THE MAGAZINE THAT FEEDS MINDS

HOW IT WORKS™

SCIENCE | ENVIRONMENT | TECHNOLOGY | TRANSPORT | HISTORY | SPACE

INSIDE

JETS

AND NINE OTHER AMAZING VEHICLES

ALIEN EARTHS
Discover the strangest exoplanets ever found

VOLCANIC LIGHTNING

Fire tornadoes

FIRE RAINBOW

FINDING FOSSILS
Unearth the secrets of our prehistoric past

DUST STORMS

Huge hailstones

\+ LEARN ABOUT
- 3D PENS
- ARMOUR
- EDIBLE MIST
- MARS CROPS
- WEIGHT LOSS
- LIGHT WAVES
- ELECTRIC EELS
- WHITE BLOOD CELLS

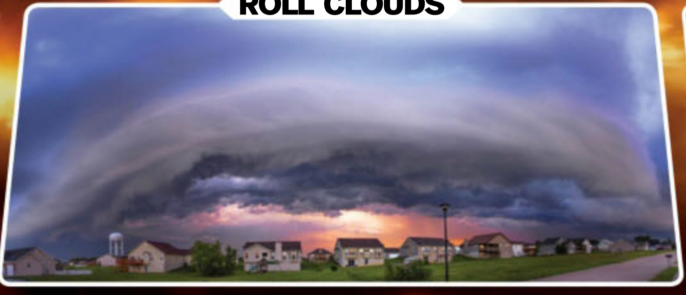
WORLD'S WEIRDEST WEATHER

288 AMAZING IMAGES & CUTAWAYS INSIDE

16 UNBELIEVABLE EVENTS AND THE SCIENCE BEHIND THEM

FALLSTREAK HOLE

ROLL CLOUDS



SPRITES AND ELVES

POWER OF CRYOGENICS
How low temperatures can save lives

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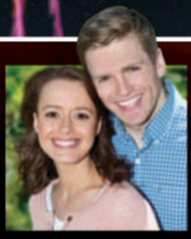
ISSUE 69

HOW WE FALL IN LOVE
Find out the surprising effects on your brain



WELCOME

The magazine that feeds minds!

Page 24
Learn all about the life cycle of a red-eyed tree frog

It's never boring in **How It Works** HQ. We've been playing with Robocop – our office robot (you helped us name him on Facebook!) – peering through microscopes (and asking you to guess what we saw on Twitter), and talking about the weather. Okay, that last one sounds pretty dull and typically British, but it's far from it. For our cover feature, we rounded up the wildest weather on the planet – frog rain and fire tornadoes included. You'd think this was the forecast from Will Smith's latest apocalyptic movie, but there's real science behind these strange phenomena. Jo had the pleasure of presenting this crazy weather report, while Jackie busied herself researching the world of cryogenics (and coming up with brilliant puns). You may have heard the rumours Walt Disney was frozen this way, but there are plenty more amazing uses for this scientific field. And a trip to the Natural History Museum and my favourite exhibit – Dippy the Diplodocus – sparked an idea for an article about how fossils are found. Hope you have as much fun reading the issue as we did making it!

Jodie

Jodie Tyley
Editor

Meet the team...

Andy
Art Editor
It's not too much longer to wait until *Jurassic World* comes stomping into cinemas, but the feature about how to find fossils should help to tide you over until then.

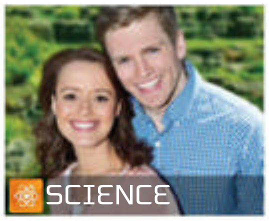
Jackie
Research Editor
Discover the coolest subject in science, literally. Cryogenics isn't all about frozen bodies. Scientists use temperatures colder than the depths of space to improve things from medical treatments to electronics.

Erlingur
Production Editor
The Earth's greatest threats article serves as a stark reminder of the growing dangers we face from objects orbiting our planet. However, there is surprisingly no mention of Decepticons.

Jo
Senior Staff Writer
Weather can be more bizarre and exciting than you might think. From animal rain to singing sand dunes, we take a look at some the oddest examples on page 14 and reveal the science behind them.

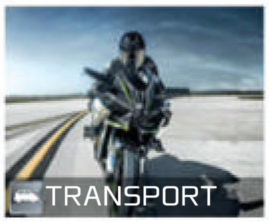
What's in store

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



What happens to our brains when we fall in love? **Page 33**

How do electric eels hunt their prey? **Page 24**



What are the most extreme vehicles on Earth? **Page 46**

How can you taste with zero calories? **Page 45**

Can we really grow crops in Mars soil? **Page 67**

How was armour made in Medieval times? **Page 78**

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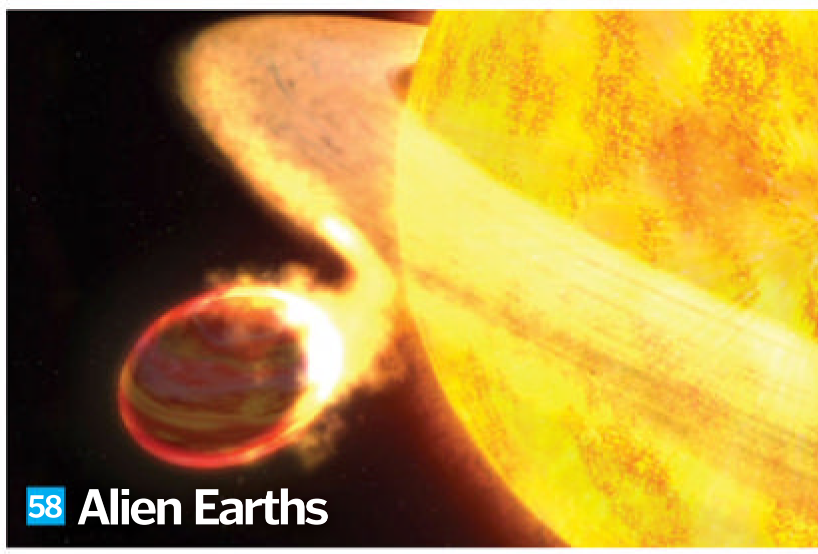
The science behind the planet's most spectacular, dangerous and bizarre weather phenomena

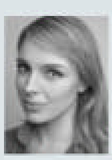
14 World's weirdest weather



58 Alien Earths

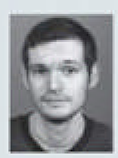
Meet the experts...

Laura Mears
Inside cryogenics
This month, science expert Laura takes on the cold world of cryogenics – the science of the production and effects of extremely low temperatures. Discover the incredible results on page 26.

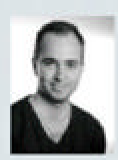


Hayley Paterek
Weight loss
How many of you have stuck to your New Year's resolution of going to the gym? If you're wondering where the pounds have gone – head to page 36 where Hayley has the answer.

James Hoare
Washington Cathedral
The Editor in Chief of **History Of War** and **All About History** shows us around the USA's second-largest church. He was delighted to discover it contains a gargoyle of Darth Vader's head!



Jack Griffiths
Sovereign yacht
Jack couldn't believe the luxury tech on board the exclusive 100-metre-long Sovereign superyacht. Find out why this is called the limousine of the ocean over on page 56.



Steve Wright
First sound in cinema
Steve is a huge movie fan as well as a history buff, so he is the perfect man to tell us how sound first came to cinema. He also explains the process of how mirrors are made.

How can you make a sparkling diamond out of peanut butter? Find out on pg 10

REGULARS

06

Taking apart a Supersonic car

Discover the inner workings of the Bloodhound Supersonic Car

In 2016, the Bloodhound Project aims to set a new land speed record of 1,610 kilometres (1,000 miles) per hour with a jet and rocket-powered car. The Bloodhound SSC contains 3,500 components, which weigh 7.5 tons in total. Its 135,000 brake horsepower comes from the Rolls-Royce EJ200 jet engine and a cluster of Nammo hybrid rockets, which were originally developed to power space launchers. A 550-horsepower supercharged Jaguar V8 engine can also be found on board, and is used to pump an oxidiser into the rocket to cause the combustion of the rocket fuel. Four aluminium wheels, a carbon-fibre shell and a 2.5-centimetre (one-inch)-thick windscreen complete the 13.47-metre (44-foot)-long vehicle.

The one to beat

Bloodhound SSC's driver Andy Green is the current land speed record holder, as he reached 1,228 kilometres (763 miles) per hour in the Thrust SSC on 15 October 1997. The car was the world's first supersonic car and was powered by two Rolls-Royce Spey 202 jet engines. Richard Noble, who broke the land speed record in Thrust2 in 1983, helped to develop the Thrust SSC, and is the project director of the Bloodhound SSC.

The 1997 record run took place at the Black Rock Desert in Nevada, USA, but a lack of rain and heavy use – mainly by the popular Burning Man festival – has left its surface in poor condition. Therefore, after an extensive search for suitable new desert locations, the Bloodhound SSC team have chosen to make the record attempt in Haksheen Pan in South Africa.

The Thrust SCC is now on display at the Coventry Transport Museum in England

The Bloodhound SSC should be able to go from 0-1,000mph in about 55 seconds

Great Blue Hole reveals ancient secrets

New clues about the fall of the Mayan civilisation discovered

A massive sinkhole off the coast of Belize has provided new evidence for the theory that major droughts caused the collapse of the Mayan civilisation. Scientists studying sediment samples from the Great Blue Hole found that it contained very little titanium and aluminium, elements pounded out of rock and into the sea by heavy rain. This suggests there were very low levels of precipitation and a drop in the frequency of tropical cyclones between the years 800 and 1000. This would have lead to major droughts during this period and between 1000 and 1100, by which time most major Mayan cities had fallen.

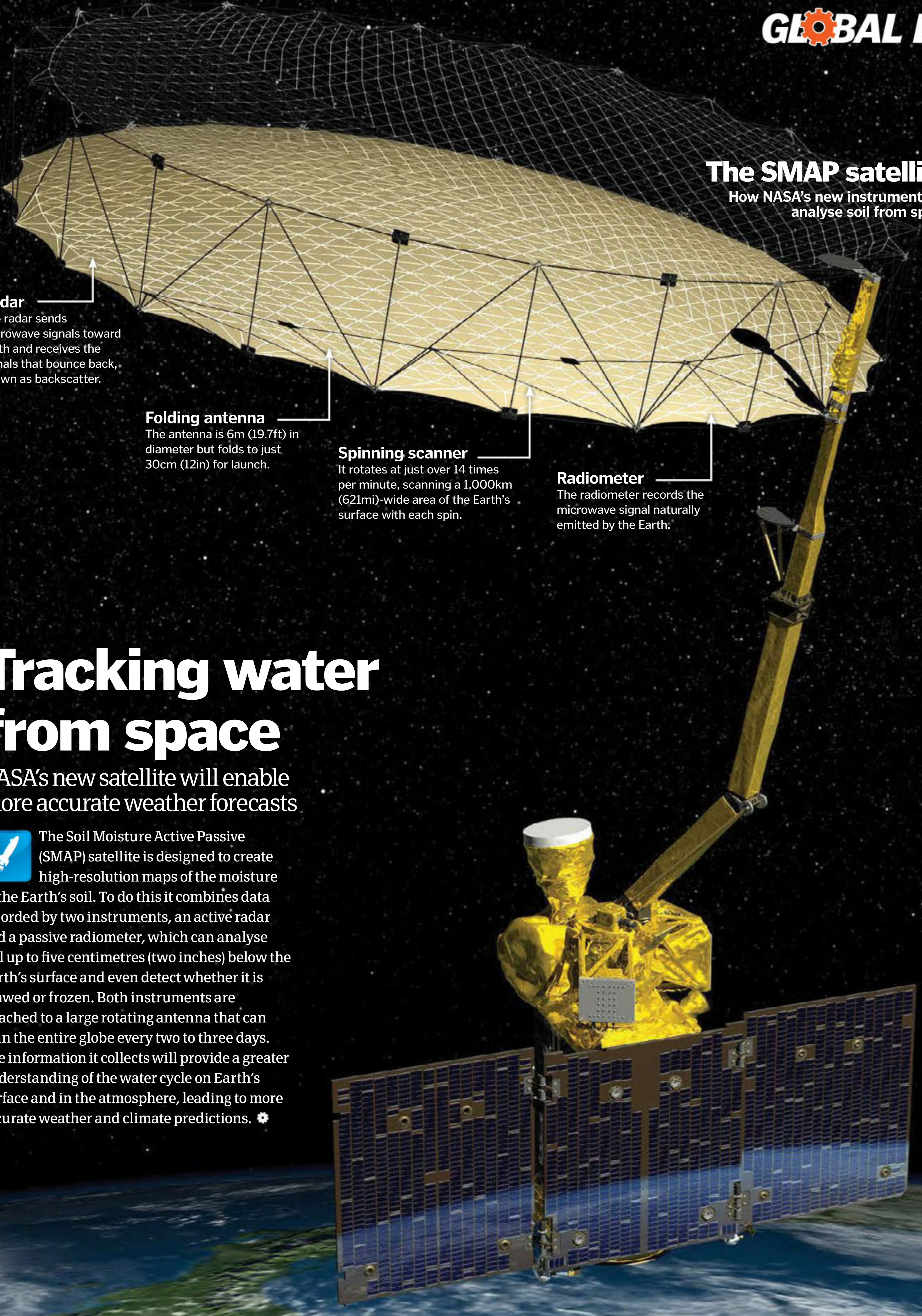
The Great Blue Hole began as a limestone cave about 150,000 years ago, but flooded to form a sinkhole

Disco clam's flashy light show

Bizarre mollusc lights up the ocean when excited or scared

The Ctenoides ales mollusc got its 'disco clam' nickname after it was seen producing a strobe-light effect. Rather than producing light itself, the creature reflects ambient light off of spheres of silica in its lips. The high-speed flashing effect is created when it quickly opens and closes. Although this behaviour was already known, scientists have only recently discovered its purpose. When either prey or a predator approaches, the flash-rate increases, signalling that the creature is excited or scared. Prey is attracted to the light, moving closer to the clam, while predators ignore it.

The disco clam is native to the coral reefs off of the coast of Indonesia



Tracking water from space

NASA's new satellite will enable more accurate weather forecasts

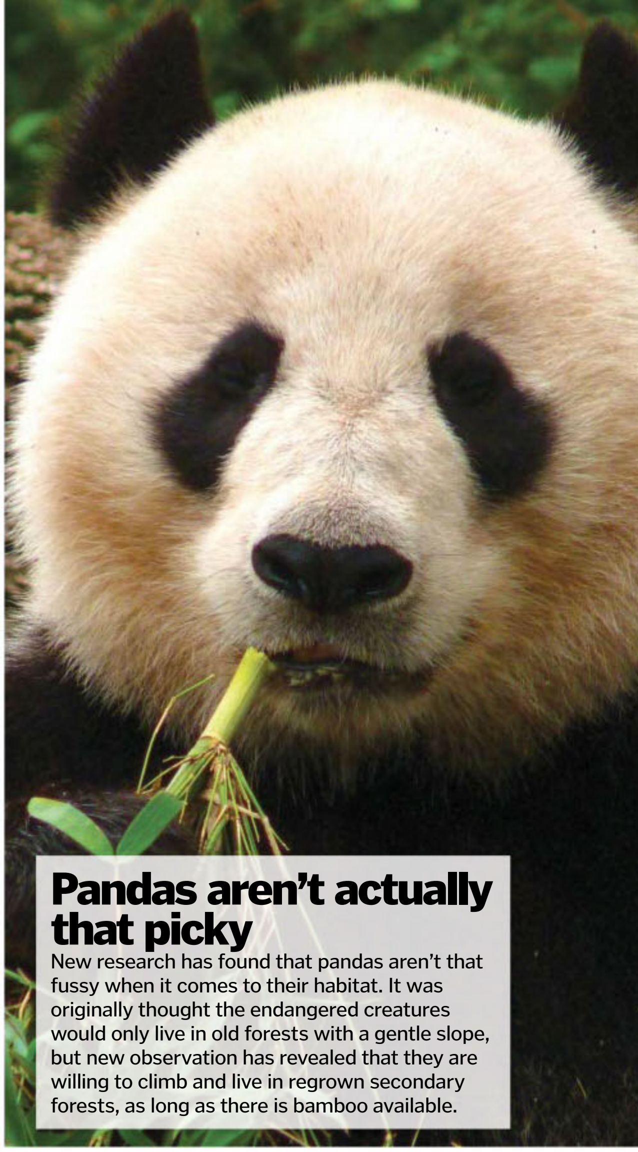
The Soil Moisture Active Passive (SMAP) satellite is designed to create high-resolution maps of the moisture in the Earth's soil. To do this it combines data recorded by two instruments, an active radar and a passive radiometer, which can analyse soil up to five centimetres (two inches) below the Earth's surface and even detect whether it is thawed or frozen. Both instruments are attached to a large rotating antenna that can scan the entire globe every two to three days. The information it collects will provide a greater understanding of the water cycle on Earth's surface and in the atmosphere, leading to more accurate weather and climate predictions.

GLOBAL EYE

10 COOL THINGS WE LEARNED THIS MONTH

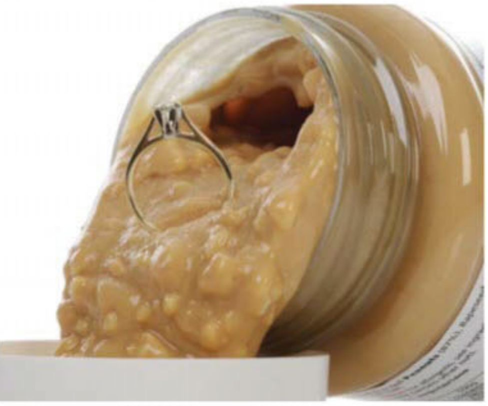
Viking conquests were a family affair

The common notion that Vikings were violent raiders and pillagers who terrorised foreign lands has been challenged. A new study of ancient Viking DNA suggests that Viking men brought their wives along when colonising new territories, instead of bringing them over once they had settled. It shows that women were a more significant part of the colonisation process than first thought and helped to grow crops and establish settlements and trade.



Pandas aren't actually that picky

New research has found that pandas aren't that fussy when it comes to their habitat. It was originally thought the endangered creatures would only live in old forests with a gentle slope, but new observation has revealed that they are willing to climb and live in regrown secondary forests, as long as there is bamboo available.



Diamonds can be made from peanut butter

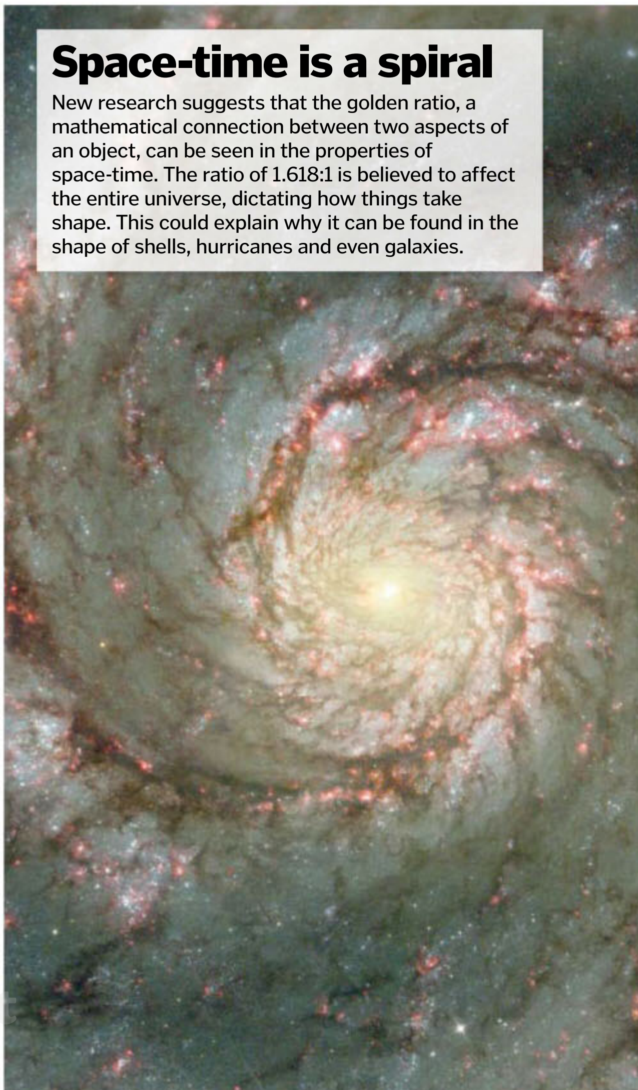
Geophysicists trying to simulate conditions inside the Earth have found a new way to create diamonds. In nature, it's thought that carbon dioxide is pulled out of the ocean and into rocks, which get drawn down into the Earth. In the mantle, iron strips it of its oxygen, leaving just the carbon, which is turned into diamond under high heat and immense pressure. By recreating this process, they were able to form diamonds from peanut butter, which contains carbon.

Rosetta inspired new submarine tech

An instrument similar to the one the European Space Agency recently landed on a comet could help to save lives on future submarines. The analyser device continuously monitors the environmental atmosphere on-board and can identify dozens of different gases in under a minute. This enables the crew to react quickly to any dangerous build-up of gases, potentially saving lives.

Space-time is a spiral

New research suggests that the golden ratio, a mathematical connection between two aspects of an object, can be seen in the properties of space-time. The ratio of 1.618:1 is believed to affect the entire universe, dictating how things take shape. This could explain why it can be found in the shape of shells, hurricanes and even galaxies.

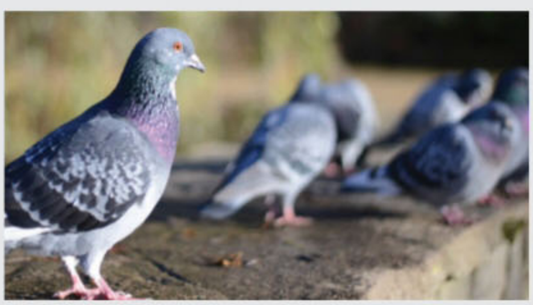


Star Wars holograms could become reality

San Francisco-based company Bleen Inc has developed a device that projects three-dimensional holographic images you don't need special glasses to view. It is designed to create a more immersive TV and gaming experience, as well as aid design and even exercise. The company has launched a crowd-funding campaign for the final development, but hopes the product will be delivered by October 2015.

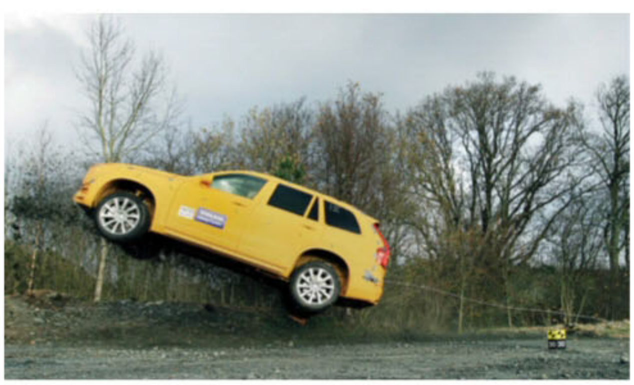
Jupiter's spot is sunburn

After analysing new data, NASA experts now believe that Jupiter's Great Red Spot is actually a product of simple chemicals being broken apart by sunlight in the planet's upper atmosphere. This contradicts the other leading theory that the reddish chemicals come from beneath Jupiter's clouds.



Pigeons have a built-in gyroscope

The method pigeons use to find their way home has always been a mystery, but experts now believe they use a gyroscope-like area in their brain to navigate. By comparing the memory of their 'home gyroscope setting' with their 'local gyroscope reading' they can set a bearing for home, but disturbances in the gravitational field will send them in the wrong direction.



A roller-coaster robot tests car safety

A visit to Legoland with his daughters inspired Volvo's safety expert Anders Axelson to develop a new method for testing seats and safety belts. He noticed the way people were thrown around by the amusement park's Robocoaster ride resembled the movements felt in a run-off road crash, and so found a robot that could mimic the same actions.

The tongue taste map is wrong

A new study has revealed that the brain has specialist neurons for each of the five taste categories. The 8,000 taste buds on the tongue can sense all tastes, but send a message to the brain to work out which is which.

GLOBAL EYE
INTERVIEW

Kevin Fong

“Mars is reachable, but it’s how much risk your crew is willing to accept”

Could we really colonise Mars? One of the world’s leading experts on extreme environments has the answer for us

Kevin Fong is a scientist, but beyond that he’s hard to categorise. An anaesthetist by profession, he’s also a lecturer on extreme environment physiology and has worked at NASA, specialising in space medicine and human space exploration. He’s presented several documentaries on space and surgery, as well as championing further study into cures for dementia as part of the £10 Million Challenge, a competition to fuel research in a particular area of scientific concern.

We caught up with Fong at the finals of the Astellas Innovation Challenge, which he helped to judge. The competition asked schoolchildren to develop an app that promotes healthy living in a bid to make the next generation keener to study STEM subjects. We focused on one of the things that is occupying an awful lot of How It Works’s attention at the moment – colonising Mars, as well as finding out about some of his recent projects and what drew him to science in the first place.

What are our chances of reaching Mars in the near future?

It’s the most extreme experiment on our horizon at the moment and it’s already on the edge of possibility. If you were willing to go now and accept significant risk and extreme discomfort you could just about get there. You’d need a lot of money and you could probably do it, but it would take the kind of investment we last saw during the Apollo project. It is eminently achievable within the 21st century at some point. If you were talking to me in 1914 you might ask what the problem is with climbing Everest, exploring the Mariana Trench or going to the Moon. All of those things would look absurd at the time but all would be done within 50 years.

