360 AMAZING IMAGES & CUTAWAYS INSIDE

THE MAGAZINE THAT FEEDS MINDS

HOW IT WORKS™

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INSIDE

CLOWNFISH
DISCOVER THE LIFE CYCLE OF THE REAL-LIFE NEMO

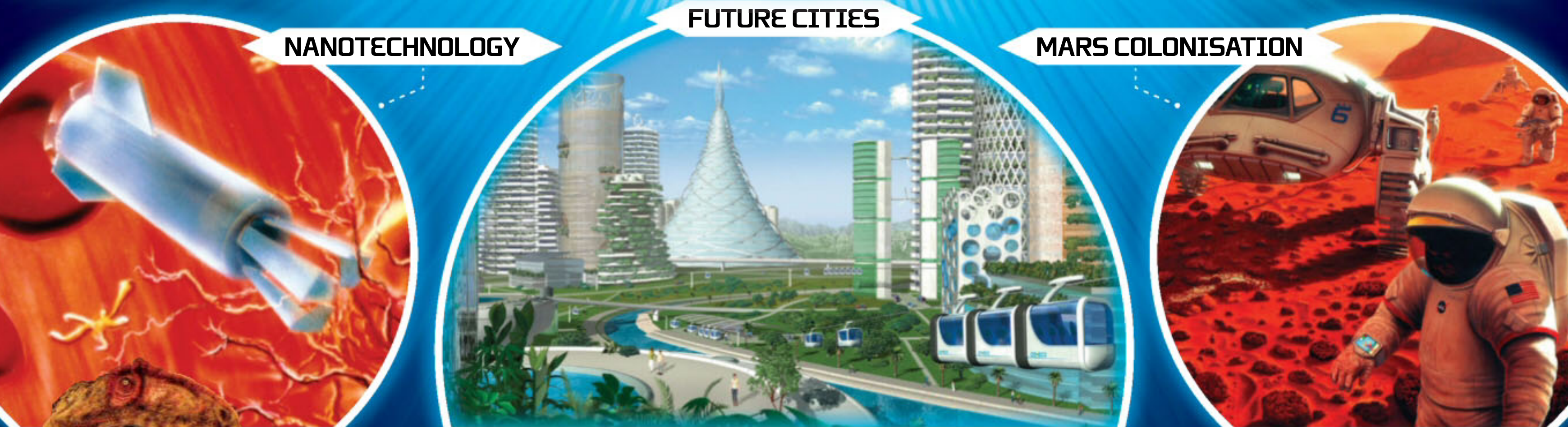
ROBOTS

FLYING CARS

DELIVERY DRONES

WORLD OF TOMORROW

REVEALED: THE LIFE-CHANGING TECH BEING DEVELOPED RIGHT NOW



NANOTECHNOLOGY

FUTURE CITIES

MARS COLONISATION

DEADLIEST DINOSAURS
Meet the scariest prehistoric beasts that ever lived

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SCIENCE OF INSOMNIA
Why your smartphone might be spoiling your sleep

+LEARN ABOUT ■ THE MOON ■ EARTHQUAKES ■ CLOUD STORAGE ■ EBOLA ■ SKELETON

ISSUE 67

WELCOME

The magazine that feeds minds!

Page 28
You'll be surprised what the life-cycle of the real Nemo entails!

Hollywood blockbusters paint a dark vision of the future, because drama lies in dark alleys, not sunshine and fields. Dystopias like the recent *Hunger Games: Mockingjay – Part 1* show an oppressed majority rising up against the overfed elite. Bright lights and whizzy technology is reserved only for those who live in the fictional Capitol, but in our future, the majority of us will be city dwellers. In fact, by 2050, it's predicted that 70 per cent of the world's population will be urban.

According to the experts, the grey buildings and smog will give way to so-called eco-cities. Farmscrapers will transform skylines into a canopy of green, and *Avatar*-style glowing trees will light our streets. A robot could be your next best friend and a drone will deliver your post. What's more is that this technology is being developed right now, and we've rounded up some of the most life-changing inventions this issue. So while 2014 may be drawing to a close, we can look forward with excitement and wonder. And not just for *Mockingjay – Part Two*.

Jodie

Jodie Tyley
Editor

Meet the team…

Andy
Art Editor
Geckos are more like *X-Men's* Magneto than I thought! Turn to page 28 to discover their amazing secret to climbing walls.

Erlingur
Production Editor
The ultimate dinosaur feature on page 72 introduced me to some brilliant new dino champs; some clever, some strong, all dastardly.

Jamie
Staff Writer
Flying cars? Check. Robot surgeons? Check. Colonising Mars? Check. Tomorrow's world looks awesome on page 12.

Jackie
Research Editor
Ever wonder where your data whizzes off to when you save it to the mysterious 'cloud'? Our tech feature has the answers!

Hannah
Assistant Designer
Did you know there are 206 bones in an adult skeleton? To find out more about our skeletons turn to page 40.

Jo
Senior Staff Writer
Earthquakes are one of Earth's deadliest natural hazards. Discover what makes the ground rumble and crack beneath us on page 22.

What's in store

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

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Revealed: The life-changing technology being developed right now

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Meet the experts...

Laura Mears
Your skeleton
This month, science expert Laura talks us through the amazing skeletal system and reveals how it supports and protects us. Did you know there are 27 bones in the human hand alone? For more, turn to page 40.

Alicea Francis
Alan Turing
As Production Editor of our sister magazine, **All About History**, who better than to tell us the story of Alan Turing? In our Heroes Of feature (page 60), you'll learn how he cracked codes no one else could.

James Hoare
St Basil's Cathedral
As editor-in-chief of **History Of War** and **All About History**, James is well-placed to fill us in on the shocking and twisted background to this beautiful historical building (page 78).

Jack Griffiths
How cars are made
Jack went all the way to Cologne, Germany, to the Ford factory. There, he discovered how the famous Ford Fiesta is put together on the production line (page 34).

Gemma Lavender
All about the Moon
All About Space writer Gemma looks to the skies and reveals all about Earth's natural satellite. On page 64, you'll find out what it's really made of (hint: it's definitely not cheese).

Which emotion lasts much longer than others?
Find out on pg 10

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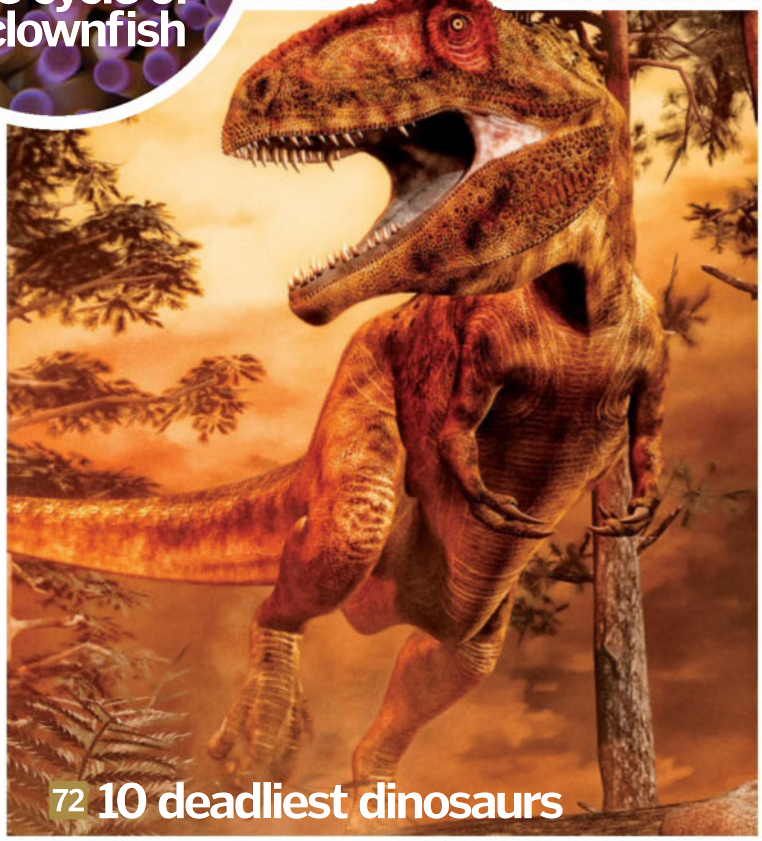

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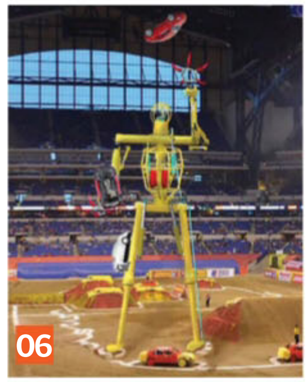


06

Aircraft for athletes

The custom Athlete's Plane will preserve peak performance for travelling sports stars

Many professional athletes are used to travelling in style, but a new aircraft concept could make their journeys even more comfortable. Design consultancy Teague has teamed up with Nike to design a custom aeroplane cabin that serves as a complete training room in the sky. Dubbed the Athlete's Plane, it provides pre and post-game necessities to maximise performance, readiness and recovery. On-board equipment will ensure optimum circulation and promotes healing, lie-flat seating to aid sleep, 'plug into plane' compression sleeves to ice sore muscles, plus it will also accommodate in-flight biometrics and analysis to accelerate injury diagnosis and treatment.

On board the Athlete's Plane

Post-game analysis

When the athletes arrive on board the plane after a game or event, information about their performance that has been gathered by wearable technology in their footwear, clothing and accessories they wore during the game is then displayed on the seat-back monitors.

Recovery aids

Biometric testing can be carried out in flight. Physiotherapy options such as massage, intravenous infusion, cold and warm contrast treatments and electro-stimulation will all be available to meet the athlete's body-recovery needs, even at 12,200 metres (40,000 feet) in the air.

Comfortable sleep

Once they have fully recovered from the game, the athletes can get some sleep on the long and spacious flat beds, which can accommodate anyone up to 2.1 metres (seven feet) tall. The seats are also designed to allow independent elevation of each leg, in case that is needed for their physical recovery.

Eco-friendly homes

Inflatable concrete housing provides a greener way of building

These strange-looking bubble buildings could be the future of low-cost, environmentally friendly living. Called Binishells, they are created by covering a flat balloon-like bladder with reinforcing bars and wet concrete before gently inflating it to form a dome structure. As construction requires very little labour, they only cost from £2,000 ($3,200) to build, plus they can also survive extreme environments such as lava flows and earthquakes. This, combined with the fact they are very quick and simple to build, makes them ideal for use in disaster relief.

Solar storm defences

The UK's eLoran system will provide a GPS backup in the event of solar flares

Solar storms can cause havoc here on Earth, triggering power cuts, damaging electronics and even disrupting GPS signals. This can be catastrophic for ships, which rely on GPS data to ensure safe navigation, so the UK government has rolled out a new backup system to protect busy shipping lanes. The eLoran system operates independently of GPS, so it can still transmit signals during outages caused by solar flares and deliberate GPS jamming. The UK has deployed several transmitters along its coastline and expects to cover all major UK ports by 2019.

Car-juggling robot

The 70ft BugJuggler could be wowing crowds very soon

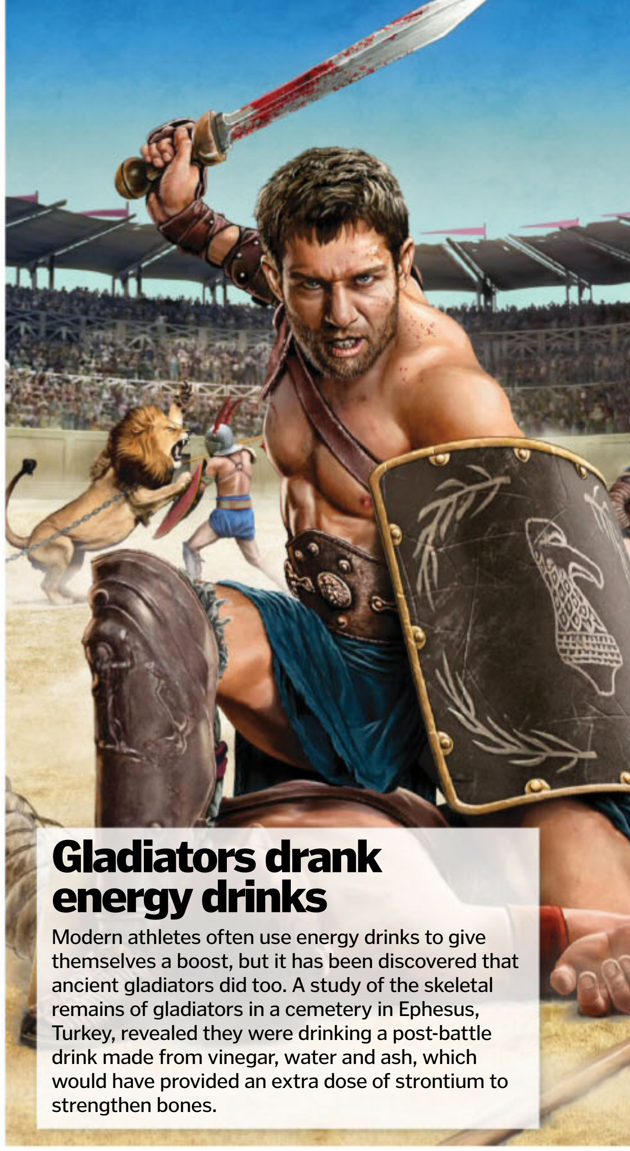
This may look like a still from the latest //Transformers// movie, but it is in fact the design for a giant robot with a very impressive party trick. Designed by Dan Granett, a former engineer at NASA's Jet Propulsion Laboratory, the so-called BugJuggler will use hydraulic cylinders to throw three VW Beetle cars into the air and catch them again. It will be operated by a human sitting in the robot's head who will be able to control its motions using a haptic feedback interface, giving them full sensory feedback from the throwing and catching forces. The project is still in the funding stages and has a full construction budget of \$2.3 million, but Dan expects to see BugJuggler wowing crowds at motoring shows in the near future.

GLOBAL EYE

10 COOL THINGS WE LEARNED THIS MONTH

Parallel universes could exist

Our universe is just one of a number of others that interact with each other, according to researchers from Griffith University, Australia and the University of California. They suggest nearby universes influence one another by a subtle force of repulsion and that the ability of quantum particles to occupy two states seemingly at once could be explained by both states existing simultaneously in different universes.

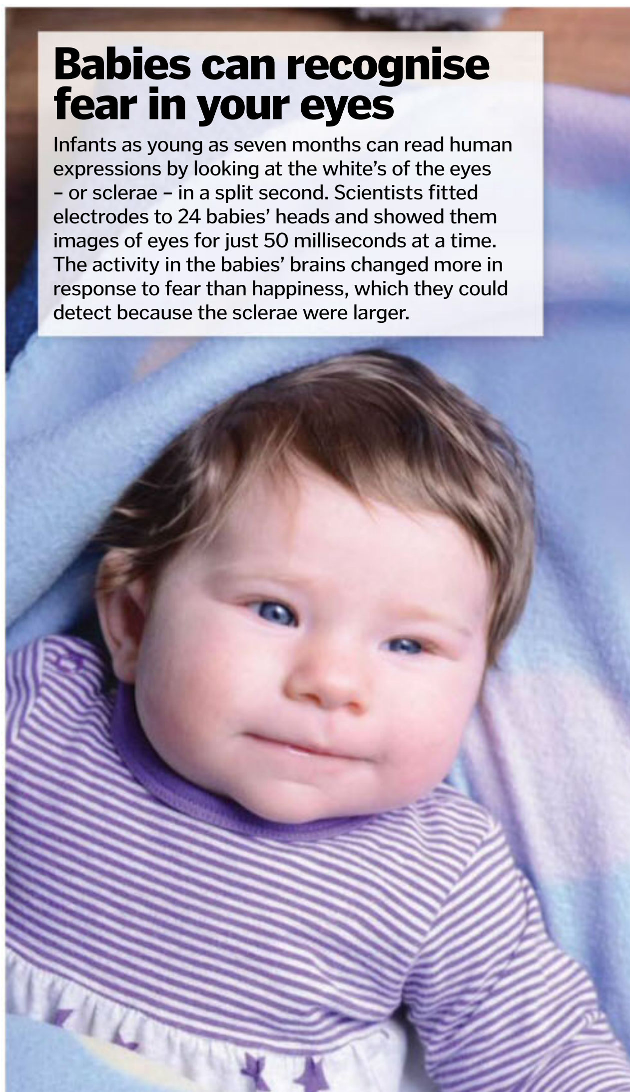


Gladiators drank energy drinks

Modern athletes often use energy drinks to give themselves a boost, but it has been discovered that ancient gladiators did too. A study of the skeletal remains of gladiators in a cemetery in Ephesus, Turkey, revealed they were drinking a post-battle drink made from vinegar, water and ash, which would have provided an extra dose of strontium to strengthen bones.

Babies can recognise fear in your eyes

Infants as young as seven months can read human expressions by looking at the white's of the eyes – or sclerae – in a split second. Scientists fitted electrodes to 24 babies' heads and showed them images of eyes for just 50 milliseconds at a time. The activity in the babies' brains changed more in response to fear than happiness, which they could detect because the sclerae were larger.



Sadness lasts longer than other emotions

If you've ever struggled to get over an unhappy period in your life, there is a scientific reason. New research has discovered that sadness lasts up to 240 times longer than other emotions. 233 students were asked to recollect recent emotional episodes and report their duration, and the study revealed it typically took 120 hours for them to stop feeling sad.

Birds can sing pop music

Scientists have discovered the hermit thrush sings in 'harmonic series', a pattern of pleasing-sounding notes commonly used in popular music. A harmonic series includes a base note followed by notes that increase in pitch based on multiples of that note. It is thought the birds sing in this way either because it more attractive to females, or because it is easier to remember, much like it is for humans.

New York has 2 million rats

The common belief that New York City contains as many rats as people has been found to be untrue. However, there are still around two million of them in the city, and they are all the same species – Rattus norvegicus, or the Norwegian rat.

Scratching makes you itch more

Ever wondered why it's so difficult to stop scratching an itch? A new study on mice has found why. Scratching produces pain, which disrupts the itch by getting nerves to carry pain signals instead of itch signals. This pain then causes serotonin to be released by the brain to control it. However, the serotonin then activates spinal-cord nerve cells that make the itch more intense.

Monkeys are as clever as children

Primates have more in common with young children than previously thought. A study of capuchin monkeys, chimpanzees and bonobos found that they share the same basic understanding of objects as three-year-olds. When shown a broken and unbroken string, each connected to food, all species knew the best one to pull when the string was visible but struggled to know what to do when it was covered.

Oceans are as old as Earth

Until recently, no one knew when or how water arrived on Earth, with some believing it didn't arrive until well after the planet had formed. However, new research has revealed water came from meteorites that arrived at the same time the planet's rock was forming.

A car's paintwork can generate energy

Mercedes-Benz has unveiled a concept car that doubles up as a solar panel. The Vision G-Code uses multi-voltaic silver paint to capture energy from solar rays and power the hybrid engine. The paint can also be charged electrostatically by the wind when moving or stationary, and kinetic energy created by the suspension can generate electricity as well.

WORLD OF TOMORROW

Experience the lean, green cities we'll soon be living in

Major cities are often viewed as grey, energy-guzzling monoliths, but the cities of the future could change everything. As the planet's store of fossil fuels dries up, we are looking for new ways to power our cities in sustainable but spectacular-looking ways.

Skyscrapers will become towering greenhouses as vertical farming takes hold. Crops would be grown between storeys, taking advantage of the Sun's energy while using minimal ground space. These ecological super-buildings would have photovoltaic solar-cell facades and be topped by wind turbines, making these homes the ultimate self-sustaining structures.

Tomorrow's city centres could look very different as groups gather below solar powered trees. These so-called eTrees offer more than just shade, as the energy produced from the solar panels transforms them into mobile phone charging stations, free Wi-Fi and night lighting. The solar energy also activates an LCD screen that displays information such as the weather and educational content.

Building upward would allow plenty of room on the ground for urban social areas as well as luminous plants. These are implanted with light-giving compounds known as luciferins, which will make the greenery glow at night as a cost-effective and eco-friendly method of illuminating tomorrow's cities.

Far from being a scary, soulless world as shown in movies like *Judge Dredd* and *Blade Runner*, the future cities promise to be bright, spacious and green, making the most of the amazing natural resources we have at our disposal already.

Virtual fitting rooms
This tech is already here! Some stores offer you the chance to superimpose clothes onto your body using a tablet or smartphone app.

TOMORROW'S TRANSPORT

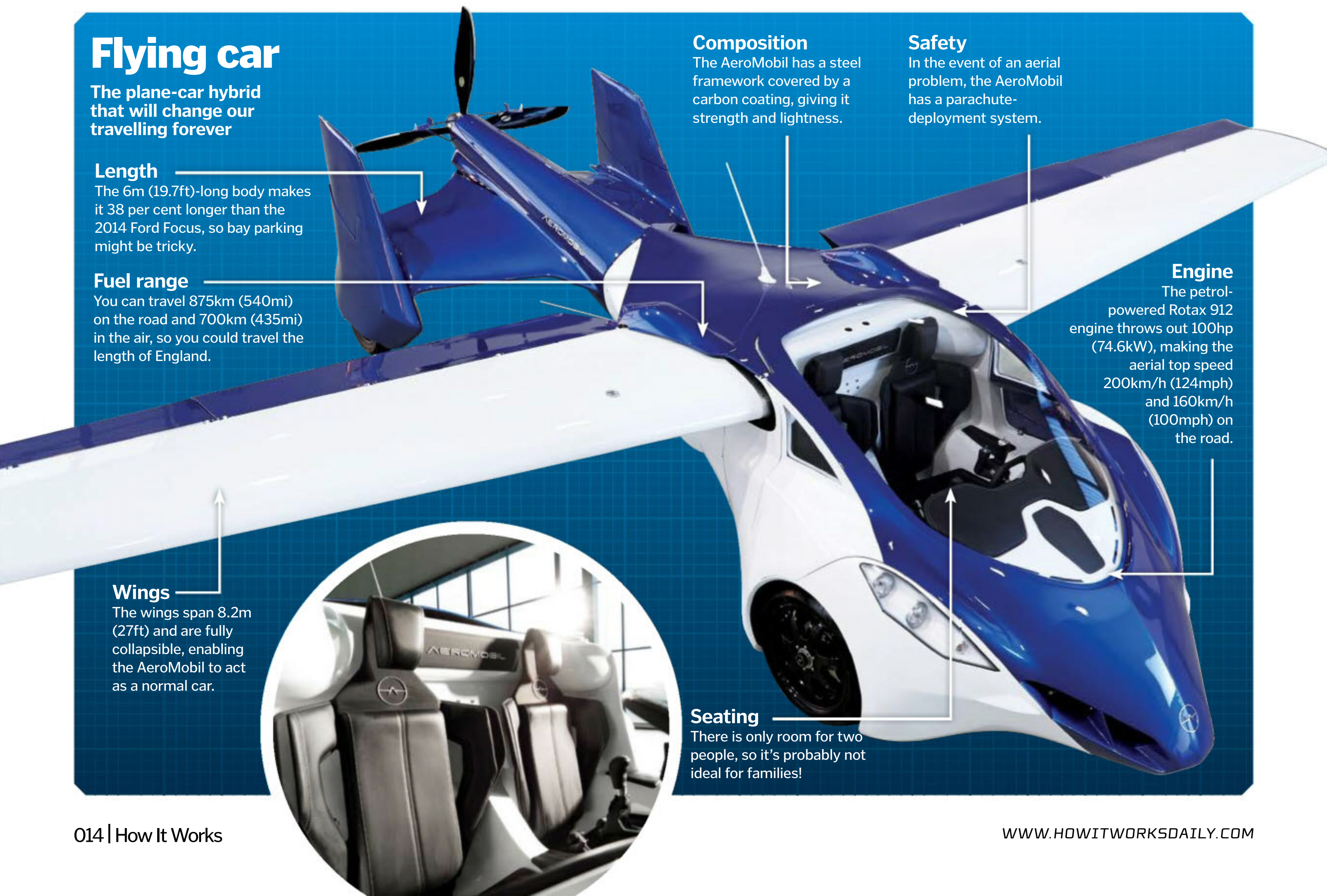
Why getting from A to B will soon involve a lot less work

When you hear the term 'transport of the future' your mind will generally turn to flying cars. Excitingly, they're already on their way. AeroMobil has unveiled the third version of its flying vehicle. Capable of switching in seconds between car and plane, you could wing your way to your destination, free from traffic jams and roadworks. On the ground, the AeroMobil uses regular petrol and fits into any standard parking space, but can reach 200 kilometres (124 miles) per hour in the air thanks to its Rotax 912 engine. This would reduce the traffic in future cities, making the streets safer for people on the ground.

Also, companies such as Amazon and DHL are trialling drones that can deliver parcels under 2.3 kilograms (five pounds), which Amazon says makes up 86 per cent of their deliveries. The use of drones will clear the streets and air as they will be battery or solar powered.

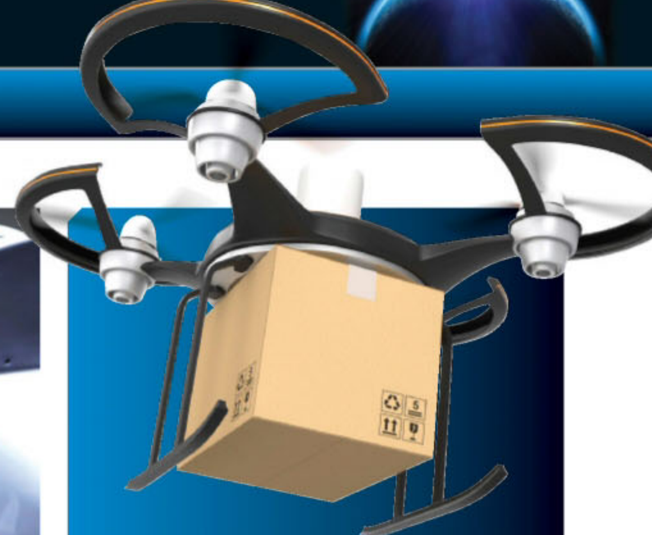
If you still felt like you wanted to stay on the ground, however, driverless taxis could ferry you around. The Google driverless car has already completed over 1,125,000 kilometres (700,000 miles) of accident-free driving using GPS satellites to map routes and on-board cameras to search for hazards.

These cars could be used as taxis – which would be summoned by a smartphone app – and would drive closer to each other and more efficiently than human drivers, meaning that no one need ever own a car. Unless it's an amazing flying car, that is.



The AeroMobil's dashboard is a little more complicated than today's cars'

TheAeroMobil's road version looks fittingly futuristic and sleek

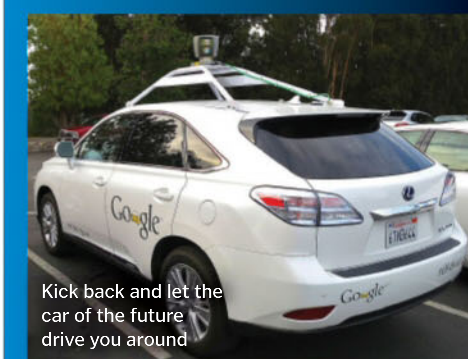


Delivery drones

At the moment delivery companies spend huge sums of money and use enormous amounts of fuel on delivering parcels, but in the city of the future drones could take on the task. Amazon and DHL are testing out drones that could deliver the majority of their products. These autonomous flying vehicles are lightweight and can be pre-programmed to reach their destination, guided by satellites.

They could deliver to hard-to-reach areas such as islands and take a huge number of vehicles off the roads. As they are powered either by batteries or solar power, they wouldn't be a drain on resources like delivery trucks either.

At the moment it is still illegal in the US for Amazon to use their drones for commercial reasons, although the company is in talks with the FAA to work around this. As the technology is already there it is looking increasingly likely that these devices could be in our skies within the next few years.



Kick back and let the car of the future drive you around

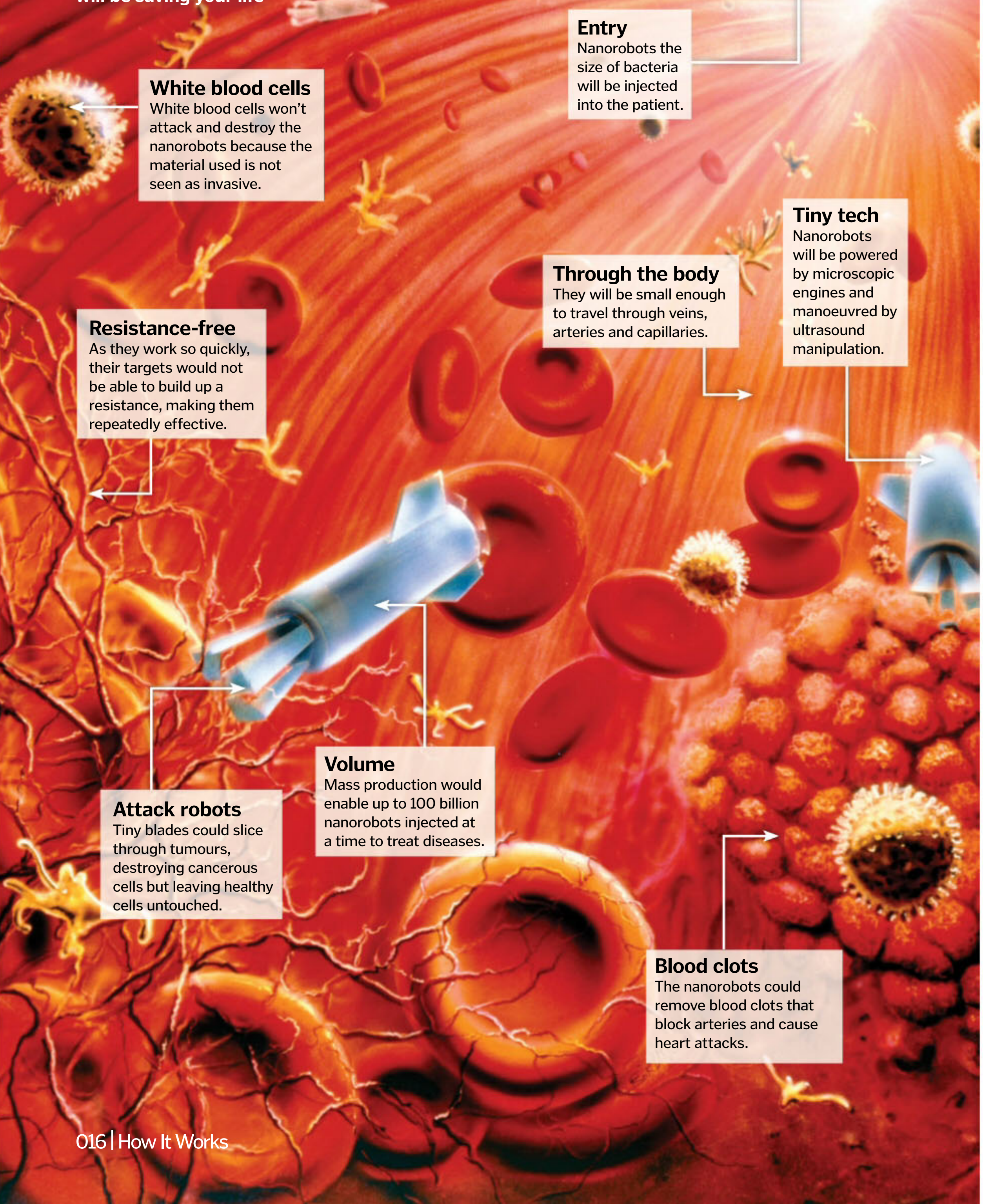
Driverless taxis

There is a very good chance that in the future, no one need ever own a car. Just like London and New York's bike-rental scheme, driverless cars could be summoned to your house and drive you to work. As they will drive themselves with much quicker reactions than humans and can't be distracted, they will be able to run at a steady speed, closer together and with fewer accidents, removing the main causes of traffic jams. Rooftop cameras will use lasers to scan the road ahead at a range beyond that of human vision. A second camera will look to the sides for hazards like pedestrians or animals. The guidance system will use GPS, altimeters and gyroscopes to keep track of where it is and where it is going. As 90 per cent of a car's life is spent parked, autonomous hire cars could become the most efficient way to get around.

TOMORROW'S MEDICINE

Nanorobotics

The microsurgeons that will be saving your life



The microscopic tech that saves your life from within

The area of nanomedicine is one that is advancing so rapidly that doctors could soon be piloting miniature robots through your body to diagnose and even battle illness. It is expected that within 20 years, molecular manufacturing will have reduced the size of robots to roughly the size of bacteria, meaning they can enter the body to spot and even cure disease.

The miniscule robots could be programmed to behave like a white blood cell, seeking out illness-causing bacteria or germs, latching onto them and slicing them up into molecules too small to do any further damage. Doctors could then remove the robots by using an ultrasound signal to direct the robots toward the kidneys where they would get washed out in urine.

Another potential use for nanorobots in medicine is actual surgery. A set of chromosomes would be manufactured outside the body and attached to a nanorobot. This would head straight toward a diseased cell, remove the damaged chromosomes and replace them with the healthy ones.

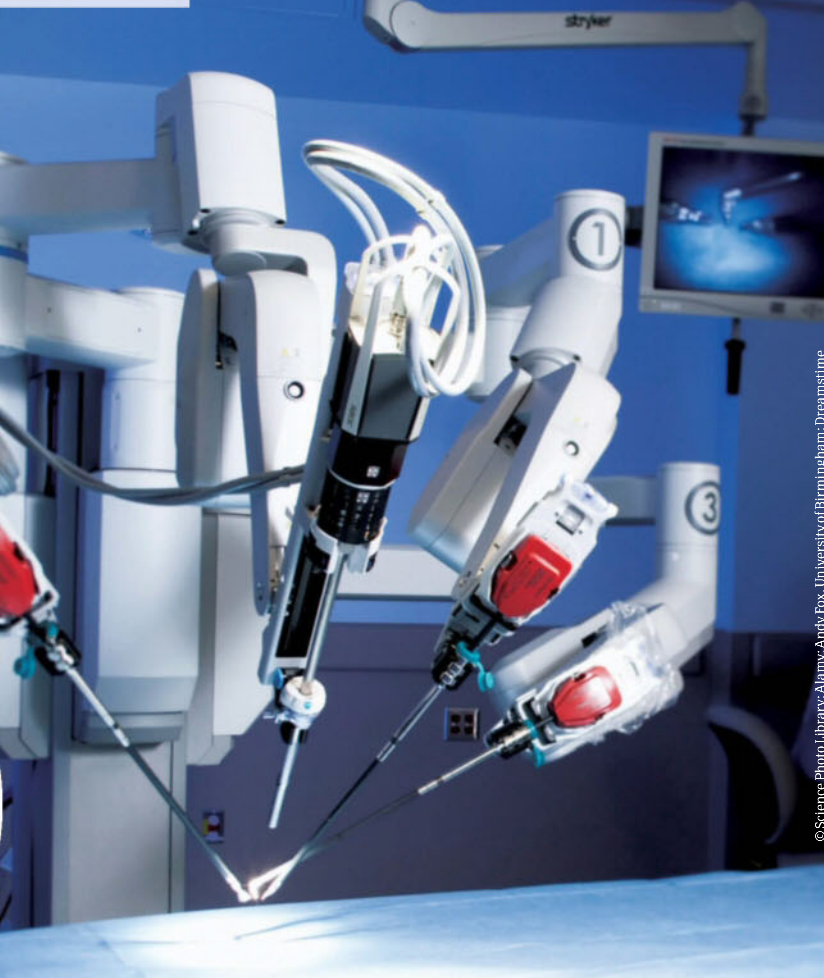
Another fascinating area of study is anti-ageing. Researchers have managed to restore the health of cells in a two-year-old mouse making it as fit as a six-month-old mouse. By injecting nicotinamide adenine dinucleotide (NAD) into the mice, scientists increased the level of communication between cells. This is very important, as a lack of communication between cells is heavily linked to diabetes, dementia and cancer. It's hoped that this scientific breakthrough will ultimately be proven successful in humans.

TOMORROW'S ROBOTS

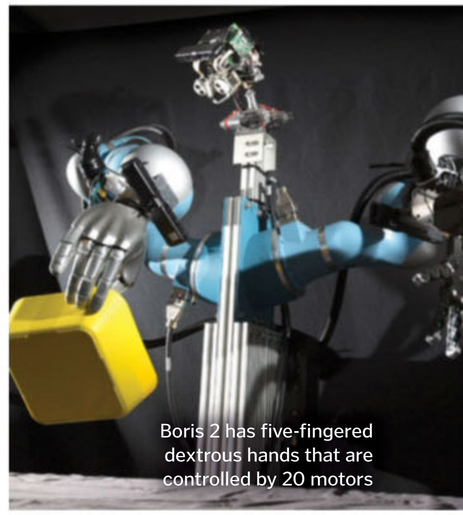
The tech that will keep us happy, healthy and up-to-date

Medical

The da Vinci SI surgical robot is the world's most advanced robotic surgeon. It is operated via a master control unit that moves the four arms of the machine while the surgeon looks through an HD camera. This allows greater precision during surgery, greatly improving patient comfort and recovery.



The four arms of da Vinci SI can be much more accurate than a surgeon



Boris 2 has five-fingered dextrous hands that are controlled by 20 motors

Domestic

A robot called Boris 2 is one of the first in the world to intelligently grip unfamiliar objects. Developed by scientists at the University of Birmingham, the autonomous robot was designed with loading the dishwasher in mind – a chore that encompasses a range of general manipulation tasks.

Pepper understands your emotions and can also express its own

Recreation

Pepper is a humanoid robot designed to live with us. Sensors are used to gauge your facial expressions, listen to you, learn your body language and react accordingly. It's a social robot that will try to cheer you up when you're sad by playing your favourite song, for example.

AUGMENTED WORLD

Discover what we'll see through the augmented-reality contact lenses

Could smart lenses replace your smartphone?

Smart lenses are contact lenses that display information such as routes, weather and your Facebook news feed into your peripheral vision. At the moment, the most likely team to crack this is Innovega with its iOptik contact lens, but this system still uses a pair of glasses that project semi-transparent screens onto the lens. The lens contains optical micro-components that change the angle of the light, focusing it into the pupil. This helps the wearer to focus on the near-eye object they otherwise wouldn't have been able to.

It is hoped that within three years a working prototype will be available that does away with the glasses entirely, using a microcamera embedded into the lens itself.

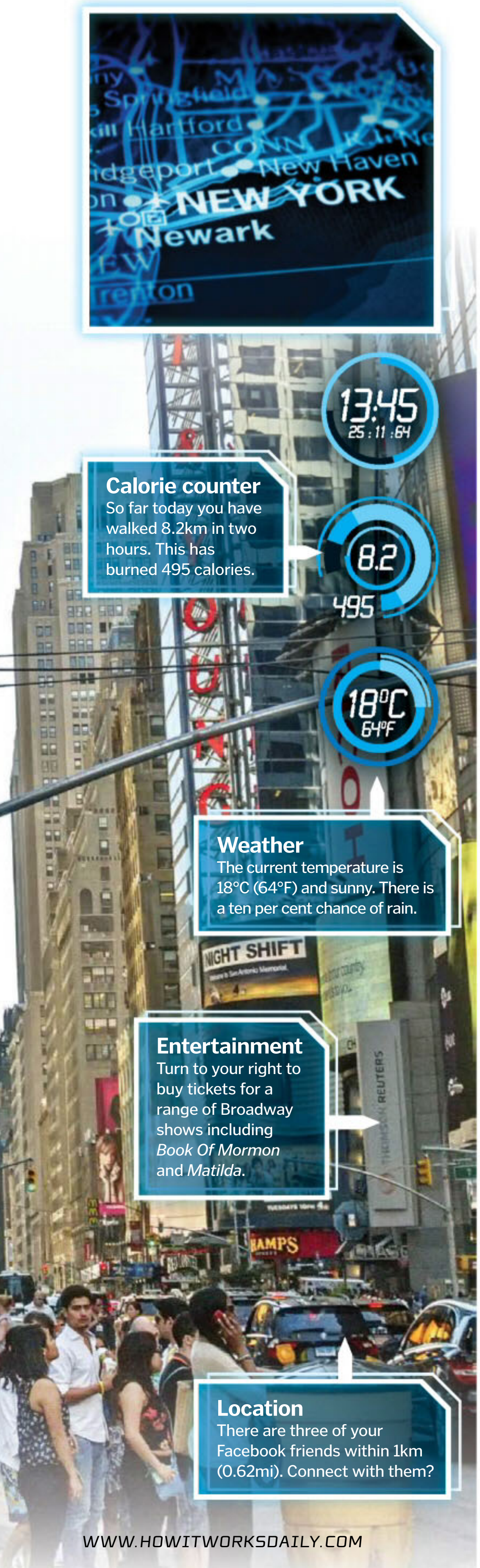
It is already possible for technology to be implanted into a contact lens. A team from South Korea has mounted an LED onto a normal contact lens, which shows the potential of adding technology to these optical aids.

TOMORROW'S ENERGY

Fusion power: clean energy for tomorrow's power stations

Nuclear fusion is an incredibly exciting new direction that could provide Earth with huge amounts of clean energy. In nuclear fusion, helium nuclei are forced together to create a new atomic nucleus. The atomic mass of the two nuclei is greater than the mass of the resulting nucleus, so the extra mass is given off as energy. This can be harvested for practical uses.

The main barrier to nuclear fusion is temperature. Nucleons are held together by strong forces, while an electromagnetic force tries to pry them apart. When protons come into close contact, the electromagnetic force pushes them apart in what is called the Coulomb barrier. 40 million degrees Celsius (72 million degrees Fahrenheit) of heat is needed to break through the Coulomb barrier and allow the nuclei to fuse. This extreme heat could be provided by the Z Machine produced by Sandia National Laboratories, USA. This machine uses electricity to create radiation that heats the walls of the facility to nearly 2 billion degrees Celsius (3.6 billion degrees Fahrenheit).



The amazing Z Machine creates enough heat for nuclei to break through the Coulomb barrier

COLONISING MARS

The tech that will help us go where no man has gone before

Ever since Neil Armstrong set foot on the Moon, there have been dreams to colonise other bodies in the Solar System, something that is becoming increasingly viable thanks to advancements in space travel and space suits.

