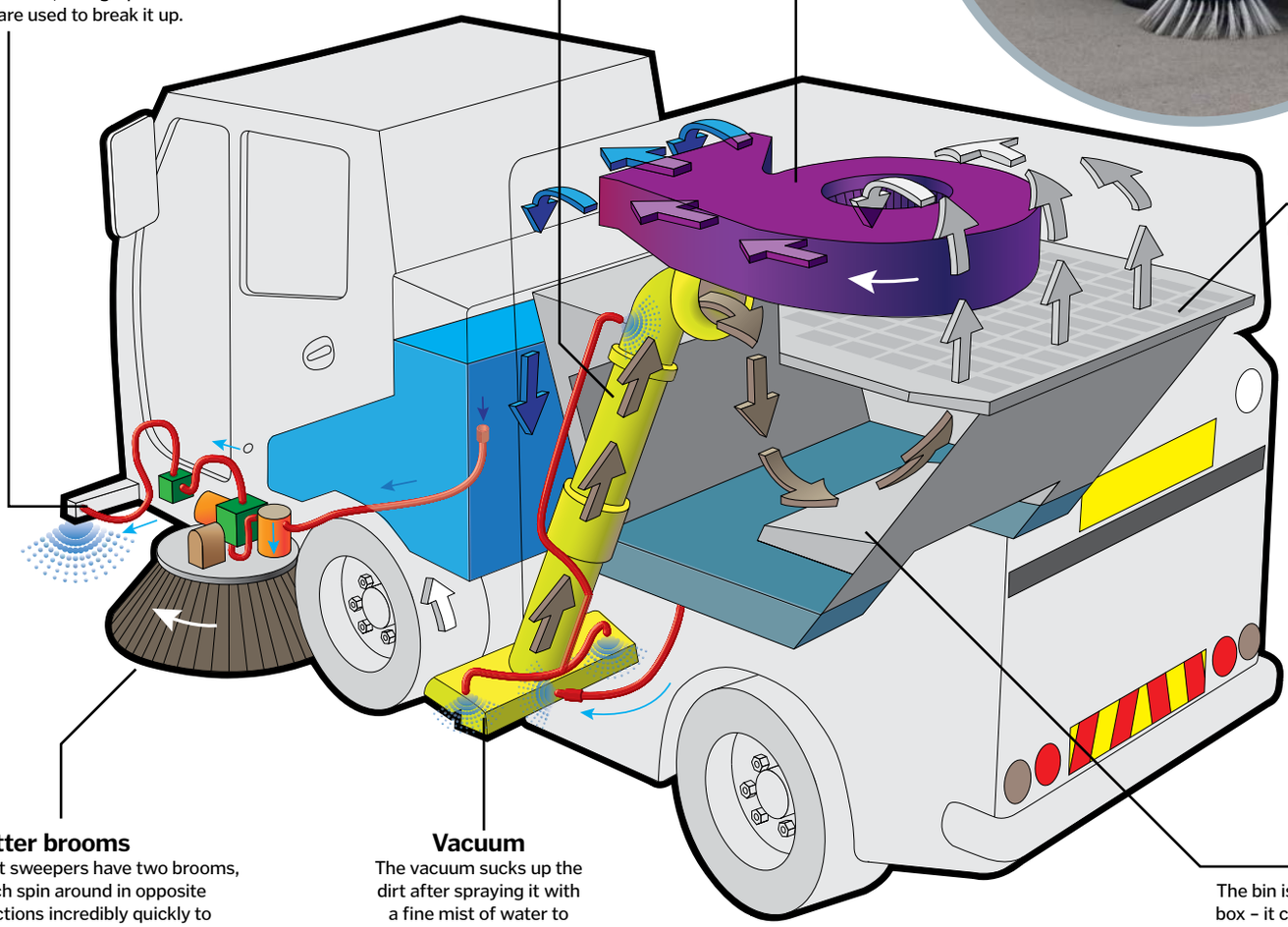
Making sweepers more 'green'

In many cities, road sweepers are in use for eight hours each day. For older systems that use diesel engines, this could lead to a fuel consumption ten times higher than that of a typical passenger car – so they could hardly be called 'clean'! But things are changing – hybrid engines that combine electric generators with either biodiesel or compressed natural gas are becoming more popular. And hydrogen fuel cells – which emit only water vapour – are being trialled too. These vehicles reduce emissions by 60 per cent, keeping the air clean, as well as the streets.

Developed by Swiss organisation Empa, CityCat H2 was the world's first fuel cell-powered sweeper

Sweep me off my street

Lots of different technologies are used to keep a city's roads clean



Water jets
Dried dirt can be tough to remove from roads, so high-pressure water jets are used to break it up.

Hose
The dampened dirt and other litter make their way into the collection bin via this hose.

Recycle
The clean, filtered air is recycled by the high-power vacuum system at the top of the vehicle.

Filter
Even the smallest dirt particles get caught in these filters, which are replaced regularly, just like in a household vacuum.

Gutter brooms
Most sweepers have two brooms, which spin around in opposite directions incredibly quickly to move the dirt into the centre.

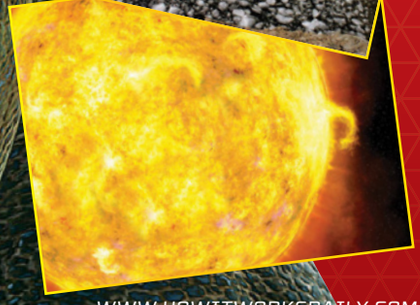
Vacuum
The vacuum sucks up the dirt after spraying it with a fine mist of water to help it stick together.

Bin
The bin is more than just a box – it can shake to break up dirt into smaller pieces.

WHAT IF...

DINOSAURS DIDN'T DIE OUT?

& 11 MORE ABSURD QUESTIONS ANSWERED WITH SCIENCE



Six million years ago, a ten-kilometre projectile slammed into our planet, leaving a 180-kilometre crater in Mexico. The impact would have killed everything nearby, triggering devastating tsunamis, acid rain, and dust clouds that blocked out the Sun for months. At around the same time, volcanoes were erupting, sea levels were dropping, and amidst the chaos, three quarters of Earth's plants and animals died out. This was the end of the dinosaurs, but what if it had never happened?

Dinosaurs dominated the world for more than 150 billion years. They were some of the most successful animals that have ever lived, and chances are, their ancestors would still be here today. Unfortunately, we would not be around to see them. The fall of the dinosaurs made way for the rise of mammals.

Until that fateful mass extinction event, mammals had struggled to gain a foothold. They lurked in the shadows, living in burrows, coming out at night, eating whatever they could find, and remaining small. These traits helped them cling on as the dinosaurs perished, and allowed them to fill the gaps that the dinosaurs left behind.

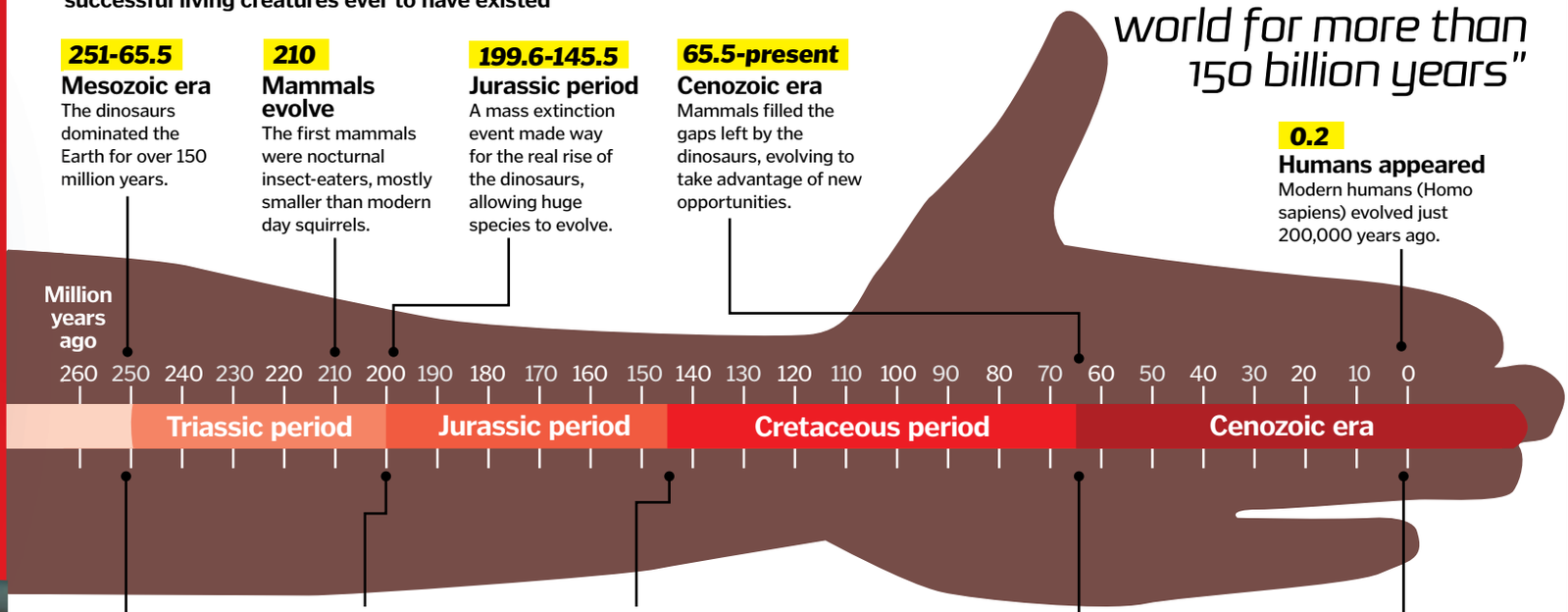
If the asteroid hadn't hit, the ancestors of dinosaurs like the T-rex, Triceratops and Hadrosaurus might still dominate the food chains on the savannahs and in the forests. It's difficult to know what dinosaurs would look like now, because they would have continued to evolve as the climate and conditions on Earth changed, but it is possible that birds would still have taken to the skies. They are descended from dinosaurs, after all.

It is even possible that there might be intelligent dinosaur species roaming the planet in our place, although this is hotly debated; big brains are costly and use huge amounts of energy. Whether any dinosaurs would have needed to go down this evolutionary path is a question that cannot be answered, but just imagine what the world would be like if they had.

The history of the dinosaurs

These giant animals were some of the most successful living creatures ever to have existed

"Dinosaurs dominated the world for more than 150 billion years"



251-65.5
Mesozoic era
The dinosaurs dominated the Earth for over 150 million years.

210
Mammals evolve
The first mammals were nocturnal insect-eaters, mostly smaller than modern day squirrels.

199.6-145.5
Jurassic period
A mass extinction event made way for the real rise of the dinosaurs, allowing huge species to evolve.

65.5-present
Cenozoic era
Mammals filled the gaps left by the dinosaurs, evolving to take advantage of new opportunities.

0.2
Humans appeared
Modern humans (Homo sapiens) evolved just 200,000 years ago.

251-199.6
Triassic period
The earliest dinosaurs lived in a hot world on the single supercontinent of Pangaea.

200
Triassic-Jurassic mass extinction
Around half of all living species died out during the last part of the Triassic period.

145.5-65.5
Cretaceous period
Flowering plants appeared, while insects, mammals and birds continued to diversify.

65.5
Cretaceous-Tertiary mass extinction
This is the catastrophic event that wiped out most of the dinosaurs.

0.01
Holocene epoch
Our current geological period began at the end of the Palaeolithic Ice Age, 11,500 years ago.


The fall of the dinosaurs made way for the rise of mammals


If the asteroid had missed, things could have been very different

Vents beneath the oceans are home to organisms that don't depend on sunlight to survive

WHAT IF...

the Sun went out?

If our star suddenly switched off, life on Earth would be in serious trouble

Without sunlight, plants would rapidly start to die, and the rest of the food chain would soon follow; almost all living things depend on our star. A few exceptions lie deep in the ocean, where there are organisms that have evolved to use hydrogen sulphide for energy instead of sunlight, feeding directly on minerals that leech out of the Earth's crust. These might hang on a little longer, but eventually the Earth would grow cold and the oceans would freeze. In reality, the Sun won't go out like a light. It will brighten and expand as it runs out of fuel, but this will bring its own problems. Fortunately, we've got around a billion years to figure out what to do.

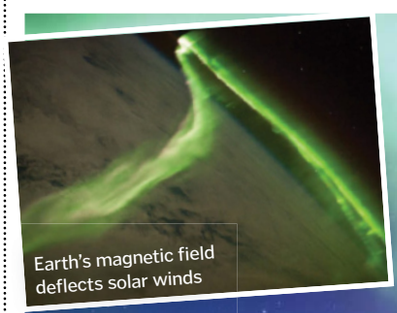
WHAT IF...

the magnetic field flipped?

The consequences of compasses pointing south

Earth's magnetic field shields us from solar winds, but north isn't always north. In recent history, the magnetic poles have switched four or five times every million years. It hasn't happened in modern history, so it's hard to know what to expect.

During a flip, the magnetic field weakens and breaks up. This would leave Earth vulnerable to the effects of solar storms, potentially disrupting communications. It could also confuse animals that use magnetic fields to navigate. However, there would be a silver lining. The magnetic field is responsible for the northern and southern lights, and as the poles switched, auroras would become visible across the globe.



Earth's magnetic field deflects solar winds

As the poles switch, auroras might become visible across the globe

Tardigrades can survive in extreme environments, and can go months without water

WHAT IF...

water didn't exist?

Is life even possible without Earth's most abundant liquid?

All life as we know it needs water to survive. Organisms need to take in materials from their environment; they need to grow, to react and to reproduce. To do these things, large, complex chemicals need to come close enough together for them to be able to react, and, for this to happen, you need something for the molecules to dissolve in. On Earth, water is the answer. There's lots of it, it can dissolve a variety of different chemicals, and it remains liquid over a wide temperature range. Take it away, and everything would die.

There are some crafty organisms that can survive for months, years, or even decades by drying themselves out and slowing their metabolisms, but if the water never returned, they would eventually succumb to dehydration.

However, just because we need water doesn't mean that there aren't alternatives. Some other liquids have the potential to support life too, albeit life that is quite different to what we are used to. One of the prime candidates is ammonia. There is lots of it, it is good at dissolving organic molecules, and it can also dissolve metals. It evaporates at a lower temperature than water, but if the pressure is high enough, it will become more stable.

Another option is hydrogen fluoride. It stays liquid over a wide temperature range, and can absorb considerable energy before it increases in temperature. The trouble is, it's pretty rare. At this stage, it's impossible to know if life could evolve in liquids other than water, but there is definitely a chance.

WHAT IF... the bees died out?

Dogs might be man's best friends, but bees are our lifeline

A single bee makes a measly one twelfth of a teaspoon of honey during its lifetime, but losing the sweet stuff is the least of our problems. Dozens of crops are pollinated exclusively by bees, and unless we want to start transferring pollen from flower to flower by hand, we need these little guys to keep our supermarkets stocked.

One colony of bees can carry pollen between 300 million flowers in a single day, and hives are transported between fields across the world to fertilise 70 per cent of our most widely consumed crops. They give us almonds, apricots, blueberries, cardamom, coriander, cranberries, grapes, kiwis, peaches, pumpkins, strawberries and vanilla, to name just a few. They also help plants to produce better crops, increase yields and trigger fruits, nuts and seeds to grow larger. It's not just fruit and veg that would go missing from our kitchens if the bees died, either. Our livestock are fed crops like alfalfa and clover, which bees also pollinate.

The bee-pocalypse wouldn't be the end of food altogether, though. Legumes such as peanuts and soybeans are self-pollinating, so they can reproduce without any outside help. Grasses such as wheat and rice spread their pollen in the wind, figs transport it via wasps and agave plants (the key ingredient in tequila) are pollinated by bats.

Flies, birds, moths and butterflies are all important pollinators too, and could keep up supplies of cashews, mangoes and papayas. But, unlike bees, these animals can't be carried conveniently from field to field in hives. If all of our hives collapsed, there could be global food shortages, fruit and vegetable prices would skyrocket, and we'd have to find new ways to produce the foods that we know and love.

Welcome to the post bee-pocalypse picnic

What would we have left to eat if all the bees died?

Managed colonies of bees transport pollen on an industrial scale

Substandard jam
Strawberries can be pollinated by wind, but bees make the crops redder, firmer and longer lasting.

Butterless crust
Bee-pollinated crops like alfalfa and clover are fed to dairy cows.

Less cotton
Bees aren't required for cotton production, but they do help to increase the amount the plants produce.

Bucketloads of bread
Wheat is a type of grass and is wind-pollinated, so bread would still be plentiful.

Lots of lemons
Citrus trees are self-fruiting, and can be grown using grafts, bypassing the need for bees.

No cucumbers
Unless we turn to hand-pollinating, cucumbers would be off the menu.

Countless crisps
Corn is wind-pollinated, so there would be no shortage of tortilla chips.

Some salsa
Tomatoes can be wind-pollinated, but without a little insect help we may have to resort to pollinating by hand.

No guacamole
Avocados very rarely self-pollinate, so they need bees to do the work for them.

Melon shortage
Bees are the best pollinators of melons – without them, the plants are unlikely to produce fruit.

30% of all food relies on pollinating insects

60% reduction in hives between 1947 and 2008 in the US

Bees pollinate **70** TYPES of crop in the UK alone

Bees are worth **£112.5** BILLION to agriculture per annum

Contains around **50,000** BEES

It takes **12** bees a lifetime's work to make one teaspoon of honey

Generates around 15kg of honey each year

One honey bee colony

Pollinates **4,000m²** of fruit trees

CAN POLLINATE **300** MILLION flowers in a day

WHAT IF... both the ice caps melted?

Would the whole world end up underwater?

The polar ice caps look alike, but beneath the surface they are very different. Arctic ice floats on the Arctic Ocean, while the Antarctic sits on solid land. This might seem like a trivial difference, but it has a huge impact on what could happen if both were to suddenly melt.

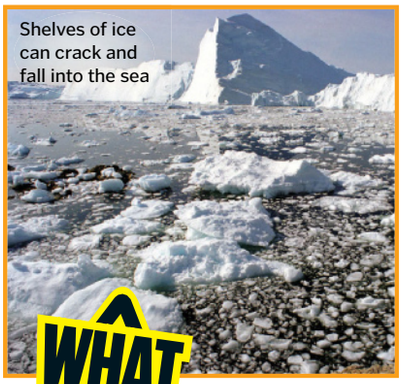
Polar ice caps melting into the sea is a bit like ice cubes melting into a drink. When you drop ice cubes into a glass, the water level rises immediately because of displacement. If those ice cubes melt, the water level doesn't rise any further. This is the current situation in the Arctic.

But, if you keep dropping more ice into the glass, eventually it will overflow. This is where the Antarctic and Greenland come in. Together, they contain 75 per cent of Earth's fresh water, and unlike the Arctic ice, it is sitting on dry land. If it melts, or if chunks fall into the ocean, it's going to cause major problems.

According to NASA, if both of these ice sheets disappeared, the sea level would rise by 75 metres, plunging major coastal cities underwater, submerging entire islands, and causing many inland rivers and lakes to burst their banks.

But this is just the beginning. Although Arctic ice is already floating in the water, it still has the potential to contribute to rising sea levels. The bright crystals of ice and snow reflect 85 per cent of the sunlight that hits them, while seawater absorbs about 90 per cent. If the Arctic disappeared to reveal the ocean beneath, the cooling effect would be removed and water temperatures would rise. In turn, this would cause more ice to melt, and less sunlight to be reflected – we would be caught in a dangerous warming cycle.

"If both ice sheets melted, the sea level would rise by 75 metres"



Shelves of ice can crack and fall into the sea

If sea levels rise, rivers will burst their banks

The world underwater

What would happen if sea levels rose by 75 metres?

1 Above the waterline
Inland areas would be safe, but many densely populated areas are along coasts.

2 The Amazon Sea
The Amazon River would flood, filling the basin with water and obliterating the rainforest.

3 London lost
The east of the UK would flood, with the capital and East Anglia submerged.

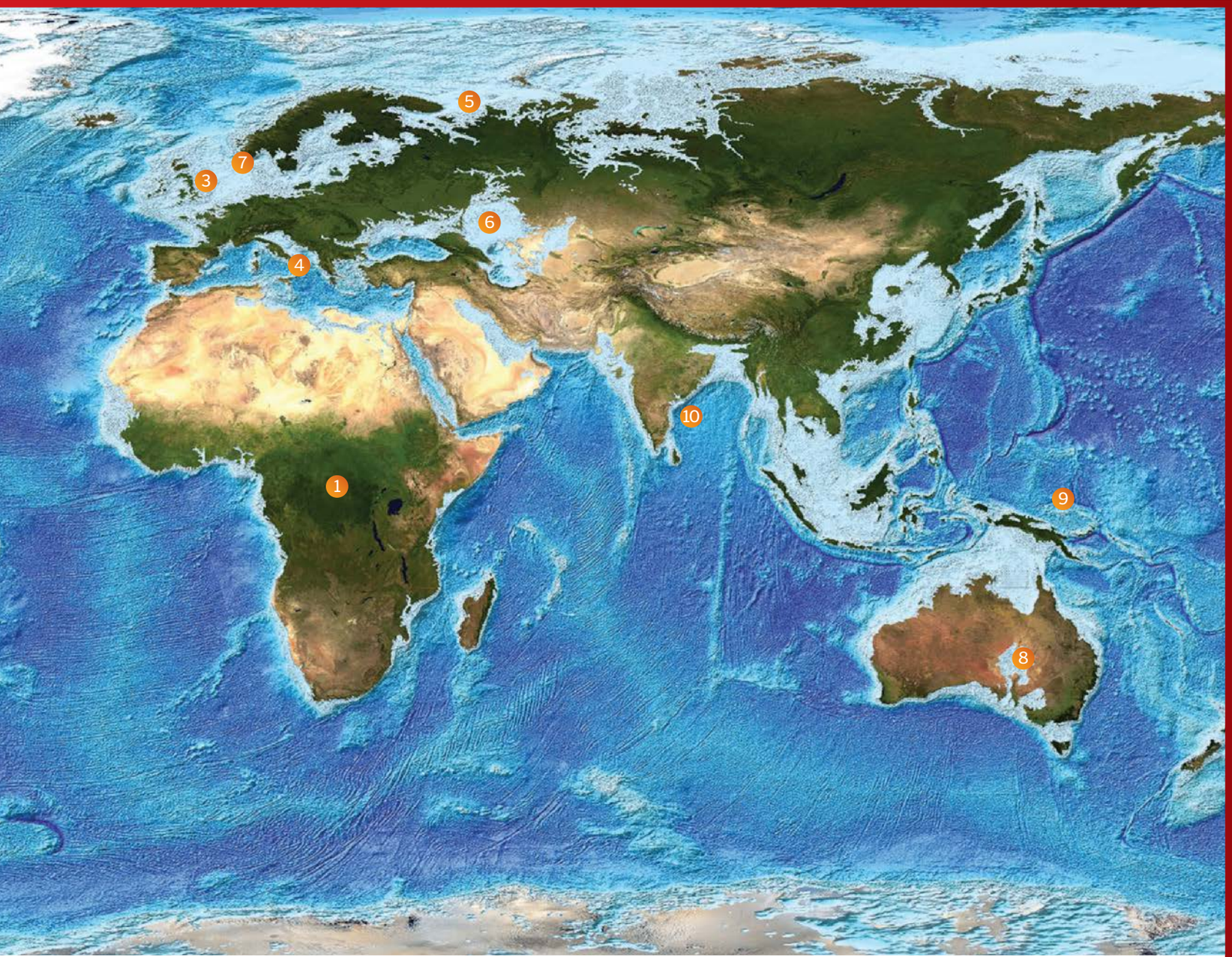
4 Venice sunk
The canals of this city would overflow, plunging houses into the sea.

WHAT IF... gravity was twice as strong?

Find out if your body could cope under the strain

If gravity had always been stronger, our bodies would have been under pressure to adapt. We might be smaller, with thicker bones and stronger muscles. But we evolved with Earth's gravity as it is, and if it suddenly doubled, we'd be in trouble. Our hearts would struggle to pump against the downward pull, and our bones, muscles and joints would experience serious strain.

Large animals, like elephants, would find high gravity environments extremely challenging



5 Russian islands
Russia would be transformed into a series of islands, separated by bodies of water.

6 Expanding seas
The Baltic and Caspian seas would creep over the land to the north.

7 Northern Europe submerged
The North Sea would spill over Germany, Denmark and Holland

8 Lake Eyre burst
Australia's lowest lying lake would expand dramatically, flooding the south of the continent.

9 Disappearing islands
Many of the tiny islands in the Pacific Ocean would be swallowed by rising sea levels.

10 Kolkata covered
One of the most densely populated cities in India would end up completely underwater.

11 Disney underwater
The entire state of Florida would end up submerged beneath the Atlantic Ocean.

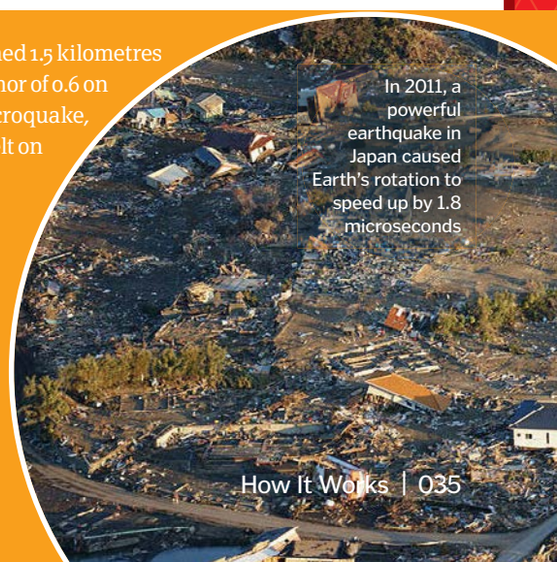
WHAT IF...

everyone jumped at once?

Find out the impact we could make if we all worked together

There are 7 billion people on the planet. If we all stood side by side we would fit into an area around the size of Los Angeles, California (1,300 square kilometres), weighing in at a formidable 350 million metric tonnes. It's tempting to think that if we all jumped together, we could do some serious damage, perhaps even altering Earth's spin. Unfortunately, this doesn't seem to be the case.

In 2012, the BBC asked 50,000 people at Reading Festival to jump at once, and measured the effects with a seismometer. The detectors, positioned 1.5 kilometres away, registered a tremor of 0.6 on the Richter scale: a microquake, but not enough to be felt on the ground. The team calculated it would require trillions of people to create an earthquake powerful enough to cause a change to Earth's spin. If only we could jump a little higher.



In 2011, a powerful earthquake in Japan caused Earth's rotation to speed up by 1.8 microseconds

WHAT IF...

we cut down all the trees?

Losing Earth's forests would change the face of the planet forever

Every second, an acre of the Amazon rainforest disappears. That's the equivalent of cutting down a forest the size of Malta every single day. Forests are described as the 'lungs of the Earth', and although they are not the biggest producers of oxygen on the planet (that honour goes to tiny organisms in the world's oceans, which kick out between 50 and 85 per cent), they are vital for removing carbon from the air and cleaning up our soil.

Plants and trees take carbon dioxide and turn it into biological molecules, locking it away in their trunks, leaves and stems. If we cut them down, burn them, or let them decay, the carbon is released back into the atmosphere, where it acts as a greenhouse gas. Trees also act as huge umbrellas when it rains, and as parasols in the sunshine. They help water to trickle slowly to the forest floor, and they regulate the temperature and humidity in the environment beneath their leaves.

The environmental effects of losing our forests would be cataclysmic. Tonnes of carbon would be released into the atmosphere, contributing to the greenhouse effect. During a downpour, water would run straight off the soil, causing rivers and lakes to swell and burst their banks. Areas of bare earth would experience droughts, and soil erosion would make growing crops impossible. The air would become dangerous to breathe without a gas mask.

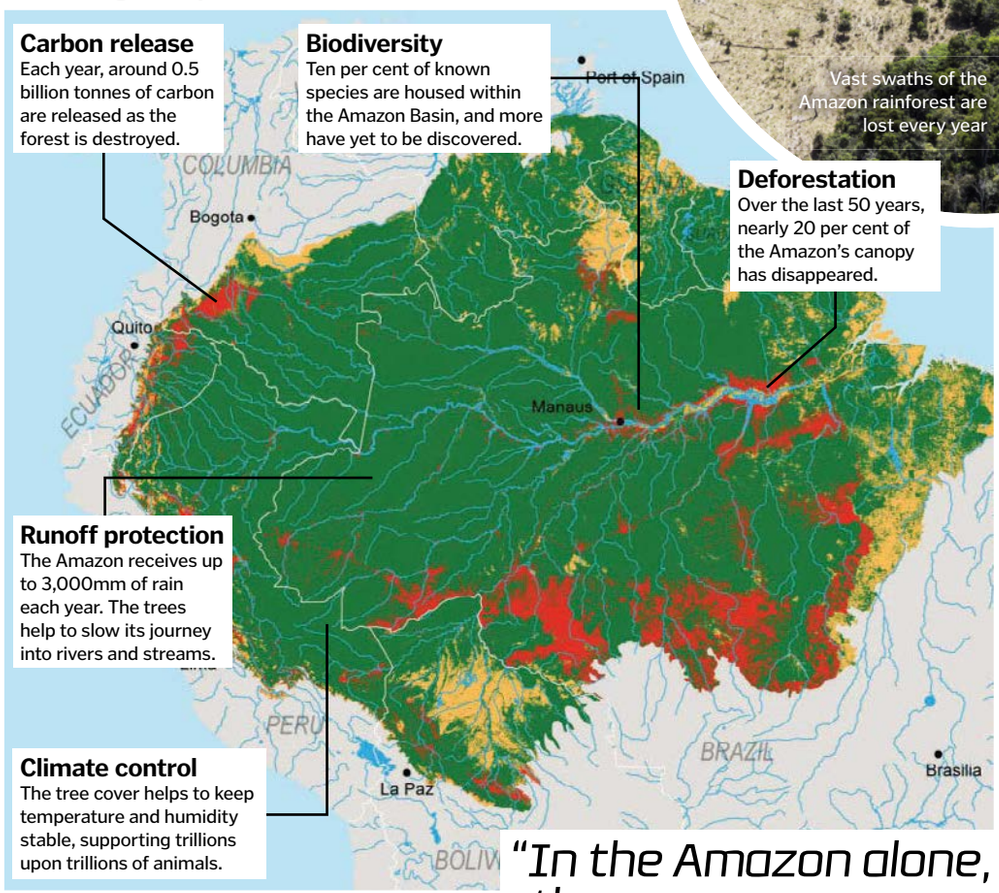
Our forests are home to half of all Earth's species and 80 per cent of all its insects. In the Amazon alone, there are over 40,000 varieties of plant, over 1,300 species of birds, more than 400 species of mammal, 3,000 species of fish, over 350 each of reptiles and amphibians, and nearly a million indigenous people. As if that weren't enough, the knock-on impact on modern living would be huge.

Without trees, there would be no paper, wood, charcoal, chewing gum, cork, or latex. The foods we harvest from trees would be gone too, so we would wave goodbye to maple syrup, cherries, apples and nuts, to name just a few.

Vast swaths of the Amazon rainforest are lost every year

The state of the Amazon

Earth's largest tropical rainforest is under serious threat



The Amazon by numbers

This forest is one of the most astonishing places on the planet

1 Acres of forest destroyed per second

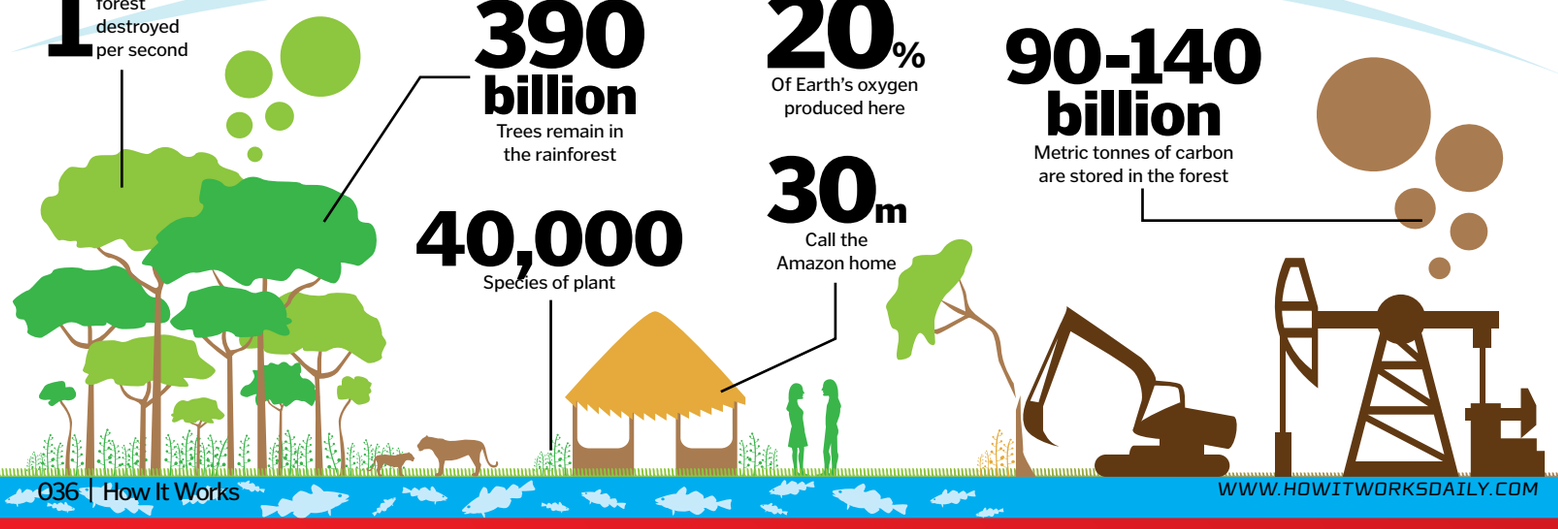
390 billion Trees remain in the rainforest

20% Of Earth's oxygen produced here

90-140 billion Metric tonnes of carbon are stored in the forest

40,000 Species of plant

30m Call the Amazon home



"In the Amazon alone, there are over 40,000 varieties of plant"

Earth would experience winds 15 times the speed of a hurricane

WHAT IF... the Earth stopped turning?