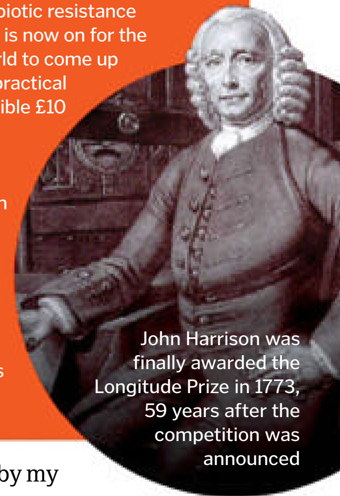
What are the obstacles to reaching Mars?

In truth there isn’t a fundamental science obstacle. That target is reachable, but it’s how much risk your crew is willing to accept. There is risk to life, discomfort and risk of catastrophic failure. I’d say the main obstacles are finance and political will, because we are not the same world as the one that went to the

Kevin (far right) with the winners of the Astellas Challenge

Big challenges

The £10 Million Challenge was conceived as a catalyst to find a solution to one of the biggest scientific issues of the day. The six issues in contention were: environmentally sound flight, world hunger, antibiotic resistance, helping people with paralysis, access to safe drinking water and aiding people with dementia. The issue of preventing the rise of antibiotic resistance came out on top. The race is now on for the brightest minds in the world to come up with a cost-effective and practical solution and win an incredible £10 million ($16 million). The competition is a modern twist on the Longitude Prize, a similar competition launched by the British government 300 years ago. The £20,000 prize was awarded to clockmaker John Harrison who devised a solution to the problem of how sailors could determine their



John Harrison was finally awarded the Longitude Prize in 1773, 59 years after the competition was announced

"If someone had offered me a seat on the Shuttle I'd have been packed and gone"

Moon. I don't think people understand the role of commercial access to space. I think the idea that someone is going to Mars in the way you might take a balloon across the Atlantic is misunderstood. There is a role for commercial access and it's the same role commercial interests have had in all programmes of exploration. The proliferation of teams in Antarctica in the mid-20th century happened because the scientists bought commercial architecture such as ships, planes and clothing. I think that's how it will happen for space. Someone like Elon Musk may make it safer and more affordable to get to low Earth orbit and I think international programmes will use that as their starting point for getting to Mars. Energetically that makes sense because the hardest 250 miles [400 kilometres] in spaceflight is the first 250 miles, so leaving that to a commercial access group could work.

What do you think about companies like Mars One offering trips to Mars?
I'm not sure what to make of Mars One. There's a generation of people who see a one-way trip to a foreign land in the same way people in the 1800s saw a one-way trip to Australia or America. Philosophically I understand it, but technologically I haven't seen enough of their plans to know if that's a real project. Of all the things that are out there at the moment in terms of Mars exploration, like NASA and ESA's projects, that's the one that has the least flesh on bones so it's difficult to judge.

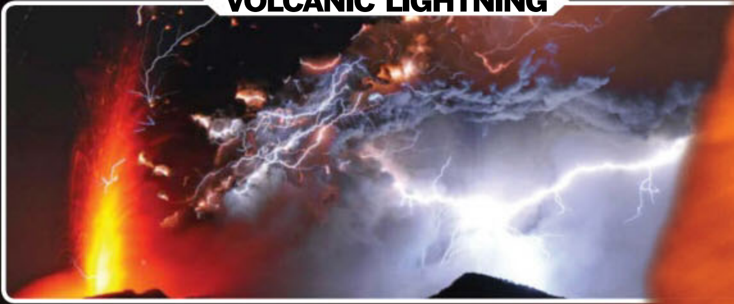
If you were offered a seat on the first spaceship to Mars, would you take it?
If someone had offered me a seat on the Shuttle I'd have been packed and gone. Soyuz; packed and gone. The Moon; after a bit of hesitation, packed and gone. Mars is an interesting one because they estimate a high risk of catastrophic failure. There's also the impact on your life to consider. Round trips are going to be a year and a half, maybe three years, and with a small family I think it would be a much different conversation. If my kids were grown up and someone offered me a seat, like they did with [the first American to orbit the Earth] John Glenn, then yeah, I probably would go.

What made you choose the fight against dementia as the cause to champion in the £10 Million Challenge?
I think it's because old age is so often overlooked. It's not the sexiest charity, it's not the one people run marathons for and you don't get big television appeals for it. With every other destination we explore, this one will be met with fear and trepidation and I would like to reduce the fear people have of that.

What sparked your interest in science?
The first thing I remember is being woken up in the middle of the night by my parents to watch the Apollo-Soyuz rocket launch in 1975. It was amazing to see the astronauts floating around and countries exchanging flags through airlocks. In truth there must have been much more, but that early memory was just the tip of the iceberg of what my parents were teaching me. Two teachers from my primary school saw my interest in science and encouraged me. In secondary school I was lucky that some of the most impressive teachers I had were science teachers or maths teachers. I didn't feel I was particularly special but I enjoyed it.

Why are events such as the Astellas Challenge so important?
We need to provide this generation with a gateway to their future and it's not going to be that Victorian ideal of rote learning, grammar and times tables. Those are still important skills, but the jobs we're preparing them for haven't been invented yet and you need to give them that agility and flexibility. You can't make people do STEM subjects; they have to enjoy them. I can't speak for anyone else, but in my job there are parts that I enjoy in the way a small child might enjoy, like bumbling off on adventures, going in helicopters and dressing up in surgical scrubs and that's got to be okay in a profession. If there's not some small part of your job that you enjoy in a way a five-year-old would enjoy then you need to find another job. It's not so much about trying to make them believe that it's fun, but making them realise the fun that's in there already.

VOLCANIC LIGHTNING



FIRE RAINBOW

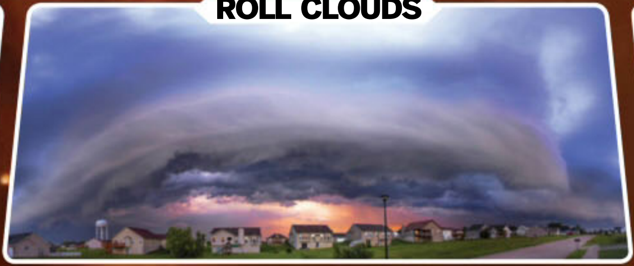
WORLD'S WEIRDEST WEATHER

The science behind our planet's most spectacular, dangerous and downright bizarre weather phenomena

Weather key: Cloud, Wind, Sun, Heat, Cold, Rain, Lightning, Hail

FALLSTREAK HOLE

ROLL CLOUDS



DUST STORMS

Have you ever seen a swirling tornado of fire, or heard a sand dune sing? Perhaps you've witnessed balls of lightning floating in the sky or even been caught in a downpour of frogs. Even if you haven't, someone elsewhere in the world definitely has.

Although most of the weather we encounter on a day-to-day basis isn't particularly exciting, it can occasionally deliver some incredibly strange surprises. From enormous hailstones the size of tennis balls to towering clouds of dust that engulf entire cities, weather has the potential to be breathtaking, destructive and even explosive.

The basis for most weather is wind, water and temperature. Thunderstorms are the perfect example, as they involve all three at once. As the Sun heats the Earth, moisture in the air rises up into the cooler regions of the atmosphere via a strong updraft. When it gets high enough, the moisture condenses into water droplets, forming clouds and eventually precipitation. Colder air also sinks in strong downdrafts that create powerful horizontal winds. Thunderstorms are often the main catalyst for some of the world's most extreme weather, spawning lightning, hail and even tornadoes. However, wind, water and temperature can sometimes work in even more unusual ways to create bizarre weather phenomena that scientists are still trying to understand. Most weather, though, no matter how rare and unusual, can be explained by relatively simple science, and over the next few pages we will explore the fascinating processes that cause some of our planet's oddest examples.

RECORD BREAKERS
HAILSTONES

20.5cm

LARGEST HAILSTONE

A hailstone measuring 20.5cm (8in) in diameter and weighing almost 1kg (2lb), even after melting a bit, fell on the town of Vivian in South Dakota, USA in July 2010.

DID YOU KNOW? Approximately 24 people are injured by hail in the United States each year, but it rarely leads to fatalities

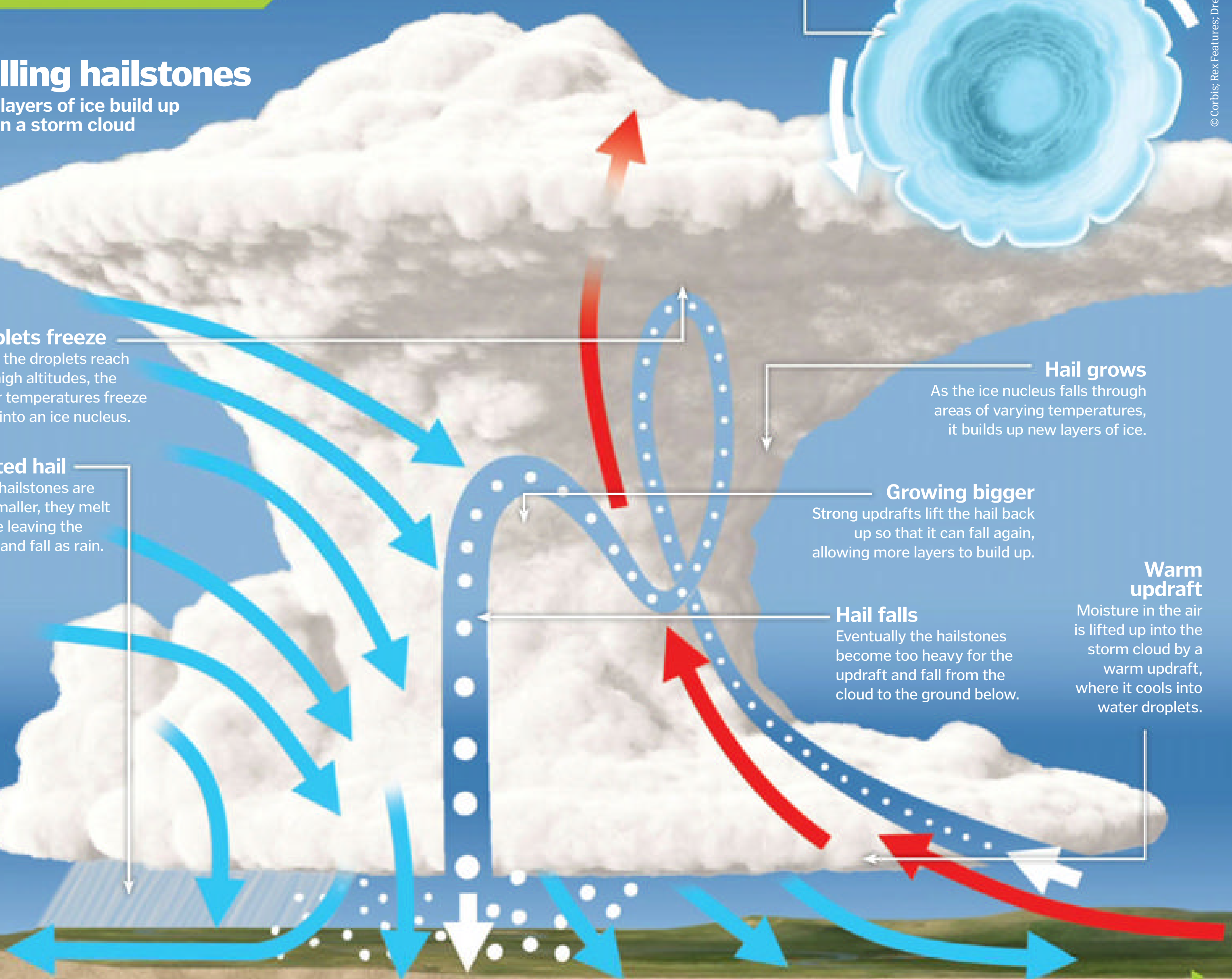
HUGE HAIL

The enormous balls of ice that fall from the sky

Rather than just being solid lumps of ice, hailstones actually consist of several layers, much like an onion. This makes them incredibly tough and allows them to grow to large sizes, creating hail that is extremely destructive. Hail is often confused with ice pellets, frozen raindrops that consist of one layer and are much weaker.

Rolling hailstones

How layers of ice build up within a storm cloud



"This lightning doesn't descend from storm clouds in the sky. It is generated within the ash cloud"

VOLCANIC LIGHTNING

The big eruptions that really light up the sky

A volcanic eruption is spectacular and violent enough as it is, but sometimes it is accompanied by big flashes of lightning too. However, this lightning doesn't descend from storm clouds in the sky. It is generated within the ash cloud spewing from the volcano, in a process called charge separation.

RECORD BREAKERS
STRIKING STATS

250 per km²

MOST LIGHTNING STRIKES

Venezuela's Catatumbo Lightning occurs almost every other night over the mouth of the Catatumbo River. On average, there are 250 lightning bolts per square kilometre per year.

DID YOU KNOW? *It's thought volcanic lightning of the Minoan eruption in 1500 BCE inspired Zeus's thunderbolts in Greek myths*

New discoveries
Volcanic lightning was a relatively understudied area of science until 2000, and its cause is still merely speculated.

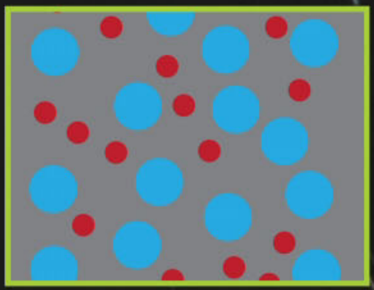
Ice crystals form
As temperatures are cooler at higher altitudes, the vapour cools and eventually turns into ice crystals, which collide to create lightning.

Difficult to study
Volcanic lightning typically occurs during the beginning stages of an eruption, making it very difficult to record and study.

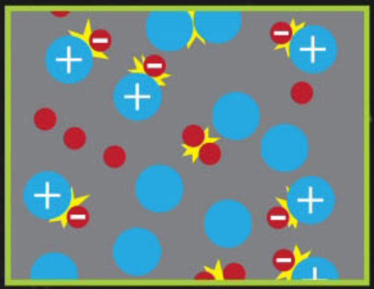
Water-laden magma
These ice particles form when water dissolved in the magma becomes vapour and rises out of the volcano during an eruption.

Initial sparks
The first sparks of lightning during an eruption are believed to be caused by ash particles colliding as they are ejected.

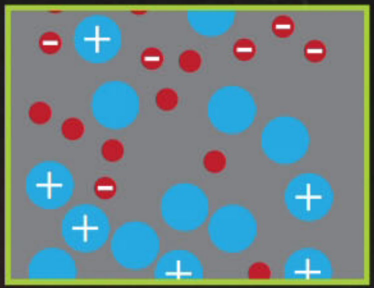
What is charge separation?



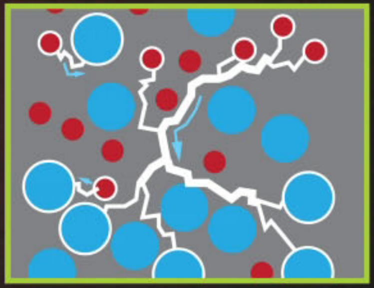
1 The particles within the cloud start out neutral, with an equal number of electrons and protons, meaning that they have neither a positive or negative charge to them.



2 As particles heat up, they collide and transfer electrons in a process known as charge separation. This causes some to become positively charged, and others negatively charged.



3 A difference in the aerodynamics of the positive and negative particles causes them to separate, so some parts of the cloud become more positive, and others become more negative.



4 The electrons flow back towards the positively charged particles when the charge separation gets too great. This forms sparks of electricity and neutralises the particles again.

"Roll clouds are a type of low horizontal cloud formation, known as an arcus cloud"

ROLL CLOUDS

The odd-shaped clouds that roll across the sky

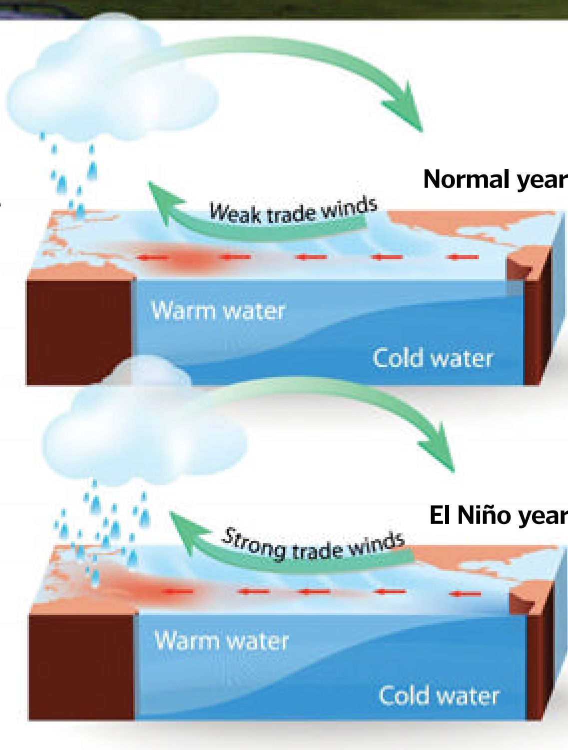
Although they look like horizontal tornadoes, roll clouds are actually completely harmless. Along with shelf clouds, which are more wedged-shaped, they are a type of low horizontal cloud formation, known as an arcus cloud. The difference is that shelf clouds are only created by thunderstorms and remain attached to the main storm cloud, while roll clouds can be formed by a number of different weather systems and are often independent from any other clouds.

They are the result of a mass of cold air meeting a mass of warm air, so can be formed by thunderstorms, cold fronts or sea breezes.

EL NIÑO

The cyclical weather change that causes unusually high ocean temperatures

Every few years, the trade winds that blow towards the west across the Pacific dwindle, causing a pool of warm water to form along the equator. As this warm water travels eastward, it triggers severe weather, such as increased rainfall and flooding in North and South America, and extreme drought in the West Pacific. South American fishermen named the phenomenon El Niño, Spanish for "The Christ Child," because it usually arrives around Christmas time.



RAINING ANIMALS

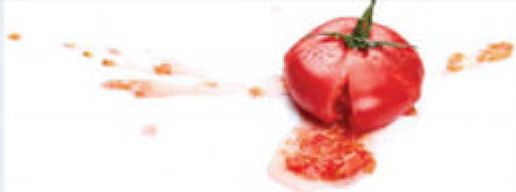
The very real threat of amphibious rain

Although there are no accounts of it actually raining cats and dogs, other animals, such and fish and frogs, have been seen to fall from the sky in some parts of the world. This occurs when waterspouts – small tornadoes that form over water – suck up low-weight items, such as small creatures, with their low-pressure core. When these waterspouts hit land, they lose some of their energy and slow down, releasing whatever it is that they are carrying. Their spinning winds can reach up to 480 km/h (300mph), helping them to suck up objects from up to 1m (3ft) below the surface.

STRANGE BUT TRUE
HARD RAIN

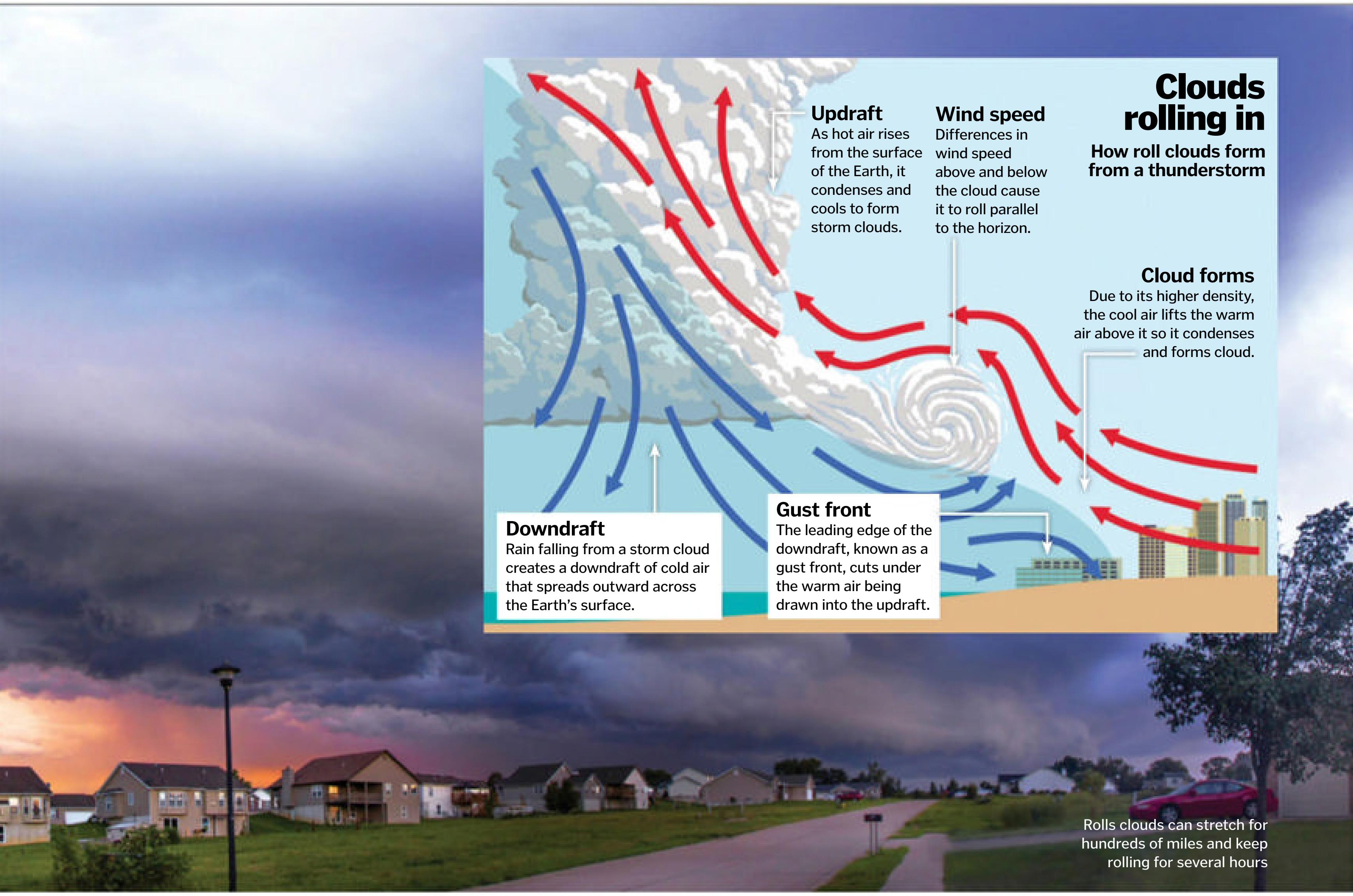
Which of these has fallen as rain?

A Tomatoes **B** Coal **C** Meat



Answer:
While frogs and other sea creatures are the most common form of unusual rain, sightings of tomato, coal and even meat falling from the sky have also been recorded. It's likely that they were picked up and dropped by strong winds and tornadoes.

DID YOU KNOW? *Hail can come from any thunderstorm, but large hail is most common in rotating thunderstorms called supercells*

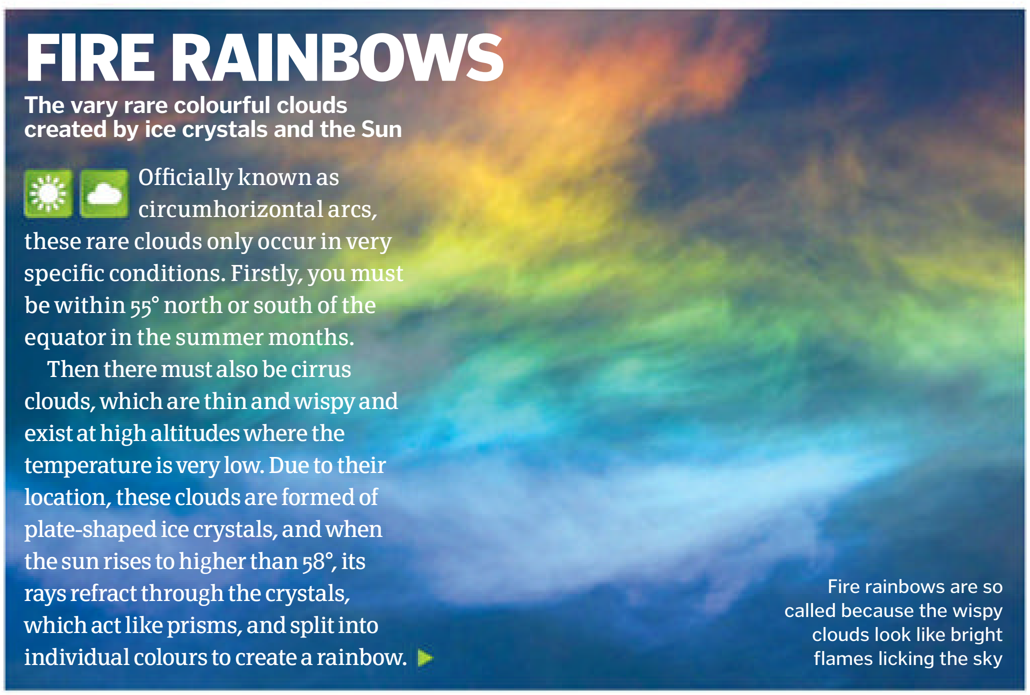


Rolls clouds can stretch for hundreds of miles and keep rolling for several hours

ST ELMO'S FIRE

The flames and sparks that climb ship masts and church steeples

Named after St Erasmus, the patron saint of sailors, St Elmo's Fire is the glow of blue flames often observed at the top of tall structures, such as ship masts, in a thunderstorm. It occurs due to charge separation, just like lightning. However, it involves a difference in charge between the air and an object, rather than the air and the ground. It is most common on pointed objects as they discharge electrical energy at a lower voltage level.



FIRE RAINBOWS

The vary rare colourful clouds created by ice crystals and the Sun

Officially known as circumhorizontal arcs, these rare clouds only occur in very specific conditions. Firstly, you must be within 55° north or south of the equator in the summer months.