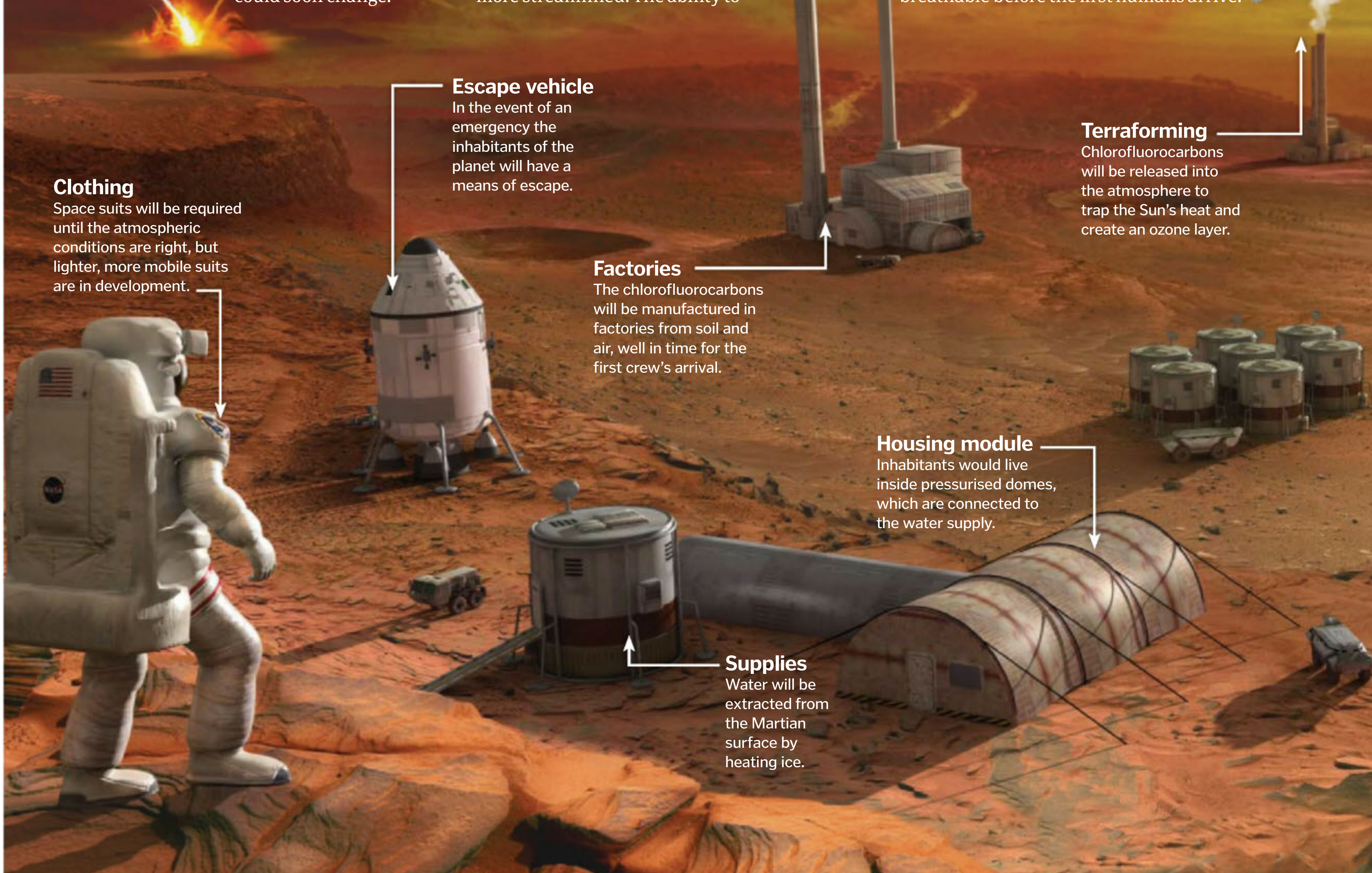
Voyager 1 has travelled just short of 20 billion kilometres (12.4 billion miles) from Earth, but so far, humans have only reached the Moon 384,400 kilometres (239,000 miles) away. The main reasons behind the difficulty of sending humans further distances are fuel storage, costs and the comfort of the astronauts. At least one of these conditions has to be compromised for a long-distance journey into space and that has held us back but that could soon change.

The reaction between nano-aluminium powder and water creates a powerful blast of hydrogen gas and aluminium oxide. This provides the thrust for a rocket to launch without weighing too much. Solar technology, such as that used on the Rosetta comet-chasing probe, will also reduce the reliance on fuel, further lightening the load.

MIT has developed a skintight space suit that essentially shrink-wraps the astronaut, providing counter-pressure to the atmosphere. This will be much lighter and more flexible than current space suits, making extended periods of wear much more bearable.

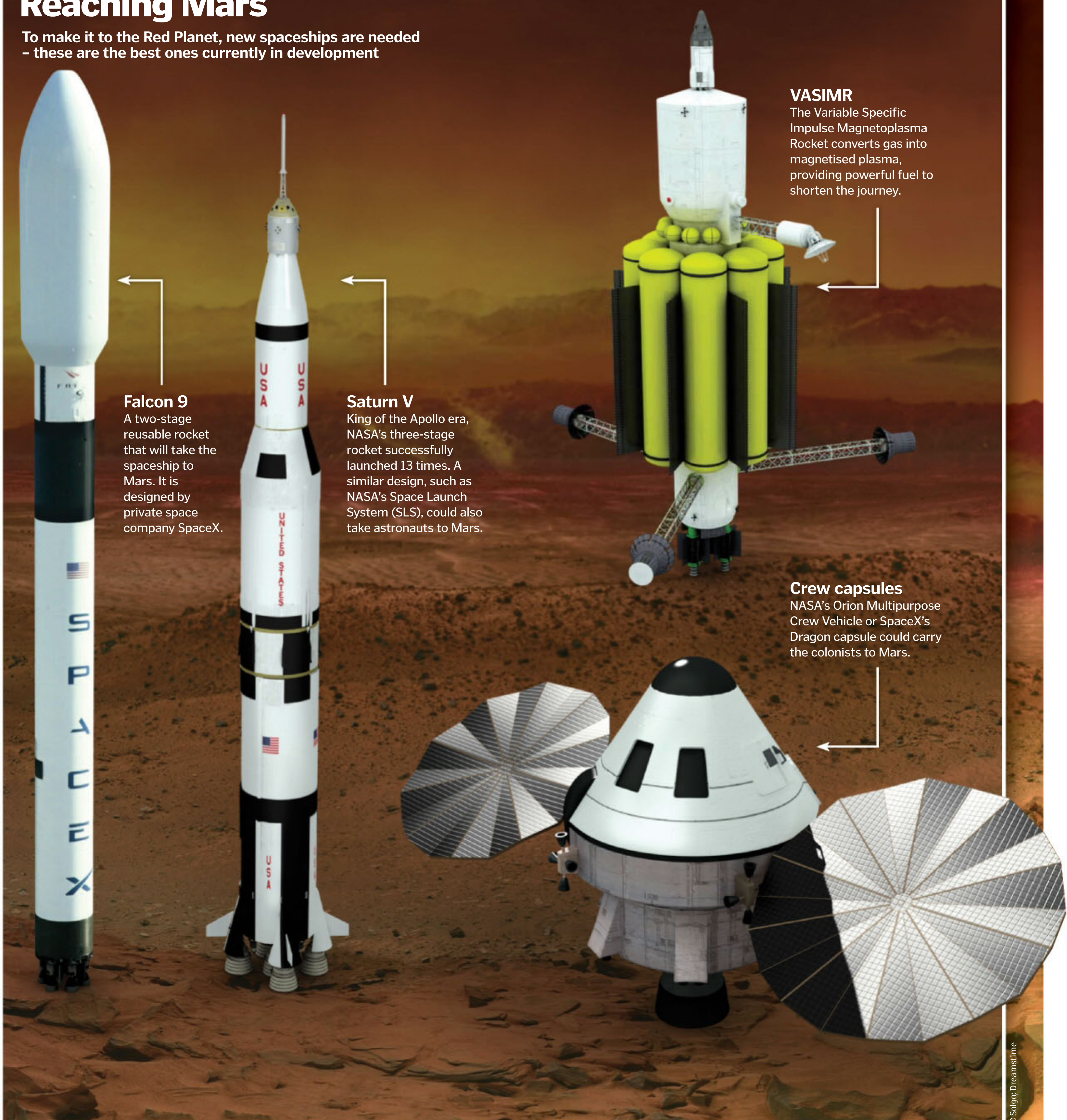
3D printing has also paved the way for missions in space to be much more streamlined. The ability to design and print anything from a tiny bolt to a huge satellite dish means that missions can leave without bulky payloads on board.

All these advances in technology have pushed forward the possibility of inhabiting another planet. Mars One is a project that aims to have humans living on Mars by 2025. They hope to achieve this by sending up rovers and life-support units within the next eight years, which will seek out a location close enough to the poles for water, close enough to the equator for solar power and flat enough to build on. The life-support units will leech water from the soil by heating subsurface ice. Some will be stored and some used for creating oxygen, nitrogen and argon, which should make the atmosphere breathable before the first humans arrive.



Reaching Mars

To make it to the Red Planet, new spaceships are needed – these are the best ones currently in development



Falcon 9
A two-stage reusable rocket that will take the spaceship to Mars. It is designed by private space company SpaceX.

Saturn V
King of the Apollo era, NASA's three-stage rocket successfully launched 13 times. A similar design, such as NASA's Space Launch System (SLS), could also take astronauts to Mars.

VASIMR
The Variable Specific Impulse Magnetoplasma Rocket converts gas into magnetised plasma, providing powerful fuel to shorten the journey.

Crew capsules
NASA's Orion Multipurpose Crew Vehicle or SpaceX's Dragon capsule could carry the colonists to Mars.

Earthquakes

What causes these devastating natural hazards and what are we doing to predict and prepare for them?

Earthquakes are one of our planet's most destructive natural hazards, with the ability to flatten entire cities, trigger enormous tsunamis that wash away everything in their path, and cause a devastating loss of life.

Part of an earthquake's immense power lies in its unpredictability, as a huge quake can strike with very little warning and give those nearby no time to get to safety. Although we do not know when they will occur, we can predict where they are likely to happen, thanks to our knowledge of plate tectonics.

The thin top layer of the Earth, known as the crust, is divided into several plates that are constantly moving. This is caused by heat from the core of the Earth creating convection currents in the mantle just below the crust, which shifts the plates in different directions.

As the plates move, they collide, split apart or slide past each other along the plate boundaries, creating faults where the majority of earthquakes occur. At divergent or constructive plate boundaries the plates are moving apart, causing normal faults that form rift valleys and ocean ridges. When plates move toward each other along convergent or destructive plate boundaries, they create a reverse or thrust fault, either colliding to form mountains or sliding below the other in a process known as subduction. The third type is a conservative or transform plate boundary, and involves the two parallel plates sliding past each other to create a strike-slip fault.

Being able to identify these fault lines tells us where earthquakes are most likely to occur, giving the nearby towns and cities the opportunity to prepare. Although the secondary effects of an earthquake, such as landslides and fires from burst gas lines, can be fatal, the main cause of death and destruction during earthquakes is usually the collapse of buildings. Therefore, particularly in developed parts of the world, structures near to fault lines are built or

5 TOP FACTS QUAKE-PROOFING

Animal inspiration
1 Scientists are trying to mimic the threads that mussels use to stay attached to their shells in order to develop construction materials that are rigid but flexible for absorbing shock.

Invisibility cloak
2 Dubbed the 'seismic invisibility cloak', 100 concentric plastic rings would be buried beneath the foundation of a building and deflect the surface waves around the structure.

Cardboard constructions
3 Architect Shigeru Ban has designed a church made of 98 giant cardboard tubes reinforced with wooden beams. The cardboard is sturdy but lightweight, so would cause little damage if it collapsed.

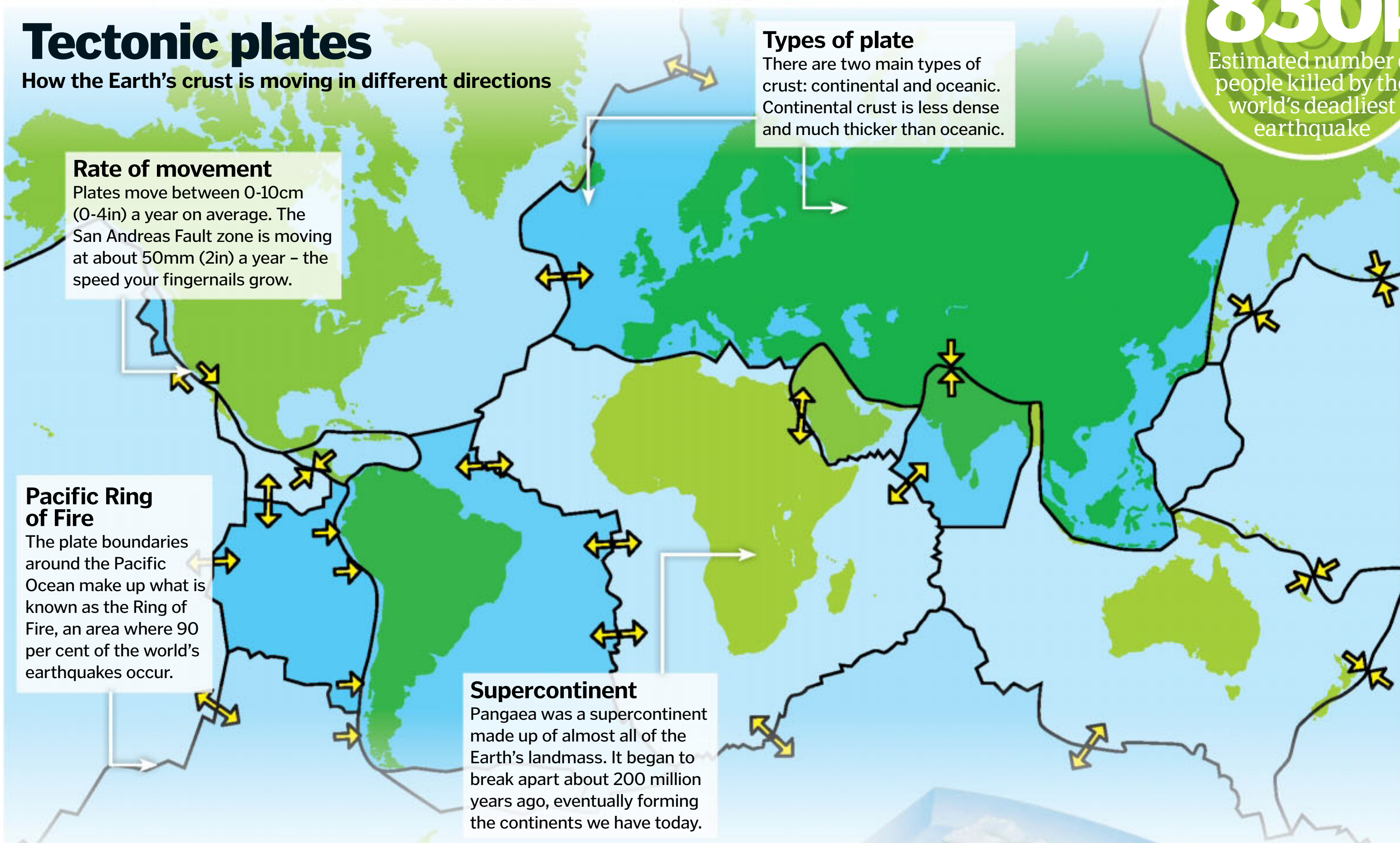
Plastic wrap
4 Fiber-reinforced plastic wrap could go around supporting columns in existing buildings. A pressurised adhesive would then be pumped between the column and the wrap.

Smart materials
5 Shape-memory alloys (SMAs) can return to their original shape after experiencing strong forces, so could be used in place of steel and concrete for more resilient buildings.

DID YOU KNOW? There are ca 500,000 earthquakes in the world each year, but only 100,000 can be felt – 100 of them cause damage

830k
Estimated number of people killed by the world's deadliest earthquake

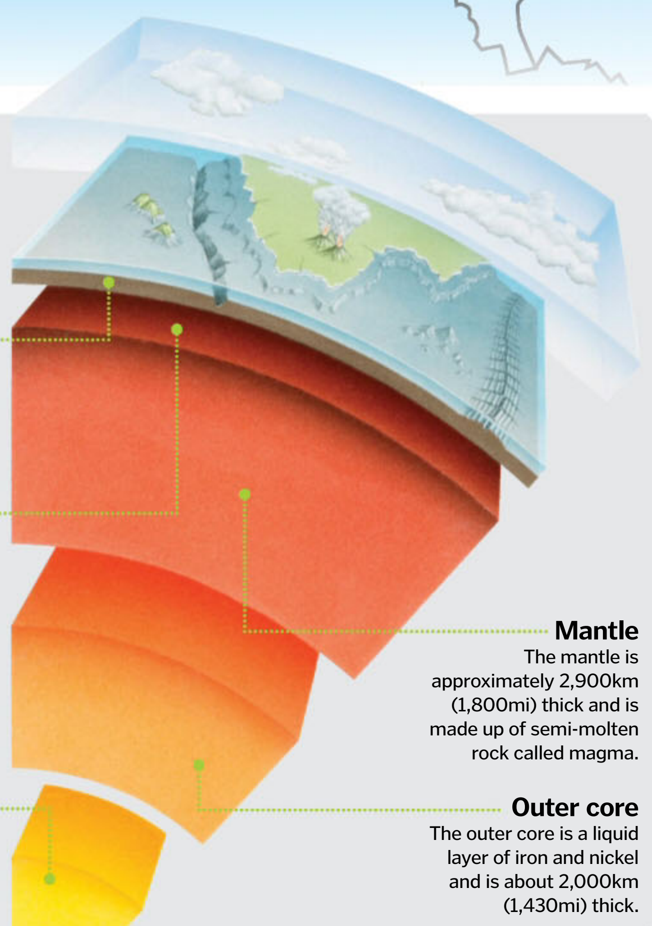
Tectonic plates
How the Earth's crust is moving in different directions



adapted to withstand violent shock waves. The surrounding population will usually carry out regular earthquake drills, such as The Great California ShakeOut, that gives people a chance to practise finding cover when a quake hits. Unfortunately, many poorer areas cannot afford to be so well prepared, and so when an earthquake strikes, the resulting destruction is often even more devastating and the death toll is usually much higher.

However, our knowledge of how earthquakes work and the development of new technologies are helping us to find potential methods for predicting when the next one will strike. Scientists can currently make general guesses about when an earthquake may occur by studying the history of seismic activity in the region and detecting where pressure is building along fault lines, but this only provides very vague results so far. The ultimate goal is to be able to reliably warn people of an imminent earthquake early enough for them to prepare and minimise the loss of life and property. Until then, being under the constant threat of an impending earthquake is unfortunately part of everyday life for those living along the Earth's constantly active fault lines.

The Earth's structure
Cut through the different layers of our planet



"Underwater earthquakes can sometimes trigger enormous destructive waves called tsunamis"

Anatomy of an earthquake

How earthquakes are caused and shake the ground beneath our feet

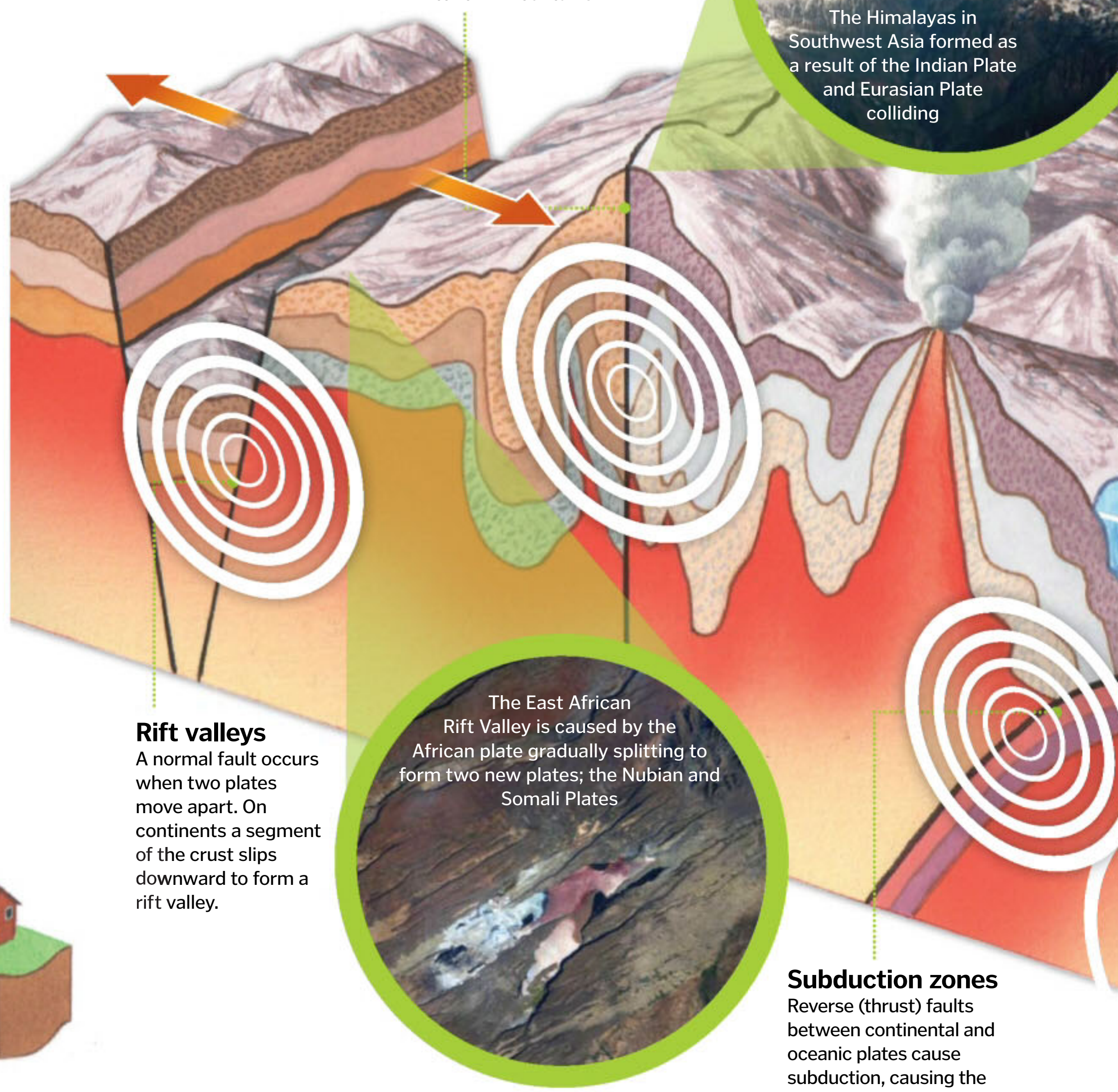
Earthquakes are caused by the build-up of pressure that is created when tectonic plates collide. Eventually the plates slip past each other and a huge amount of energy is released, sending seismic waves through the ground. The point at which the fracture occurs is often several kilometres underground and is known as the focus or hypocentre. The point directly above it on the surface is the epicentre, and this is where most of the damage is caused. Earthquakes have different characteristics depending on their type of fault line, but when they occur underwater, they can sometimes trigger enormous destructive waves called tsunamis.

Fault lines

How the Earth's crust moves along different plate boundaries

Mountain formation
When two continental plates collide along a reverse (thrust) fault, the Earth's crust folds, pushing slabs of rock upward to form mountains.


The Himalayas in Southwest Asia formed as a result of the Indian Plate and Eurasian Plate colliding



Rift valleys
A normal fault occurs when two plates move apart. On continents a segment of the crust slips downward to form a rift valley.

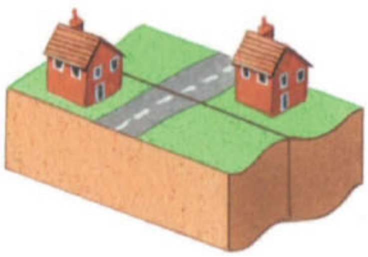
The East African Rift Valley is caused by the African plate gradually splitting to form two new plates; the Nubian and Somali Plates

Subduction zones
Reverse (thrust) faults between continental and oceanic plates cause subduction, causing the higher-density oceanic plate to sink below the continental plate.

How earthquakes occur

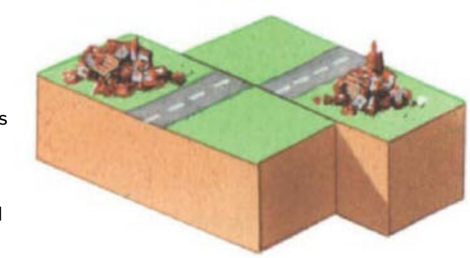
The build-up of pressure that causes the ground to move and shake

Friction causes pressure
As the tectonic plates are pushed past or into each other, friction prevents them from moving and causes a build-up of immense pressure.



Energy is released
When the pressure finally overcomes the friction, the plates will suddenly fracture and slip past each other, releasing energy and causing seismic waves.

The process starts again
Once the energy has been released, the plates will assume their new position and the process will begin all over again.



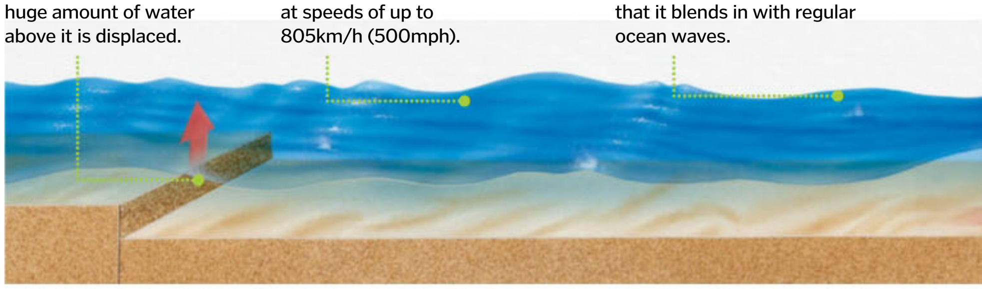
Tsunamis

How underwater earthquakes trigger enormous and devastating waves

Water displacement
As two oceanic plates slip past each other and cause an earthquake, a huge amount of water above it is displaced.

Small beginnings
Small, rolling waves begin to spread outward from the earthquake's epicentre at speeds of up to 805km/h (500mph).

Tsunami in disguise
The tsunami's long wavelength and small wave height – usually less than 1m (3.3ft) – means that it blends in with regular ocean waves.



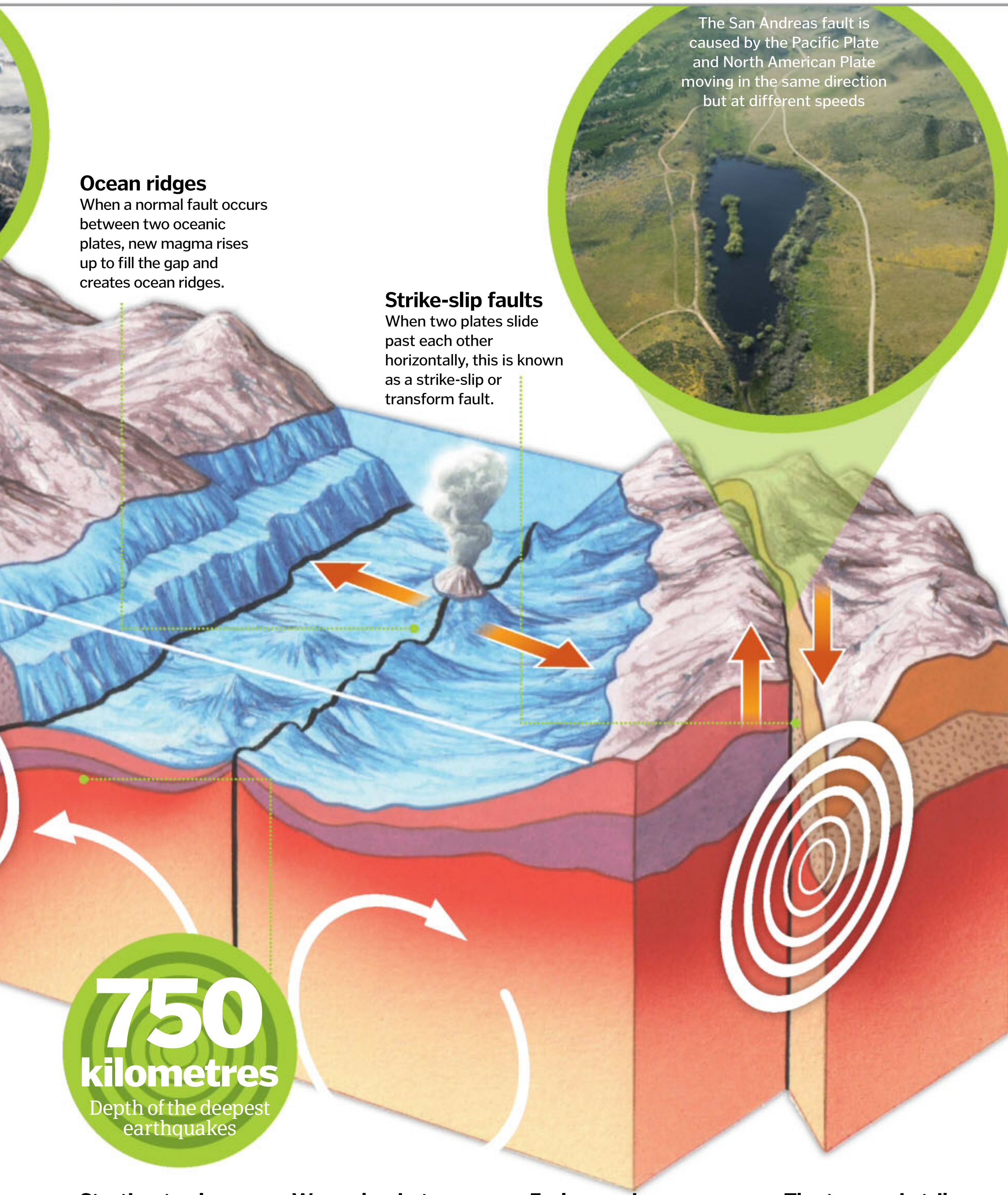
RECORD BREAKERS
BIG TREMOR

9.5

MOST POWERFUL EARTHQUAKE

The largest earthquake ever recorded happened on 22 May 1960 in southern Chile. It was caused by the subduction of the Nazca Plate under the South American Plate.

DID YOU KNOW? *Tsunamis and tidal waves are different things as the latter is caused by gravitational activity, not earthquakes*



Ocean ridges

When a normal fault occurs between two oceanic plates, new magma rises up to fill the gap and creates ocean ridges.

Strike-slip faults

When two plates slide past each other horizontally, this is known as a strike-slip or transform fault.

750 kilometres
Depth of the deepest earthquakes

Starting to slow

As they reach the shallower waters of the coast, the rising sea floor causes friction that slows the waves down.

Waves begin to grow

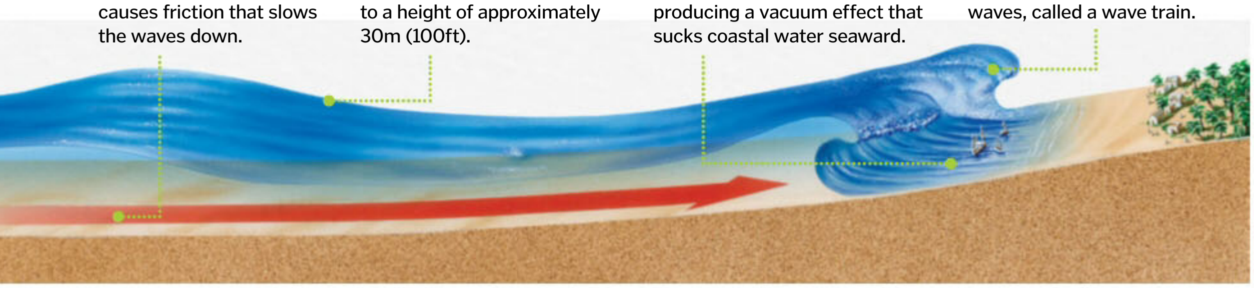
As they slow down, the wavelengths begin to shorten, causing the tsunami to grow to a height of approximately 30m (100ft).

Early warning

A tsunami's trough, the low point beneath the wave's crest, often reaches shore first, producing a vacuum effect that sucks coastal water seaward.

The tsunami strikes

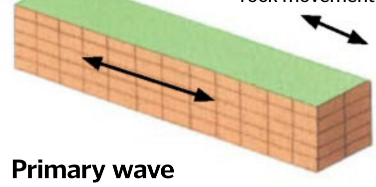
A few minutes later, the tsunami's crest will hit the shore followed by a series of more waves, called a wave train.



Earthquake waves

How seismic waves travel through the Earth's crust

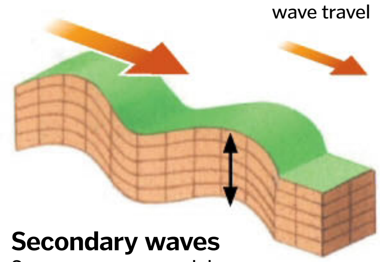
Direction of rock movement



Primary wave

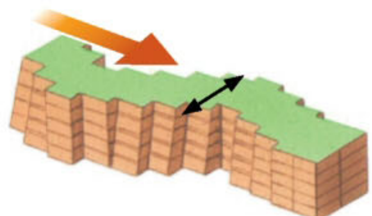
P waves travel back and forth through the Earth's crust, moving the ground in line with the wave. They are the fastest moving of the waves, travelling at about 6-11km/s (3.7-6.8mi/s) , and so typically arrive first with a sudden thud.

Direction of wave travel



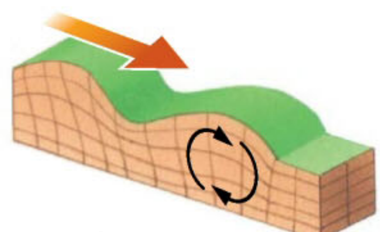
Secondary waves

S waves move up and down, perpendicular to the direction of the wave, causing a rolling motion in the Earth's crust. They are slower than P waves, travelling at about 3.4-7.2km/s (2.1-4.5mi/s), and can only move through solid material, not liquid.



Love waves

Unlike P and S waves, surface waves only move along the surface of the Earth and are much slower. Love waves, named after the British seismologist AEH Love, are the faster of the two types and shake the ground side to side, perpendicular to direction of the wave.



Rayleigh waves

Rayleigh waves, named after the British physicist Lord Rayleigh, are surface waves that cause the ground to shake in an elliptical motion. Surface waves arrive last during an earthquake but often cause the most damage to infrastructure due to the intense shaking they cause.

“Early-warning systems give people a few seconds or minutes to prepare before the earthquakes hit”

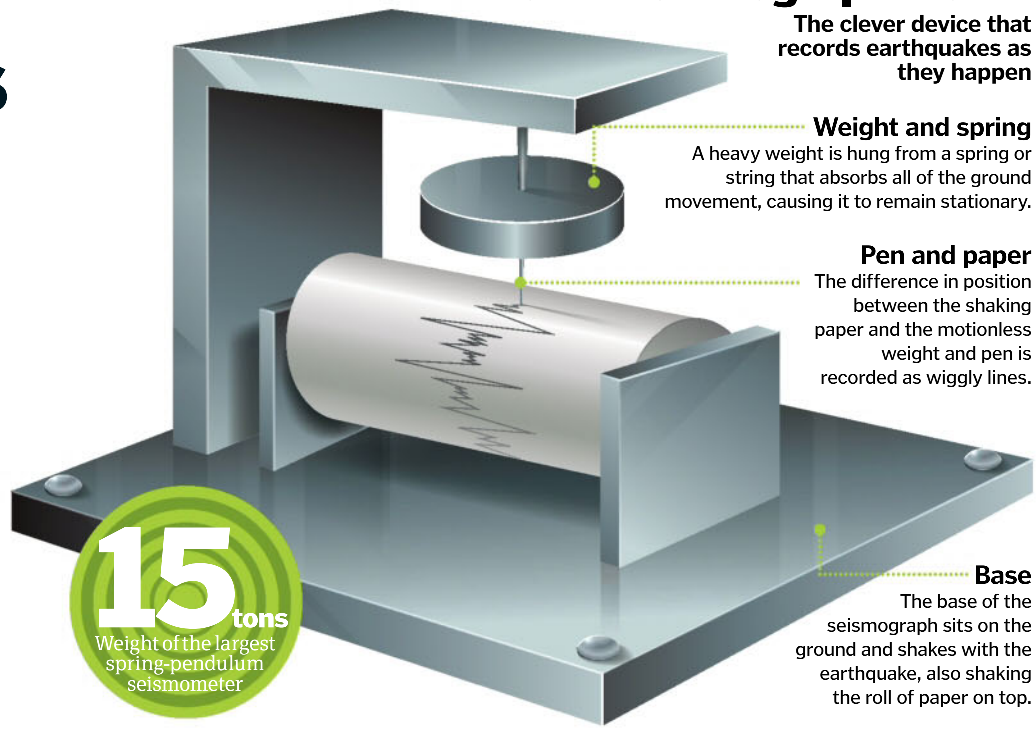
Monitoring earthquakes

Earthquake-recording methods of the past and present

Earthquakes are measured using an instrument called a seismograph, which produces a visual record of tremors in the Earth's crust. This shows the seismic waves of the earthquake as a wiggly line, allowing you to plot the different waves types. The small but fast P waves appear first, followed by the larger but slower S waves and surface waves. The amount of time between the arrival of the P and S waves shows how far away the earthquake was, allowing scientists to work out the exact location of the epicentre. The size of the waves also helps them determine the magnitude or size of the earthquake, which is measured using the Richter Scale.

How a seismograph works

The clever device that records earthquakes as they happen

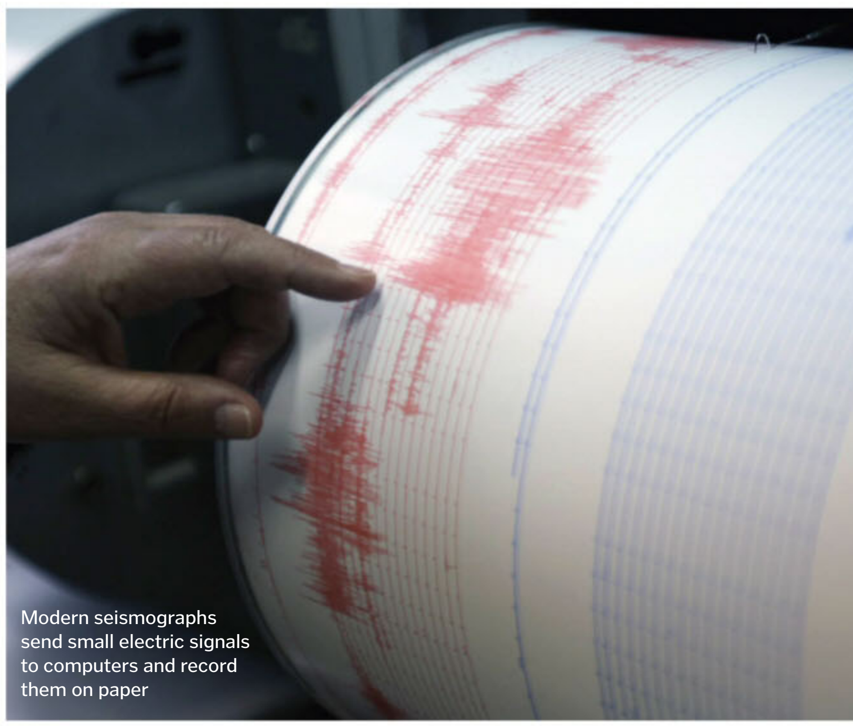


15 tons Weight of the largest spring-pendulum seismometer


The earliest known seismograph resembled a wine jar and had a diameter of 1.8m (6ft)

The first seismograph

The earliest known seismoscope was invented by Chinese philosopher Chang Hêng in 132. It didn't actually record ground movements, but simply indicated that an earthquake had hit. The cylindrical vessel had eight dragon heads around the top, facing the eight principal directions of the compass, each with an open-mouthed toad underneath it. Inside the mouth of each dragon was a ball that would drop into the mouth of the toad below when an earthquake occurred. The direction of the shaking could be determined by which dragon released its ball. It is not known what was inside the vessel, but it is thought that some kind of pendulum was used to sense the earthquake and activate the ball in the dragon's mouth. The instrument reportedly detected a 650-kilometre (373-mile)-distant earthquake which was not felt by people at the location of the seismoscope.


Modern seismographs send small electric signals to computers and record them on paper

The Richter Scale

Measuring the magnitude of earthquakes using US seismologist Charles F Richter's system

0-2.9 There are more than 1 million micro earthquakes a year but they are not felt by people.

3.0-3.9 Minor earthquakes are felt by many people but cause no damage – there are as many as 100,000 of these a year.

4.0-4.9 Felt by all, light earthquakes occur up to 15,000 times a year and cause minor breakages.

5.0-5.9 A moderate earthquake causes some damage to weak structures. There are around 1,000 of them a year.

AMAZING VIDEO! SCAN THE QR CODE FOR A QUICK LINK

How the quake catcher network works

www.howitworksdaily.com

DID YOU KNOW? *The earliest recorded evidence of an earthquake has been traced back to 1831 BCE in China's Shandong province*

Laser beams are used to detect small movements of the ground in Parkfield, California

With a little bit of warning, people can hide under tables and desks to protect them from falling debris in an earthquake

Predicting earthquakes

Modern methods that could help us plot future seismic activity

Currently, earthquakes cannot be predicted far enough in advance to give people much notice, but there are some early warning systems in place to give people a few seconds or minutes to prepare before the serious shaking starts. When seismometers detect the initial P waves, which don't usually cause much damage, they can estimate the epicentre and magnitude of the earthquake and alert the local population before the more destructive S waves arrive. Depending on their distance from the epicentre, people should then have just enough time to take cover, stop transport and shut down industrial systems in order to reduce the number of casualties.

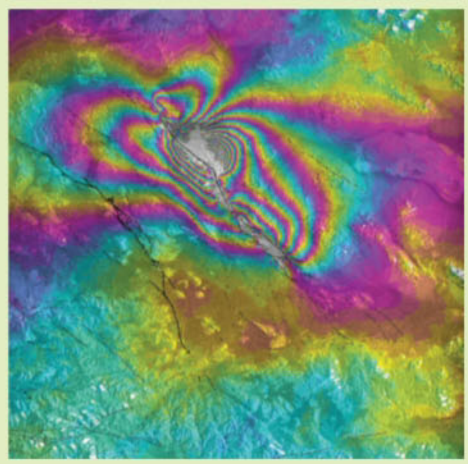
Scientists are also enlisting the help of the general public to help them develop early warning systems. The Quake-Catcher Network (QCN) is a worldwide initiative supplying people with low-cost motion sensors that they can fasten to the floor in their home or workplace. These sensors are then connected to their computer and send real-time data about seismic activity to the QCN's servers, with the hope that earthquake warnings can be issued when strong motions are detected in any of these.