Mondays would last for months and we'd always be complaining about the weather

If the Earth gradually stopped turning, day and night as we know them would cease to exist. As Earth orbited the Sun, light would creep painfully slowly over the surface, with each spot along the equator spending six months in near total shadow. Half of the year would be spent in daytime, half would be night, and the temperatures would be extreme.

Beneath the surface of the planet, it's likely that the molten iron core would also stop moving, killing our protective magnetic field. Without it, we would be completely exposed to harmful winds from the Sun. If the planet stopped spinning suddenly, the situation would be even more dire. The atmosphere would continue to move around, becoming a circulating wind that would whip across Earth's surface at almost 500 metres per second – about 15 times the speed of a hurricane.

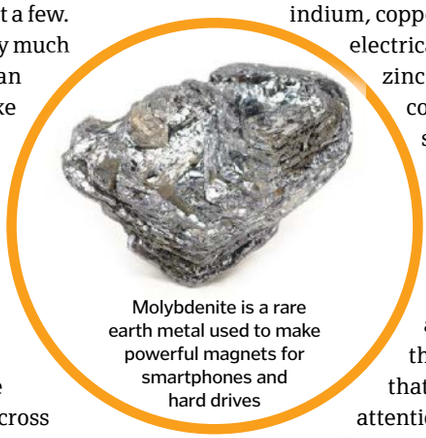
Thankfully, according to NASA, the Earth is not going to stop turning any time in the next few billion years.

WHAT IF... we ran out of rare earth metals?

The 17 rare earth elements are key ingredients in our most beloved technologies

The rare earth metals behave quite unlike other elements in the periodic table, and they have found their way into smartphones, hybrid cars, wind turbines, televisions, MRI scanners and lasers, to name just a few.

They are actually much more abundant than precious metals like gold, but they are difficult to mine, and we are already running out of good spots to dig. They are often bound up with radioactive materials, they are spread unevenly across the globe, and extracting them is expensive, dangerous, and damaging to the environment. China, who used to supply 95 per cent of the world's rare earth metals, has already restricted its exports.



Molybdenite is a rare earth metal used to make powerful magnets for smartphones and hard drives

Without these critical elements, the modern world as we know it could fall apart, but there are other more pressing problems to tackle. Before we run out of rare earth metals, we are likely to start running out of other vital elements too. Antimony and lead (used for batteries), indium, copper and gold (used in electrical components), and zinc (used to prevent corrosion) are all starting to run low.

The most obvious solution is to cut back, to find alternatives, and to recycle the metals that we have already extracted, but there is a fourth option that has sparked the attention of some intrepid explorers: searching in space. NASA, along with private companies like Planetary Resources, have set their sights on near-Earth asteroids, rich in useful elements. If we really did manage to burn through all of Earth's supplies, space mining could be a way to keep our technologies going.

Sleep is thought to help flush toxins from the brain

WHAT IF... you never slept?

The results are deadlier than you think

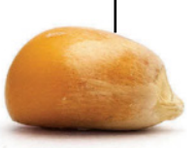
Without sleep, the mental and physical decline is rapid. It is so essential that the urge is nearly impossible to resist, but for a handful of people, a genetic disease prevents proper rest. Fatal familial insomnia is a genetic disease that results in near total deprivation of sleep. The results are severe: hallucinations, weight loss, dementia and eventually death.

Why does popcorn pop?

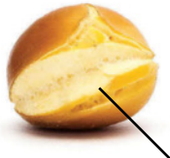
The explosive science that turns tough kernels into a tasty cinema treat

Popcorn can be either 'mushroom' (left) or 'butterfly' shaped (below), depending on how evenly it expands when popping

1 Critical temperature
Temperature is key; only 30 per cent of kernels pop when heated to 170°C, compared to over 90 per cent at the optimum 180°C.



2 Water content
Popcorn kernels are about 10-20 per cent water. When heated, the pressure in the kernel increases as the water vaporises.



3 Breaking point
Once the pressure inside the kernel reaches a certain level, the tough outer shell bursts open.

4 Pop!
High-pressure steam escaping through the kernel fracture causes the characteristic popping sound.

5 Starch
As the kernels cook, starch molecules expand and soften to form spongy 'flakes'.

6 Jumping
Scientists discovered that a 'leg' of starch expanding against the pan's surface propels the popping corn into the air.

7 Spinning
The kernel appears to turn inside out as it rotates, with the soft, starchy innards expanding outwards.

"High-pressure steam escaping through the kernel fracture causes the characteristic popping sound"

THE COLOURS OF BLOOD

Animals have evolved some colourful methods of getting oxygen around their bodies

Red

Humans and most other vertebrates

Humans and most other vertebrates have red blood thanks to a protein called haemoglobin. Iron atoms in the haemoglobin molecule bind to the oxygen we breathe in order to carry it around the body. This reaction changes the haemoglobin's structure so it absorbs and reflects light differently; oxygenated blood appears bright red while deoxygenated blood is darker.

Green

Marine worms and leeches

Certain species of marine worms and leeches have a molecule called chlorocruorin in their blood. Although this protein is very similar in structure to haemoglobin, it makes their blood green rather than red. Some animals' blood contains a mixture of both chlorocruorin and haemoglobin, so overall it appears red.

Blue

Octupuses, squid and spiders

Octupuses, squid, crustaceans, spiders and some molluscs have blue blood because it contains a protein called haemocyanin. Unlike haemoglobin (which is bound to red blood cells) haemocyanin flows freely in the vessels, and contains copper atoms rather than iron. Although the oxygenated form of this blood is a shade of blue, it is actually colourless when deoxygenated.

Purple

Marine worms and brachiopods

Some species of marine worms and brachiopods have blood that contains a protein called haemerythrin, which gives it a purple-pink hue when oxygenated. However, similar to haemocyanin, haemerythrin is colourless in the absence of oxygen. While this protein also contains iron atoms, compared to haemoglobin it isn't as well suited to binding with oxygen molecules.

WWF ADOPTION

© KLEIN & HUBERT / WWF

ADOPT HIM TODAY. OR LOSE HIM FOREVER.

Will you help the snow leopard claw its way back from the brink?

The purrrfect gift!

Snow leopards have survived in the Himalayas for thousands of years. But right now, there are as few as 300 left in Nepal. The harsh reality is that they're being hunted by poachers for their bones and precious fur – and they urgently need your help if they are to live on.

By adopting a snow leopard today, you'll help protect this endangered big cat for future generations.

Your present. Their future.
For as little as £3 a month, you or your loved one will receive an adoption pack, an adorable cuddly toy and regular updates from people on the ground working tirelessly to help save the beautiful snow leopard.

What's more, you'll have the satisfaction of knowing you're helping us to train and equip courageous anti-poaching rangers. And you'll discover what it takes – and how it feels – to help save a species.


a gorgeous snow leopard toy

+


an adoption pack

+


regular updates from the field

= *from just* **£3 a month**

Adopt a snow leopard today by filling in the form below, visiting wwfsnowleopard.com or calling 0845 200 2392

Yes, I would like to adopt a snow leopard today

Please indicate how much you would like to give each month

I would like to give ☐ £3 ☐ £5 ☐ £7 ☐ £10

My choice £ ☐ each month (min. £3)

Purchaser details

Title:_____ Initial:_____ Surname: _____

Address:_____

_____ Postcode: _____

Tel no: _____ Date of birth: _____

Email:* _____

*Please supply if you would like to receive emails from WWF (you can unsubscribe at any time)

Gift recipient details (if applicable)

☐ Tick this box if your adoption is a gift, then complete the details of the recipient below

Title:_____ Initial:_____ Surname: _____

Address:_____

_____ Postcode: _____

Gift recipient's date of birth: _____

Would you like us to send the adoption pack directly to the recipient? ☐ Yes ☐ No

We'd like to keep you up to date with our projects and activities by post and telephone. If you'd prefer not to receive information in this way you can email us at supportercare@wwf.org.uk or call us on 01483 426333.

DIRECT DEBIT – WWF-UK

DIRECT Debit

Instruction to your Bank or Building Society to pay Direct Debits.

Service User Number 9 9 1 4 7 3

1. Name and full postal address of your Bank or Building Society Branch

To the manager of:_____ Bank or Building Society

Address:_____

_____ Postcode: _____

2. Name(s) of account holder(s)

3. Branch sort code ☐☐-☐☐-☐☐

4. Bank or Building Society account number ☐☐☐☐☐☐☐☐

5. WWF-UK Reference Number (Office use only)

6. Instructions to your Bank or Building Society

Please pay WWF- UK Direct Debits from the account detailed on the instruction subject to the safeguards assured by the Direct Debit guarantee. I understand that this instruction may remain with WWF-UK and, if so, details will be passed electronically to my Bank/Building Society. Banks and Building Societies may not accept Direct Debit Instruction for some types of account.

Signature(s): Date:

Your money will support our work to help save the snow leopard as well as other vital conservation projects.

Freepost RTSK-ZCLS-EEUZ, WWF-UK, York House, Wetherby Road, Long Marston, York, YO26 7NH

APU001192

FRSB give with confidence

Understanding diabetes

Peek inside the body to see what happens when blood sugar gets out of control

Gorging on a rich, moist piece of chocolate cake is a guilty pleasure for many, but people with diabetes have to think twice before taking a bite. Diabetes is a long-term medical condition where the body can't process sugar in the bloodstream properly, so sweet treats can be dangerous for more than just their waistline.

Sugar in the blood comes from what we eat and drink and is regulated by the hormone insulin, which is produced by the pancreas. This organ is about 15 centimetres long and located behind the stomach. The pancreas mainly secretes digestive enzymes, but a small part produces hormones. Insulin is produced by beta cells, which are clustered in groups called the islets of Langerhans (named after the scientist who first described them).

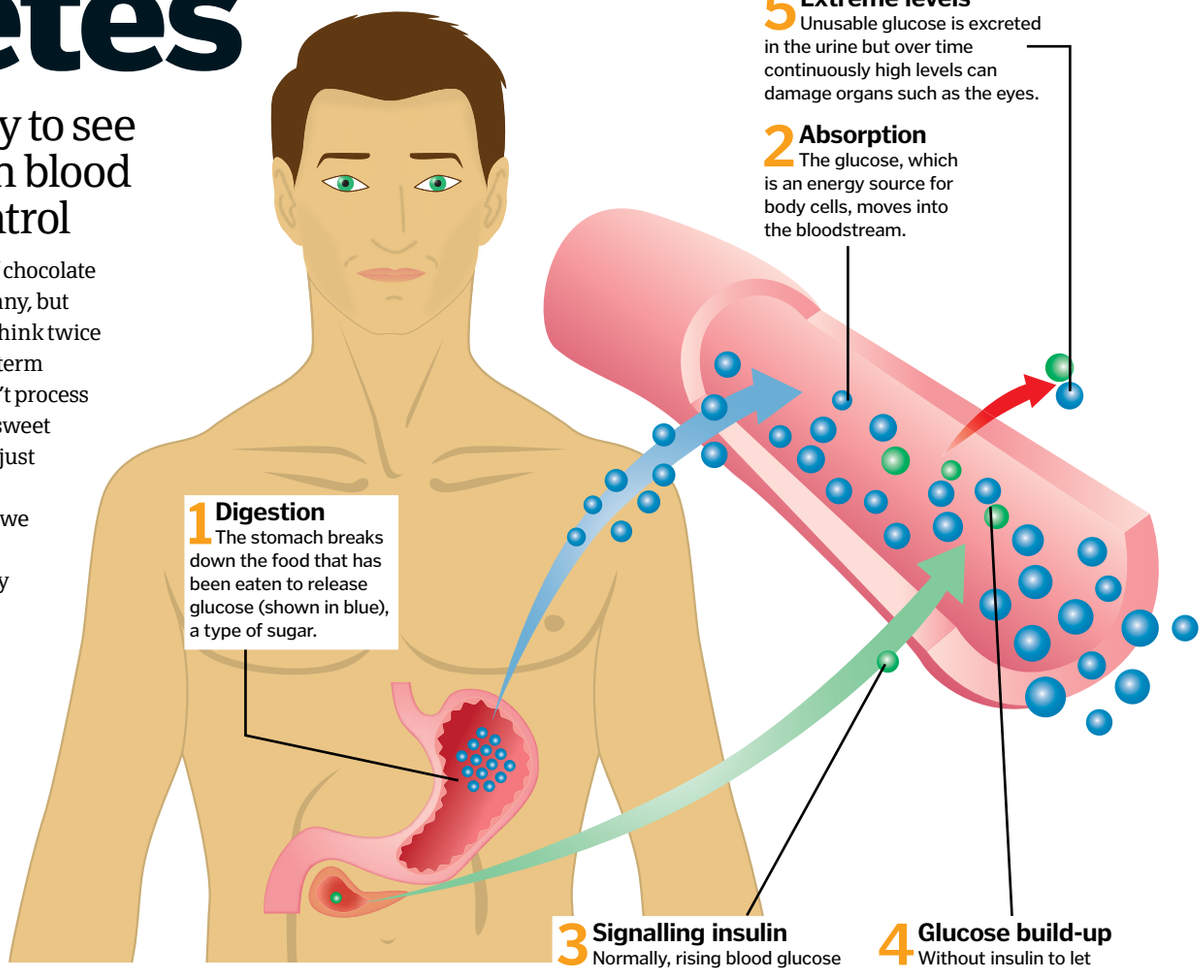
In diabetes, the normal process of producing insulin and regulating blood sugar goes awry. This can happen in two different ways. In type 1 diabetes, the pancreas doesn't produce any insulin because the body's immune system attacks the beta cells and kills them. In type 2, not enough insulin is produced, or the body becomes resistant to insulin and is unable to respond to it. Both types can lead to high blood sugar levels called hyperglycaemia, which can damage the eyes, kidneys, nerves and blood vessels over time.

The symptoms for both types of diabetes include extreme thirst, urinating more frequently, tiredness, unexplained weight loss, blurred vision and the slow healing of cuts. Both types can develop at any age, but type 2 diabetes is much more common, and is often associated with obesity.

There is currently no cure for diabetes. People with type 1 diabetes have to control their blood sugar for the rest of their lives by monitoring the levels and injecting insulin. People with type 2 diabetes have to make lifestyle changes, and often need to take medication.

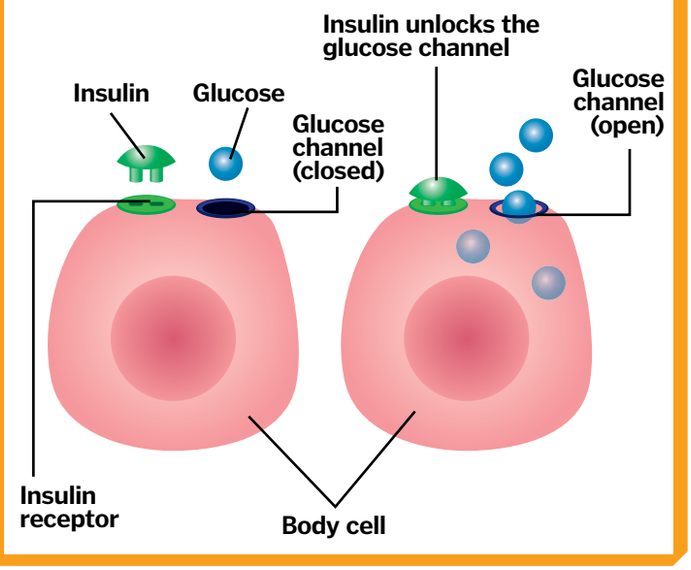
Type 1 diabetes

When the pancreas doesn't make insulin, glucose hangs around in the blood



How insulin works

Sugar, in its simplest form as glucose, is an energy source for our body's cells. It moves into cells most efficiently when a signal is given by the hormone insulin. When blood glucose rises after a meal, insulin is released from the pancreas into the bloodstream and acts like a key to unlock and open the glucose channels on the cell surface, allowing glucose to enter. When there is no insulin or the cells can't respond to it, the levels of sugar in the blood build up, leading to hyperglycaemia. Conversely, when blood glucose gets too low, it is known as hypoglycaemia.



Diabetes and exercise

Exercise can cause blood glucose levels to fluctuate, though this is less drastic in people with type 2 diabetes than those with type 1. Low blood sugar (hypoglycaemia) can occur because muscles use glucose as energy and the body becomes more sensitive to insulin. High blood sugar (hyperglycaemia) can be triggered by other hormones, such as adrenaline, which are released during exercise.

Maintaining an optimal blood sugar target in type 1 diabetes requires balancing the insulin dose with what the person eats and drinks and the amount of exercise they do, taking into account external factors like temperature. Everyone's diabetes is different and individuals react differently to exercise. Physical activity, however, can help improve blood glucose management and the efficient working of insulin.

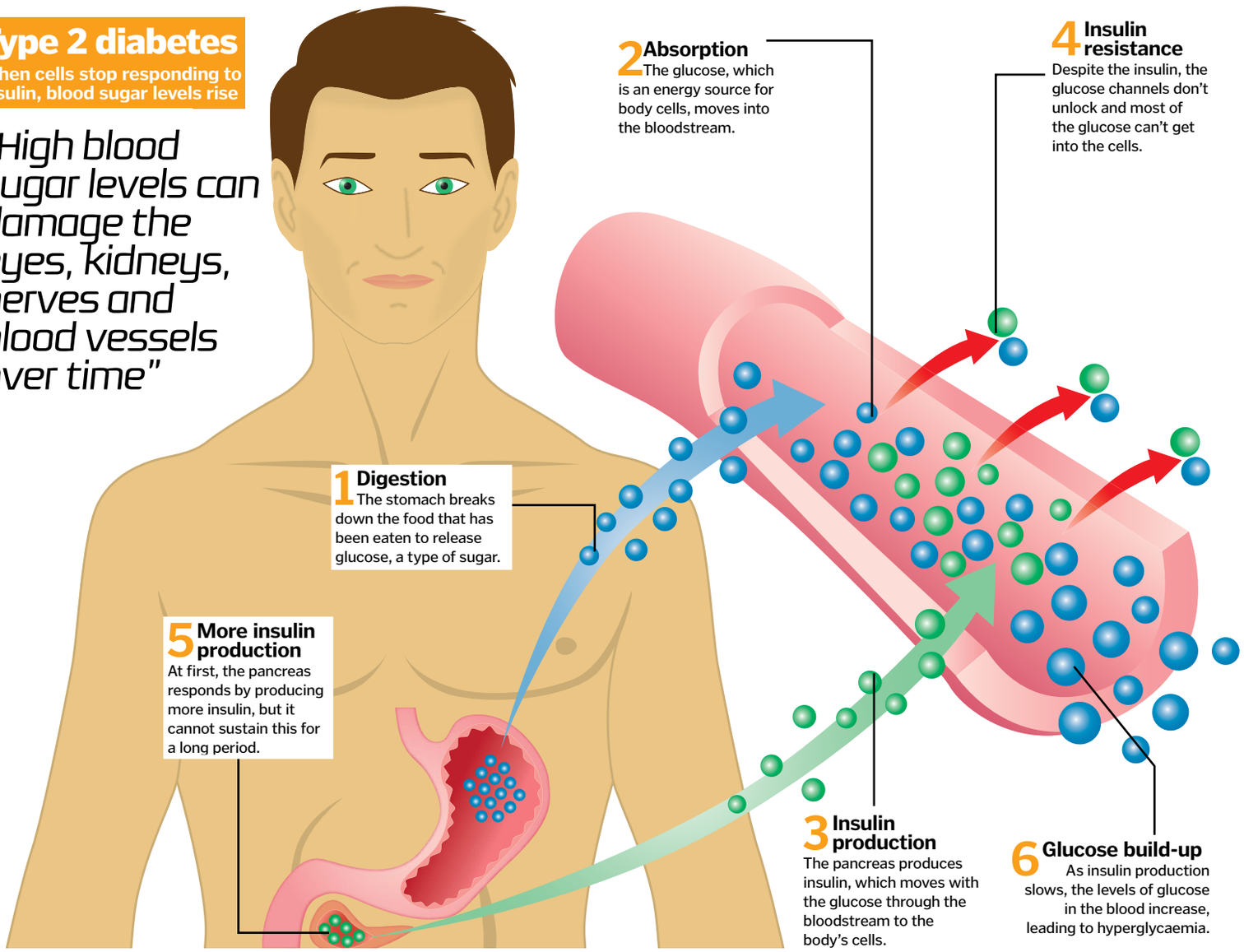
Cycling is a physically challenging endurance sport and Team Novo Nordisk, an all-diabetes pro-cycling team, must monitor their blood glucose before, during and after racing with a continuous glucose monitor. The cyclists will 'carb-load' (eat high carbohydrate foods) before a race and will have a high-carbohydrate drink afterwards. During a race, riders frequently check their blood glucose. If their blood sugar is above target, they may take medication to lower it, and if the level is below target, they may consume a carbohydrate-rich food or drink to bring it back up.

Athletes with diabetes, like the members of Team Novo Nordisk, monitor blood glucose before, during and after exercise

Type 2 diabetes

When cells stop responding to insulin, blood sugar levels rise

"High blood sugar levels can damage the eyes, kidneys, nerves and blood vessels over time"



1 Digestion
The stomach breaks down the food that has been eaten to release glucose, a type of sugar.

2 Absorption
The glucose, which is an energy source for body cells, moves into the bloodstream.

3 Insulin production
The pancreas produces insulin, which moves with the glucose through the bloodstream to the body's cells.

4 Insulin resistance
Despite the insulin, the glucose channels don't unlock and most of the glucose can't get into the cells.

5 More insulin production
At first, the pancreas responds by producing more insulin, but it cannot sustain this for a long period.

6 Glucose build-up
As insulin production slows, the levels of glucose in the blood increase, leading to hyperglycaemia.

60 SECOND SCIENCE

States of matter

THE CHEMISTRY OF SOLIDS, LIQUIDS, GASES AND PLASMA EXPLAINED

BACKGROUND

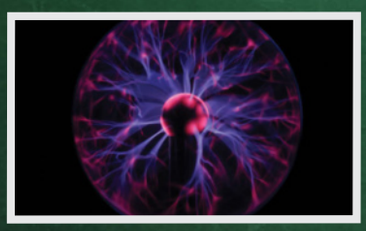
Matter can exist in different forms depending on the environment. There are four fundamental states: solid, liquid, gas and plasma. On Earth, we are most familiar with the first three, but the most common state in the universe is actually plasma.

There are several other states of matter that are rarer, including Bose-Einstein condensates, quark-gluon plasma, and degenerate matter.

IN BRIEF

The states of matter that we are all familiar with are solids, liquids and gases. The particles that make up solids are packed so tightly together that they barely move. They can be made up of mixtures of different atoms, or from repeating patterns of the same atoms that fit together to form crystals.

Liquids are looser. The particles are close together, but aren't in fixed positions. This means that they can flow. Gases are more loosely packed. The particles are far apart, and they move around rapidly in different directions, expanding to fill a container. The fourth state of matter is plasma. It is a bit like gas, but the atoms themselves have broken apart, becoming ionised and forming a sea of free electrons and atomic nuclei.



As electricity passes through gas, it breaks down to form filaments of glowing plasma

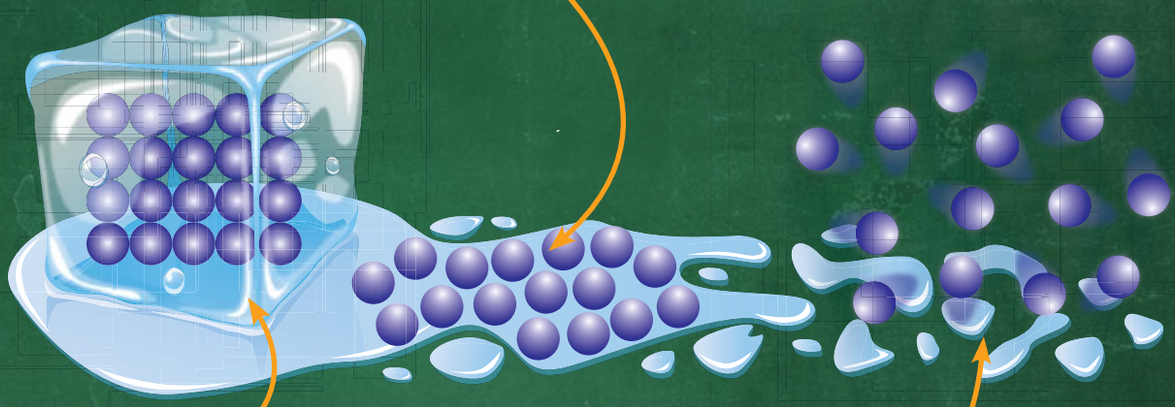
SUMMARY

The main states of matter are solids, liquids and gases. Their properties differ; particles in solids are static, in liquids they move more freely, and in gases they move quickly in all directions.

States of water

On Earth, water naturally exists in all three states

Water
Between 0 and 100 degrees Celsius, water is liquid. The molecules are still close together, but they move more freely. Clumps of molecules slide past one another, and groups form and break apart as the liquid flows.



Ice
Below 0 degrees Celsius, water is a solid. The molecules line up to form a neat crystal structure, and barely move from their original positions.

Steam
Above 100 degrees Celsius, water becomes a gas. Individual molecules are far apart and can't hang on to each other to form groups or solid structures. Instead, they move around on their own.

"As the temperature increases, the particles gain energy and are able to move past each other"

FROM ONE STATE TO ANOTHER

IN NATURE, MATTER CAN TRANSITION BETWEEN THE FUNDAMENTAL STATES, TURNING FROM PLASMA, TO GAS, TO LIQUID, TO SOLID AND BACK AGAIN. AT COLD TEMPERATURES, PARTICLES HAVE LITTLE KINETIC ENERGY AND ARE FIXED IN POSITION, FORMING A SOLID. AS THE TEMPERATURE INCREASES, THE PARTICLES GAIN ENERGY AND ARE ABLE TO MOVE PAST EACH OTHER. AT THIS POINT THE MATTER IS IN A LIQUID STATE. WITH A FURTHER TEMPERATURE INCREASE, THE PARTICLES HAVE ENOUGH ENERGY TO MOVE FREELY, AND THE MATTER IS A GAS. UNLESS THEY ARE IN A CONTAINER, THE ATOMS WILL SPREAD OUT INFINITELY. IF THE ATOMS BECOME HOT ENOUGH, THEIR ELECTRONS ARE STRIPPED AND THEY BECOME PLASMA.

Machines assemble minifigures using precise amounts of pressure

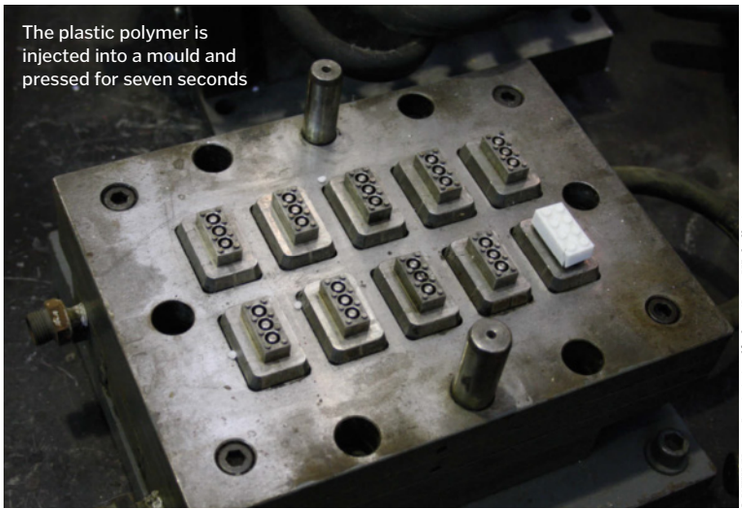
How Lego is made

The chemistry of the world's most popular toy revealed

With a little imagination, LEGO bricks can be whatever you want them to be: a boat, a dragon or a shrunken skyscraper. At a chemical level, however, the bricks are made from a mixture of three different compounds – acrylonitrile, 1,3-Butadiene and styrene – creating a plastic known as ABS.

Separately, these small compounds are known as monomers, but many of them can react together to create long molecules known as polymers. A simple analogy for this is a beaded necklace: the individual beads are small, but lots of them can be strung together to form a long chain. The trio of monomers in ABS gives LEGO bricks certain properties: acrylonitrile makes the bricks strong, 1,3-Butadiene helps stop them snapping, while styrene gives them a shiny surface.

To create the bricks, small grains of ABS and colourants are melted together at 230 degrees Celsius. This molten mixture is injected at high pressure into moulds of the required shape, left to cool and set, then ejected – all in less than ten seconds. To make sure different pieces always fit together perfectly, the moulds are designed by computer software that's accurate to within two-thousandths of a millimetre!



The plastic polymer is injected into a mould and pressed for seven seconds

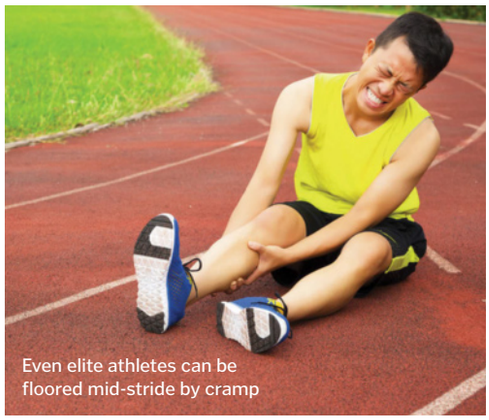
Muscle cramps

What causes these unexpected and painful spasms?

Cramp occurs when your muscles involuntarily contract very quickly and do not relax again straight away. These sudden spasms commonly affect the calves and last just a few seconds, but can persist for 15 agonising minutes or more. Normally, your calf muscles contract to raise your heels and relax to lower them, allowing you to walk, run and jump. However, during a cramp these muscles contract tightly and unexpectedly, leaving you unable to control them until the contraction subsides. The affected muscles remain tense and painful while they refuse to relax.

Despite being such a common experience, nobody knows exactly what causes these random contractions. It's thought that excessive strain on the muscles or a restriction in blood supply could be contributing factors, but one of the most prevalent theories is that cramps are caused by abnormal nerve activity.

Receptors within muscles and tendons constantly monitor the body's movement and position. These receptors send reflex signals (which bypass the brain) to protect the muscles from potential damage. One reflex encourages muscle contraction, to prevent overstretching, while the other promotes relaxation to control tension. These reflexes are normally balanced, but can be disrupted so that the contraction signal overwhelms the relaxation one, resulting in the unexpected, intense and painful muscle spasm of cramp.



Even elite athletes can be floored mid-stride by cramp

They are often associated with exercise, but cramps can also strike when you least expect them. According to the NHS, 75 per cent of leg cramp cases occur during sleep. It's the ultimate in rude awakenings.