Then there must also be cirrus clouds, which are thin and wispy and exist at high altitudes where the temperature is very low. Due to their location, these clouds are formed of plate-shaped ice crystals, and when the sun rises to higher than 58°, its rays refract through the crystals, which act like prisms, and split into individual colours to create a rainbow. ▶

Fire rainbows are so called because the wispy clouds look like bright flames licking the sky

"Firenadoes can move quickly and eject flaming debris, helping to spread the fire further"

FIRENADOES

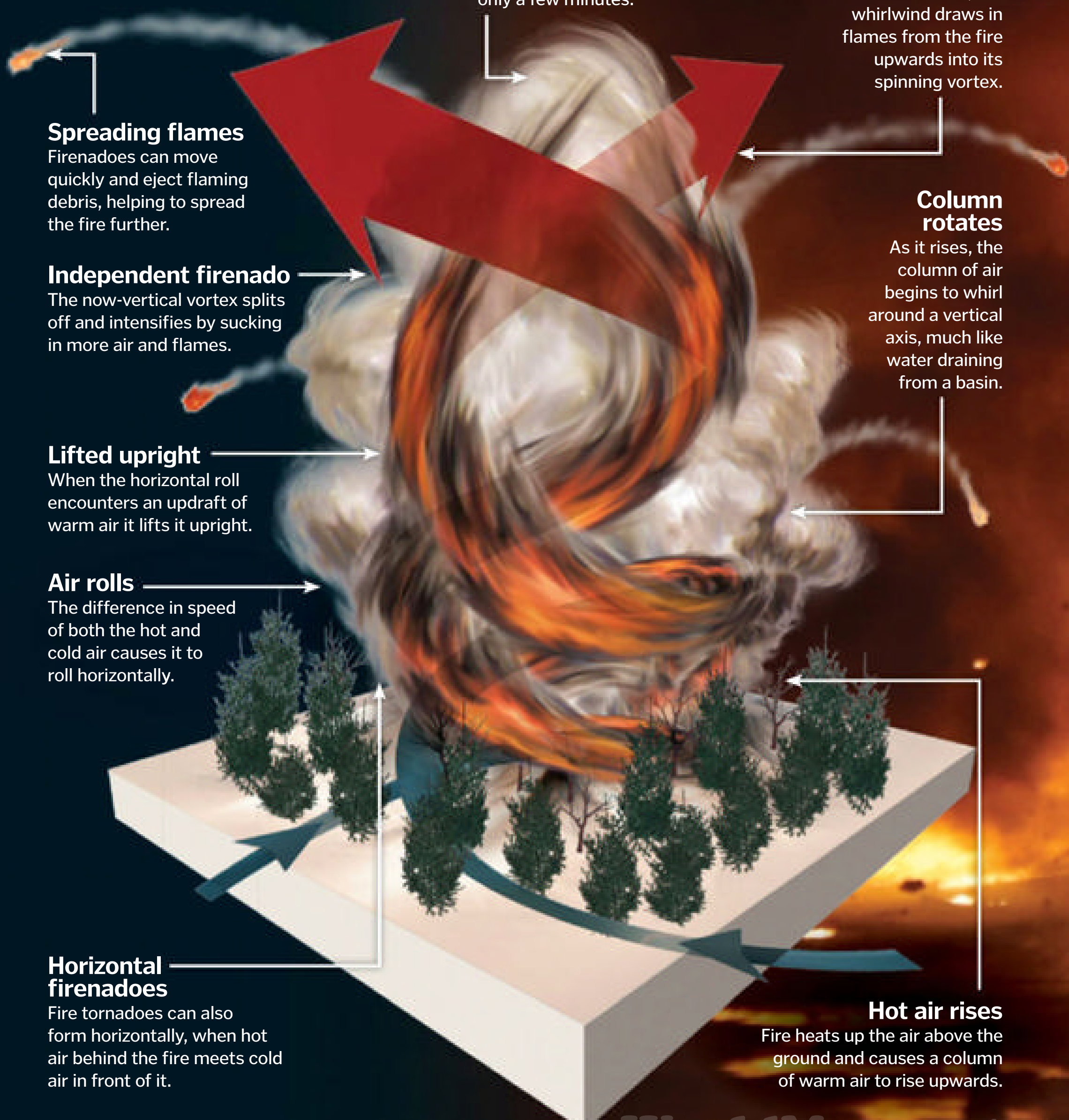
The deadly tornadoes with added fire

Firenadoes are actually more closely related to whirlwinds and dust devils than tornadoes, which is why they are also known as fire whirls and fire devils. They usually grow from wildfires, but have been spotted at the scene of house fires too, and can vary greatly in size.

Firenadoes are usually small, but some have grown to be 122m (400ft) tall and 15m (50ft) wide

Great whirls of fire

What fuels a dangerous spinning vortex of flame?



5 TOP FACTS DUST STORMS

Haboobs
1 Dust storms are named after the winds that generate them. So a haboob is generated by the strong wind that occurs primarily along the southern edges of the Sahara in Sudan.

Amazon lifeline
2 20 million tons of dust is transported from the Sahara to the Amazon rainforest each year, supplying it with essential minerals and nutrients to keep the soil fertile.

The Dust Bowl
3 Severe drought in the USA's Great Plains in the 1930s caused a period of dust storms called the Dust Bowl. Agriculture was severely affected and hundreds of thousands of people were displaced.

Blood rain
4 Clouds can transport dirt from dust storms for thousands of miles. It eventually falls as rain, which leaves a reddish dust when it dries, leading it to be labelled 'blood rain'.

Harmful dust
5 The dust in dust storms can sometimes carry pollutants and toxins, such as salt, sulphur and pesticides, that can damage crops and be harmful to living things.

DID YOU KNOW? Specific sprites are classified by shape. Carrot sprites, broccoli sprites and jellyfish sprites have all been identified

DUST STORMS

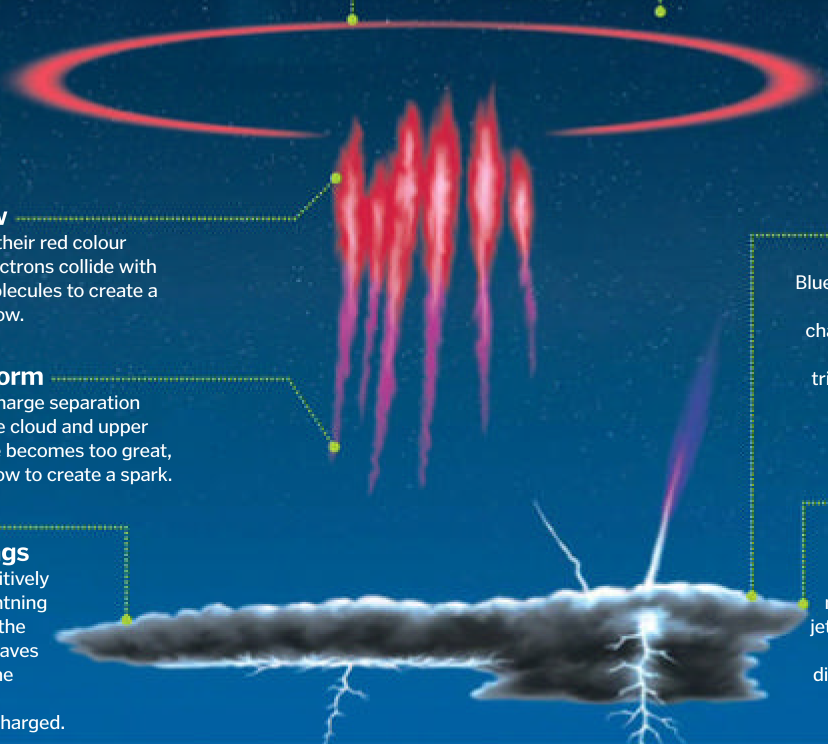
The blizzards of dirt that black out the sky

Dust storms are started by gust fronts, the downdrafts of cold air from thunderstorms that hit the ground and spread outward. As the wind passes over the ground, it moves the dust particles and starts a process called saltation. When the particles bounce along to the surface, they start a chain reaction, hitting other particles and causing them to bounce too. As these particles hit each other and the ground, they acquire a negative charge that repels them from the positively charged surface. This lifts them higher, where they get picked up by the wind and blown further.

Dust storms originate in arid or semi-arid regions where the soil is dry and loosely held on the surface

Elusive light show

What causes transient luminous events?



Electromagnetic pulse
Elves are caused by the abrupt, rapid acceleration of electrons, known as an electromagnetic pulse (EMP), in a lightning strike.

Colourful halo
As this energy passes upward through the base of the ionosphere and spreads outward, it causes gases to glow red.

Red glow
Sprites get their red colour because electrons collide with nitrogen molecules to create a colourful glow.

Sparks form
When the charge separation between the cloud and upper atmosphere becomes too great, electrons flow to create a spark.

Sprite beginnings
When a positively charged lightning bolt strikes the ground, it leaves the top of the storm cloud negatively charged.

Upwards lightning
Blue jets occur when a large positive charge at the top of a storm cloud triggers an upward lightning strike.

Tall storm clouds
The higher the storm cloud, the more likely a blue jet is to appear, but they are not directly associated with cloud-to-ground lightning.

SPRITES, ELVES AND BLUE JETS

The flashes of light that occur high above storm clouds

As well as the regular lightning that we experience in the troposphere, the lowest layer of the Earth's atmosphere, thunderstorms can also generate further activity much higher up. Transient luminous events (TLEs) are colourful flashes of light that occur in the middle and upper atmosphere and take the form of sprites, elves or jets. As they are very rare and last for just a fraction of a second, these phenomena are usually impossible to see with the naked eye and very difficult to capture on camera and study. Very little is known about them, but high-sensitivity cameras and observations from space are helping scientists to learn more.

"Secondary rainbows appear fainter because only some of the light is reflected a second time"

The colours in secondary rainbows are reversed, with blue on the top and red on the bottom

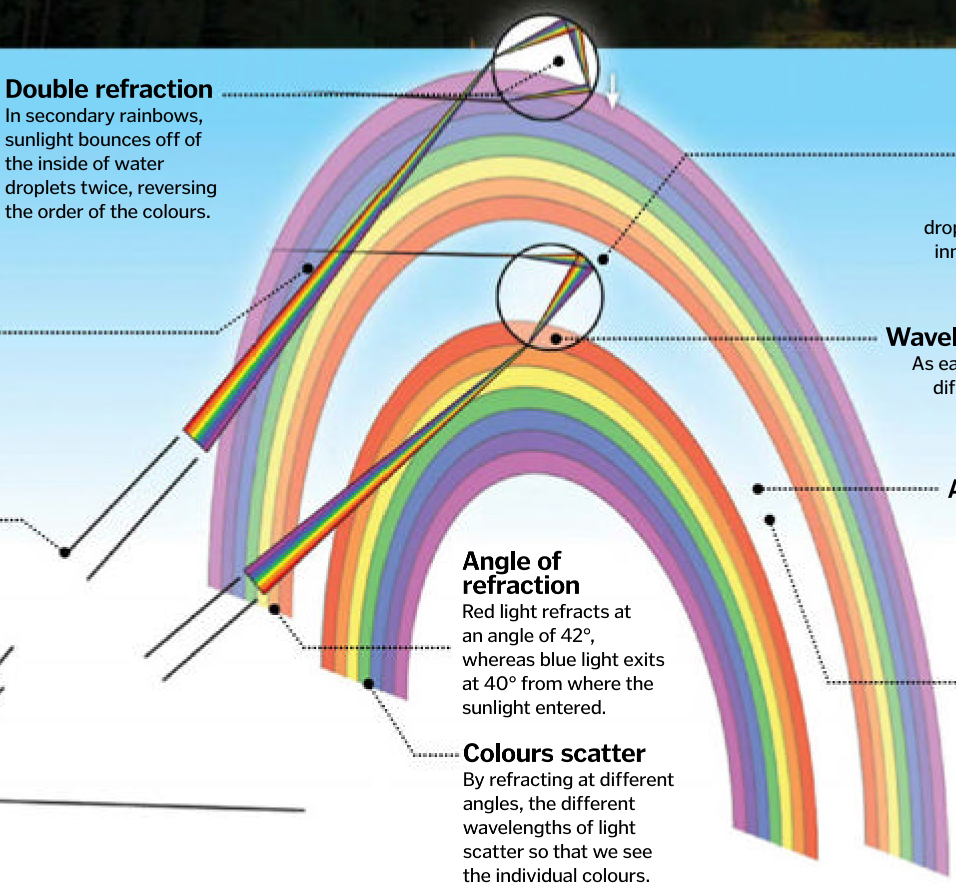
MULTIPLE RAINBOWS

The awe-inspiring double, tertiary and quaternary rainbows

Rainbows form when sunlight bounces off of the inside of water droplets suspended in the air. To create one rainbow, the light must bounce once inside the droplet. However, if the light bounces multiple times, more rainbows form. It is thought that larger water droplets that have been flattened by the surrounding air are needed to form double rainbows. These so-called 'burgeroid' droplets have a larger surface area for reflecting light more than once. If the light bounces three or four times, tertiary or quaternary rainbows form, but they are usually too faint for the naked eye to see.

Inside a double rainbow

How multiple refractions create multiple rainbows



Double refraction
In secondary rainbows, sunlight bounces off of the inside of water droplets twice, reversing the order of the colours.

Refraction
In primary rainbows, sunlight enters a water droplet and bounces off its inner surface in a process known as refraction.

Fainter effect
Secondary rainbows appear fainter because only some of the light reflected a second time reaches your eyes.

Wavelengths separate
As each colour of light has a different wavelength, it is refracted at a slightly different angle.

Greater angles
The red light refracts at 52° and the blue at 54°, so a secondary rainbow appears 9° above a primary rainbow.

Alexander's Band
The area between the two rainbows is known as Alexander's Band, named after Alexander of Aphrodisias who first noticed it.

Angle of refraction
Red light refracts at an angle of 42°, whereas blue light exits at 40° from where the sunlight entered.

Rainbow effect
Only one colour from each droplet will refract at the exact angle necessary to directly reach your eye.

Colours scatter
By refracting at different angles, the different wavelengths of light scatter so that we see the individual colours.

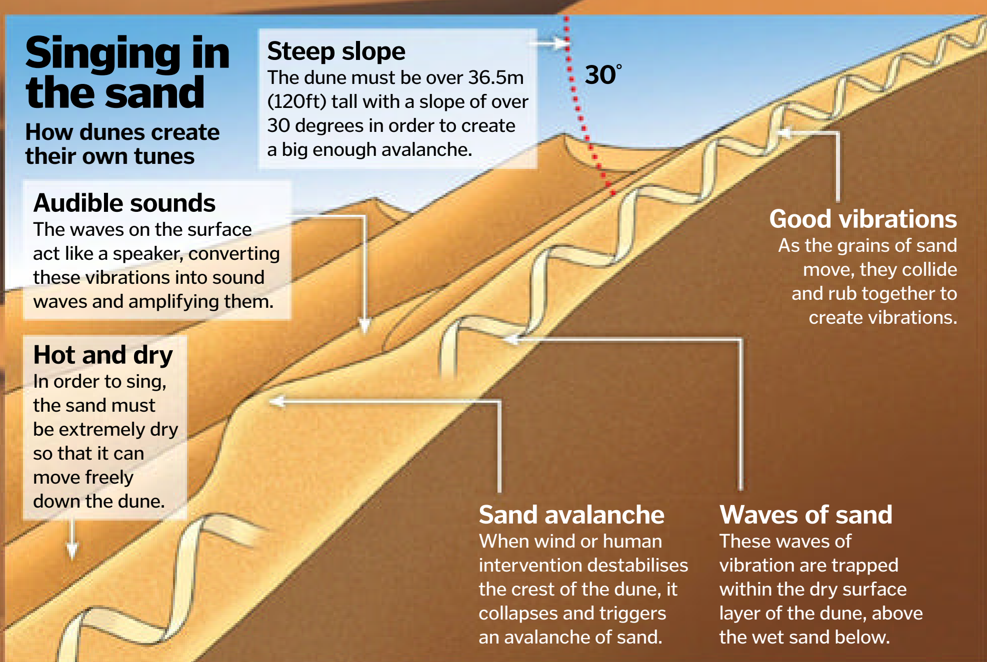
Darker in-between
Alexander's Band appears to be extra dark because the droplets within it are refracting light at angles that don't reach your eyes.

DID YOU KNOW? *The noise levels of some singing sand dunes have reached 110 decibels, which is as loud as a motorbike*

SINGING SAND DUNES

The mountains of sand that can hit the low notes

In several of the world's driest climates, sand dunes regularly emit a strange low-pitched rumbling noise that can be heard from up to ten kilometres (six miles) away. These singing or booming sand dunes baffled scientists for decades, but it is now believed that the sound comes from sand vibrating within the top layer of the dune. This produces a single musical note, typically G, E or F. The thicker the top layer of sand, the lower the note it creates.



Ball lightning only lasts for a few seconds, as it disappears once the silicon oxide has burned out

BALL LIGHTNING

Mysterious orbs of light that float across the sky

When lightning strikes the ground, it vaporises silicon oxide in the dirt. If the soil also contains carbon, perhaps from dead leaves, it will steal oxygen from the silicon oxide, turning it into pure silicon vapour. As the silicon recombines with oxygen in the air, the reaction creates an orb of light.

These so called 'hole-punch clouds' are the result of extremely localised snowfall

FALLSTREAK HOLE

The phenomenon that punches a hole in the clouds

Cirrocumulus and altocumulus clouds are composed of 'supercooled' water droplets that are below freezing temperature, but can't freeze because they don't have any particles around which ice crystals can form. When an aeroplane passes through the cloud, it triggers an expansion of air that causes the surrounding temperature to drop below -40°C (-40°F). This is cold enough to freeze the droplets, which fall as snow and leave behind a hole in the cloud.

"Electric eels are capable of producing such a shock as they have electric internal organs"

A tree frog's life cycle

Discover how the elusive red-eyed tree frog begins its life in water before moving to land

Developing tadpoles
A surrounding jelly-like substance keeps the eggs in place so they can develop into fully formed tadpoles.

Fertilising the eggs
The female tree frog will then deposit 30-50 eggs onto the underside of a leaf that hangs directly above water. The male will then fertilise the eggs.

Finding a mate
Between October and March, the male red-eyed tree frog will attract a female by croaking. It will then latch onto her back.

Adult life
Within three months, the young red-eyed tree frog is ready to move from the water into the nearby trees and begin the cycle anew.

Entering the water
After about a week, the tadpoles will hatch and drop from the leaf into the waiting water below.

Growing limbs
Within six to nine weeks, the tadpole will begin to develop its back legs, shortly followed by the front legs.

How electric eels hunt

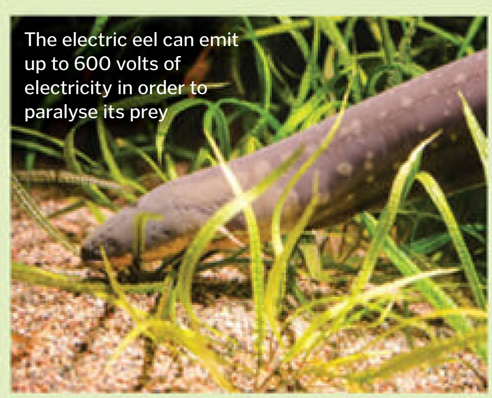
Discover how the electric eel shocks its unsuspecting prey into submission

The electric eel is a formidable freshwater predator that has the ability to emit a powerful voltage of electricity underwater. This unique shock tactic is used in order to immobilise passing prey in murky surroundings.

Releasing pulses of electricity actually makes hunting fish much easier for the eel. Put simply, the sharp electric bursts have a direct effect on a fish's muscles, often causing them to twitch or convulse, which in turn gives away their position to the predator.

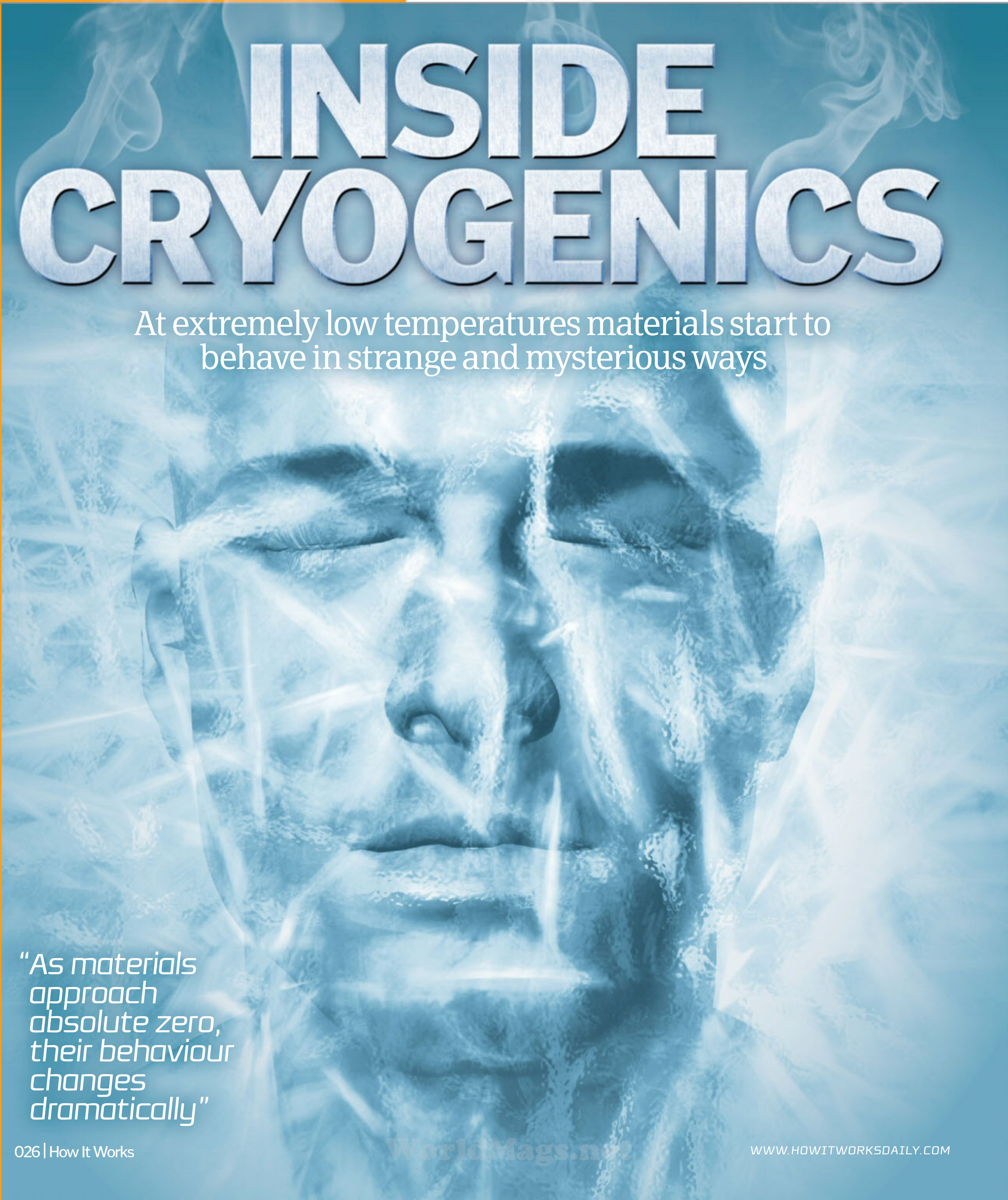
Electric eels are capable of producing such a shock as they have electric organs, which can store power like a battery. Once the eel plans to attack, thousands of specialised electrocyte cells within the organs will discharge, enabling the eel to emit a powerful burst of electricity up to 600 volts!

Due to their poor eyesight, electric eels will use the same technique to ward off predators and navigate in their gloomy freshwater surroundings too, but will emit a lower charge when doing so.


The electric eel can emit up to 600 volts of electricity in order to paralyse its prey

INSIDE CRYOGENICS

At extremely low temperatures materials start to behave in strange and mysterious ways



"As materials approach absolute zero, their behaviour changes dramatically"

5 TOP FACTS
USES OF CRYOGENICS

Superconducting magnets
1 Electromagnets in MRI scanners are cooled using cryogenic liquids, making superconductors that can transmit current with zero resistance.

Recycling breakdown
2 Cryogenic temperatures make many materials very brittle. This property is used in the recycling industry to break down waste into manageable chunks.

Making parts fit
3 Cryogenics can be used in the assembly of machinery. Items are supercooled, so they contract, and then fitted into place. As they heat up, they expand, forming a tight seal.

Cooling telescopes
4 Many space telescopes are designed to detect infrared light. The instruments are cooled with liquid helium, allowing accurate measurements to be taken.

Drug production
5 The active ingredients in the popular cholesterol-lowering group of drugs known as statins are produced at temperatures below -100°C (-148°F), using cryogenic technology.

DID YOU KNOW? *Liquid nitrogen is used by chefs to rapidly freeze ice cream, giving the dessert an unusually smooth texture*

ICY DEAD PEOPLE
Cryogenics versus cryonics

When people talk about cryogenics, one of the first things that comes to mind is frozen bodies waiting patiently in tanks for future reanimation. This idea was popularised by science fiction, and is performed in specialist facilities in the United States, but the scientific evidence is severely lacking.

Scientists are careful to separate the real science of cryogenics from the practice of freezing human bodies, and the field has its own name – cryonics. After a cryonics patient is pronounced dead, their blood is removed and replaced with a cocktail of chemicals that aim to protect the delicate cells from the freezing process.

Once this procedure is complete, the body is frozen using liquid nitrogen and stored in a holding tank. There is no requirement for cryonics companies to be scientifically or medically certified, and some of the work is carried out by volunteers. Despite the undeniably exciting concept, there is still no evidence that whole-body freezing procedures are effective.