To be able to predict earthquake further in advance, a characteristic pattern or change that precedes each earthquake needs to be identified. One suggestion is that increased levels of radon gas escape from the Earth's crust before a quake, however this can also occur without being followed by seismic activity, so does not provide conclusive evidence of a earthquake.

Scientists are even trying to determine whether animals can predict earthquakes better than we can, but no widespread unusual behaviour has been linked to earthquakes. Other potential earthquake-predicting methods are being tested in Parkfield, California along the San Andreas fault. Among other things, scientists are using lasers to detect the movement of the Earth's crust, sensors to monitor groundwater levels in wells, and a magnetometer to measure changes in the Earth's magnetic field, all with the hope that this will allow them to predict the next big quake.

Radar mapping

One of the more recent developments in earthquake monitoring is interferometric synthetic aperture radar (InSAR). Satellites, or specially adapted planes, send and receive radar waves to gather information about the features of the Earth. The reflected radar signal of a fault line is recorded multiple times to produce radar images, which are then combined to produce a colourful interferogram (below). Each colour shows the amount of ground displacement that has occurred between the capturing of each image, mapping the slow warping of the ground surface that leads to earthquakes. This technique is sensitive enough to detect even tiny ground movements, allowing scientists to monitor fault lines in more detail and detect points where immense pressure is building up. It is hoped that this data will eventually enable scientists to tell when this pressure has reached a hazardous level, leading to more reliable earthquake predictions that give the public days or even weeks to prepare.



6.0-6.9

Over 100 strong earthquakes happen each year, causing moderate damage in populated areas.

7.0-7.9

A loss of life and serious damage over large areas are the result of major earthquakes that happen around ten times a year.

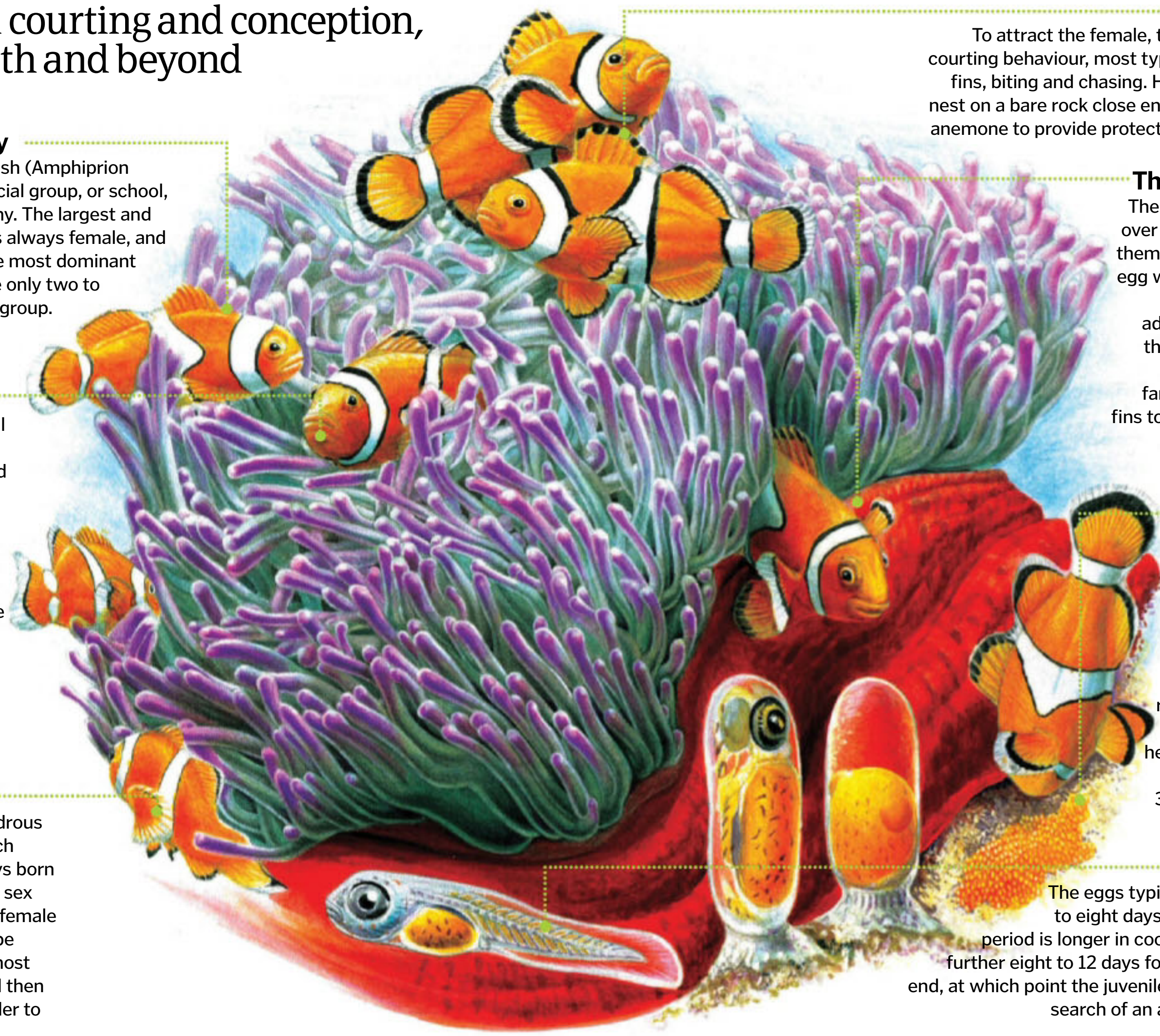
8.0 & higher

There are fewer than three earthquakes classed as 'great' each year, but they cause severe destruction and loss of life over large areas.

"Clownfish are protandrous hermaphrodites, they are always born male but can change sex later"

Life cycle of a clownfish

From courting and conception, to birth and beyond



Group hierarchy
The clown anemonefish (Amphiprion ocellaris) lives in a social group, or school, with a strong hierarchy. The largest and most dominant fish is always female, and she will mate with the most dominant male. They will be the only two to reproduce within the group.

Breeding time
Breeding can occur all year round, but is typically concentrated around the full moon. This is thought to be because of increased visibility, stronger water currents for distributing the larvae and greater food supplies due to other fish spawning at the same time.

Changing sex
Clownfish are protandrous hermaphrodites, which means they are always born male, but can change sex later. If the dominant female in the group were to be removed or die, the most dominant male would then become female in order to carry on the life cycle.

Courting
To attract the female, the male will exhibit courting behaviour, most typically via extended fins, biting and chasing. He will also build the nest on a bare rock close enough to their native anemone to provide protection from predators.

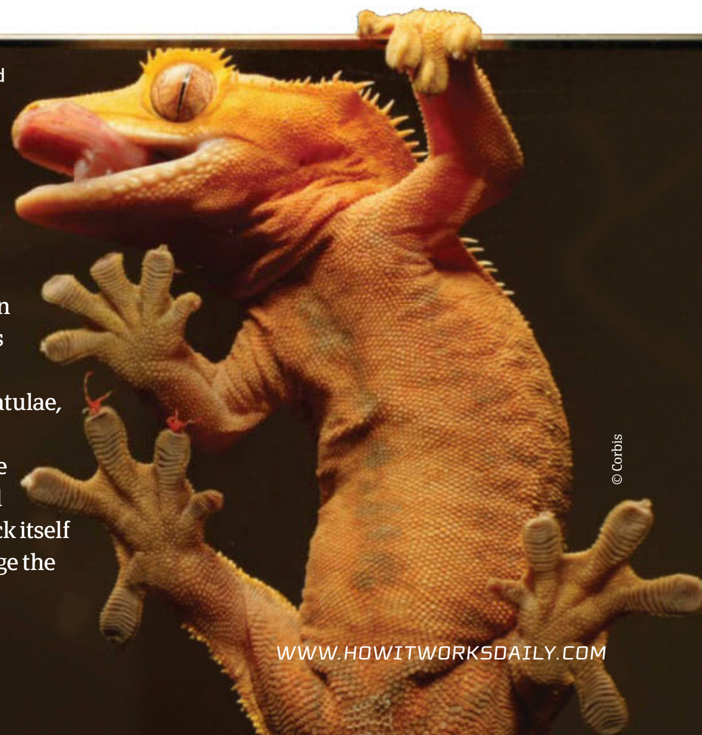
The father's role
The male will then pass over the eggs to fertilise them, and each fertilised egg will remain attached to the rock by fine adhesive threads. It is then the male's job to look after the eggs, fanning them with his fins to remove debris and prevent algae and fungi growth.

Laying eggs
Once the nest is built, the male will then chase the female towards it. Over several hours she will make a few passes over it, releasing 100-1,000 eggs, depending on her age. The eggs are orange and about 3-4mm (0.11-0.16in) in size.

Hatching
The eggs typically hatch after six to eight days, but the incubation period is longer in cooler water. It takes a further eight to 12 days for the larval stage to end, at which point the juvenile fish will then go in search of an anemone to inhabit.

How do geckos climb walls?

The science behind their clever feet



Geckos' feet are covered in tiny hairs, increasing their surface area for more contact

Rather than using sticky secretions or suction to stick to surfaces, geckos (Gekkonidae) use the van der Waals force. A gecko's toes are covered in millions of microscopic hairs called setae, and each hair is split into hundreds of bristles called spatulae. The molecules of these spatulae have either a positive or negative charge, and when they are in close proximity to another surface, they interact with its molecules and create an opposing positive or negative charge, resulting in an attractive force. The van der Waals force is very weak, but because of the gecko's lightweight body and huge number of spatulae, it can stick to almost anything, even wet surfaces. Their toes repel water and create air pockets to enable them to stay dry and stick on wet and slippery leaves. To unstick itself from a surface, the gecko just has to change the angle of its setae by moving its feet.

"The oak's growth will begin to slow, but this shouldn't happen until over 80 years or so have passed"

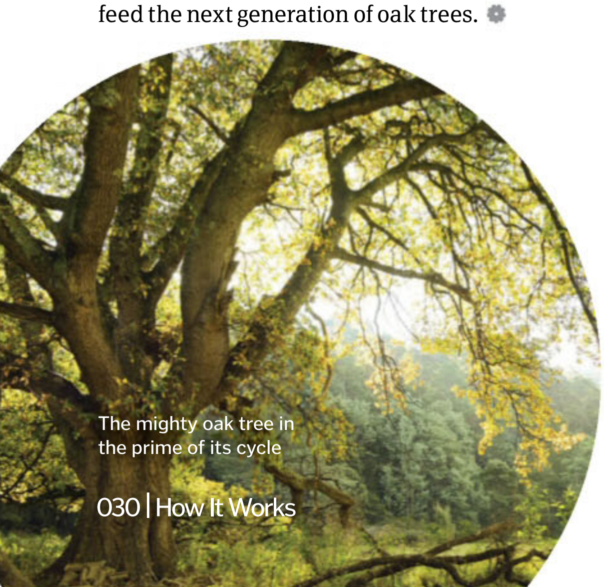
The life of an oak tree

Discover the amazing way mighty oak trees keep on surviving

All oak trees begin their life cycle as an acorn. This is the seed of the oak tree, which falls as the tree reaches maturity or is dislodged by weather or animals. Acorns that fall at least 27 metres (89 feet) from the tree have the best chance of surviving long enough to grow, as there will be less competition for space and nutrients. Once on the ground, the acorn will begin to germinate, absorbing water to hydrate its enzymes. Hydration instigates growth by causing the enzymes in the acorn to become more active. A tap root begins to form, burying down into the earth. This root absorbs nutrients and water from the soil, allowing a shoot to begin growing upward. This is known as the seedling stage.

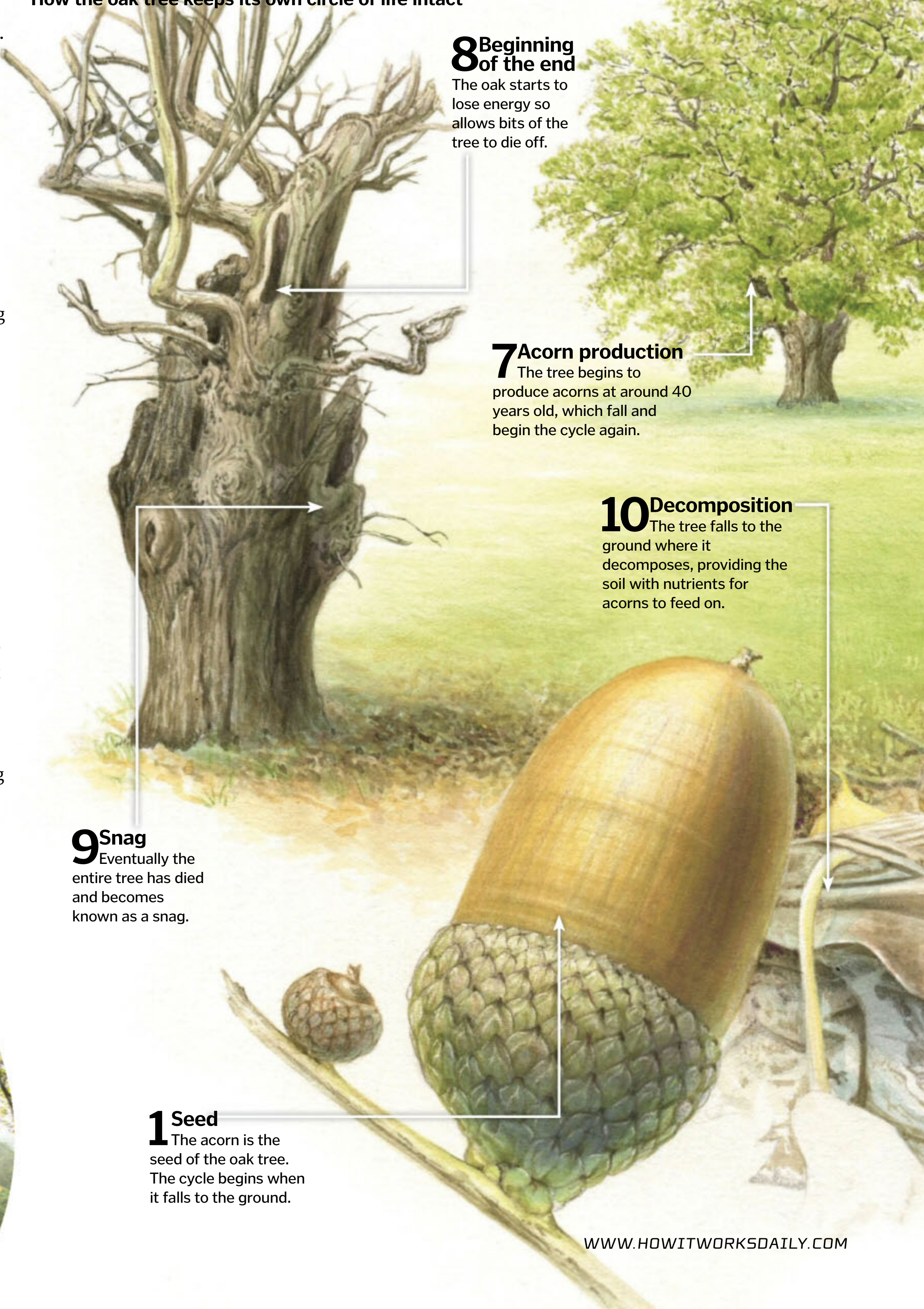
It continues to grow upward and outward, thickening its shoot until it has a trunk diameter of 7.5 centimetres (three inches), where it officially becomes a sapling. After around a year, it will have grown to a height of 30.5 centimetres (12 inches) when it is classified as a pole. The oak will begin to produce acorns after around 40 years when it should be approximately 10.5 metres (34 feet) tall and is fully matured.

The oak's growth will begin to slow, but this shouldn't happen until over 80 years or so have passed. Acorn production eventually stops, but the tree can comfortably live for over 1,000 years. Eventually parts of the tree begin to die as the oak is forced to conserve what little energy it has left. A dead oak is known as a snag and will fall to the ground, decomposing and providing the soil with the nutrients that will feed the next generation of oak trees.


The mighty oak tree in the prime of its cycle

The oak tree from seed to snag

How the oak tree keeps its own circle of life intact

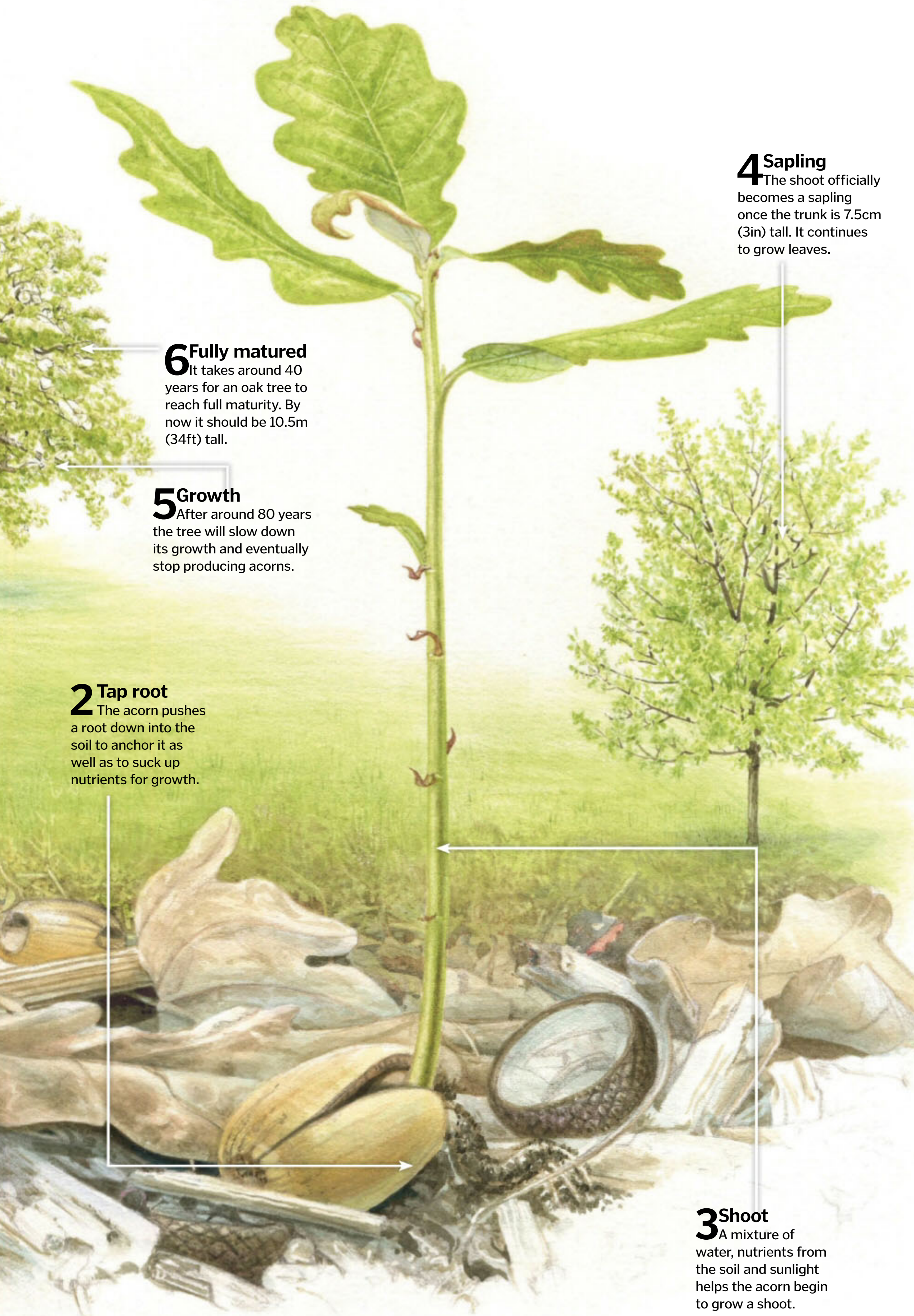


13,000years

OLDEST OAK

The Jurupa Oak is the oldest living oak colony in the world at 13,000 years old. It has lived this long by constantly cloning itself.

DID YOU KNOW? The oak tree is the most common species of tree in the UK and is a national symbol



Uses for oak

Before the Industrial Revolution oak was the most commonly used material for boat building. Its strength and durability made it perfect for constructing ships. It was replaced by iron partly because iron is stronger, but also because oak has to grow for 150 years before it can be used. It is still used as a material for furniture and floor wood, as well as barrels for storing wine, as the wood imparts the unique and distinctive flavours that differentiate types of wine. The bark of the oak tree contains both main types of tannin, a crucial ingredient in turning animal hides into leather. Tannins are extracted from the bark and rubbed into the hides. This alters the collagens in the hides, pulling them together, drawing out water and strengthening the hide into leather. This method has been in force since Roman times.


Ships such as the HMS Victory were constructed from oak timber

Britain's favourite tree

In 2002, The Major Oak in Sherwood Forest was voted Britain's favourite tree. The Quercus robur is over 800 years old and legend has it that it hid Robin Hood and his merry men from the Sheriff of Nottingham.

The tree's branches spread across 28 metres (92 feet) long and have been held up – first by metal chains and now by wooden struts – for over 100 years to stop them sagging under their enormous weight.

The Major Oak weighs around 23 tonnes, about the same as four fully-grown African elephants, and its ten-metre (33-foot) circumference trunk would need six adults to create a ring around it while holding hands.

"When a volcano erupts beneath the sea, super-hot lava gushes out, just like you might see on land"

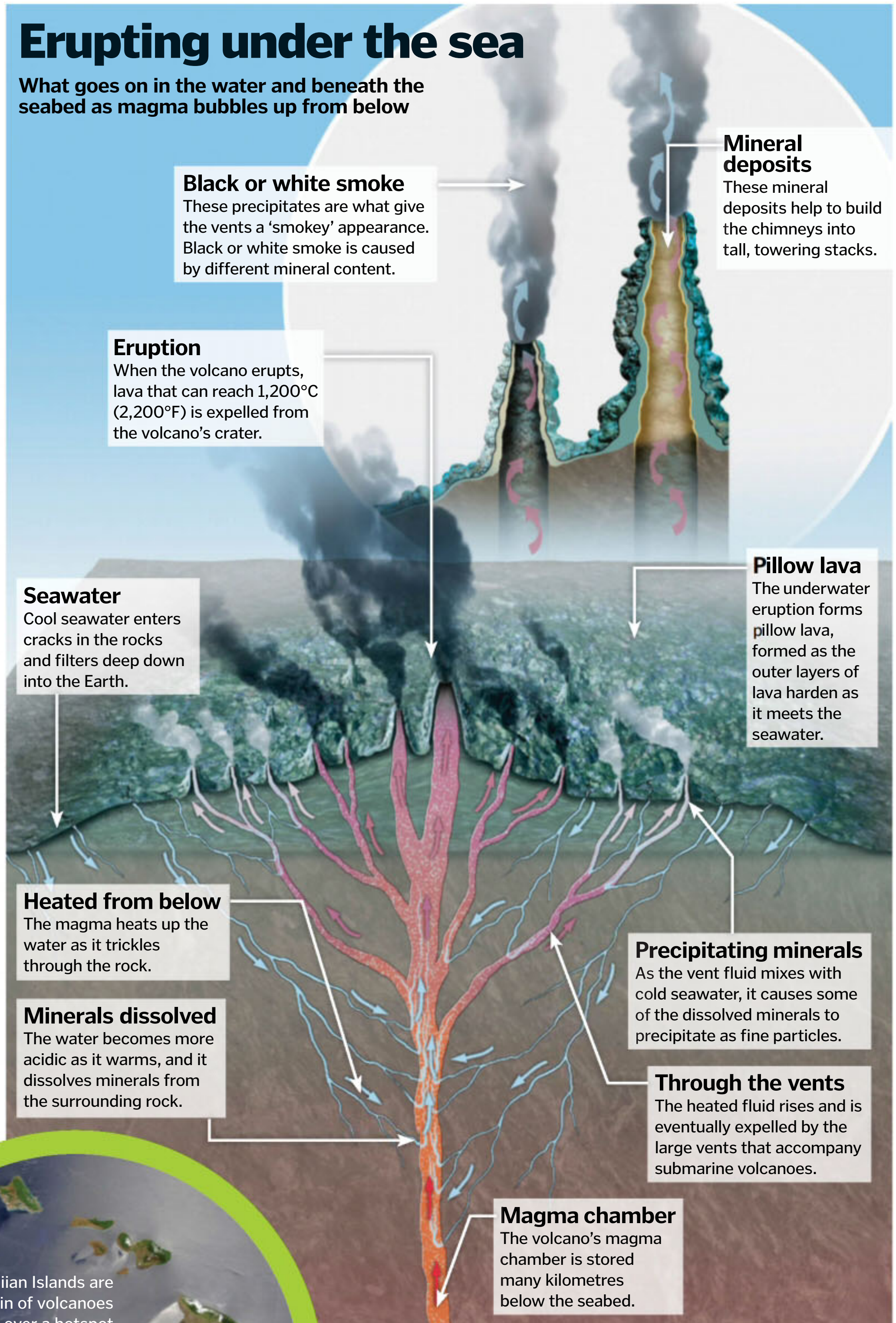
Submarine volcanoes

Our planet's most productive volcanic activity happens at the crushing depths of ocean ridges

The boundaries of Earth's tectonic plates are areas of pure fire and brimstone! Where the plates rub up against one another, or pull apart from each other, the super-heated innards of our planet are waiting to spill out, and this is where volcanoes can be found.

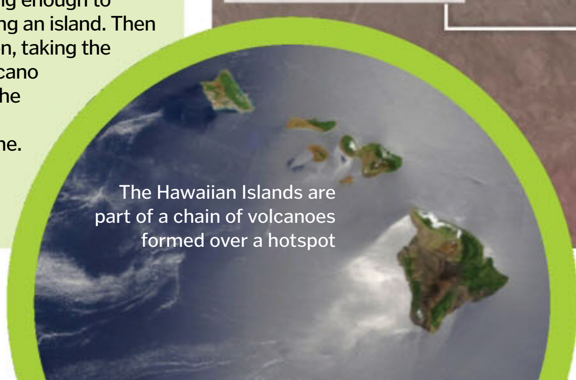
An underwater volcano forms when magma – molten rock from underneath the Earth's crust – builds up in a deep chamber. As the pressure increases, the magma finds its way upward until it reaches the seabed and the pressure is released in the form of a gigantic lava flow.

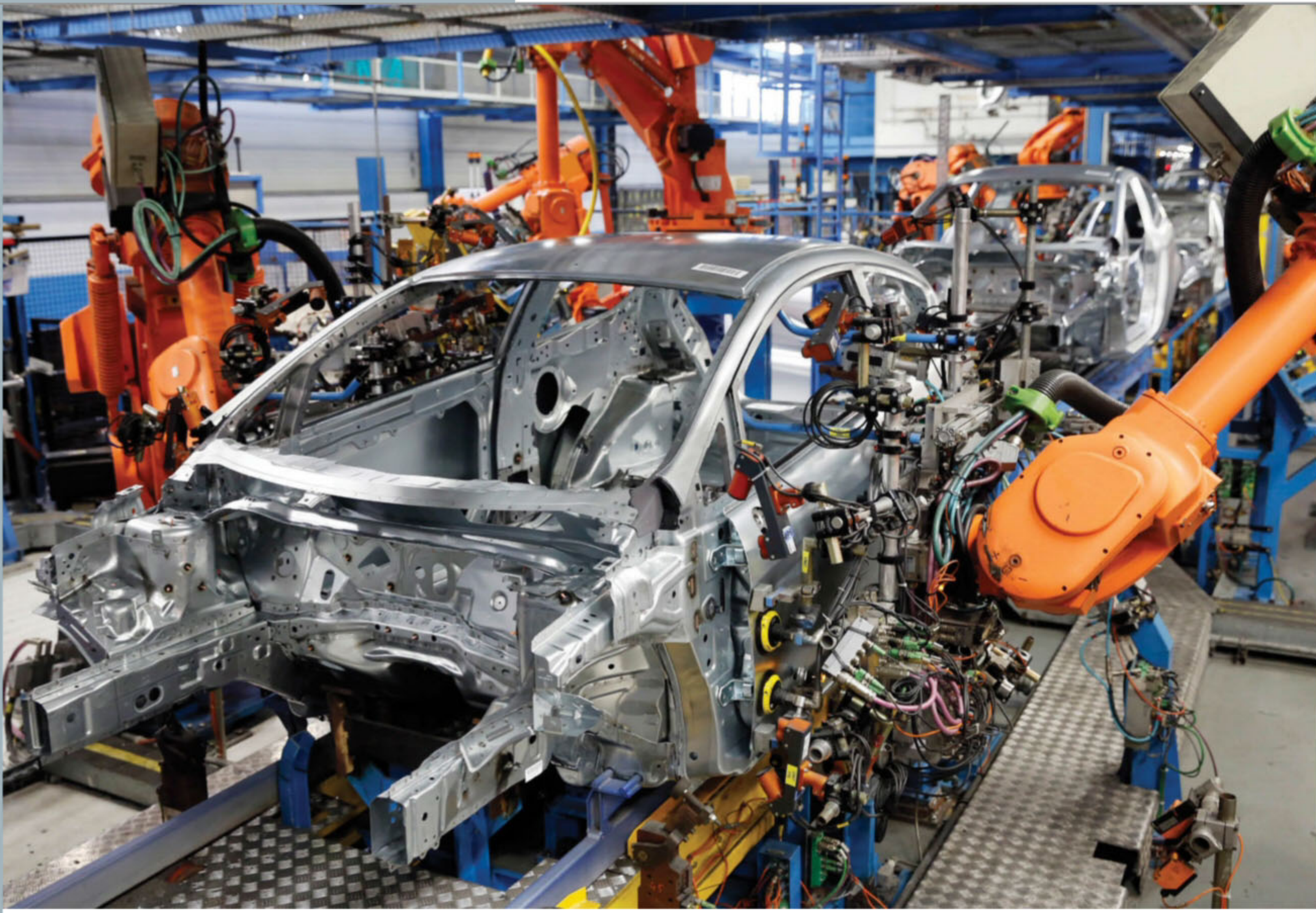
When a volcano erupts beneath the sea, super-hot lava gushes out, just like you might see on land. In relatively shallow water, this can send a spray of rocks, ash and gas through the water and out into the air. Deep-sea volcanoes are under crushing pressure from the water above, but the sheer force of the eruption still sends lava out of the fissure. Lava that oozes out is quenched almost as soon as it hits the water, and so the most common type of lava flow from an underwater volcano is 'pillow lava'. The outside of the lava flow hardens, but the inside stays molten, breaking through the end of the quenched blob and splurging forward – building up a string of pillow shapes before hardening to solid rock. These eruptions build layer upon layer of rock, and this i6s how the volcano grows in size.



Volcanic chains

Not all submarine volcanoes are located at tectonic boundaries. Long, linear chains of volcanoes such as the Hawaiian Islands and their underwater neighbours can form in the middle of oceanic basins. This is a by-product of continental drift – the gradual movement of tectonic plates. As the plate rests over a magma plume (an intense build-up of magma beneath the Earth's crust, sometimes known as a 'hotspot') the magma pushes its way up to the surface and a volcano will form, a process that takes thousands of years. The volcano may even stay active long enough to breach the ocean surface, forming an island. Then as the continental plate moves on, taking the volcano with it, a brand-new volcano eventually forms on the part of the continental crust that is now positioned over the magma plume. This means the volcanoes in the chain get older the further they extend from the magma plume.


The Hawaiian Islands are part of a chain of volcanoes formed over a hotspot



How a car is made

We travel to Germany to witness cars being born on the European production line

It's 8.30am on a cold September morning in Cologne as we shuffle our way into the European headquarters of the international motoring giant Ford. Along with a select few from the media, we are the first-ever members of the press to have been invited for a sneak peak behind the factory gates. The statistics say a new Ford Fiesta rolls off the production line every 86 seconds, so let's begin the tour to see how.

It starts at the body shop where a robot will attach the car door to the vehicle. Laser lines are used to ensure a precise fit. The body of the car is then cleaned in the body washer to prepare for the paint job. More robot arms then coat the car in its new colour and the body then goes into the wax oven before heading to the assembly plant. Next comes the 'marriage' – the most important part of automobile production. This is where the engine is united with the body and the wheels are fixed.

Speaking of engines, 26 million of them have been made at the factory since it opened its doors on 12 February 1962. Our tour leader and Plant Quality Manager Axel Jaedicke explained that this was enough to make a line from Los Angeles and back! It was fascinating to see how an engine is carefully made from scratch, but most impressive of all was the skill in which it was put together so expertly and efficiently.

The vast hangar ran like clockwork and the whole process to build an entire engine takes a very speedy four hours and 12 minutes. To maintain the high quality levels expected, one in every 5,000 engines enters into a "teardown audit" where engineers analyse and measure the completed machine.

Ford also considers the efficiency of the production process as well as the engine itself. It ▶

DID YOU KNOW? *Ford's robots can manufacture parts with an accuracy of ten microns – ten per cent the thickness of a human hair!*

The three stages of assembly

How the production line is divided up

1 Trim line

The first line attaches the smaller parts of the car such as the pedals, horn, seat belts, electrical switches, wipers and shock absorbers.

2 Chassis line

As the name suggests, this line deals with larger bits of kit such as axles, fuel pipes, exhausts, tyres and bumpers.

3 Final assembly line

The last few essential parts are brought on board on this line, like glove boxes, sun visors, parking brakes and the license plate lamp.

Engine timeline

The cylinder blocks queue up to be automatically machined in the state-of-the-art CNC machining centres.

A close-up view of a finished crankshaft being inspected for any visual flaws.

The cylinder block is bolted to a fixture on the assembly platen. The engine can now be rotated providing access to all sides of as it moves through the line.

The front view of a fully assembled engine, prior to its shipment to the vehicle assembly plant.

A side-elevation view of the intake side of the fully built and assembled engine.

"It has won the 'International Engine of the Year' award for the third time in a row in 2014"

uses a technique called Minimum Quantity Lubrication (MQL), which drastically reduces the amount of coolant and lubricant required to keep the factory's cutting tools working properly, saving both resources and power.

The EcoBoost has the lowest fuel consumption levels in its class and the majority of its main rivals use four-cylinder versions. Happily for petrolheads, Ford claims there is no loss of sound quality despite having one less cylinder than many other cars in its power range. Overall it's a pretty nifty piece of kit, but what's an engine without a car to put it in?

Before the car is born, between 60 and 80 potential designs are sketched and eight clay models are made to fine-tune the final product. At the beginning of the line, the car is an empty, hollow grey shell, a far cry from the sleek supermini it will end up being. A concrete jungle of welding machines, hydraulic robot arms and conveyer belts, the

Testing the Fiesta

The rigorous testing the supermini is put through

Power run

A test driver positions the Fiesta on a rolling road and will try to max out the car's power as it is held in place but allowed to accelerate. This test measures the torque of the wheels and the power of the flywheel to see if they are reaching the required level.

Water immersion

After the power is tested, the structural integrity of the vehicle must be assessed. Water is sprayed powerfully from every direction so any gap will be exposed. **HIW** sat shotgun during the test, hoping the car was leak free!

Bumpy road

The last test **HIW** witnessed was to decide whether the suspension was up to scratch. Traversing over all manner of rough and uneven roads, the Fiesta was put through its paces to make sure it could handle all surfaces.

THE STATS
BUILDING THE PERFECT FIESTA

310 PANELS WELDED INTO THE CAR IN ASSEMBLY

3.5 HOURS AN ENGINE SPENDS ON THE PRODUCTION LINE

£106 ($169) MILLION INVESTED IN THE ECOBOOST FACILITY

72 COUNTRIES THE FIESTA IS AVAILABLE IN

29 SIZE OF THE FACTORY IN FOOTBALL PITCHES

350,000 ECOBOOST ENGINES BUILT PER YEAR

DID YOU KNOW? *EcoBoost turbochargers spin at over twice the rpm of the ones powering F1 engines – over 4,000 times per second!*

Writer Jack Griffiths (second from left) on tour at the Ford factory

A fully assembled and ready-to-drive Ford Fiesta, fresh off the production line

The future of the assembly line

It seems as if all the new technology in the world today goes through Google in some way and now assembly lines can be added to that list. In partnership with international robotics company Foxconn, the focus is on increased automation and robotic use within the factories, taking the strain off manual labour. Tesla is another firm inventing new assembly robots. However, Tesla's stance is that less is more as it is creating robots suited to more than one function, for example able to put on wheels as well as attaching a door. This will hopefully have the dual effect of lowering costs while increasing efficiency at the same time.

Focus on quality

Interview with Harald Stehling, the head of the factory's quality control

What is the role of Ford Cologne in Ford's global and European operations?
Cologne is the lead global Ford Fiesta Plant.

What products does the factory produce and what is its 'flagship' product?
At the Cologne plant the 1.0-litre EcoBoost engine and the Ford Fiesta are produced. These are also the 'flagship' products.

Is a whole car created here or just part of the process?
At the Cologne plant it is stamping, body, paint, trim and final assembly, and the supplier park is connected to the production line as well. Most parts of the vehicle are created in Cologne.

What parts of the car are handmade and what is machine made? Why is this?
Parts are machine made, assembly mostly handmade. The reason for this is the high volume and cost for parts. The assembly is difficult to automate (such as wheel automation).

Does the Cologne plant have any competition with other factories?
Yes, in all metrics you can imagine, like safety, quality, volume and harbour report.

building is a hive of activity. On each vehicle 310 panels are welded together along with 1.2 kilometres (0.75 miles) of wiring. This is done at temperatures of up to 1,400 degrees Celsius (2,552 degrees Fahrenheit) so it was lucky we were behind protective glass when we got close!

Although the process looks like it never alters, 11,400 variations of the Fiesta are made between the three-door, five-door, ST and van models. The Fiesta's assembly is completed by a full immersion into an electro-coat fluid to add a corrosion-resistant layer, and the addition of waterproofing and vibration reducing sealer. But this is not the end of the journey; last but not least are Ford's rigorous testing procedures.

Each model will undergo 40 real-world crash tests, experience temperatures from -40 degrees Celsius (-40 degrees Fahrenheit) to 82 degrees Celsius (180 degrees Fahrenheit) and 130 hours of wind-tunnel testing at speeds of 130 kilometres (81 miles) per hour. HIW had a go at the water test – where torrential rainfall was imitated – and the suspension test, where some bumpy surfaces had to be navigated.

The Fiesta passed both with flying colours as the interior was left completely dry and little discomfort was felt on the rocky road. In addition to the physical exam, Ford employees utilise the power of the 3D Cave Automatic Virtual Environment (CAVE) to perform 5,000 virtual crash simulations. This system allows intricate details to be tested and improved upon without the need for more twisted metal and fuel consumption.

From the original concept ideas to the final touches on the assembly line, the life of a car is an extensive one even before it hits the showroom. It's fascinating how years in the making boils down to 86 seconds on the production line.

> "Brass and bronze are the main types of frame used because of their resistance to rust and pressure"

How portholes get their strength

How ships' windows have been made for centuries

Portholes have provided a window onto the seas for hundreds of years. The window's glass is a combination of silica, ash and lime, which is mixed together and then heated and cooled several times in huge furnaces. This is known as tempering and it strengthens the glass. On submarine vessels, the portholes can be several inches thick.

Brass and bronze are the main types of frame used because of their resistance to rust and pressure. The porthole is placed onto the ship, over a rubber sealing gasket to prevent water leakage and bolted in place.

They have been used on ships ever since cannons on Henry VI's ships became too large for traditional mounting. Shipbuilder James Baker made holes in the side of the ship and poked the cannons through. When the cannons were not in use, hinged covers would be put over the holes. Even though ships no longer have cannons on them, portholes are still useful for passenger ships as windows during bad weather.

Driverless Tube trains

How will the Tube trains of tomorrow cross London?

London's Tube lines may still be a relic of the Victorian age, but its trains could soon be amazing driverless machines, packed with digital screens and air-cooled cars.

The new designs, which could be in place as early as 2022, have a number of features that will improve the passenger experience. These include air-cooled carriages, digital screens that display real-time travel information and will be made up of walk-through carriages, increasing capacity on lines by up to 60 per cent.

The biggest development, though, is the fact that they could be self-driving. The trains, which will run on the Piccadilly, Bakerloo, Central and Waterloo & City lines, could run autonomously in just eight years' time.

One of the other developments in store is wider doors to speed up station transitions and tall barriers with sliding doors on the platform edges to increase safety.

The new trains could be driving themselves in less than a decade

Wider doors will reduce time at station platforms

THE STATS
CLAAS-Y NUMBERS

WEIGHT **18,920kg**
CAPACITY 12,500l
BLADES **108**
HEADER WIDTH **12.3m**
TYRE HEIGHT 1.65m
TOP SPEED 30km/h

DID YOU KNOW? *The combine harvester has around 17,000 different parts, nearly three times as many as a standard car*

Inside a combine harvester

How the Lexion 780 separates the wheat from the chaff

GPS
Satellites track where the machine is and where it has been to make the harvesting process as efficient as possible.

Comfort cab
The cab's leather seat contains sweat-wicking technology and its suspension system absorbs 40 per cent of vibrations.

Engine
The 780 is powered by a V8 Mercedes-Benz OM 502 engine with a rated engine speed of 1,900rpm.

Conveyor belt
The crops get pushed into the middle of the machine by rotating screws and up a conveyor belt to be threshed.

Tyres
The 780 runs on 76cm (30in)-wide, 1.65m (5.4ft)-diameter tyres. The pressure can be controlled from the cab.

Threshing
The 61cm (24in)-wide drum rotates at up to 1,150rpm, bashing the crops, separating the grain and the chaff.

Header
The 12.3m (40.4ft)-wide header is able to gather in a lot of crops per sweep.

APS pre-thresh
The crops are sped up from 3m/s (9.8ft/s) to 20m/s (65.6ft/s), pre-separating up to 90 per cent of the grains.

Reel
The reel rotates, forcing the crop stalks into the blades.

Cutter
108 hydraulic-powered, pincer-like blades snap open and shut, slicing through the stalks.

How the combine harvester changed farming

Right up until the early-19th century harvests were taken in by hand. Teams of workers would slice the wheat stalks with scythes before pummelling the grain out of the husk.