Types of cramp

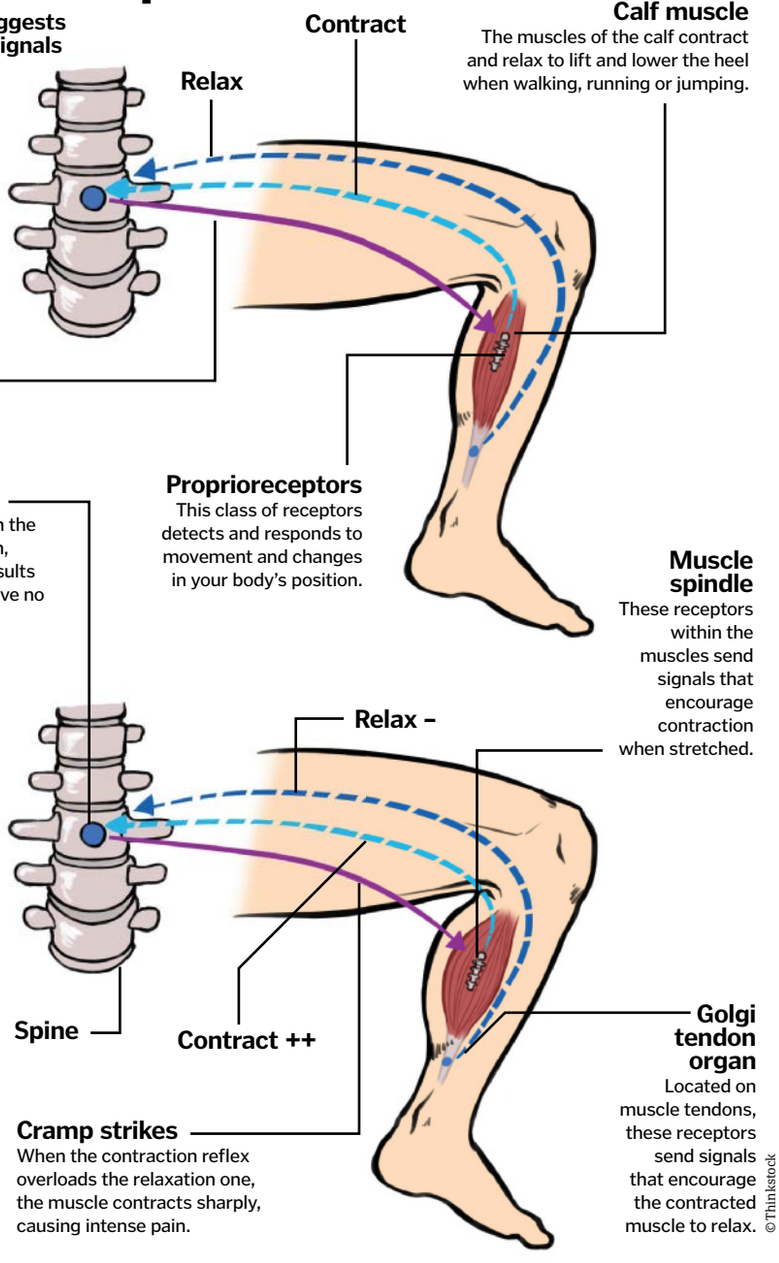
Apart from being an inconvenience, cramps are generally harmless. However, if they persist for more than 15 minutes, or reoccur regularly, they may be a symptom of an underlying problem.

Leg cramps can be divided into two categories: idiopathic or secondary. Idiopathic leg cramps seemingly happen for no reason, like those that occur just as you're drifting off to sleep. Secondary leg cramps are related to pre-existing conditions or particular activities, such as infections, neurological disorders, strenuous exercise or dehydration. Pregnant women may also become vulnerable to cramps, as the weight of the growing foetus puts extra strain on their legs.

The best way to ease idiopathic cramps is by stretching and massaging the affected muscle

What causes cramp?

The leading theory suggests that disrupted nerve signals may be to blame



TRAVEL 2050

YOUR TICKET TO THE HIGH-TECH HOLIDAY OF THE FUTURE

It's 2050 and taking a vacation is easier than ever, thanks to the latest technological breakthroughs. Over the next few pages, we'll guide you through every step of your trip, from planning and booking, to travelling and making the most of your stay.

Some of the technology involved might seem unbelievable, but all of it was in fact already real, or under development, in the year 2016. Take the process of booking your trip, for example. You may have been using comparison websites to find the best deals, but now you don't need to enter your information, as online travel agents already know your preferences. Gareth Williams, CEO and co-founder of travel company Skyscanner, said: "Travel search and booking will be as easy as buying a book on Amazon."

There's no longer any guesswork involved in picking your destination either, as Nik Gupter, Skyscanner's director of hotels, predicted back in 2016: "In ten years' time a traveller will be able to take a virtual reality walk through the hotel he is planning to book in real-time."

The stress of travelling is long gone and getting to your destination is almost as enjoyable as the holiday itself. In 2016, Melissa Weigel from design studio Moment Factory said: "In the near future, airports will be an intrinsic part of the holiday experience." Since then, automated check-in and speedy security scanning has made boarding your flight a breeze.

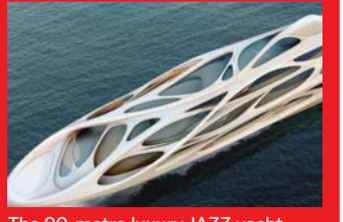
Holiday destinations have also changed a great deal, as futurist Daniel Burrus predicted: "Relatively affordable trips in low Earth orbit that enable you to experience a few minutes of weightlessness will happen very soon." Now we've our sights on the Moon and Mars.

CHOOSE YOUR MODE OF TRANSPORT

Dassault Systèmes' concept for a flying cruise liner

The Spike S-512 jet will mirror the speed of Concorde

Avoid the airport altogether by taking your TF-X flying car



The 90-metre luxury JAZZ yacht features an indoor pool

BOOKING YOUR HOLIDAY

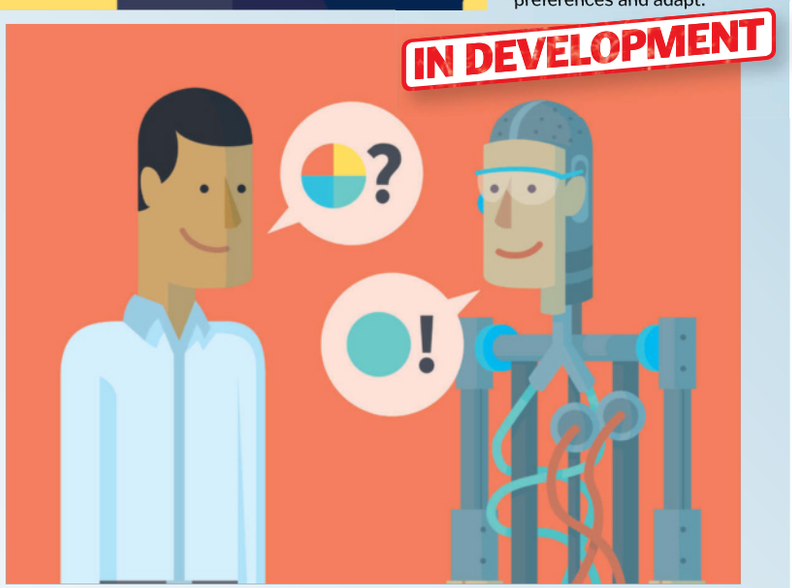
Get the VIP treatment from the off

Choose a destination

Social media and online retailers use members' profiles to monitor activity and alter the content they see. Travel brands now operate in a similar way, logging your likes and dislikes, while facial coding algorithms, as developed by Affectiva, enable search engines to read human expressions and gauge how happy you are with the results.

Use an e-agent

You can rent an artificially intelligent e-agent from your local travel company to help plan your trip. The tech is similar to JIBO – the personal assistant released in 2015 that uses two hi-res cameras to recognise faces and algorithms to learn your preferences and adapt.



Take a virtual vacation

VR headsets enable you to try before you buy. By using dual lenses with a slightly different image in front of each eye, it recreates your normal stereoscopic vision and fools your brain into thinking virtual worlds are real. Disney's Revel system, developed in 2012, uses electrical signals to create the feeling of touch.

Book with ease

While apps like Expedia enabled 2016 holidaymakers to arrange most aspects of their trip, 2050 takes the tech a step further. You can use a one-stop app to book your flights, hotel and holiday activities with a couple of taps of your smartwatch. Even transport to the airport will be taken care of.

AT THE AIRPORT How tech will take the stress out of travelling

Smart tags

As you drop off your bags, they're fitted with tags containing Near Field Communication (NFC) chips. When they come into close contact with another NFC chip inside the scanner, your personal and flight data is transferred wirelessly. You can then track each scan via an app.

Biometric scans

Instead of a passport, a biometric data card is used to identify you. Images of your eye, taken with a camera that records visible and infrared light, capture the exact position of the iris' unique patterns and features. As you board the plane, your eyes are scanned and matched.

Speedy checks

The Picosecond Programmable Laser is a scanner that vibrates the molecules in your body and possessions to identify different substances, from traces of gunpowder to the contents of your stomach. It's 10 million times faster than a conventional scanner.

ON THE PLANE

Your journey will fly by as you explore the onboard entertainment options

Instead of waiting around at the gate, you are free to explore the airport's rooftop gardens, art exhibitions and shops at your leisure, safe in the knowledge that a 3D holographic assistant will appear to tell you when the plane is boarding.

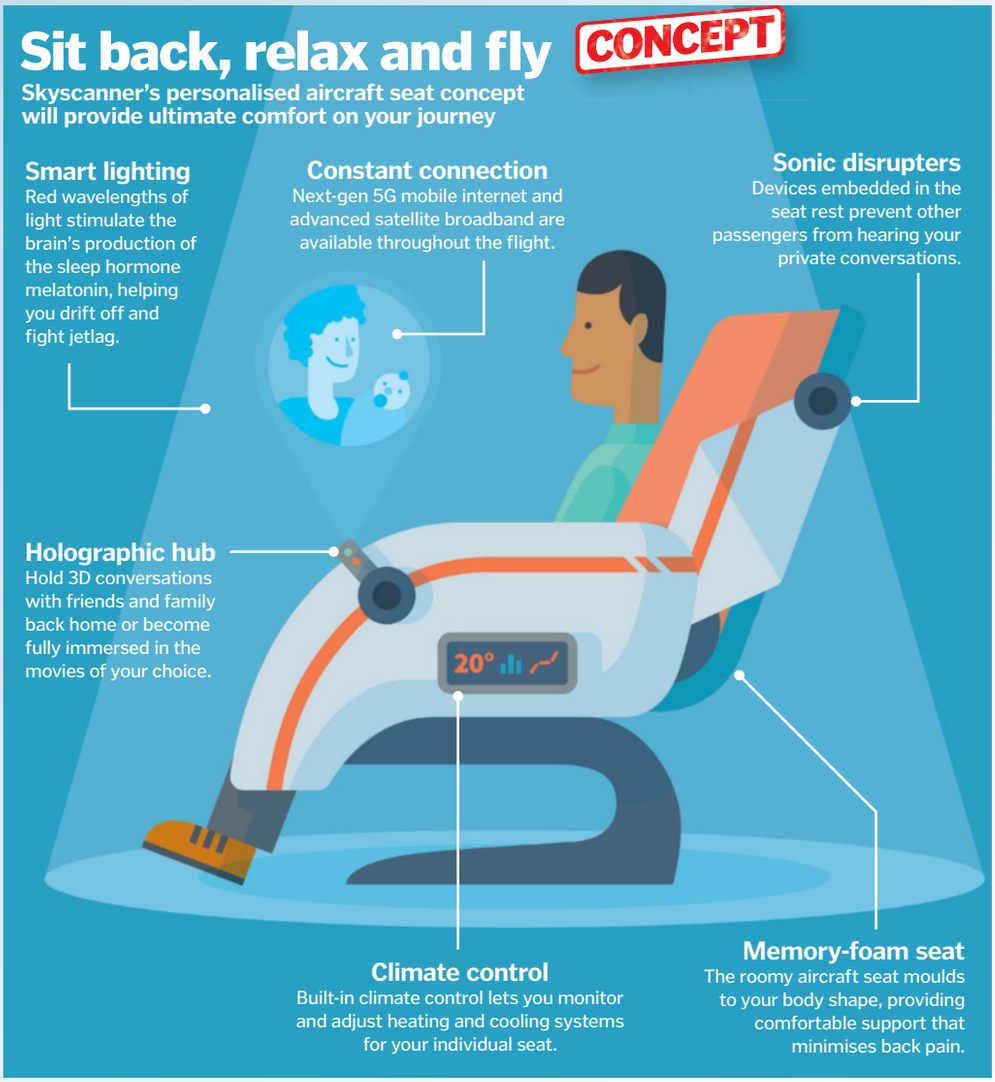
Holograms have been around since the development of lasers in the 1960s, but recent advancements in technology mean they're now much more impressive. They used to be created by splitting a laser beam in two and directing each beam towards an object using mirrors. The beams were then reflected off the object and at the point where they recombined, a still hologram of the original object formed. In recent years, we've mastered moving holographic images, resulting in ultra-realistic 3D content for entertainment and practical uses.

When it's time to stroll onto the plane, you'll find that the Airbus Concept Cabin has become reality, and you're no longer confined to your own seat. First class and economy have been replaced with zones tailored to your different needs, whether you want to relax, mingle with other passengers or play some games.

Sit back, relax and fly

CONCEPT

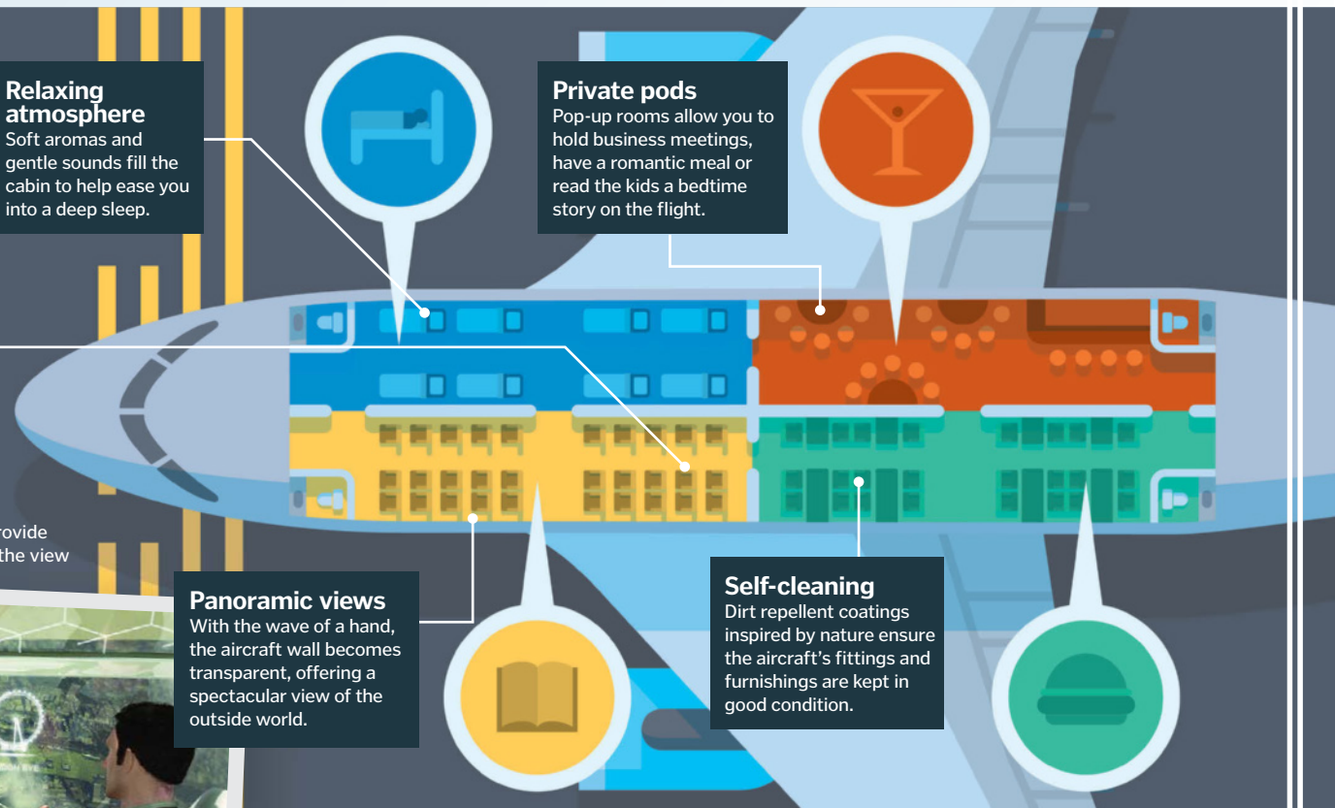
Skyscanner's personalised aircraft seat concept will provide ultimate comfort on your journey



CONCEPT

Modular aircraft

A cabin design with zones for work, rest and play



Interactive window displays provide interesting information about the view

YOU HAVE REACHED YOUR DESTINATION

The smart hotel room will ensure the stress-free experience continues

Once you've stepped off the plane and swiftly passed through immigration with your biometric card, you will find another driverless taxi waiting to take you to your hotel. Instead of having to pick up your room key at the check-in desk, you can proceed straight to your room and unlock it using your smartphone, a system that was adopted early by Hilton and Marriott hotel chains.

Your bags are delivered to your door by a robot butler, such as Botlr, the droid employed by Aloft Hotels at their Californian establishments. He can be summoned via an app to bring you any toiletries you may have forgotten to pack, or deliver a tasty snack to help you refuel after your long journey.

Just as everything in your own home is connected to the internet, all of your hotel room's appliances are smart and intuitive too. You can even upload your home temperature preferences to the room's Nest thermostat, and display family photos on the digital wall displays, to help you feel really at home.

A good night's rest is guaranteed as the Sleep Number x12 bed features sensors that monitor your sleep, ensuring the alarm clock gently wakes you at the optimum time, and can tilt the pillows to stop your partner snoring. All of this tech already existed as of 2016, but has since been adopted by hotels throughout the world.

EXISTS

Future hotel rooms

The intuitive tech-filled rooms that will provide a home away from home

Motion sensors
Upon entering the room, the lights automatically switch on and the coffee machine whirs into action.

Smart mirror
As you get ready for the day, the local weather, news stories and your emails are projected over your reflection.

Touchscreen control
A central interactive hub gives you control over all internet-connected appliances to fully customise the temperature, humidity and lighting in your room.

Keyless entry
Avoid check-ins by downloading your key code onto your phone and scanning it at your hotel room door.

Biometric safe
Keep your personal possessions secure in a safe that only opens when it scans your fingerprint or retina.

Robot butler
Your luggage, room service, fresh towels and more are delivered by a robot that you can summon via an app.

Wireless charging
Forget to bring your phone charger or plug adapter? Don't worry, there's an inductive charger built into the bedside unit.

VR headset
Get a taster of local attractions by paying a virtual visit via the VR headset in your room.

WEIRD HOTELS THAT ACTUALLY EXIST

©ICEHOTEL/Paulina Holmgren

The frozen hotel

Made entirely from 'snice' – a mixture of snow and ice – the Icehotel in Sweden melts in the summer and is rebuilt every winter, with construction taking just six weeks. Temperatures inside the hotel are between -5 and -7 degrees Celsius.

The salt palace

Located on the edge of the world's largest salt flats in Bolivia, the Palacio de Sal has been built using one million blocks of salt and features 16 rooms, a spa and a golf course. Everything from the walls to the beds is made entirely from salt.

The jumbo experience

If you haven't had enough of airplanes by the time you leave the airport, then Jumbo Stay will let you dwell in one too. The converted 747-200 jumbo jet is grounded near Arlanda Airport in Sweden and features over 30 rooms.

World View's helium-filled balloon will float a capsule full of space tourists to the edge of space

At the spaceport

IN DEVELOPMENT

Catch a space plane into orbit from your local spaceflight hub

WANT TO KNOW MORE?
Learn all about Spaceport America and its mission
PAGE 70

SPACE TOURISM

Take a trip that's literally out of this world

If you really want to escape from it all, then how about leaving the planet altogether? Space tourism is a billion dollar market in 2050 and there are several companies offering trips. Blue Origin, the company set up by Amazon founder Jeff Bezos, can offer you breathtaking views from its New Shepard spacecraft as you soar over 100 kilometres above Earth.

You'll need to arrive at the desert launch site in West Texas two days before your flight so you can begin your astronaut training. You'll receive mission and vehicle overviews, in-depth safety briefings and instructions on how to move in a weightless environment. When the morning of your flight arrives, it's time to scale the steps of the launch tower and climb through the hatch of the capsule, which sits on top of an 18-metre tall rocket.

Once you're strapped in and have received final clearance for launch, the countdown to lift-off will begin. The extreme acceleration will force you back into your seat and you'll experience over 3 g for 150 seconds and then the booster engine will cut off as you glide into space. The capsule will separate from the booster, and from the serene silence will come the signal to release your harness.

As you float out of your seat and marvel at the weightless freedom, you'll forget that you're travelling faster than Mach 3 – three times the speed of sound – and stare back at Earth out of the capsule window. Before descent, you will return to your seat to strap in for re-entry. Forces of over 5 g will push against you before the parachutes deploy and thrusters fire, reducing your speed as you gently float back to Earth. Once you've landed, just miles from where you launched, you can go and collect the complimentary souvenirs of your thrilling trip. That's right; novelty keyrings still exist in 2050.

Blue Origin first vertically landed a booster in 2015, paving the way for reusable rockets

XCOR Aerospace is planning to launch its Lynx spaceplane from its Curaçao spaceport

UNDERWATER HOTELS

Sleep, eat and relax with the fishes

Back in 2016, the closest thing to an underwater suite was the five-star Atlantis, The Palm, in Dubai. The floor-to-ceiling views of a colossal aquarium created such a spectacular illusion that celebs like Kim Kardashian were willing to splash the cash to stay there.

But while a fully-fledged underwater haven like the Water Discus Hotel was just a concept in 2016, its doors are open in Dubai in 2050. Once you arrive by boat or helicopter from the shore, you can relax in your room and watch the marine critters swim by, or sign up for a diving course to get even closer to the action. You don't even need to go back up to the surface in order to get in the water, as there's sea access direct from the underwater disc.

Underwater suites at The Palm, Dubai, offer views of 65,000 marine animals

CONCEPT

The Water Discus

Get up close with marine life in Dubai's ocean hotel

Upper disc
Located five to seven metres above the water, this disc features a restaurant, spa, swimming pool, garden and helipad.

View to the sky
A wide shaft with a view of the sky helps to minimise any claustrophobic feelings you may have underwater.

Remote-controlled cameras
Underwater vehicles equipped with cameras can be operated from inside the hotel, giving you an even closer view of your marine surroundings.

Safety first
The underwater disc will automatically float to the surface in the event of an emergency, such as an earthquake.

Sturdy structure
The two large discs of the structure are anchored to the seabed by four legs, and joined by a vertical shaft containing a lift and stairway.

Underwater disc
Submerged around ten metres below sea level, this disc features 21 hotel rooms, an underwater dive centre and a bar.

Underwater airlock
Divers can go straight out into the ocean from the underwater disc, which is equipped with a decompression chamber.

The metals in your phone

Discover the hidden treasure inside your handheld device

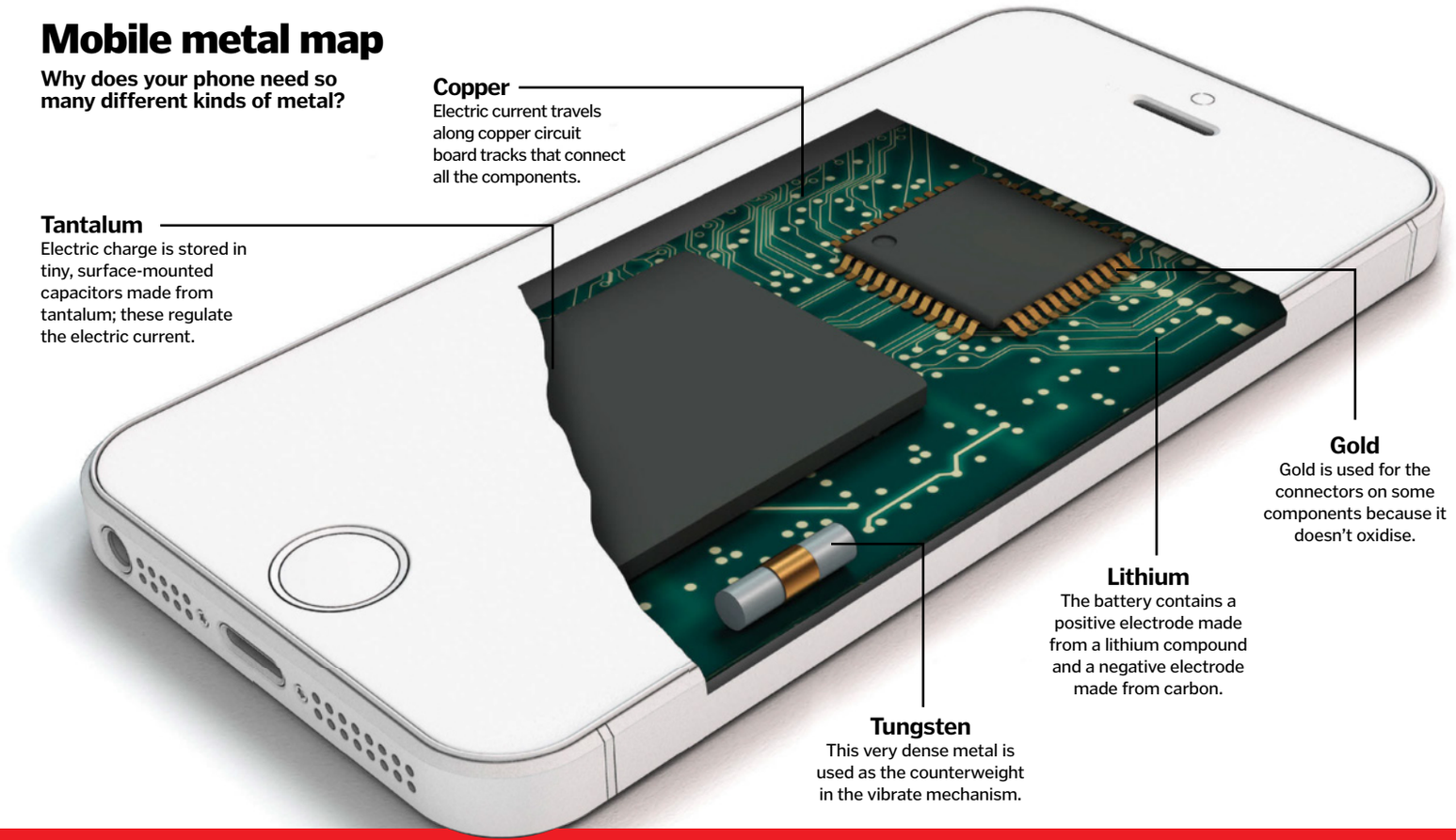
The average smartphone contains up to 62 different metals, some of which are rare and valuable. As much as 15 per cent of the phone's weight is accounted for by copper, which is used to make the tracks that conduct electricity between components. Copper is used because it has low resistance and is fairly soft.

Gold is nearly 600 times more expensive than copper and actually has slightly higher resistance, but it is still favoured for certain connections on a phone circuit board because it doesn't corrode. It's harder to solder than copper is though, because it dissolves into the normal tin-silver-copper solder alloy used in the electronics industry. Gold contacts need to be attached using special indium-tin solders or bonded directly using both heat and ultrasound energy.

Another important element used in smartphones is the silver-grey precious metal tantalum. Although a typical smartphone only contains about 40 milligrams of this metal, it is absolutely crucial to the miniaturisation of mobile phone technology. Tantalum is used to make powerful capacitors, which store electricity and are a fraction of the size of ordinary electrolytic capacitors.

Mobile metal map

Why does your phone need so many different kinds of metal?



Copper
Electric current travels along copper circuit board tracks that connect all the components.

Tantalum
Electric charge is stored in tiny, surface-mounted capacitors made from tantalum; these regulate the electric current.

Gold
Gold is used for the connectors on some components because it doesn't oxidise.

Lithium
The battery contains a positive electrode made from a lithium compound and a negative electrode made from carbon.

Tungsten
This very dense metal is used as the counterweight in the vibrate mechanism.

How do computers detect robots?

Bot spotting is an arms race between websites and spammers

Distorted text is designed to catch robot spammers

When you register at a new website, the line of wavy or distorted text that you have to type in is called a CAPTCHA. This stands for Completely Automated Public Turing test to tell Computers and Humans Apart and it's designed to prevent automated 'bot' programs from spamming users with hundreds of fake accounts.

A CAPTCHA is supposed to be easy for a human, but difficult for computers. In 2003, when CAPTCHA was invented, reading text against a busy background was insurmountably hard for bots. But AI research has improved a lot and the best bots can now read these simple CAPTCHAs with 99.8 per cent accuracy, which is actually better than humans!

More advanced CAPTCHAs now ask you to click on all the pictures of dogs in a grid of animal snaps, or identify whether a basketball, rugby ball or ice cream should go with the picture of a basketball hoop. Google's reCAPTCHA goes one step further and watches how you interact with the website. The pattern of clicks and mouse movements can betray the difference between a human and a bot.

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Chainsaws

Learn about the inner workings of this cutting-edge tool

The first chainsaw was actually a medical instrument, invented in 1785 by a Scottish doctor called John Aitken, for cutting through bone. In the early 19th century, logging companies experimented with steam-driven bandsaws, and in 1929 Andreas Stihl came up with the first petrol engine 'tree felling machine', but it weighed almost 50 kilograms and required two people to lift it!

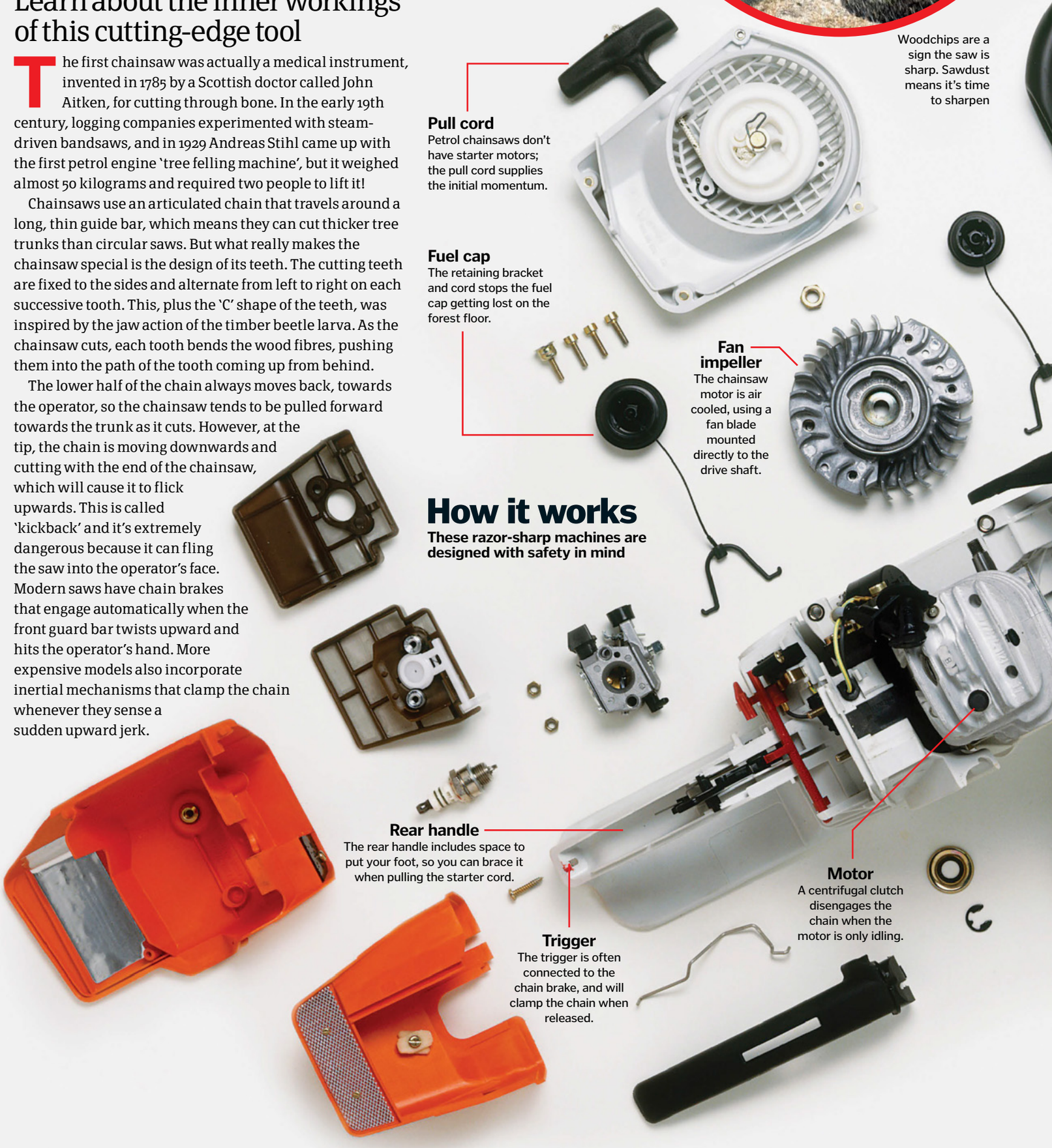
Chainsaws use an articulated chain that travels around a long, thin guide bar, which means they can cut thicker tree trunks than circular saws. But what really makes the chainsaw special is the design of its teeth. The cutting teeth are fixed to the sides and alternate from left to right on each successive tooth. This, plus the 'C' shape of the teeth, was inspired by the jaw action of the timber beetle larva. As the chainsaw cuts, each tooth bends the wood fibres, pushing them into the path of the tooth coming up from behind.

The lower half of the chain always moves back, towards the operator, so the chainsaw tends to be pulled forward towards the trunk as it cuts. However, at the tip, the chain is moving downwards and cutting with the end of the chainsaw, which will cause it to flick upwards. This is called 'kickback' and it's extremely dangerous because it can fling the saw into the operator's face. Modern saws have chain brakes that engage automatically when the front guard bar twists upward and hits the operator's hand. More expensive models also incorporate inertial mechanisms that clamp the chain whenever they sense a sudden upward jerk.