Cryonics is the practice of freezing human remains in the hope that one day they might be brought back to life

Cryogenics is the science of extreme cold. Research in this field aims to understand how to produce and maintain temperatures below 123 degrees Kelvin, or minus-150 degrees Celsius (minus-238 degrees Fahrenheit), and to study the effects of these freezing environments on various different physical, chemical and biological processes.

Heat is generated by the random movement of molecules, and as the temperature drops they start to slow down. According to the laws of thermodynamics this cannot continue indefinitely – there must be a bottom, a point at which molecular motion stops completely. This point, the coldest possible temperature, is known as absolute zero, or zero degrees Kelvin (minus-273.15 degrees Celsius / minus-459.67 degrees Fahrenheit).

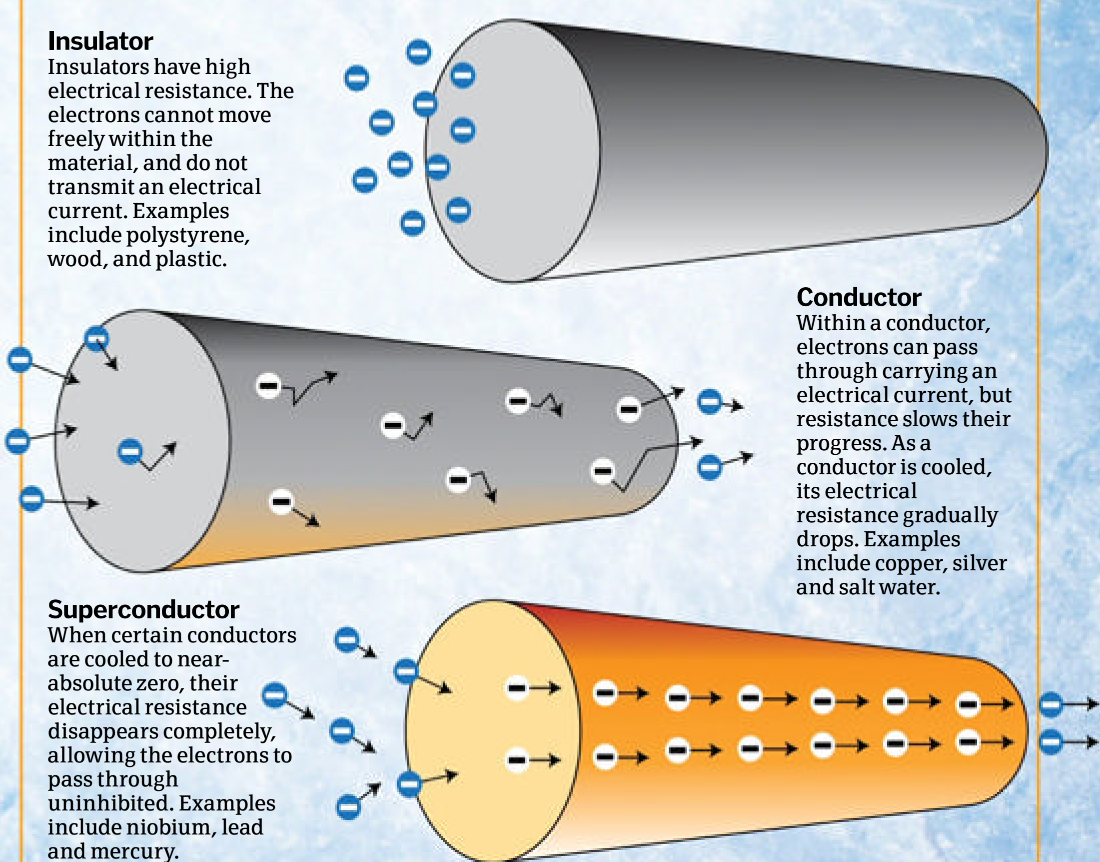
As materials' temperature approaches absolute zero, their behaviour changes dramatically. When permanent gases such as nitrogen and oxygen reach temperatures in the tens of Kelvins, they can be turned into liquids, which can be used as fuel for spacecraft, to rapidly cool food for preservation, or even for the surgical removal of damaged cells in the body. When niobium alloys drop close to absolute zero, they completely lose their electrical resistance, and become superconductors, capable of producing powerful electromagnets that can accelerate subatomic particles to almost the speed of light. And when the temperature reaches 2.19 degrees Kelvin or lower, helium loses its viscosity and becomes a superfluid that can, amazingly enough, crawl up the sides of glass beakers.

Join us as we investigate some of the ways cryogenics is pushing the frontiers of science as we know it.

KEEPING CERN COOL WITH CRYOELECTRONICS

The flow of electrical current through a conductor is opposed by material resistance, but as the temperature of certain metals falls, this resistance drops away. In some cases, at these super-low cryogenic temperatures, electrical resistance suddenly drops to zero, creating a superconductor.

The main magnets that guide particle beams around the Large Hadron Collider at CERN are cooled with liquid helium to a temperature of 1.9 degrees Kelvin (-271.3 degrees Celsius / -456.3 degrees Fahrenheit) – that's colder than in outer space. Their resistance completely disappears, preventing energy being lost as heat.



> "Using cryogenic technology, the imperfections and stresses in heat-treated metal can be removed"

The core stage of NASA's new Space Launch System (SLS) will be powered by four RS-25 liquid-fuel engines

Fuelling rockets

One of the major applications of cryogenics is in space travel; the first cryogenically fuelled rocket was NASA's Centaur upper stage, first successfully launched in 1963.

The most commonly used cryogenic pairing is liquid hydrogen fuel (LH_2), burnt using liquid oxygen (LO_2 or LOX). Hydrogen is a light gas that burns cleanly in the presence of oxygen, and by cooling both gases to extremely low temperatures, more fuel can be crammed into each tank.

The tanks are exposed to a number of different heat sources during space flight, from the engine's exhaust to friction as the craft travels through the atmosphere, and the heat from the Sun. To keep the fuels liquid, the tanks must not only be well insulated, but also able to withstand the extremely low temperatures of the cryogenic fluids inside.

The fuels are traditionally contained in heavy metal tanks, but NASA and Boeing are working on a revolutionary composite fuel tank, 30 per cent lighter than standard cryogenic tanks. In the future, these tanks will allow more fuel to be carried, taking cargo farther into space than ever before.

MAKING METALS STRONGER

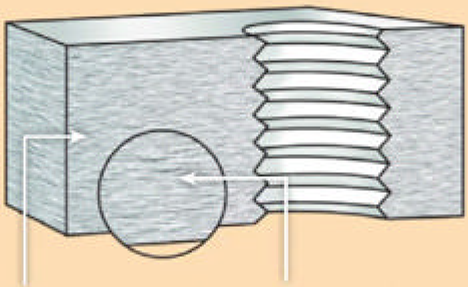
As metal cools from a liquid to a solid, it forms a crystal structure, with the individual atoms arranged into a regular lattice, but there are often imperfections to this. Traditionally, these are minimised using heat treatment, allowing the metal to become liquid again to relieve stress and fill in the gaps, but the process is incomplete. Using cryogenic technology, the imperfections and stresses in heat-treated metal can be removed.

Following heat treatment, the metal is slowly cooled to near-absolute zero. The process allows certain elements within the structure to move, filling in the microscopic defects and making the structure more uniform. This relieves stress and results in a denser, more resilient metal. Cold-treated metals are used in sport to create golf clubs and baseball bats with less vibration, so more energy can be transferred to the balls.

BEFORE

Heat-treated steel

Steel is traditionally heat-treated to improve its strength. At high temperatures, the imperfect internal structure melts and can reform evenly.



Quenching

Heat-treated steel is cooled slowly, allowing 60-80 per cent of the molecules to settle into a tight, regular structure.

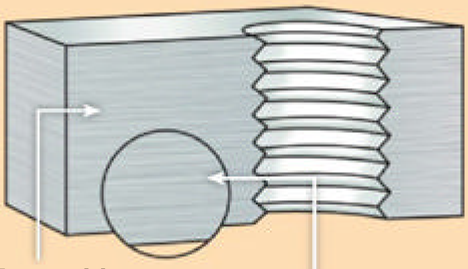
Stress

The cooling process introduces stresses as the outside contracts before the red-hot centre has had time to cool.

AFTER

Cryogenic treatment

After heat-treating, the temperature of the metal is gradually lowered toward absolute zero.



Martensitic structure

As the metal cools and contracts, the structure is forced into line, transforming into a uniform structure.

Stress relief

Cryogenic treatment allows the molecules within the metal to redistribute gradually, relieving stresses introduced by heat treatment.

1. COLD

Wood frog
These survive winters by packing their cells with sugar to prevent dehydration as their blood freezes, braving temperatures of -15°C (5°F).

2. COLDER

Red flat bark beetle
These Alaskan beetles use cryoprotectants to stop ice crystal formation, and can survive temperatures as low as -150°C (-238°F).

3. COLDEST

Tardigrade
Also known as water bears, these microscopic creatures can survive temperatures close to absolute zero and have even braved outer space.

DID YOU KNOW? *Silvered vacuum vessels known as Dewars used for cryogenic liquids led to the invention of the Thermos flask*

TREATING SPORTS INJURIES

Not all cryogenic techniques are well established, and in the sporting world, there is an emerging field in whole-body cryotherapy (WBC). Traditionally, ice and cold-water immersion have been used to treat sports injuries, but this new approach, based on research originally pioneered in Japan in the 1970s, aims to relieve the symptoms of athletic injury, muscle and joint pain, and arthritis by cooling the entire body in a cryogenic chamber. Air is a poor conductor compared to water, so there is a much lower chance of the core body temperature being affected than with traditional techniques.

Entering the nitrogen-cooled chamber, people are exposed to temperatures lower than minus-100 degrees Celsius (minus-148 degrees Fahrenheit) for a period of around three minutes. Their extremities are protected with clothing, gloves, socks, facemasks and underwear, but other than that, their skin is exposed to extreme temperatures. The body's natural response is to cut off the blood supply to the skin, redirecting it to the core in order to minimise heat loss and maintain a healthy internal body temperature. A by-product of this is the release of natural painkillers known as endorphins, which can induce feelings of well-being and euphoria.

ENTERING THE CRYOCHAMBER

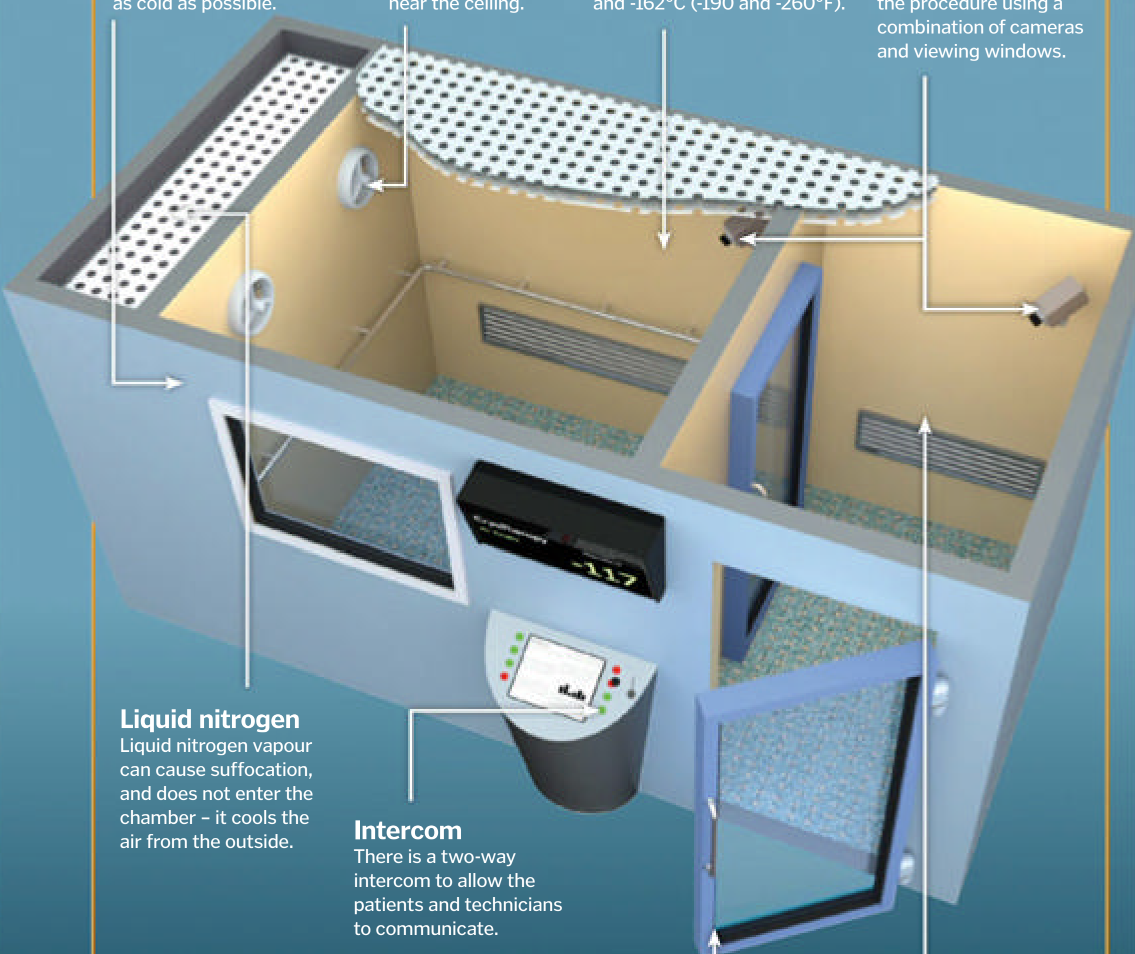
Patients spend up to three minutes in these superchilled rooms

Insulated walls
The walls of the chamber are insulated to ensure the temperature inside remains as cold as possible.

Air diffuser
Normal air enters the chamber through vents near the ceiling.

Main chamber
The air in the main treatment chamber is maintained at temperatures between -123 and -162°C (-190 and -260°F).

Monitoring cameras
The patients are monitored throughout the procedure using a combination of cameras and viewing windows.



Liquid nitrogen
Liquid nitrogen vapour can cause suffocation, and does not enter the chamber – it cools the air from the outside.

Intercom
There is a two-way intercom to allow the patients and technicians to communicate.

Magnetic doors
The doors are closed using magnets, allowing the patients to leave easily if they need to.

Pre-chamber
Patients acclimatise to the cold in the first chamber, kept at a slightly warmer -40 to -62°C (-40 to -80°F).

Treating arthritis

Cryotherapy is being researched for its use in treating illnesses such as arthritis. Exposure to low temperatures slows down nerve conduction, helping to reduce muscle spasm by decreasing the rate of firing of the muscle spindles. This effect is easy to see in your own body – just try undoing the buttons on your coat with frozen fingertips after you come in from the cold.

Cold temperatures are also thought to decrease the activity of damaging enzymes present within arthritic joints, known as collagenases, which break down the protective collagen cartilage that covers the bones.

Studies in patients with a variety of joint disorders have shown that these techniques can temporarily reduce pain for periods of around 90 minutes, allowing patients to undergo physiotherapy and other interventions, which might otherwise have been too uncomfortable. So although it does not have a long-term effect, when used in conjunction with other therapies, there is the potential for significant medical benefit.

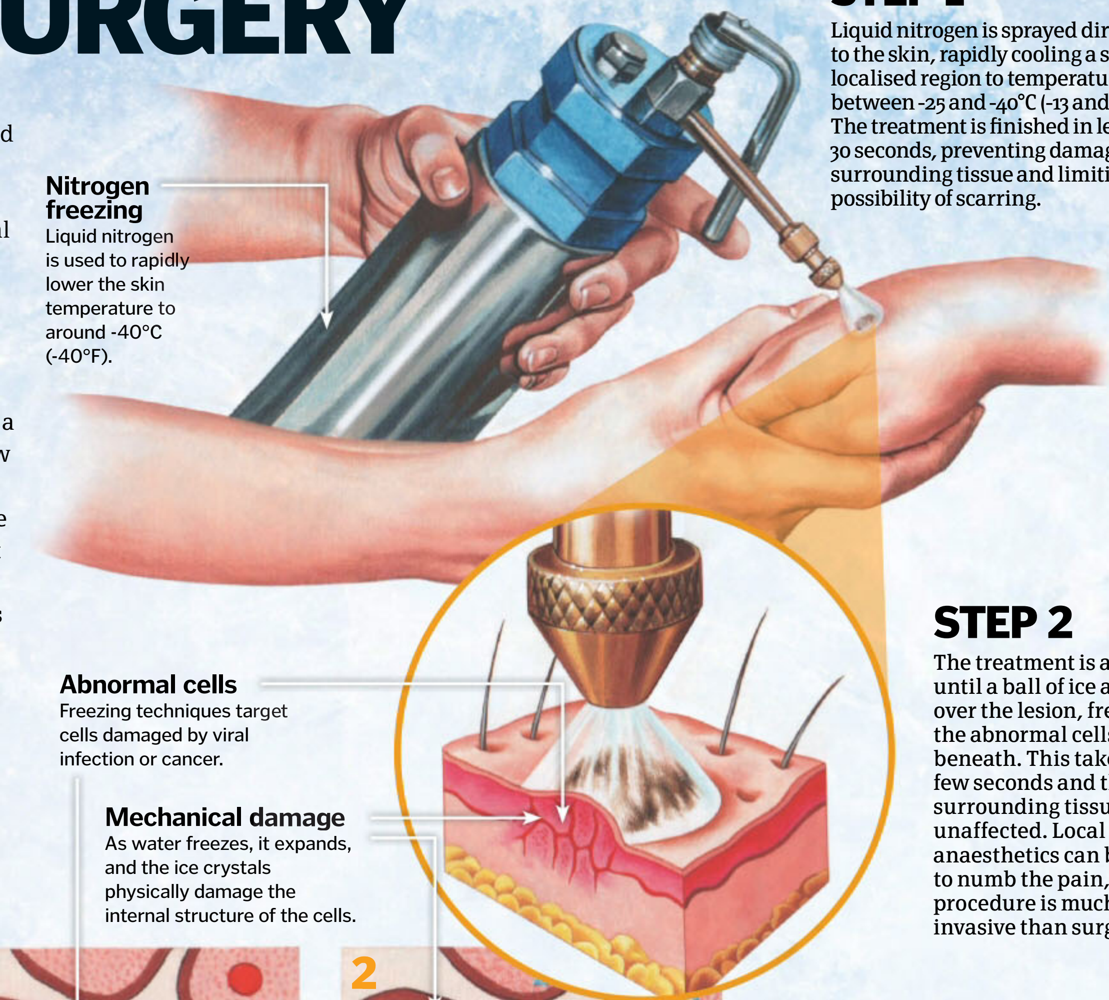
"The extreme chill of liquid nitrogen is routinely used to destroy abnormal cells, from warts to cancers"

CRYOSURGERY

The damaging effects of cryogenic temperatures have been harnessed for use in medical treatment. The extreme chill of liquid nitrogen is routinely used to destroy abnormal cells, from warts to cancers. The technique varies slightly depending on the specific condition, but generally involves applying the liquid nitrogen directly to the affected area, using a cotton bud, a spray gun, or a hollow tube known as a cryoprobe. This rapidly freezes the damaged tissue and destroys the abnormal cells. It is much more specific than drug treatment, causes little pain and is less traumatic to the surrounding tissue than surgery.

STEP 1

Liquid nitrogen is sprayed directly on to the skin, rapidly cooling a small, localised region to temperatures between -25 and -40°C (-13 and -40°F). The treatment is finished in less than 30 seconds, preventing damage to the surrounding tissue and limiting the possibility of scarring.



Nitrogen freezing
Liquid nitrogen is used to rapidly lower the skin temperature to around -40°C (-40°F).

Abnormal cells
Freezing techniques target cells damaged by viral infection or cancer.

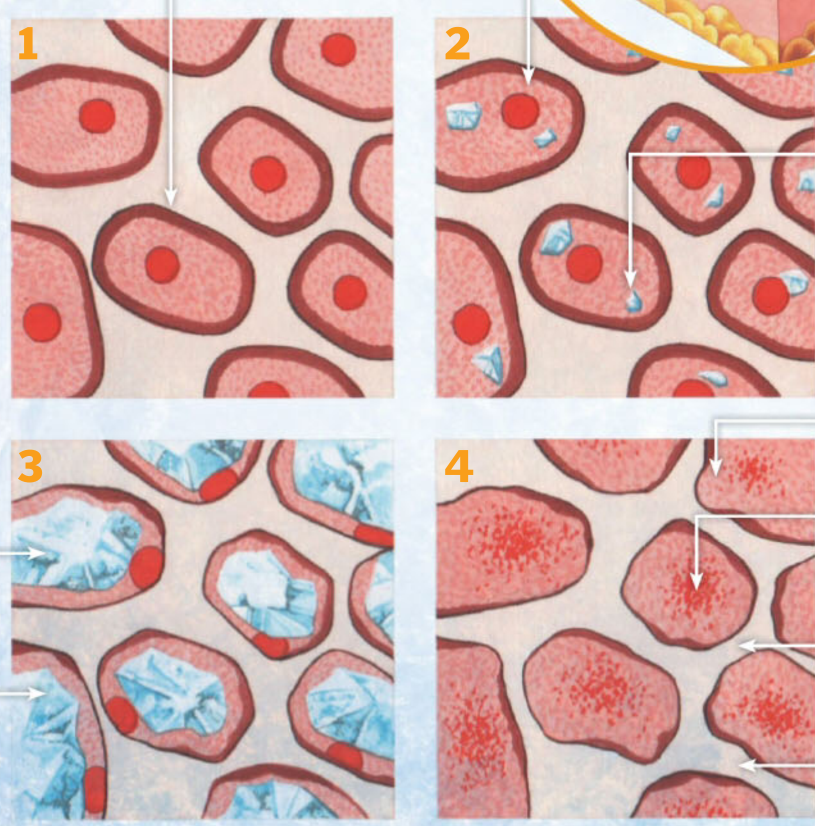
Mechanical damage
As water freezes, it expands, and the ice crystals physically damage the internal structure of the cells.

STEP 2

The treatment is applied until a ball of ice appears over the lesion, freezing the abnormal cells beneath. This takes just a few seconds and the surrounding tissue is unaffected. Local anaesthetics can be used to numb the pain, but the procedure is much less invasive than surgery.

STEP 3

As water freezes, it expands, forming jagged crystals, which burst through the membranes of the cells, causing irreparable damage. The cells become dehydrated, and by the time the ice thaws, the abnormal cells are already damaged beyond repair, and are cleared away by the body.



Ice-crystal formation
As the liquid nitrogen cools the cells, the water inside transforms into ice, forming sharp crystals.

Chemical damage
The concentrated solutes left behind when the water freezes chemically damage the components of the cell.

Dehydration
As water turns to ice, the dissolved salts, ions and proteins are left behind, leaving the cell dangerously dehydrated.

Thawing
By the time the ice thaws, the damage done to the abnormal cells is irreparable.

Damaged components
All that is left behind are the shells of the abnormal cells – their components are damaged, and they are no longer able to function.

Inflammation
The body responds by initiating inflammation, bringing blood and immune cells to the area to initiate repair.

Clearance
The damaged cells are cleared away and the wound heals rapidly with minimal scarring.

DID YOU KNOW? *The field of cryogenics began in 1877, when Louis-Paul Cailletet and Raoul Pictet liquefied oxygen for the first time*

CRYOPRESERVATION

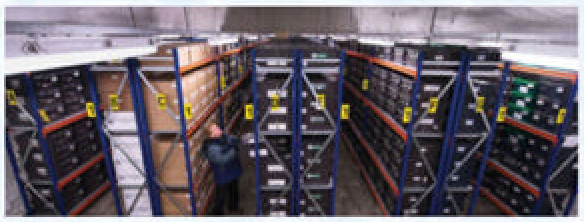
At very low temperatures, biological processes come almost to a complete stop. Without heat energy, enzyme activity slows down and living cells can be preserved almost indefinitely. However, preparing living cells for cryopreservation is far from simple. The delicate microscopic structures of cells can be torn to shreds as water freezes, and as the pure water forms ice, dissolved ions, salts and other molecules become concentrated, upsetting the delicate chemical balance inside the cells.

To prevent this, cells are prepared with chemicals known as cryoprotectants. Glycerol, dimethyl sulphoxide (DMSO), or sugars are introduced to replace the water, helping to stop the formation of ice crystals, or to alter their shape and size. Liquid nitrogen is then used to rapidly cool the cells past a point known as the glass transition temperature; at this point, water freezes to form a solid more like glass than ice. The cells can then be stored safely in liquid nitrogen vapour.

Cryopreservation can be used to preserve plants, seeds and even cells

Seeds

Many seeds can withstand the winter cold and, if air-dried, can remain dormant for decades at temperatures of around -18°C (-0.4°F). Cryopreservation is used for long-term storage and protection of valuable or endangered species. The seeds are soaked in glycerol and sucrose for protection against ice and then rapidly frozen in liquid nitrogen.



At the Svalbard Global Seed Vault, precious seeds are stored in man-made caves inside the Arctic permafrost

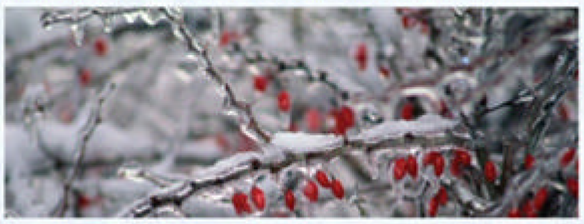
Blood

Red blood cells have a short life span and in order to supply transfusion demands, whole blood and blood products are cryogenically stored. They are cryopreserved with glycerol and either frozen slowly at -80°C (-112°F), or snap frozen in liquid nitrogen. If they are stored correctly, frozen red blood cells can last for at least ten years.