The first method of transport that entered the fields was the reaper. The reaper, which was essentially the header, was pushed through the field by a team of horses. It sliced at the base of the stalks, which were then pushed out of a chute into a waiting wagon. The wagon would then take the crops to a central threshing machine that would beat the grain out of the stalks.

The modern combine harvester can be traced back to the 1830s when Hiram Moore combined the two machines, aiming to create an all-in-one reaper and thresher. It was not accepted for many years until its true value was recognised, where it became the subject of a raft of lawsuits from various people claiming to have originally invented it.

YOUR SKELETON

This incredible living framework provides more than just structural support

The 206 bones of the adult human skeleton make up a strong, flexible framework that protects our vital organs and allows our bodies to move, as well as being a mineral store and stem-cell reserve.

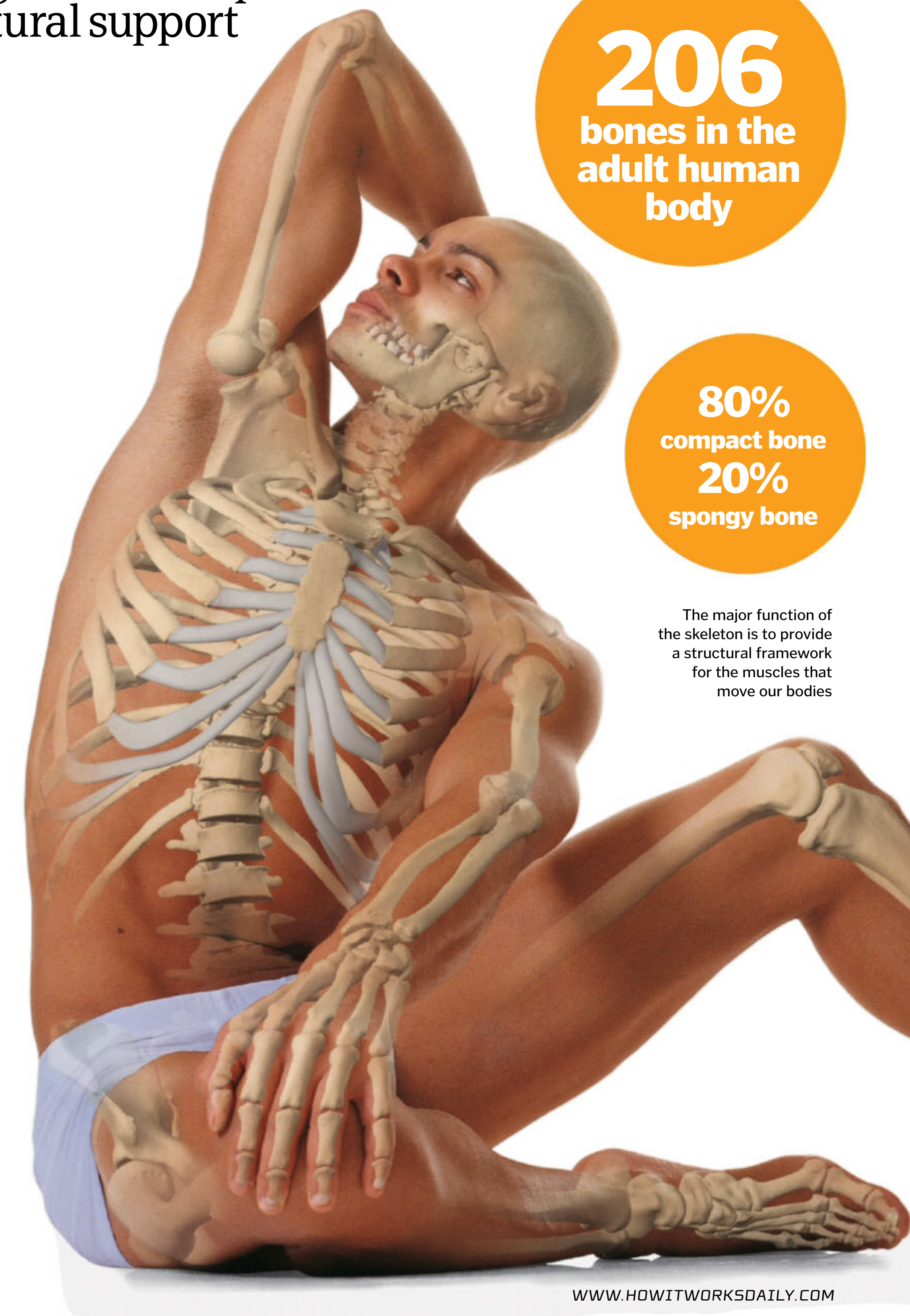
Bone is a composite material, constructed from three basic ingredients: collagen strands, a sugary protein glue and inorganic calcium salts. The collagen fibres are arranged in alternating layers, crossing over one another, providing a flexible scaffold, and calcium salts are glued in between for strength and rigidity.

The outside of each bone is composed of plates, or hollow tubes, of dense cortical bone, supported on the inside by a honeycomb network of spongy trabecular bone. This network is slightly flexible and helps to distribute the load, curving the tensile and compressive forces across the ends of the bone, while providing maximum strength.

Spongy bone is also home to the bone marrow, and which houses stem cells capable of producing most of the cells of the blood and immune system. They are constantly active, and millions upon millions of new red and white blood cells are produced every minute.

Embedded within the bone matrix are cells known as osteocytes. They do not move, but are capable of detecting stresses inside the bone itself, and can trigger the formation of new bone in a process known as remodelling. The old bone is broken down by large cells known as osteoclasts, and new collagen and minerals are deposited by smaller osteoblasts.

Together, the two cell types are able to release and store calcium and phosphorous in the skeleton for use elsewhere in the body. They are under the influence of hormones released by glands in the brain, and when levels of minerals run low in the body, the signals encourage the osteoclasts to begin wearing away at the surface of the bone, releasing minerals into the bloodstream. When mineral levels are high, osteoblasts lay down new bone, replenishing the store.



206
bones in the adult human body

80%
compact bone
20%
spongy bone

The major function of the skeleton is to provide a structural framework for the muscles that move our bodies

1. LONG

Seventh rib
The seventh rib, which is the lowest fixed rib, is the longest bone in the rib cage, measuring about 24cm (9.5in) in length.

2. LONGER

Humerus
After the three leg bones, the next-longest bone in the human body is the humerus in the upper arm, measuring around 36cm (14in).

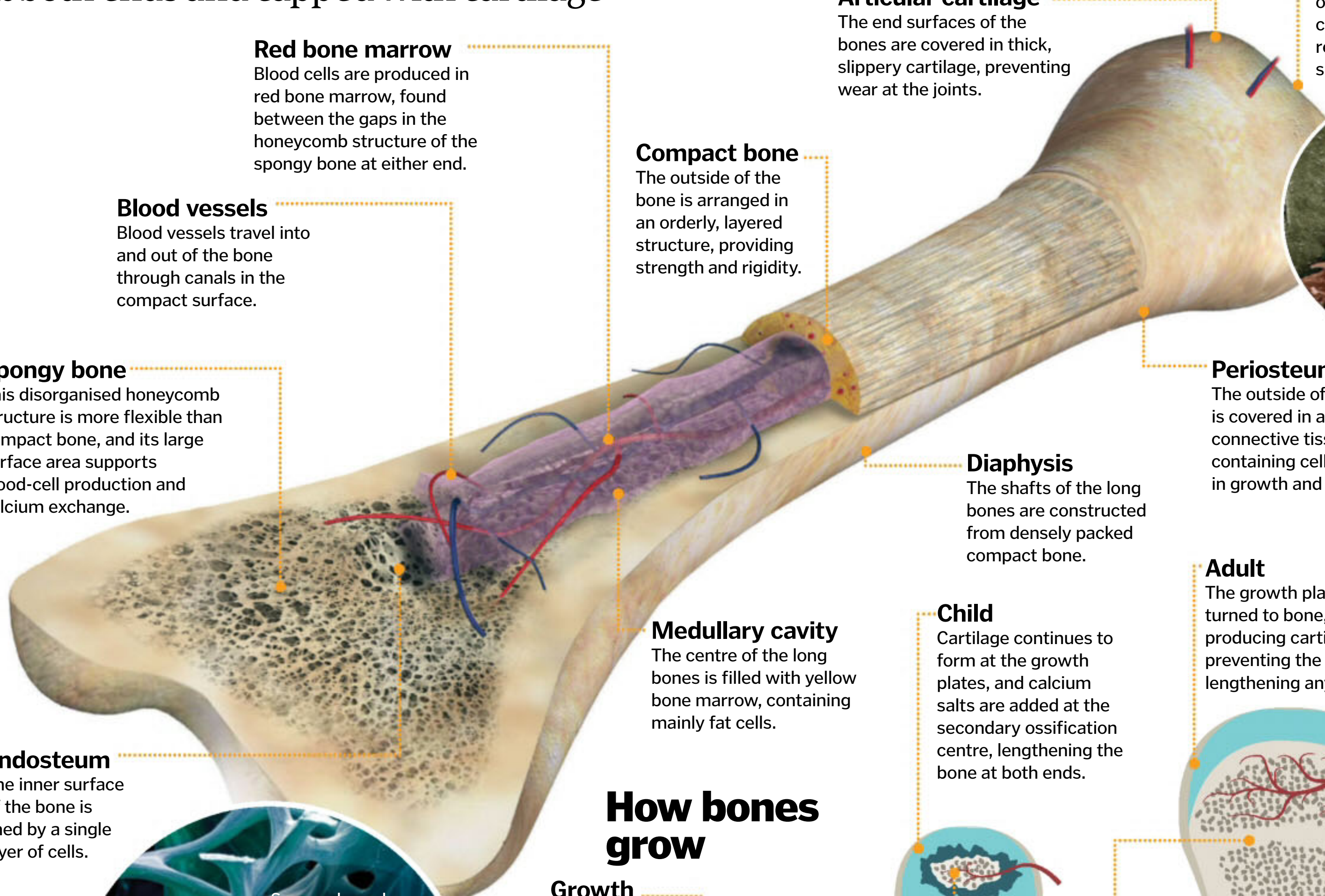
3. LONGEST

Femur
The femur, or thigh bone, is the longest bone in the human body by some margin, measuring around 50cm (20in) in the average adult.

DID YOU KNOW? *The hands and feet contain over half of the bones in the body, with a total of 106 between them*

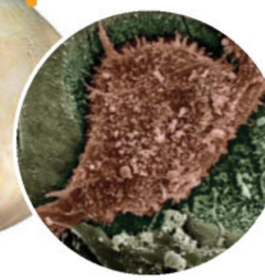
Bone structure

The long bones are formed into tubes, closed at both ends and capped with cartilage



Epiphysis
The ends of the long bones act as shock absorbers, with a casing of tough compact bone supported by a spongy core.

Articular cartilage
The end surfaces of the bones are covered in thick, slippery cartilage, preventing wear at the joints.



BELOW Cells known as osteoclasts constantly remodel the surface of bone

Red bone marrow
Blood cells are produced in red bone marrow, found between the gaps in the honeycomb structure of the spongy bone at either end.

Compact bone
The outside of the bone is arranged in an orderly, layered structure, providing strength and rigidity.

Blood vessels
Blood vessels travel into and out of the bone through canals in the compact surface.

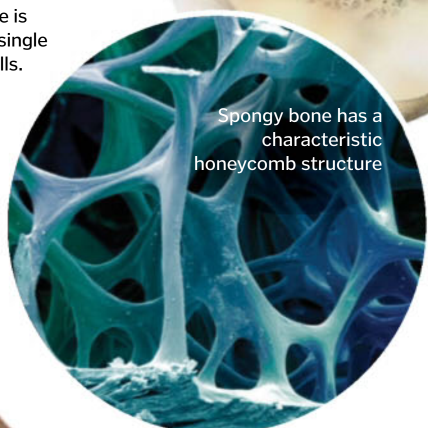
Spongy bone
This disorganised honeycomb structure is more flexible than compact bone, and its large surface area supports blood-cell production and calcium exchange.

Periosteum
The outside of the bone is covered in a layer of connective tissue, containing cells involved in growth and repair.

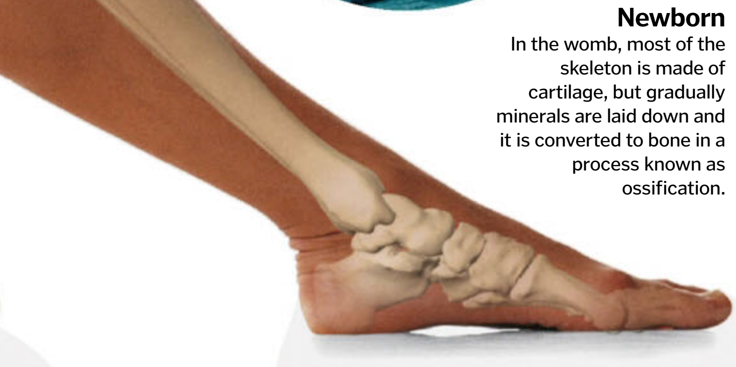
Diaphysis
The shafts of the long bones are constructed from densely packed compact bone.

Medullary cavity
The centre of the long bones is filled with yellow bone marrow, containing mainly fat cells.

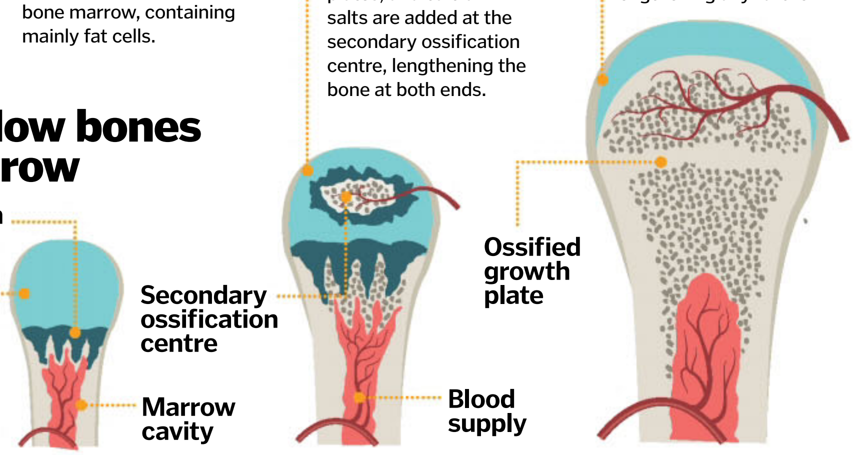
Endosteum
The inner surface of the bone is lined by a single layer of cells.



Spongy bone has a characteristic honeycomb structure



How bones grow



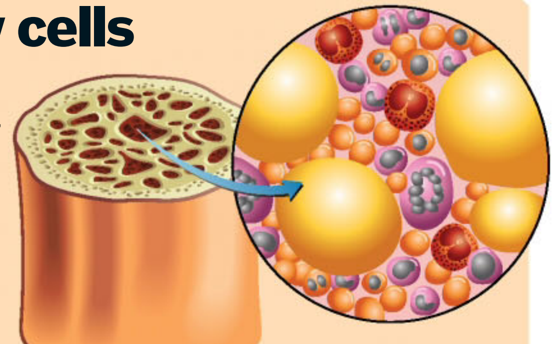
Newborn
In the womb, most of the skeleton is made of cartilage, but gradually minerals are laid down and it is converted to bone in a process known as ossification.

Child
Cartilage continues to form at the growth plates, and calcium salts are added at the secondary ossification centre, lengthening the bone at both ends.

Adult
The growth plate itself is turned to bone, and stops producing cartilage, preventing the bones from lengthening any further.

Bone marrow cells

There are two types of bone marrow in the human body; yellow marrow is found in the shafts of the long bones, like the femur, and red marrow is mainly found in the flat bones, like the ribs. Yellow marrow is mostly made up of large fat cells, whilst red marrow contains stem cells. These are capable of producing most of the cells of the blood and immune system, and concealed within the bones are many immature cells in the process of development.

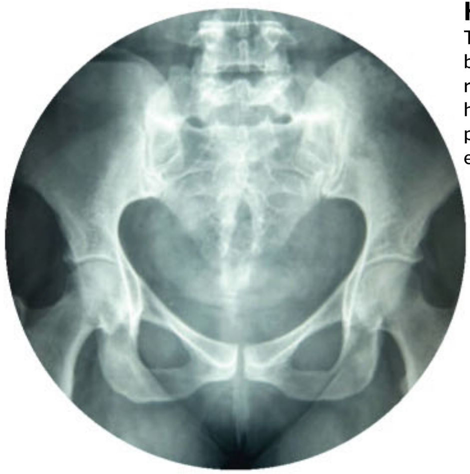


"The axial bones form the central core of the skeletal system, including the skull, spine, rib cage and pelvis"

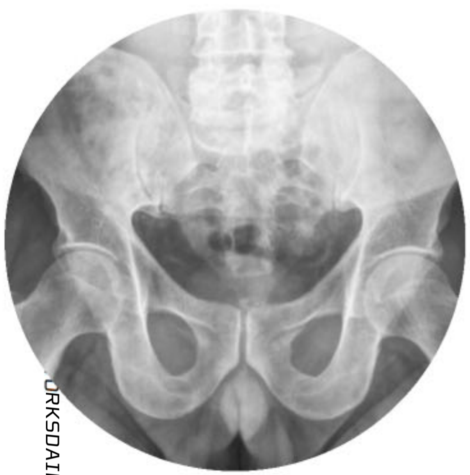
Skeletal system

Get to know the bones in your body with our guide to the human skeleton

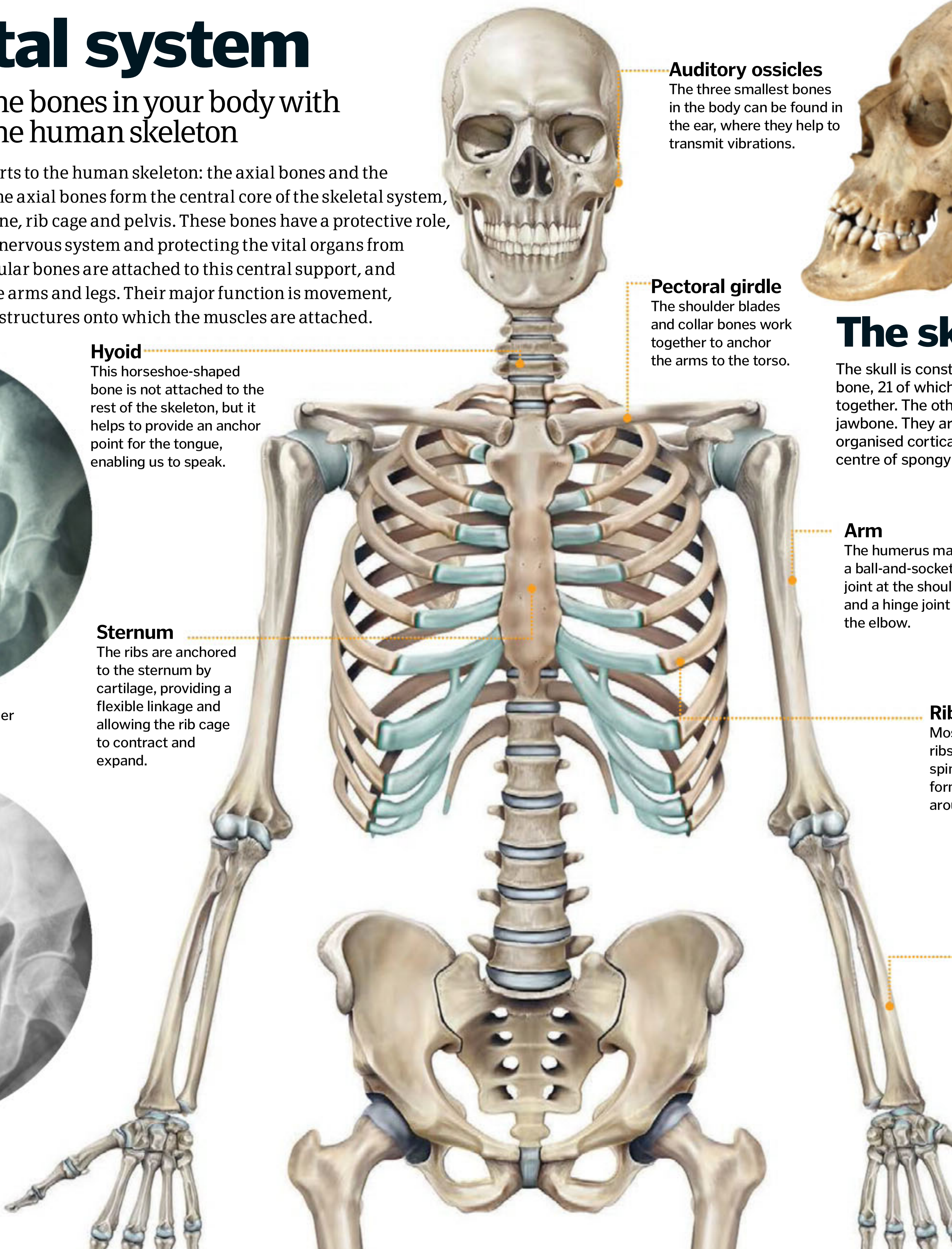
There are two major parts to the human skeleton: the axial bones and the appendicular bones. The axial bones form the central core of the skeletal system, including the skull, spine, rib cage and pelvis. These bones have a protective role, supporting the central nervous system and protecting the vital organs from damage. The appendicular bones are attached to this central support, and include the bones of the arms and legs. Their major function is movement, providing rigid jointed structures onto which the muscles are attached.



ABOVE Females have a larger opening inside the pelvis, aiding with childbirth



ABOVE The male pelvis is relatively narrow and the opening is heart-shaped



Hyoid
This horseshoe-shaped bone is not attached to the rest of the skeleton, but it helps to provide an anchor point for the tongue, enabling us to speak.

Sternum
The ribs are anchored to the sternum by cartilage, providing a flexible linkage and allowing the rib cage to contract and expand.

Auditory ossicles
The three smallest bones in the body can be found in the ear, where they help to transmit vibrations.

Pectoral girdle
The shoulder blades and collar bones work together to anchor the arms to the torso.

Arm
The humerus makes a ball-and-socket joint at the shoulder, and a hinge joint at the elbow.

Ribs
Most people have 12 pairs of ribs that, together with the spinal column and sternum, form a protective cage around the heart and lungs.

Forearm
The two bones of the forearm split the load; the ulna bears weight near the elbow, and the radius bears weight near the wrist.

The skull

The skull is constructed out of 22 plates of flat bone, 21 of which are permanently fused together. The other is the mandible, or jawbone. They are made from a thick layer of organised cortical bone, sandwiched around a centre of spongy bone.

10 years to replace your entire skeleton

RECORD BREAKERS
A BONE TO PICK

3.5mm

THE SMALLEST BONE IN THE HUMAN BODY

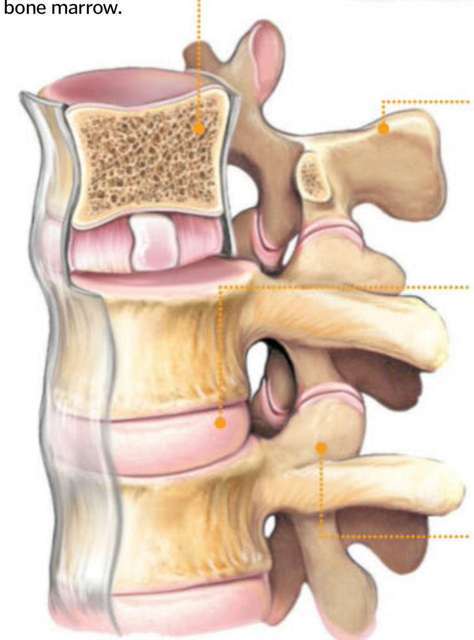
The stirrup-shaped stapes is one of three bones responsible for transmitting vibrations to the inner ear. It measures just 3.5mm (0.14in) across and weighs only 3mg (0.0001oz).

DID YOU KNOW? *Tendons attach muscles to bones, while ligaments attach bones to bones and are involved in stability*

The spine

There are 33 vertebrae in the spinal column, divided into categories according to their shape and location. There are seven cervical in the neck, 12 thoracic vertebrae in the chest, each of which attaches to a pair of ribs, and five load-bearing lumbar vertebrae in the lower back. The remainder of the vertebrae are fused to form the sacrum and coccyx.

33 vertebrae in the spine



Vertebral body
Each vertebra contains a core of spongy bone and red bone marrow.

Spinous process
Muscles attach to protruding bone at the back of each vertebra.

Intervertebral disk
A disk of cartilage between each vertebra provides cushioning and protection.

Articular process
Each vertebra has four articular processes, connected to the adjacent vertebrae by ligaments.

27 bones in the human hand

Wrist, hand and fingers
There are 27 bones in each hand, eight of which make up the wrist.

Lower limb
The weight of the body is supported by the femur (thigh bone) and the tibia (shin bone), while the fibula is involved in anchoring the muscles of the foot.

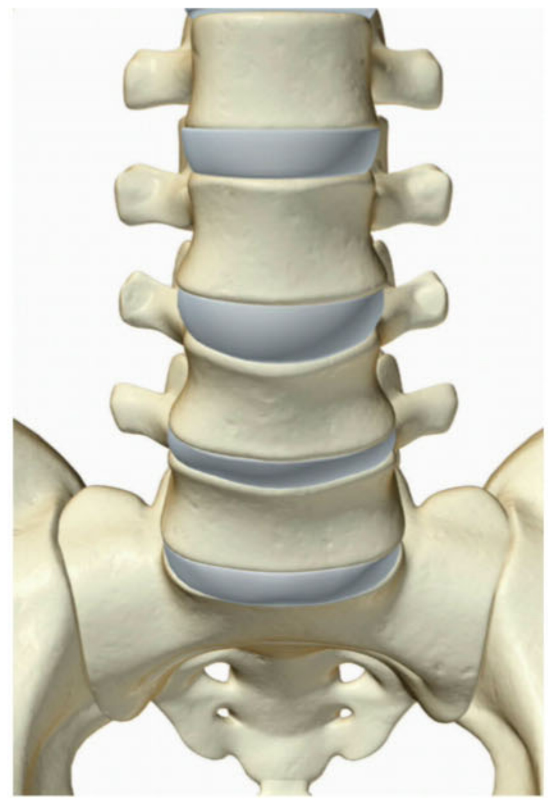
Foot
There are 26 bones in each foot, held together by a series of ligaments.

Learn more

Get your own giant 1.3m high poster to help explore every bone in the human skeleton – great for home and schools. Drawn to scale and anatomically detailed by leading medical artist, Joanna Culley. A matching muscle poster is also available all from www.uAnatomy.com.

Shock absorbers

Between the vertebrae of the spine are disks of a springy tissue known as fibrocartilage, made up of long chains of collagen and bound together by gel of sugary proteins, known as glycoproteins. These have a strong affinity for water, so as a result, the entire tissue is filled with fluid. It acts like suspension, compressing and deforming under load and protecting the bones from the stress of day-to-day impact.



"The bones are joined by a rigid gel-like tissue known as cartilage, which allows for compression and stretching"

Joints

For individual bones to function together, they must be linked by joints

15% body weight contributed by the skeleton

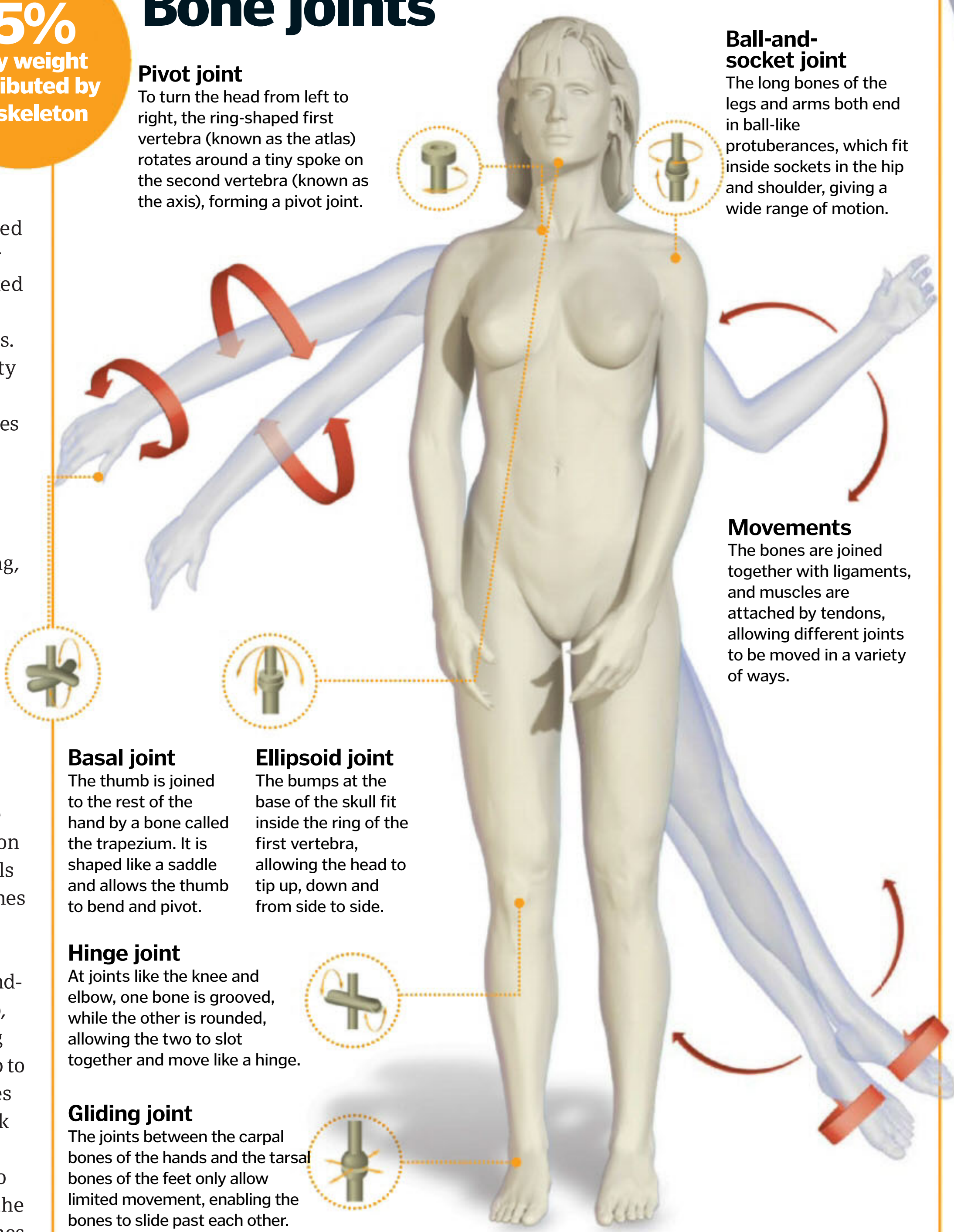
Some bones, like those in the skull, do not need to move, and are permanently fused together with mineral sutures. These are known as fixed joints and provide maximum stability.

However, most bones need flexible linkages. In some parts of the skeleton, partial flexibility is sufficient, so all that the bones require is a little cushioning to prevent rubbing. The bones are joined by a rigid gel-like tissue known as cartilage, which allows for a small range of compression and stretching. These types of joints are used where the ribs meet the sternum, to provide flexibility when breathing, and between the stacked vertebrae of the spinal column, allowing it to bend and flex without crushing the spinal cord.

Most joints require a larger range of movement. Covering the ends of the bones in cartilage provides shock absorption, but for them to move freely in a socket, the cartilage must be lubricated to make it slippery and wear-proof. At synovial joints, the ends of the two bones are encased in a capsule, covered on the inside by a synovial membrane, which fills the joint with synovial fluid, allowing the bones to slide smoothly past one another.

There are different types of synovial joint, each with a different range of motion. Ball-and-socket joints are used at the shoulder and hip, and provide a wide range of motion, allowing the curved surface at the top end of each limb to slide inside a cartilage covered cup. The knees and elbows have hinge joints, which interlock in one plane, allowing the joint to open and close. For areas that need to be flexible, but do not need to move freely, such as the feet and the palm of the hand, gliding joints allow the bones to slide small distances without rubbing.

Bone joints



Hypermobility

Some people have particularly flexible joints, so have a much larger range of motion than others. This is sometimes known as being 'double jointed.' It is thought to result from a combination of factors, including the structure of the collagen in the joints, the shape of the end of the bones, and the tone of the muscles around the joint.

Mobile

The synovial joints are the most mobile in the human body. The ends of the bones are linked by a capsule, which contains a fluid lubricant, allowing the bones to slide past one another as they move. Synovial joints come in different types, including ball-and-socket, hinge, and gliding, and they are the most common type of joint in the body.

Semimobile

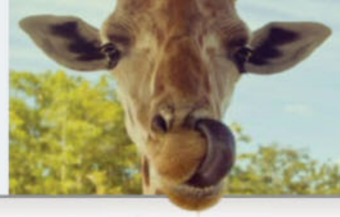
Cartilaginous joints do not allow free motion, but provide cushioning for smaller movements. Instead of a lubricated capsule, the bones are joined by fibrous or hyaline cartilage. The linkage provides less flexibility than a synovial joint, but acts as a shock absorber, so the bones can move apart and together over small distances.

Fixed

Some bones do not need to move relative to one another, so instead of a flexible joint, they are permanently fused. The best example is the cranium, which starts out as separate pieces, allowing the foetal head to change shape to fit through the birth canal, and fuses after birth to encase the brain in a solid protective skull.

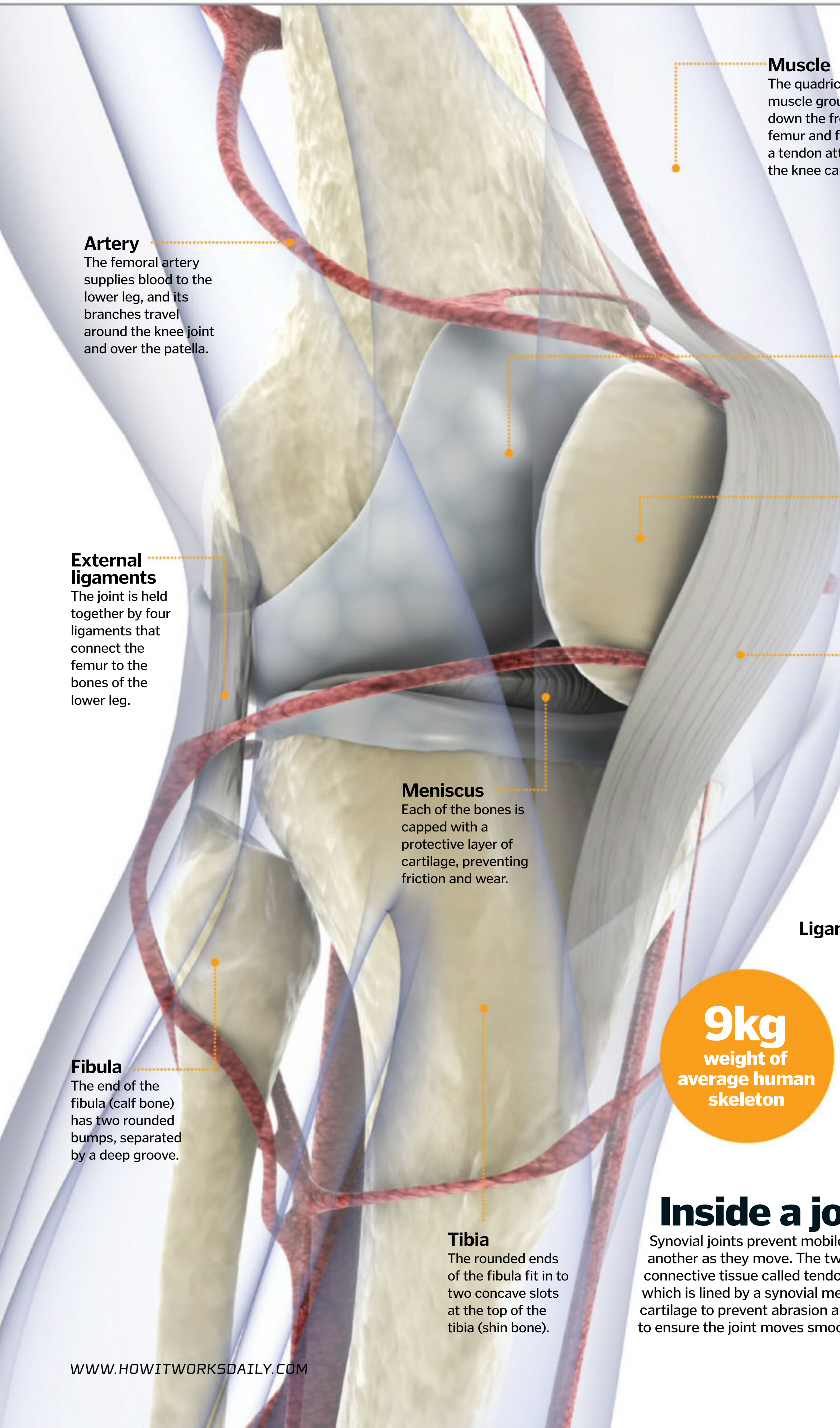
Who has more neck vertebrae, a human or a giraffe?

A Human **B** Giraffe **C** Same



Answer:
Amazingly, giraffes have just seven vertebrae in their necks, the same as a human being. But unlike us, their bones are joined by ball-and-socket joints, allowing them much more flexibility.

DID YOU KNOW? The bone marrow produces between two and three million new red blood cells every second



Muscle
The quadriceps muscle group runs down the front of the femur and finishes in a tendon attached to the knee cap.

Artery
The femoral artery supplies blood to the lower leg, and its branches travel around the knee joint and over the patella.

Synovial membrane
The membrane surrounding the interior of the joint produces a lubricant called synovial fluid.

Knee cap
The patella prevents the tendons at the front of the leg from wearing away at the joint.

External ligaments
The joint is held together by four ligaments that connect the femur to the bones of the lower leg.

Patellar ligament
The patellar ligament connects the kneecap to both the quadriceps in the thigh and the tibia in the lower leg.

Meniscus
Each of the bones is capped with a protective layer of cartilage, preventing friction and wear.

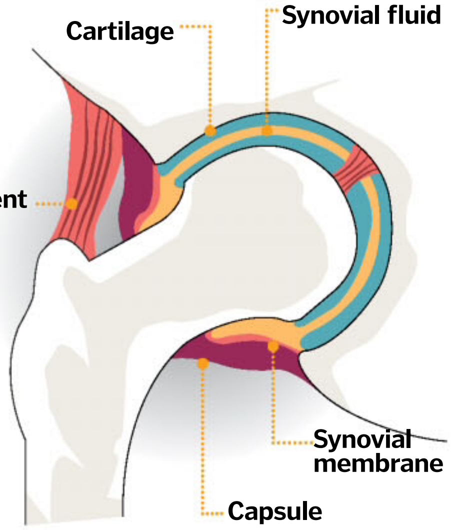
Fibula
The end of the fibula (calf bone) has two rounded bumps, separated by a deep groove.

Tibia
The rounded ends of the fibula fit in to two concave slots at the top of the tibia (shin bone).

Why our joints crack

The synovial fluid used to lubricate the joints contains dissolved gasses. The fluid is sealed within a capsule, so if the joint is stretched, the capsule also stretches, creating a vacuum as the pressure changes, and pulling the gas out of solution and into a bubble, which pops, producing a cracking sound.

300+ bones in a newborn baby



9kg weight of average human skeleton

Inside a joint

Synovial joints prevent mobile areas of the skeleton from grinding against one another as they move. The two bones are loosely connected by strips of connective tissue called tendons, and the two ends are encased in a capsule, which is lined by a synovial membrane. The bones are covered in smooth cartilage to prevent abrasion and the membrane produces a nourishing lubricant to ensure the joint moves smoothly.

"Force is measured in Newtons and is worked out by calculating the object's mass multiplied by its acceleration"

Wave diffraction

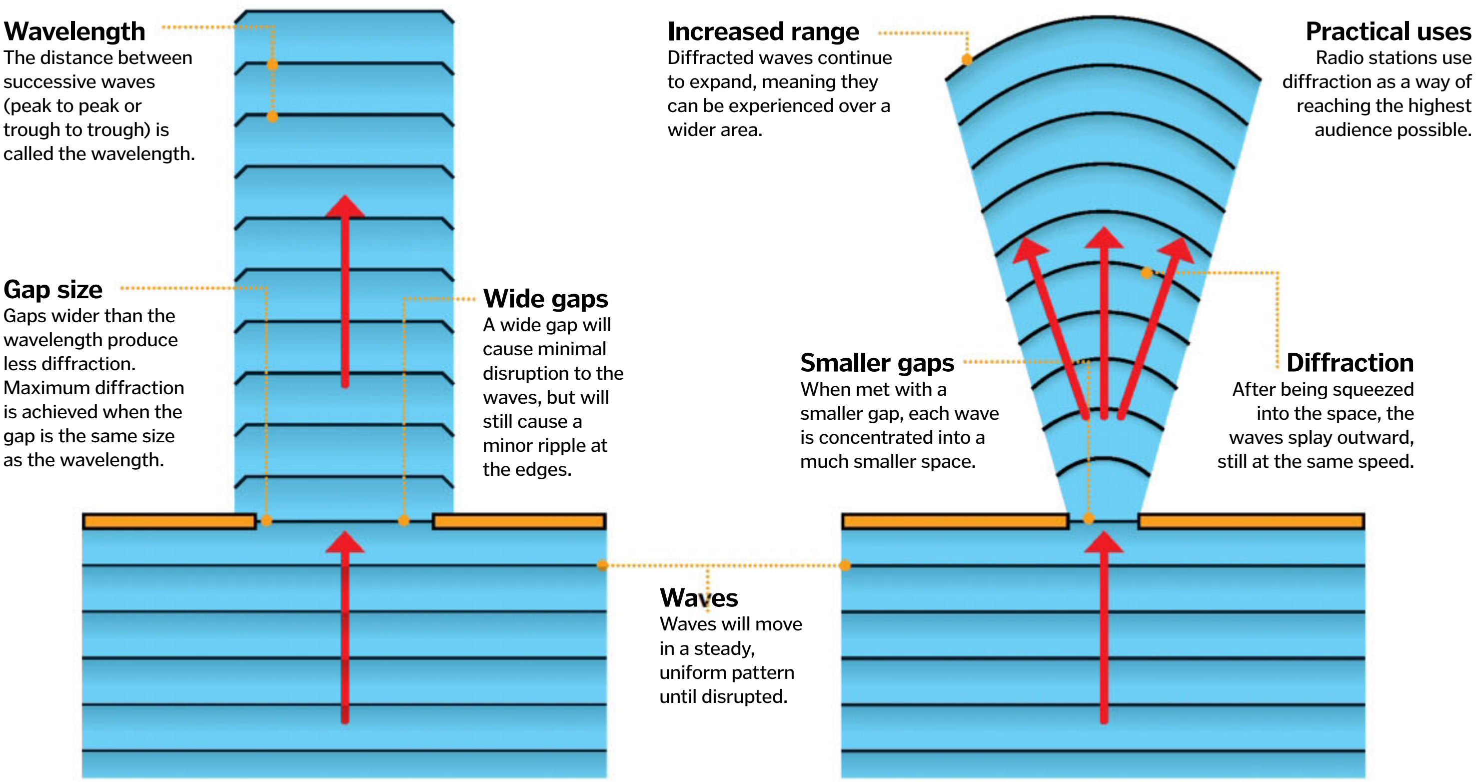
What force makes waves spread outward?