Woodchips are a sign the saw is sharp. Sawdust means it's time to sharpen

How it works

These razor-sharp machines are designed with safety in mind



Pull cord
Petrol chainsaws don't have starter motors; the pull cord supplies the initial momentum.

Fuel cap
The retaining bracket and cord stops the fuel cap getting lost on the forest floor.

Fan impeller
The chainsaw motor is air cooled, using a fan blade mounted directly to the drive shaft.

Rear handle
The rear handle includes space to put your foot, so you can brace it when pulling the starter cord.

Trigger
The trigger is often connected to the chain brake, and will clamp the chain when released.

Motor
A centrifugal clutch disengages the chain when the motor is only idling.

"Chainsaw teeth were inspired by the timber beetle larva"

Front guard
The front guard engages the chain brake when pushed forward, either deliberately, or by the force from a kickback.

Guide bar
This provides the guide track for the chain. Some guide bars also automatically lubricate the chain.

Bumper spikes
These are mounted at the base of the saw and allow it to be pivoted smoothly around a trunk.

Chain
The chain always rotates so that the top edge is moving away, to avoid spraying sawdust at the operator.

The sharpest link

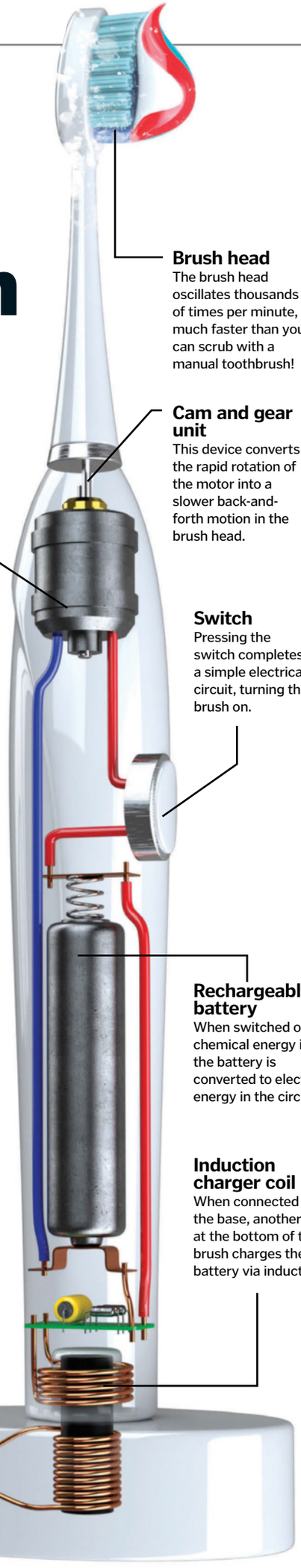
The teeth of the chainsaw are attached to the side plate of every second or third link on the chain. They are made of chromium steel, which is much harder than the rest of the chain. The sharpened edge of each tooth faces forward and sits just behind a rounded guard, called a depth gauge, or raker. As the chain comes into contact with the wood, the raker hits first and controls how deeply the tooth bites into the wood. When the cutting edges of the teeth are sharpened, the rakers need to be filed down slightly as well, or the chainsaw will cut less and less deeply into the wood. But filing the rakers down too far is very dangerous, because the chain can snag in the wood and kick back. 'Safety chains' have a long slope at the front of the rakers to reduce the chance that they will snag suddenly.

'Full complement' chains have one tooth every two links, compared to one every three for 'full skip'

Inside an electric toothbrush

Find out how these battery-powered brushes deliver a dental deep clean

Electric brushes are proven to be more effective than manual ones



Brush head
The brush head oscillates thousands of times per minute, much faster than you can scrub with a manual toothbrush!

Cam and gear unit
This device converts the rapid rotation of the motor into a slower back-and-forth motion in the brush head.

Motor
The electric motor converts electrical energy into mechanical energy, and rotates at high speed.

Switch
Pressing the switch completes a simple electrical circuit, turning the brush on.

Rechargeable battery
When switched on, chemical energy in the battery is converted to electrical energy in the circuit.

Induction charger coil
When connected to the base, another coil at the bottom of the brush charges the battery via induction.

Charging base
Electricity from the mains flows through an inductive coil in the base.

How smoke detectors work

They may annoy us when toast burns, but these ear-piercing devices save lives

There are two main types of smoke detector: optical and ionisation. Optical detectors contain an infrared light beam pointing toward a photocell, which generates electricity when light falls on it (like on solar panels). When there is no smoke, the light reaches the photocell unobstructed. This is registered by the internal circuitry so the alarm is not triggered. When there is a fire, smoke enters the detector and blocks the beam of light, so the photocell can no longer produce an electric current. This change is picked up by the circuitry, triggering the alarm and alerting people to danger.

Ionisation detectors contain a small sample of a radioactive substance, typically americium. This element constantly emits alpha particles (positively-charged helium nuclei), which pass between two charged metal plates called electrodes. The alpha particles collide with air molecules and split them into positive ions and negative electrons. These charged particles are then attracted to opposite electrodes, causing a current to flow. Smoke particles can attach to ions and neutralise them, so they are no longer attracted to the electrodes. A sensor detects the drop in current and the alarm is triggered.

Detectors are placed high up because hot smoke is less dense than air, so it rises

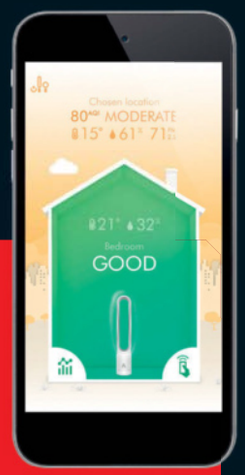
Dyson's air purifier

The fan that removes 99.95 per cent of indoor allergens and pollutants

We're all familiar with the allergens and pollutants lurking in the air outside, but did you know that air pollution inside your home can be up to five times worse? As we usually keep our windows and doors closed to retain heat and block out noise, potentially harmful particles often get trapped inside. These indoor air pollutants are too small to see with the naked eye and include gases from cooking and central heating, as well as mould, pet hair and pollen.

"When we talk about physical pollutants in the air we split them into average size brackets identified with a PM [particle matter] number," says Matt Kelly, a mechanical engineer at Dyson. "Most purifiers are reasonably good at capturing PM2.5, which are often linked to health hazards." That's because these particles have a diameter of only 2.5 microns – around 30 times smaller than a human hair – so they can enter the lungs. "But what we have focused on with the Dyson Pure Cool Link is the next size down, PM0.1," Kelly says, "which are particles just 0.1 microns in size and small enough to pass into your bloodstream."

These physical pollutants get trapped inside the mesh of the purifier's dense glass filter, but behind that sits a second filter designed to absorb the toxic and strong-smelling volatile organic chemicals released by cleaning solvents, deodorants and scented candles. Together, these filters remove 99.95 per cent of pollutants from the air that passes through the machine and is pumped back into your home. It also doubles up as a fan to cool you in the summer.



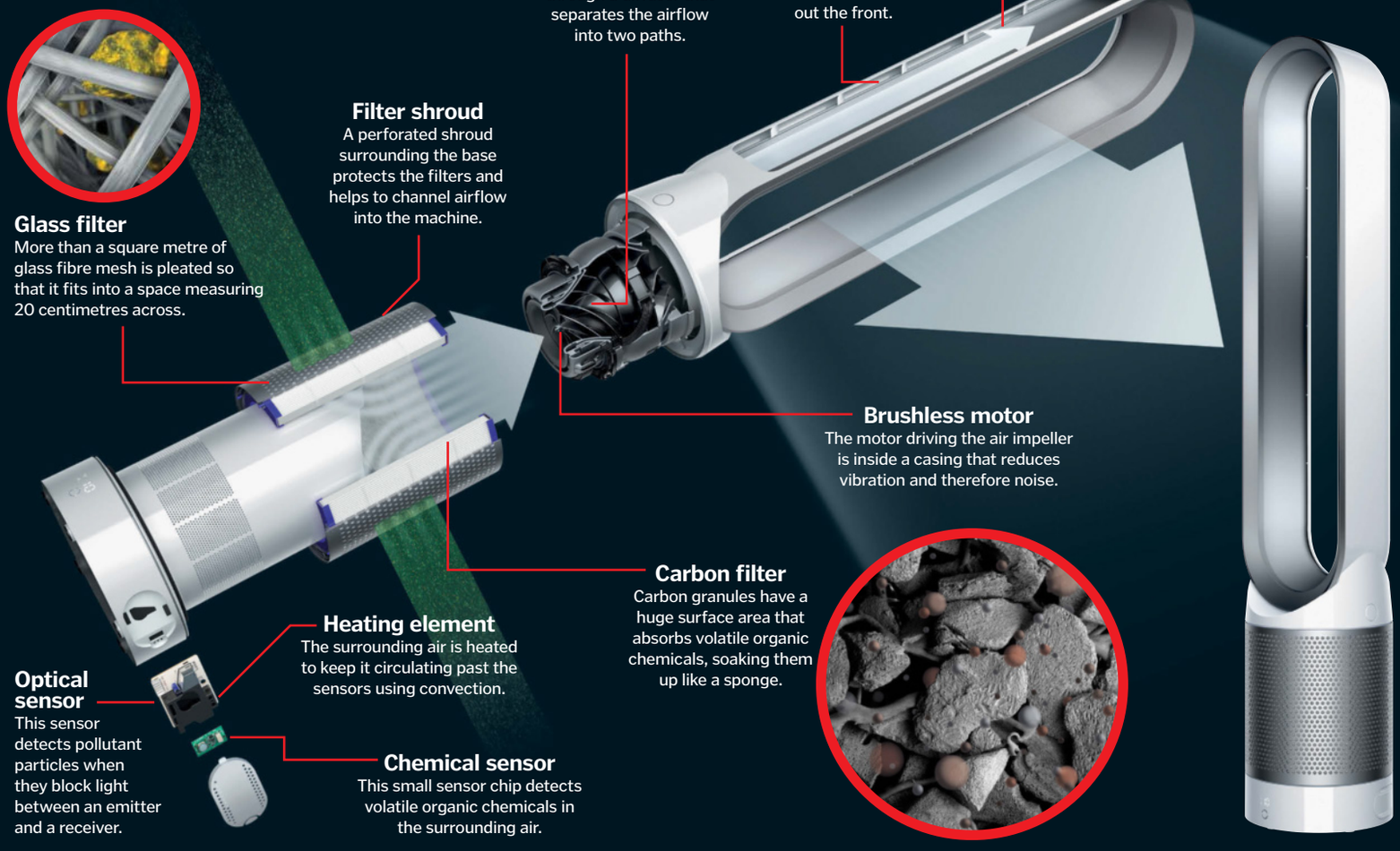
Monitoring air quality

Two sensors located in the base of the Dyson Pure Cool Link constantly monitor the quality of the surrounding air. If they detect a particularly high level of contaminants, such as from the plume of hot air released when you open the oven door, the machine will ramp up its operation to cope with the additional pollution. The information recorded by the sensors is also sent to the Dyson Link app on your smart device, allowing you to keep track of the air quality history in your home, as well as monitor it in real-time.

The Dyson Link app lets you monitor the air quality from inside and outside of your home

Inside the Dyson Pure Cool Link

How does this clever machine clean the air?



Glass filter
More than a square metre of glass fibre mesh is pleated so that it fits into a space measuring 20 centimetres across.

Filter shroud
A perforated shroud surrounding the base protects the filters and helps to channel airflow into the machine.

Mixed flow air impeller
An internal fan draws air in at the bottom and forces it up through a diffuser that separates the airflow into two paths.

Aperture
After passing through this slot which runs around the back of the loop, the air travels along the inside wall and exits out the front.

Amplifier loop
The two airflow paths travel around the hollow insides of the loop and out through the aperture.

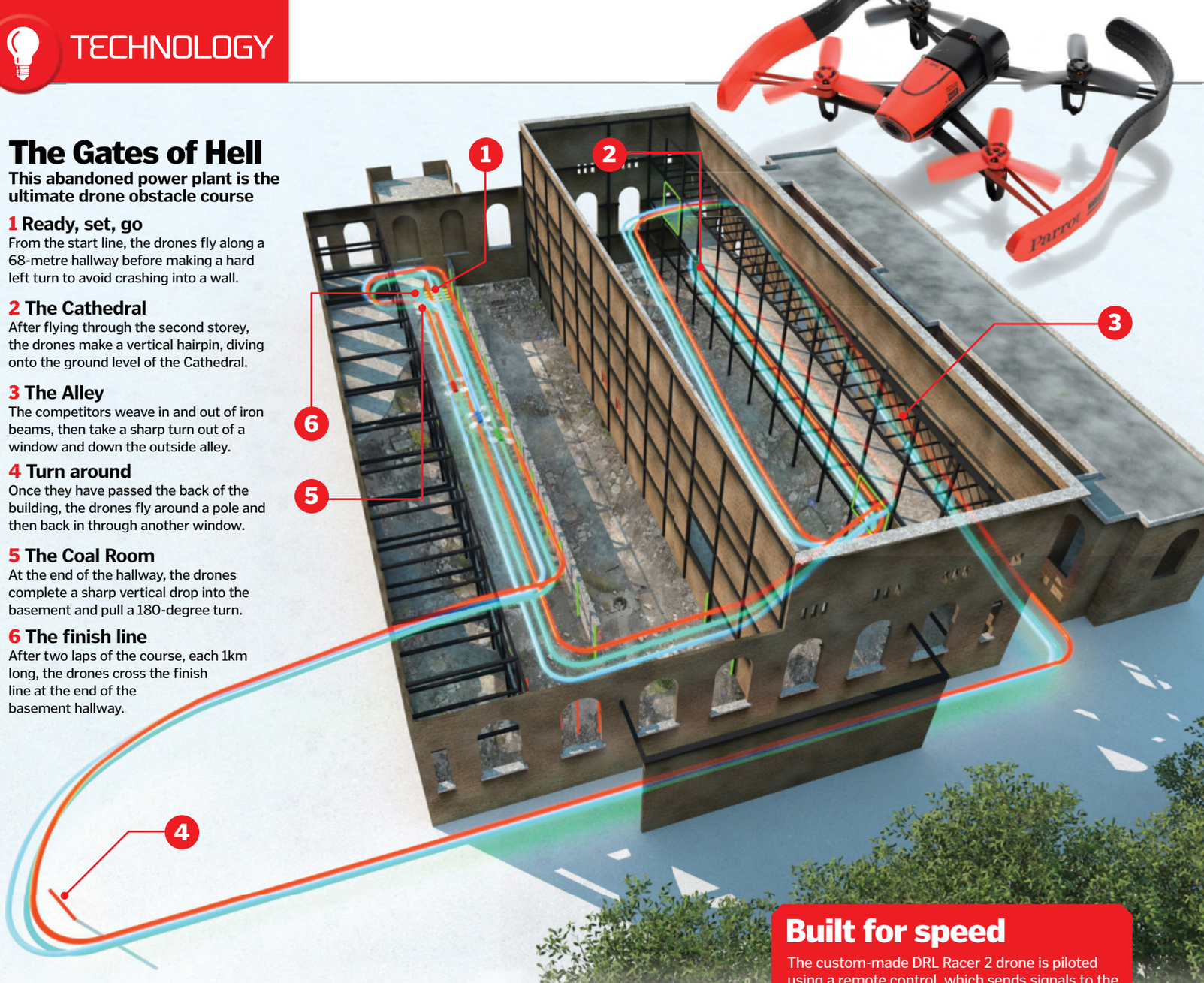
Brushless motor
The motor driving the air impeller is inside a casing that reduces vibration and therefore noise.

Carbon filter
Carbon granules have a huge surface area that absorbs volatile organic chemicals, soaking them up like a sponge.

Heating element
The surrounding air is heated to keep it circulating past the sensors using convection.

Optical sensor
This sensor detects pollutant particles when they block light between an emitter and a receiver.

Chemical sensor
This small sensor chip detects volatile organic chemicals in the surrounding air.



The Gates of Hell

This abandoned power plant is the ultimate drone obstacle course

1 Ready, set, go
From the start line, the drones fly along a 68-metre hallway before making a hard left turn to avoid crashing into a wall.

2 The Cathedral
After flying through the second storey, the drones make a vertical hairpin, diving onto the ground level of the Cathedral.

3 The Alley
The competitors weave in and out of iron beams, then take a sharp turn out of a window and down the outside alley.

4 Turn around
Once they have passed the back of the building, the drones fly around a pole and then back in through another window.

5 The Coal Room
At the end of the hallway, the drones complete a sharp vertical drop into the basement and pull a 180-degree turn.

6 The finish line
After two laps of the course, each 1km long, the drones cross the finish line at the end of the basement hallway.

Drone racing

The new high-octane sport putting quadcopter pilots to the test

Swooping through the air at 130 kilometres per hour, flying through narrow hallways and veering around tight corners, this isn't your average quadcopter flight. In the world of professional drone racing, pilots' skills are pushed to the limits as they manoeuvre their flying machines around some of the toughest obstacle courses on Earth.

One of the biggest tournaments of this kind is the Drone Racing League (DRL), a global competition that sees the world's top drone pilots compete for prize money and, more importantly, world champion status. This Formula 1 for drones features a series of races held in enormous sports stadiums and derelict buildings around the world. All of the competing pilots fly the same model of drone, the DRL Racer 2, in order to test their skills on a level playing field. In each race, they score points by passing checkpoints and finishing the course within the allotted time, and at the end of the heats the pilot with the most points is crowned the winner.

The 2016 season is already underway, with the first race held in New York at a course nicknamed 'The Gates of Hell'. Lit by neon lights and featuring multiple floors, this three-dimensional racetrack is a true test of aerobatic skill as the pilots must fly their drones right, left, up and down at great speed. There are plenty of daring manoeuvres and spectacular crashes to keep the audience entertained and inspire the next generation of master pilots.

Built for speed

The custom-made DRL Racer 2 drone is piloted using a remote control, which sends signals to the craft via radio link. DRL's patented new radio technology ensures reception is never lost, even when the drone flies out of sight through hallways and underground, so the pilot is always in control. HD cameras mounted on the drone transmit a live video feed, also via radio link, to goggles worn by the pilot, enabling them to get a drone's-eye view of the course as if they were in the cockpit.

The drones themselves are made from lightweight carbon fibre, so they only weigh around 800 grams, and can reach top speeds of 130 kilometres per hour. 100 colour LEDs make each quadcopter easily identifiable and are bright enough for the audience to see the action from hundreds of metres away. After every lap, each pilot's drone is replaced with a new fully-charged model, ensuring they can go the distance.

All DRL pilots have a fleet of DRL Racer 2 drones to use for each race

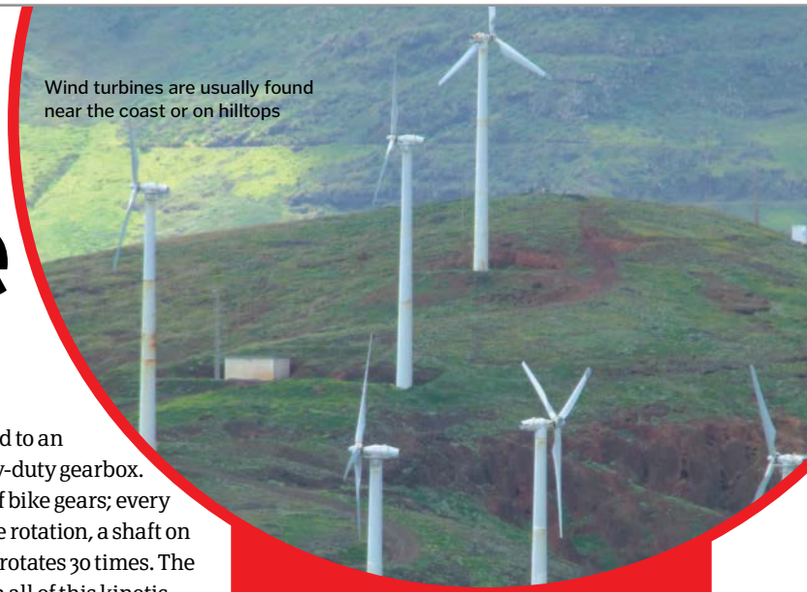
Inside a wind turbine

The process of generating clean electricity from the power of the wind

Wind turbines are a familiar sight on hilltops and coastlines, their huge blades turning high above the ground. They're tall for a reason – as wind flows over the land and around buildings, it's broken into uneven packets of air that are too slow to turn a turbine's enormous blades. To capture the smoothest, fastest wind, the blades need to be far off the ground.

Each of the turbine's blades shares its shape with bird and airplane wings – they are rounded on one surface and flat on the other. This design is called an aerofoil and gives the blade lift as it turns, so it can use the energy from wind more effectively. Inside the wind turbine's cabin, the rotating blades are connected to an electric generator via a heavy-duty gearbox. Essentially, it acts like a set of bike gears; every time the blades complete one rotation, a shaft on the other side of the gearbox rotates 30 times. The generator's job then is to turn all of this kinetic – or moving – energy into electrical energy.

For this it uses electromagnetic induction, where a moving wire in a magnetic field produces electricity. In a wind turbine's generator, a huge magnet surrounds a loop of wire connected to the gearbox's shaft. Thanks to the wind, the blades rotate, spinning this wire up to 1,800 times every minute, and generating a stream of electricity in the process.



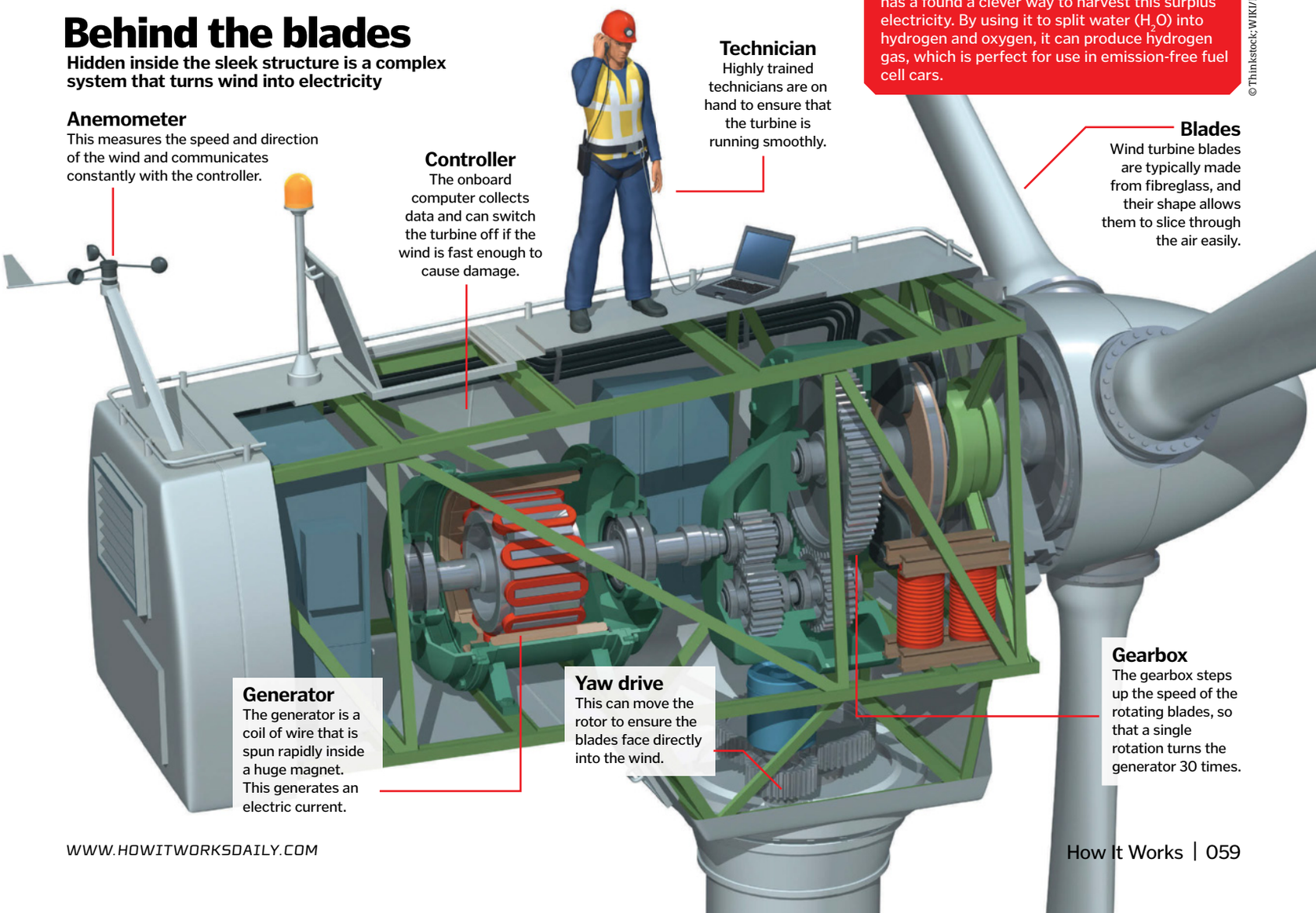
Wind turbines are usually found near the coast or on hilltops

What can we use wind energy for?

In countries like Denmark, wind turbines produce enough electricity to power millions of homes, and it makes its way to them via the grid – a nation-wide network of cables and pylons. However, the amount of electricity they produce is tricky to manage, because wind turbines produce electricity intermittently (only when the wind blows). Often, much of the electricity they produce is wasted, but the German city of Mainz has a found a clever way to harvest this surplus electricity. By using it to split water (H_2O) into hydrogen and oxygen, it can produce hydrogen gas, which is perfect for use in emission-free fuel cell cars.

Behind the blades

Hidden inside the sleek structure is a complex system that turns wind into electricity



Anemometer
This measures the speed and direction of the wind and communicates constantly with the controller.

Controller
The onboard computer collects data and can switch the turbine off if the wind is fast enough to cause damage.

Technician
Highly trained technicians are on hand to ensure that the turbine is running smoothly.

Blades
Wind turbine blades are typically made from fibreglass, and their shape allows them to slice through the air easily.

Generator
The generator is a coil of wire that is spun rapidly inside a huge magnet. This generates an electric current.

Yaw drive
This can move the rotor to ensure the blades face directly into the wind.

Gearbox
The gearbox steps up the speed of the rotating blades, so that a single rotation turns the generator 30 times.

CATS VS DOGS

It's time to settle this rivalry once and for all. Which pet comes out on top?

It's no surprise that dogs and cats have the majority vote as domestic pets. Humans are a tactile bunch, and nothing gets the pleasure centres in our brains firing more than petting an adorable animal. Nearly half of all UK households have pets, with 24 per cent having a dog and 17 per cent owning a cat.

We are hard-wired to take care of things we find cute and helpless like our own offspring, so we can't help but coo over little puppies as if they *were* our own. This relationship is enhanced by the almost intuitive way that our pets respond to us, and when you realise that dogs and humans have evolved together, it's not hard to comprehend how the mutts have been branded as 'man's best friend'.

Recent studies have proven that dogs can recognise emotion on faces, display jealousy and they're even able to coherently watch TV (when there are animals involved). They learn in the same way that children do, are susceptible to emotional contagion (try yawning next to your pup and see if he yawns too) and have a distinct awareness of time.

Although cats, as solitary creatures, aren't fussed about joining in every aspect of our lives, they've been proven to pay more attention than we often assume. Cats can recognise our moods and react accordingly, they can get us to help them without us even noticing and even replicate sounds that subliminally galvanise us into action. Cats also see humans as their surrogate family – has your kitty ever brought you back a live-or-dead gift? She's actually trying to impart her hunting knowledge. Kittens are raised by their mothers, who will begin to teach them by bringing back dead prey. If Tibbles is delivering you large, live prey to dispatch yourself, then congratulations – you're ready to accompany her on the hunt.

Felines are the natural survivors of the pet world and although we love caring for them, cats could survive just fine without our help. Interestingly, evolutionary research has shown that cats have been involved in the extinction of over 40 dog species by outcompeting them for food.

Whether you're a cat person or a dog person, read on to find out the amazing attributes of both species, and you might just switch your side.

Round 1: Physical ability

Cats are the gymnasts of the pet world – they are light, nimble and have an amazing 'righting' reflex that means they always land on their paws. They also have impressive night vision, acute hearing and two ways to sense smells. Ever seen your cat lifting his lips in a snarl? That's him using his Jacobson's organ to home in on a scent.

So in the battle of the senses, the kitties seem to win by a whisker – apart from in the nose category. Dogs 'see' the world through scent, and can sniff out some odours in parts per trillion – the equivalent of detecting one teaspoon of sugar in a million gallons of water! A study has also shown that dogs favour using different nostrils, depending on how the smell makes them feel.

When it comes to physical strength and stamina, the moggies put up an excellent fight, but the hounds have the edge. There's a breed for every task, and dogs are capable of going to extremes. Cats can run fast, with a top speed of 48 kilometres per hour, but dogs can run fast for a very long time. Cats can jump high, but dogs can jump far, time and time again. Greyhounds can hit 68 kilometres per hour, huskies can brave sub-zero temperatures, collies are super agile, and there are even Newfoundland dogs that jump into water from helicopters to save human lives.

Vision
A dog sees the world like human red-green colour-blindness, and their field of view stretches 240 degrees – wider than a cat.

Hearing
18 muscles help to move a dog's ears into perfect position, and they can hear up to 45 kHz.

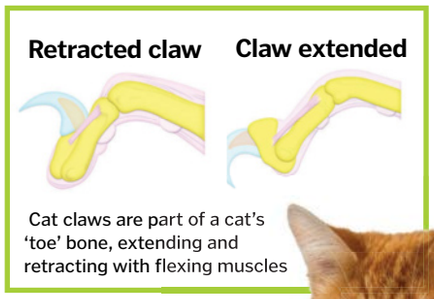
Smell
A dog's nasal cavity is lined with at least 125 million sensory receptors, compared with our 5 to 10 million.

Teeth
Adult dogs have 42 permanent teeth with large canines and incredibly strong jaws.

Strength
Each breed of dog has different strengths, but most have incredible stamina – able to run for three kilometres or more at high speed.

When a dog inhales, some of the air is respired and the rest is dedicated to scent identification

The front paws have additional pads to protect the bones in the foot, acting like shock absorbers



Cat claws are part of a cat's 'toe' bone, extending and retracting with flexing muscles

Your cat's rough tongue has many tiny backwards-facing barbs (papillae) for rasping meat and grooming

Vision
With light-reflective layers in their eyes, cats use twice as much available light as humans to see.

Hearing
Their large, pointed ears swivel to hear frequencies up to 80kHz, while humans can only hear 20kHz.

Smell
As well as using their nose, cats have a Jacobson's organ in the roof of their mouth, which they also use for scent.

Tail
Tails help with balance, communication and act as a rudder to steer the body when running at full speed.

Skeleton
The feline's super-flexible spine and lack of collarbone helps it to twist the body and fit through tiny gaps.

Evolutionary advantages

Dogs have been domesticated for a very long time. Last year, a genetic study suggested the process began over 30,000 years ago, and that modern-day domestic dogs are descended from various regional wolf populations.

It's thought that wolf domestication happened as opportunistic animals followed nomadic humans, benefitting from their scraps. The aggressive wolves would likely have been eradicated as humans would not have tolerated toothy predators. In time, the gentler wolves would have been selectively bred.

In contrast, domestic cats first appeared around 9,500 years ago, probably in the Middle East. Their ancestors are wildcats, which still roam various wildernesses across the world today and whose lineage can be traced back 130,000 years. It's thought that domestication occurred as plentiful rodent populations attracted wildcats to live near human settlements, and then they may have been fed and homed in order to keep rat numbers down.

The first domesticated dogs descended from grey wolves, most likely from China

All domestic cats are thought to descend from the European wildcat

Round 2: Communication

Dogs and cats spend a huge amount of time with us. We cuddle them, stroke them and let them into every part of our daily lives – so it's not surprising that our furry friends have developed intuitive ways to communicate with us.

Vocalisations play a large part. Dogs have a hugely flexible range, including whimpering, yipping, growling and barking. Adult wolves don't bark (although juveniles do), so barking has been developed through human-dog evolution specifically as a language for us to understand. Dogs will also use eye contact to connect with us and even follow our gaze in order to figure out what we're looking at. This is a purely domestic habit, as wolves in the wild don't make eye contact with humans.

Cat meows have an even more ingenious hook than a dog's woof, however. From living alongside humans for so long, cat noises have evolved to contain acoustic patterns that connect with us on a subliminal level. A cat's 'solicitation purr' – a mix of purr and loud meow that no one can resist – uses the same frequency as a baby's cry and kick-starts our instinctual desire to protect and care.

Body language plays an even larger part in pet communication. This is how animals show their emotions. A happy cat that wants to be stroked will arch his back under your hand and purr, but if a cat shrinks away, he's not interested. Flattened ears can mean they're worried or anxious, and hissing and spitting means they're ready to fight. Conversely, when your cat does that curious 'slow-blink' at you, this is a relaxed gesture that means all is well with the cat's world.