Donated blood can be kept fresh for years in cryogenic storage

Plants

Many plant tissues can be stored at extremely low temperatures. Plants face the same ice-related dangers as animal cells, and must be prepared before freezing. Many plants already have mechanisms to resist the frost, and preparation techniques vary, including air-drying to remove moisture and submersion in cryoprotectants.



Many plants can withstand freezing temperatures, but for cryogenic storage they need a bit of extra help

Cells

Single cells, from bacteria to human sperm, are now routinely frozen for long-term storage in liquid nitrogen. Cryoprotectants are used to prevent damage from the near-absolute cold, but the chemicals used are sometimes toxic, so a careful balance must be achieved to ensure that the cells can be thawed successfully for use later.

Sperm is stored in liquid nitrogen for use in assisted reproduction and IVF

Is it possible to freeze whole organs?

Cryogenic techniques could prolong organ survival time for transplants

Scientists are now able to reliably freeze and thaw single cells, replacing the water with cryoprotectants to prevent the damaging formation of ice, but freezing entire organs is not so simple. The cells within an organ are so closely packed together that it is much more difficult to protect them all, leaving many vulnerable to ice crystals. During the freezing process, ice forms in blood vessels, damaging their structure, and it creeps between cells, prising them apart and leading to micro-fractures.

In 2002, Greg Fahy and his team at 21st Century Medicine in California achieved something unusual. They cooled a rabbit kidney to -130 degrees Celsius (-202 degrees Fahrenheit) for 20 minutes, thawed it and successfully transplanted it into a living rabbit.

They used a solution known as M22, which helps water turn to a glass-like solid at low temperatures. They pumped the liquid through the blood vessels in the kidney, allowing it 25 minutes to reach all the cells, and then rapidly froze it using nitrogen vapour. They then gradually warmed the kidney back to normal temperature, using even more of the protective fluid as it thawed.

This finding was a one-off and has not since been repeated, but it shows the idea of preserving organs by freezing is potentially a viable one.

Today, researchers continue to work on the problem, taking inspiration from antifreeze proteins made by animals resistant to the extreme temperatures of polar ice, and using cutting-edge technology to watch how water behaves inside organs they freeze.

Preserving entire organs is a complex challenge, and although it is still a distant dream at the moment, cryogenic techniques could significantly extend the life of organs destined for transplant in the future.

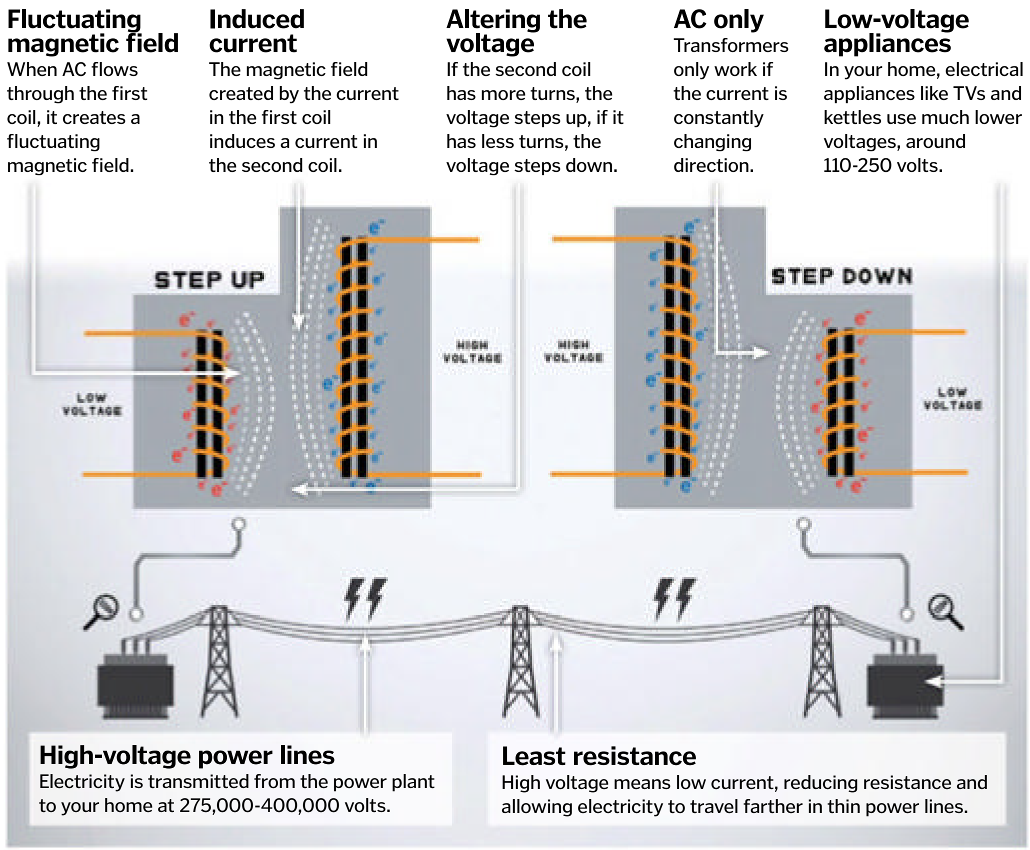
"In AC circuits, the electrons change direction a number of times every second"

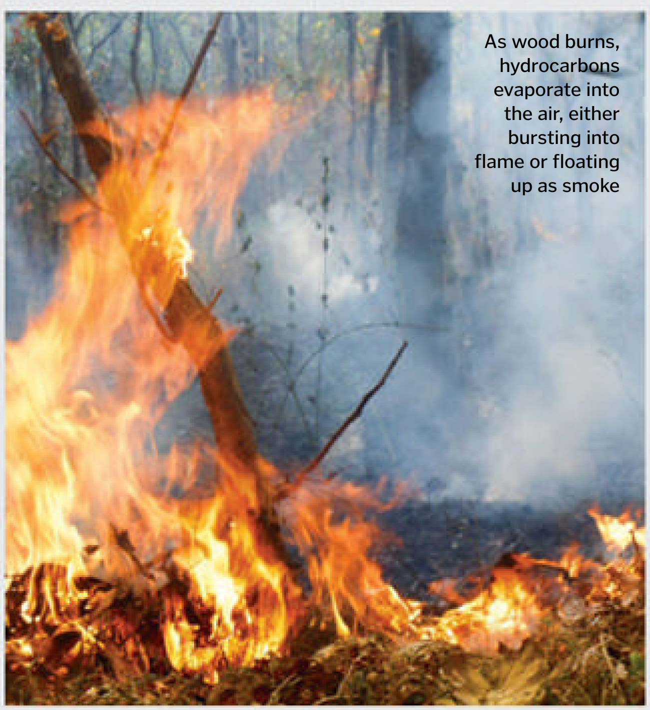
What is AC/DC current?

The difference between alternating and direct current explained

The electricity that is produced by a battery, and the electricity that comes out of a mains socket are slightly different. The mains delivers alternating current (AC) and batteries deliver direct current (DC). In DC circuits, the electrons always move in the same direction, from the negative terminal to the positive, but in AC circuits, the electrons change direction a number of times every second.

Basic AC generators, also known as alternators, are constructed using a magnet that rotates around a set of wires. As the field rotates, north and south poles are constantly changing position, and the voltage in the circuit switches direction. The major advantage of AC is that the voltage can be easily altered using transformer. As AC flows through a coil of wire, it creates its own changing magnetic field. This field can be used to induce another AC current in a second coil of wire. Simply changing the number of coils in each wire can alter the voltage of the secondary current.




As wood burns, hydrocarbons evaporate into the air, either bursting into flame or floating up as smoke

What is smoke?

Find out what happens when a fire burns without enough oxygen

Wood is made from a combination of water, hydrocarbons, and minerals. As the temperature rises above 149 degrees Celsius (300 degrees Fahrenheit), the hydrocarbons start to vaporise, floating up into the air. They combine with oxygen, burning and releasing energy that is visible as a hot flame. As they burn, they release carbon dioxide and water vapour, both colourless gases that you cannot see.

Sometimes there is not enough oxygen for these evaporated components to burn, and instead, they continue to float upwards, rising in the hot air. The evaporated oils and tars clump together as they rise, forming fine particles known as smoke. The particles move about randomly, and as they collide with the invisible particles that make up the air, they change direction, producing the ever-changing swirling patterns of smoke.

After all of these volatile hydrocarbons have evaporated, all that is left is charcoal, nearly pure carbon. The charcoal does not evaporate, so as it burns there is no flame, just glowing embers. Once the charcoal is gone, all that remains is ash, the minerals like magnesium and potassium that do not burn at all.

5 TOP FACTS ABOUT LOVE

Aphrodisiac food
1 Chocolate contains phenylethylamine, a chemical that causes the release of dopamine and norepinephrine, the key hormones that help us fall in love.

Instant attraction
2 It only takes between 90 seconds and four minutes to decide if you fancy someone, and 55 per cent of attraction is based on body language alone.

Monogamous animals
3 Only three per cent of mammals mate for life. Animals that do find a lifelong partner include gibbons, swans, wolves, albatrosses, penguins, eagles and termites.

Natural painkiller
4 Simply looking at a photo of the one you love, or even thinking about them, increases levels of oxytocin, the body's natural painkiller.

Broken Heart Syndrome
5 Also called stress-induced cardiomyopathy, it is caused by an emotionally stressful event, such as a break-up, and causes sudden intense chest pain.

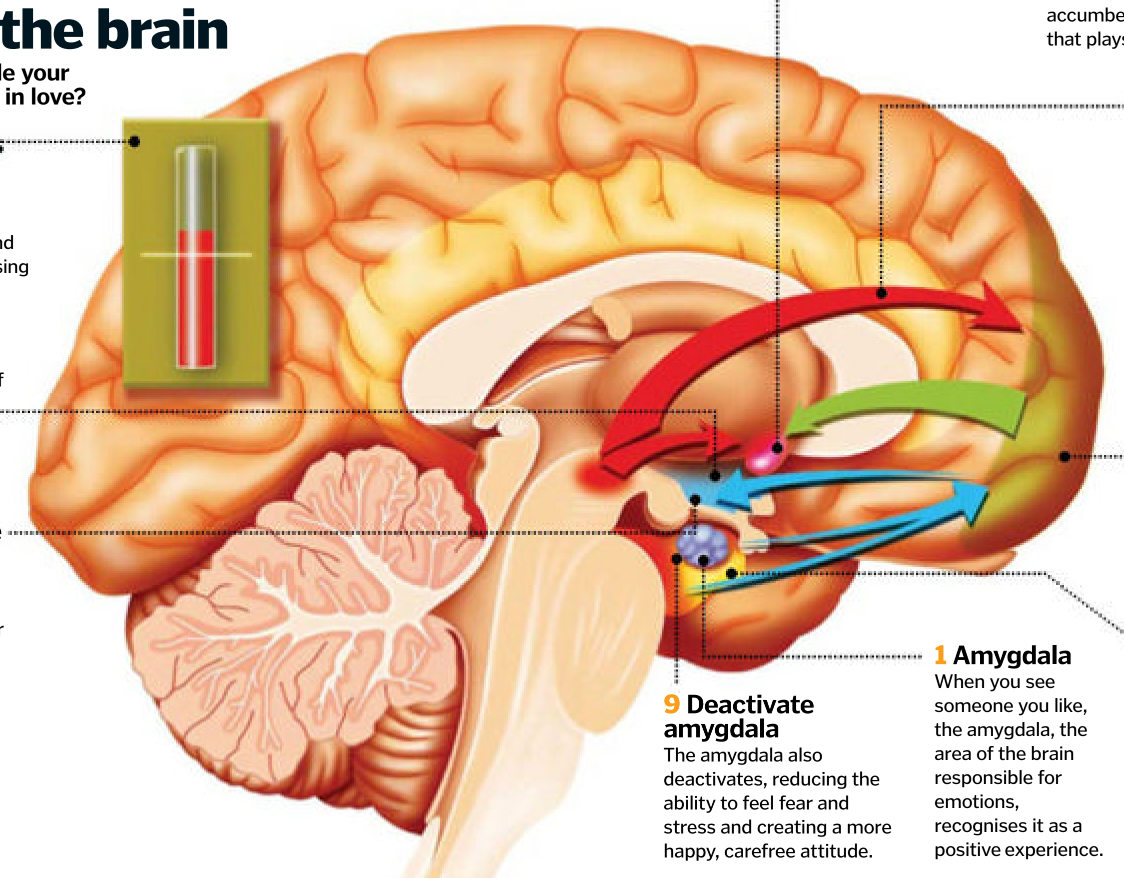
DID YOU KNOW? *Gazing into the eyes of the one you love for three minutes causes your heart rates to synchronise*

The science of love

The hormones and chemicals that cause us to fall head over heels

Love on the brain

What goes on inside your head when you fall in love?



6 Hormone levels
As dopamine levels increase, levels of serotonin, the hormone responsible for mood and appetite, decrease, causing feelings of obsession.

2 Hippocampus
The hippocampus, the memory forming area of the brain, records this pleasant experience making you want to seek it out again.

5 Norepinephrine
Norepinephrine, another neurotransmitter similar to adrenalin, is also released, which gets your heart racing and causes you to sweat.

7 Nucleus accumbens
The secretion of dopamine stimulates the nucleus accumbens, an area of the brain that plays a vital role in addiction.

8 Deactivate prefrontal cortex
The nucleus accumbens then pushes the prefrontal cortex for action, but it deactivates, suspending feelings of criticism and doubt.

3 Prefrontal cortex
Messages are then sent to the prefrontal cortex, the brain's decision-making centre, where it judges if the potential romantic partner is a good match.

9 Deactivate amygdala
The amygdala also deactivates, reducing the ability to feel fear and stress and creating a more happy, carefree attitude.

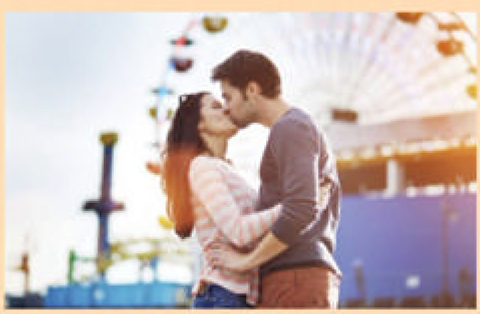
1 Amygdala
When you see someone you like, the amygdala, the area of the brain responsible for emotions, recognises it as a positive experience.

4 Hypothalamus
If the attraction is there, the prefrontal cortex stimulates the hypothalamus, which releases the neurotransmitter dopamine, causing feeling of ecstasy.

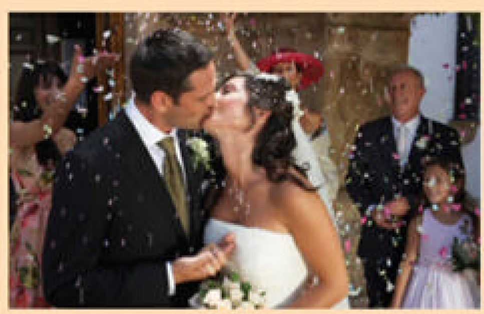
The three stages of falling in love

Lust
When we reach puberty, testosterone and oestrogen become active in our bodies. These hormones create the desire to experience love, and so we start looking for a mate. Who we lust after is influenced by a number of factors. Looks and personality play a roll, and research has revealed that we tend to be attracted to people who remind us of our parents. We also sniff out potential mates, and studies have found that we tend to prefer the smell of others who have an immune system that is different to our own.

Attraction
When you become attracted to someone, a series of chemicals are released in the brain. Dopamine produces the feeling of bliss, leading to a loss of appetite and sleepless nights. Norepinephrine activates stress responses, causing an increased heart rate and sweating, and a protein called nerve growth factor is produced. Serotonin levels fall, making it difficult to keep the object of your desire out of your thoughts, idealising them and becoming oblivious to their flaws.



Attachment
If a relationship is going to last, a strong bond must form. Two key hormones, oxytocin and vasopressin, are involved in forming this commitment. Oxytocin is released when we hug, kiss and have sex. It helps to establish trust and intimacy. Vasopressin, a hormone responsible for regulating the body's retention of water, is also released during sex and encourages monogamy. Endorphins also play a key role in attachment, suppressing pain and creating a sense of security when released.



"Every single lymphocyte is specifically trained to attack a different pathogen"

Immune cells

White blood cells are the army that defend your body against infection

Your immune system is made up of a combination of cells, each with a specific job. Macrophages are large cells that patrol the tissues of your body, vacuuming up dead cells and debris, and searching for anything out of the ordinary. If they encounter an infection, they release chemical messengers encouraging other white blood cells to leave the bloodstream and join the fight.

In the early stages of infection, macrophages are assisted by two major cell types; neutrophils and natural killer (NK) cells. Neutrophils are able to swallow and digest bacteria and fungi, while NK cells inject granules into unhealthy cells, causing them to self-destruct and killing any viruses hiding inside.

These cells are quick to respond to infection and can be on the scene within minutes, but they are not very specialised. In order to target an invading pathogen more effectively, the immune system needs to train cells to attack the bacteria or virus directly; this is where the lymphocytes come in.

Lymphocytes come in two major types, T-cells and B-cells, and every single one is specifically trained to attack a different pathogen, delivering a highly targeted assault. T-cells help to coordinate the immune response, can kill virally infected cells, or help to stop the immune response getting out of hand. Meanwhile, B-cells make antibodies that stick to the surface of pathogens, immobilising them and flagging them up for destruction by other cells.

Dendritic cells chop up invading pathogens and stick the pieces on the surface of their membranes. When a T or B-cell sees its matching fragment displayed it becomes activated, and divides thousands of times to produce an army. This response takes several days to develop, but when the infection is cleared, a few lymphocytes stick around, and if the same pathogen tries to infect again, these memory cells will be ready to divide and defend immediately.

A macrophage white blood cell (purple) engulfing a tuberculosis (Mycobacterium tuberculosis) bacterium (pink) by the process of phagocytosis

AMAZING VIDEO!

SCAN THE QR CODE FOR A QUICK LINK

Take a look at a T-cell attacking a cancer cell

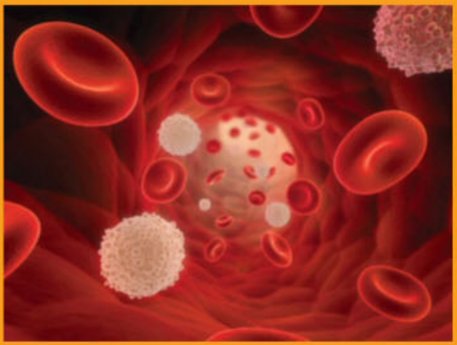
www.howitworksdaily.com

DID YOU KNOW? Your bone marrow releases around a trillion infection-fighting neutrophils into your bloodstream every day

How do white blood cells know what to attack?

Bacteria, viruses and other pathogens make products the body does not recognise. White blood cells like macrophages and dendritic cells have a group of proteins called Toll-like receptors (TLR), which detect these danger signals, putting the immune system on immediate alert and triggering the first stages of the immune response. These danger signals can tell the immune system in general terms what kind of invader it is fighting, whether it is a bacterium, virus, or something else.

In order to activate a more specific immune response, the immune system needs to know exactly what it is up against. Macrophages and dendritic cells are known as antigen-presenting cells, and can take the pathogens they ingest, break them into pieces, and stick those pieces out on their membranes for inspection by other cells. T-cells and B-cells are trained to respond to a different pathogen; if they spot their matching fragment, they are activated and begin a specific attack.



Red and white blood cells in the bloodstream

"It's a biochemical process, which converts molecules in fat cells into usable energy"

How does the body burn fat?

Discover how we transform fat into useful energy when we shed the pounds

Billions of fat cells exist in all body types, no matter their shape, sandwiched between the skin and muscle tissue. It's not the amount of fat cells that dictate a person's weight, though; it's the size of them, which can fluctuate depending on how much fat they are storing.

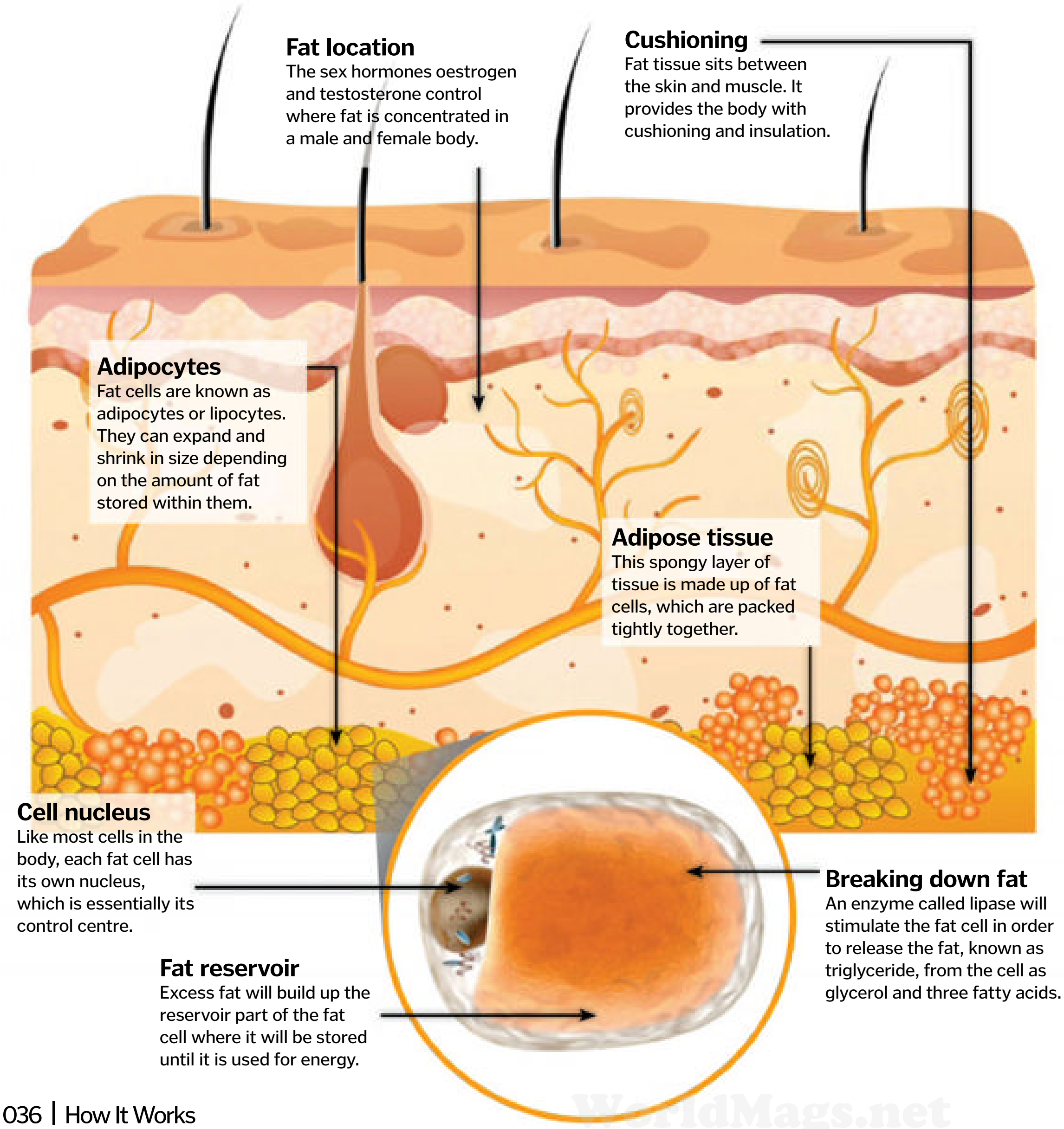
So how does this build up of fatty deposits get broken down when you're working on losing weight? Put simply, it involves a biochemical process, which converts these space-demanding molecules in fat cells into usable energy.

The entire process begins once you start to increase activity levels and reduce calorie intake; calories indicate how much potential energy is in certain foods. By consuming fewer calories than you're burning, the body will react to the reduction of available energy by producing fat-mobilising hormones, which in turn signal important enzymes, which help break down fat reserves for more energy.

The key enzyme in this process is lipase. Lipase stimulates fat cells so that they release triglycerides (the form of fat within the fat cell). Each triglyceride molecule is then broken down into glycerol and three fatty acids. The glycerol is broken down further by the liver to release energy, while the free fatty acids are transported directly to muscles via the bloodstream. The enzyme lipoprotein lipase helps the muscle cells absorb the fatty acids, which can be burned for extra energy.

Fat-cell biology

Discover where fat is stored within the body



Loose skin

Skin is incredibly elastic, so in most cases you can expect it to ping back and fit snugly around your new body shape once you've lost weight. This is all thanks to a protein called collagen. Collagen enables the skin to stretch, which is why it's so important as we grow. However, collagen fibres will weaken over time, resulting in wrinkles as we age.

The production of collagen can also be slow, especially when it comes to sudden weight gain or growth, which in turn leads to overstretched skin as well as noticeable stretch marks. As a result of this, significant or very quick weight loss can often leave you with overhanging, excess skin that can only be removed by a surgical procedure.

Losing weight slowly, with a balance of good food and exercise, can help minimise the risk of loose skin, so don't rush into shedding stones with a quick-fix crash diet.

Collagen helps to keep skin stretchy and enables it to ping back when you lose weight

WORLD'S MOST AMAZING STRUCTURES

The incredible tech behind the most advanced buildings

Ever since the pyramids of the Egyptians or the temples of the Greeks, humans have been racing to build bigger, better and smarter structures. However, with greater height comes greater responsibility, so the race for the skies has meant more advanced technology is required to keep the world's skyscrapers safe from winds and earthquakes.

This has led to a surge of structures modelled on a computer before a single brick or pane of glass is put in place. The technology available to designers and architects changed the design of the Sydney Opera House and showed that rotating Burj Khalifa – the world's tallest building – by 120 degrees would reduce stress from high winds. New structures are also being loaded with technology to enhance the user experience, make them more eco-friendly or relay structural information to the authorities.