Sound waves move very much like those you see in water, except that they're invisible to the human eye

Waves are very uniform and will happily travel in straight lines forever. Unfortunately for them, there are lots of things that get in their way and when something does, it causes the waves to spread out. This is called diffraction.

When a wave meets an obstacle, it wraps itself around it, so even though it doesn't change speed it does change direction. Waves that have had to negotiate an obstacle tend to fan out, like expanding ripples on a pond.

Diffraction explains how you are able to hear things despite not being in a direct line with the source. Someone standing around the corner from you can utter a sound, which travels along in a wave. As it reaches the edge of the wall, it's able to spread out, which is how you can hear around corners even though you can't see around them.



What is pressure?

Find out how this powerful force is measured

Pressure is an invisible force that is always acting on us, even if we can't feel it. That is because all matter, regardless of its size, has mass.

Pressure is measured by dividing the amount of force exerted by an object by the area of that object. Force is measured in Newtons and is worked out by calculating the object's mass multiplied by acceleration.

An object with force of ten Newtons and an area of ten square metres (107.6 square feet), therefore creates one Pascal of pressure. Even something as light as air exerts a force, so right now, the atmosphere around us is exerting pressure on us. Having a weight placed on your head or going underwater increases the pressure on your body simply because the force acting on you is increased.

GYROSCOPE.COM

The **Super Precision Gyroscope** has been designed and built to the highest precision from the very start, made from solid brass with a light-weight aluminium frame. Carefully chosen stainless-steel miniature ball bearings allow it to run smoothly and almost silently. The gyroscope operates at over **12,000 rpm** using the provided **electric motor** and battery pack. The gyroscope comes with a number of attachments allowing numerous configurations to perform scientific, educational or simply mesmerising experiments. The brass disk is machined to **microns precision**, ensuring the disk is incredibly symmetrical and well balanced. The disk is then **computer balanced** to an impressive 250th of a gram accuracy! Thus giving the gyroscope a highly balanced, super smooth feel, longer spin and even quieter operation.

Visit **www.gyroscope.com** for details and to see our other products.

Tel 0845 838 1555

This twin cylinder Stirling engine is superbly made and a delight to watch. A modified scotch yoke links the mechanisms of the two cylinders which is entrancing when in action. The engine can even run from the heat of your hand.

These miniature 3cc V-Twin combustion engines run off butane or propane gas. They are small enough to run on your desk and have an awesome v-twin sound. Just turn the valve and flick the flywheel to get it started.

This Vulcan stove fan is driven using Stirling engine technology using just the heat from a stove. It requires no power source such as batteries or AC power. The fan circulates the stove's warmth quietly, efficiently and inexpensively.

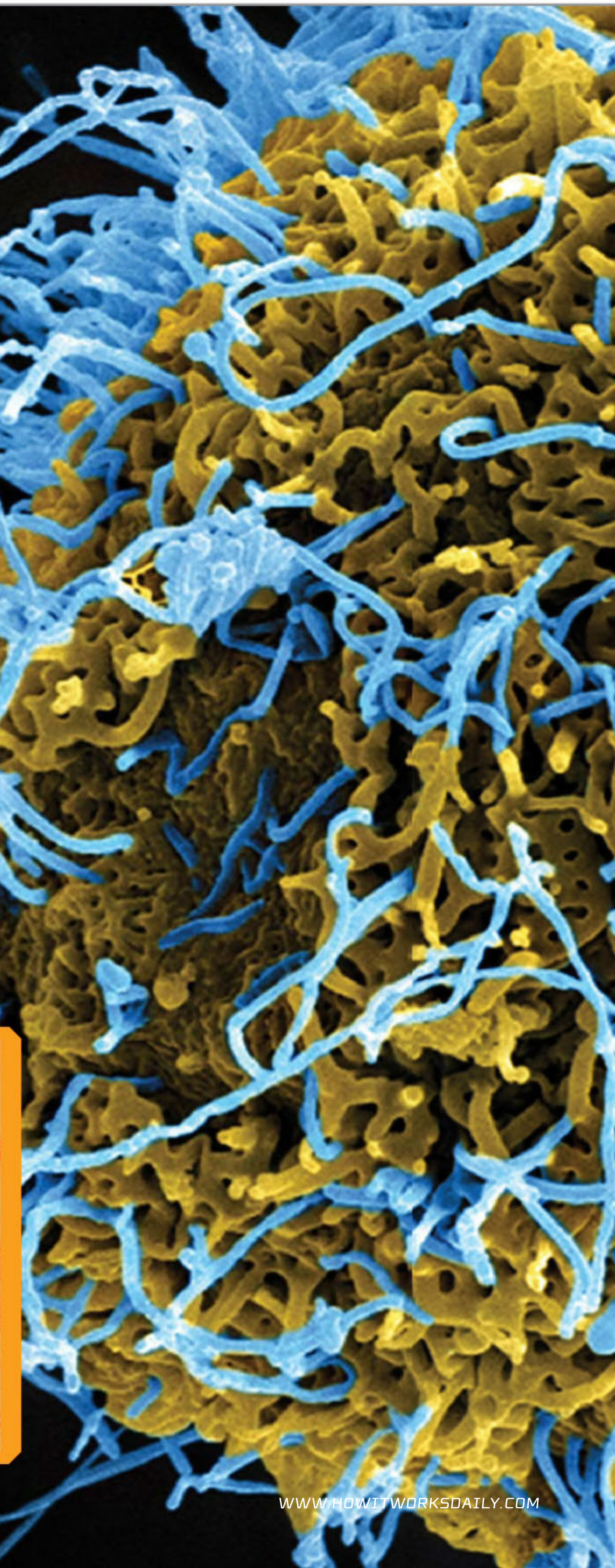
Newly invented, this tractor beam magnet contains a number of magnets in a special arrangement. The special arrangement creates a unique magnetic field that can hold another magnet a fixed distance away.

This is a Hero Steam turbine. Syringe in some water. Fill the burner with methylated spirits and light it. Moments later you have a steam turbine running. Two tiny jets of steam coming out of the side of the brass ball spins it up to 2500rpm.

These are highly polished solid metal flip over tops. They have a chrome like finish and are excellently machined. Simply spin it as normal and watch it suddenly flip over and then continue to spin upside-down.

Ferrofluid is a runny fluid that is magnetic. Hold a magnet to it and watch how it reacts. Some of the shapes you can create are mesmerizing.

"A person with Ebola only becomes infectious once their symptoms start to show"



Ebola virus

Discover how this deadly virus attacks the body and spreads between humans

If you've looked at a newspaper or television in the past couple of months, then it's likely you will have heard of Ebola. The 2014 outbreak in West Africa has caused thousands of deaths across Guinea, Liberia, and Sierra Leone, leaving many people confused and scared about this infectious and often fatal disease.

Ebola virus disease (EVD) is spread via contact with the blood, bodily fluids and organs of an infected person or animal. A person only becomes infectious once their symptoms start to show, which is usually two to 21 days after infection. The initial symptoms are a sudden onset of fever fatigue, muscle pain, headache and sore throat, followed by vomiting, diarrhoea and rashes, eventually leading to impaired kidney and liver function, as well as internal and external bleeding.

There have been many outbreaks since the disease first appeared in 1976, but the most recent has the highest death toll due to it spreading to urban areas instead of being contained in rural villages.

There is currently no licensed treatment for Ebola, but there are potential vaccines currently being developed and tested. However, the chances of survival are significantly improved if the body is quickly rehydrated, buying time for it to fight off infection.

Why is Ebola so deadly?

Instead of being sphere-shaped, like most viruses, the Ebola virus is actually long and thin, giving it a larger surface area for attacking a larger number of cells. The virus is also covered in attachment proteins that bind to the receptor sites of human cells and release the virus's genetic material, allowing it to take over healthy human cells and replicate itself into new copies of the virus. Once it enters the body, it will first aim to disarm the immune system so that the white blood cells can't fight off the virus before it spreads quickly. As a haemorrhagic fever virus, the infected cells release proteins which cause blood to leak out of the vessels. This is what causes the most extreme and often fatal symptoms of Ebola, impaired kidney and liver function, a drop in blood pressure and internal and external bleeding.

The shape and structure of the Ebola virus makes it a particularly virulent one

5 TOP FACTS
EBOLA

First appearance
1 Ebola first appeared in 1976, with two simultaneous outbreaks in Nzara, Sudan, and Yambuku, Democratic Republic of Congo – a village close to the Ebola River, from which the disease takes its name.

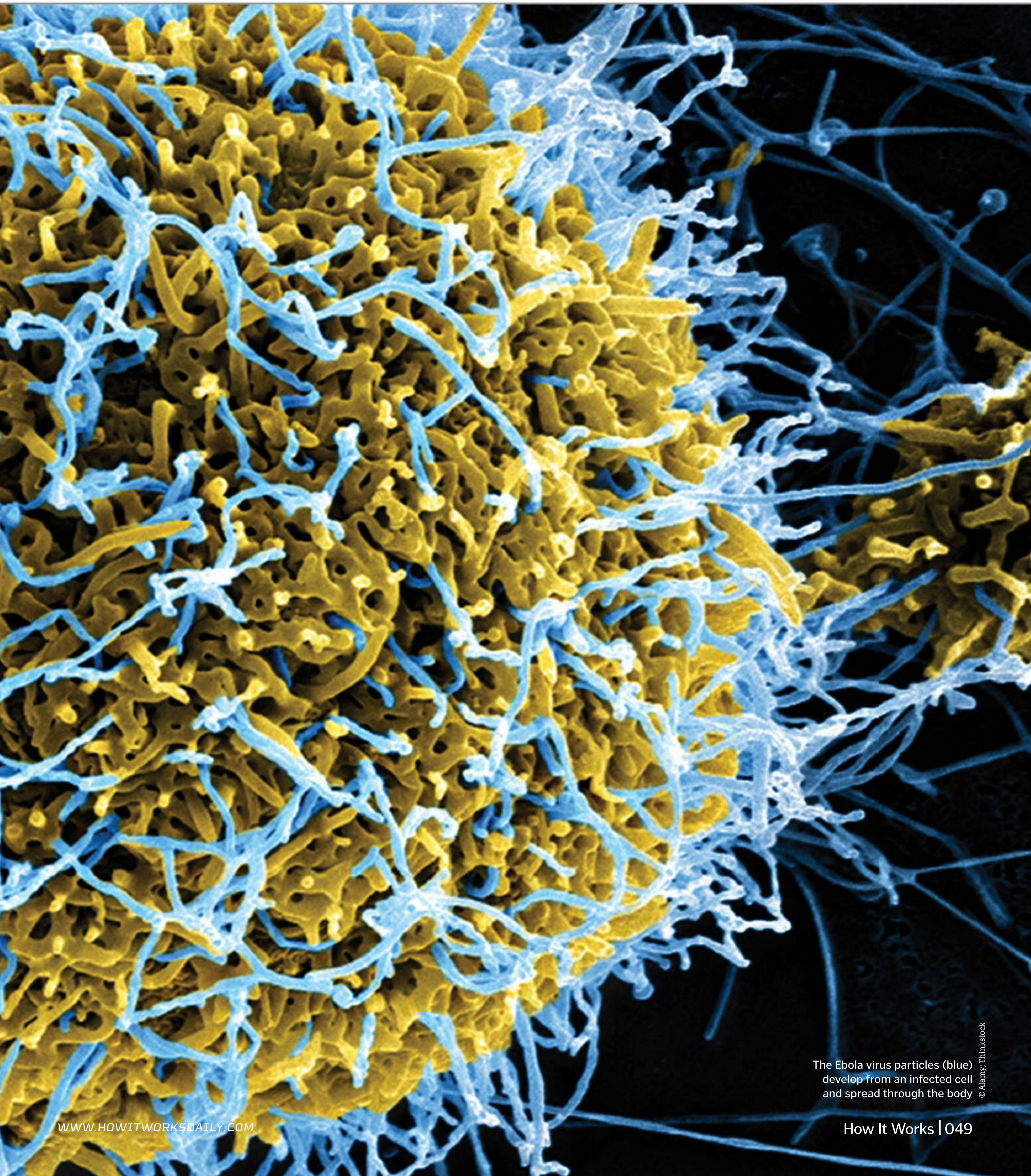
Origin
2 The original hosts of Ebola are thought to be fruit bats that passed it on to humans via contact with their bodily fluids and that of other animals they had infected.

Virus family
3 The Ebola virus is part of the Filoviridae virus family, and there are currently five different species. The one causing the recent outbreak in West Africa belongs to the Zaire species.

Fatality rate
4 Ebola virus disease is fatal in 50 to 90 per cent of cases. However, chances of survival are significantly improved by the giving of oral or intravenous rehydration and the treatment of symptoms.

Contagious after death
5 Traditional African burials are thought to be one reason for the quick spread of Ebola, as mourners often make direct contact with the body of the still-infectious deceased person.

DID YOU KNOW? Men who have recovered from Ebola can still transmit it through their semen seven weeks after recovery



The Ebola virus particles (blue) develop from an infected cell and spread through the body

"Blood clotting is part of a vital process called haemostasis, which your body uses to heal wounds"

Blood clots

Discover how blood clotting has both vital benefits and deadly consequences for the human body

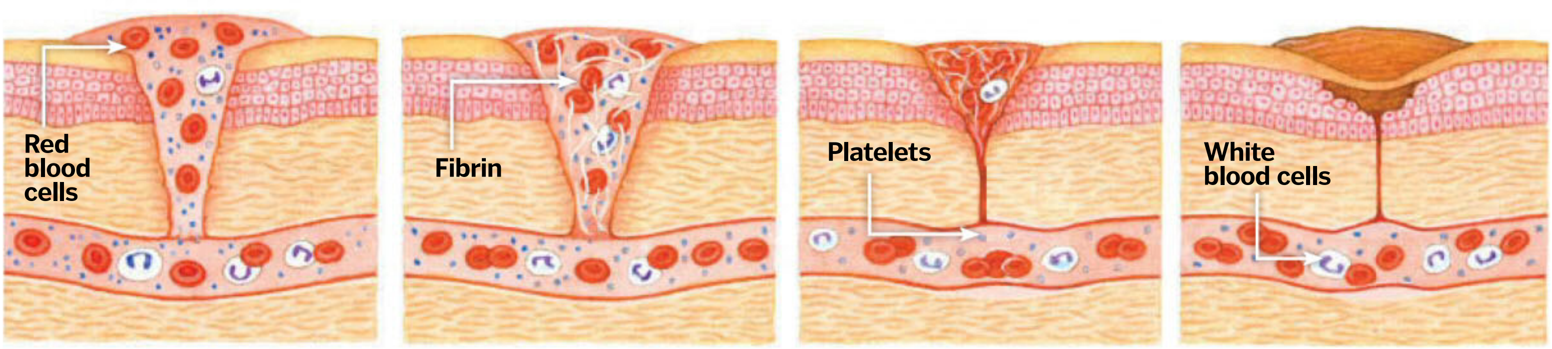
We've all accidentally scraped a knee by falling over or sliced a finger when cooking, but luckily our bodies are extremely resilient and able to patch up wounds. Blood clotting is part of a vital process called haemostasis, which your body uses to stop you bleeding and heal blood vessels. The official medical term for a blood clot is a thrombus and the bodily process that causes that to form is called coagulation.

However, if a blood clot forms inside a blood vessel when it is not needed, it is known as thrombosis and can have serious negative consequences for your health.

Venous thrombosis is the development of a blood clot inside a vein. It often occurs when you have been immobile for an extended period of time, such as on a long-haul flight, causing the blood flow to slow, pool and clot along the walls of the vein, sometimes blocking it entirely. When this occurs in a deep vein, often in the leg, calf or thigh, it is called deep vein thrombosis (DVT). If a clot inside a vein breaks away from its point of origin, it becomes an embolus and travels through the heart to the lungs. Here it can block the pulmonary artery, cutting off blood flow to the lungs and cause a dangerous pulmonary embolism. The best way to prevent VTE is to stay active and healthy to keep your blood circulating.

How cuts heal

Vital blood clotting that stops you bleeding and heals blood vessels



Platelet plug
When the blood vessel's lining breaks, it automatically constricts to slow down blood flow. Platelets in the blood adhere to the damaged area to start plugging the gap.

Chemical attraction
The proteins collagen and thrombin help the platelets stick together while they release other proteins and chemicals to entrap more platelets. This enlarges the plug in a process called platelet aggregation.

Fibrin mesh
Thrombin then converts fibrinogen, a plasma protein, into long sticky threads of fibrin. The fibrin forms a mesh that entangles the platelets and blood cells to form a spongy mass.

Blood clot forms
As the mass gradually hardens it forms a blood clot. Once the blood vessel has healed, an enzyme called plasmin dissolves the fibrin so the body can break down and reabsorb the clot.

Blood clots in arteries

Arterial thrombosis, a blood clot that forms in an artery, is caused by atherosclerosis. This is where fatty substances, known as plaques, clog up an artery and cause it to harden and narrow. As the muscles continue to try and force blood through, pressure can build up and cause the plaque to rupture or burst. A blood clot can then form at the site of the rupture, restricting the blood flow even more or blocking it entirely. This is particularly dangerous as it can cause cardiovascular disease (CVD). For example, if blood flow to the heart is blocked, this can cause a heart attack, and if the blood flow to the brain is blocked, a stroke can occur. You are most at risk from atherosclerosis if you smoke, are overweight or have diabetes, high blood pressure or high cholesterol.

Atherosclerosis (and the resulting cardiovascular diseases) is the single biggest cause of death in the developed world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The new Scooba® 450 Floor Scrubbing Robot cleans hard floors at the touch of a button, removing dirt, grime and up to 99.3% of bacteria. Simply fill the tank, switch on, go out, do anything you want to do. Scooba won't just transform your floors – it will transform the way you live.
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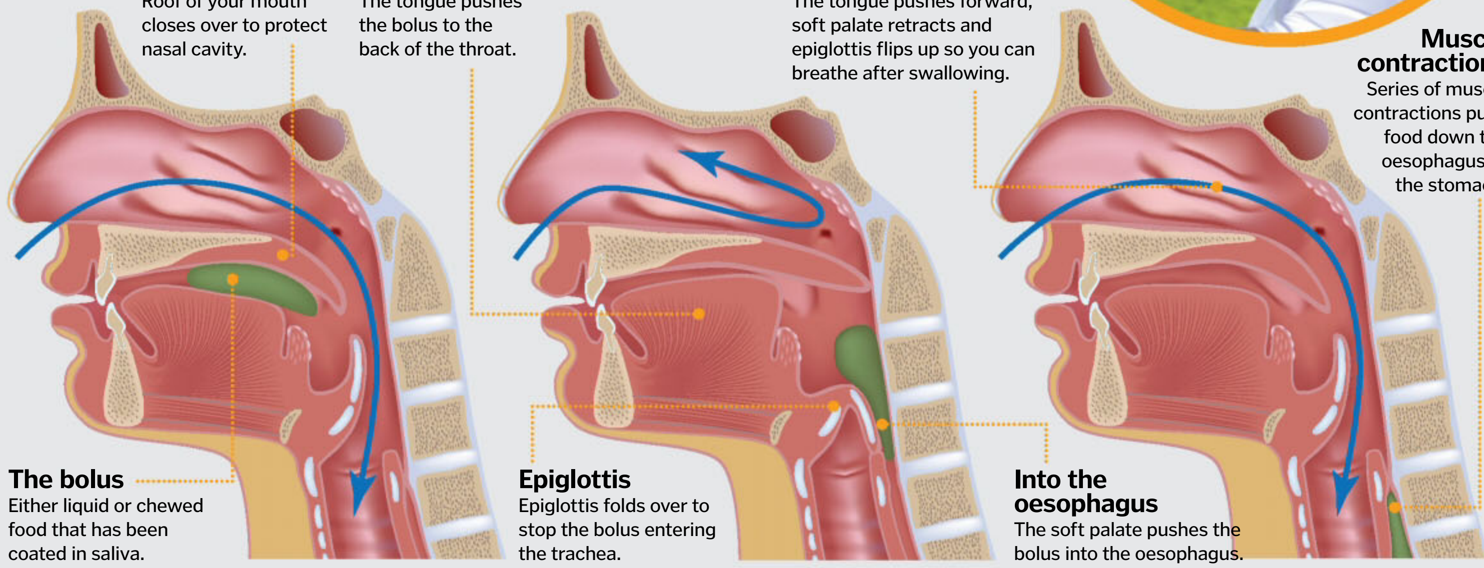
"The needle pushes through the epidermis, the top layer of skin, and deposits a drop of ink"

How we swallow

The process of getting your food from mouth to stomach



Swallowing is a whirlwind of action that all happens in a rapid but controlled order. Your tongue pushes the chewed food (bolus) to the back of your throat and the muscle on the roof of your mouth – your soft palate – pushes the food or drink down into the pharynx. The bolus is prevented from going down the windpipe thanks to the epiglottis, a small flap of skin folding over the larynx. This forces what you are swallowing to head down the oesophagus. All of this happens in less than a second.

However, sometimes things do go wrong. We've all experienced food or drink 'going down the wrong pipe.' This is called pulmonary aspiration and occurs when the epiglottis hasn't covered the trachea in time and the bolus has entered your breathing tube. This uncomfortable sensation generally ends with you coughing and spluttering until it is cleared.

Tattooing

What exactly makes tattoos permanent?

Tattoos are created by injecting ink into skin using an electrically powered needle. Capable of puncturing the skin up to 3,000 times per minute, it only penetrates about a millimetre (0.04 inches) deep. The needle pushes through the epidermis, the top layer of skin, and deposits a drop of ink on the dermis layer just below. The needle moves on, depositing more ink and creating the image. Your body thinks it's under attack and responds by sending infection-fighting white blood cells to the site of the wound. Specialised cells called macrophages try to 'eat' this foreign material, but the ink particles are too large for them to ingest so the tattoo remains in the dermis for all to see.

Tattoos are laid just beneath the top layer of skin

1. SHORTEST

Giraffe
Giraffes require less sleep than any other mammal, typically getting 20-30 minutes per day for five minutes at a time.

2. AVERAGE

Human
The amount of sleep we need varies from person to person, but we typically require about eight hours per night.

3. LONGEST

Koala
Koalas are some of the heaviest sleepers, clocking up approximately 15 hours of snoozing per day.

DID YOU KNOW? *Light affects the sleeping pattern of blind people, as ganglion cells are different from those that allow us to see*

The science of insomnia

Why checking your phone before bed could be spoiling your sleep

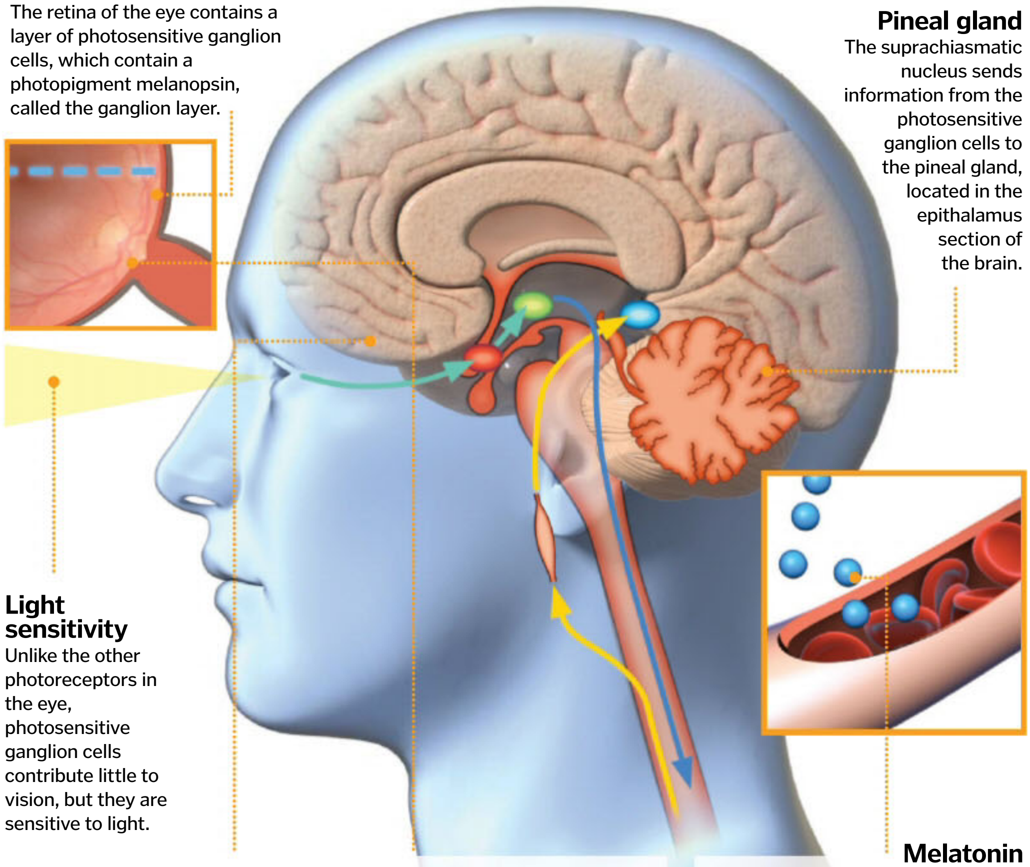
Most of us experience insomnia at some point in our lives, finding it difficult to drift off and stay asleep despite having plenty of opportunity to. Typical causes of insomnia include stress and anxiety, but did you know that your gadgets could be to blame, too?

Our sleepiness and wakefulness throughout the day and night is regulated by our circadian rhythm. This is essentially our body clock, creating physical, mental and behavioural changes that occur in our bodies over a roughly 24-hour cycle. Circadian rhythms are found in most living things, including animals, plants and many tiny microbes, and are created by natural factors in the body. However, they also respond to signals from the environment, such as light, so that we remain in sync with the Earth's rotation.

All forms of light, both natural and artificial, affect our body clock, as when the photosensitive retinal ganglion cells in our eyes detect light, they send this information to the suprachiasmatic nucleus (SCN) – the group of nerves in the brain that controls circadian rhythms. When light is detected, the SCN will delay the production of melatonin, a hormone that sends us to sleep. However, the retinal ganglion cells have been found to be particularly sensitive to the blue light with a short wavelength of 480 nanometres emitted by most computer, smartphone and tablet screens. Exposure to a lot of this type of light in the hours before we go to bed has been proven to suppress melatonin levels, making it difficult for us to get to sleep.

Light sensitivity

How light affects your ability to sleep



The ganglion layer
The retina of the eye contains a layer of photosensitive ganglion cells, which contain a photopigment melanopsin, called the ganglion layer.

Pineal gland
The suprachiasmatic nucleus sends information from the photosensitive ganglion cells to the pineal gland, located in the epithalamus section of the brain.

Light sensitivity
Unlike the other photoreceptors in the eye, photosensitive ganglion cells contribute little to vision, but they are sensitive to light.

Suprachiasmatic nucleus
The suprachiasmatic nucleus is a tiny area of neurons, located in the hypothalamus area of the brain, which controls circadian rhythms.

Optic nerve
The photosensitive ganglion cells have long fibres that connect to the optic nerve and eventually reach the suprachiasmatic nucleus.

Melatonin
When the photosensitive ganglion cells detect darkness, a message is sent to the pineal gland to produce melatonin, a hormone that causes drowsiness.

Blocking blue light

The best way to reduce your exposure to blue light is to avoid staring at a screen in the two hours before you go to bed. Instead illuminate the room with the warmer longer-wavelength light from regular incandescent bulbs or even candles.

However, if you just can't resist staring at your computer or phone before bed, then there are ways that you can do so and still get a good night's sleep. Wearing special glasses with amber-coloured lenses will filter out blue, low-wavelength light, allowing you to stare at your screen for as long as you like. Companies such as Uvex (uvex-safety.co.uk) make blue-blocking glasses and goggles in a range of styles. Alternatively, you could use computer software such as f.lux (justgetflux.com) and smartphone apps such as Twilight (play.google.com) that automatically adjusts your screen to filter out blue light between sunset and sunrise, replacing it with a softer red light.

Filter out blue light with a pair of amber-tinted glasses or by using smartphone apps

CLOUD STORAGE

Your ultimate guide to cloud computing

"The cloud" is a major buzzword in computing right now, but its meaning is rather, well, cloudy for most people. Nevertheless, chances are high that you've already used the cloud, even if you may not have known it at the time. Media sharing services like Flickr, Instagram and YouTube? They use the cloud. Webmail clients like Gmail and Hotmail? Banking apps? Those too. Read on and we'll see if we can't dispel the fog a little...

At its heart, cloud computing involves using the power of the internet to outsource tasks you might traditionally perform on a personal computer – anything from handling simple storage to complex development and processing – to a vast and powerful remote network of interconnected machines.

This outsourcing is handy for the casual user who is fed up of having to free up space on their hard drive or purchase new storage for all the cat/baby/food photos they can't stop taking. It's even better for businesses that want to use the cloud for processing and storage – because users only pay for what they use.

Think about it. Back in the day, companies purchased computing infrastructure based on what they figured they might need now and in the next couple of years. Fearing what would happen if they underestimated demand, they tended to over-buy only to then have the equipment sit around idle. Not only that; business software is expensive. Not to mention the servers, networks, bandwidth, power, cooling, office space, and the experts needed to install, configure and run the whole caboodle.

Cloud computing allows businesses to run essential programs and applications through the Internet, saving them time, space, hassle and lots and lots of money. Billing for cloud services works just like the way you pay for utilities like gas and electricity in your home; it's pay-as-you-go. The cloud is also extremely flexible. For heavy tasks, clients have instant access to scaled-up computing power on the fly. When they're done with it they simply release it back to the cloud.

HEAD2HEAD BIGGEST CLOUD SERVERS

1. BIG

Google Drive
Served 240 million active users as of October 2014; criticised some other services' figures not differentiating between users and active users.

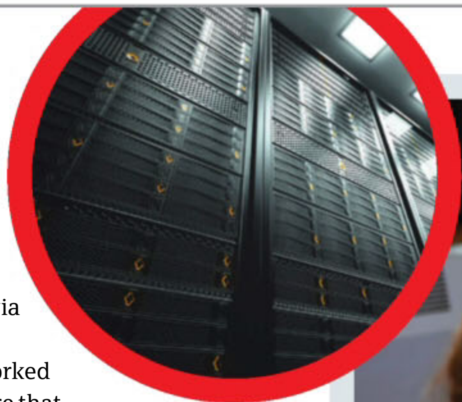
2. BIGGER

Dropbox
Storage cloud service Dropbox added 100 million users in just six months in 2014, bringing the total number of users to about 300 million.

3. BIGGEST

Apple iCloud
Boasting 320 million registered users by midway through 2013, Apple's iCloud service leads the pack in terms of sheer popularity.

DID YOU KNOW? *A new server is added to the cloud for every 600 smartphones or 120 tablets*



What is the cloud?

The first thing you need to know is that "the cloud" exists in far-flung data centres, which you access via the internet. It is a collection of networked computer hardware that works together to provide many aspects of computing in the form of online services. You can't physically touch the hardware itself in the public cloud, but you control it remotely via web interfaces.

One of the central features of the cloud is virtualisation. Virtual machines are created with software that subdivides the computing power, memory and storage of a given machine into multiple smaller units, each running their own operating system. This virtualisation allows computing resources to be shared and allocated efficiently across the cloud.

Cloud computing is a general term that is better divided into three categories: Infrastructure as a Service (IaaS) – where big players like Amazon and Google rent out immense computing infrastructure to other companies; Platform as a Service (PaaS) – online spaces where developers create online applications for specific sets of users; and Software as a Service (SaaS) – where clients use software over the internet.

Even the average web surfer at home has interacted with at least some of these. Facebook, Twitter and Gmail are all examples of SaaS cloud applications. One of the things that make it so powerful is the fact that – in the case of the former two – thousands, even millions, of people can interact with the same bit of information simultaneously.

The other giant boon for individual users is that services like Dropbox and Apple's iCloud allow them to store their photos, email, music, calendars, contacts and other data in a central location, accessible from whatever device happens to be handy. These can be set up to automatically sync with the cloud, ending an era of fumbling with USB cables and cursing yourself for bringing the wrong data stick to a meeting. Relax! That appointment you just noted in your phone will appear seamlessly in your desktop calendar, leaving you free to kick back and enjoy the music you're streaming from your collection on distant servers. ▶

Heavy computer processes are often made faster by the help of the cloud's processing power

450 million
Registered users on Apple's iCloud

Cloud storage vs cloud computing

Cloud storage involves stashing data on hardware in a remote physical location, which can be accessed from any device via the internet. Clients send files to a data server maintained by a cloud provider instead of (or as well as) storing it on their own hard drives. Dropbox, which lets users store and share files, is a good example. Cloud storage systems generally encompass hundreds of data servers linked together by a master control server, but the simplest system might involve just one.

Cloud computing also involves clients connecting to remote computing infrastructure via a network, but this time that infrastructure includes shared processing power, software and other resources. This frees users from having to constantly update and maintain their software and systems, while at the same time allowing them to harness the processing power of a vast network. Familiar everyday services powered by cloud computing include social networks like Facebook, webmail clients like Gmail, and online banking apps.

14 million
Jobs cloud computing will create by 2015

Cloud jargon buster!

1 Server
A computer that processes requests and delivers data to client computers over a local network or the internet. Typically configured with extra processing, memory and storage capacity, it enables clients to share data and resources with others.

2 Data centre
A purpose-built facility that houses cloud infrastructure such as servers, storage systems and networking.

3 Virtualisation
Where individual servers are fooled into thinking they're multiple servers with independent operating systems – a trick that reduces the need for more physical machines.

4 Redundancy
The additional machines built into cloud-computing systems to make back-ups and cover in the event of a failure in the systems' main machines.

5 Elasticity
The characteristic that allows cloud systems to automatically scale up or down the provision of resources to meet current demand.

6 SaaS (Software as a Service)
Software or applications that are accessed over the internet and require no end-user installation. Examples include webmail services like Gmail.

7 PaaS (Platform as a Service)
A tool-rich environment where software developers can create, customise, test and deploy new applications.

8 IaaS (Infrastructure as a Service)
Computing infrastructure such as memory, storage, processing and networking, which users purchase based on consumption instead of having to buy hardware outright. Distinct from physical hosting, where customers purchase a physical server in a data centre.

"Your data may be physically stored in many different places, countries or even continents"

Where's my stuff?

Two words: data centres. Anything you've uploaded to the cloud, or that you run from the cloud, exists on dedicated servers and storage volumes housed in vast warehouses, often situated on campuses full of such warehouses. Data centres are owned by cloud service providers, who are responsible for keeping the servers up and running.

The job of all data centres, however big or small – and yes, some of them can be tiny – is to keep your data physically safe from theft and destruction, and to make sure it's available whenever you want to access it. They run extensive cooling systems to keep the electronics from overheating and have at least one backup generator in case of power outages.

Once you've put your data in the cloud, it may be physically stored in many different places, countries or even continents, depending on where the service provider's data centres are located. In fact, cloud providers actually make multiple copies of the data you upload and purposely store these in disparate locales to ensure that it won't get destroyed or be inaccessible in the event that a natural disaster takes out one of the centres.

The physical location of their stored data is irrelevant to the majority of people, since it can be called together over the internet almost instantly. But for organisations using the cloud for certain sensitive types of data – government documents or health records, for example – understanding where the data is headed and which data-protection and privacy laws apply in those places becomes critical.

How safe is the cloud?

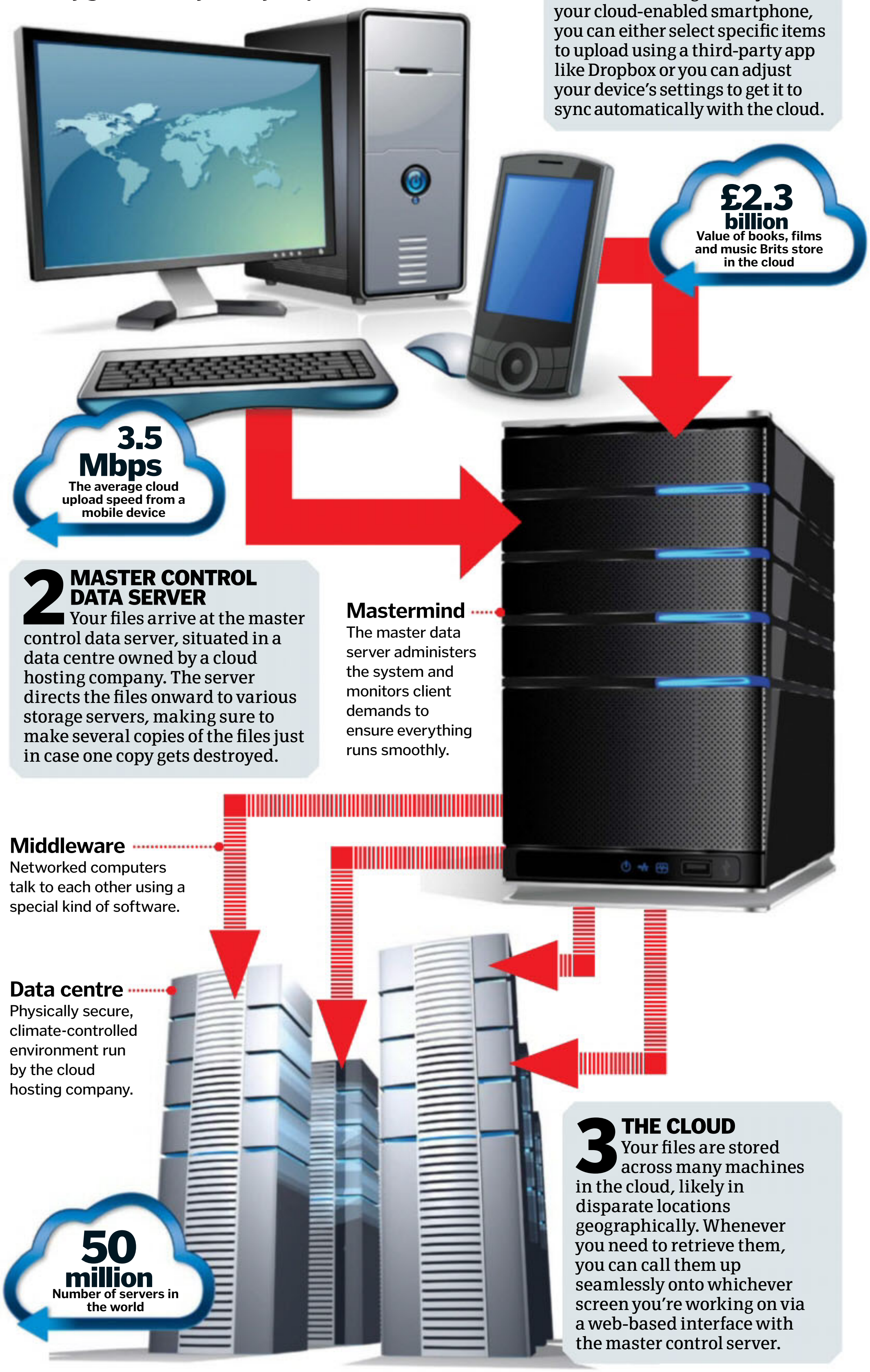
The cloud may promise to lift the burden of our ever-increasing data storage needs, but how do we know our data is truly safe when we entrust it to a cloud provider? What measures do they take to address our two biggest concerns: reliability and security?

We've already learned that cloud providers store backups in multiple locations. Systems that detect smoke, suppress fires and provide emergency power are also standard features of data centres, and these secret locations are heavily reinforced, guarded and internally protected to prevent intruders or disgruntled employees from physically harming or stealing the storage hardware.

To secure your data so no one else can get at it, cloud systems use authentication processes like usernames and passwords to limit access, and

Head in(to) the clouds

Where do your photos, appointments, and music actually go when they leave your phone?



1 DEVICE UPLOAD
Keeping your data backed up, neatly organised and accessible on the go is easy. From your cloud-enabled smartphone, you can either select specific items to upload using a third-party app like Dropbox or you can adjust your device's settings to get it to sync automatically with the cloud.

2 MASTER CONTROL DATA SERVER
Your files arrive at the master control data server, situated in a data centre owned by a cloud hosting company. The server directs the files onward to various storage servers, making sure to make several copies of the files just in case one copy gets destroyed.

Mastermind
The master data server administers the system and monitors client demands to ensure everything runs smoothly.

Middleware
Networked computers talk to each other using a special kind of software.

Data centre
Physically secure, climate-controlled environment run by the cloud hosting company.

3 THE CLOUD
Your files are stored across many machines in the cloud, likely in disparate locations geographically. Whenever you need to retrieve them, you can call them up seamlessly onto whichever screen you're working on via a web-based interface with the master control server.

DID YOU KNOW? *A 2012 survey found 51% of Americans wrongly believe stormy weather can interfere with cloud computing!*

data encryption (see boxout below) to protect data that is stolen or intercepted en route. And yet, passwords can be hacked; often it's the service provider who holds the encryption keys to your data, meaning that rogue employees could access it; and your data isn't immune to search and seizure by government entities.

So, to entrust or not to entrust? In any case, you can rest assured that – since cloud storage companies live and die by their reputation – they take great pains to employ the most advanced security techniques and provide the most reliable service possible. But the bottom line is that we live in an age where national governments have been exposed for tapping into supposedly private cloud data. Savvy surfers would be wise to keep anything truly sensitive stored on their personal computer or private cloud behind a firewall, and never upload it to the public cloud.