Dogs also use body language in many different ways. When Fido's ears are perked up, his head high and tail wagging, he's a happy boy. But if he's hiding, with ears down or flattened with his tail between his legs, this is a sign of a dog that's worried or frightened. A truly content dog will lie on his back, exposing his neck and tummy to the world. When a dog strikes this pose, scratch away – he'll love it. Yet when a cat does it, you might just get a scratch yourself, as this generally isn't an invitation.

Science shows us that pets can calm us down and make us happy

Stress relievers

Both cats and dogs are winners when it comes to helping us relax. Studies have shown that petting a furry friend lowers the heart rate and blood pressure, reduces the stress hormone cortisol and promotes the release of feel-good hormones serotonin and oxytocin. Cats and dogs provide unconditional love, and can relieve loneliness and help with depression. Both types of pets can work as therapy animals, where they make visits to hospitals and care homes to cheer up those in need.

Emotions and our pets

It's no secret that our pets seem to be in tune with our emotions, but how much do they actually know? One recent study presented dogs with pictures and sounds showing both positive and negative emotions in humans. They found that the animals spent more time focusing on the image when it matched the sound of the associated emotion. Instead of being a learned response as previously thought, this highlights that dogs can distinguish moods.

Another recent study was able to show that cats exhibit – albeit modestly – different behaviours by taking cues from their owners. For example, if the owner was happy, the cat was more likely to purr and want to be close to them. It's possible that cats associate their owner's good mood with rewards, in turn making the cat happy. The fact that dogs show stronger reactions could be because they have had longer to adjust to life with humans.

Reactions to our moods

Happy

- Mouth open
- Tail wagging
- Energetic and bouncy

- Purring
- Closeness
- Slow blinking

Angry

- Tail between legs
- Ears back
- Cowering, hiding
- Avoidance
- Waving tail
- Jumping up high

Round 3: Intelligence and trainability

The average dog has the intelligence of a two-year-old child, and they also have a larger brain in comparison to their body size than cats. However, cats have a larger cerebral cortex than dogs, which is the area of the brain responsible for cognitive information processing.

As these animals are different species with wildly different histories and lifestyles, it's difficult to compare them to decide who is the beast with the biggest IQ (as opposed to comparing dog breeds for intelligence – the border collie wins, in case you were wondering) but each species has intelligent attributes in its own right.

One thing to consider is training. Dogs are very easy to train because they love to work for a reward. They also learn in the same way that human children do. But it's not widely known for cats to perform so well. This is because they're fiercely independent animals, but don't be fooled; although it's difficult, they *can* be trained, just not in the specific way that dogs can (although there are some cases that claim otherwise). If your cat wakes you up in the night and you get up to feed him, you've unintentionally trained him to do this again and again.

Cats are very perceptive, and will use your actions and reactions to govern their behaviour as it benefits them. Some might say that this is an even more intelligent attribute than a dog's ability to do a handstand on demand!

Numeracy

Recent studies have shown dogs can identify higher numbers of dots when faced with a selection of images. This is likely to be because dogs are pack animals, and in the wild, wolves need to know numbers of their own as well as rival groups. Dogs can also detect simple additions and subtractions.

But how do cats fare? A numeracy test isn't really a fair game, because as solitary creatures it's more important for them to be able to perceive size rather than numbers. This is the outcome of a few tests on moggies, but it's also notoriously difficult to hold their interest in these kinds of tests, making it hard to gain a clear comparison!

Dogs can perceive numbers somewhat better than cats, who aren't really interested in being tested!

Do our pets listen?

The doggy brain interprets voices rather like ours do. MRI scans of dogs and people showed that similar regions of the brain responded to human voices – the first time this has been witnessed in non-primates. Dogs also respond to the emotion conveyed in the voice, explaining why vocal communication between humans and dogs is so successful.

With cats it's a slightly different story; although they can recognise their owners' voice over that of a stranger, studies show that compared to dogs, they don't place as much significance on this and easily ignore us. It's thought that this is because cats weren't actively domesticated by humans in the same way as dogs.

By placing dogs in an MRI scanner, researchers found their brains react to voices in the same way as human brains

German shepherds are bold, athletic and brainy, making them ideal dogs for police work

Dogs with jobs

Canines are keen to please and love nothing better than to complete tasks for a reward – whether that's a tasty treat or a quick tug of war. This trainability coupled with their amazing senses can be honed for a huge array of jobs for human benefit. Service dogs such as guide dogs, therapy dogs and medical detection dogs make everyday lives easier. Search and rescue dogs, police dogs, sniffer dogs and military dogs work hard to keep us safe. They can also be trained for other manual work, such as herding, sledding, retrieval and even pulling carts.

What is cloud seeding?

It's possible to make it rain, snow or shine through artficial means. Here's how...

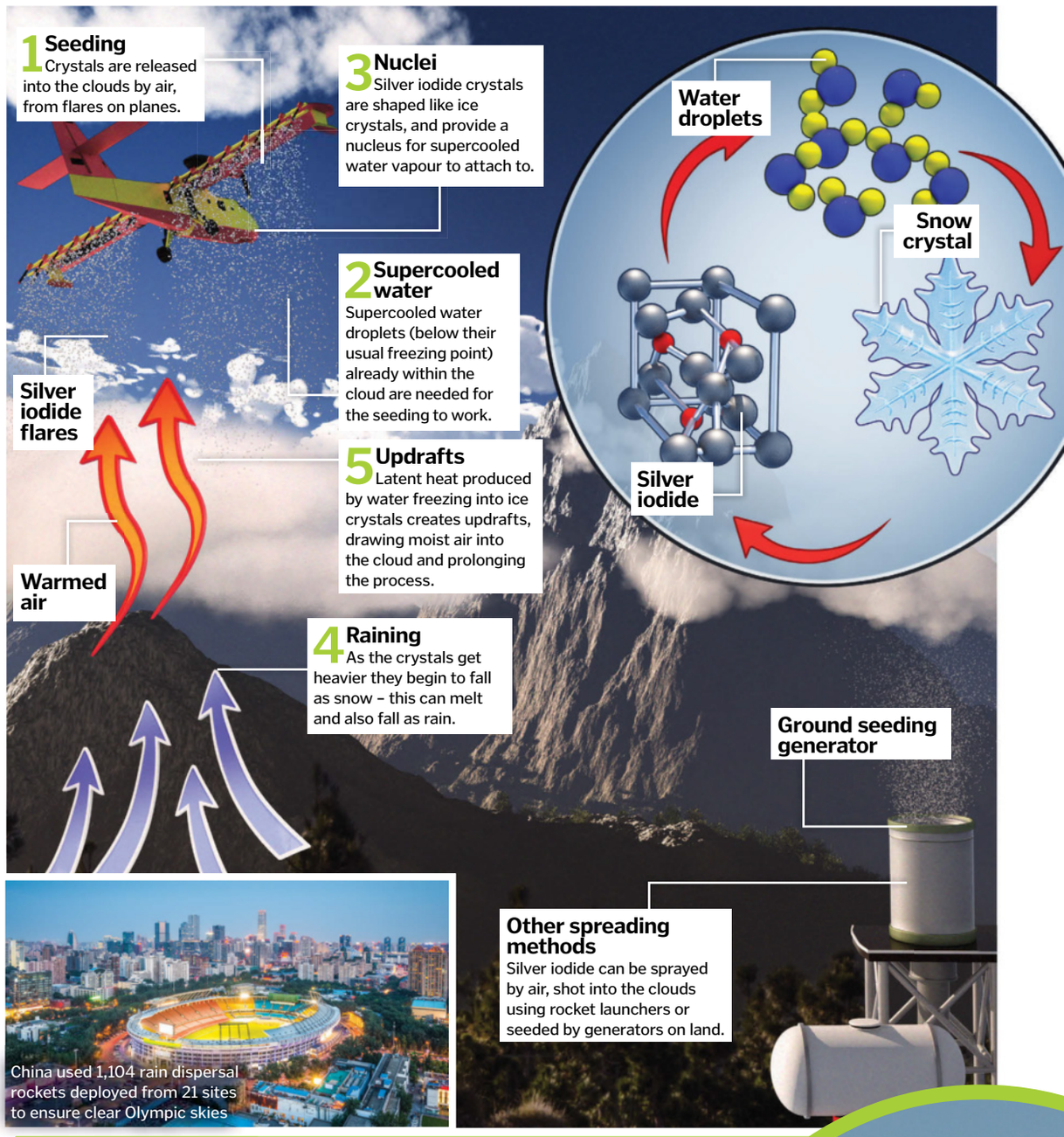
Cloud seeding is a clever way of manipulating the weather to alter how much rain falls. It was first discovered one hot July in New York, 1946. Dr Vincent Schaefer was experimenting with creating clouds and placed a lump of dry ice inside a chamber to cool it down. He noticed that the water vapour in the chamber formed a cloud around the dry ice. This replicates one of the ways that clouds form naturally – as air cools, water vapour clings to tiny particles floating in the air, such as salt and dust, called aerosols. This is known as condensation. As more water vapour sticks to the aerosols, the drops get larger and start sticking to other droplets, forming clouds. Then, as the droplets grow, they become raindrops.

It's this principle that is used in cloud seeding, which can manipulate conditions for both rain and shine. Particles are sprayed into the air to act as nuclei for the water vapour to condense with. The substances used for this include calcium chloride, silver iodide or solid carbon dioxide (dry ice), depending on the climactic conditions of the area. These substances, sprayed from aircraft or launched via rockets, have similar physical structures to ice crystals and other aerosols that act as nuclei for condensing water vapour.

With careful planning, as well as a bit of luck, rain can be produced in dry areas. Seeding can also produce clear skies by ensuring that the rain falls in another area. This was employed by the Chinese government to ensure that the 2008 Beijing Olympic Games weren't washed out by the rainy season.

Make it rain

How dynamic cloud seeding in cool climates can bring the snow and the rain



China used 1,104 rain dispersal rockets deployed from 21 sites to ensure clear Olympic skies

Different types of cloud seeding

Static cloud seeding
Chemicals such as silver iodide are sprayed into clouds. It helps them to use the moisture that's already available more efficiently, allowing them to form additional droplets and produce even more rain.

Dynamic cloud seeding
This method makes use of the latent heat that is given off when cloud seeding causes the water vapour to turn into ice crystals. The heat can boost the strength of updrafts and thermals. This causes the cloud to draw in more moisture and grow larger.

Hygroscopic cloud seeing
This method is used in the tropic regions, because the air is too warm for the other techniques that rely on ice crystals forming. It uses salts to form nuclei, which go on to become larger droplets. These in turn create heavier clouds and eventually rain.


Aircraft use flares to spread large amounts of seeding stimulants into the clouds

Crystal giants

Deep under a Mexican desert lies a mysterious cave that's beautiful but deadly

Two brothers were drilling in the Naica mine in Mexico when they uncovered a geological wonder of the world, hundreds of thousands of years in the making. The Cueva de los Cristales, or Cave of Crystals, is a glittering palace covered in some of the largest crystals anyone has ever seen. Measuring over 11 metres – roughly the length of a bus – they have thrived in the extreme conditions of the cave.

Temperature is a sweltering 44 degrees Celsius and up to 100 per cent humidity means the air you breathe quickly condenses inside your lungs. Geologists hell bent on exploring the cave and living to tell the tale had to don specially designed suits, strewn with ice packs. If they had taken their respirator mask off for more than ten minutes, they would have fallen unconscious. However, what proves deadly for humans are the perfect conditions for growing crystals.

These monstrous structures are made of a soft mineral called selenite, and formed from groundwater saturated with calcium sulphate, which was heated by a magma chamber below. As the magma cooled, the minerals in the water started to transform into selenite and steadily built up. The cave's oldest resident is 600,000 years old – forming at the time when the ancestors of modern humans first appeared!

The crystals only stopped growing when miners unintentionally drained the cave in 1985 while they lowered the water table. But when the mine stops being profitable, the owners of the Naica mine will remove the pumps and the cave will flood once more. The crystals will be lost, but we can take comfort in knowing there must be more hidden marvels like this. "We know more about the outer edges of the Solar System than we do about the first kilometre of the Earth's crust," Professor Iain Stewart told the BBC after exploring the caves. "We can be sure there will be discoveries even more spectacular than Naica."

"The cave's oldest resident is 600,000 years old"

The effects of eutrophication

Its name means 'well nourished', but this process can seriously damage the environment

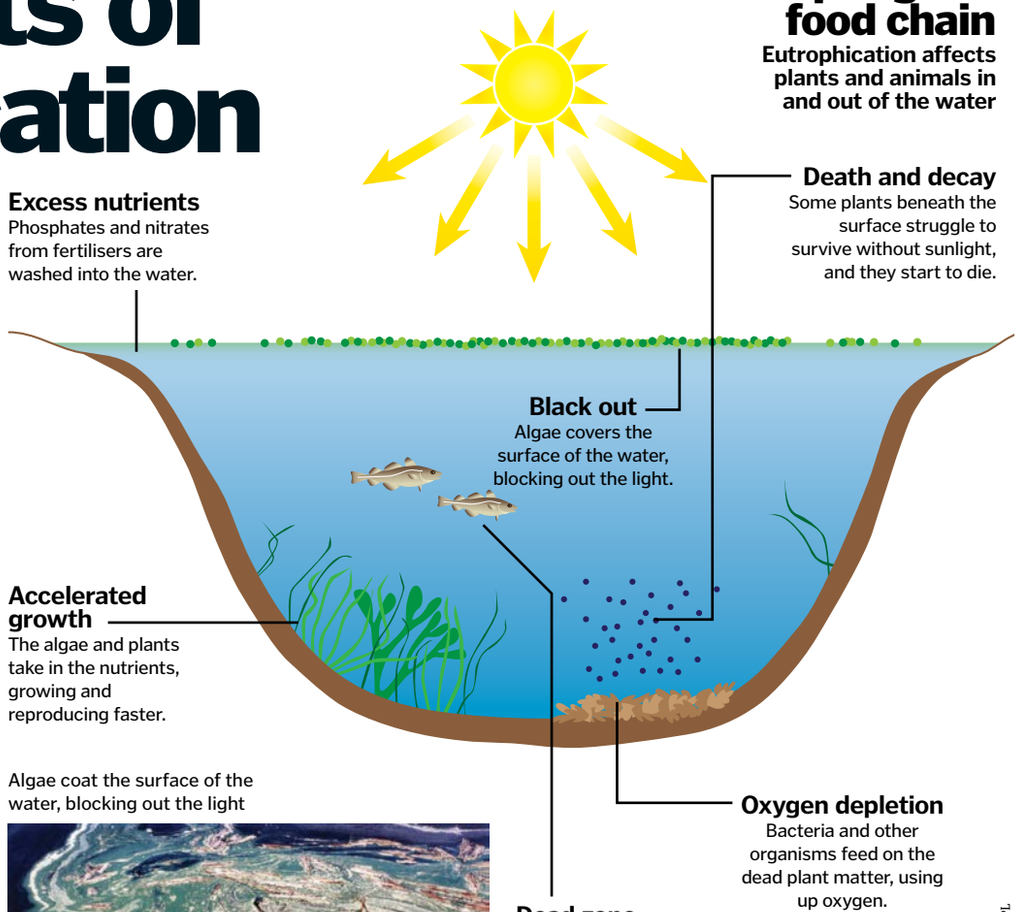
Our lakes, rivers and oceans are home to billions of organisms that use photosynthesis to survive. Algae and plants use sunlight to convert water and carbon dioxide into sugar, tapping into an almost unlimited source of energy.

With these three resources so freely available, you might wonder why we aren't overrun by plant life, but there is something stopping them from taking over. They need nutrients like nitrates and phosphates to survive, and these are usually in short supply. When excess nutrients from fertilisers are washed off the land by rainwater into rivers and lakes, the plants and algae go into overdrive. This is eutrophication, and it can cause serious problems.

When exposed to excessive nutrients, algae grow rapidly, covering the surface of the water and blocking out the Sun. This starves the plants below. As the plants die, they stop producing oxygen, and as they decompose, bacteria and other organisms increase their oxygen usage. As a result the water becomes hypoxic (deficient in oxygen). In some cases, the oxygen level can become so low that fish and other animals die.

Disrupting the food chain

Eutrophication affects plants and animals in and out of the water



Algae coat the surface of the water, blocking out the light

Fossilised lightning

When a lightning bolt hits damp sand, something incredible happens

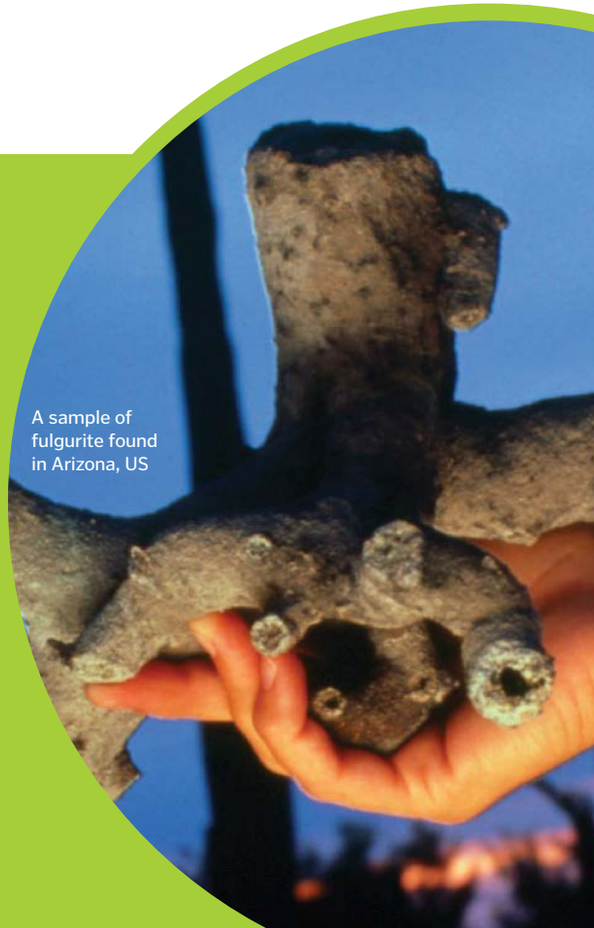
Lightning lasts for only fractions of a second, but when conditions are just right, traces can be preserved for centuries. If a bolt strikes sand, it can form a stone tube called a fulgurite.

Sand is made from ground-up particles of rocks, minerals, and the shells and skeletons of living organisms. The exact composition varies depending on where you are in the world, but one of the most common components is silica – the key ingredient used to make glass.

Glass is made by melting sand at temperatures in excess of 1,700 degrees Celsius, and a lightning strike provides more than enough energy to make it happen naturally.

Sand doesn't normally conduct electricity, but when it is wet it provides a path for the lightning. Gaps between sand grains trap water, and when lightning strikes, it passes through the liquid. The intense energy release produces searing heat, melting the grains and leaving behind a glassy cast that traces the outline of the bolt.

Fulgurites can be made naturally, but it's also possible to encourage their formation artificially by planting a conductive metal rod into wet sand, standing back and waiting for a storm!



A sample of fulgurite found in Arizona, US

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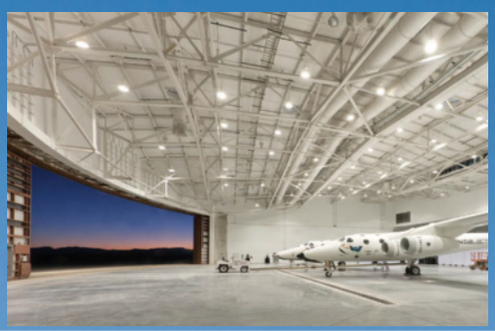
Inside Spaceport America

In the town of Truth Or Consequences is the world's first commercial spaceport

Spaceport America is described as the world's "first purpose-built commercial spaceport". It is an impressive 10,000-square-metre terminal building with a 3,657-metre runway, nestled in the remote Jornada del Muerto desert basin in New Mexico, US. Its ambitious organisation is on a mission "to make space travel as accessible to all as air travel is today".

The $200 million facility was designed by UK-based Foster and Partners, and funded by New Mexico state taxpayers. It was built to mirror the spacecraft that it will one day house, with a curved outline, skylights, and a three-storey glass front looking out over the taxiway.



The airport's hangar is known as the Gateway to Space building

The structure sinks down into the ground to maximise energy efficiency, and winds whistle through to control the temperature inside. Like a standard airport, it has hangars and a departure lounge, but it is also fitted out with a control room, space for astronauts to don their suits, and training facilities for flight preparations to be carried out.

The spaceport officially opened in 2011, with Virgin Galactic signing a 20-year agreement as the primary tenants back in 2008. However, it has been a slow start for this ground-breaking project. Virgin Galactic plans to use the facility to take passengers into space onboard SpaceShipTwo, but after a tragic fatal accident in 2014, the project is now running several years behind schedule.

A number of smaller private companies have paid to use the facilities and over 20 launches have been made, but this is far fewer than originally expected, and the building is losing money. Time will tell whether Spaceport America will achieve its dream of becoming a bustling hub for commercial space travel. For now, it seems that while the building is ready, the spacecraft aren't quite prepared for take-off.

Catching a spaceplane

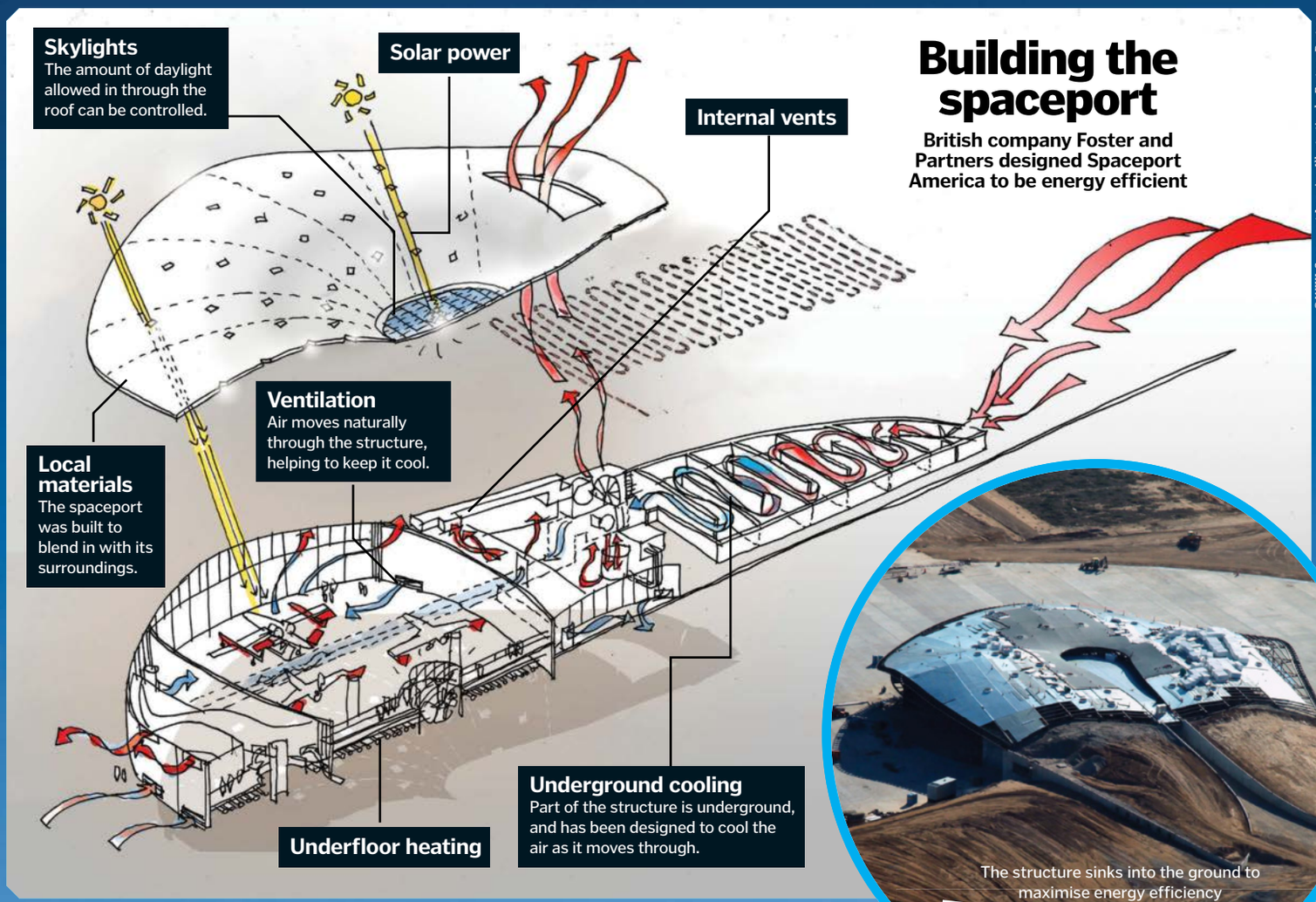
In the future, it is hoped that Spaceport America will be the top destination for tourists looking to catch a glimpse of the world from outer space. Virgin Galactic intends to prep their would-be astronauts with an intense three-day training course on site. Health and safety is a priority, with emergency response taking the number one spot on their planned training protocol. Medics will also be on hand, to ensure that passengers are physically and mentally ready for the intense experience of the space environment. They will be exposed to g-forces in simulators and light aircraft in preparation for the big day. Once the trip is over, SpaceShipTwo will land on the runway like an airplane, and the passengers will be able to celebrate in style back at the spaceport.

Virgin Galactic's WhiteKnightTwo will help launch SpaceShipTwo into space

The runway is almost 4km long

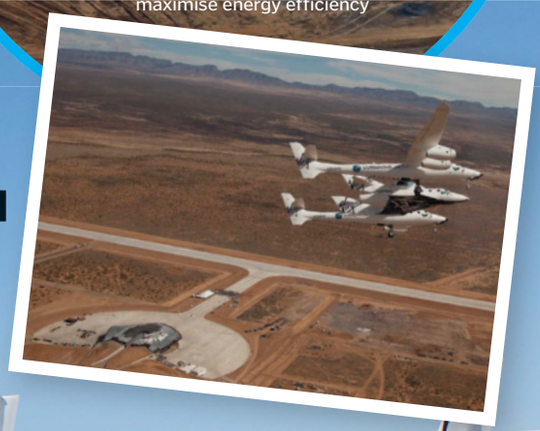
Building the spaceport

British company Foster and Partners designed Spaceport America to be energy efficient



The structure sinks into the ground to maximise energy efficiency

Spaceports of America



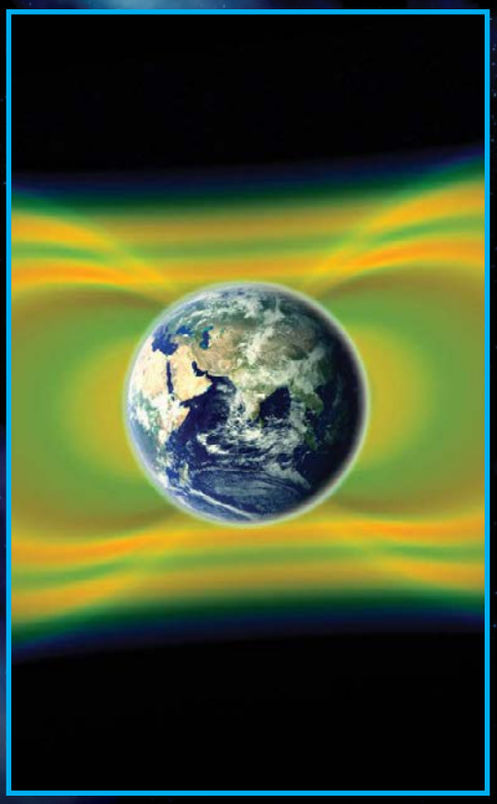
"Like a standard airport, the spaceport has hangars and a departure lounge"

Space radiation

The universe is crammed with high-energy particles and electromagnetic waves

Galactic cosmic radiation

Distant supernova explosions are thought to be the source of these high-energy ions. They travel across the galaxy at close to the speed of light, and can easily pass through the walls of a spaceship. With current technology at least, they cannot be shielded against.



Trapped radiation

Earth's magnetic field can trap charged particles from the solar wind. They become confined to the Van Allen belts, two doughnut-shaped magnetic rings encircling the planet. This type of radiation does not pose a threat unless astronauts travel through the magnetic field.

Solar energetic particles

These high-energy particles are released by the Sun during periods of intense activity known as solar particle events. Although these events are hard to predict, astronauts and vulnerable equipment can be protected from this form of radiation using shielding materials.

The interstellar medium

The space between the stars may not be as empty as we once thought

Outer space is often referred to as a vacuum, but that's not strictly true. Even the emptiest voids between the stars contain gas and dust, known as the interstellar medium (ISM).

Ninety-nine per cent of the ISM is made up of hydrogen and helium gas, but at an extremely low density. The air we breathe has a density of approximately 30 billion billion atoms per cubic centimetre; the same volume of ISM would only contain a single atom.

The remaining one per cent of ISM is interstellar dust, which consists of extremely small particles of carbon or silicate. These tiny grains are formed in relatively cool and dense environments, such as in the outer atmospheres of red giants. When they are ejected by solar winds, radiation pressure, or in stellar explosions, these grains become scattered across the galaxy.

Interstellar dust particles play a role in the formation of new star systems. Two hydrogen atoms in the ISM will rarely collide to make a molecule of their own accord, but they may fuse if they both stick to the surface of dust particles, providing a platform where new molecules can form.

In this Hubble image, the interstellar gas glows blue as it is blasted by strong stellar winds

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Dinner in space

The ultimate out-of-this-world dining experience is not as glamorous as it sounds

British chef Heston Blumenthal is renowned for his experimental approach to cooking, but his latest challenge took food science to new heights. In collaboration with the UK Space Agency, Blumenthal created a selection of dishes for astronaut Tim Peake to enjoy on board the International Space Station.

NASA has strict regulations dictating what food can go into space and how it must be prepared, so sending restaurant-quality meals into orbit is no easy task. Everything must be heated to 140 degrees Celsius for two hours to kill off any bacteria that could make the crew ill, while anything that creates crumbs is strictly forbidden – they could easily float into instruments or equipment and cause serious damage.

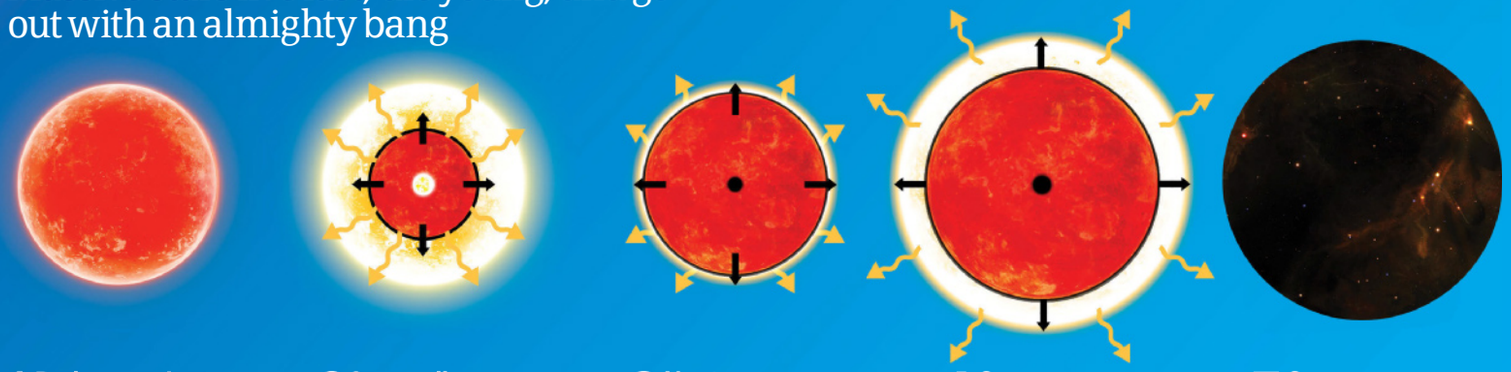
Eating in space is not always a particularly enjoyable experience, either. Microgravity causes body fluids to pool around the astronauts' heads, which compresses their sinuses. This affects their sense of smell and taste, so strong flavours are needed to stop food tasting bland. Another factor Blumenthal had to consider was the psychological impact of a six-month stint on the ISS. He created some of Peake's favourite dishes – including space-friendly bacon sandwiches, beef stews and Thai curries – to remind him of home.

To stop food floating away, it is attached to the table with Velcro or elastic cables

Prior to launch, Blumenthal spent two years developing Major Peake's meals

What happens when stars die?

Massive stars live fast, die young, and go out with an almighty bang



1 Red supergiant
When a star with the mass of ten Suns or more runs out of hydrogen fuel, it starts to fuse heavier elements. The core gains mass and the outer layers expand.

2 Core collapse
The core becomes so big that it collapses under its own gravity. This creates a shockwave that compresses and heats the star's outer layers, creating a bright flash.