From bridges to sports stadiums, technology plays an increasingly important part in building planning. The modern need for Wi-Fi connectivity and smartphone-controlled devices in the home and office has increased the challenge for architects. It is getting increasingly difficult to continue breaking the record for the world's tallest building, so the development of green technology, solar panels and other smart technology is becoming a key battleground for companies trying to design headline-grabbing structures. A mixture of necessity and posturing has accelerated the development of smart buildings, so let us take you through some of the coolest structures in the world today.

HEAD 2 HEAD
BUILDING FAILS

1. DANGEROUS

Leaning Tower of Pisa
Soft ground and poor foundations caused the Italian bell tower to lean during construction. Work was halted for nearly 100 years.

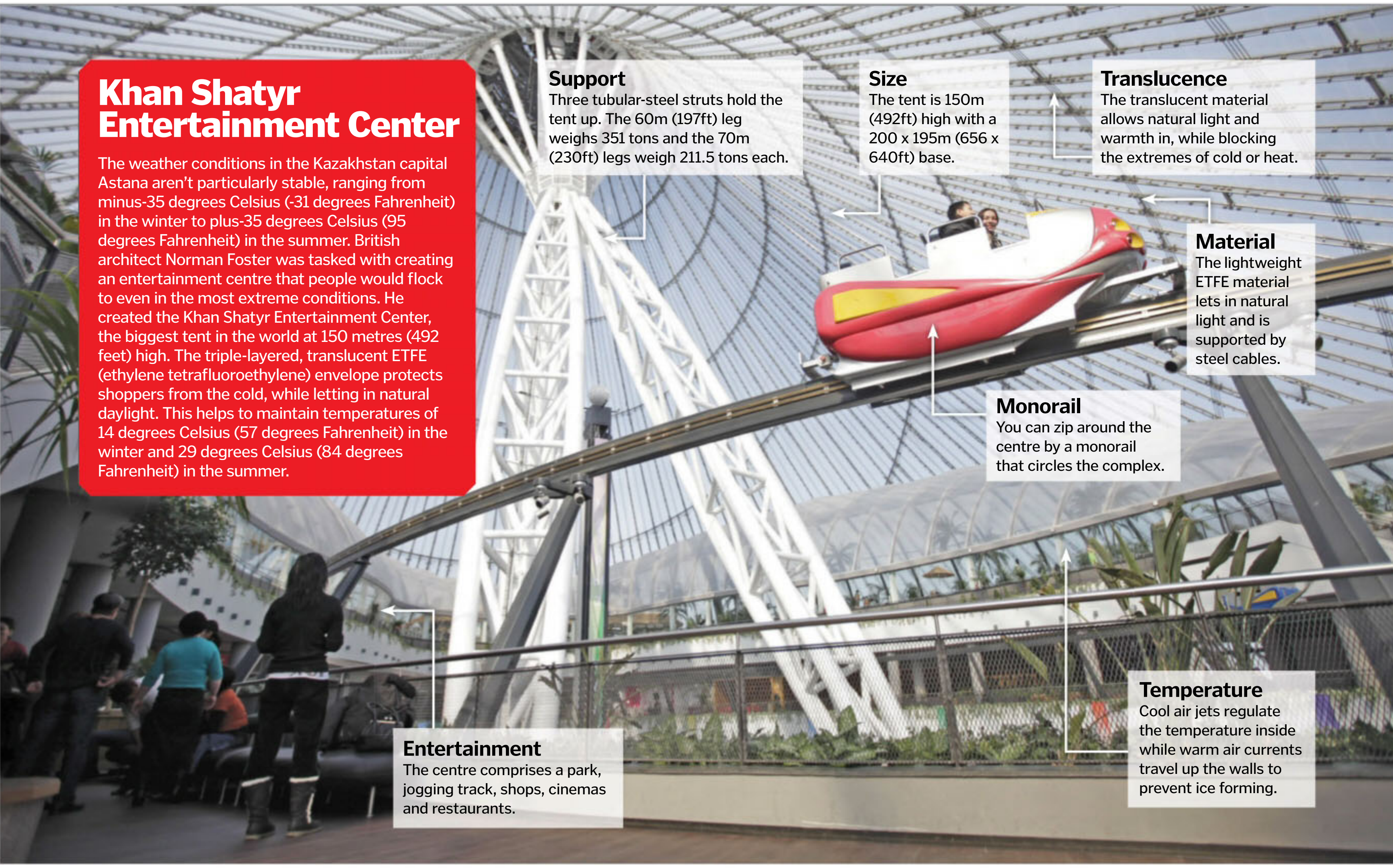
2. MORE DANGEROUS

Palau de les Arts Reina Sofia
Valencia's opera house looks visually stunning but has fallen into ruin with ceramic tiles falling on the heads of passers-by.

3. MOST DANGEROUS

20 Fenchurch Street
Nicknamed the Walkie-Talkie, this London building's concave design focuses the Sun's rays with such intensity it can melt cars.

DID YOU KNOW? *St Anthony Falls Bridge was completed two months ahead of its scheduled Christmas Eve 2008 deadline*



Khan Shatyr Entertainment Center

The weather conditions in the Kazakhstan capital Astana aren't particularly stable, ranging from minus-35 degrees Celsius (-31 degrees Fahrenheit) in the winter to plus-35 degrees Celsius (95 degrees Fahrenheit) in the summer. British architect Norman Foster was tasked with creating an entertainment centre that people would flock to even in the most extreme conditions. He created the Khan Shatyr Entertainment Center, the biggest tent in the world at 150 metres (492 feet) high. The triple-layered, translucent ETFE (ethylene tetrafluoroethylene) envelope protects shoppers from the cold, while letting in natural daylight. This helps to maintain temperatures of 14 degrees Celsius (57 degrees Fahrenheit) in the winter and 29 degrees Celsius (84 degrees Fahrenheit) in the summer.

Support
Three tubular-steel struts hold the tent up. The 60m (197ft) leg weighs 351 tons and the 70m (230ft) legs weigh 211.5 tons each.

Size
The tent is 150m (492ft) high with a 200 x 195m (656 x 640ft) base.

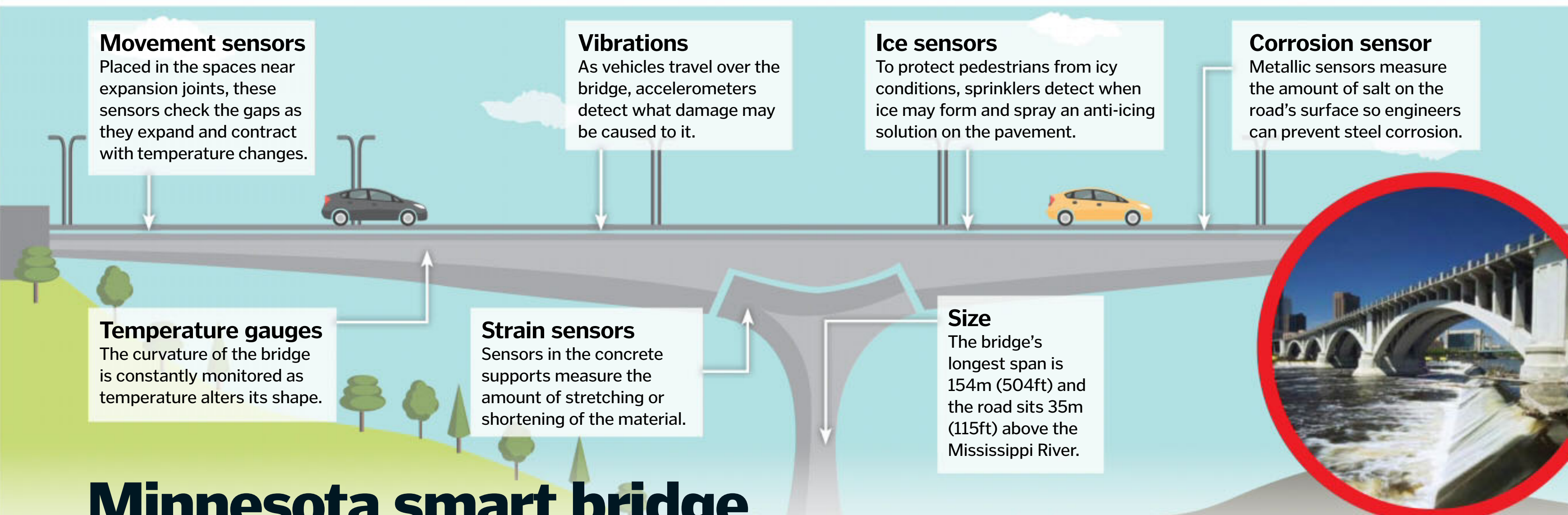
Translucence
The translucent material allows natural light and warmth in, while blocking the extremes of cold or heat.

Material
The lightweight ETFE material lets in natural light and is supported by steel cables.

Monorail
You can zip around the centre by a monorail that circles the complex.

Temperature
Cool air jets regulate the temperature inside while warm air currents travel up the walls to prevent ice forming.

Entertainment
The centre comprises a park, jogging track, shops, cinemas and restaurants.



Movement sensors
Placed in the spaces near expansion joints, these sensors check the gaps as they expand and contract with temperature changes.

Vibrations
As vehicles travel over the bridge, accelerometers detect what damage may be caused to it.

Ice sensors
To protect pedestrians from icy conditions, sprinklers detect when ice may form and spray an anti-icing solution on the pavement.

Corrosion sensor
Metallic sensors measure the amount of salt on the road's surface so engineers can prevent steel corrosion.

Temperature gauges
The curvature of the bridge is constantly monitored as temperature alters its shape.

Strain sensors
Sensors in the concrete supports measure the amount of stretching or shortening of the material.

Size
The bridge's longest span is 154m (504ft) and the road sits 35m (115ft) above the Mississippi River.

Minnesota smart bridge

When the Mississippi River Bridge in Minneapolis, Minnesota collapsed in 2007 one of the key features of its replacement – the Saint Anthony Falls Bridge – was the ability to monitor the condition of the bridge so it could never happen again. The $234 (£150)-million bridge took under a year to complete and is now known as 'America's smartest bridge'. The 371-metre (1,216-foot)-long bridge contains a number of sensors that measure the amount of movement caused by weather, air temperature and traffic. It then transmits this data to Minnesota University. Accelerometers are also placed at the mid-point of each girder to check for excessive vibrations.

"This $1.2-billion American football stadium is packed to the rafters with amazing technology"

SMART STADIUMS

The rise of sport on TV and internet streaming is making it tougher for sports teams to lure fans to the stadium, but the new home of the San Francisco 49ers, the Levi's Stadium, could turn the tide. This $1.2-billion (£788-million) American football stadium is packed to the rafters with amazing technology, such as 4K televisions, Wi-Fi access for all and an app that guides you to your seat. All this tech is aimed at getting fans off the sofa and to the ground by offering the multimedia experience they can enjoy at home while savouring the atmosphere only live entertainment can bring. ▶

Levi's screens

From giant scoreboards to smartphone apps, Levi's Stadium is incredibly well connected

1 Seat finder The app can detect where you are and guide you to the entrance nearest your seat.

2 Solar power 1,858m² (20,000ft²) of solar panels are capable of providing the energy for all ten of the team's home games each year.

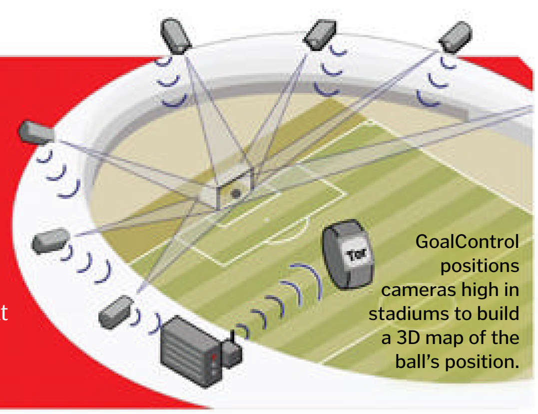
3 On the box 70 4K televisions are installed in the executive suites with a further 2,000 Sony TVs around the stadium.

4 On-the-go food You can order food via the app, which will be delivered to your seat.

5 Wi-Fi connectivity An incredible 40Gb/s of bandwidth can service speedy Wi-Fi access for 60,000 fans.

Goal-line technology

The clamour for goal-line technology in football became too loud for FIFA to ignore following the 2010 World Cup, so several methods were trialled. Hawk-Eye and GoalControl employ 14 high-speed cameras running at 500 frames per second to follow the ball all game, building up a 3D image of its position on the pitch. If the ball crosses the line a signal is sent to the referee's watch. Other systems such as Cairos GLT and GoalRef use a combination of magnetic fields and electronics. The goal is surrounded by low magnetic fields and the ball contains an electronic circuit. The ball's circuit causes a measurable change in the magnetic field when it enters the goal. Sensors detect this change and instantly alert the referee.



GoalControl positions cameras high in stadiums to build a 3D map of the ball's position.

DID YOU KNOW? *France's Karim Benzema scored the first goal-line-tech confirmed goal, at the 2014 World Cup against Honduras*

Skycam

Skycam is a Sony HDC-P1 camera hooked up to a Steadicam harness. This harness is secured by four cables that stretch to each corner of a stadium. These are manipulated to allow the camera to rise, fall, rotate 360 degrees and track the action at up to 40 kilometres (25 miles) per hour. The 23-kilogram (50 pound) device also contains an obstacle avoidance system that detects a hazard and automatically re-adjusts. It can even broadcast live action in 3D.

If there is an aerial shot of the game then chances are a Skycam took it

6 Scoreboards The stadium has two huge LED-lit scoreboards, the larger of the two measures 61 x 14.6m (200 x 48ft).

7 Instant replays If you've missed anything you can get instant replays on your phone.

8 Bathrooms breaks The app also helps you find the food stands and bathrooms with the shortest queues.

9 Eco-grass The Bermuda Bandera grass uses 50 per cent less water than normal grass.

10 Access points There are 1,500 internet access points in the stadium, more than double than the amount at last year's Super Bowl venue.

Appy and you know it

Stadiums are starting to use apps to enhance the fans' experience. The Levi's Stadium app allows fans to order food and drink, find seats and toilets and watch instant replays. The Wembley Stadium app displays the view from a particular seat before the ticket is bought and features a travel planner. The Dallas Cowboys have gone for the entertainment angle, using the Wi-Fi connection to sync up all users' smartphones and create a light show.

The Dallas Cowboys' AT&T Stadium has screens and an app to deliver an amazing fan experience

"Architects have to account for earthquakes, wind, weight, occupants and any number of variables"

REACH FOR THE SKY SKYSCRAPERS

How the world's tallest buildings are breaking new ground

The challenges in building skyscrapers are as enormous as the structures themselves. Architects have to account for earthquakes, wind, weight, occupants and any number of variables to ensure their creation stands the test of time. The ultimate aim is to be the biggest, but when that's not achievable, a skyscraper has to innovate to be the standout part of their city's skyline. Awe-inspiring shapes, eco-friendly technology and lightning-fast lifts are just some of the ways technology is making these modern monoliths among the most incredible sights in the world.

Kingdom Tower, Saudi Arabia

The skyscraper in Jeddah that is set to be the tallest in the world

Height
When finished, Kingdom Tower will be 1,000m (3,281ft) tall, the first building ever to reach 1km (0.62mi). It is due for completion by 2018 at a cost of $1.2bn (£778mn).

Sky terrace
On the 157th floor the tower has a unique 30m (98ft)-diameter balcony. This so-called 'sky terrace' will provide residents of the penthouse floor with outdoor space.

Wind analysis
Canadian engineering firm RWDI was hired to perform wind analysis on the Kingdom Tower. This was essential because of fierce winds whipping off the Red Sea.

Rising up
Despite the competition from its nearby neighbours the Shanghai Tower is the tallest building in China, standing 632m (2,073ft) tall, and is second tallest in the world.

Eco-friendly
The glass skin allows natural light into the building to keep electricity costs down. 270 wind turbines provide the energy for the building's upper floors and the exterior lighting.

Lift
The Kingdom Tower will be home to the world's fastest double-decker lift at 10m/s (33ft/s). Kone will build eight of these as well as 50 other lifts and eight escalators.

Multipurpose
The building will have a number of uses. Certain floors have been earmarked for a hotel, offices and apartments. 160 of the floors will be inhabited in one way or another.

Keeping still

A major consideration in the construction process for buildings in areas prone to earthquakes is how to make sure they stay standing. The Taipei 101 skyscraper in Taiwan has a 730-ton ball hanging from its roof which swings slightly when the building starts to shake, counteracting any movement and drastically reducing the amount of sway. Other buildings such as the Utah State Capitol (below) use a different system known as base isolation. Almost 300 rubber-topped isolator devices are installed under the floor of the Capitol, acting like a suspension system to keep the building stable during strong seismic events.

KEY DATES
LAST FIVE TALLEST BUILDINGS

1972
The original 417m (1,368ft)-high World Trade Center took the title from the Empire State Building.

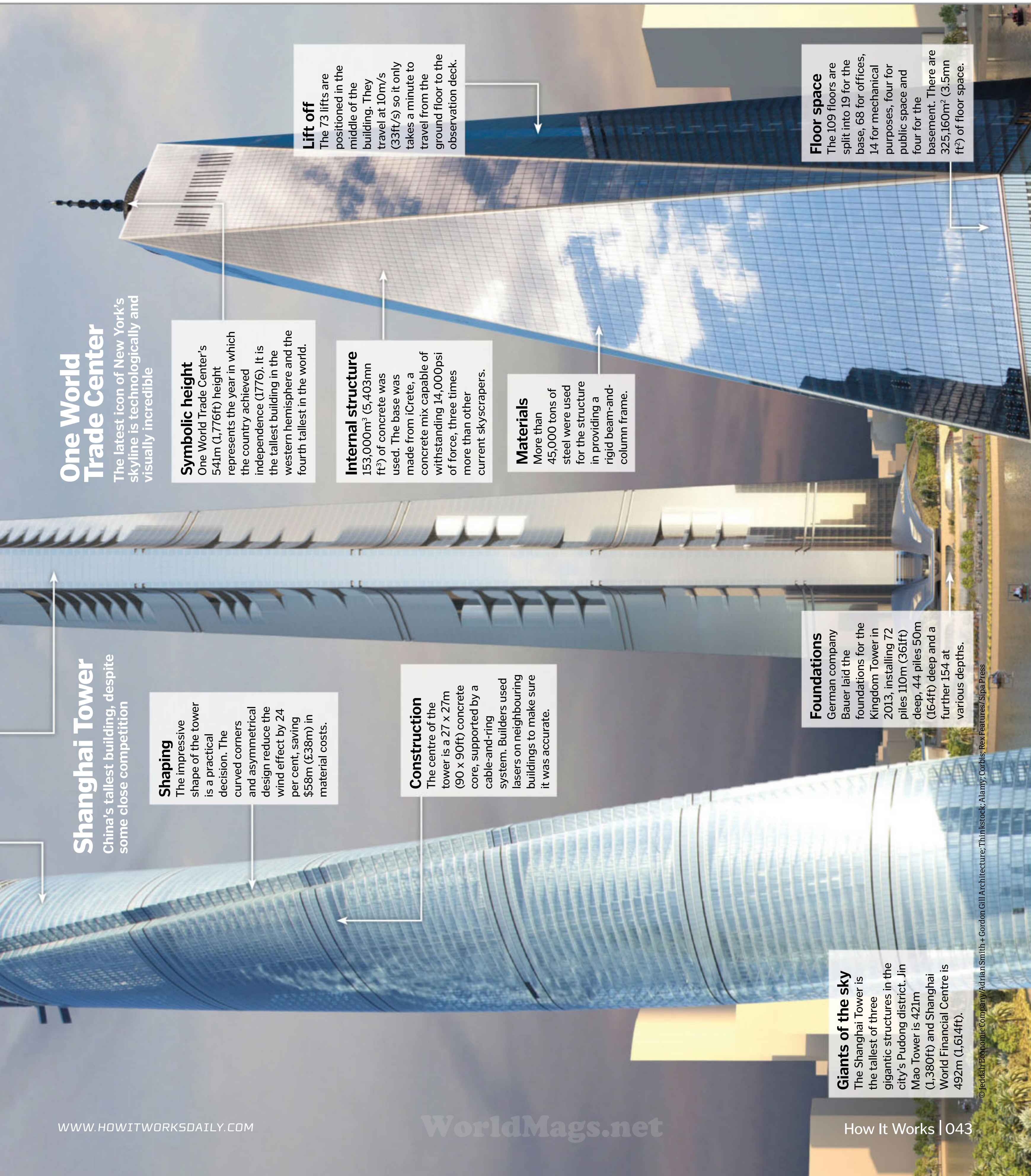
1973
In 1973 Willis Tower in Chicago, formerly known as the Sears Tower, became the world's tallest building at 442m (1,450ft).

1998
Malaysia's Petronas Towers became the record holder after a legal battle as the Willis Towers' antenna made the latter taller.

2004
Taipei 101 stands an impressive 509m (1,670ft) above the ground, taking the crown.

2007
Burj Khalifa has held the title since 2007, standing an incredible 828m (2,717ft) tall.

DID YOU KNOW? By moving just 1.5m (5ft) in any direction, the damper reduces sway in Taipei 101 by up to 40 per cent



One World Trade Center

The latest icon of New York's skyline is technologically and visually incredible

Symbolic height
One World Trade Center's 541m (1,776ft) height represents the year in which the country achieved independence (1776). It is the tallest building in the western hemisphere and the fourth tallest in the world.

Lift off
The 73 lifts are positioned in the middle of the building. They travel at 10m/s (33ft/s) so it only takes a minute to travel from the ground floor to the observation deck.

Internal structure
153,000m³ (5,403mn ft³) of concrete was used. The base was made from iCrete, a concrete mix capable of withstanding 14,000psi of force, three times more than other current skyscrapers.

Materials
More than 45,000 tons of steel were used for the structure in providing a rigid beam-and-column frame.

Floor space
The 109 floors are split into 19 for the base, 68 for offices, 14 for mechanical purposes, four for public space and four for the basement. There are 325,160m² (3.5mn ft²) of floor space.

Shanghai Tower

China's tallest building, despite some close competition

Shaping
The impressive shape of the tower is a practical decision. The curved corners and asymmetrical design reduce the wind effect by 24 per cent, saving $58m (£38m) in material costs.

Construction
The centre of the tower is a 27 x 27m (90 x 90ft) concrete core, supported by a cable-and-ring system. Builders used lasers on neighbouring buildings to make sure it was accurate.

Foundations
German company Bauer laid the foundations for the Kingdom Tower in 2013, installing 72 piles 110m (361ft) deep, 44 piles 50m (164ft) deep and a further 154 at various depths.

Giants of the sky
The Shanghai Tower is the tallest of three gigantic structures in the city's Pudong district. Jin Mao Tower is 421m (1,380ft) and Shanghai World Financial Centre is 492m (1,614ft).

"Once the heated plastic leaves the nozzle, it quickly solidifies into a strong, stable structure"

The 3Doodler

How does this pen let you draw in the air?

The world's first 3D-printing pen – WobbleWorks's 3Doodler – was launched on KickStarter in 2013, where it received over £1.3 million ($2 million) in funding in just 34 days. This gizmo enables you to turn drawings into full-3D models on any surface, without the need of any software or computer. Unlike a normal pen, however, the 3Doodler doesn't use ink, instead relying on filaments of ABS or PLA plastic, materials also used by most desktop 3D printers.

Similar to its more expensive desktop counterparts, the 3Doodler prints by heating three-millimetre (0.1-inch)-thin strands of plastic, which need to be loaded into its back. After turning the 3Doodler on and waiting a few minutes for it to warm up, the LED indicator light will turn blue, which means the heated plastic can then extrude from the 3Doodler nozzle's metal tip – the only potentially dangerous part, which can get as hot as 270 degrees Celsius (518 degrees Fahrenheit).

Once the heated plastic leaves the nozzle, it quickly solidifies into a strong, stable structure, allowing you to build shapes with ease. Because the heated plastic can be drawn over almost any surface, including other plastic, even items like an iPhone case can be personalised in a variety of colours.

There are two temperature settings so users can switch between the different melting points of ABS and PLA, and two main speed control buttons allow for the heated plastic to flow quicker or slower. This makes it possible to create large items with a sizeable area to fill, as well as more intricate, delicate details.

The 3Doodler allows anyone to draw straight into the air by heating ABS or PLA plastic

3Doodler 2.0

The new update to the original 3Doodler is this year's 3Doodler 2.0, which is 75 per cent smaller and over 50 per cent lighter than the first 3Doodler at only 50 grams (1.8 ounces).

Enhanced airflow from the top of the pen allows for plastic to be kept cool more quietly and efficiently while requiring less than half the power, while a new manual temperature optimisation option lets artists control minor flow adjustment to their extruded results.

The nozzle has also been redesigned to improve accuracy, and a fully re-engineered drive system, including the option for both speed control and a double click for continuous flow, has been added.

The difference between ABS vs PLA for 3D printing

One of the most common plastics around today is ABS, or Acrylonitrile Butadiene Styrene. Made of oil-based resources, it's much stronger and less likely to snap when bent compared to PLA, and has a higher melting point at 225 to 250 degrees Celsius (437 to 482 degrees Fahrenheit) for the 3Doodler. It forces out a more flexible material from the pen, and is easier to peel off of paper than the 3Doodler PLA. In traditional 3D printing, ABS is a plastic that can easily deform if not being printed on a heated surface, such as a heated build platform.

PLA, or polylactic acid, is a biodegradable polymer, so it is considered better for the environment when properly recycled compared to ABS. It also comes in a huge variety of colours and can even be translucent. However, due to the lower melting point of 190 to 240 degrees Celsius (374 to 464 degrees Fahrenheit) for the 3Doodler, PLA is more prone to overheating and can droop if it gets too hot. It also adheres very well so may not be suitable for peeling off paper like ABS is; though this is an advantage for mixed media, such as sticking 3Doodle creations to a glass surface.