1.5 million
Requests Amazon's S3 storage service processes per second

How data encryption works

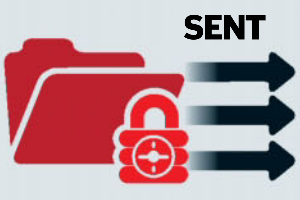
Public-key encryption uses a combination of cryptographic keys to keep your data safe

1 Public-private key pair
Your computer owns two unique cryptographic keys that are mathematically related to each other: one is public, while one is completely private.

2 Key hand-out
It makes your public key freely available to any other computer that wants to send a file to you.

3 Encryption
When someone sends you a file, their computer encrypts it with a symmetric key, meaning it can only be opened with the identical key.

4 Public key encryption
Both the encrypted file and the key needed to decode it are placed in a file and encrypted using the public key.



5 File transfer
The public-key encrypted file is sent to your computer.

6 Decryption step 1
Files encrypted with your public key can only be decrypted by your private key; even if the message is intercepted by another computer that knows your public key, only your computer can decrypt its contents.

7 Extraction
Your computer extracts the encrypted file and the symmetric key needed to decode it.

8 Decryption step 2
The computer decodes the file using the symmetric key.

9 File unlock
Voila! The contents of the file are now yours to view.

How was the iCloud hacked?

On 31 August 2014, a cache of almost 200 personal photos of (mostly female) celebrities – many of them explicit – was posted online. *X-Men* and *Hunger Games* star Jennifer Lawrence and recording artist Rihanna were among those whose private pictures, taken on their iPhones and automatically backed up to the iCloud, were stolen and distributed. Following the attacks, one survey found that 20 per cent of respondents had become less confident in the security of the iCloud, while a further 40 per cent were worried about storing photos and data in any cloud service. How was this security breach allowed to happen?

In an interview in the *Wall Street Journal*, Apple CEO Tim Cook dispelled rumours that the victims' user IDs and passwords were taken from the company's servers in a brute force attack. Instead, he explained, the hackers obtained the information via a combination of phishing emails and correctly answering the celebrities' security questions. "That's not really an engineering thing", he commented, but conceded that Apple should have done more to make users savvier about choosing strong passwords and protecting themselves.

Since the scandal, Apple has beefed up its security measures by expanding its two-factor ID verification system (see "keeping your data safe" boxout left) to include any time a new device attempts to access or download iCloud data. Users will also receive an email alert or push notification whenever someone tries to do these things or change the account password. Apple plans to aggressively encourage iCloud users, the majority of whom still haven't enabled two-factor authentication, to turn on the feature immediately.

Jennifer Lawrence was one of over a hundred female celebrities to have personal photos stolen from their iCloud accounts

Keeping your data safe

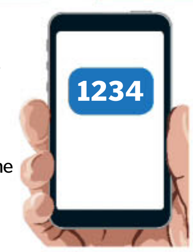
Apple's two-factor verification prevents others from accessing your account, even if they know your password

my.name@icloud.com

••••••••••••••••

Sign in
Whenever you sign into iCloud, or make a purchase in iTunes, iBooks or the App Store, you are asked to enter your Apple ID and password for confirmation.

Added layer
If you're signed up for two-factor, Apple sends a four-digit verification code by SMS or Find My iPhone to one of the trusted personal devices you've registered.



1 2 3 4

Verification
Entering this code into the web browser verifies your identity and completes the sign-in process, allowing you to securely access your account and make purchases as usual.

"A tiny projector shines the data onto the inside of the helmet's visor, in front of the pilot's eyes"

Fighter pilot helmet of the future

BAE Systems' new combat helmet offers night vision without goggles

Fighter aircraft usually have displays built into the windscreen so the pilot can see the information coming from their instruments (speed, altitude, warnings and such) without needing to look down. This might seem a small thing, but if you are in the midst of a dogfight, taking your eyes off your adversary even for a second could be deadly. Rather than using a projector to shine the data onto the windscreen, though, the new Striker II has incorporated the display into the helmet.

A tiny projector shines the data onto the inside of the helmet's visor, directly in front of the pilot's eyes. Not only does this mean the instrument information is always in view but the Striker also uses motion sensors to track where the pilot is looking.

BAE has taken advantage of this display technology to incorporate night vision. Night-vision goggles are already used in fighter aircraft, but they have so far been separate goggles that must be put on when needed. On top of that, they are hefty pieces of kit, which can add to the load on the pilot's neck. Instead, the Striker II has a compact night-vision camera in the top of the helmet. This keeps the weight of the system in line with the head instead of hanging off the front. The night-vision picture is then combined with the helmet display so the pilot does not need to change over to the goggles and when they look around they have a synchronised view of the outside world, whatever the time of day.

Advanced warfare

BAE Systems' business development manager Alan Jowett on the benefits of Striker II

How does it help the pilot to have a display built into the helmet?

As the display is on the visor it is always visible wherever the pilot looks, which reduces pilot fatigue because they don't need to look down at their instruments. That could mean the difference between targeting or being targeted.

What sort of information is provided to the pilot?

The helmet provides the usual cockpit information, such as speed, altitude and heading, but the display is like a computer monitor and can show anything required by the mission, such as controlling the weapons.

How does the integrated night vision help?

The Striker I had separate night-vision goggles. The weight of these put a strain on the pilot's neck during manoeuvres and could catch on the inside of the cockpit. The new system turns on instantly and provides better manoeuvrability both inside and outside the cockpit.

A fighter-pilot helmet is much more than just a safety feature

Head tracking and virtual reality

In linking head movement to the display the Striker II is displaying real pictures, in this case from the night-vision camera, as if they were virtual reality (VR). One of the factors that has held up VR is the ability to update the view fast enough for head movement. If there is too much time lag between the movement and the display changing, it causes nausea and undermines the illusion. VR developer Oculus Rift has been working on just this problem and believes that if it can refresh the display at least every 20 milliseconds it will appear smooth to normal human perception.

Oculus Rift has developed a virtual-reality headset for 3D gaming

5 TOP FACTS
STRIKING VIEW

Multipurpose camera
1 The night-vision camera continues to work in the daytime as a cockpit-recording camera, doing the job of two previous – and larger – cameras.

Bespoke moulded inner
2 The Striker II is tailored to each user; their head is scanned and a bespoke soft inner shell is designed and manufactured specifically to their shape.

High resolution
3 The detailed display projected onto the inside of the visor is equivalent to high-definition TV resolution, so nothing should go unnoticed.

Helmet steering
4 The plane's computer knows where the pilot is looking, which can control other things, like targeting based on the pilot's gaze, instead of where the plane is pointed.

Landscape awareness
5 Any data can be included with the display, so the system can draw in highlights to warn where power cables are, or show the runway position of a fog-covered airfield.

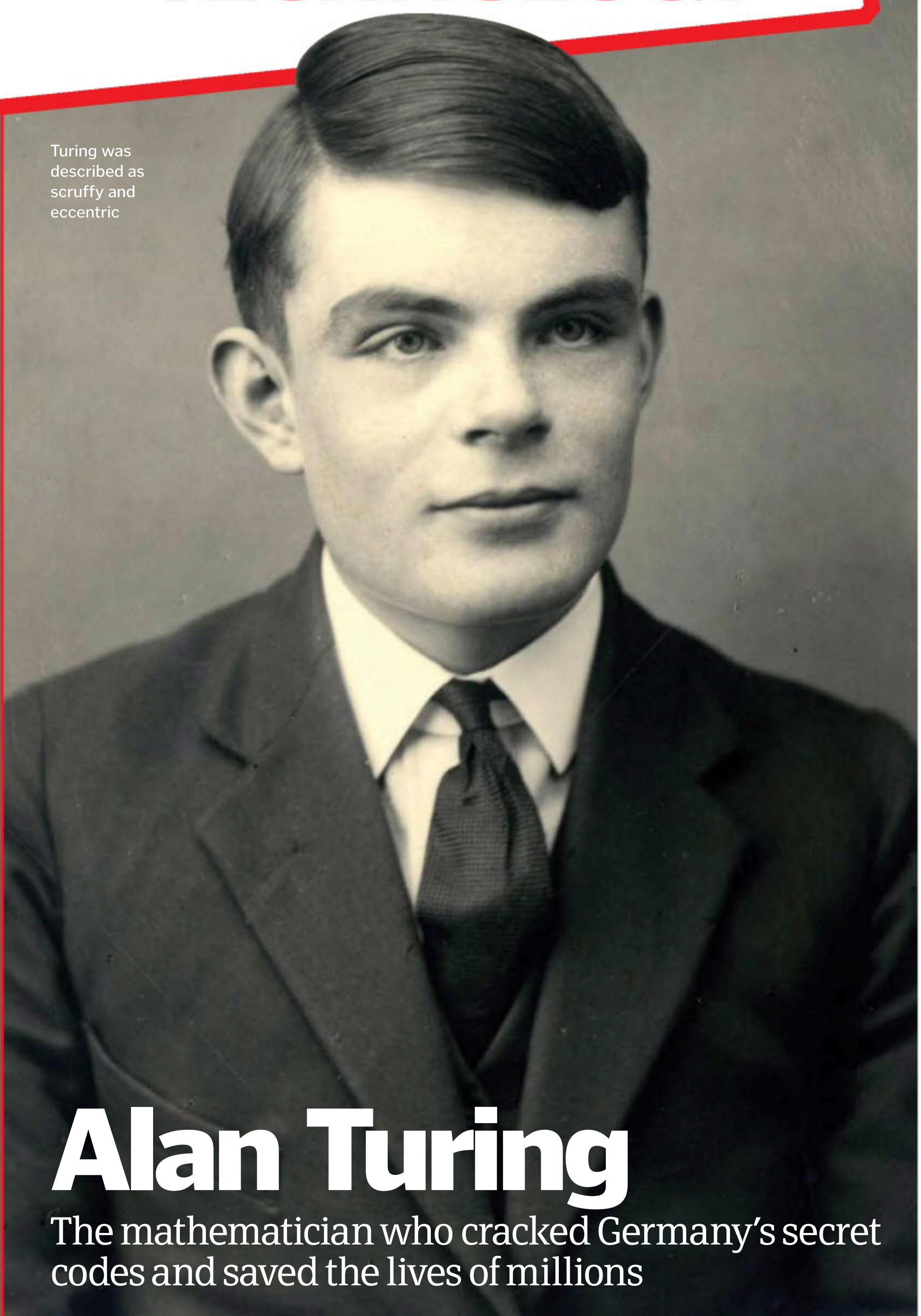
DID YOU KNOW? *Pilots' helmets have to be lightweight as they will feel many times heavier while flying under high g-forces*

Under the skin

A tremendous amount of technology is packed into the Striker II

The Striker II can be used in any military aeroplanes or helicopters

HEROES OF... TECHNOLOGY



Turing was described as scruffy and eccentric

Alan Turing

The mathematician who cracked Germany's secret codes and saved the lives of millions

Code-breaking played a fundamental part in the Allied forces' victory in the Second World War. The Germans had invented an 'Enigma machine', which was used to encrypt secret messages containing important military information, such as the positions of their deadly U-boats. When a message was typed into the machine, it was scrambled into one of nearly 159 quintillion (159 billion billion) possible combinations. To do this, it used an algorithm, or 'key.' The key would be changed every 24 hours, making it extremely difficult for even the most brilliant minds to decipher the messages.

But there was one mind that did succeed, and it belonged to a man named Alan Turing. Born in 1912, Turing had a relatively privileged upbringing, attending a renowned independent school in Dorset, England, before studying mathematics at Cambridge University. He was awarded a first and was elected a fellow, and in 1936 he came up with the idea for a programmable computer known as a 'Turing machine.' With it, he proved that any mathematical problem could be solved, as long as it was representable as an algorithm. Many argue this machine was the model for all modern computers.

Turing then began working part-time for the Government Code and Cypher School. On the outbreak of the Second World War, Turing was given secret orders to report to Bletchley Park, an ageing mansion in Buckinghamshire. Little did he know it was to become the centre for British war intelligence.

Building on Polish research into the Enigma code, he and mathematician Gordon Welchman developed an electromechanical machine called

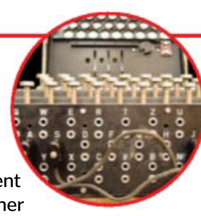
"He proved that any mathematical problem could be solved, as long as it was representable as an algorithm"

A life's work

The highs and lows of Alan Turing's remarkable life and career

1912
Turing is born in London to Julius and Ethel Turing, while Julius is on leave from the Indian Civil Service.

1931
Turing is accepted into Cambridge University to study mathematics and graduates with a First three years later.



1938
The Government Code and Cypher School employ Turing part-time to work on cryptanalysis of the Enigma code.

1939
War breaks out and Turing is posted to Bletchley Park, the central site for British intelligence.

The Bombe

Many of the messages encrypted by the Germans contained a short piece of predictable text, such as 'Heil Hitler.' When cryptographers at Bletchley Park thought they had found some of this text, they would analyse it to produce a 'menu' – a graph consisting of letters linked up like a London Underground map. This would then be passed onto a Bombe operator, who would wire up the letters on the machine according to the menu. The Bombe was then set running, and ever so often it would stop and the operator would write down the possible password, or 'key', it had found. This was then tested to find out if it was the correct one.


The bombe's rotating drums mirrored the rotating discs on the Enigma machine


A statue of Turing made entirely of slate still stands at Bletchley Park

a 'Bombe.' Though the Poles had succeeded in reading Enigma messages on the simplest key systems, this machine allowed any message to be deciphered, so long as the hardware of the Enigma was known and a plain-text 'crib' of about 20 letters could be guessed correctly. It is believed that Turing's work shortened the war in Europe by at least two years.

After the war, Turing worked on the design for an Automatic Computing Engine (ACE), which performed its first program in 1950. He also wrote a chess program, in which the computer took about half an hour to make each move. However, his work was interrupted in 1952, when he was charged with gross indecency for having a sexual relationship with a man. Turing pleaded guilty, but rather than face prison, he agreed to undergo hormonal treatment. If that were not punishment enough, he was also banned from continuing his work for the government. Two years later, he took his own life. In 2013, Turing was granted a pardon under the Royal Prerogative of Mercy after a campaign supported by thousands, including Professor Stephen Hawking.

Top 5 facts: Alan Turing

1 He was a talented distance runner

Turing was a keen sportsman, and his best marathon time of two hours and 46 minutes was only 11 minutes slower than the time clocked by the winner in the 1948 Olympic Games.

2 He was an eccentric

Scruffy and nail-bitten, Turing was renowned at Bletchley for being an eccentric; he chained his coffee mug to the radiator so that no one else could use it!

3 He proposed to a Bletchley co-worker

In 1941, Turing proposed to Hut 8 coworker Joan Clarke, but ended the engagement after admitting he was homosexual.

4 He was an unsung hero

Even after the war, the British authorities couldn't reveal they had cracked the Enigma code, so his work was unknown to the public until decades after his death.

5 He received a government apology

In 2009, British Prime Minister Gordon Brown issued an official apology for his prosecution, saying "you deserved so much better."

In their footsteps...

Genevieve Feinstein

Feinstein was an American Signal Intelligence Service cryptanalyst, involved in the decryption of Japanese messages sent during WWII. In 1940, she made a discovery that enabled the SIS to build an analogue decipher machine. Following the war, she worked on a US project called 'Venona', decrypting information sent by Soviet Union intelligence agencies.

Clifford Cocks

A British cryptographer, he discovered one of the first public-key cryptosystems, known as RSA. It can encrypt messages, which can then be deciphered by the receiver without either party requiring secret keys. Developing it in 1973, he kept the information secret. It was rediscovered and published by three American mathematicians, who named RSA after themselves.

1940
The first code-breaking 'Bombe' machine is installed at Bletchley Park.

1942
Turing travels to the USA to work on the Naval Enigma and Bombe construction in Washington.

1945
Turing is awarded an OBE for his contribution to the war effort, but his work remains secret for many years.

1948
Appointed Reader in the Mathematics department at the University of Manchester, he begins writing a chess computer program.

1952
Turing pleads guilty to gross indecency for having a sexual relationship with a man and begins hormone treatment.

1954
Turing commits suicide by cyanide poisoning, aged 41.

DID YOU KNOW? *As of 5 November, there have been only seven reported fatal shark attacks in 2014, four in Australia*

Solar-powered cooking

How we can harness the Sun to get our sausages sizzling

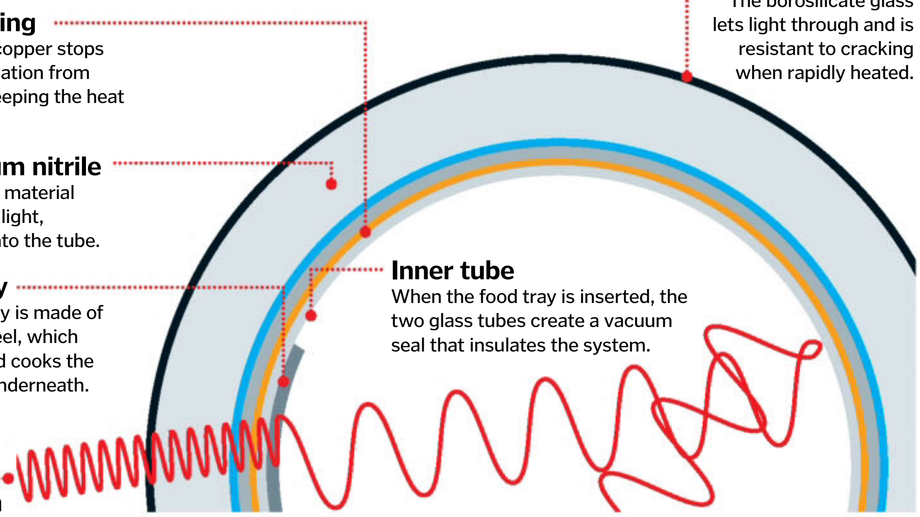
A new stove has been invented that uses an evacuated tube to cook food using solar energy. The evacuated tube on the GoSun Stove consists of two heat-resistant borosilicate glass cylinders, which create a vacuum seal when the cooking tray is inserted. Around the inner cylinder is an aluminium nitrile ring that catches and absorbs sunlight and a copper ring that prevents infrared radiation from escaping. This aluminium nitrile draws over 80 per cent of sunlight in and the copper keeps it there even after the Sun has set.

The highly reflective aluminium housing makes the system even more efficient. When fully opened, the curved surface deflects light onto the evacuated tube.

The chef loads up the stainless-steel semicircular tray with food and slots it into the 0.6-metre (two-foot)-long tube, which the inventors say is big enough to hold 12 standard hot dogs and can cook four of them in a quick ten minutes.

Inside the GoSun

How does this fuel-free stove cook food so efficiently?



Sharkstopper

An amazing tech to prevent shark attacks

An ankle bracelet has been developed that uses whale noises to ward off sharks. Sharkstopper emits the call of killer whales on specific frequencies of less than 500 hertz, which sharks are very responsive to. The call scares the sharks away as killer whales are one of two creatures in the world that are known to hunt and kill sharks, the other being humans.

This audio assault keeps swimmers safe but doesn't harm the shark or the wearer in any way. It can also be used on buoys to keep sharks away from a particular area or fishing boats to stop them getting tangled in nets. The ten-centimetre (four-inch)-long device weighs the same as a smartphone and uses a water-activated sensor to start emitting sounds. The battery lasts for seven hours and vibrates when it needs to be recharged via USB. Sharkstopper has already been proven to repel hammerhead, bull, tiger and great white sharks among others.

The Sharkstopper sends out whale sounds on a specially tested frequency to repel sharks

All about the Moon

It took a walk on the Moon to reveal our natural satellite's many secrets

"One small step for a man, one giant leap for mankind", said the ghostly black-and-white shape of a man on live TV, broadcast to the whole world. This wasn't any ordinary man, though, and this wasn't an ordinary television broadcast, which had household upon household across the globe glued to their screens.

This was the summer of 1969 and Neil Armstrong had put spacesuit boot to soft, powdery lunar soil in a feat that had never been achieved before by anyone: he was the very first man to walk on the Moon. You might remember the Apollo 11 mission when it happened, or maybe you weren't even born, but you've managed to piece together what a momentous day it was for space exploration from newspaper cuttings, books or even from a story recounted by your relatives. Armstrong's bootprint signalled a historic change in how we see the Moon.

All throughout human history the Moon had been just a bright disc in the sky, its shape changing with a monthly regularity as different parts of it are illuminated by the Sun as it orbits Earth. Then, with the beginning of the Space Race between the USA and the Soviet Union, the Moon became a target to be reached, first by robotic probes and then by human beings. It transformed from a silvery disc into a real world, one that we have since come to understand better in part thanks to the astronauts who bravely travelled the 384,400 kilometres (238,855 miles) to its heavily cratered surface. ▶

Lunar maria
These large, dark areas, mostly on the lunar near side, are vast areas of frozen lava that filled giant impact basins billions of years ago.

Craters
The Moon is covered in craters. Most date back to 4.1-3.8 billion years ago. The largest craters are the basins that form the maria.

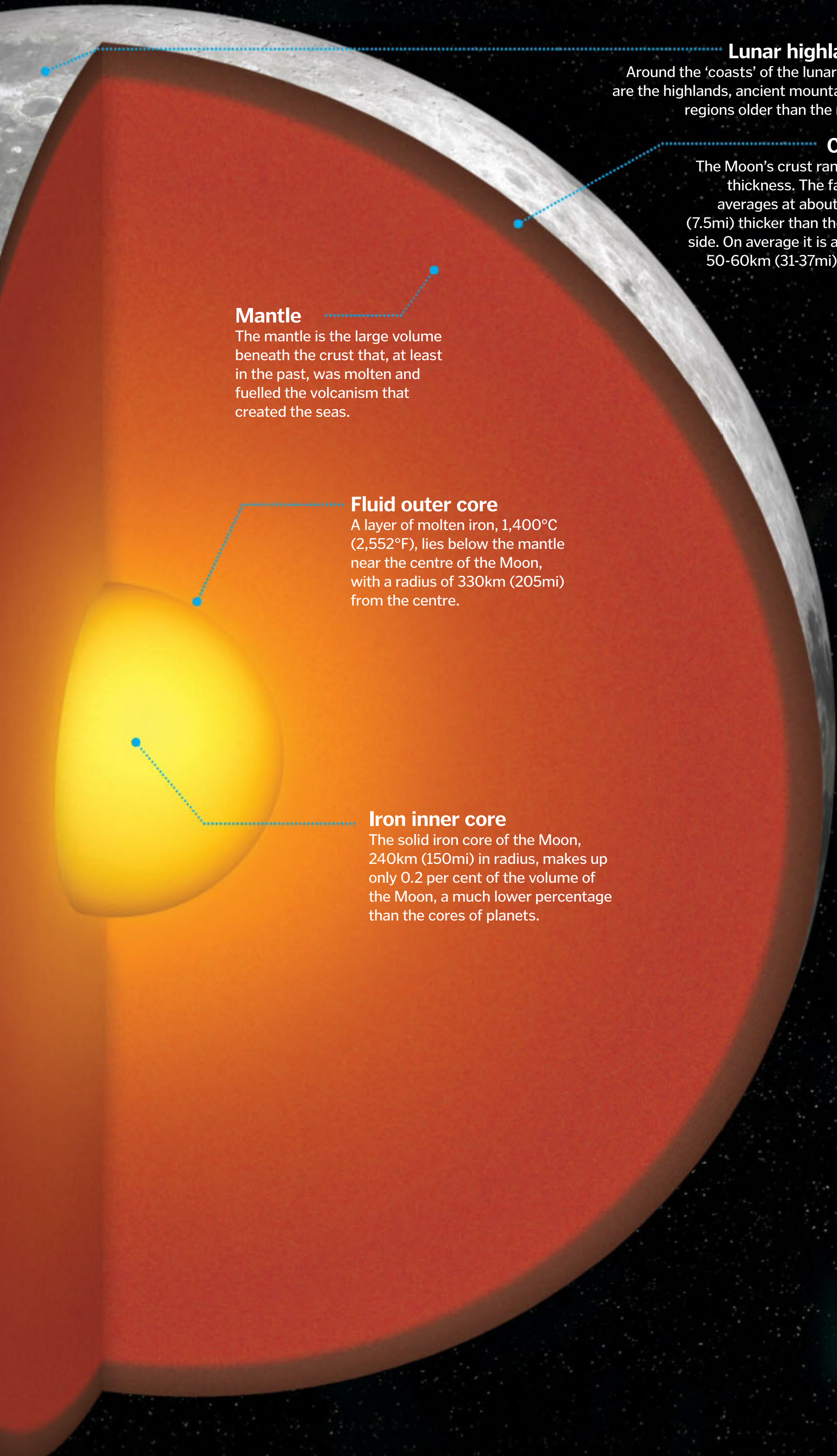
How craters are carved

Craters are the scars of impacts by comets and asteroids. Most of the craters on the Moon were formed during the Late Heavy Bombardment of 4.1-3.8 billion years ago, when an influx of asteroids invaded the inner Solar System. Craters can be dozens to hundreds of kilometres across, sport central peaks or mountains, and splash debris across the surface.

THE STATS
THE MOON

3,475km DIAMETER
LENGTH OF DAY 27.3 Earth days
MASS 7.35×10^{22}kg
SURFACE AREA 37.9mn km²
GRAVITY 1/6th Earth's gravity
TEMPERATURE -233°C to 123°C

DID YOU KNOW? *There is no such thing as the 'dark side of the Moon' – both sides of the Moon get equal amounts of sunlight*



Making of the Moon

1 In for the kill
Around 4.4 billion years ago, a Mars-sized protoplanet called Theia is thought to have struck a young Earth at speed of 4km/s (2.5mi/s).

2 A planetary mix-up
The collision happened with such force that Theia's iron core sunk into the Earth, while the mantles of both planets mixed together.

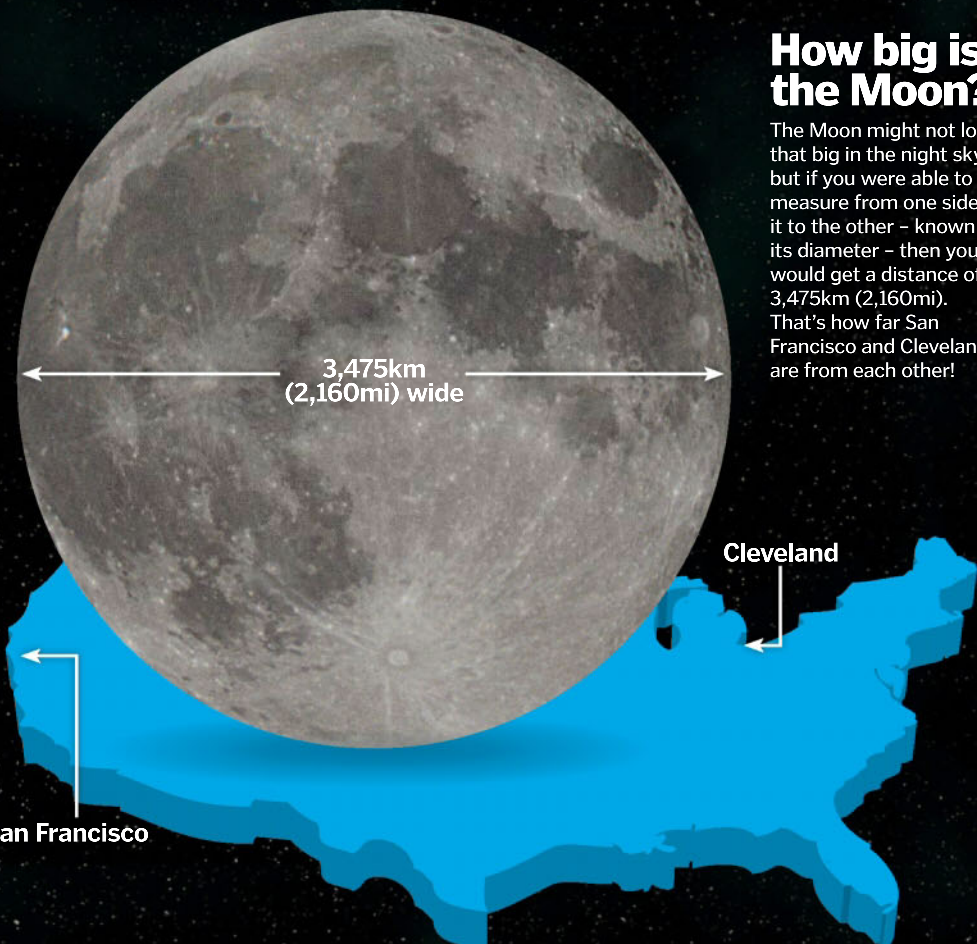
3 The shape of things to come
Not all of the planetary material mixed together, though – some of the mantle was tossed into orbit around Earth. These pieces would later combine to become our Moon.

4 A companion for life
Gravity rounded off the ejected material, leaving behind the bright natural satellite that we see in the sky.

> "Our lunar companion's gravity pulls the large bodies of water toward it, generating two tides per day"

Armstrong, who was Apollo 11's commander, wasn't alone on the lunar surface that day. Fellow astronaut and lunar module pilot Buzz Aldrin followed him down the ladder of their lunar lander, the Eagle, and took in the alien landscape of the Sea of Tranquility. Together, they collected samples of lunar material – dust and rocks – to bring back to Earth for scientists to study and learn more about the nature of the Moon, its history and its origins. Meanwhile, third crew member and command module pilot Michael Collins stayed in lunar orbit above them, waiting for Armstrong and Aldrin to return from the surface for the trip back to Earth.

They, and the other ten astronauts to walk on the Moon after them, left footprints in the lunar dirt that will remain on the Moon for probably as long as the Moon exists. The Moon is airless; there is no wind, no erosion other than the feather touch of tiny micrometeorites that pitter-patter the surface. Scientific instruments left behind on the Moon by the Apollo astronauts have detected the seismic waves of Moonquakes, but overall the Moon today is dead and inactive. Its most active period was three to four billion years ago, when the inner Solar System was bombarded by comets and asteroids. These impacts created most of the craters we see on the Moon, and this bombardment was followed by a period of intense volcanism on the Moon. The dark patches we can see on the Moon – the seas or 'maria' – are huge frozen plains of volcanic lava that filled the largest impact sites. It is the maria that contribute the pattern of facial features of the 'Man in the Moon.'



How big is the Moon?

The Moon might not look that big in the night sky, but if you were able to measure from one side of it to the other – known as its diameter – then you would get a distance of 3,475km (2,160mi). That's how far San Francisco and Cleveland are from each other!

1,600 miles
The diameter of the Moon's largest crater

Harvest Moon
The Full Moon closest to the autumn equinox

12
The number of Moon walkers

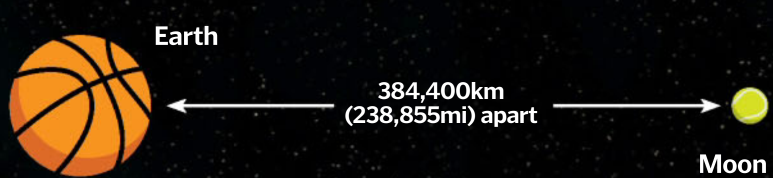
When there are two Full Moons in a month, we call the second one a...
Blue Moon

Percentage of the Moon visible from Earth
59%

382kg
Weight of all the rock samples returned by Apollo

How far is the Moon?

Astronomically speaking, the Moon isn't that far away. An analogy would be if you used a basketball to represent the Earth and a tennis ball to represent the Moon, they would only be 7.3m (24ft) apart!



Gravity explained

Since it's lighter than Earth, our Moon's gravity is lower – that means you can jump higher on the lunar surface!

STRANGE BUT TRUE
TEEING OFF

What did astronaut Alan Shepard send soaring across the Moon?

A Lunar buggy **B** Golf ball **C** A paper aeroplane

Answer:
As commander of Apollo 14, Shepard took a golf club (actually a six-iron head attached to a lunar sample scoop handle) and ball with him to the Moon. In a demonstration of how low the gravity is on the Moon, Shepard hit the golf ball "miles and miles and miles."

DID YOU KNOW? *The Moon is moving away from Earth by 3.8cm (1.5in) a year. It was 22,530km (14,000mi) away when it formed*

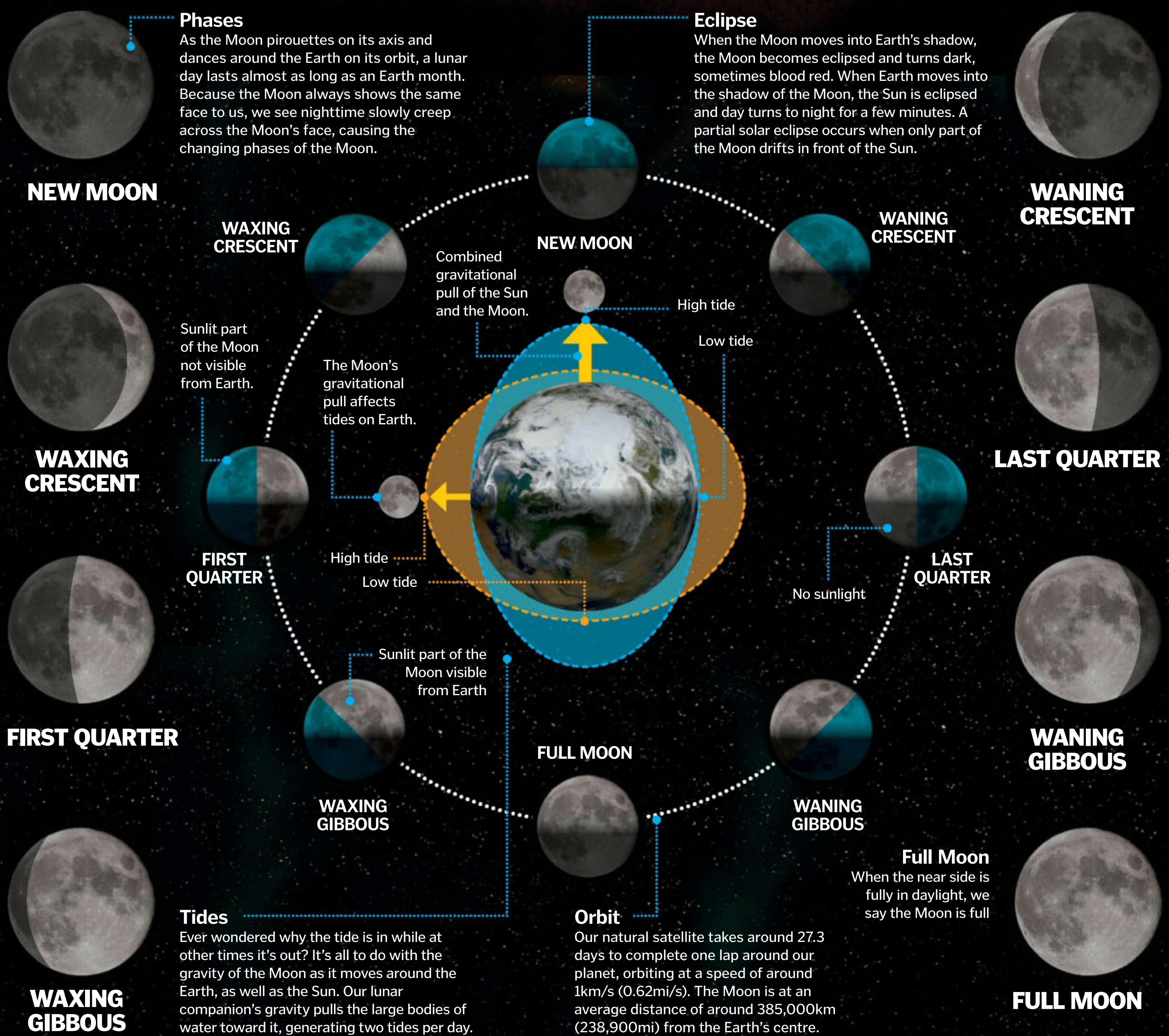
Phases of the Moon

Our companion in space, the Moon plays an important part in some interesting phenomena

New Moon
When the near side is completely in night time, with the far side in day time, we call it a New Moon

Phases
As the Moon pirouettes on its axis and dances around the Earth on its orbit, a lunar day lasts almost as long as an Earth month. Because the Moon always shows the same face to us, we see nighttime slowly creep across the Moon's face, causing the changing phases of the Moon.

Eclipse
When the Moon moves into Earth's shadow, the Moon becomes eclipsed and turns dark, sometimes blood red. When Earth moves into the shadow of the Moon, the Sun is eclipsed and day turns to night for a few minutes. A partial solar eclipse occurs when only part of the Moon drifts in front of the Sun.



Full Moon
When the near side is fully in daylight, we say the Moon is full

Tides
Ever wondered why the tide is in while at other times it's out? It's all to do with the gravity of the Moon as it moves around the Earth, as well as the Sun. Our lunar companion's gravity pulls the large bodies of water toward it, generating two tides per day.

Orbit
Our natural satellite takes around 27.3 days to complete one lap around our planet, orbiting at a speed of around 1km/s (0.62mi/s). The Moon is at an average distance of around 385,000km (238,900mi) from the Earth's centre.

"The last astronaut to walk on the Moon, Gene Cernan of Apollo 17, did so in 1972"

Once upon a time, the lunar seas were thought to be seas of water by early astronomers. In reality the Moon is bone dry – the lunar rock samples brought back by the Apollo missions have been analysed over and over again and have been found to contain barely any water molecules at all, containing just a few parts per million. However, while there may not be much water inside the Moon – a result of the way the Moon formed from the debris of a giant impact on Earth – in deeply shadowed regions at the poles of the Moon, on crater floors where no sunlight ever reaches, large quantities of water-ice lurk. This ice has been brought to the Moon by comets and asteroids that have crashed into it, and we discovered this by crashing our own impactor into the lunar surface.

A NASA spacecraft, called LCROSS, the Lunar Crater Observation and Sensing Satellite, found water-ice inside a crater at the lunar south pole called Cabeus. The upper stage of the rocket that launched LCROSS crashed into the crater ahead of LCROSS, allowing the NASA probe to measure the amount of water in the debris plume from the impact. Then India's Chandrayaan-1 satellite, orbiting the Moon, discovered an estimated 600 million tons of water-ice in permanently shadowed craters at the lunar north pole. The poles would be ideal places to locate future human bases: the water could be used for drinking, but also broken apart into oxygen atoms for breathing and hydrogen for rocket fuel.

Unfortunately, there is no sign we'll be going back to the Moon soon. The last astronaut to walk on the Moon, Gene Cernan of Apollo 17, did so in 1972. Since then there have been many plans to return, but each time they have been cancelled. NASA are currently building the Space Launch System, featuring the most powerful rocket since the Saturn V took the Apollo mission to the Moon, which could feasibly one day return humans to our nearest neighbour. The Chinese are also showing an interest in making a flight to the Moon. Whenever we go back, it may be for good, and when we do, it will fully transform the Moon into a new home away from home.

Far side

This is the side of the Moon we can't see without taking a mission to the Moon. You might be surprised to learn that it looks different to the near side.

18 per cent visibility

Since the Earth undergoes libration – in other words it oscillates in its orbit – then we catch a glimpse of 18 per cent of its far side.

Thinner crust

The near side of the Moon has a thinner crust than the far side. The Moon's chaotic formation is thought to be responsible for this.

Near side

The near side of the Moon is the face – or hemisphere – that we always see. This is because the Moon and Earth's spins are synchronised.

Unexplored

The far side of the Moon was seen for the first time by the Soviet spacecraft Luna 3 in 1959.

Heavily cratered

The Moon's surface on the far side is covered in many more craters than the near side. It is home to one of the largest craters in the Solar System – the South Pole-Aitken basin.

Large basins

Large lava-filled impact basins, which are also known as lunar seas or lunar maria, are more common on the near side.

Lunar highlands

Lighter-toned regions on the Moon's surface are the Moon's highlands, often referred to as terrae.

Moon exploration history

1959

The third space probe to be sent to the Moon, the Soviet spacecraft Luna 3, was an early attempt at imaging the far side of the Moon.

1968

The second human spaceflight mission to the Moon, Apollo 8, became the first manned spacecraft to enter lunar orbit before safely returning to Earth.

1969

Carrying Americans Neil Armstrong and Buzz Aldrin, Apollo 11 represented "one small step for a man, one giant leap for mankind" when they became the first to step onto the lunar surface. Astronaut Michael Collins piloted the command spacecraft in lunar orbit.

1971

Dubbed as the most successful manned mission of its time, Apollo 15 was the first mission on which the Lunar Roving Vehicle was used. Its astronauts spent three days on the Moon.

AMAZING VIDEO!

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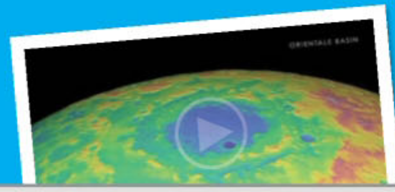
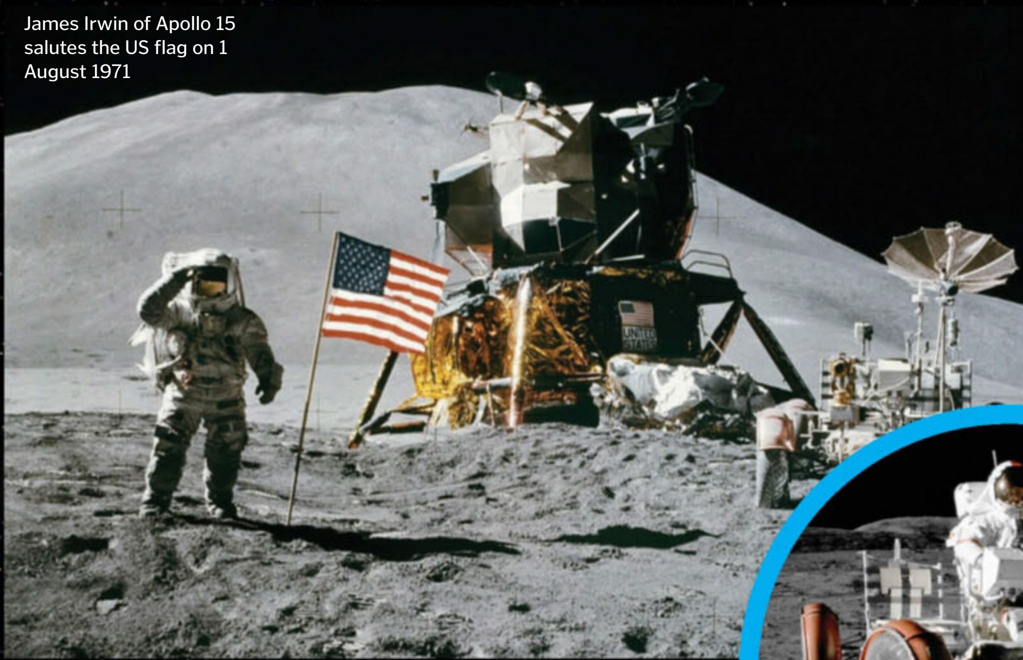


DID YOU KNOW? *The Solar System has four moons larger than Earth's Moon: Jupiter's Ganymede, Io and Callisto, and Saturn's Titan*



James Irwin of Apollo 15 salutes the US flag on 1 August 1971

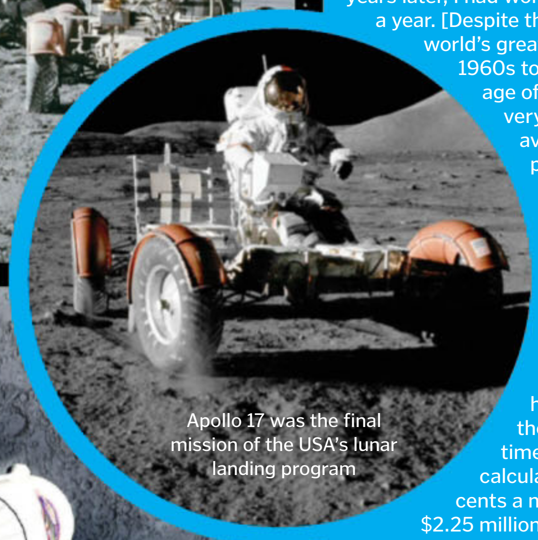
The Lunar Crater Observation and Sensing Satellite (LCROSS) mission found water in the southern lunar crater Cabeus

Moon-walking

A chat with Walt Cunningham, Apollo 7's Lunar Module pilot

Why did you decide to become an astronaut?