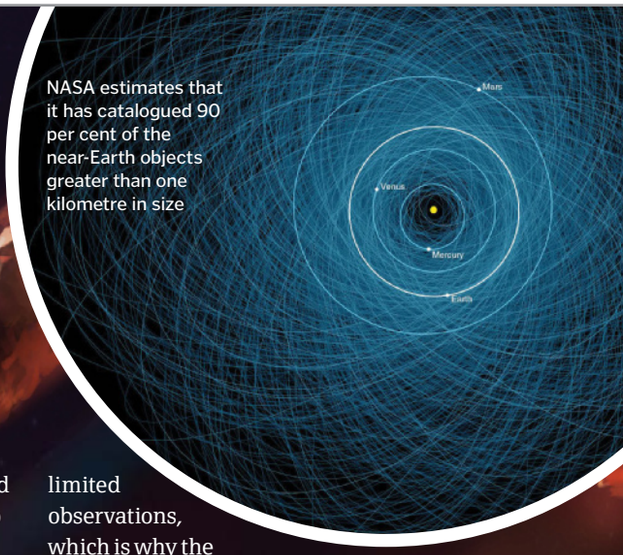
3 Neutron core
The implosion causes the core to shrink. The incredibly dense neutron core is about the mass of our Sun, but packed into a sphere just a few kilometres across.

4 Supernova
The shockwave is accelerated outward, ripping the star apart in an incredibly bright explosion. At this time, supernovas can even outshine the galaxies they are in.

5 Supernova remnant
The ejected material blasts through space. A vast nebula is left in the supernova's wake, and the former core compacts to become a neutron star.

Near-Earth near-misses

Don't panic! The science behind sensationalist headlines explained



NASA estimates that it has catalogued 90 per cent of the near-Earth objects greater than one kilometre in size

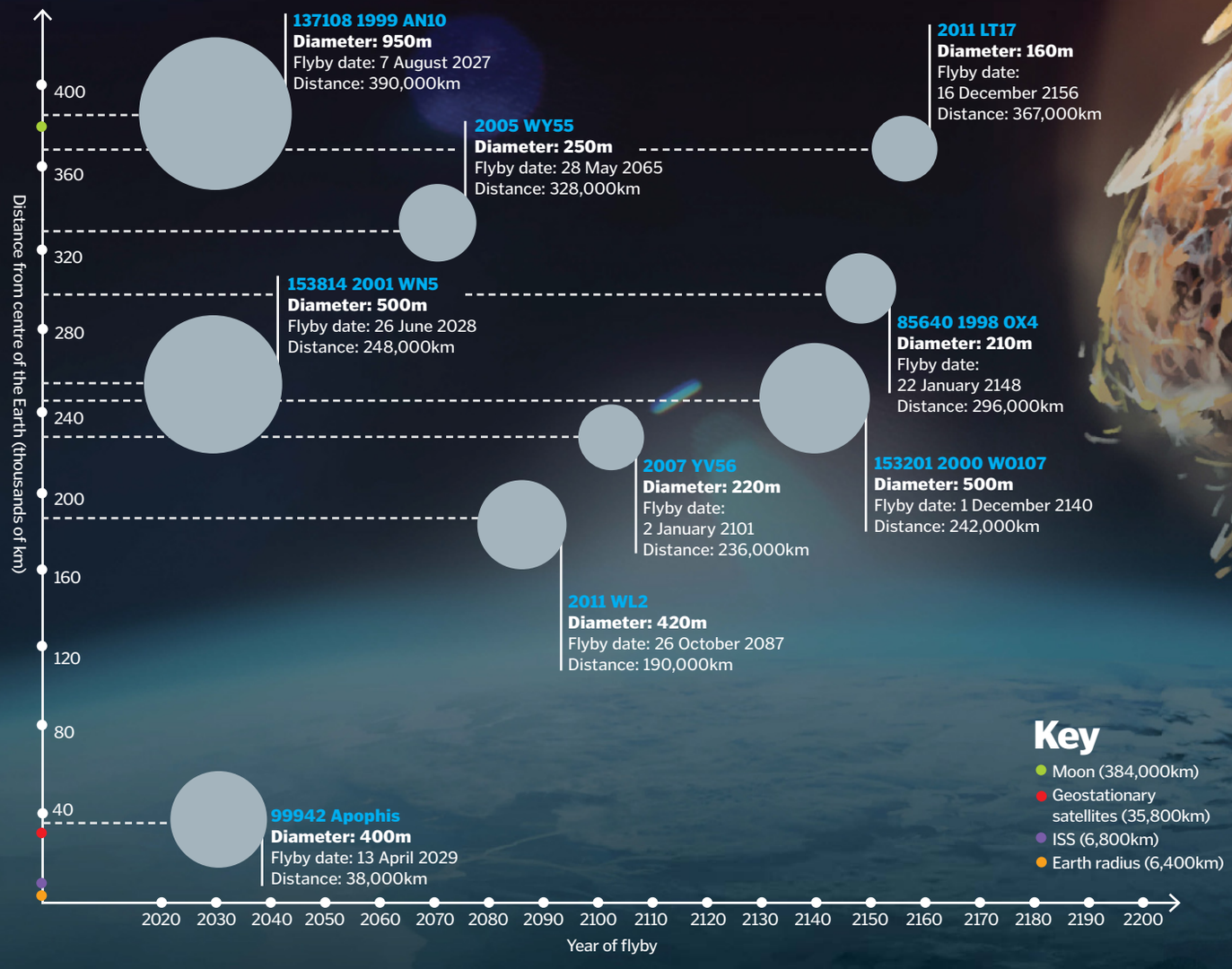
Headlines of an asteroid *Armageddon* may sell papers, but in reality these space rocks rarely pass within the Moon's orbit. In February, NASA announced that the asteroid 2013 TX68 could pass as close as 17,000 kilometres, or as far as 14 million kilometres from Earth's surface. It is this huge range of uncertainty that often causes a stir among media outlets; when experts appear to be so unsure, it can seem somewhat unsettling.

NASA's Near-Earth Object Program detects and tracks asteroids and comets that pose a threat to our planet. The most important part of the programme is identifying Potentially Hazardous Asteroids (PHAs), which could impact Earth in the future. These are classified as asteroids that are over 150 metres wide, on orbits that will bring them within 7.5 million kilometres of us.

Initial estimates of these PHAs often appear threatening because they are based on quite limited observations, which is why the range of distances and flyby dates tend to vary. These relatively inaccurate predictions are refined as more data is collected, providing better figures. Several weeks after the announcement, NASA updated their predictions for 2013 TX68, which swooped safely past us at a distance of 4 million kilometres.

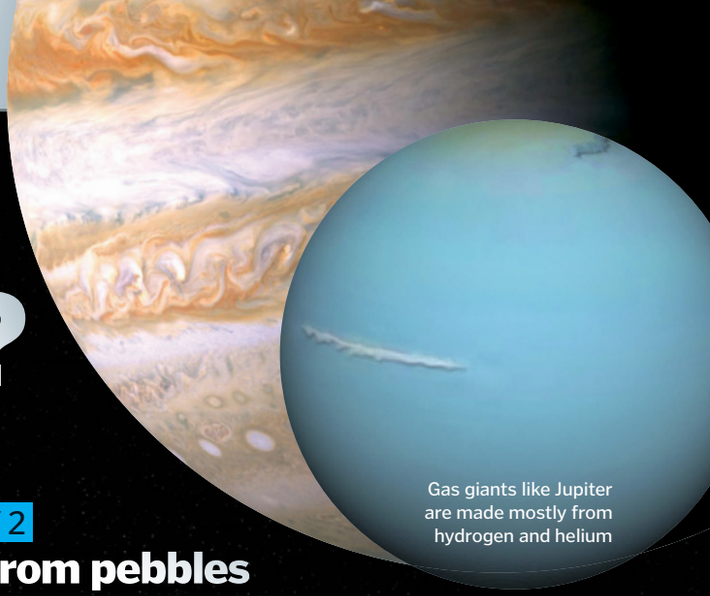
Potentially Hazardous Asteroids

The space rocks that could come too close for comfort in the next 200 years



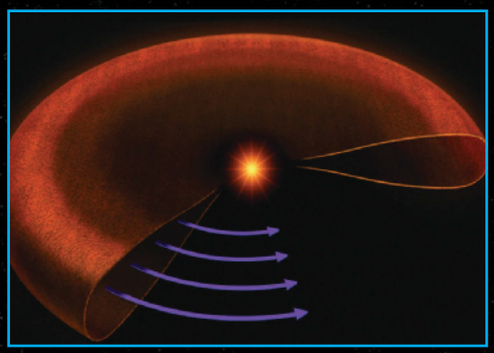
HOW DO GAS GIANTS FORM?

There are two competing theories to explain the birth of planets like Jupiter and Saturn

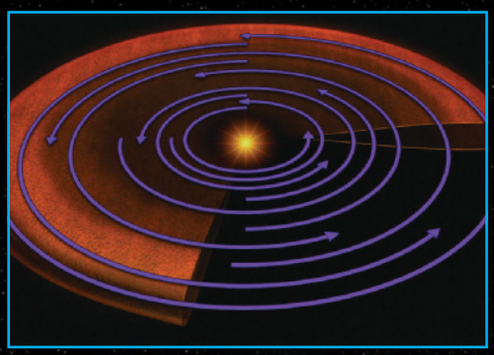


Gas giants like Jupiter are made mostly from hydrogen and helium

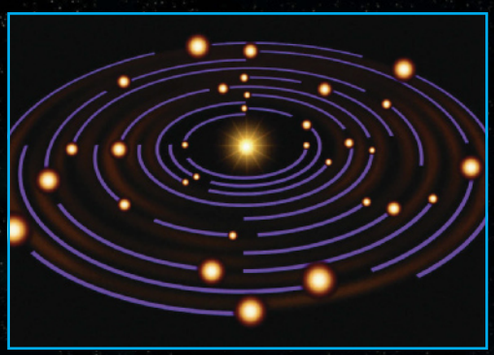
THEORY 1
Cosmic cannibalism



Cosmic debris
The process begins as the dust and gas left over when stars form flatten out into a disc shape, and over time the particles inside start to collide. As they bump into each other, rocky flecks stick together.



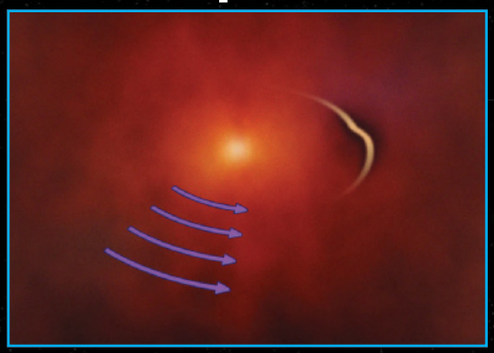
Core formation
As the clumps of rocky debris get larger, their gravitational pull gets stronger, and they begin to attract more and more debris from the surrounding gas cloud. Clumps merge, and then planets start to form.



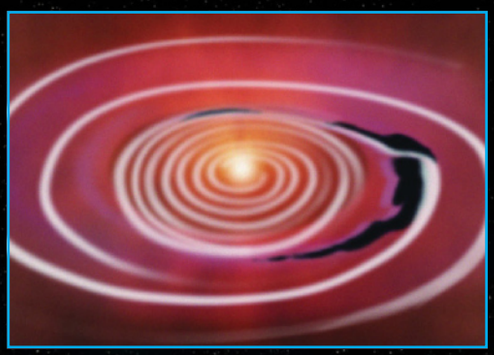
Picking up gas
The rocky planets closest to the star are battered by stellar winds, which blow light gases away, but those further away are shielded. They accumulate excess gas, steadily growing in size.

Destroying the competition
The gas giants in the outer part of the star system swallow up their smaller neighbours. Collisions between planets can tilt their orbits, and can throw smaller ones out into space.

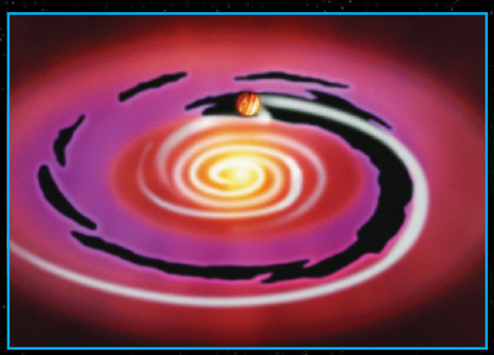
THEORY 2
Born from pebbles



Planetary pebbles
A more recent idea suggests that gas giants form from icy 'pebbles'. These clumps start small, at just the width of a ruler, but as they sweep through the gas cloud they grow.



Gathering dust
The pebbles orbit through the dust cloud surrounding the young star, gathering material rapidly as they go. Small particles cling to the surface of the newly forming planets, adding more bulk.



Carving a path
As the gas giants grow in size, they carve out paths in the disc. Instead of forming from a series of collisions, this theory suggests that gas giants hoover up particles in the disc as they orbit.

The aftermath
This process happens quickly, over a few million years. Once the gas giants have cleared the way, rocky planets can start to form closer to the parent star, which produces the planets' heat and light.

EUREKA!

10 accidental discoveries that changed the world

It's no secret that the best ideas often come to us when we least expect them to. For some it may be on the drive home from work or in the middle of the night, while others may have their lightbulb moments while taking 'time out' in the bathroom. The Ancient Greek mathematician Archimedes was in the latter group, having famously realised how to measure the volume of irregular objects while taking a bath. When he climbed in, the water level rose, and it occurred to him that the volume of water displaced must be equal to his own. How he maintained his reputation after running naked through the streets screaming 'Eureka', we're not sure!

It's not just ideas that can come to us by chance; sometimes it's a physical invention. While it's true that most of history's greatest discoveries were made after years of painstaking research, others happened completely by accident. Take the humble ice lolly, for example. Arguably a lifesaving invention during the hot summer months, it was initially the result of a failed attempt at making soda. In 1905, an 11-year-old boy called Frank Epperson had been trying to make himself a sugary beverage, but left his concoction outside overnight with the stirrer still in the cup. Being the middle of winter, the liquid froze, and in the morning Frank enjoyed a frozen treat on a stick. Eighteen years later, he realised the commercial possibilities his accidental invention could have, and he began selling them on California beaches.

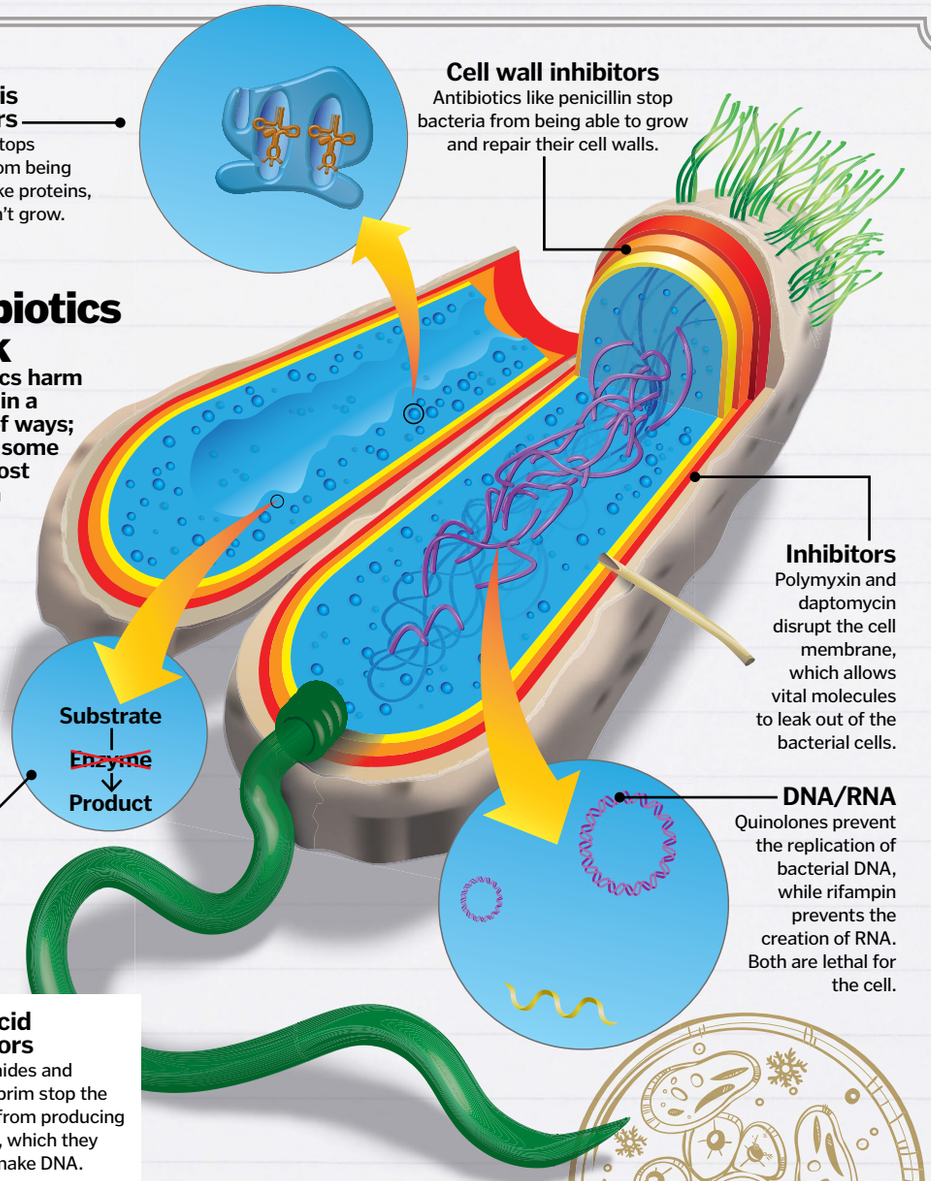
So whether it's the result of a clumsy spill or a contaminated laboratory, accidental inventions are just a slapdash scientist away, as long as they are able to realise the potential. Naked celebrations are, of course, optional.

Penicillin

1 A contaminated experiment is any scientist's worst nightmare, but in the case of biologist Alexander Fleming, it would be his making. While studying the influenza virus, he accidentally left a petri dish out of the incubator while he was away on holiday. Upon returning, he discovered that the petri dish, in which he had been growing staphylococcus bacteria, had also begun to grow mould. When Fleming examined the dishes more closely he noticed that there was a ring around the mould where the bacteria had not grown. The 'mould juice' was actually penicillin, produced by the Penicillium mould that had contaminated the dish. Fleming later found that it was able to kill many different types of bacteria. It was two other scientists, Howard Florey and Ernst Chain, who turned penicillin into a drug, but without Fleming, antibiotics may never have been invented.

How antibiotics work

Antibiotics harm bacteria in a variety of ways; here are some of the most common

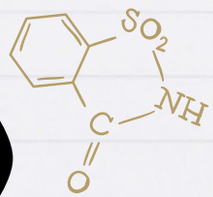


DISCOVERER CASE FILE

Sir Alexander Fleming

Born in Scotland in 1881, Fleming went on to study at St Mary's Hospital, London, where he completed a bachelor's degree in medicine. His accidental discovery of penicillin earned him a Nobel Prize, which he shared with Florey and Chain.

Plastics (Bakelite)



2 Throughout the 19th century, scientists tried desperately to solve the mystery of polymers – very large molecules that can be expanded and moulded. In 1870 an American inventor modified a naturally occurring polymer called cellulose to create an incredible new material called celluloid, which could be moulded or rolled when heated. But it would be another 40 years before the first wholly synthetic plastic was made. The discoverer, Leo Baekeland, had been experimenting with synthetic resins. After heating the liquid, he found that it produced a solidified matter, which was insoluble in solvents and did not soften when heated. He called it 'Bakelite', and it was soon used in the production of everything from electricals to jewellery.

DISCOVERER CASE FILE

Leo Baekeland

A Belgian chemist born in 1863, Baekeland left his homeland for New York aged 23. Here he invented Velox photographic paper, which allowed developments under artificial light, before turning to plastics.

Bakelite was used to make telephone casings because it was electrically nonconductive and heat-resistant

Microwave

3 Not only was the microwave discovered by accident, it was also discovered by a man who had not even completed high school. At the age of 12, Percy Spencer left education to work in a spool mill and was later hired to install electricity in a nearby paper mill. In the 1920s, Spencer began working as an engineer for Raytheon, a company that went on to improve radar technology for Allied forces in World War II. One day, he was stood in front of an active radar magnetron when he noticed the chocolate bar in his pocket had melted. He began testing the effects of magnetrons on other foods, and invented the first true microwave oven by attaching a high-density electromagnetic field generator to an enclosed metal box. The oven was a success, and in 1945 the company filed a patent for the first commercial microwave.

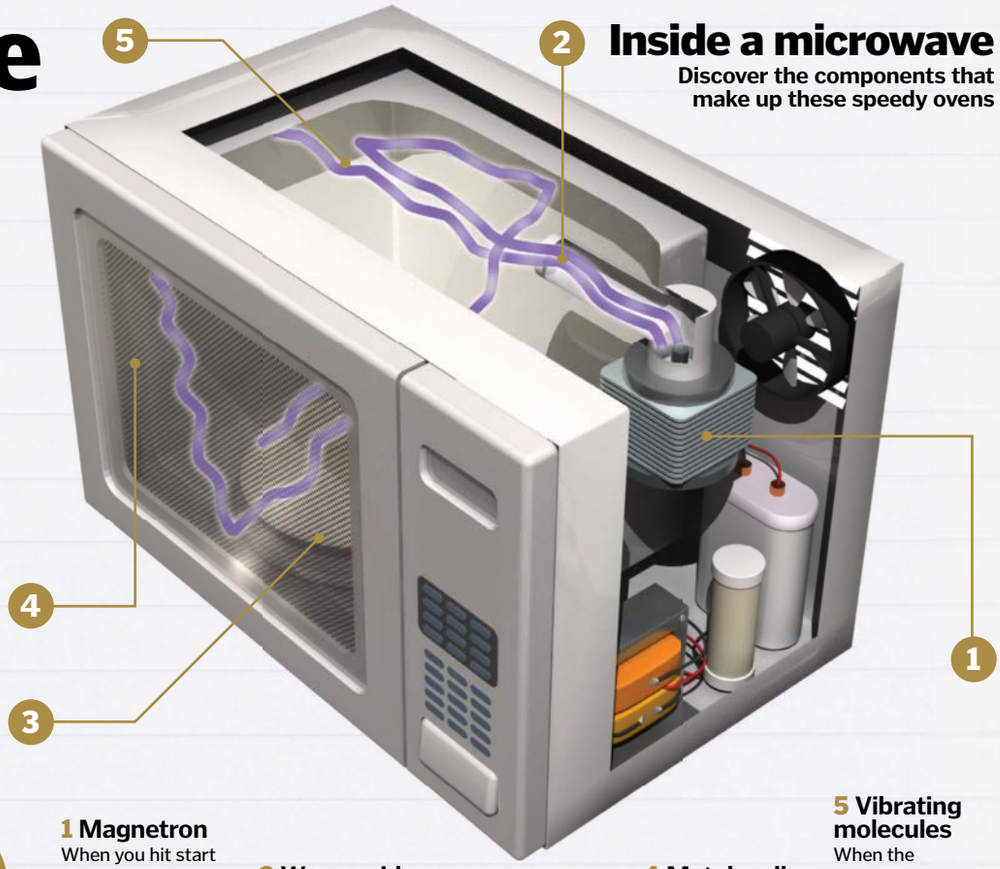
DISCOVERER CASE FILE

Percy Spencer

Born in 1893, at eighteen months old Spencer's father died and his mother left him in the care of his aunt and uncle. Despite his difficult start, he would become one of the world's most famed physicists.

Inside a microwave

Discover the components that make up these speedy ovens



1 Magnetron
When you hit start on a microwave, the magnetron takes electricity from the power outlet and converts it into high energy microwaves.

2 Wave guide
These waves are blasted into the food compartment through a channel called a wave guide.

3 Turntable
The food spins around on a turntable, allowing it to be cooked evenly.

4 Metal walls
The microwaves bounce off the reflective metal walls to hit the food from different angles.

5 Vibrating molecules
When the microwaves penetrate the food, they cause the molecules inside it to vibrate faster. This quickly heats the food up.

Artificial sweetener

4 The first artificial sweetener, saccharin, was discovered by a Russian chemist called Constantin Fahlberg. He had been experimenting with preservatives in his work, and while eating a bread roll, he noticed that it had been sweetened by the substance left on his hands. He went back to the lab and retraced his steps, until he was able to synthesise the sweetener in bulk.

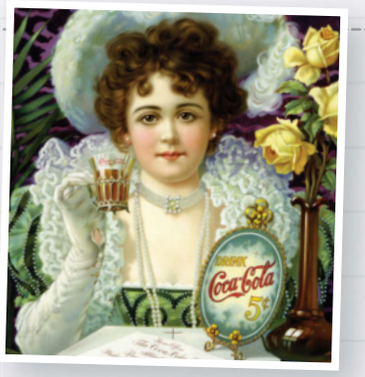
DISCOVERER CASE FILE
Constantin Fahlberg
Fahlberg was initially hired to analyse the purity of sugar.

Saccharin rose to popularity during World War II, when sugar became scarce

Superglue

5 This super-sticky substance was discovered by accident – twice! Chemist Harry Coover had been attempting to make clear plastic gun sights for the Second World War, and one formulation he tested produced an extremely quick bonding adhesive. It was useless for his gun sights, though, and he forgot about it until almost ten years later, when he stumbled across it again while developing heat-resistant canopies for jet airplanes. This time he realised its potential, and the product was put on the market.

DISCOVERER CASE FILE
Harry Coover
Coover worked as a chemist for Eastman Kodak.



Coca-Cola

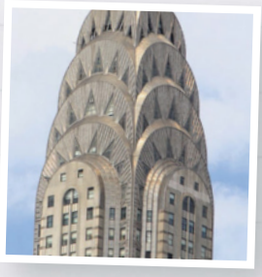
6 After being wounded in the American Civil War, pharmacist John Pemberton became addicted to morphine. Seeking an alternative, in 1886 he began experimenting with coca – the plant from which cocaine is derived. He eventually stirred up a fragrant, caramel-coloured liquid that he combined with carbonated water and put on sale for five cents a glass. The soda, named Coca-Cola, would become the world's fourth most valuable brand.

DISCOVERER CASE FILE
John Pemberton
Pemberton established a wholesale drug business.

Stainless steel

7 Steel has been forged for millennia, but it wasn't until 1913 that a metallurgist called Harry Brearley discovered a way to stop it rusting. He had been tasked with finding an erosion-resistant metal to prolong the life of gun barrels. Legend has it that as attempt after attempt failed, his pile of scrap metal grew bigger, and he later noticed that one of the scraps hadn't rusted like the others. He had invented stainless steel, and quickly saw its potential in the cutlery industry.

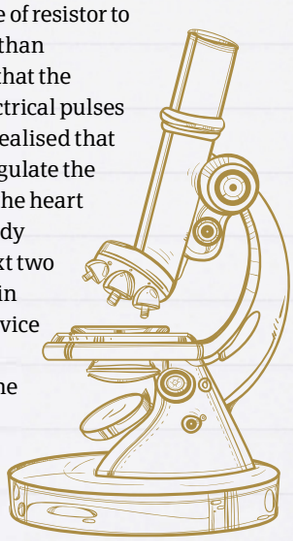
DISCOVERER CASE FILE
Harry Brearley
Brearley was lead researcher at Brown Firth in 1908.



The pinnacle of New York's Chrysler Building is clad with non-rusting stainless steel

8 Pacemaker

Pacemakers have existed in a very rudimentary form since the 19th century, when it was discovered that electrical impulses could be used to provoke a heartbeat. However, the devices that followed were large and bulky and had to be plugged into a mains current, putting the patient at risk of electrocution. It wasn't until 1960 that battery-powered implantable pacemakers came into use, having been invented four years previously. Electrical engineer Wilson Greatbatch was working on a heart-rhythm recorder when he added the wrong size of resistor to the circuitry. Rather than recording, he found that the device produced electrical pulses instead. He quickly realised that it could be used to regulate the electrical activity of the heart and guarantee a steady rhythm. Over the next two years, he succeeded in miniaturising the device and making it safe from bodily fluids. The first patient, a 77-year-old man, went on to live for a further 18 months.



DISCOVERER CASE FILE

Wilson Greatbatch

The American engineer and inventor was born in New York in 1919, and served in World War II before completing a degree in electrical engineering. By the time of his death in 2011, he held over 325 patents.

How a pacemaker works

Discover how these amazing pieces of tech can keep our hearts beating

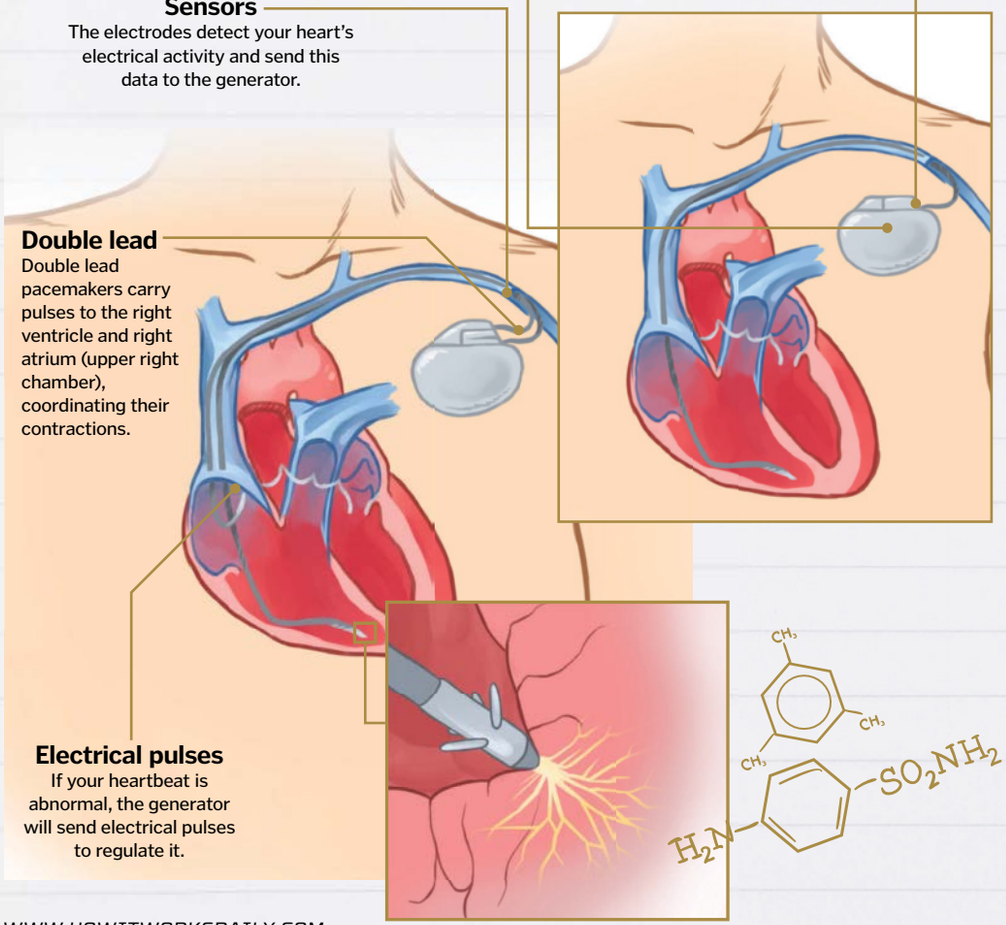
Composition
A pacemaker consists of a battery, a generator and a series of wires with sensors (electrodes) at their tips.

Single lead
Single lead pacemakers usually carry pulses from the generator to the right ventricle (the lower right chamber of the heart).

Sensors
The electrodes detect your heart's electrical activity and send this data to the generator.

Double lead
Double lead pacemakers carry pulses to the right ventricle and right atrium (upper right chamber), coordinating their contractions.

Electrical pulses
If your heartbeat is abnormal, the generator will send electrical pulses to regulate it.



9 Teflon

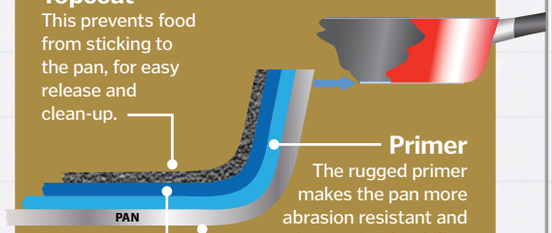
The non-stick substance found on frying pans was inadvertently invented by a man called Dr Roy Plunkett. He had been trying to synthesise a non-toxic alternative to refrigerants like sulphur dioxide and ammonia, and was experimenting with tetrafluoroethylene (TFE). After storing the gas in cylinders, he opened one to discover that it had polymerised into a waxy white powder that was extremely sticky and had a very high melting point. Three years later, the substance, which was named Teflon, was patented.

DISCOVERER CASE FILE
Roy Plunkett
Plunkett received the John Scott Medal for the "comfort of humankind".

Protecting a pan

Peel back the layers to find out what makes modern frying pans so practical

Topcoat
This prevents food from sticking to the pan, for easy release and clean-up.



Primer
The rugged primer makes the pan more abrasion resistant and enhances its durability.

Midcoat
A tough midcoat provides resistance to scratches and abrasions.

Base
The hard base is usually made from aluminium or stainless steel.

10 X-Rays

It was while German physicist Wilhelm Röentgen was investigating the effects of cathode ray tubes that he made a curious discovery. During an 1895 experiment, he evacuated the tube of all air and filled it with gas before passing an electric current through it. Despite it being covered with black paper, he noticed that a screen several feet away was illuminated by the invisible rays, which he named 'X' to indicate the unknown. They were later found to pass through human tissue, allowing for the imaging of bones.