Both PLA and ABS can be used with the pen, which heats at two different temperatures

1. CRAZY

Nitro-ice-cream buggy
The ice-cream-making buggy uses liquid nitrogen to make its product in a hurry and can reach nearly 10km/h (6mph).

2. CRAZIER

Levitron
This invention uses ultrasonic sound waves to levitate a droplet of alcohol that you can grab out of the air.

3. CRAZIEST

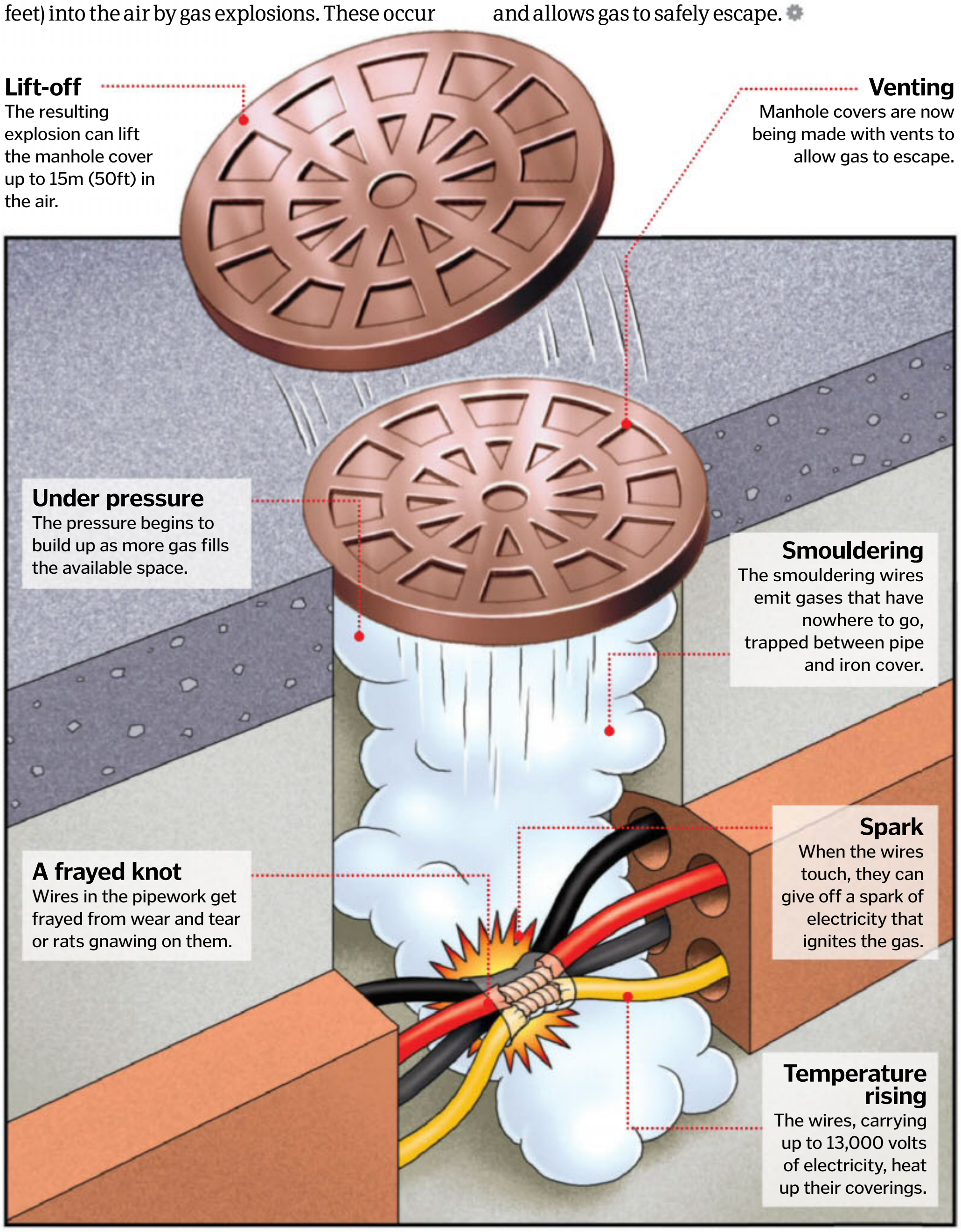
Ice-cream pottery
Ice cream, a potter's wheel and some liquid nitrogen come together to create a wonderful ice-cream bowl.

DID YOU KNOW? *The first manhole covers were constructed in the early-19th century and were used for covering pipelines*

Exploding manhole covers

A cast-iron way to keep the smell of the sewers off the streets

Manhole covers are metal discs that prevent people and vehicles from falling into sewer-access pipes. They can weigh as much as 136 kilograms (300 pounds), but it's possible for them to be blasted up to 15 metres (50 feet) into the air by gas explosions. These occur when frayed or gnawed cables heat up and begin to smoulder. The combination of gas, an ignition spark from the wires and a build-up of pressure is enough to launch the cover into the air. Adding vents into the design stops this pressure build-up and allows gas to safely escape.



Edible mist machine

Taste 200 flavours with zero calories

The Edible Mist Machine uses ultrasonic vaporisation to create flavoured mist. Rhys Saunders from Lick Me I'm Delicious, the company that made the machine, explains the technology behind the process: "The liquid is made up of flavour essences mixed with a water solution to create the optimum viscosity to carry flavour and still produce a mist. The mist is created by pulsing ultrasonic vibrations through the liquid."

When the mains-powered unit vibrates at a frequency of over 20 kilohertz, the water absorbs the energy of the vibrations. The water droplets begin to vaporise as mini-currents start to flow throughout each droplet, dispersing the molecules. This creates the mist, which rises up through the central tube into the upper bowl.

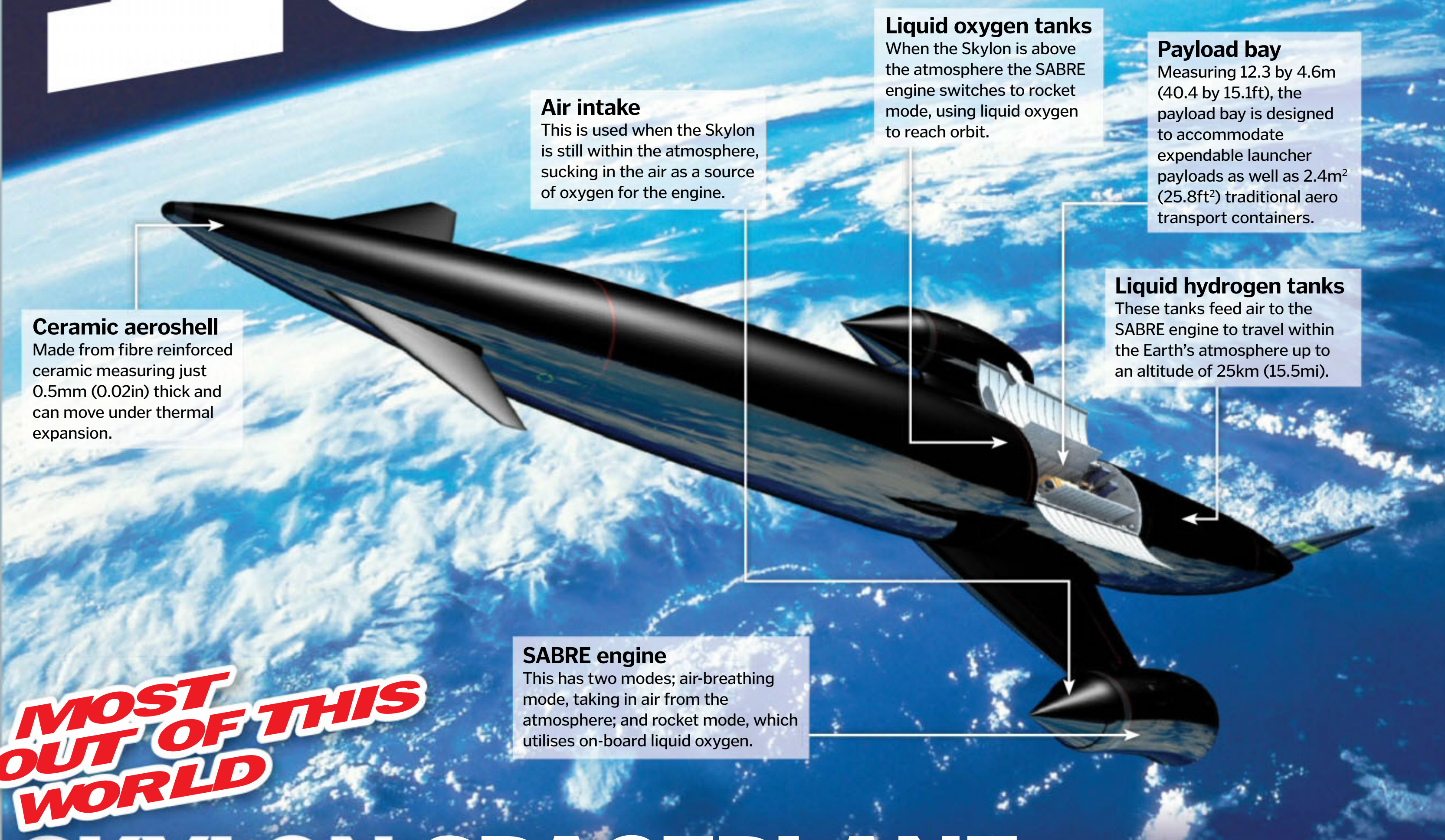
The curved shell design helps to push the mist out toward the user while the domed top keeps it from escaping. Once here the flavoured mist can be sucked up through straws providing a calorie-free taste sensation. The high-powered LEDs change colour depending on the flavour being produced.

The machines use ultrasound to create edible mist and LEDs that change colour

© Lick Me I'm Delicious

10 AMAZING VEHICLES

Counting down the fastest, toughest and most powerful rides around



MOST OUT OF THIS WORLD

SKYLON SPACEPLANE

High above the section of sky normally populated by international airliners, the Skylon spaceplane could well be the first of its kind to make spaceplanes a viable mode of transport on the edge of our atmosphere. Unpiloted, the Skylon is a reusable aircraft (unlike one-use spaceships in operation to date) that, when fully developed, will be able to transport up to 15 tons of cargo into space. The cutting-edge technology of the Skylon lies in its combined air-breathing and rocket-powered cycles that mean the craft can take off and land on a runway either side of flying directly into orbit.

As well as being able to carry cargo and personnel as per a traditional airliner, the Skylon craft can link supplies to space stations thanks to a specially designed interface, and can launch multiple small satellites thanks to an onboard carrier rack. Skylon will also be able to deliver payloads to low-Earth-orbit satellites for telecoms companies, cementing its status as a multi-purpose craft for use in space.

The statistics...

SKYLON

Speed: Mach 25
Unladen weight: 41,000kg
Passengers: 30
Length: 82m
Wingspan: 25m
Fuel mass: 220,000kg

HEAD 2 HEAD
SIZING THEM UP

Aeroscraft Pelican
The Pelican is the smallest airship from Aeroscraft and does not have a cargo bay, so it can't entertain a payload.

Aeroscraft ML 866
This airship has a 67 x 12 x 9m (220 x 40 x 30ft) cargo bay, with space for a 66t payload over a range of 5,741km (3,567mi).

Aeroscraft ML 86X
The biggest Aeroscraft can carry 7.5 times the weight of the mid-range ML 866, with a range of 9,445km (5,869mi).

DID YOU KNOW? *The F-22 Raptor can comfortably cruise at over 1.5 times the speed of sound*

MOST ADVANCED FIGHTER JET

The statistics...

F-22 RAPTOR

Length: 18.9m
Speed: Mach 2
Crew: 1
Cost: $412 million each
Range: 3,000km
Weight: 19,700kg (empty)

Engine
Two powerful engines enable the plane to travel faster than the speed of sound.

Body components
The F-22 Raptor is made from 39% titanium, 24% composites, 16% aluminium and 1% thermoplastic.

Wings
Rear wings help stabilise the craft in the sky, while the composite ribs can pivot slightly from a composite pivot shaft to aid manoeuvring.

Weapon pylon
This stores weapons including bombs and air-to-air missiles.

Air-to-air missiles
The Raptor stores AIM-9 sidewinder air-to-air missiles in radar-repellant compartments ready for deployment.

Landing gear
The Raptor's landing gear includes Michelin Air-X steel-belted radial tyres.

Ejection seat
The pilot can exit the aircraft immediately at the press of a button as the parachute-enabled seat is fired away from the craft.

Active radar
The active array radar helps find and locate targets up to 25km (15.5mi) away, in the sky or on land.

Missile detection
The Missile Launch Detection system alerts the pilot when the craft is being targeted.

F-22 RAPTOR

Considered by aviation experts to be the pinnacle of war-based flight, the F-22 Raptor is billed as practically unbeatable in air-to-air combat and is the only fighter jet that can also conduct air-to-ground combat missions, all while remaining undetectable to the enemy. The key to the new generation F-22 Raptor's arsenal is its stealth: the lithe warplane maintains a low radar signature by deflecting radar 'pings' and storing weapons in internal bays. Speed is also key to the fifth-generation fighter jet: thanks to two powerful Pratt & Whitney F-119-PW-100 engines, the F-22 can accelerate far past the speed of sound and even cruise at supersonic speeds without using afterburners or thrust vectoring, unlike its predecessor. The deadly arm of the Raptor's arsenal is equally thrilling, with an assortment of on-board weapons such as AIM-120 AMRAAM air-to-air missiles (the number depending on the particular configuration) and eight GBU-39 small-diameter bombs.

F-22 Raptor
Max speed: 2,000km/h (1,243mph)

Formula 1 car
Max speed: 400km/h (248mph)

FASTEST ELECTRIC COUPE

DETROIT ELECTRIC SP:01

Marking the start of a new era for the automotive sector, the Detroit Electric SP:01 is one of the fastest production electric sports car on Earth. Fittingly built at the spiritual home of the automobile in Detroit in the United States, the SP:01 is a two-seater sports car that accelerates to 100 kilometres (62 miles) per hour in less than four seconds before powering all the way to 249 kilometres (155 miles) per hour.

Where the rear-wheel-driven vehicle differs from other sports cars with similarly impressive performance figures is in its engine – or lack thereof. Instead of utilising an internal combustion engine like a traditional car, the SP:01 is powered by a mid-mounted electric motor that features a rechargeable battery pack. The advanced technology on the car means the electric motor is compact, maintaining the necessary lightweight status for a sports car.

The SP:01 aims to produce traditional sports-car-like performance via renewable energy means

The SP:01 can race flat-out from London to Manchester on one charge.

The statistics...

SP:01

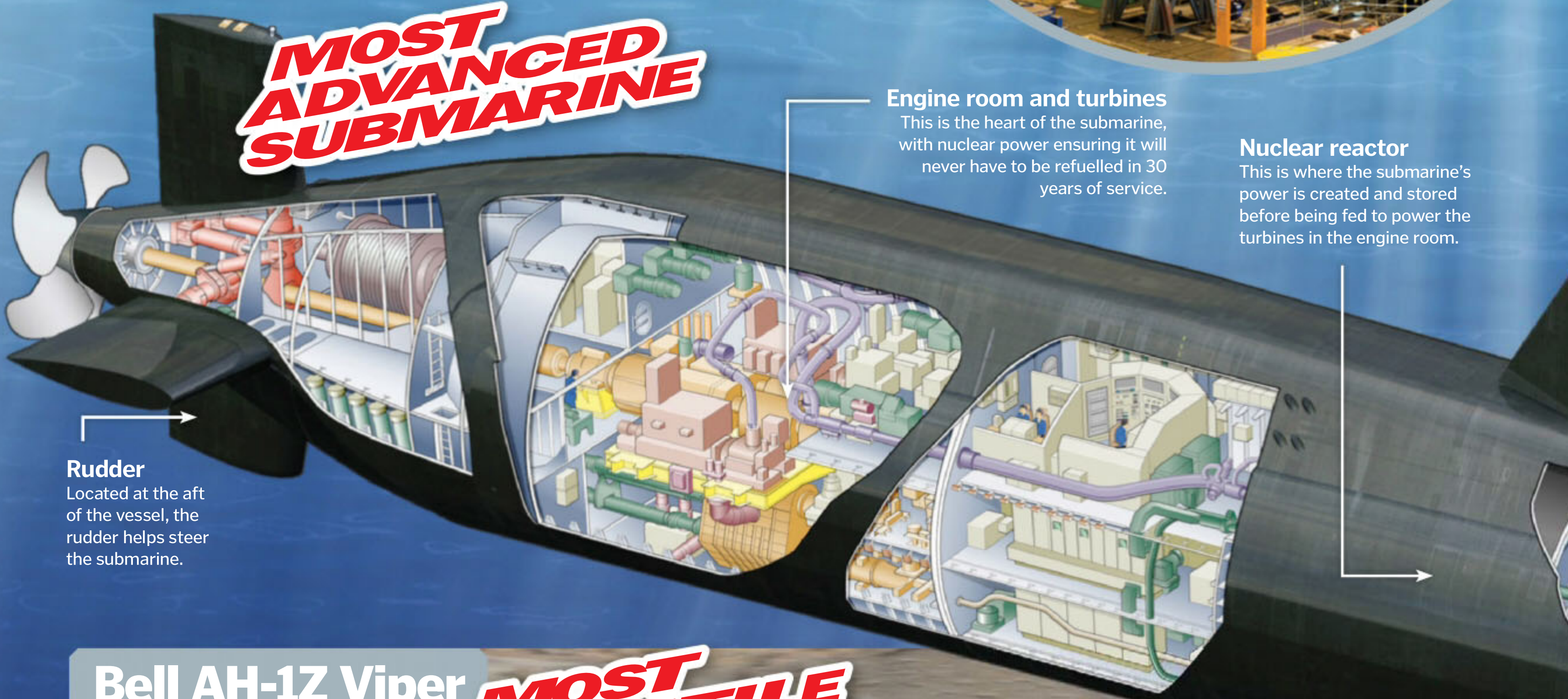
Top speed: 249km/h
0-100km/h: 3.9s
Electric power: 210kW
Torque: 280Nm
Unladen weight: 1,175kg
Electric range: 288km

"HMS Artful is only limited in dive endurance by the amount of food it can carry for the crew"

HMS ARTFUL

MOST ADVANCED SUBMARINE

One of the newest additions to the Royal British Navy fleet, HMS Artful is one of the most advanced nuclear submarines on the planet. The new attack submarine boasts ultra stealth, huge listening power (the Thales Sonar 2076 sonar suite has the processing power of 2,000 laptop computers) plus unrivalled nuclear power that means the submarine will never need to be refuelled. What's more, the all-new submarine is able to strike targets up to 1,000 kilometres (621 miles) away with pinpoint accuracy, and can easily circumnavigate the world in one dive. In fact, HMS Artful, third in the Navy's new fleet of Astute class submarines, is only limited in dive endurance by the amount of food it can carry for the crew. It manufactures its own oxygen and fresh water from the ocean, and instead of being fitted with the traditional 'optical periscopes,' the vessel uses high specification video technology to stream images to television screens via fibre-optic cables.



Bell AH-1Z Viper

MOST VERSATILE

A proud addition to the US military's fleet, the AH-1Z Viper is a lethal attack helicopter produced by Bell. Featuring an enviable selection of avionics and countermeasures such as laser, radar and missile warning systems, the helicopter is also fitted with an array of weapons for air-to-air and air-to-surface combat. These include a three-barrelled Gatling gun, two AIM-9 Sidewinder missiles, 16 Hellfire missiles (eight on each wing), plus rocket pods. The AH-1Z Viper is also one of the most powerful helicopters in the skies today, with a composite four-bladed main rotor (instead of the usual two) aiding flying characteristics. In the event of a crash, the Viper has energy-absorbing landing gear, self-sealing fuel tanks and crashworthy seats to help minimise fatalities.

The statistics...

AH-1Z Viper

Power: 3,600shp
Cost: $31 million
Unladen weight: 5,580kg
Rate of climb: 14.2m/s
Cruise speed: 296km/h
Crew: 2

STRANGE BUT TRUE
STUCK IN DEVELOPMENT

When was the F-22 Raptor first commissioned?

A The 1980s B 2010 C Yesterday

Answer:
The F-22 Raptor was commissioned decades ago in the 1980s, but the ever-increasing costs of producing the next-gen war plane meant the first official deployment of the aircraft in an act of war was for air strikes in Syria in September 2014.

DID YOU KNOW? HMS Artful is the second boat to be given the name in the Royal Navy since 1947

CIGARETTE AMG ELECTRIC DRIVE

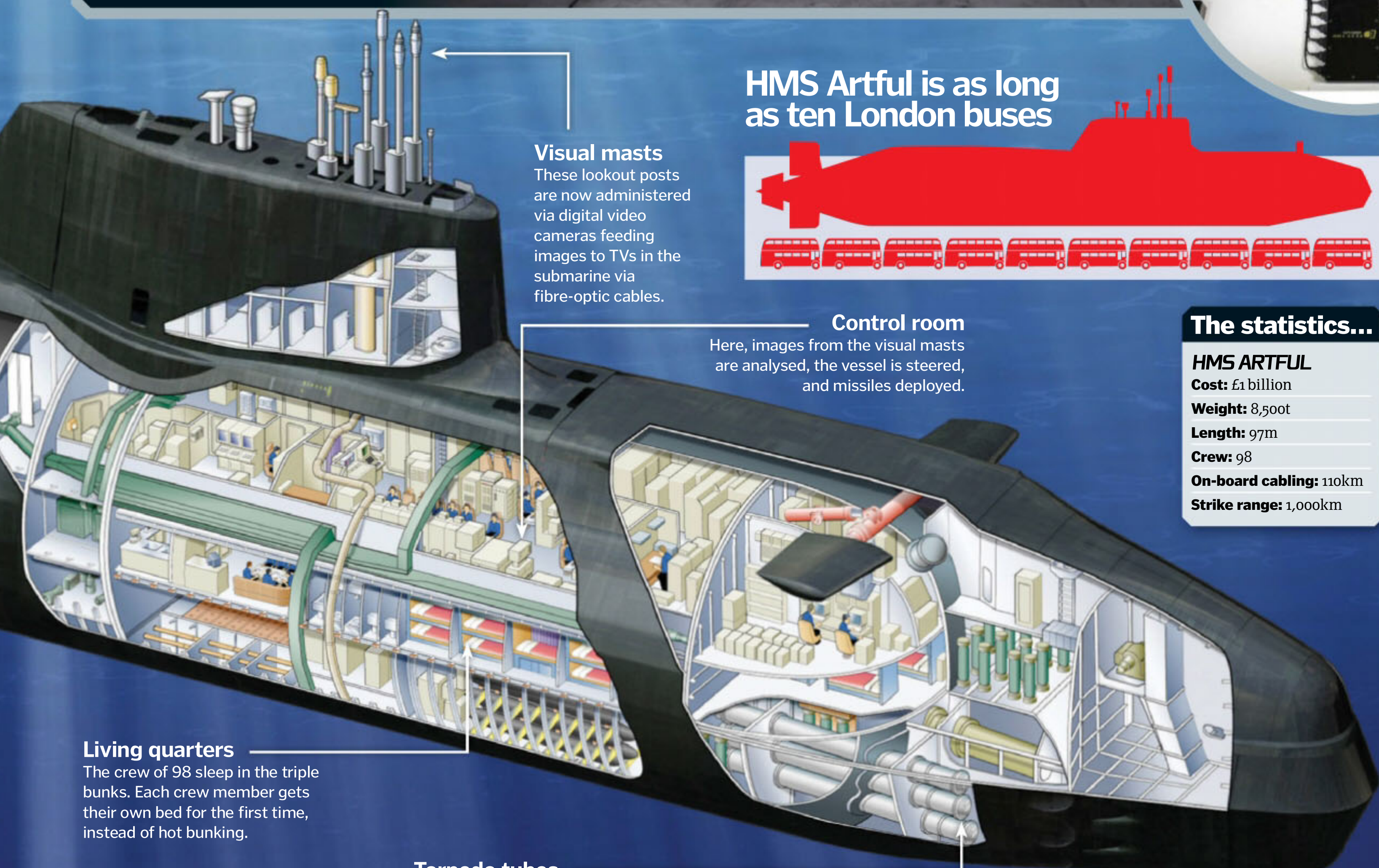
Built by Stuttgart-based automotive manufacturer Mercedes AMG for the famous US Cigarette powerboat racing team, the Cigarette AMG Electric Drive is the most powerful electric performance boat in the world. Utilising motors from the SLS AMG Electric Drive supercar, the all-new powerboat has two powertrains mounted symmetrically on either side of the boat. Each powertrain contains six compact motors capable of providing 138 kilowatts of output. The powertrains, transmissions and batteries are mounted low down at the back of the boat for optimum performance, meanwhile producing zero emissions. This low centre of gravity is ideal in making the 11.6 metre (38 feet) performance powerboat even more agile than its combustion-engined contemporaries.

MOST POWERFUL SPEEDBOAT

The statistics...

AMG ELECTRIC

- **Electric motors:** 12
- **Powertrains:** 2
- **Power:** 2,220hp
- **Torque:** 3,000Nm
- **Length:** 11.6m
- **Emissions:** 0



Visual masts
These lookout posts are now administered via digital video cameras feeding images to TVs in the submarine via fibre-optic cables.

Control room
Here, images from the visual masts are analysed, the vessel is steered, and missiles deployed.

Living quarters
The crew of 98 sleep in the triple bunks. Each crew member gets their own bed for the first time, instead of hot bunking.

Torpedo tubes
Based at the fore of the submarine, the torpedoes and other missiles are housed internally with flaps moving during their deployment.

HMS Artful is as long as ten London buses

The statistics...