(Laughs) I can tell you, it wasn't for the money! My starting salary when I went to work for NASA was $13,050 a year. When I left eight years later, I had worked my way up to $25,000 a year. [Despite the low pay] it was one of the world's greatest jobs and from the 1960s to the 1970s were the golden age of manned spaceflight. It was very much like the 1920s of aviation – we weren't flying planes with silk scarves and training out of a cockpit but you know, we felt like it.



Apollo 17 was the final mission of the USA's lunar landing program

Why was your salary so low?

We weren't covered by NASA's flight insurance due to the high risk. If we had been, the rate would have been too high for all of the employees of NASA. One time, I did sit down and calculate that if I got paid 50 cents a mile, I would have made $2.25 million.

What does NASA look for when selecting their astronauts?

Individuals are hired on experience and qualifications but you must be willing to stick your neck out. We [commander Walter Schirra and Command Module pilot Donn Eisele] didn't shy away from the unknown and we were willing to take a risk. We depended on each other for our lives. Exploration isn't about eliminating risk, it's about managing risk. Future astronauts have the opportunity to accomplish much in the exploration of the Red Planet, Mars. We have the resources and the technology, but it's up to future generations to have the will to tackle this next frontier. This will expand our universe and change the way we all look at our world.

1972

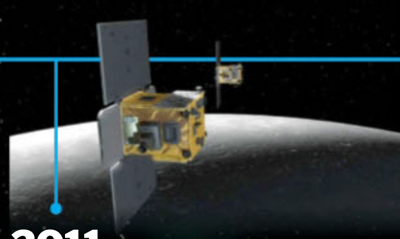
Apollo 17 marked the end of the America's lunar landing program. Being a 'J-type mission', Apollo 17 included a three-day lunar surface stay and a Lunar Roving Vehicle.

2008

India's first lunar probe, Chandrayaan-1, was comprised of a lunar orbiter and impactor. The impactor probe struck the south pole of the Moon.

2009

The Lunar Reconnaissance Orbiter (LRO), which is currently in orbit around the Moon, maps the lunar surface to identify safe landing sites.



2011

Made to crash into the Moon's surface when its mission came to an end in 2012, the Gravity Recovery and Interior Laboratory (GRAIL) was made of two probes that mapped the Moon's gravitational field.

2013

China's Yutu rover, also called Jade Rabbit, marks the first soft landing on the Moon. While it's currently unable to move it is collecting useful data.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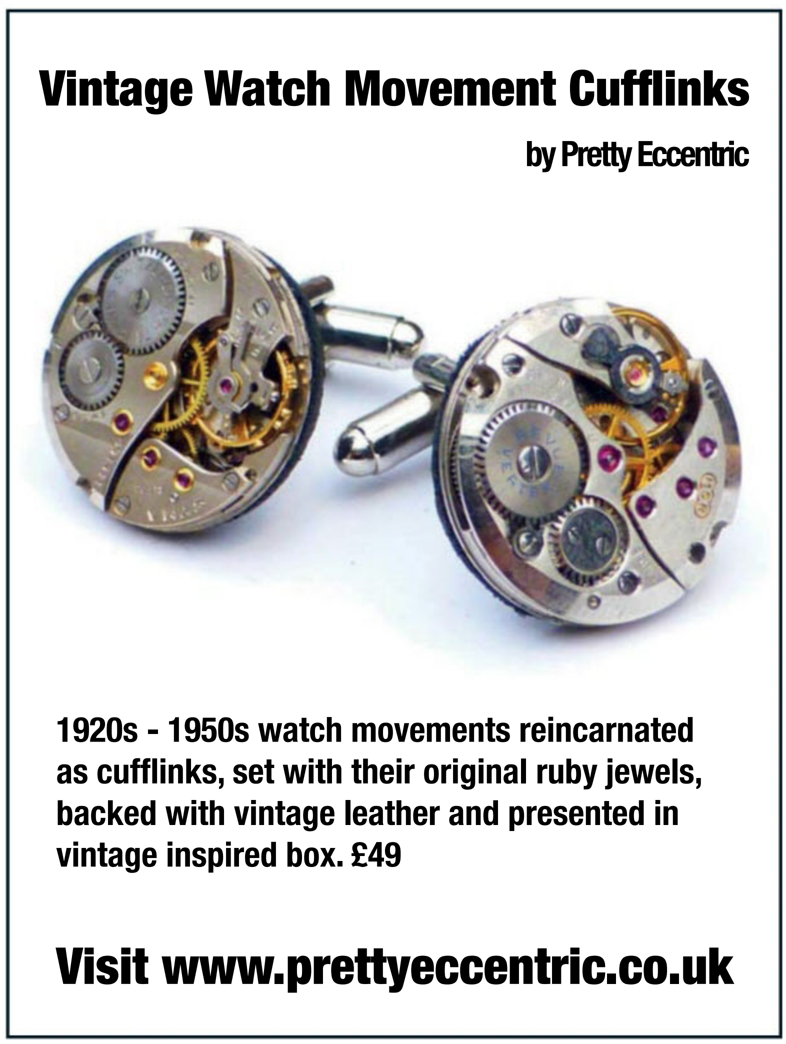
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10 deadliest dinosaurs

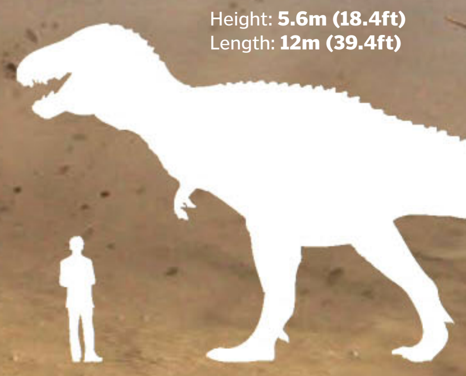
Counting down the fiercest, most terrifying beasts that ever lived

Tyrannosaurus rex

Tyrannosaurus rex ("tie-RAN-a-SORE-uss rex") needs no introduction; its reputation as the ultimate carnivore and most badass dinosaur ever to roam the Earth precedes it. Tyrannosaurus rex (T-rex for short) literally means "tyrant lizard king", and there can be no doubt that it lived up to its name.

Standing over five metres (16.4 feet) tall and 12 metres (39.4 feet) long, and weighing a staggering seven tons (15,400 pounds), T-rex was once thought to have been the largest terrestrial carnivore in history, but subsequent discoveries of fellow titans Carcharodontosaurus, Giganotosaurus and Spinosaurus challenged this. It walked on a pair of powerful hind legs and could run as fast as a professional footballer, but balance issues meant that Giganotosaurus could outrun it. Its brain was twice the size of most other predatory giants, but its intellectual prowess wasn't a patch on that of raptors like Utahraptor. So how does T-rex manage to cling to its crown?

It may not have been the biggest, fastest, heaviest, or smartest, but the king was the ultimate all-rounder. Its extraordinary sense of smell allowed T-rex to track prey over long distances and sniff out abandoned carcasses to scavenge. And then there is its not-so-secret weapon: its phenomenal bite, which was stronger than that of any land animal that ever lived. Its bone-splintering jaws chomped down with a force almost as huge as its own body weight, bringing to bear its 60 saw-edged conical teeth. Other dinosaurs had to close their mouth around prey multiple times to bring it down; T-rex only had to bite once.



5 TOP FACTS
DEADLY ASSETS

Evolution
1 Dinosaurs roamed the Earth for over 160 million years, but our ten deadliest all lived in the last 60 million years of that time frame, most within the final 30 million years.

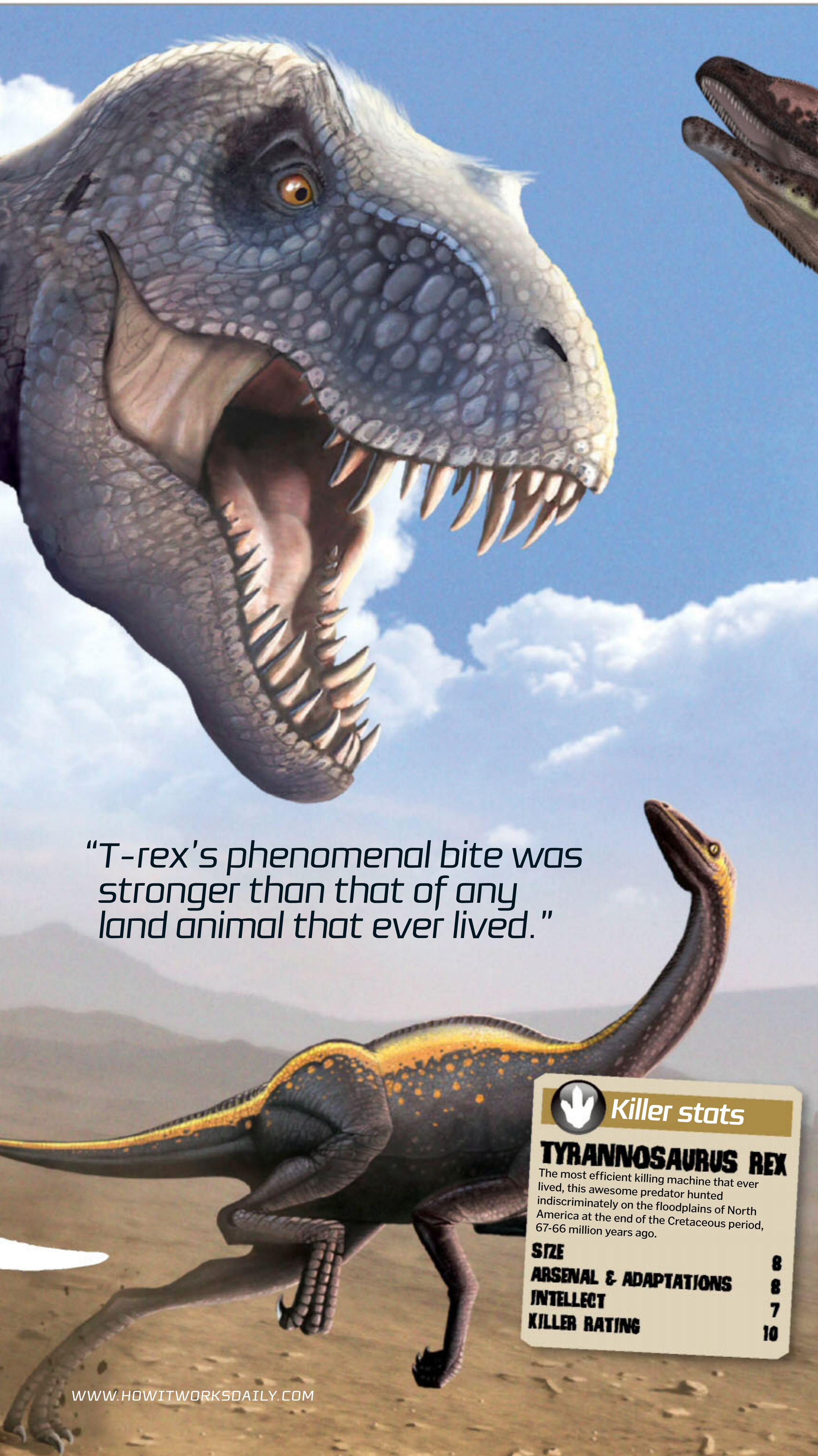
Straight legs
2 Dinosaurs could dominate because their legs were straight and perpendicular to their bodies, rather than in a speed-limiting sprawling stance like today's reptiles.

Bipedal motion
3 Theropods walked upright on a pair of powerful back legs. This allowed them to run with greater speed and agility than their clumsier quadruped prey.

Inward-curving teeth
4 These helped give predatory dinosaurs a good grip on their prey, which prevented it from escaping in a struggle. If a dinosaur lost a tooth in battle, a new one grew to replace it.

Sharp weapons
5 Be it teeth, finger claws or retractable toe claws, every one of our top ten was kitted out with some form of cutters for striking whenever an opportunity arose.

DID YOU KNOW? *Watch out for your crown, T-rex: on average, a new species of dinosaur is discovered every six weeks*



"T-rex's phenomenal bite was stronger than that of any land animal that ever lived."

Killer stats

TYRANNOSAURUS REX

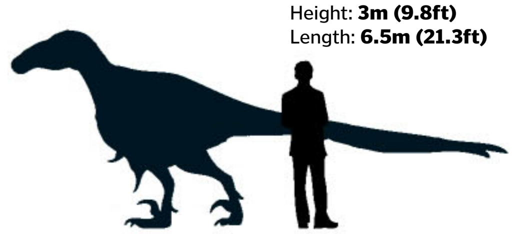
The most efficient killing machine that ever lived, this awesome predator hunted indiscriminately on the floodplains of North America at the end of the Cretaceous period, 67-66 million years ago.

SIZE	8
ARSENAL & ADAPTATIONS	8
INTELLECT	7
KILLER RATING	10

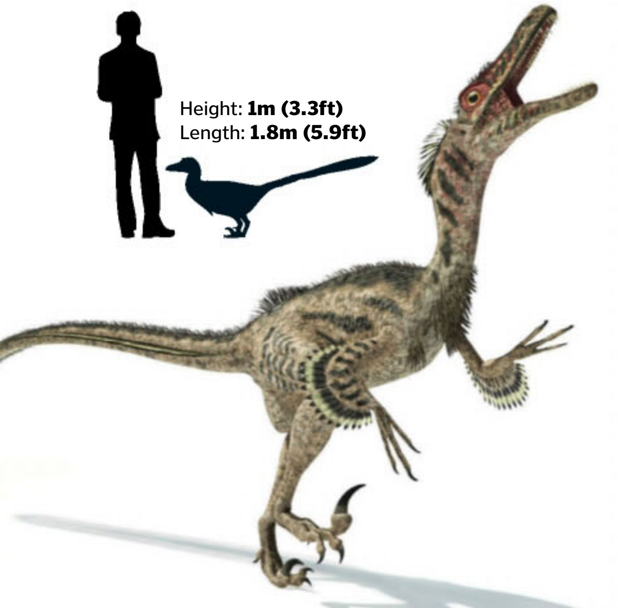
Utahraptor

The mighty Utahraptor ("YOU-tah-RAP-tor") was three times larger and meaner than its cousin, the Velociraptor. Armed with a 30-centimetre (12-inch)-long sickle-shaped claw on each hind foot, it would kick, rip and tear its prey to death. Its leg bones were unusually thick, in order to support the powerful muscles dedicated to repeatedly driving the killing claw into its prey. In keeping with its smaller raptor cousins, it's possible that Utahraptor hunted in packs, like terrible three-metre (9.8-foot)-tall 500-kilogram (1,100-pound) wolves, and targeted prey many times larger than itself.

Height: **3m (9.8ft)**
Length: **6.5m (21.3ft)**

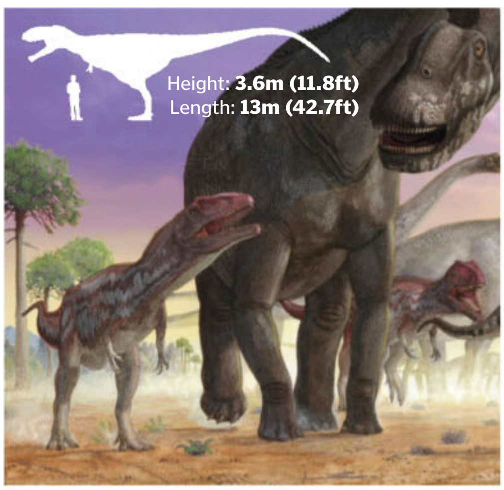


> "A pack of alert and agile Troodons could easily bring down much bigger animals"



Velociraptor

Star of the infamous kitchen scene in *Jurassic Park*, the curious creature with the deadly curved toe claw has been terrorising nightmares for two decades. The film may have overstated their size and stripped them of their feathers, but it did get some things right: Velociraptors ("vel-OSS-e-RAP-tors") were fast and polished predators that oozed agility and intelligence, and may have hunted in packs.



Mapusaurus

A close cousin and look-alike of Giganotosaurus, Mapusaurus ("MAH-puh-SORE-uss") hunted some of the largest dinosaurs that ever lived – the 35-metre (115-foot)-long herbivore Argentinosaurus. Its narrow blade-like teeth were ideal slicing tools, and the discovery of bones from several individuals found in one place has experts speculating that they formed groups or hunted in packs for extra lethality.

Killer stats

TROODON

This diminutive dinosaur used cunning and cooperation to slay supposedly superior beasts in the wilds of North America during the Late Cretaceous Era, 74-65 million years ago.

SIZE	3
ARSENAL & ADAPTATIONS	8
INTELLECT	10
KILLER RATING	8

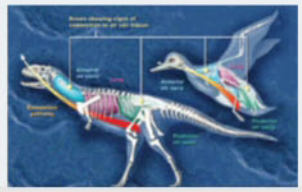
Troodon

Deadliness doesn't always come down to bulk and bite force. Troodon ("TROH-oh-don") – standing just 1.3 metres (4.3 feet) tall and weighing in at 40 kilograms (88 pounds) – was a wily whippet that made up for its lack of brawn with a whole lot of brain. In fact, it had the highest brain-to-body-weight ratio of any known dinosaur. Not only that; reconstructions of its brain have revealed nascent signs of folding – where more neural cells are packed into the same area for more efficient brain functioning – making it the most neurologically advanced specimen too.

The shape of fossilised skull remains suggest it possessed huge orb-like eyes that gave it superior vision – as well as the ability to see in low-lighting conditions and hunt nocturnally – and its slight frame made it extremely fleet of foot. While they may have been dwarfed by many of the behemoths on this list, a pack of alert and agile Troodons hunting as a pack could easily have brought down much bigger animals.

What athletic trait do today's birds share with theropods?

A Efficient breathing **B** Fast two-legged running and hopping **C** The ability to fly



Answer:
A system of air sacs adjacent to the lungs ensured theropods a constant supply of oxygen-rich air – whether breathing out or in. This same adaptation that made theropods tenacious in chase allows modern birds to fly long distances without getting tired.

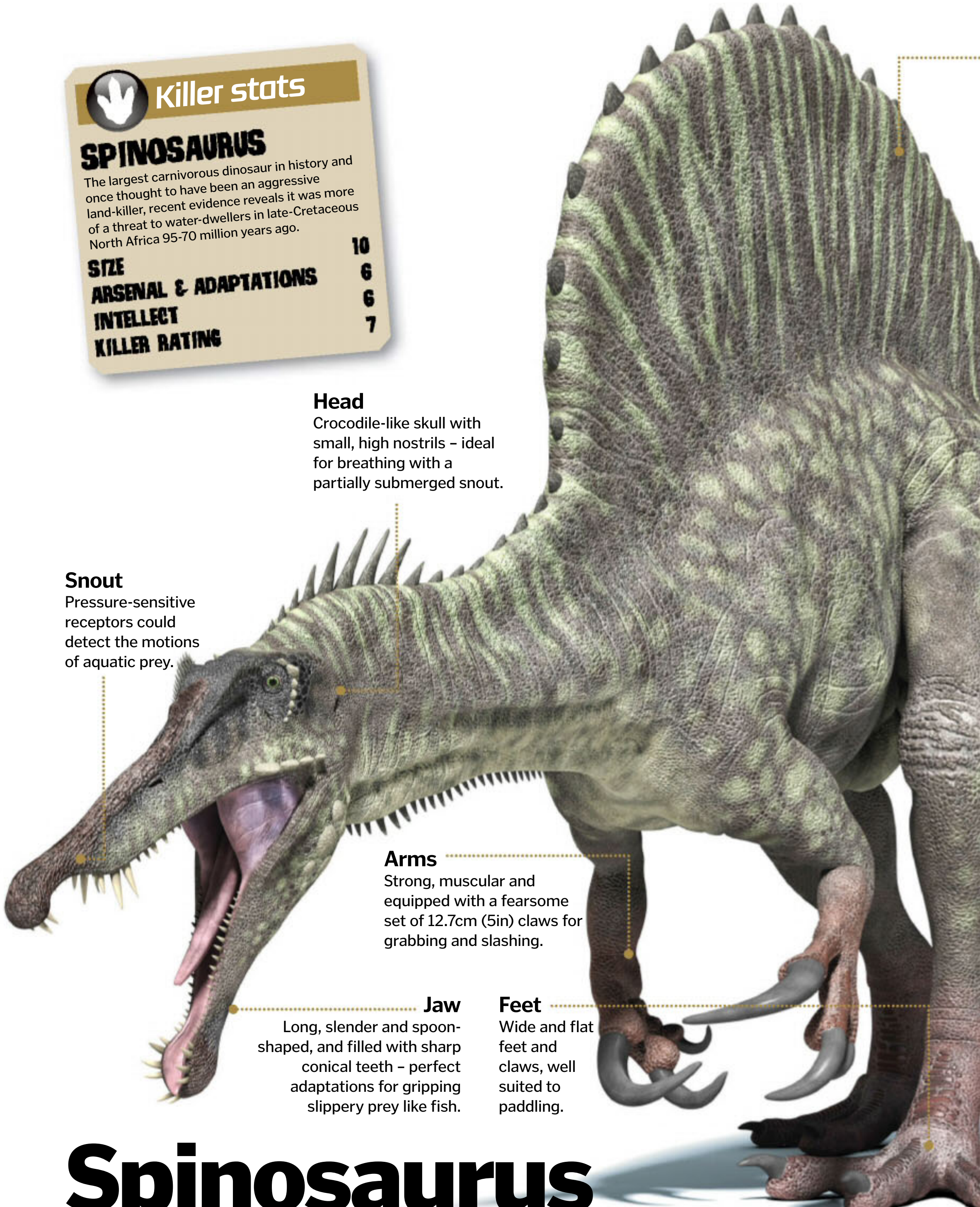
DID YOU KNOW? *We can identify the colours of feather-covered dinosaurs thanks to fossilised melanosome structures*

Killer stats

SPINOSAURUS

The largest carnivorous dinosaur in history and once thought to have been an aggressive land-killer, recent evidence reveals it was more of a threat to water-dwellers in late-Cretaceous North Africa 95-70 million years ago.

SIZE	10
ARSENAL & ADAPTATIONS	6
INTELLECT	6
KILLER RATING	7



Sail
Anchored by a series of spines extending from the dorsal vertebrae; possibly used for display or temperature regulation.

Head
Crocodile-like skull with small, high nostrils – ideal for breathing with a partially submerged snout.

Snout
Pressure-sensitive receptors could detect the motions of aquatic prey.

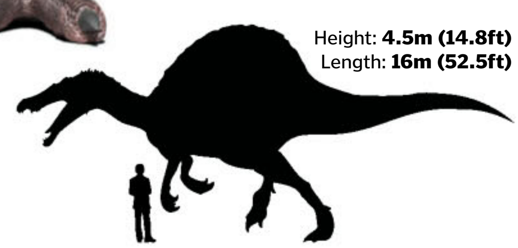
Arms
Strong, muscular and equipped with a fearsome set of 12.7cm (5in) claws for grabbing and slashing.

Jaw
Long, slender and spoon-shaped, and filled with sharp conical teeth – perfect adaptations for gripping slippery prey like fish.

Feet
Wide and flat feet and claws, well suited to paddling.

BELOW Although Spinosaurus mainly hunted for fish, it was fully capable of defending itself

Spinosaurus



Taking the title for the largest carnivorous dinosaur ever to stalk the Earth, Spinosaurus ("SPIN-oh-SORE-uss") is thought to have been as long as one and a half double-decker London buses – 16 metres (52.5 feet) – and as heavy as a heard of full-grown Asian elephants, or 20 tons. Its vertebrae were 20 per cent larger than those of T-rex and to top it off, it sported a gigantic sail of skin supported by two-metre (6.6-foot)-long spines protruding from its back.

Despite its imposing physique, recent evidence suggests Spinosaurus spent more of its time terrorising the water than it did the land, and would only supplement its fishy diet with scavenged carrion. Its crocodile-like jaw had smooth, conical, pointed teeth, well adapted to spearing slippery prey like Onchopristis – eight-metre (26-foot)-long prehistoric sawfish – rather than ripping flesh from bone. Special structures in its snout helped it detect pressure waves caused by prey moving in the water.

Nevertheless, Spinosaurus was fast, strong and possessed a cruel set of claws, meaning it could likely hold its own against other massive predators, like Carcharodontosaurus, who shared its territory.

> "Carcharodontosaurus had jaw-full of 20-centimetre (eight-inch)-long serrated teeth"

Killer stats

CARCHARODONTOSAURUS

Among the largest and heaviest carnivorous dinosaurs known, this hulking mouthful of razors terrorised North Africa during its reign in the mid-Cretaceous Era, 100-93 million years ago.

SIZE	8
ARSENAL & ADAPTATIONS	7
INTELLECT	3
KILLER RATING	8

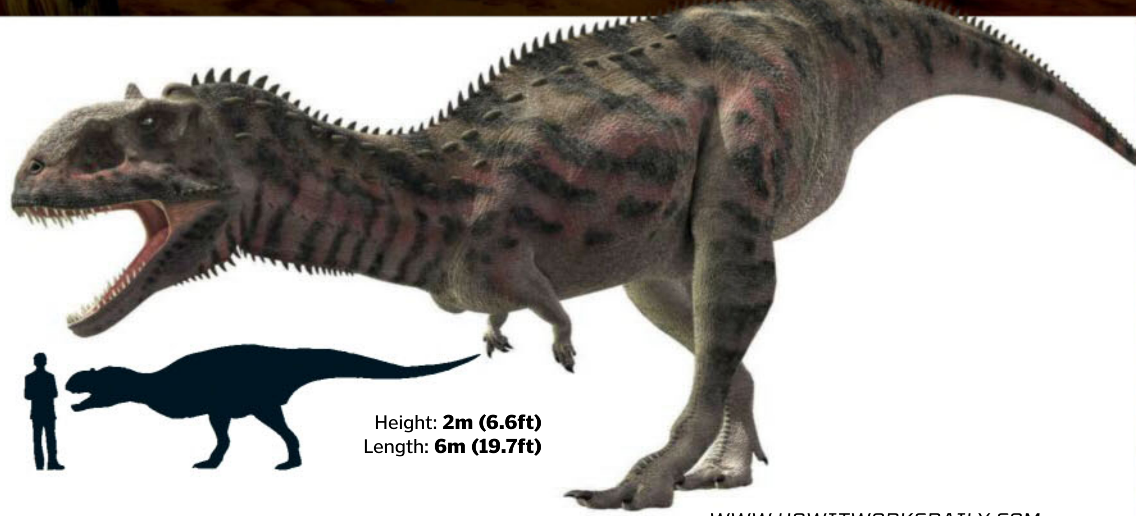
Carcharodontosaurus

Its name is a mouthful in more ways than one; Carcharodontosaurus ("Kar-KAR-o-don-toe-SORE-uss") means "shark-toothed lizard" and refers to the beast's jaw-full of 20-centimetre (eight-inch)-long serrated teeth. These could slice through flesh like switchblades through butter and leave enormous gaping wounds that would quickly incapacitate prey.

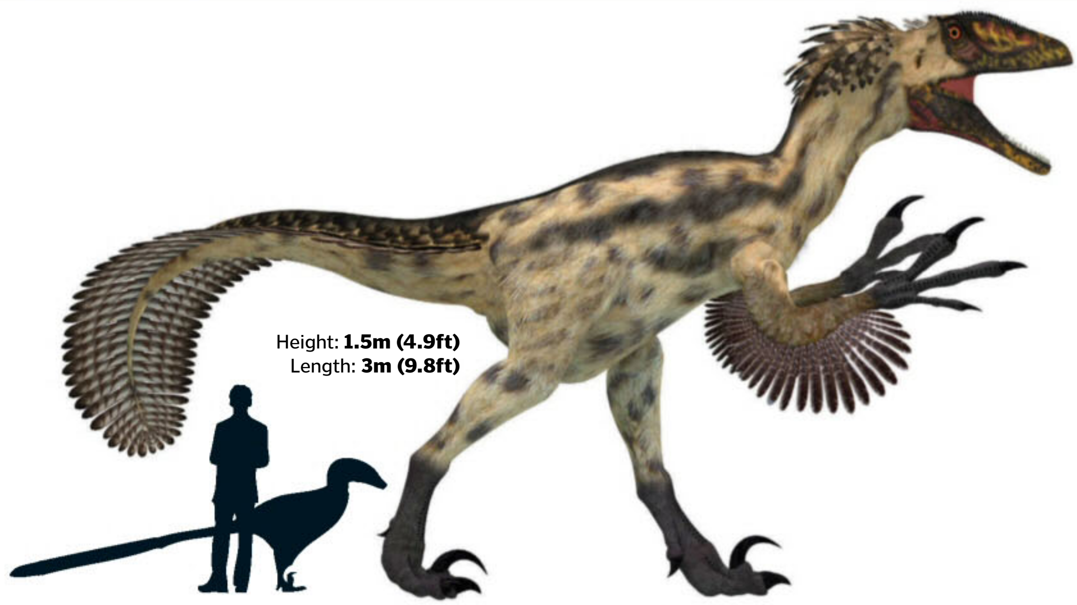
Although it was larger than T-rex and had an enormous skull the size of a person, Carcharodontosaurus – along with its close cousins Giganotosaurus and Mapusaurus – was a more primitive dinosaur with a smaller brain. Instead, it had powerful legs and fossilised tracks suggest it was capable of outrunning T-rex – at about 32 kilometres (20 miles) per hour. Whether or not it actually did – given that its disproportionately small arms would be incapable of bracing its seven-ton weight in a fall – is another matter.

Majungasaurus

Majungasaurus ("Mah-JUNG-a-SORE-uss") has a bit of a bad-lizard reputation; telltale tooth marks on Majungasaurus bones, found on its native island of Madagascar, line up perfectly with Majungasaurus's own dental patterns. That's right – the evidence suggests this one-ton theropod feasted on its own kin, at least occasionally – surely the hallmark of a ruthless killer? What isn't known, though, is whether these were the spoils of active hunts or just efficient tidying up of already-dead relatives.



DID YOU KNOW? *T-rex could eat the equivalent of 1,500 sausages a day. That's one heck of a barbeque*



Deinonychus

The discovery of Deinonychus ("Dee-NON-i-KUSS") in 1964 overhauled our perception of dinosaurs as languid and lumbering; here was a creature clearly built for speedy pursuit. Almost twice the size of Velociraptor (insider tip – the 'Velociraptors' in *Jurassic Park* were actually modelled after the bigger, badder Deinonychus!), but a similar weight, it was a sprightly and most likely a quick-witted pack hunter. Among other advantages, it possessed interlocking vertebrae that allowed its tail to stiffen for balance when running, and a retractable 13-centimetre (five-inch) claw on each foot to disembowel prey restrained in its hands and jaw.

Giganotosaurus

Carcharodontosaurus's South American cousin, Giganotosaurus ("GIG-a-NOTE-o-SORE-uss") was another beast to rival T-rex for size. Depending on the specimen, it is thought to have been slightly smaller than Carcharodontosaurus, but longer, taller and more slender than T-rex. It was the fastest of the three, besting the others by at least 16 kilometres (ten miles) per hour, perhaps thanks to its superior balance.

It had a very large skull but, like Carcharodontosaurus, it was more neurologically primitive than T-rex; its brain was a puny half the size of T-rex's. Still, evidence suggests it had a keen sense of smell, which coupled with its athletic prowess and eight-ton bulk made it a formidable foe.

Like Carcharodontosaurus, Giganotosaurus's teeth were serrated and laterally compressed – wide in profile but narrow when viewed from the front – making them ideal tools to deliver a series of injurious slices to the body of its prey, which would eventually keel over from exhaustion and blood loss.

Killer stats

GIGANOTOSAURUS

This giant razor-mouthed athlete roamed the swamplands of South America during the late-Cretaceous period, around 100-97 million years ago.

SIZE	9
ARSENAL & ADAPTATIONS	9
INTELLECT	2
KILLER RATING	9

"Inside the layout is equally unusual, with maze-like corridors that are both high and incredibly narrow"

Saint Basil's Cathedral

Why is Moscow's most iconic landmark so bizarre?

One of Russia's most iconic holy sites was born from one of the country's most infamous rulers. Far from holy, the vicious and paranoid Ivan the Terrible had risen from grand prince of Moscow to become the first tsar of all the Russias through conquest of the wild eastern expanses of Kazan, Astrakhan and Siberia.

Ivan ordered the construction of Saint Basil's – originally called Cathedral of the Intercession of the Virgin on the Moat – to commemorate his victory over the Tatars at Kazan in 1552. Work began in 1555 and was completed in 1561, but beyond that the building's origins are subject to as many myths as the cruel tyrant who commissioned it.

One story from Russian folklore is that Ivan had the architect (or architects) blinded so that he'd never be able to replicate the unique grandeur of Saint Basil's, which features nine different-sized towers overlapping and interlocking to create a seemingly chaotic, fairy-tale effect. Inside, the layout is equally unusual, with maze-like corridors that are both high and incredibly narrow.

One theory is that after destroying the Qolsärif Mosque in Kazan, elements of the design were incorporated into the structure. Like Saint Basil's, the mosque had eight minaret towers surrounding a dome. Other influences may have come from Greek craftsmen fleeing the fall of Constantinople (now Istanbul in Turkey), Italians who brought with them a taster of the Renaissance, as well as German and English plasterers and stonemasons, creating a truly unique mix of style that reflects the unpredictable mind-set as well as the blood-soaked triumphs of Russia's mad monarch.

Saint Basil's in detail

What to look out for in Russia's most incredible church

Belltower
Added to the cathedral 1680-1683, the bells were melted down following the Russian Revolution in 1918, only restored in 1997.

Onion domes
Saint Basil's onion-shaped domes are the oldest in Russia. They may have been inspired by the domes on mosques.

Colours of heaven
Saint Basil's was originally painted white to match the palace next door. It was repainted in stages from the mid-17th century to reflect the colours of heaven described in the *Bible*.

Who was Saint Basil?

Another testament to Ivan the Terrible's unpredictable nature, Saint Basil's was later named after the only man bold – or crazy – enough to humiliate him.

Basil was a yurodivy, which means 'holy fool.' In the Russian Orthodox branch of Christianity, holy fools were religious men who chose to behave as if they were insane in order to make a point. Basil shoplifted to give to the poor, turned over food stalls that sold undercooked pastry, wore no clothes, bound himself in chains and admonished Ivan for his bloodletting and for not paying attention in church.

While cruelty remained Ivan's defining characteristic, he protected Basil, showered him with gifts and even carried his coffin at his funeral. That he was able to survive the Russian winter naked and homeless was considered a miracle, and he was made a saint shortly after his death, sometime before the cathedral's completion in either 1552 or 1557.

KEY DATES
SAINT BASIL'S VS DESTRUCTION

1737 A fire damages the cathedral; restoration begins giving the building its current colour scheme.

1812 Napoleon Bonaparte orders Saint Basil's blown up. A sudden rain reportedly puts out the fuse.

1924 After the Russian Revolution, it becomes a museum. After Lenin's death in 1924 its fate hangs in the balance.

1933 Stalin orders architect Pyotr Baranovsky to survey the church for demolition. He refuses and is imprisoned.

1947 Restoration work begins following WWII after the Communist Party realises the church's historical significance.

DID YOU KNOW? *During renovation work in the 1970s, a spiral staircase was discovered that had been hidden for centuries*

Brick is beautiful
While other churches used statues and carved sculptures added after the construction, all of Saint Basil's original decorations are part of the brickwork

Ceremonial entrance
The Chapel of the Entry of Christ into Jerusalem was used as a ceremonial entrance for the patriarch – the head bishop in the Russian Orthodox Church – on Palm Sunday.

Tiled gallery
The warren of narrow passages connecting the chapels were tiled over in the 17th century and given increasingly more eye-catching designs.

Main entrance
The main entrance to Saint Basil's opens out onto Red Square facing the Kremlin – the fortress complex that contains the presidential palace.

Ninth Chapel
This smaller ninth dome was added in 1588 to serve as a tomb for Saint Basil, his name then spread to the rest of the building.

Iconostasis
The iconostasis – a beautifully decorated wall of religious paintings – in the main chapel (Intercession Chapel) dates from the late-19th century.

How was Saint Basil's built?

Restoration work on St Basil's in the mid-1950s discovered that behind the walls was a timber frame on white stone foundations, suggesting a skeleton was erected first and then built around in red brick. Previous Moscow churches had been entirely wooden and built from either pine or fir, which was plentiful in north Russia.

Red brick was a relatively new building material, first used in Moscow on the Kremlin Wall in 1485, 70 years before work started on Saint Basil's, and has contributed to the longevity of Saint Basil's Cathedral.

LEFT Ivan the Terrible ordered the building of St Basil's Cathedral

BRAIN DUMP

Because enquiring minds need to know...

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MEET THE EXPERTS

Who's answering your questions this month?

Giles Sparrow

Giles studied Astronomy at UCL and Science Communication at Imperial College, before embarking on a career in space writing. His book *The Universe: In 100 Key Discoveries* is out now.

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.

Alexandra Cheung

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

Laura Mears

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

Shanna Freeman

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

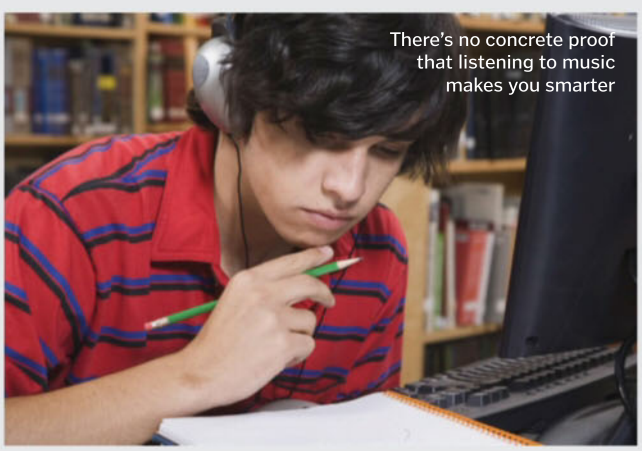
The Apollo spacesuits incorporated 21 separate layers of material to keep the astronauts safe on the Moon

How much does a spacesuit weigh?

Bethany Chamberlain

■ The weight of a spacesuit depends on its design, and that crucially depends on where you're going to be using it. Early Soviet and US space pilots who didn't plan to leave their spacecraft simply wore modified flight pressure suits weighing around ten kilograms (22 pounds), but astronauts who planned to walk in space or on the Moon wore much heavier outfits with many protective layers. Including life-support backpacks and other equipment, the Apollo astronauts wore kit that weighed around 82 kilograms (180 pounds) on Earth. Fortunately, however, the Moon's low gravity meant it weight just one-sixth of that on the lunar surface, so they could move around easily despite the bulk.

Advances in protective materials mean that modern suits worn on the International Space Station aren't as bulky, and of course in orbit they're weightless anyway, but engineers are designing a number of new, lightweight suits that could be used on Mars, where gravity is just less than one-third of Earth's. **GS**



There's no concrete proof that listening to music makes you smarter

Does Mozart make you smarter?

Nick Palmer

■ There is no scientific proof that listening to Mozart or any other musician makes you smarter. However, it can have positive effects. In the 1950s, a medical professional claimed that Mozart's music helped people with speech and auditory disorders. This led to further experiments. One particular study in the 1990s showed that students' IQ scores increased by at least eight points after listening to Mozart for ten minutes. This became known as the Mozart effect. However, one of the researchers involved in the study pointed out that listening to Mozart increased performance on spatial tasks, but didn't necessarily make the participants more intelligent. **SB**

Does the sea ever get warm or is it too big?

The Red Sea is one of the warmest seas in the world

The sea does change temperature, but given the huge amounts of water it contains, warming happens very slowly. It also takes much more energy to heat or cool water compared to the same volume of air. While surface water changes temperature with the seasons and depending on latitude, the deep ocean never gets warmer than two or three degrees Celsius (35.6 or 37.4 degrees Fahrenheit). One of the warmest seas in the world is the Red Sea, where surface waters frequently hit 30 degrees Celsius (86 degrees Fahrenheit). Ocean temperatures around the world are gradually increasing as a result of global warming, however. **AC**

FASCINATING FACTS

Our phones really do change our thumbs

Using phones and playing video games has been proven to change the shape of our thumbs, but in the same way that other body parts grow and change if you exercise them, so it is not an evolutionary adaptation.

Can a human spontaneously combust?

Anna Smith

Known as spontaneous human combustion (SHC), there is no concrete evidence that a human can instantly go up in flames. However, there is also no evidence that one can't. It is very difficult for a human body to burn, because it is largely composed of water. But there are various theories that attempt to explain how SHC might occur. For example, some scientists believe the human body produces small amounts of acetone, particularly when unwell and that, combined with a spark, they catch fire. However, no one knows for sure if SHC is possible. **SB**

Why do certain smells make pregnant women ill?