DISCOVERER CASE FILE
Wilhelm Röentgen
Born the only child of a cloth merchant in 1845, Röentgen studied mechanical engineering.

Röentgen took this radiograph of his wife's left hand

The Ministry of Food issued every man, woman and child with a ration book

Food rationing

How the British government controlled what went into a shopping basket during World War II

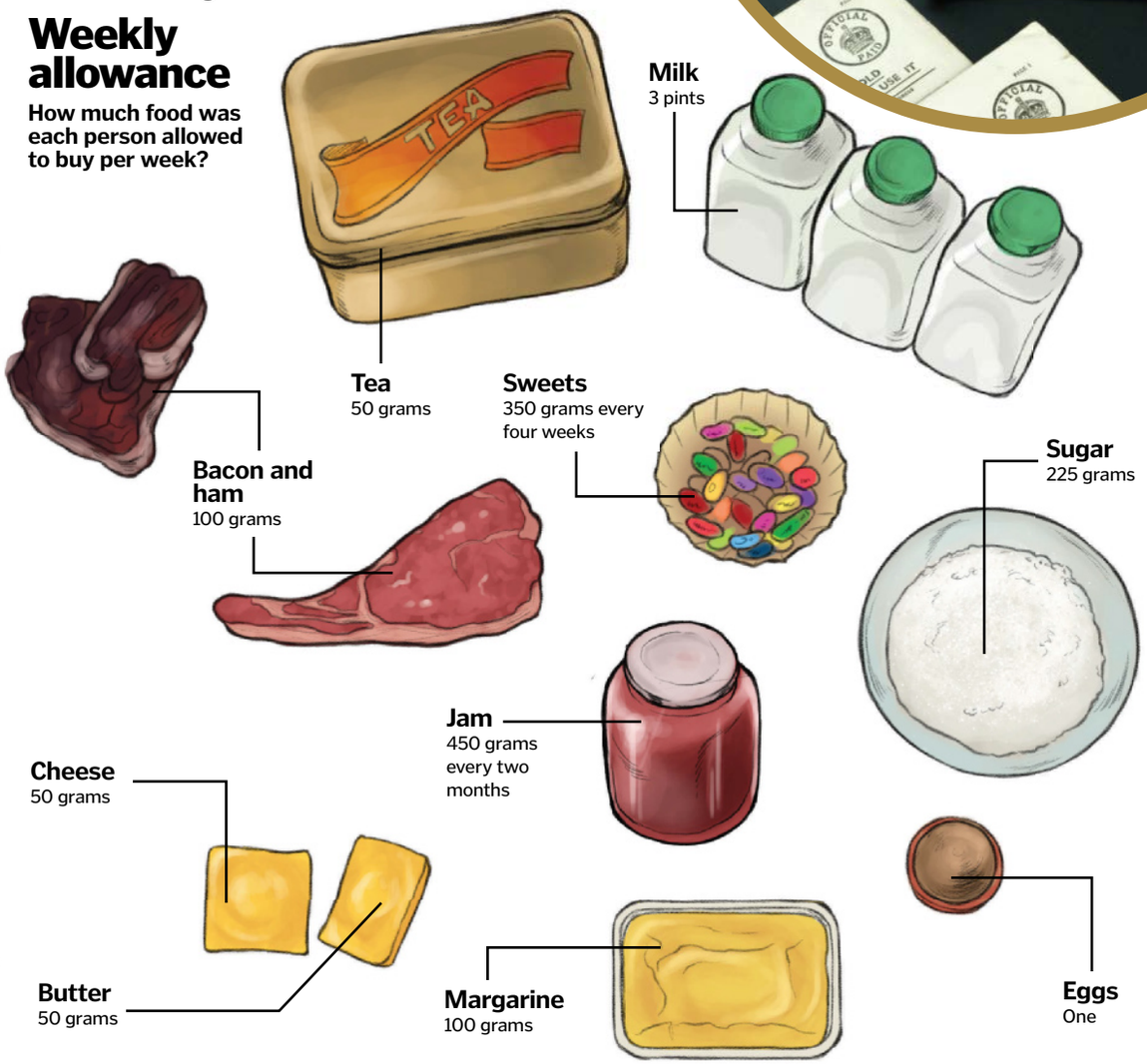
Before World War II, Britain was importing about 55 million tonnes of food from all over the world each year. However, when the war started in 1939, German submarines began to bomb the supply ships that delivered goods to British shores in an attempt to make their enemy weaker. Worried this would lead to food shortages, the British government introduced a system of rationing to limit the amount of some items that people could buy each week.

Every person in Britain was issued a ration book, and had to register and buy their food from certain shops. When they wanted to purchase an item, they would hand over a coupon from their ration book along with the money, and the shopkeeper would cross off the item in the book to ensure they couldn't buy any more until the following week.

The weekly ration varied from month to month as foods became more or less plentiful, and long queues would often form outside shops when a particular item came back in stock. The rationing of food lasted 14 years, ending nine years after the war in 1954.

Weekly allowance

How much food was each person allowed to buy per week?



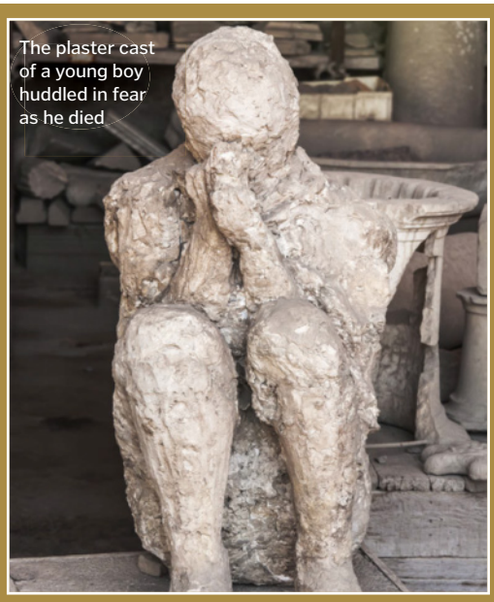
Preserved Pompeii

How the victims of Vesuvius were frozen in their final moments

When Mount Vesuvius erupted in 79 CE, the nearby cities of Pompeii and Herculaneum were completely destroyed, as pyroclastic surges of hot gas and ash engulfed everything in their path. In Herculaneum, the inhabitants were instantly incinerated, but further away in Pompeii, people were buried under five metres of volcanic material.

After the fine ash encased their bodies, it began to harden into a shell of porous pumice rock. As the soft tissue inside decayed and leached away through the rock, it left their final pose at the moment of their death perfectly preserved.

In 1864, after the site of the disaster was finally discovered, the director of excavations, Giuseppe Fiorelli, invented a method for preserving the victims. Plaster was poured into the hollow shells and left to harden for a few days, and then the outer layers of hardened ash were chipped away to reveal a detailed cast of the victim in their final moments. Since then, some casts have been made using resin instead of plaster, as it is more durable, transparent and does not destroy the victims' bones.


The plaster cast of a young boy huddled in fear as he died

Roman crime and punishment

Hold on to your coin purse and take a trip down the mean streets of ancient Rome

During the first century CE it is estimated that the city of Rome supported 1 million inhabitants. As with any city, densely populated areas with wide class divides can easily become criminal hotspots.

The foundation of Roman law was known as the Twelve Tables, a dozen rules that every citizen had to obey. The Twelve Tables were so important that schoolchildren learnt to read and write by copying laws down and reciting them.

While some soldiers, volunteers and officials were tasked with keeping the peace, the city had no dedicated police force, so upholding the law could be difficult. Harsh punishments were the main deterrents, ranging from a brutal beheading to elaborate public executions at the Colosseum.

The crimes committed and punishments received often depended on the social standing of the accused. High-class citizens convicted of major crimes were often given the option of exile rather than execution. Slaves, on the other hand, were punished harshly. If one slave was caught committing a crime, it was not uncommon for all the other slaves of the household to be punished as well, to discourage uprisings.

The Praetorian Guard was very influential and played a role in the removal and accession of several emperors

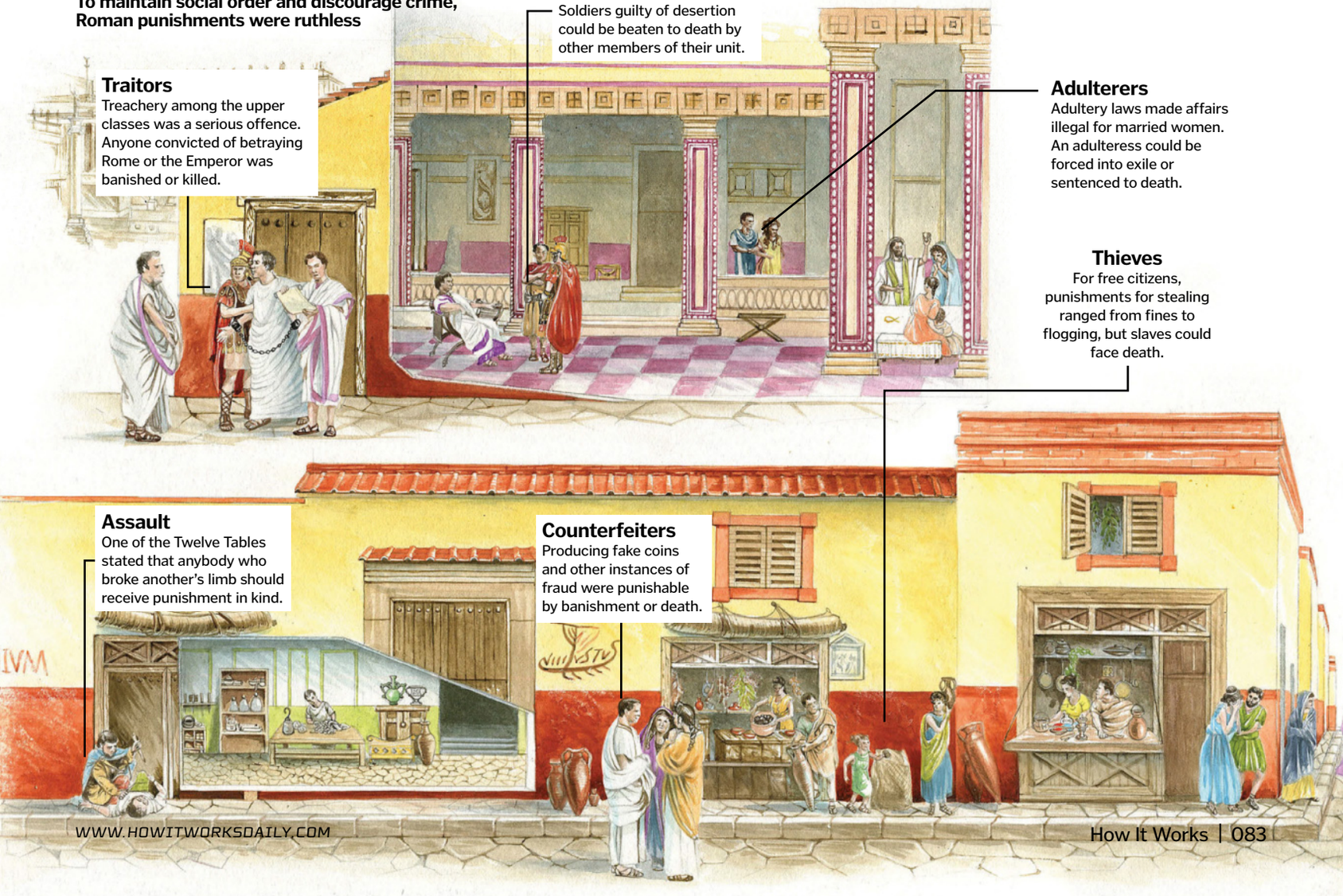
Keeping the peace

While there was no official police force in Ancient Rome, leaders enlisted some groups to be in charge of crime prevention. Vigiles were volunteers who performed the dual role of police and firefighters. They patrolled the city at night, scouting for potential criminals or runaway slaves, while also helping to extinguish fires. Urban cohorts were soldiers that played the role of riot police. Rather than patrolling the streets, they were only summoned if a situation got out of hand.

The Praetorian Guard was responsible for protecting the Emperor, like bodyguards. Despite only having a single person to protect, at times the Praetorian Guard consisted of over 1,000 men. None of these groups were tasked with catching criminals after a crime was committed. If Roman citizens were victims of crime, it was their responsibility to catch the perpetrator and take him or her to the magistrate for a trial.

Criminals of Rome

To maintain social order and discourage crime, Roman punishments were ruthless



Deserters
Military discipline was severe. Soldiers guilty of desertion could be beaten to death by other members of their unit.

Traitors
Treachery among the upper classes was a serious offence. Anyone convicted of betraying Rome or the Emperor was banished or killed.

Adulterers
Adultery laws made affairs illegal for married women. An adulteress could be forced into exile or sentenced to death.

Thieves
For free citizens, punishments for stealing ranged from fines to flogging, but slaves could face death.

Assault
One of the Twelve Tables stated that anybody who broke another's limb should receive punishment in kind.

Counterfeiters
Producing fake coins and other instances of fraud were punishable by banishment or death.

BRAIN DUMP

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MEET THE EXPERTS

Who's answering your questions this month?

Tom Lean

Tom is a historian of science at the British Library where he works on oral history projects. He recently published his first book, *Electronic Dreams: How 1980s Britain Learned To Love The Home Computer.*

Laura Mears

Laura studied biomedical science at King's College London and has a master's from Cambridge. She escaped the lab to pursue a career in science communication and also develops educational video games.

Alexandra Cheung

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

Sarah Bankes

Sarah has a degree in English and has been a writer and editor for more than a decade. Fascinated by the world in which we live, she enjoys writing about anything from science and technology to history and nature.

Shanna Freeman

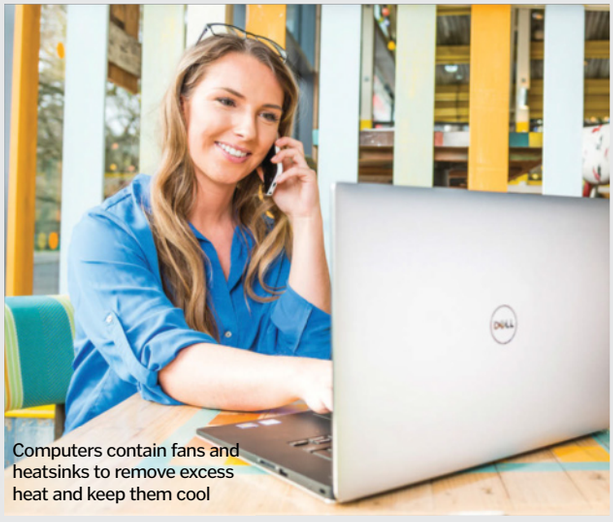
Shanna describes herself as somebody who knows a little bit about a lot of things. That's what comes of writing about everything from space travel to how cheese is made. She finds her job comes in very handy for quizzes!

A summer birthday means it's more likely to be dry and sunny for outdoor celebrations

Why do British monarchs have two birthdays?

Aled Carter

In true British style, the reason for a British monarch having two birthdays is due to the weather. To mark the occasion, official celebrations are held on a Saturday in late May or June, as the weather is more likely to be dry and sunny. This is because birthday celebrations involve lots of outdoor activities, such as the Trooping the Colour military parade. The tradition dates back to the 18th century when the annual summer military cavalcade became a celebration of King George II as well as the armed forces – but his birthday was in chilly November. Since then, the official birthday of a monarch has been held during the summer. **SB**



Computers contain fans and heatsinks to remove excess heat and keep them cool

Why do computers get hot as you use them?

Zoe Landale

All of the electronic components inside your computer have electrical resistance. This means that some of the electric energy that flows through the computer gets dissipated as heat energy as current passes through the electronics, just like the heating element in an electric fire or cooker. Moving parts and motors, such as discs spinning inside hard drives, can also generate heat. The faster your computer is running then the hotter it will get. However, high temperatures can damage the sensitive electronics in computers, so the heat has to be removed somehow. Even though most desktop and laptop computers have fans and heatsinks to keep the electronics cool, the processor can be hot enough to fry an egg. **TL**

Whether you love or loathe coriander, it's probably in your genes

Why do some people hate the taste of coriander?

Amie-Jo Sharples

Coriander is considered an essential herb in numerous cuisines, but it's also a polarising ingredient – you either love it or loathe it. Coriander preference isn't just a simple matter of taste, though. Scientists have found that it's actually a matter of genetics. They've even linked two specific genetic variants to people who think that coriander tastes like soap. There's also a divide among cultures. South Asians, Hispanics, and Middle Easterners – those who are more likely to use coriander in ethnic cuisine – are more likely to enjoy it than East Asians and people of European or African descent. **SF**

Why do we get more nose hair as we grow older?

Eloise Lunn

We all have hair follicles inside our noses and ears, but for most of our lives the hairs are short and hard to see. They become more noticeable as we age due to the effects of hormones. Hair follicles are sensitive to the male sex hormone, testosterone, and over time they start to change. Testosterone is responsible for the growth of armpit hair during puberty, and it is also the culprit behind male pattern baldness, gradually killing off head hairs over time. Women also have testosterone, although its effects are dampened by the female sex hormone, oestrogen. After the menopause, when oestrogen levels drop, women get more ear, nose and facial hair too. **LM**

Testosterone drives the growth of body hair as we age

White noise contains equal amounts of all the frequencies you can hear

What is white noise?

Duncan Howe

To our ears white noise is a sort of hissing sound. Just like white light contains all the colours of the spectrum, white noise is made up of all the different frequencies the human ear can hear. It's a bit like listening to all of them at once, at the same level. Because of this, white noise is a very constant sound that can mask others. Some people who can't sleep at night use the static between FM radio stations, which sounds like white noise, to mask sounds that might keep them awake. **TL**

Why do chickens have combs?

Yani Ochyra

Chicken combs actually help keep the birds cool. Chickens can't sweat, so when they overheat, blood rushes into the cooler combs on the tops of their heads. Combs are also a good indicator of a chicken's health; a bright red comb is normal, while a pale or darker comb may mean illness. Comb colour, shape and size vary by breed, but males have larger combs than females. They also play a part in mating; a healthy comb is more attractive and signals that a chicken is ready to mate. **SF**

This rooster's brilliant red comb keeps him cool and shows that he's fighting fit

FASCINATING FACTS

Who invented the hourglass?

Nobody knows. Ancient civilisations used water clocks and may have invented sand clocks too, but hourglasses only became common in the 1300s. Either way, the inventor's name is lost in the sands of time. **TL**

Hourglasses have been used for centuries, but the inventor is unknown

BRAIN DUMP

'Mouthwatering' doesn't seem to be a reflex in humans

Why does seeing food make your mouth water?

Alim Pasha

It seems instinctive that this happens as a reflex, because we associate the sight of food with eating. Russian researcher Ivan Pavlov showed this to be true in dogs, by training them to associate the sound of a bell with food (and therefore salivating), simply by repeatedly ringing it at mealtimes. However, in a small study on humans in 2011, scientists found no evidence that a similar reflex exists in humans. Saliva flow does increase when you handle food though, and this is likely to be related to the smell of it triggering saliva to be secreted. **LM**

Voyager 1 has travelled further from Earth than any other spacecraft

How far can we send a spacecraft before we lose contact with it?

Alexander Crighton-Smith

How far a space probe can go before communication becomes impossible is limited only by the radio technology we develop. Voyager 1, launched in 1977, is currently over 20 billion kilometres away, but we are still able to exchange information with it using radio signals. On Earth, huge antennae pointed towards the spacecraft pick up its incredibly weak signals, which are then amplified. Advances in this technology have allowed us to receive transmissions far longer than expected, and newer spacecraft with more powerful transmitters could in theory extend this range even further. We will lose contact with Voyager when it runs out of energy in around 2025. **AC**

FASCINATING FACTS

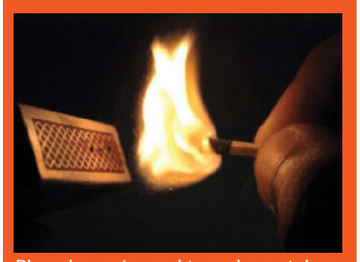
Why is NYC called the Big Apple?

During the 19th century, the phrase 'big apple' was used to refer to something very special and desirable. If you 'bet a big apple', you were confident about the outcome of an event. In the 1920s, the New York horse racing circuit was termed The Big Apple, but it didn't officially became the city's nickname until the 1970s. **SF**

New York's nickname was popularised in the 1970s

When was the first element discovered?

We have known about elements like gold and silver since ancient times, but the first element to be identified scientifically was phosphorus in 1649. It was discovered by German alchemist Hennig Brand. **LM**



Phosphorus is used to make matches

Who named Earth?

The word 'Earth' has Germanic and Anglo-Saxon origins, meaning 'ground', but it's difficult to determine when its definition evolved to include our whole planet. **AC**

Every language has its own name for planet Earth

They don't really get thirsty, but some fish do need to take in extra water

Do fish get thirsty?

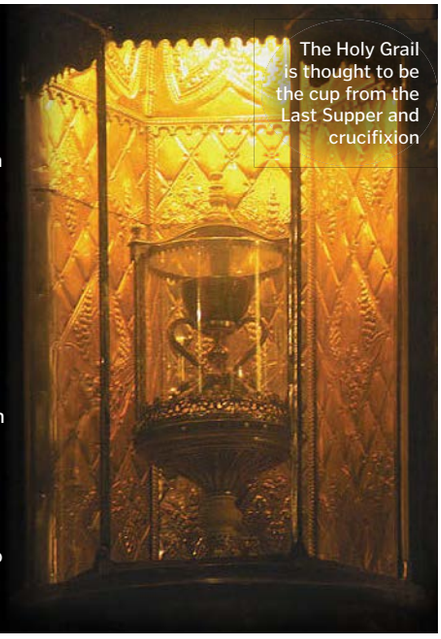
Helen Ferrett

They don't get thirsty like people do, but some fish do need to replenish the liquids in their body. Freshwater species don't need to drink because their tissues have a higher salt concentration than their environment, so their bodies absorb water by osmosis. On the other hand, saltwater fish have a lower salt concentration in their blood than the sea water they swim in, so they lose water through their skin instead. They have no choice but to drink the sea water to avoid becoming dehydrated, so they have specialised gills that pump out the excess salt. **SF**

What is the Holy Grail?

Nicolas Bartley

The Holy Grail is a Christian legend expressed in Western European literature and art. The Grail itself is considered the most sacred Christian relic, most commonly said to be the cup from which Jesus drank at the last supper, and in which Joseph of Arimathea collected Jesus's blood at the crucifixion. Joseph of Arimathea is said to have then taken the cup to England, where it was hidden for hundreds of years. The knights of King Arthur made it their principal quest to find the cup because, according to the legend, it had special powers. **SB**



The Holy Grail is thought to be the cup from the Last Supper and crucifixion

Why is a day 24 hours long?

Jade Pocklington

Our 24-hour day is derived from solar time: the time it takes for the Sun to reach the same position on the local meridian (as measured by a sundial, for example). An apparent solar day varies in length throughout the year by about 16 minutes either side of 24 hours, due to our planet's elliptical orbit and tilted axis. However, the average day length is equal to 24 hours, which is what we base our clocks on. This is slightly longer than the time it takes for the Earth to complete a full rotation around its axis: 23 hours, 56 minutes and 4.09 seconds. **AC**

We base our clocks on time measured according to the Sun's motion

The policy of designing products to break easily is called planned obsolescence

Are electronics designed to break?

Holly Meakings

Many devices are only designed to have a short life. In some cases it's because designing them to last longer would make them expensive, yet often it's deliberate. Manufacturers use materials they know will wear out or break easily, make maintenance difficult, or design circuits to get gradually degraded by too much heat. Ideally, this leads to products failing just after the warranty runs out. **TL**

What's in 'flower food' packets?

Isobel Loxton

When flowers are cut from a plant, they no longer receive the plant's nutrients. These therefore need to be replaced in order to keep the flowers alive and slow down the rapid ageing process that would otherwise result. Flower food packets contain nutrients and pH regulators to restore the balance of the flowers and make them resistant to cell and stem deterioration. The flowers are then able to develop just as they would if they hadn't been cut. The food packets also contain water softeners and water absorption promoters, which help the stems to drink the water. **SB**

Flower food packets contain nutrients, pH regulators and more to help keep them alive

BRAIN DUMP

Why does airplane food taste so bad?

Johnny Molony

It's challenging enough to serve up meals in flight, but these can seem even more unappetising due to the effects of low humidity, lower air pressure, and background noise on our sense of taste. Dry air and low pressure reduce the sensitivity of your taste buds to sweet and salty flavours – although bitter, sour and spicy foods are less affected. Dryness affects our nasal passages, making us less sensitive to smells, which are important in our perception of taste. The loud humming on planes has also been shown to make food seem blander. **AC**

Modified seasoning can help to improve our enjoyment of airplane meals

FASCINATING FACTS

What happened to the Venus de Milo's arms?

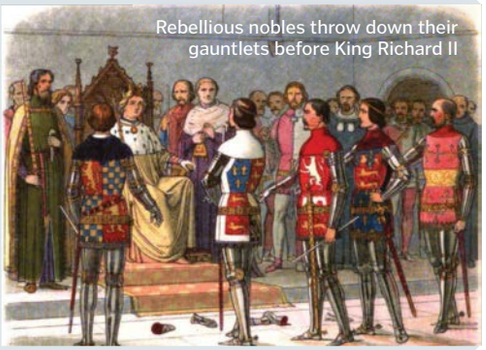
Most scholars believe the arms of this Ancient Greek sculpture were already missing when it was found, but some believe they were broken off in a fight in 1820. **SB**

Venus is also missing her left foot, headband and metal jewellery

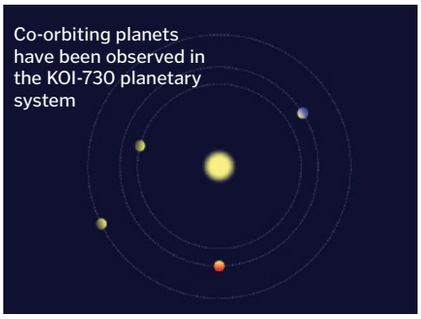
Where does the saying 'throw down the gauntlet' come from?

Yasmeen Pietras

To a Medieval knight a gauntlet was a sort of armoured glove worn to protect the hands from injury as part of their suit of armour. Violence was often used to settle disagreements in the Middle Ages, and one knight could challenge another to fight a duel by taking off his gauntlet and throwing it to the floor in front of his rival. 'Throwing down the gauntlet' was both an insult and a challenge. A knight would risk dishonour and humiliation if he refused to accept such a challenge, or 'take up the gauntlet', another saying which is still with us today. **TL**



Rebellious nobles throw down their gauntlets before King Richard II



Co-orbiting planets have been observed in the KOI-730 planetary system

Can two planets share the same orbit?

Rebecca McTague

Planets can share an orbit, as exemplified by two distant planets in the KOI-730 system spotted by the Kepler Space Telescope. This type of configuration is rare since a shared orbit will usually lead to one planet being flung outwards, or the two colliding. The only exception is if the larger planet sits in a 'sweet spot', 120 degrees in front of or behind the smaller planet. These locations are called Lagrangian points, where gravitational forces exerted by the other planet and the star cancel each other out, creating a relatively stable system. **AC**

Birds can use landscape features, celestial objects and other methods to migrate

How do birds know how to migrate?

Steve Kolgraf

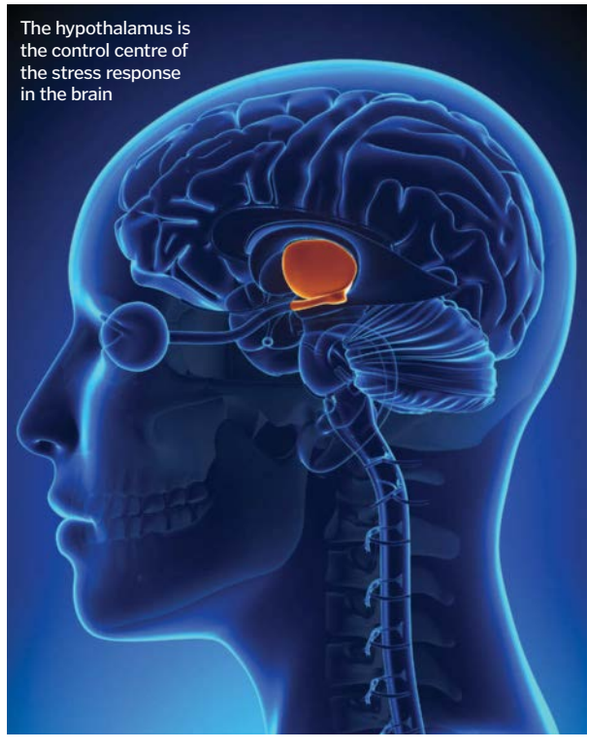
Some birds migrate more than 70,000 kilometres to escape the cold weather and find more food. Scientists believe there are several methods for migrating. The one most similar to human navigation relies on looking for landscape features, such as coastlines and mountains. A step up from this is to use the position of the Sun and stars, which many birds do. Some are able to use the Earth's magnetic field to migrate, using a part of their brains that acts like an internal compass. Most birds know when to migrate based on the length of the day as well as the temperature. These factors have an effect on their hormones, so birds get an instinctive feeling when the time is right. Not all migration is innate, though – some birds have to be taught, either by their parents or by humans if raised in captivity. **SB**

How does stress affect the body?

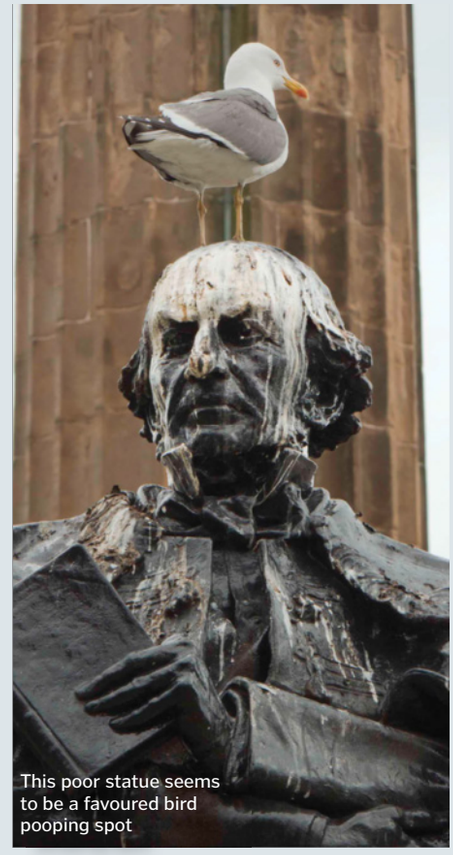
Theo Randall

The hypothalamus is a small structure that sits in the middle of the brain. It makes two key chemicals that kick-start the stress response: corticotropin-releasing hormone and vasopressin. Corticotropin-releasing hormone, as the name suggests, triggers the release of a second chemical called corticotropin. This travels in the bloodstream to the adrenal glands, which sit on top of the kidneys, and signals for them to make the steroid hormone cortisol.

Cortisol is also known as the 'stress hormone', and it has effects all across the body. It helps to return systems to normal during times of stress, including raising blood sugar, balancing pH and suppressing the immune system. Vasopressin also travels in the blood to the kidneys, but its function is slightly different. It increases the re-uptake of water, decreasing the amount of urine produced and helping the body to hold on to the reserves that it has. **LM**



The hypothalamus is the control centre of the stress response in the brain



This poor statue seems to be a favoured bird pooping spot

Why is bird poo white?

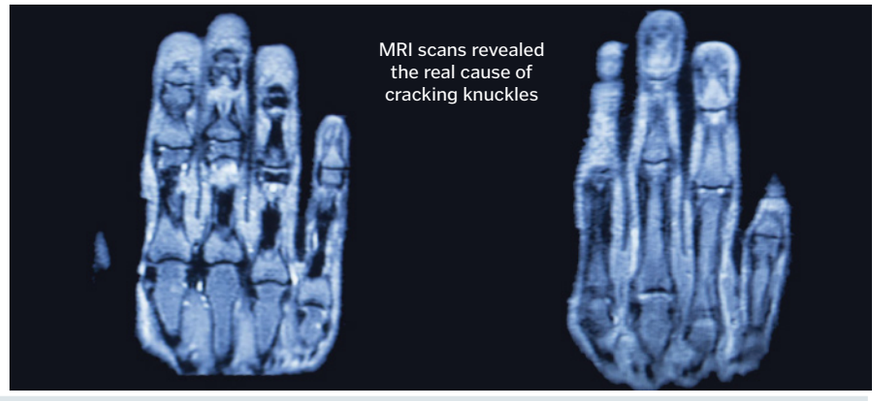
Carinya Mahoney

Most animals make brown poo, but birds are an exception. Instead of having a separate anus for solid waste and a urethra for liquid waste, most birds have a single opening called a cloaca. It's a multipurpose orifice used to excrete waste, lay eggs, and procreate. Birds release urine in the form of uric acid, and it's processed in a way to keep liquid loss to a minimum – hence the white splatter instead of yellow. Often you'll notice a dark blob in the centre; that's the solid waste, or poo. **SF**

Why do my knuckles crack more when it's cold?