Tom Walker

The sickness associated with pregnancy can often be blamed on a heightened sense of smell, thanks to rising levels of the hormone oestrogen. However, which specific odours will make a pregnant woman ill varies by individual. Often strong food odours, such as seafood, coffee, or eggs are to blame. Some scientists have posited that this sensitivity may be beneficial to the baby, because an aversion to the smell of items such as coffee and cigarettes means the pregnant woman is rejecting harmful substances. Yet so far additional studies haven't shown them to rank the smells of toxins or chemicals to be any more offensive than other smells. **SF**

Why do my muscles still ache the day after exercise?

Jake Dinley

Known as delayed onset muscle soreness (DOMS), this temporary aching usually occurs 24 hours after exercise and can last several days. It happens when an exercise regime significantly changes, whether that's the activities involved or the intensity. It can also occur if someone is completely new to exercise. DOMS is the result of your muscles working harder than usual or in a different way. Medical scientists believe microscopic damage is caused to the muscle fibres, which causes the aching, but actually improves fitness in the long term. Once your muscles have adapted to the new exercise, they recover and build strength, ultimately improving stamina. **SB**

Why are spiders so scary (not to you, of course)? Find out on page 82


We usually only remember dreams if we wake up in the middle of them

Why can't I remember my dreams?

Colin Oldfield

The main reason we forget most of our dreams is because our brains just aren't designed to remember stuff while we sleep. Some experts link this to the lack of a hormone called norepinephrine, which seems to play a big role in long-term storage of memories in our brains, and whose production diminishes during the phases of 'rapid-eye-movement' (REM) sleep associated with dreams. Others think it's the lack of structure or relevance to most dreams that stops our brains forming the same network of links to help us remember them – this may be why more vivid, realistic dreams stay with us longer. **GS**

Why are so many people afraid of spiders?

Henry Rowley

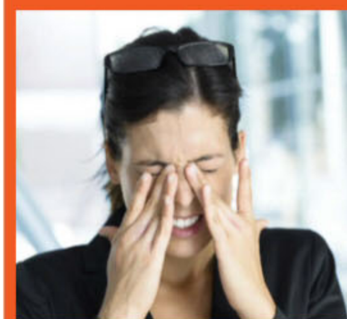
There are several opposing theories about the origins of arachnophobia, but many scientists believe it might be a protective mechanism left over from our ancestors, who would regularly encounter dangerous spiders. This idea was first proposed in the 1970s, and is used to explain many common phobias, such as heights, snakes and the dark. A study carried out in 2012 showed that young children are able to recognise pictures of spiders much more rapidly than pictures of non-threatening items, like mushrooms and even cockroaches, indicating that even at an early age, we are aware of these eight-legged creepy crawlies. **LM**


Only a handful of spider species are capable of harming humans – most are not dangerous at all

FASCINATING FACTS

The crusty morning eyes explained

Rheum consists of a thin mucus produced by the cornea mixed with conjunctiva, along with dead blood and skin cells, which collects at the inside corners of your eyes overnight.

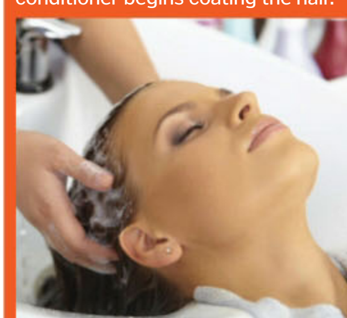


The world's biggest phone camera

In terms of photo resolution, the Nokia Lumia 1020 can give you 41-megapixel snaps. Its sensor is a mighty 2.5/3.8 centimetres (1/1.5 inches), more than twice the size of the sensor on the Apple iPhone 6.

How two-in-one shampoo and conditioner works

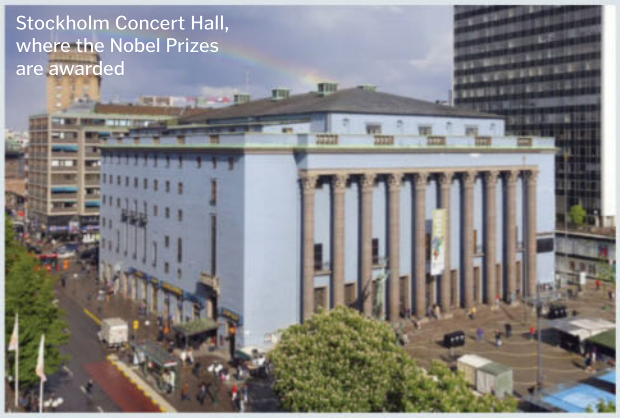
Dirt and excess oil in hair is washed away by surfactants, the main cleaning agent in shampoo. While the shampoo is being rinsed, the conditioner begins coating the hair.



What's the difference between a fan oven and a normal one?

Rachel van Lertens

A fan oven, as its name suggests, contains a fan that spins at high speed. The oven's heating element is circular and surrounds the fan at the back of the oven, so that hot air is blown away from the element and circulated into all parts of the oven. In contrast, air in a normal (non-fan) oven is often heated by an element at the bottom and simply rises up to collect at the top of the oven, leaving the bottom relatively cool. So fans give a much more even distribution of heat, which in return should mean better and faster cooking. **GS**



Stockholm Concert Hall, where the Nobel Prizes are awarded

Why are the Nobel Prizes awarded?

Ryan Garfield

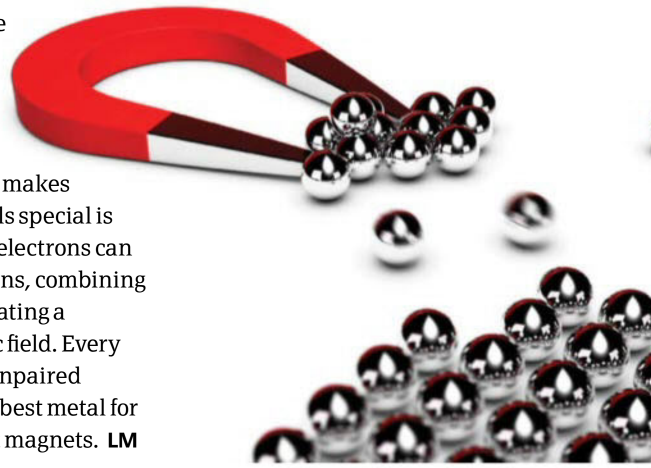
The Nobel prizes are the brainchild of Alfred Nobel, a Swedish chemist and engineer who donated a large sum of money in order to reward those who made the greatest advances for the benefit of mankind. Nobel was a prolific inventor, making his fortune largely due to his invention of dynamite and other explosives. When he died in 1896, he left 31 million Swedish kronor, about £165 million ($265 million) today, to establish five annual prizes in chemistry, physics, literature, peace and physiology or medicine. Today each Nobel prize is worth about £680,000 ($1.09 million), shared between up to three laureates. **AC**

Why is it only metal that's magnetic?

Charlotte Price

When most people talk about magnetic materials, they are usually referring to the properties of three elements known as the ferromagnetic metals; iron, nickel and cobalt, but all elements have magnetic properties of some kind.

Each electron in every atom acts like a miniature magnet, and can either be spinning 'up' or 'down'. They are arranged into shells around the nucleus of the atom, and organised into pairs according to their spin. When two electrons spinning in opposite directions are paired together, their magnetic properties are cancelled out. What makes ferromagnetic metals special is that their unpaired electrons can organise into domains, combining their effects and creating a detectable magnetic field. Every iron atom has four unpaired electrons, so it's the best metal for creating permanent magnets. **LM**



There are just three magnetic metals; iron, nickel and cobalt

What is the slowest speed an aeroplane can go but still stay in the air?

Scott Woodbury

The slowest speed an aeroplane can fly and still stay up depends on many factors, including its weight, type and configuration, as well as the temperature and the plane's altitude. Heavier aeroplanes need more lift and speed. Hotter air is less dense than cooler air and requires greater speeds for the same lift. For a commercial jet, for example, this works out to about 259 kilometres (161 miles) per hour. Slower than that and the jet wouldn't have enough lift to keep from descending. A smaller and lighter plane, however, might go as slow as 74 kilometres (46 miles) per hour. **SF**

A small propeller aeroplane like this one doesn't have to go very fast to stay airborne

Can you tell a buffalo and bison apart? Find out on page 84

What's the difference between a buffalo and a bison?

Hank Carson

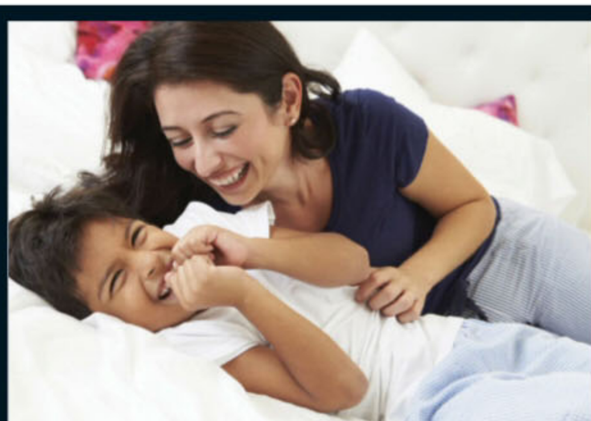
Many Americans know their local animals as 'American buffalo', but these large herbivores are actually bison (main image). The naming confusion arose when European settlers came to the continent and noticed the similarities to animals they had seen in Africa and Asia.

Buffalos and bisons can be easily distinguished by their heads and horns. African cape buffalo (inset) have thick horns, which grow together in a large wig-like structure on top of their heads. Asian water buffalo have huge separated horns with a backward curve. Meanwhile, American bison have smaller horns, large heads and a characteristic furry hump at the shoulders. **LM**

FASCINATING FACTS

Venus is almost as popular as Mars

Our nearest neighbour in space, Venus, has been targeted by almost as many space probes as Mars (more than 40). Depending on whether you count some failed launches, it may even be the most popular target of all!



Why does tickling make us laugh?

Hugh Wright

Tickling stimulates the hypothalamus, the same part of the brain that anticipates pain, leading evolutionary biologists to theorise that laughing in response is a way of indicating submissiveness when we are in danger. Tickling occurs when a light touch stimulates our nerve endings. Some of our most ticklish parts, such as our necks or underarms, are also the most vulnerably to injury, and laughing when an aggressor gets a bit too close to these might just be a way of defusing the situation. Gorillas also laugh when tickled, suggesting this behaviour evolved 30 to 60 million years ago. **AC**

What is the biggest insect in the world?

Vanessa Choi

In 2013, a giant dobsonfly was discovered in China's Sichuan province, sporting a massive wingspan of 21 centimetres (8.27 inches), so it may be the world's largest aquatic insect. There's an even longer insect than that in existence, though; a type of stick insect found in Borneo called Phobaeticus chani has a body measuring 35.7 centimetres (14 inches) long and a total length of 56.7 centimetres (22 inches). If your criterion is heft instead of length, the giant weta of New Zealand is one of the world's heaviest insects at 71 grams (2.5 ounces) fully grown while the African goliath beetle can weigh up to 100 grams (3.5 ounces) as larvae. **SF**


Cold weather restricts blood flow to the body's extremities

Why do my lips and nails turn blue in cold weather?

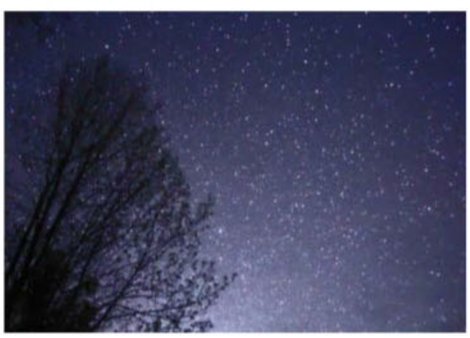
Robert Hall

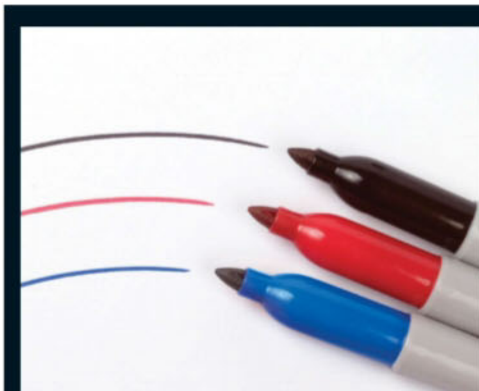
■ Blue lips or nails are a sign of low blood oxygen. Oxygen-rich blood is bright red, but blood carrying less oxygen is much darker, appearing blue because of the way our skin filters light. When it's very cold our blood vessels are constricted, conserving body heat by slowing the flow of blood to peripheral areas such as hands or feet. The blood in these areas becomes deoxygenated, giving them a bluish tinge known as cyanosis. This disappears as soon as you warm up and normal circulation is restored. However, more persistent cyanosis can be a symptom of serious respiratory or heart diseases. **AC**

What is the time difference between a star burning out and us no longer seeing it?

Wayne Eagle

■ The length of time it takes us to see the light from the more distant stars depends on their distance from us. Therefore, the length of time it would take for us to cease viewing the light from a burned-out star depends on its distance. If the star is 100 light years away and it died five years ago, for example, its light will continue to reach Earth for 95 years. It's a common myth that many of the stars we see at night have already died. Stars live for millions or billions of years and there are more than 100 billion of them in our galaxy alone. So although we may be viewing light from the few stars per century on average that go supernova in our galaxy, most of the light we see comes from stars that are still going strong. **SF**





What makes permanent markers permanent?

Sophie Tucker

■ A marker must contain a colourant, a carrier and a resin in order to be permanent. And by permanent, we mean it adheres to most surfaces and is water resistant. The ink gets its permanent properties through the combination of ingredients in the ink formulation. The dyes or pigments used to give a marker its colour also determine the extent of its fading. A pigment is an insoluble colouring matter, while a dye is a solvent. Therefore, pigmented ink is far more likely to resist fading. Most permanent markers contain an alcohol solvent, which evaporates fast and means the marker dries quickly. **SB**


Focusing on a fixed point acts as a reference point to keep you balanced

Why does focusing on something help you balance?

Steven Dorana

■ In order to balance, your body needs to know where it is in space, and does so by combining three incoming signals: a reference point from your eyes, head position from the inner ear and information about the positions of your muscles and joints.

The inner ear system functions like a miniature spirit level, with three fluid-filled canals, each detecting movement in a different direction. When balancing, focusing on a fixed point gives your brain a static reference point to aim at, so adjustments can be made to keep you upright. **LM**

New Brain Dump is here!

■ Don't miss issue 19 of **Brain Dump**, the digital sister magazine to **How It Works**, which landed on the virtual newsstand on 1 December. You'll learn all about how atoms decay, what exactly sea sickness is, as well as the answer to whether we can erase people's memories. There are loads more trivia snippets for you to get stuck into, giving you the knowledge hit you need without having to lug an encyclopaedia around! Packed with beautiful imagery, it's not one to miss! Download the new issue of **Brain Dump** on the first day of every month from iTunes or Google Play. If you have a burning question, you can ask at **www.facebook.com/BraindumpMag** or Twitter – the handle is **@BrainDumpMag**.

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REVIEWS
All the latest gear and gadgets

High-end kitchen tech

We round up the gadgets designed to help you create culinary masterpieces

Checklist
- ✔ Water dispenser
- ✔ Toaster
- ✔ Juicer
- ✔ Induction hob
- ✔ Stand mixer
- ✔ Ice-cream maker
- ✔ Food processor

The countless cooking and baking shows on television has made us keen to try our hand in the kitchen, but being **How It Works**, we need the latest and coolest gadgets to help us. Cooking tech has come a long way from the mechanical whisk, so enjoy the most useful tech the kitchen has to offer.

1 Multi-dessert maker
Sage Smart Scoop
£349.99/$N/A
www.sageappliances.co.uk
At £350, you will need to be dead serious about ice cream to get this machine. We love the 12 hardness settings to decide whether you want sorbet, gelato or ice cream. It works quietly, is easy to clean and it produces delicious ice cream.
Verdict: 5/5

2 See-through toaster
Magimix Vision Toaster
£160/$249.95
www.houseoffraser.co.uk / www.amazon.com
The Magimix is everything we've ever wanted in a toaster. The double-insulated glass windows let you watch your bread as it's toasting, so you'll never burn it again. It also has a bagel setting for single-side toasting, a defrost setting that adds 30 seconds to the cycle and the design is really unique.
Verdict: 5/5

3 Mobile hob
Tefal Induction Hob
£49.99/$N/A
www.homeandcook.co.uk
The portable Tefal Induction Hob is a light, compact piece of kit that can be easily transported and set up in seconds. It comes with nine heat settings and six presets for various types of cooking, such as frying and boiling. However, it is frustrating that it's only compatible with certain pots.
Verdict: 4/5

4 Power blend
Magimix 5200 XL Premium food processor
£369.99/$499.95
www.houseoffraser.co.uk / www.williams-sonoma.com
This food processor may be massive and heavy, but in terms of food preparation, it is superb. The slicer cuts thinly, rapidly and evenly. The processor chops incredibly quickly and effectively. It also juices, blends, whisks and purées to perfection.
Verdict: 5/5

Quartz cooking
The element on the Vision is made of quartz and it cooks using infrared radiation.

Smart Scoop
The machine detects when the mixture is hard enough so doesn't need constant supervision.

Ferromagnetic materials
You must use magnetic pots and pans because induction hobs heat food by using a magnetic field.

Citrus centre
It is also a citrus press, extracting juice extremely quickly with minimal adjustment.

5 Pulpless juice

Novis Vita Juicer
£349.99/$N/A
www.lakeland.co.uk
This machine is pretty big, so it's only for sizeable kitchens. The set-up is easy and quick, but we would like a bigger feed tube and our juice was quite frothy. Results are rapid and it's easy to clean, but there are cheaper options on the shelves.
Verdict:

6 Hot and cold

BIBO water dispenser
£439/$N/A
www.bibowater.co.uk
BIBO boils then chills the water giving you a perfect morning cuppa or clear, cold water. It learns what temperature you like your hot or cold water and even the size of your mugs and glasses! The BIBO is easily connected to your home water supply and passes through a multistage filtration system.
Verdict:

7 Mixer magic

kMix Stand Mixer
£269/$599.99
www.johnlewis.co.uk / www.kenwoodworld.com (Chef Major)
The stand mixer is the must-have gadget for all serious bakers. The five-litre (1.3-gallon) bowl is easily big enough for most home baking and the 500W motor is beefy enough to mix the thickest of dough. Its fold function keeps air inside the mixture and the attachments are easily interchangeable. The only downside is that it's rather loud, even for a food mixer.
Verdict:

EXTRAS

Everything you want to get cooking

BOOK

The Science Of Good Cooking

Price: £24.63/$40
Get it from: www.amazon.com
The science of cooking is as fascinating as the technology. This book explains how and why certain recipes work in cooking. Packed with science, recipes and illustrations to explain what goes on inside the pan.

APP

Paprika

Price: £2.99/$4.99
Get it from: iTunes/Google Play
This app is your all-in-one mobile cookbook. It allows you to store all your favourite recipes in one place and categorise them so they are easily found. It also syncs to all your devices so your phone can be your shopping list.

WEBSITE

www.foodnetwork.co.uk

This site has a superb range of recipes for you to try your hand at as well as loads of features and lists for the food fanatic in you. They have video tutorials and a raft of competitions too.

DSLRs

Cameras for capturing stunning images of any scene

Multi-purpose
The 700D can record full-HD videos as well as capture 18MP photos.

Quick fire
Continuous shooting mode fires off five frames per second when you hold down the shutter button.

1 Canon EOS 700D/Rebel T5i (with 18-55mm lens)

Price: £749.99/$849.99
Get it from: www.amazon.com

Those looking to make their first step up from a basic compact camera or camera phone should be satisfied with the 700D. Although it feels a little cheaply made, its plastic exterior makes it extremely lightweight for a DSLR, so you'll have no problem carrying it around with you everywhere. Smartphone lovers will also welcome the inclusion of a touchscreen, which makes focusing, taking a photo and navigating the menus as simple as tapping or swiping the LCD. The screen even flips outward to help you shoot from high or low angles, or take self-portraits.

As well as manual and semi-manual modes, there's also a small selection of useful scene modes to help you deal with tricky shooting situations, and Creative Auto mode provides an easy first step out of fully automatic shooting. The Quick Menu buttons gives you easy access to all the key settings you'll need and a built-in feature guides provides helpful hints and tips as you navigate the menus. Focusing is a little slow when using Live View, but speeds up when using the viewfinder, and overall image quality is excellent. Photos are crisp and clear, even in low light, and the colours are vibrant and lifelike.

Verdict: 5/5

2 Nikon D5300 (with 18-55mm lens)

Price: £679.99/$899.95
Get it from: www.store.nikon.co.uk / www.amazon.com

The Nikon D5300 is a solid and sturdy but easily portable DSLR. The attractive animated display on the fully adjustable LCD makes exploring key settings a breeze, and novice photographers can use the Help button for advice on the camera's many functions. An extensive array of scene modes is on offer to aid you, no matter what you're shooting. You can even apply creative filters to your photos, including toy camera and selective colour effects, to give them a unique twist in-camera.

The photos produced by the D5300's 24.2-megapixel sensor are of very high quality with plenty of detail and accurate colours. Poor lighting leaves shots with very little grain, and focusing is fast using the viewfinder, struggling a little when the LCD display is switched on.

Once you've taken your shots, you can share them online straightaway using the Wi-Fi function to transfer the files over to your smartphone. Connecting to your device also enables you to use it as a remote viewfinder, controlling the camera from a distance, plus the built-in GPS automatically tags your shots with the location in which they were taken.

Verdict: 4/5

ON THE HORIZON

Take the next step up to a larger full-frame sensor

Nikon D610
The 24.3MP FX (full-frame) sensor promises smooth detailed images, even in low-light conditions when the sensitivity is increased.

Canon EOS 6D
The larger sensor can capture the entire wide-angle view when using full-frame lenses, without cropping off the edges of the shot.

Colour-changing LEDs
The LED lights go green when shooting still images and red when recording video.

Fast focus
A whopping 79 autofocus points enable incredibly quick and accurate focusing.

3 Pentax K-S1
(with 18-55mm lens)

Price: £599.99/$799.95
Get it from: shop-uk.ricoh-imaging.eu / www.amazon.com

The unusual and angular design of the Pentax K-S1 makes it quite uncomfortable to hold and its chunky shape is anything but sleek and stylish. It also comes in a range of bright colours, so it stands out from the crowd even more. The LED lights on the camera's grip give it a futuristic feel but seem to be a bit of a useless gimmick. They become more useful when providing a visual countdown in self-timer mode, but the fixed screen doesn't help when trying to position yourself in the shot.

The mode dial is situated on the back of the camera, instead of the top, making it a little awkward to adjust, but does provide you with a great deal of shooting options. A visual guide on the LCD provides a clear view of the settings, but the choice of functions on offer will be a little overwhelming for beginners, especially as there is no built-in guide to help you. You do get good value for money, though.

Focusing is painfully slow and noisy, producing a horrid whirring sound every time you go to take a shot, but the image quality is good with adequate detail.

Verdict:

4 Sony A77 II
(with 16-50mm lens)

Price: £1,549 /$1,798.99
Get it from: www.sony.co.uk / www.amazon.com

It may have a rather hefty price tag, but the Sony A77 II gives you a whole lot of camera. The bulky and heavy design might be off-putting for those looking for an everyday portable camera, but the performance and image quality on offer is superb.

The LCD screen folds up and down for creative framing opportunities, and a small illuminated display on the top of the camera gives a quick view of current settings when shooting in low light.

The abundance of buttons available is likely to confuse those without much existing photography knowledge, and aside from a few scene modes, there's not much guidance when venturing out of auto. However, once you get to grips with the controls, there is plenty of scope to customise modes and speed up operation.

Focusing is incredibly quick, and the A77 II is capable of shooting an impressive 12 frames per second to increase your chances of getting the perfect high-speed shot. The stunning image quality produces accurate detail and colours, and the supplied kit lens is a pleasure to use too. Then you can use the built-in Wi-Fi and NFC to instantly show off your shots online.

Verdict:

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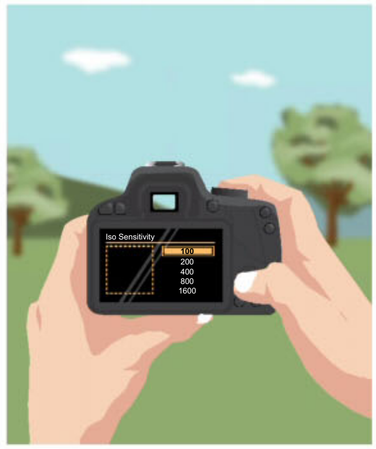
Take the perfect portrait

Master camera modes and lighting to create pro-style shots of friends and family

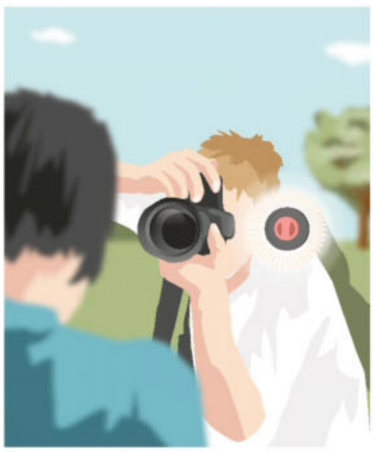
1 Set your mode

When shooting with a camera that has manual modes, set it to aperture priority (the letters A or AV on the mode dial). This mode lets you set the lens's aperture and ISO, while the camera takes care of the other exposure setting: shutter speed. Set a wide aperture (small f-number) to create a big opening in your lens that will produce a shallow depth of field, thus blurring the background to isolate your subject.



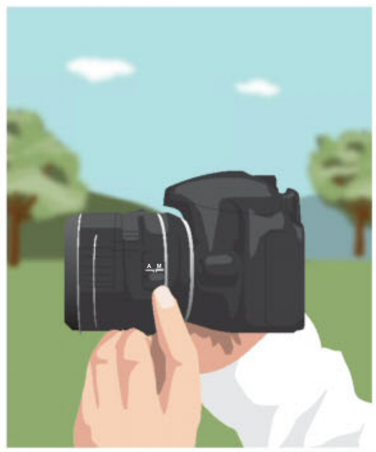
2 Control the exposure

The other exposure value you need to set is the ISO. This controls the sensitivity of your camera's sensor to light, with a higher value making it more sensitive and therefore brightening your shots. If you are shooting in bright daylight, then use a low ISO, as raising it can reduce the quality of your images. However, if the conditions are dark and you're not using an additional light source, increase it.



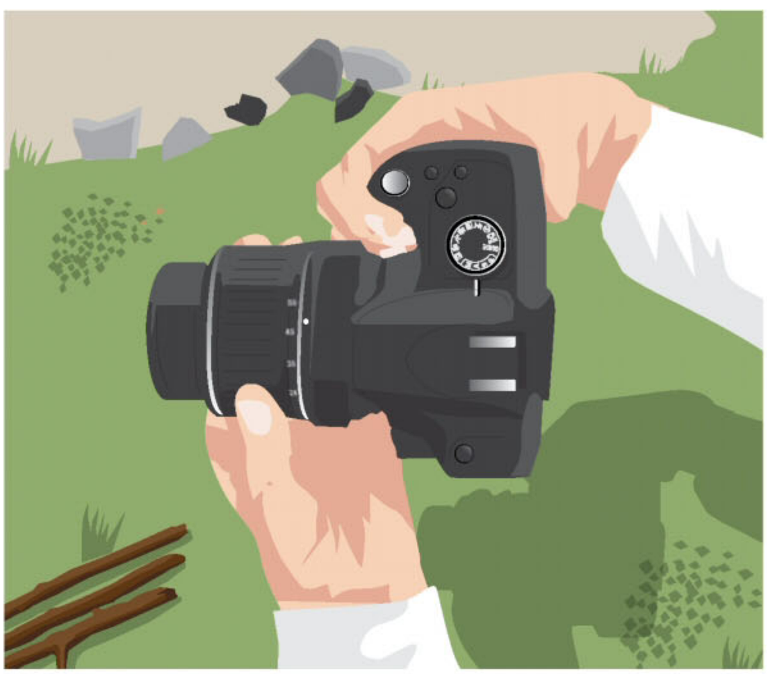
3 Light the shot

Natural light is great for portraits, but it's tricky to control and can create unwanted shadows across your subject's face. Using a ring light, such as the Rotolight RL48-B (**rotolight.com**), will help to eliminate any unflattering shadows in your shot, giving you an even coverage of light. If you don't have a ring light, try using your camera's built-in flash, diffusing it with translucent material to soften the harsh light.



4 Focus accurately

When using a small f-number, it is important to make sure that your subject is perfectly in focus, otherwise they could become part of the blurry background. If your camera has manual focus mode, turn it on via the switch on the lens, and then twist the focus ring around the lens barrel until your subject comes into focus. Alternatively, use selective autofocus and position the focus point over their face.



5 Zoom in

Although using a short focal length (10-35mm) will allow you to fit lots in the frame, it can be quite unflattering for portraits. The distortion it creates will exaggerate your subject's features, producing an unnatural photo. Instead, zoom in to around 50-85mm to keep everything in proportion and allow yourself to shoot a close-up from a comfortable distance. Now, you are ready to press the shutter button and create your photo.

In summary…

Using the perfect camera settings, you should be able to create a stunning image with your subject bright and pin-sharp and the background reduced to a creamy blur. To blur the background even more, use a lower f-number, zoom in further or increase the distance between it and your subject.

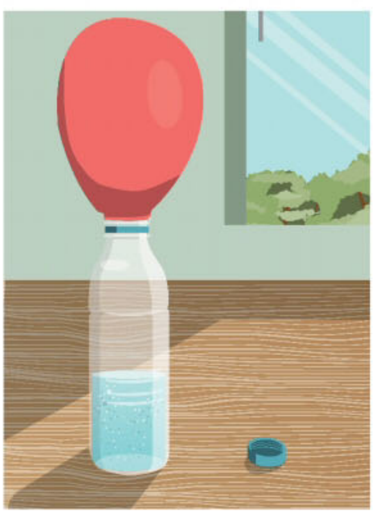
NEXT ISSUE
- Exercise at home
- Manipulate sound waves

Self-inflating balloons

How to inflate a balloon with vinegar and baking soda

1 Preparation
Open up a balloon by stretching it and pour in a couple of tablespoons of bicarbonate soda (baking soda). Use a funnel to make things easier. Make sure all the powder is gathered in the bulb of the balloon, with none left in the neck, as that would begin the reaction too early. Then pour about 120 millilitres (four fluid ounces) of vinegar into a bottle that's at least 500 millilitres (17.6 fluid ounces). This will give plenty of space for the chemical reaction to take place.

2 Blow it up
Fit the neck of the balloon over the rim of the bottle, making sure the body is hanging down so no baking soda gets into the bottle before you're ready. Once you're confident it's fitted snugly over the rim with no room for any air to escape, lift the body of the balloon up so all the baking soda falls into the bottle in one go. In under a second, the mixture will begin to bubble and your balloon will inflate rapidly.



3 The science bit
The baking soda and vinegar mix to create an acid-base reaction. This occurs when an acid, like vinegar, and a base, like bicarbonate soda, are mixed. The base neutralises the acid and produces water, a salt, and carbon dioxide. The carbon dioxide rises, filling the balloon. As a further experiment after this one, fill another balloon with only your breath and drop them both at the same time. As pure carbon dioxide is heaver than air, it should fall faster to the ground.

In summary...
Reactions between substances that don't seem very reactive can sometimes be surprisingly volatile. Even water can create crazy displays when mixed with elements like magnesium. This shows the amazing way different substances react with each other and shows how by-products are formed.

QUICK QUIZ

Test your mind with ten questions based on this month's content to win an Airfix model of a Ford Fiesta RS WRC car.

Answer the questions below and then enter online at **www.howitworksdaily.com**

1. How long does it take to build a Ford 1.0-litre EcoBoost engine?
2. What colour are clownfish eggs?
3. How long does it take an oak tree to fully mature?
4. What type of lava flow is typically produced by underwater volcanoes?
5. What year could driverless Tube trains start running?
6. Who ordered the construction of Saint Basil's Cathedral?
7. How many bones are in an adult human body?
8. How long after infection do Ebola victims become infectious?
9. Where did Alan Turing break the Enigma code?
10. Which company developed the Striker II pilot helmet?

ISSUE 66 ANSWERS
1. *The Gadget Show* **2.** Benoist XIV **3.** Seven **4.** Plasma **5.** 1798 **6.** Osteoblast **7.** 32 **8.** Intercostal muscles **9.** Opsins **10.** 401

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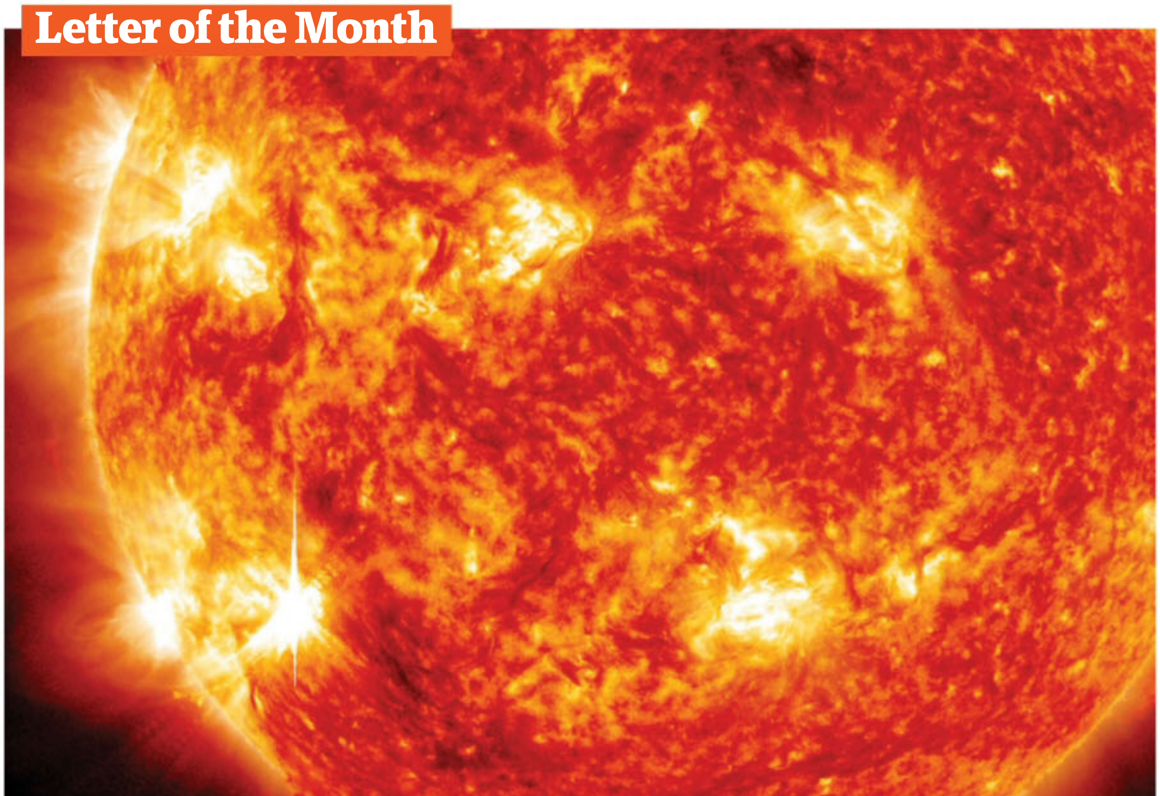
We enjoy reading your letters every month, so keep us entertained by sending in your questions and views on what you like or don't like about the mag. You may even bag an awesome prize for your efforts!

AMAZING PRICE FOR NEXT ISSUE'S LETTER OF THE MONTH!

MUSIC ON THE GO

Next issue's letter of the month will win an awesome Sony iPod dock. Get crystal-clear audio from your MP3 player on the go as it's portable as well.

Letter of the Month



Great balls of fire

The Sun isn't burning in a conventional way, instead producing energy from colliding hydrogen atoms

Dear **HIW**,

I love your magazine, it demonstrates perfectly how science reaches every corner of our lives; even the things we take for granted have science behind them without us realising it. But I personally like those bits of science that always seem to contradict the things we were taught at school.

Please therefore answer me this question: When to extinguish a fire one only needs to starve it of oxygen, how is it possible for the Sun to burn away, and spew out solar flares, while it is suspended in a total vacuum such as space?

David Moss

Very good point, David. Fire does indeed require oxygen to burn, but the crucial thing to learn is that the Sun isn't actually burning in the way fire does on Earth.

What is actually happening on our Solar System's star is a vast number of nuclear reactions. Hydrogen atoms are constantly smashing together at huge speeds to create helium, releasing energy that we experience as heat and light. This nuclear reaction is what keeps the Sun 'burning', as opposed to the chemical reaction that occurs when you light a match and oxygen helps ignite a spark.

© NASA; Corbis

Relatively useful theories

Dear **HIW**,

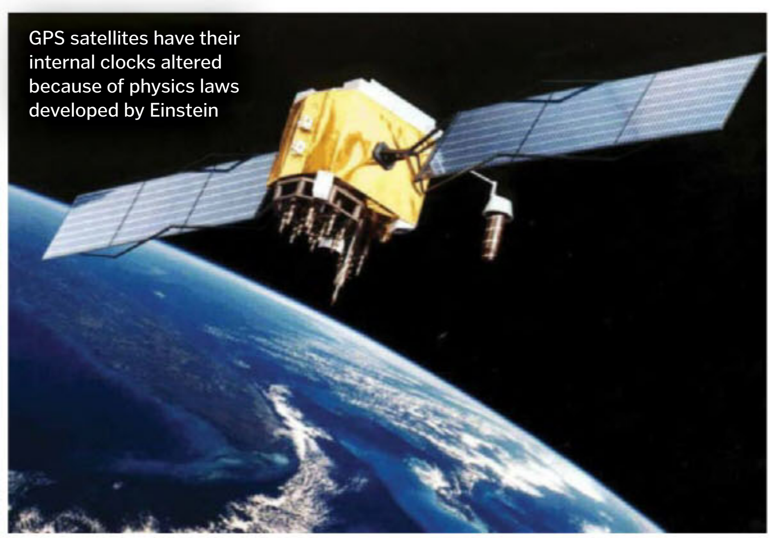
As a non-physicist I have a very basic understanding of Einstein's theories. What is its significance in our everyday lives? How did the theories revolutionise our understanding of the world?

Geoff

Einstein's theories changed what we knew about time by showing it wasn't always constant. Essentially, special relativity shows that time on a moving clock will run slower than the time on a stationary one. General relativity states that the closer you are to a large mass, the slower time seems to pass for you. But these effects are only noticeable on a large scale.

An example of both theories in action is the use of GPS devices, just like those in your smartphone or satnav. These determine your location thanks to the network of GPS satellites orbiting Earth. Because satellites travel so fast, their clocks run slower compared to the clock on your Earthbound device, as per the theory of special relativity.

However, due to general relativity, time also runs faster because satellites are further away from the huge mass of our planet. Since the satellites aren't travelling anywhere close to the speed of light the effects due to general relativity are dominant so overall, time runs faster on the satellites than they do on Earth. If GPS satellites didn't correct for this time difference, your device would not be able to tell you where you were!



GPS satellites have their internal clocks altered because of physics laws developed by Einstein

Robots already make decisions on their own such as Asimo

Robotic reactions

■ Dear **HIW**,
There is a question that has always been bothering me. I know a robot is a computer, but is a robot programmed differently to a computer so its reactions are more intense and effective? And if it's a yes, what is the difference between them? Also, in the future, will robots be able to react with independent emotions, thoughts and expressions? I would be grateful if you can answer.
Adithya Siddhathan

It's pretty tough to actually tie down a definition of a computer or a robot because the goalposts are moving all the time in terms of what is possible. Robots will often perform a physical function, like the robotic arms that build cars, while computers will run programs and complete technical tasks. Robots tend to be more mobile as well. As regards the future of robotics, there's a great article in issue 58 that explains how robots with artificial intelligence – even emotional intelligence – would work.

"General relativity states that the closer you are to a large mass, the slower time seems to pass for you"

Moon mining

■ Dear **HIW**,
Are there minerals underneath the lunar surface? If so, what type are they and could they be useful to us here on Earth?
Tom Read

Yes Tom, there are plenty of minerals on the Moon. Substances such as aluminium, calcium, magnesium, titanium and iron can all be found on the Moon. It can be mined but would take an enormous effort to do so. The most valuable substance on the Moon is helium-3, which could revolutionise our future energy needs as it would be a very efficient fuel for fusion reactors.

The Moon holds many similar minerals to Earth as well as the hugely valuable helium-3

What's happening on... Twitter?

We love to hear from **How It Works'** dedicated followers. Here we pick a few tweets that caught our eye this month...

Andy Giles Associates
Boom! @RothAudio POWA-5 wins **@HowItWorksmag** Bluetooth speaker group test. The only 5/5 product on show, too.

Meshell Heelbeck
@HowItWorksmag Sweet dreams are made of cheese (who am I to dis-a-brie) #cheesesongs

Rebecca Fletcher
@HowItWorksmag Can this be gotten from local newsagents? My little hero is obsessed with cars. Would absolutely make his day!

Adrian R
@HowItWorksmag Issue 65 pg 80, we are all being pulled into the Sun all the time. It's what keeps us in orbit.

Cory West
How to make a car in 86 seconds **howitworksdaily.com/how-to-make-a-car-in-86-seconds/** via **@HowItWorksmag**

Colin Bowett
@HowItWorksmag Dr Haven't Got a Clue #LesserBondMovies

Laura Berg
The architecture of the underground spaces – still impressive! **Howitworksdaily.com/roman-architecture/** via **@HowItWorksmag**

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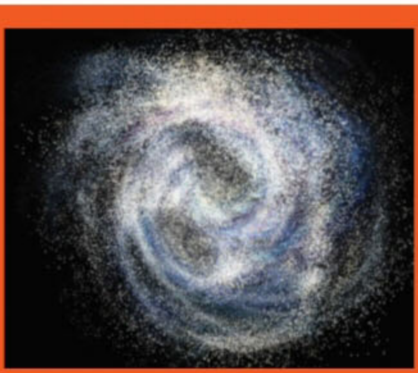
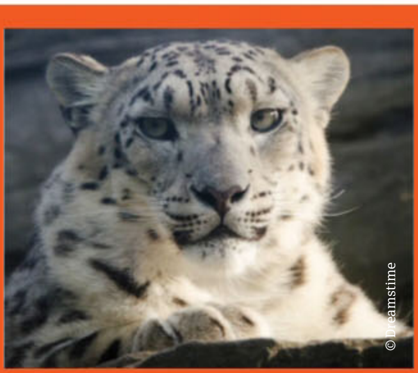


Come on an alphabetical journey through space



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