Georgina Dublin

In 2015, researchers at the University of Alberta, Canada showed once and for all that the cracking sound made in finger joints is down to the formation of bubbles. As you pull, the surfaces of the joint come apart and a cavity appears in the fluid between. This makes the noise. To crack your knuckles again, you have to wait for the bubble to disappear. The researchers didn't look at the effect of climate, but it could be that something about the cold effects the behaviour of the fluid in your joints, helping the bubbles to disperse more rapidly. **LM**



MRI scans revealed the real cause of cracking knuckles

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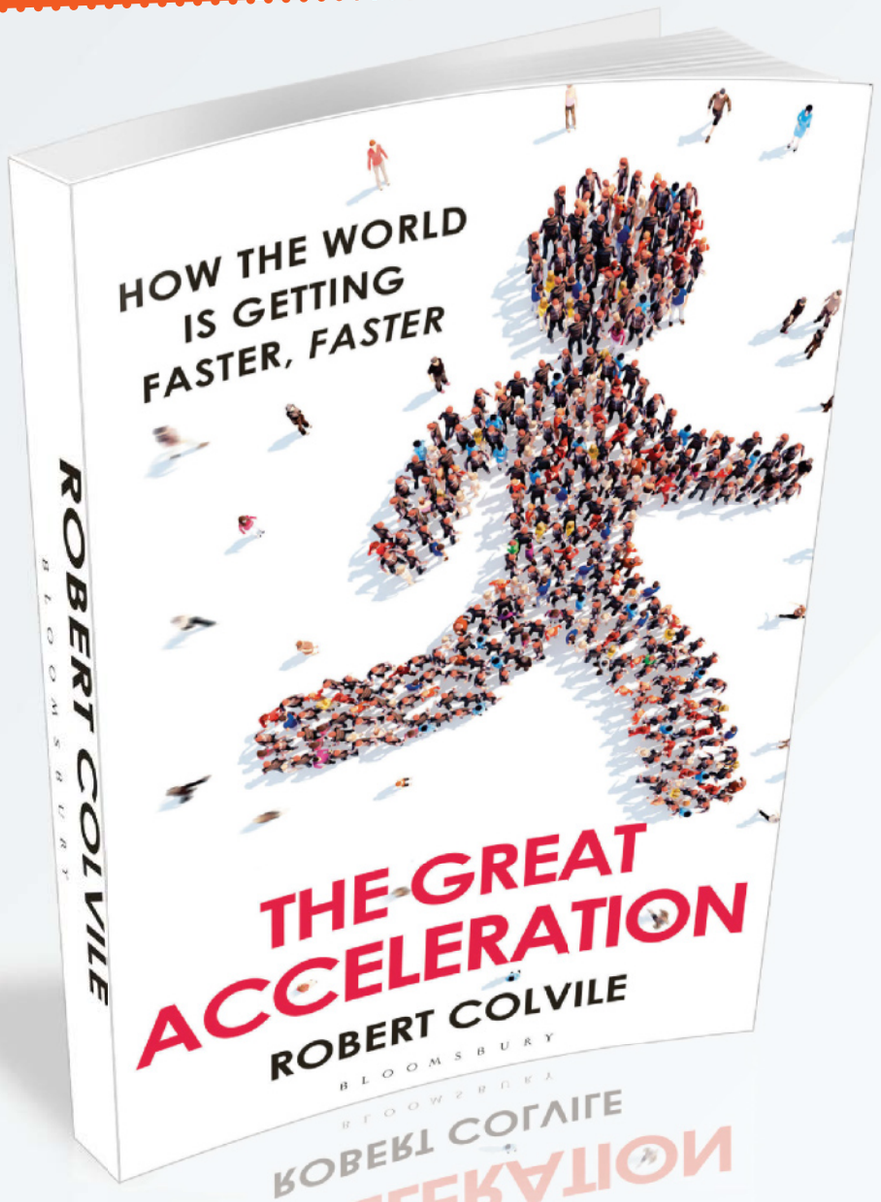
BOOK REVIEWS

The latest releases for curious minds



The Great Acceleration

A race to the future

- Author: **Robert Colvile**
- Publisher: **Bloomsbury Publishing**
- Price: **£16.99 / $28.00**
- Release date: **Out now**

It's an undeniable truth that for the last few hundred years, life has been progressively 'lived' at a faster pace. Normally we would say 'for lack of a better term', but in this instance the phenomenon has a name: acceleration, a concept that Robert Colvile examines in his latest book.

The hallmarks of acceleration are hard to avoid. For instance, where news was once disseminated through bulletins on TV and radio, coupled with daily doses of print media, today 24-hour news and social media have taken hold, and the battle over who will be the first to come out on top is constant. As a former news director of BuzzFeed UK, Colvile has first-hand experience.

It's not just online activity that's quickening the pace, however. This book tackles technology, art, politics, food – you name it, acceleration has probably changed it. Using the latest research, the author examines what this means for our bodies and the natural environment. Packed with factoids and surprising statistics (did you know that chickens grow four times quicker than they did 50 years ago?) this book never fails to engage and enlighten.

The question this inevitably leads to is whether acceleration is doing us any harm. Are we becoming less intelligent? Not according to Colvile. While he concedes that the ever-shifting work-life balance doesn't do our stress levels any favours, our capacity to think remains the same. This positivity is endemic throughout the book; while acceleration is apparently happening, it isn't necessarily presented as all that much of a problem.

Colvile examines the extent to which it has permeated our everyday lives: from dating and watching films, to the stock market and global warming. Yet overall, his outlook is an optimistic one; the conclusion reached is that inevitably some will nip ahead as others fall behind in the great race that is life. Even the prospect of Artificial Intelligence, the ultimate acceleration, doesn't seem to cloud Colvile's upbeat demeanour.

While large swaths of *The Great Acceleration* won't exactly break new ground for many readers, it still provides food for thought. After all, in light of the progress that has been made, sometimes what's needed is to sit back and take stock.

★★★★☆

YOU MAY ALSO LIKE...

Steve Jobs: The Exclusive Biography

Author: **Walter Isaacson**
Publisher: **Abacus**
Price: **£14.99 / $20.00**
Release date: **Out now**

Read about the extraordinary life of the late Apple founder Steve Jobs, based on over 40 interviews with the man himself, as well as candid chats with his family and friends who knew him best.

Future Crimes

Author: **Marc Goodman**
Publisher: **Corgi**
Price: **£8.99 / $17.00**
Release date: **Out now**

Technology has changed our lives, but the price of progress can be a steep one, as this book makes clear. Find out how those on the wrong side of the law are exploiting technological advances for their own gains.

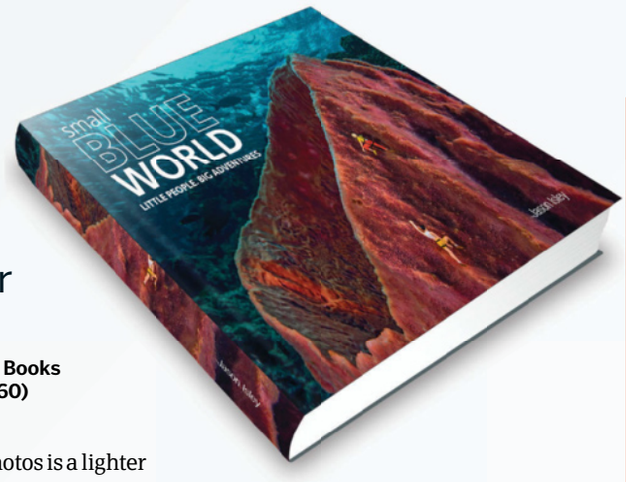
Here Be Dragons: Science, Technology And The Future Of Humanity

Author: **Olle Häggström**
Publisher: **Oxford University Press**
Price: **£25.00 (approx $36.00)**
Release date: **Out now**

This is a fascinating look at what may or may not arise in the distant future.

Small Blue World

Life is much better down where it's wetter

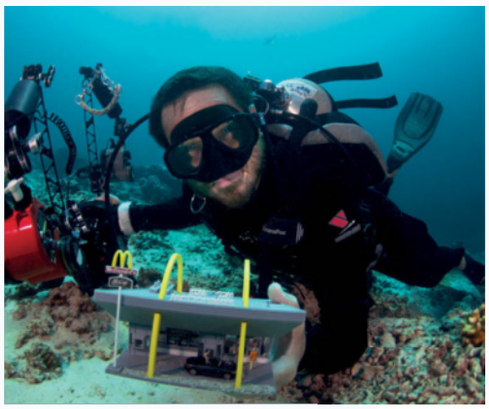


- Author: **Jason Isley**
- Publisher: **Michael O'Mara Books**
- Price: **£12.99 (approx $18.60)**
- Release date: **Out now**

This playful collection of photos is a lighter way to look at man's impact on the environment. The opening of the book sets up a future world in which the sea levels have risen and humans are forced to live under the waves.

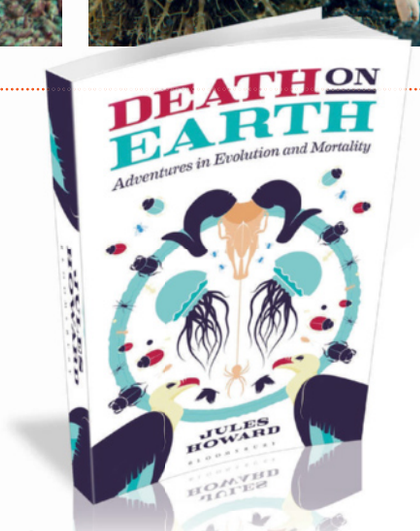
Tiny models of humans are placed into submerged environments and expertly photographed, with funny little descriptions placed by each one. The whole thing might seem like a joke, but there's an important message hidden here as well – a comment both on man's poor ability to co-exist with other species, and on the future of the planet. It's well worth a look.

★★★★☆



Death On Earth: Adventures In Evolution And Mortality

A story about death, life, and more death



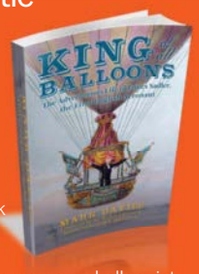
- Author: **Jules Howard**
- Publisher: **Bloomsbury Sigma**
- Price: **£16.99 / $27.00**
- Release date: **Out now**

You may be thinking that the subject of death is a heavy one. With any other author, you'd be right, but where this succeeds is in its personality, and approachable nature. It's explained through first-person stories, callbacks to great scientists, and seemingly unrelated stories that all tie back into the overarching theme. It's written like a story in flowing prose, and the result is a book that not only educates but also entertains. You may, at points, forget that you're reading a non-fiction book – and that's exactly why you never feel uncomfortable reading about what could be a pretty morbid topic.

★★★★★

King Of All Balloons

Unlocking the lost history of the first truly British balloonatic



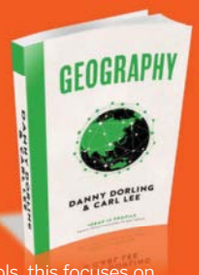
- Author: **Mark Davies**
- Publisher: **Amberley**
- Price: **£20.00 / $34.95**
- Release date: **Out now**

You might think that the title of 'first aerial traveller in Britain' went to Vincenzo Lunardi, but Lunardi simply lived and studied in the United Kingdom. As this book explains, James Sadler was born the son of a pastry cook in 1753, and left behind his lowly upbringing to become Britain's first homegrown balloonist. In this soaring tale, Davies covers his multiple journeys, from attempted channel-crossings to an ill-fated flight over the Irish Sea. It's a fascinating read, cleverly reconstructed with input from all kinds of sources, including famous literary onlookers and newspaper clippings. Just be prepared – it's tough going if you're not already invested in the subject matter.

★★★☆☆

Geography

Taking a trip around the modern world



- Author: **Danny Dorling, Carl Lee**
- Publisher: **Profile Books**
- Price: **£8.99 (approx $13.00)**
- Release date: **Out now**

Everyone has studied geography at some point in their lives – whether it's sitting at a desk in school and reading about glaciers, or standing on a beach looking at the rocks at your feet. As Dorling and Lee's book clearly states, "geography is all around us". However, unlike the lessons taught in schools, this focuses on topics such as globalisation, sustainability and equality. If you were considering geography as a profession, this book will only convince you to pursue it. It poses big, exciting questions, and, in answering, creates more questions that you will want to go and research for yourself. It's inspirational stuff.

★★★★☆

Restless Creatures

A billion-year history of movement

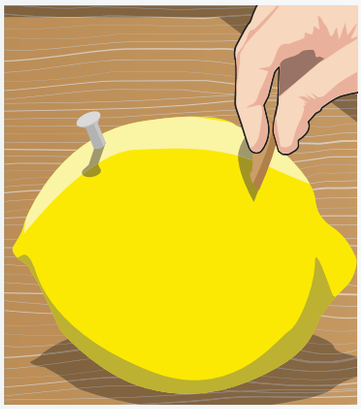
- Author: **Matt Wilkinson**
- Publisher: **Icon Books**
- Price: **£20.00 / $28.99**
- Release date: **Out now**

Movement is an integral part of life – as Wilkinson points out in the opening paragraph, when he asks readers to get up and walk around. It's fundamental to our existence, but we take it for granted every day. Wilkinson strives to show that we really shouldn't do so throughout the book, which takes a much closer look at ground-based movement, flying, and even the locomotion of plants in a comprehensive and easy-to-understand cross-section of movement and its evolution over time. It's genuinely interesting – you'll soon find yourself hooked, even if you've never really thought about movement before.

★★★★★

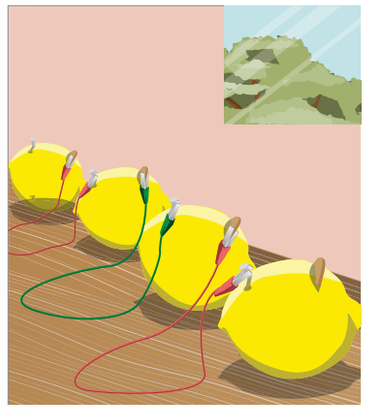
Make a lemon battery

How you can power an LED bulb with some citrus fruits



1 Add the electrodes

Cut two parallel slits a couple of centimetres apart in one side of the lemon. In one hole, slot in a copper coin, which will act as the positive electrode, and in the other place a galvanised nail (a nail that is coated in zinc), which will be the negative electrode. Make sure the two do not come into contact with each other inside the lemon, and then repeat the process with three more lemons.

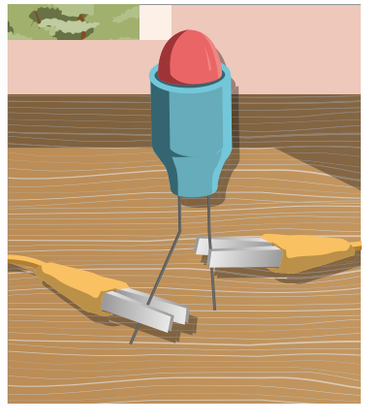


2 Join the batteries

Connect the lemons together using three crocodile clipped copper wires. Clip one end of the first wire to the coin in the first lemon, then clip the other end to the nail in the next lemon. Repeat this along the line with the other two wires until they are all joined together. This will help to accumulate the power produced by the batteries so it is enough to power a bulb.

3 Measure the charge

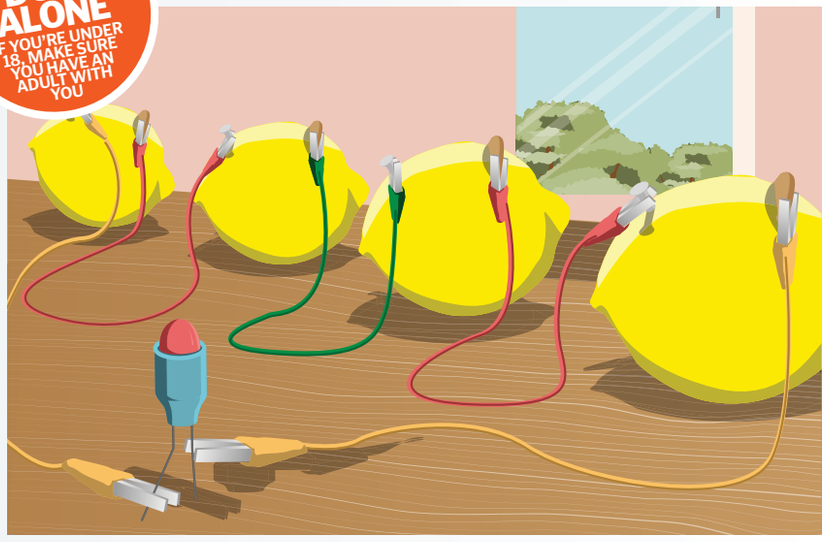
Test that your battery works using a multimeter, an instrument that measures voltage. Attach two additional crocodile clipped copper wires to the remaining coin and nail at either end of your battery line-up, then connect the free ends to the multimeter. If it gives a reading of around 3.50 volts, then you have set up your experiment correctly. If not, then repeat steps one and two.



4 Connect the bulb

Disconnect the multimeter and connect the free ends of the copper wires to an LED bulb. Make sure you connect the wire leading from the furthest right-hand coin to the negative connector of the LED and the wire leading from the furthest left-hand nail to the positive connector. The negative and positive connectors of the LED should be clearly labelled with plus and minus signs.

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



5 Light it up

Now that your circuit is complete, the LED bulb should light up using the power generated from your lemon batteries. If you don't have four lemons handy, you can still try this experiment. Simply place all four copper coins and galvanised nails into the same lemon, making sure they don't touch each other, and connect them in the same way, as this will also help to accumulate more power.

In summary...

Batteries are essentially made of two electrodes, one positive and one negative, and a conductive solution called an electrolyte. This solution kick-starts an oxidisation process, allowing ions to move from the positively charged electrode to the negatively charged electrode, creating a flow of charge, or electricity. In a lemon battery, the citric acid in the lemon juice acts as the electrolyte, the coin is the positive electrode and the nail is the negative electrode.

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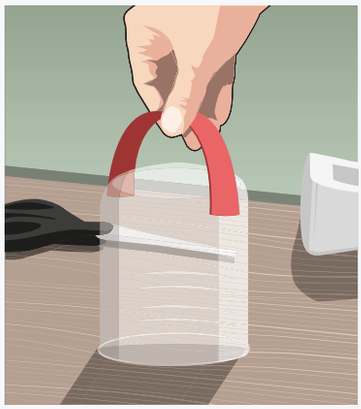
Build a vacuum cleaner

Help out with the chores by creating your own hand-pumped device that sucks up crumbs

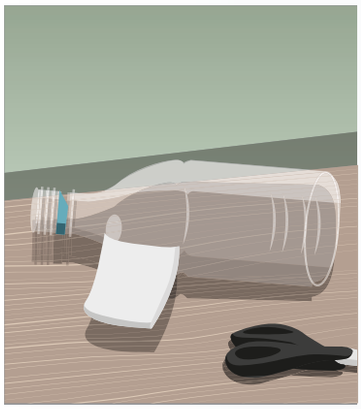
1 Create the piston

Take an empty two-litre plastic bottle and cut off the bottom third with scissors or a box-cutter. Once you have removed the bottom, cut a slit down one side of it. This will allow you to slide it inside the top part of the bottle so that it can act as the piston for your hand-pumped vacuum cleaner. The top of the bottle will act as the cylinder.



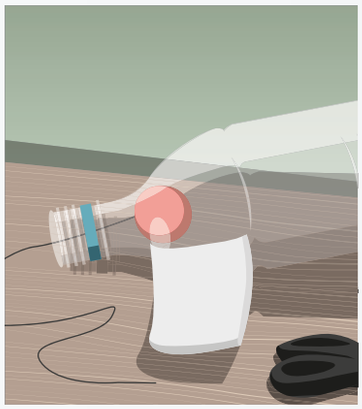
2 Attach a handle

Now cut out a 15 x 7 centimetre strip of paper and fold it in half lengthways to make it extra strong. Alternatively, you could use some strong card instead. Tape the end of the strip to each side of the bottom third of the bottle, so that it forms a handle over the closed off end. This will help you move the piston inside the top section of the bottle.



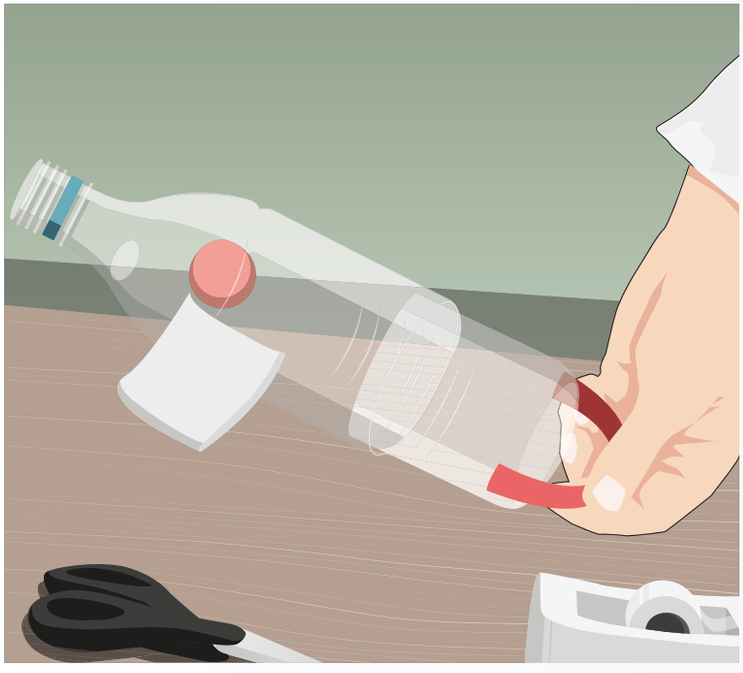
3 Fit a filter bag

In the top part of the bottle, cut a two-centimetre hole about three centimetres below the neck. This will be the place where we attach the filter bag. To make the bag, take a 10 x 15 centimetre piece of tissue paper and fold it in half, then tape up two of the sides. Next, tape the open side of the bag over the hole in the neck of the bottle.



4 Create the valve

Take a piece of thread and tape one end to a ping-pong ball. Place the ball in the top part of the bottle and feed the free end of the thread through the opening where the lid usually goes. Tape the end of the thread to the outside of the bottle, so that the ping-pong ball hangs just below the bottle's neck. This will act as the valve.



5 Try it out

Using the handle, push the bottom part of the bottle into the top part. This will force the ping-pong ball into the neck of the bottle, so that any air can only leave through the hole into the filter bag and not through the opening at the top. When you pull the handle back sharply, it will suck up any small items nearby, and when you push it back, they will be forced into the filter bag.

In summary...

When you pull back the handle, the air pressure inside the bottle decreases because there is a bigger space for the same amount of air. This lower pressure creates suction, pulling in high-pressure air from outside the bottle and any small items with it.

NEXT ISSUE
- Crush a can with science
- Make a bouncy ball

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AMAZING PRIZE FOR LETTER OF THE MONTH!
SMALL BLUE WORLD
Explore underwater worlds to learn how humans and nature can exist in harmony

Letter of the Month

Wheel spin

Dear **HIW,**
I subscribe to HIW because it is the only info magazine I find interesting enough to read from cover to cover. My question is; if you see a spoked vehicle passing across a TV screen, why do the wheels appear to be rotating backwards?
Ted Hirst

This strange phenomenon is known as the 'wagon-wheel' effect and is caused by the camera capturing the footage. When video cameras record a scene, they don't actually capture a continuous piece of film. Instead, they capture a series of still images in quick succession to create what we see as smooth video footage.

The speed at which the camera captures these images is known as a frame rate, and is typically 24 frames per second. If the frequency of the wheel's spin matches the frame rate of the camera – for instance, if it completes one full revolution every 1/24 seconds – the wheel will appear motionless in the footage. Therefore, if the wheel spins slower than this, it will appear to rotate backwards, as it hasn't quite completed a full rotation each time an image is taken. Alternatively, if the wheel spins faster, it will seem to rotate forwards, but much slower than the car appears to be moving.


Cars on TV and in movies often fall victim to the 'wagon-wheel' effect

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Writing in space

Dear **HIW,**
I am a subscriber to this magazine and **All About Space** and this is my personal favourite! Can you write with ink in space?
Michael (aged 13)

A regular ink pen would not work in zero gravity, as there would be nothing to pull the ink towards the tip. Plus, if any air mixed with the ink, it would quickly evaporate or oxidise, rendering the pen useless. During early space missions, astronauts simply used pencils, but as they were flammable and the shavings could cause damage to spacecraft instruments, they were deemed too dangerous. The solution was the 'Space Pen', developed by the Fisher Pen Company in the 1960s. It uses pressurised nitrogen to get the ink flowing in the right direction, and is still used to this day.


Space Pens can operate at any angle, in extreme temperatures and even underwater


Tigers hide among the trees and ambush their prey from close range

Hunting tactics

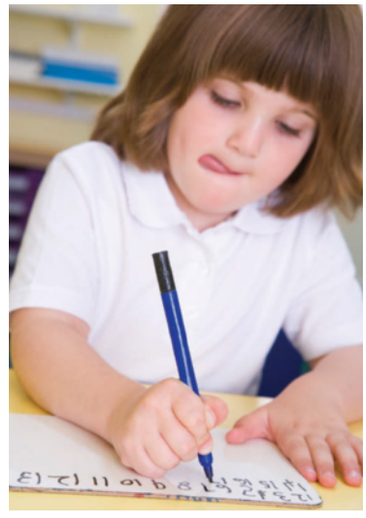
Dear **HIW,**
I really enjoy reading your magazine. It is by far the best on the market! I was wondering, why do wolves and lions hunt in a group and tigers don't?
Ollie Carroll (aged 11)

It's all down to where and what they hunt. Lions and wolves prowl open plains and stalk animals that live in herds, making it difficult for them to avoid detection. Hunting in a group enables them to attack from several directions at once, leaving the prey with no escape. However, tigers hunt in dense jungle where it is much easier to sneak up on their prey if they work alone.

Tongue movements

Dear **HIW,**
I love your magazine – it's so interesting! My question is: why do we stick out our tongues? I hope you can answer that!
Joshua Potts

Sticking out your tongue can help you concentrate on the task at hand. Your tongue is a huge muscle that is constantly sending vast amounts of data to your brain. Touch receptors on its surface help to update the mental map of the shape of your mouth, and its constant movements help you swallow and even form the shape of words as you think of them. By sticking out your tongue, you reduce its movements and limit the amount of information it can send, freeing up more brainpower for concentration.


Sticking out or biting your tongue can help improve your concentration

HOW IT WORKS

Imagine Publishing Ltd
Richmond House, 33 Richmond Hill
Bournemouth, Dorset, BH2 6EZ
☎ +44 (0) 1202 586200
Web: www.imagine-publishing.co.uk
www.howitworksdaily.com
www.greatdigitalmags.com

Magazine team

Editor Jodie Tyley
jodie.tyley@imagine-publishing.co.uk
☎ 01202 586274
Senior Art Editor Duncan Crook
Deputy Editor Jackie Snowden
Research Editor Katy Sheen
Features Editor Jo Stass
Assistant Designer Briony Duguid
Editor in Chief Dave Harfield
Photographer James Sheppard
Picture Editor Tim Hunt
Publishing Director Aaron Asadi
Head of Design Ross Andrews

Contributors
Stephen Ashby, Sarah Bankes, Ella Carter, Alexandra Cheung, Ed Crooks, Alicea Francis, Nicholas Forder, Shanna Freeman, Rebecca Greig, Rebekka Hearl, Tom Lean, Adrian Mann, Adam Markiewicz, Laura Mears, Katrina Megget, Philip Morris, Alex Pang, Lee Sibley, Jo Smolaga, The Art Agency, Luis Villazon, Laurie Winkless, Steve Wright

Cover images
Tomoyuki Nakane, Thinkstock

Photography
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Advertising
Digital or printed media packs are available on request.

Head of Sales Hang Deretz
☎ 01202 586442
hang.deretz@imagine-publishing.co.uk

Account Manager Lee Mussell
lee.mussell@imagine-publishing.co.uk

International
How It Works is available for licensing. Contact the International department to discuss partnership opportunities.

Head of International Licensing Cathy Blackman
☎ +44 (0) 1202 586401
licensing@imagine-publishing.co.uk

Subscriptions
subscriptions@imagine-publishing.co.uk

For all subscription enquiries
☎ 0844 815 5944
Overseas +44 (0)1795 418680
Email: howitworks@servicehelpline.co.uk
13 issue subscription (UK) – £43.50
13 issue subscription (Europe) – £53
13 issue subscription (USA) – £53
13 issue subscription (ROW) – £64

Circulation
Circulation Director Darren Pearce
☎ 01202 586200

Production
Production Director Jane Hawkins
☎ 01202 586200

Finance
Finance Director Marco Peroni

Founder
Group Managing Director Damian Butt

Printing & Distribution
Wyndeham Peterborough, Storey's Bar Road, Peterborough, Cambridgeshire, PE1 5YS

Distributed in the UK, Eire & the Rest of the World by: Marketforce, 5 Churchill Place, Canary Wharf, London, E14 5HU
☎ 0203 787 9060
www.marketforce.co.uk

Distributed in Australia by: Gordon & Gotch Australia Pty Ltd, 26 Rodborough Road, Frenchs Forest, New South Wales 2086
☎ + 61 2 9972 8800
www.gordongotch.com.au

ISSN 2041-7322

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USAIN BOLT BROKE THE 100-METRE WORLD RECORD AT THE 2008 BEIJING OLYMPICS WITH HIS SHOELACES UNTIED

In Ancient Egyptian burials, the deceased's brain was removed via the nostrils with an iron hook

PIT CREWS CAN CHANGE ALL FOUR WHEELS OF A FORMULA 1 CAR IN LESS THAN TWO SECONDS

500

The number of homes a single wind turbine can power

Before the eruption of Mount Vesuvius, Pompeii was a popular holiday resort for rich Romans

CATS USE TWENTY DIFFERENT MUSCLES TO CONTROL THEIR EARS

7

To date, there have only been seven space tourists. They all visited the ISS on board Soyuz rockets

THE FIRST MEAL TO BE EATEN IN SPACE CONSISTED OF MEAT PÂTÉ AND CAVIAR

A Lego brick made in 1958 would still interlock with a brick made today

SCIENTISTS HAVE RECENTLY BEGUN DRILLING INTO THE 'DINOSAUR CRATER' IN MEXICO TO LEARN MORE ABOUT THE ASTEROID'S IMPACT

JUPITER IS 2.5 TIMES MORE MASSIVE THAN ALL OF THE OTHER PLANETS IN THE SOLAR SYSTEM COMBINED

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Bees prop up a global industry worth upwards of $30 billion dollars

WHEN DOGS POO THEY PREFER TO DO IT IN ALIGNMENT WITH THE EARTH'S MAGNETIC FIELD

24-26

It normally takes a hen between 24 and 26 hours to produce and lay one egg

"The ice lolly was the result of a failed attempt at making soda"

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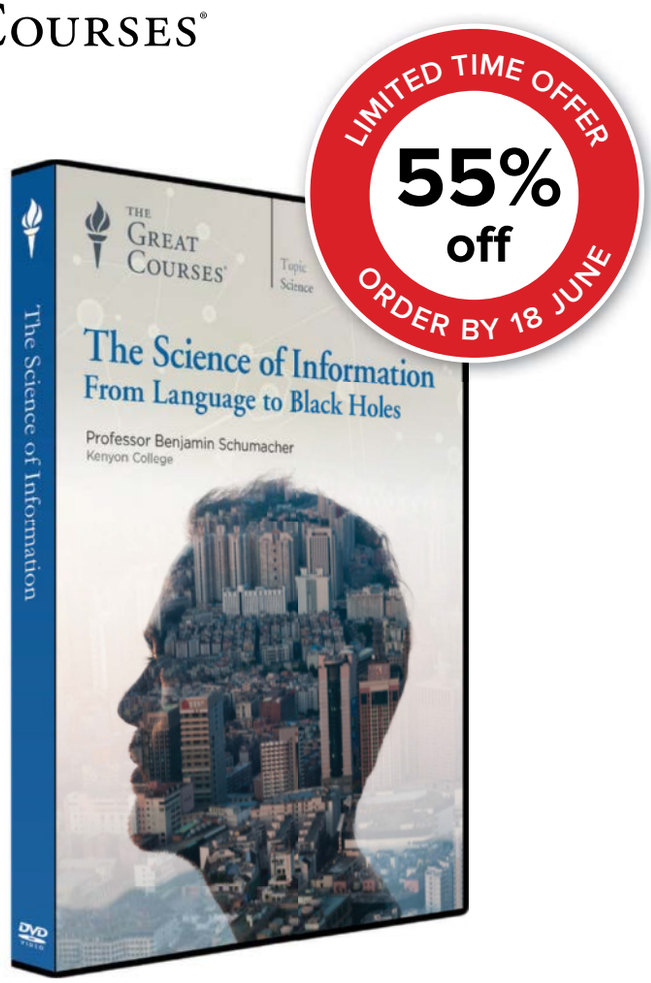

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