HMS ARTFUL

- **Cost:** £1 billion
- **Weight:** 8,500t
- **Length:** 97m
- **Crew:** 98
- **On-board cabling:** 110km
- **Strike range:** 1,000km

"The Aeroscraft is capable of vertical takeoff and landing, even at maximum payload"

TOUGHEST TANK

The statistics...

CHALLENGER 2
Power: 1200bhp
Combat weight: 62,500kg
Top speed: 59km/h
Length: 13.5m (gun forward)
Height: 2.5m
Crew: 4

CHALLENGER 2

A radical evolution over its Challenger 1 predecessor, the Challenger 2 is the British Army's main battle tank and without question one of the toughest in the world. Improved armour over the Challenger 1 means it's extremely well protected, with new thermal-observation and gunnery displays magnifying the image for the commander and gunner in charge. To aid viewing from inside the tank, the Challenger 2 provides the commander with a gyro-stabilised panoramic sight with laser range finder. The driver is treated to an image-intensifying day and night periscope, providing enhanced observation and vision for a tank that is capable of speeds of 59 kilometres (37 miles) per hour on good terrain. The Challenger 2 has a range of 250 kilometres (155 miles) cross-country on one tank of diesel fuel.

MOST ADVANCED HYPERBIKE

KAWASAKI 2015 NINJA H2R

Kawasaki is no stranger to producing some of the most decorated superbikes in the world, but the H2R model from the legendary Ninja range utilises an array of minute cutting-edge devices that in concert create the most technologically advanced superbike on the planet. Boasting high-revving forced induction via a supercharger with a 3D-machined impeller that spins at 9.2 times the speed of the crankshaft, pumping 200 litres (53 gallons) of air per second into the engine – without the need for a heavy intercooler. Advanced traction control keeps the bike on the asphalt with constant analysis of the bike's performance parameters, while huge 33-centimetre (13-inch) Brembo racing brakes (usually seen on top-spec supercars) provide stopping power. The carbon-fibre body is super lightweight with advanced aerodynamics generating significant downforce. The high-tensile steel frame allows for an open design, aiding heat dissipation and improving performance.

The statistics...

NINJA H2R
Price: $50,000
Kerb weight: 216kg
Displacement: 998cc
Length: 2m
Width: 0.8m
Ground clearance: 13cm

The Kawasaki Ninja H2R is the most extreme hyperbike of today, recognisable by its chrome fuel tank

KEY DATES
THE HISTORY OF THE TANK

Feb 1915
Winston Churchill chairs the Landships Committee, which looks at building a trench-crossing machine with mounted guns.

Sep 1915
After a number of failed tank attempts, the 'Little Willie' design features the rhomboid track frame still seen today.

1939-45
Out of necessity during WWII, tank designs are developed to improve range, armour and manoeuvrability.

1960s
The British Army's Chieftain is more powerful than ever, with a multi-fuelled engine and a powerful 120mm main gun.

1983
First Challenger tanks feature hydropneumatic suspension for better cross-country traversal.

DID YOU KNOW? Unlike a conventional helicopter, the pilot of the AH-1Z Viper sits in the back, with the gunner sitting up front

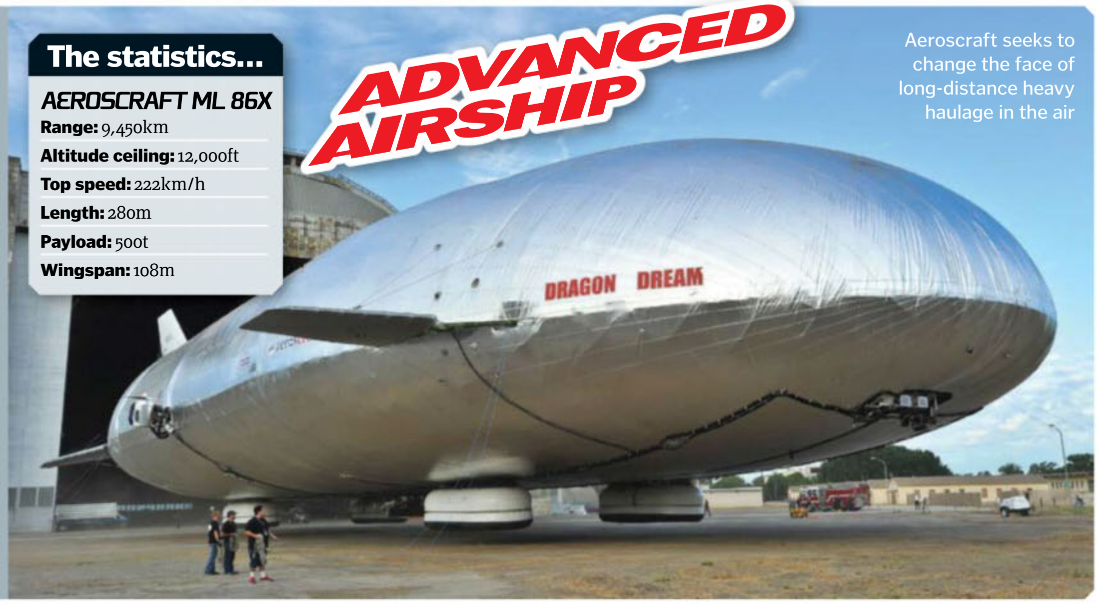
AEROSCRAFT

Self-billed as heralding a new century of aviation innovation, the Aeroscraft is a prototype airship designed to transport huge volumes of cargo via the skies. It does so via its patent-pending Control Of Static Heaviness (COSH), which allows the pilot to control the airship's buoyancy inside multiple helium pressure envelopes (HPEs) to ensure it is lighter than air for flight and heavier than air for landing. This means the Aeroscraft is capable of vertical takeoff and landing at maximum payload, and can hover over unprepared or unconventional aircraft landing surfaces to unload cargo. Unlike other contemporary airships that do not have a rigid structure (and rely on the gases that fill them to take their shape) the Aeroscraft has a rigid structure made from aluminium and carbon fibre that allows for the mounting of engines, cockpits and propulsion systems.

The statistics...

AEROSCRAFT ML 86X

Range: 9,450km
Altitude ceiling: 12,000ft
Top speed: 222km/h
Length: 280m
Payload: 500t
Wingspan: 108m



Aeroscraft seeks to change the face of long-distance heavy haulage in the air

The statistics...

JLTV

Kerb weight: 6,350kg
Length: 5.4m
Range: 483km+
Top speed: 113km/h
Power generation: 75kW
Operational height: 2.2m

Lockheed Martin JLTV

Although the Humvee has long been the armoured vehicle of choice for the US Army, its replacement, Lockheed Martin's Joint Light Tactical Vehicle (JLTV), is billed as the new 'best' in protection, payload and performance. Every area has been improved upon, from fuel efficiency to acceleration, ride quality and protection from explosives. The Lockheed JLTV ensures protection from roadside IEDs without the added weight from bodywork being detrimental to performance. Meanwhile, the push toward a relatively more lightweight setup means the JLTV can now be transported by CH-47 and CH-53 lift helicopters. Adjustable air suspension aids handling and ride quality over rough terrain, and the Lockheed also generates 75 kilowatts of power, well above the US government's required minimum of ten kilowatts.

Putting airships back into the limelight

Interview with Director John Kiehle of Aeroscraft

What advanced tech does the Aeroscraft fleet utilise?
The Aeroscraft integrates a proprietary and innovative internal buoyancy management system called COSH, or Control Of Static Heaviness – the first prototype of which was demonstrated aboard one of Aeros' traditional airships – alongside other sub-systems needed when moving cargo to austere environments – internal rigid structure, vectored thrust, low-speed control, air-bearing landing system, fiber-optic enhanced fly-by-wire avionics, and so on.

How important is the ability to perform a vertical takeoff and landing?
It is essential. VTOL is significantly important for accessing austere locations and eliminating supporting infrastructure requirements. Airships requiring a 'running start' for aerodynamic benefits to takeoff at maximum payload will be tied to airports and need shorter but wide runways. Without internal buoyancy control found on the Aeroscraft, competitive hybrid designs will not achieve true VTOL flight or infrastructure independence, limiting delivery to the most austere locations and limiting project cargo delivery capabilities.

What boundaries have you had to overcome in the project?
Cargo-airship utility has been historically hindered by external ballast exchange requirements as well as lack of VTOL flight capability, slow speed, and non-rigid structural design that has limited payload capacity, aerodynamic loading (speed) and propulsion flexibility. The Aeroscraft's validated self-ballasting design overcomes all these limitations.

"The AirWheel incorporates a fast-charging battery, like the ones used in the latest eco-friendly cars"

The AirWheel

This device could make walking a thing of the past

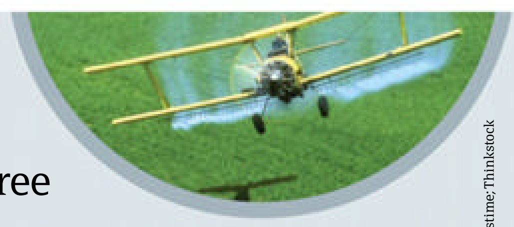
The brand new AirWheel – a self-balancing unicycle – could really liven up your daily commute. By simply leaning in the desired direction, you will be transported to wherever you want to go with the minimum of fuss. The AirWheel incorporates a fast-charging battery, like the ones used in the latest eco-friendly cars, and cutting-edge gyro technology that helps maintain its self-standing orientation.

A single charge will last for up to 45 kilometres (28 miles) and when the battery is spent it will gently lean back rather than cutting out sharply. Better still, when you go downhill or slow down, the battery will start to regenerate some of its lost juice. Waterproof and made of a comfortable elastic silicone, the AirWheel has been ideally designed whether it's for your nine-to-five or a quick jaunt down the shops. Even stairs don't faze the device, with a built-in carry handle that can be safely stowed away when not in use.

The AirWheel is priced between £509.99 and £799 ($849 and $1,333) and comes in six different unicycle models

Crop dusting is now a specialised profession that requires a commercial pilot's licence

Crop dusting



The million-dollar planes that keep our farms pest and weed-free

Buzzing over farmland between 30 and 100 times a day, crop dusting or 'aerial application' has been an effective way to tend to crops since the early-20th century. Originally balloons and biplanes were used, but in 2015, planes have intricate GPS systems and application methods designed to spread pesticides evenly. The aircraft can also be used as water bombers to put out forest fires and are particularly effective against locust hordes. Often there is no landing strip, so pilots are required to have at least 250 hours of flight experience before taking to the skies in one of these planes.

The practice eliminates the risk of damage by heavy tractor wheels and does not cause soil compaction, which can affect the yield. There is a growing fear that insects are getting wise to the chemicals and are hiding further down the plants, so crop dusting is now done at night to catch the little critters off-guard.


BUILT FOR ADVENTURE
HAWK
T100
SUPERLIGHT
POLYCARBONATE CASE
T100 GTLS
SELF - POWERED
ILLUMINATION
HAWK
200m
IN THE PHOTO:
Camping underneath the Aurora Borealis,
Iceland. Captured by Tim Nunn.
FOLLOW OUR CONTRIBUTOR ADVENTURES - OR TELL US YOURS
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HEROES OF... TRANSPORT

Earhart piloted a Lockheed Vega aeroplane in a First National Women's Air Derby

Amelia Earhart

Get to know the American aviator who mysteriously disappeared while attempting to break a record

Amelia Earhart deservedly remains one of the world's most celebrated aviators of all time. Remembered predominantly for her achievements and record-breaking experiences in the air, Earhart's courage and ambition have been inspirational to people across the globe.

Born Amelia Mary Earhart to Samuel 'Edwin' and Amelia 'Amy' Earhart in 1897, she had a somewhat difficult start in life. With an alcoholic father, Earhart and her sister were sent to stay with grandparents where home life became tough. The sisters created their own adventures – Earhart was quite the tomboy – but they had an unsettled childhood to say the least. Frequently changing schools inevitably had an impact on the quality of their education. Despite this, Earhart graduated from Hyde Park High School having excelled in chemistry, and with a particular admiration for women who had succeeded in male-orientated fields.

Although Earhart went on to attend Ogontz School, a visit to her sister in Toronto, Canada, exposed her to the harsh realties of World War I and she became a nurse's aide for the Red Cross in a military hospital, tending to wounded soldiers. Earhart returned to college as a premedical student, but her studies were interrupted again, as she moved to California to be closer to her parents. It was here that her interest in aviation turned into a serious hobby. After a ten-minute plane ride at an air show in 1920, Earhart knew she had to fly. She took her first lesson in 1921 and had saved enough money to buy her first plane within six months. She nicknamed the second-hand, bright-yellow Kinner Airster 'The Canary'. Seven years later, Earhart was asked if she would like to be the first woman to fly across the Atlantic. She completed the trip in approximately 21 hours on 17 June 1928 in a Fokker F.VII.

> "After a ten-minute plane ride at an air show in 1920, Earhart knew she had to fly"

A life's work

The high-flying milestones of Amelia Earhart's eventful life and career

1897
Amelia Mary Earhart is born on 24 July in Atchison, Kansas, USA, to Edwin and Amy Earhart.

1915
Earhart graduates from Hyde Park High School.

1916
Earhart attends the girls' finishing school Ogontz in Philadelphia.

1917
Earhart visits her sister in Toronto, Canada. She sees injured soldiers from WWI and volunteers as a nurse's aide.

1920
Pilot Frank Hawks gives Earhart a ride in a plane that makes her realise she has to fly.

The big idea

Following a number of aviation successes, Earhart decided that 1937 was to be the year of her ultimate achievement: she was going to become the first woman to fly around the world. After a failed attempt in March of that year, the ever-determined Earhart set off on 1 June with navigator Fred Noonan. Inaccurate maps and unexpected weather conditions proved challenging, but the pair travelled 35,400km (22,000mi) of the 46,670km (29,000mi) trip before tragedy struck. No one knows exactly what happened, as Earhart's last radio transmissions were of a poor quality. Despite an extensive search, this was called off after 17 days, and their fate remains a mystery.


Budge Wins 3 Titles, Wimbledon Record

RADIO MEN HEAR EARHART'S VOICE FAINTLY ASKING FOR AID

ELLABEE TAKES FIRST DELAWARE RACE BY NECK

Trailing New Suspects In Kidnap Case

BUDGE-MAKO TEAM CAPTURES DOUBLES TITLE

FLASH

BRITAIN WARNS AGAINST SEIZURE OF SPANISH LAND

Denhardt Is Accused In Party Girl's Death

WEAK MESSAGE PLACES PLANE NEAR EQUATOR

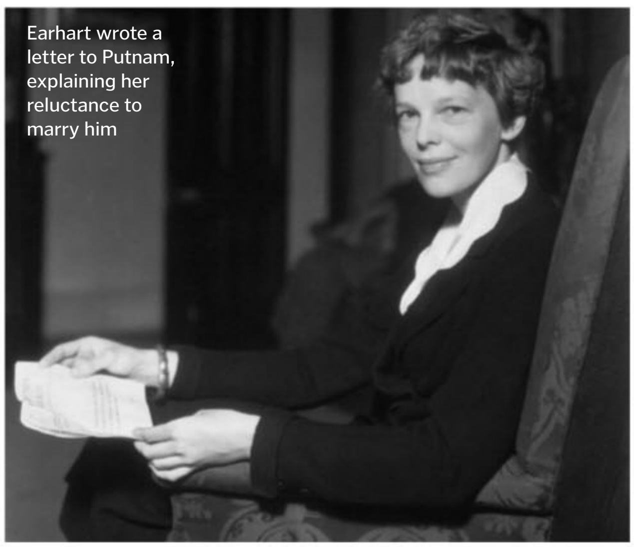
FLASH

FLASH

AB WRIGHT HITS

As a result of this flight, Earhart developed a friendship with publisher George P Putnam, and married him in 1931. Although a happy marriage, it was perhaps lacking in passion and romance, maybe because aviation was Earhart's first love. Over the years that followed, Earhart won aviation awards, took part in notable flights and broke even more records. She decided her ultimate challenge was to become the first woman to fly around the world. Taking off on 1 June 1937 with navigator Fred Noonan, Earhart intended for this to be her final challenge. Unfortunately it turned out to be final in more ways than one, as the pair ran into difficulties after 35,400 kilometres (22,000 miles). With only 11,265 kilometres (7,000 miles) to go, contact was lost during the flight between Lae, New Guinea, to Howland Island, and the pair went missing without a trace. Despite a $4-million search, neither they nor the plane were found. The following year, a lighthouse was constructed on Howland Island in Earhart's memory.


Earhart was determined, courageous and inspirational to people all over the world


Earhart wrote a letter to Putnam, explaining her reluctance to marry him

Five Earhart facts

1 She was nicknamed after a man

Earhart was nicknamed Lady Lindy because many people at the time thought her slim build and facial features resembled US aviator Charles Lindbergh.

2 She rejected flying clothes

Preferring dresses or suits instead of traditional flight gear, Earhart also wore a hat rather than a helmet, and only her goggles when out of sight.

3 The search cost millions

When she went missing, the US spent $4 million searching for her. It was the most expensive and intensive air and sea search in history at the time.

4 She planned to teach Eleanor Roosevelt

Earhart and Eleanor Roosevelt developed a strong friendship. Roosevelt had a student pilot license and Earhart said she would teach her to fly, but this never happened.

5 She didn't always like planes

When Earhart first saw a plane, aged ten, she thought it was "not at all interesting." It was a whole decade later that her interest in aviation was born.

In their footsteps…

Geraldine Mock

Born in 1925 in the United States, Geraldine (or Jerrie) Mock was the first woman to fly solo around the world. The trip took place in 1964, and took 29 days to complete. Inspired by Earhart, Mock was known as the 'flying housewife'. She covered nearly 37,000km (23,000mi), made 21 landings and, of course, made history too. She died aged 88 in 2014.

Amelia Rose Earhart

Born in 1983, Amelia Rose was named after Amelia Earhart, but she is not related to her namesake. Amelia Rose felt the need to honour the first Amelia and complete her flight. In July 2014, Amelia Rose became the youngest woman to circumnavigate the world in a single-engine aircraft. She's president of the Fly With Amelia Foundation, which grants flight-training scholarships to young women.

1921
Earhart has her first flying lesson and buys her first plane in the same year.

1928
Earhart becomes the first woman to fly across the Atlantic Ocean. The flight takes place in a Fokker F.VII.

1931
Earhart marries book publisher and publicist George Putnam.

1935
Earhart becomes the first person to fly solo across the Pacific between Hawaii and California.

1937
On attempting to become the first woman to fly around the world, Earhart never reaches her final destination. Her fate remains a mystery.

"The Sovereign superyacht could be one of the classiest vessels ever to take to the seas"

Inside the limousine of the ocean

Ride the waves in sophistication and comfort on board the Sovereign Yacht

100 metres (328 feet) of luxury craftsmanship, the Sovereign superyacht could be one of the classiest vessels ever to take to the seas. So classy in fact, it has been conceived with international royalty in mind. The yacht was designed in 2011 by Gray Design and will open its doors to kings, queens and monarchs for cross-ocean travel. An excellent idea, but what about the execution?

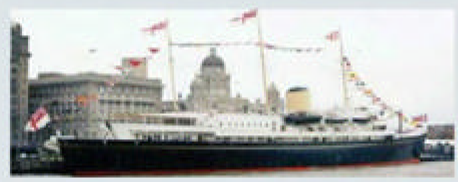
The Sovereign gets top marks from the environment with its three MTU engines backed up by a readily available supply of wind and solar energy. This renewable system also powers the electronics on board and could potentially act as a template for greener solutions in the future. The rest of the Sovereign's features are quite simply jaw-dropping. From a reinforced glass helicopter pad, to both a wet and dry garage complete with limousine and speedboat, this yacht is the definition of luxury.

Sunburn will also be a thing of the past with a retractable cover over the pool area on the bow. This all makes the two illuminated swimming pools pale in comparison! There are ten guest suites on the yacht so even an extended royal family could happily spend weeks away from dry land.

The Royal Yacht Britannia

For all its grandeur, the Sovereign is merely a pretender to the throne of luxury yachts. Serving the queen and the British royal family for almost 44 years, the Royal Yacht Britannia is the most recent of the royal yachts. Providing space for up to 250 guests, the royal family were catered for by 271 royal yachtsmen who communicated with a series of hand signals as shouted orders were banned.

The vessel made a mammoth 696 overseas visits in its operational lifetime. It is powered by two geared steam turbines and its facilities allow it to double up as a hospital ship if required. It is designed with modern tastes in mind with a clipper bow and modified cruiser stern alongside a cinema capable of showing 3D films. Such a luxurious vessel didn't come cheap, and in 1997 the Britannia was decommissioned due to its high running costs.



Could the combination of luxury and renewable energy feature in all yachts of the future?

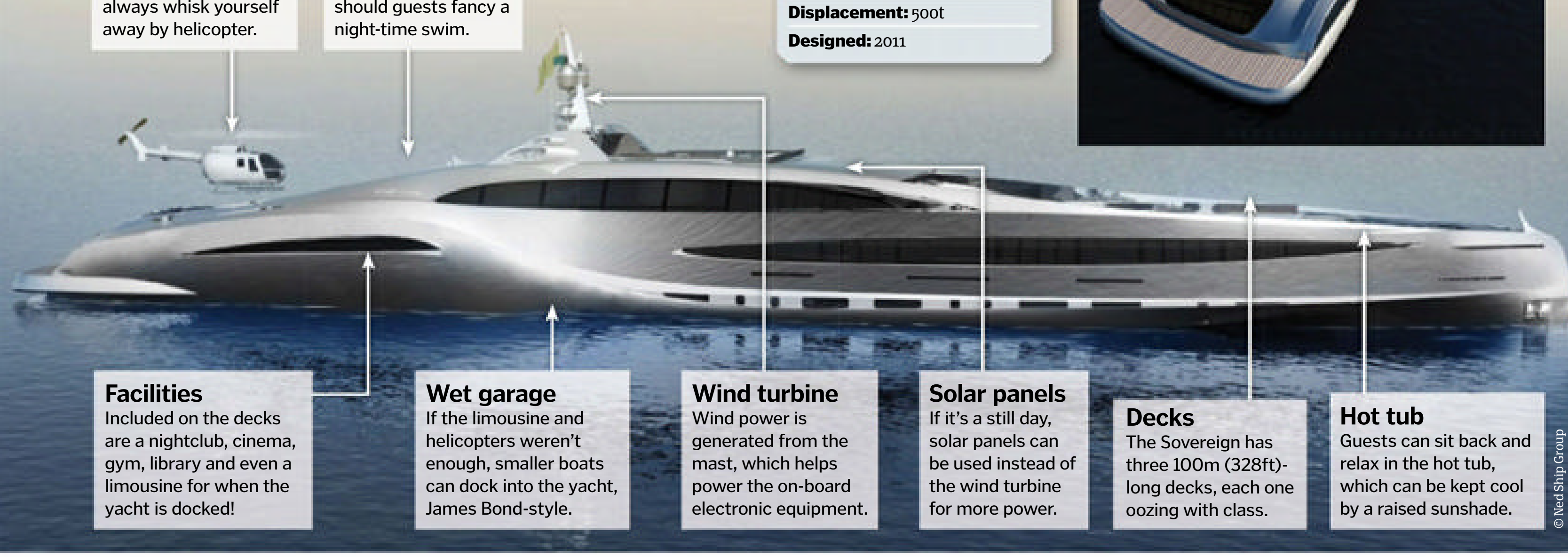
A tour of the Sovereign

All aboard the hi-tech luxury yacht that generates its own power

The statistics...

Sovereign

Length: 100m (328ft)
Water capacity: 7,500l (1,981ga)
Fuel capacity: 42,000l (11,095ga)
Engines: 3x MTU
Top speed: 30 knots
Displacement: 500t
Designed: 2011



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CALL FOR ENTRIES

Alien Earths

Discover the five strangest exoplanets ever found

To boldly go – in *Star Trek* the starship Enterprise would visit new planets every week from the Sixties onwards, but until 1995 we didn't even know whether planets around normal stars existed. Then astronomers found the first hot Jupiter, called 51 Pegasi b, which is a gas giant like our Jupiter, but extremely close to its star. That discovery opened the floodgates and today we know of over 1800 confirmed planets of all types – large and small, hot and cold, gas and ice.

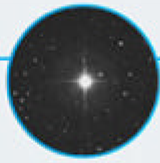
To differentiate them from the planets of our familiar Solar System home, astronomers call these alien worlds extra-solar planets, or exoplanets for short. Of all these planets, less than two dozen have actually been photographed (and in the pictures they are just points of light). The others are detected through several methods, the two dominant ones called the radial velocity technique and the transit method. The former makes use of the gravitational interaction between a star and a planet – the star orbits the centre of mass between the star and planet, and so to us it appears to wobble, sometimes by just a few centimetres, but this causes its light to be Doppler shifted. The size of the Doppler shift and the period of the wobble tells us about the mass of the orbiting exoplanet and the size of its orbit.

Transits happen when a planet passes in front of its star. Our telescopes are not powerful enough to resolve the silhouette of the planet in front of its star, but we can detect the tiny dip in the star's light. The size of the dip, and the regularity with which the transits happen tell us the diameter of the planet and how far from its star it is. If astronomers are able to see a transit and measure the radial velocity, they can then measure both the mass and diameter of the planet, and calculate its density and work out whether it is rocky, gaseous or some mixture of the two.

Exoplanets are discovered with both ground-based telescopes and space-based telescopes, like the Kepler planet-finding satellite, and with a new wave of planet-finding space missions being built, as well as giant ground-based telescopes, we can expect to discover thousands more planets, and perhaps even the holy grail of a planet just like Earth.

KEY DATES
EXOPLANET DISCOVERIES

1992
The first exoplanets were found by astronomers Dale Frail and Alexander Wolszczan.



1995
The first planet around a Sun-like star, 51 Pegasi, is discovered by Michel Mayor and Didier Queloz.

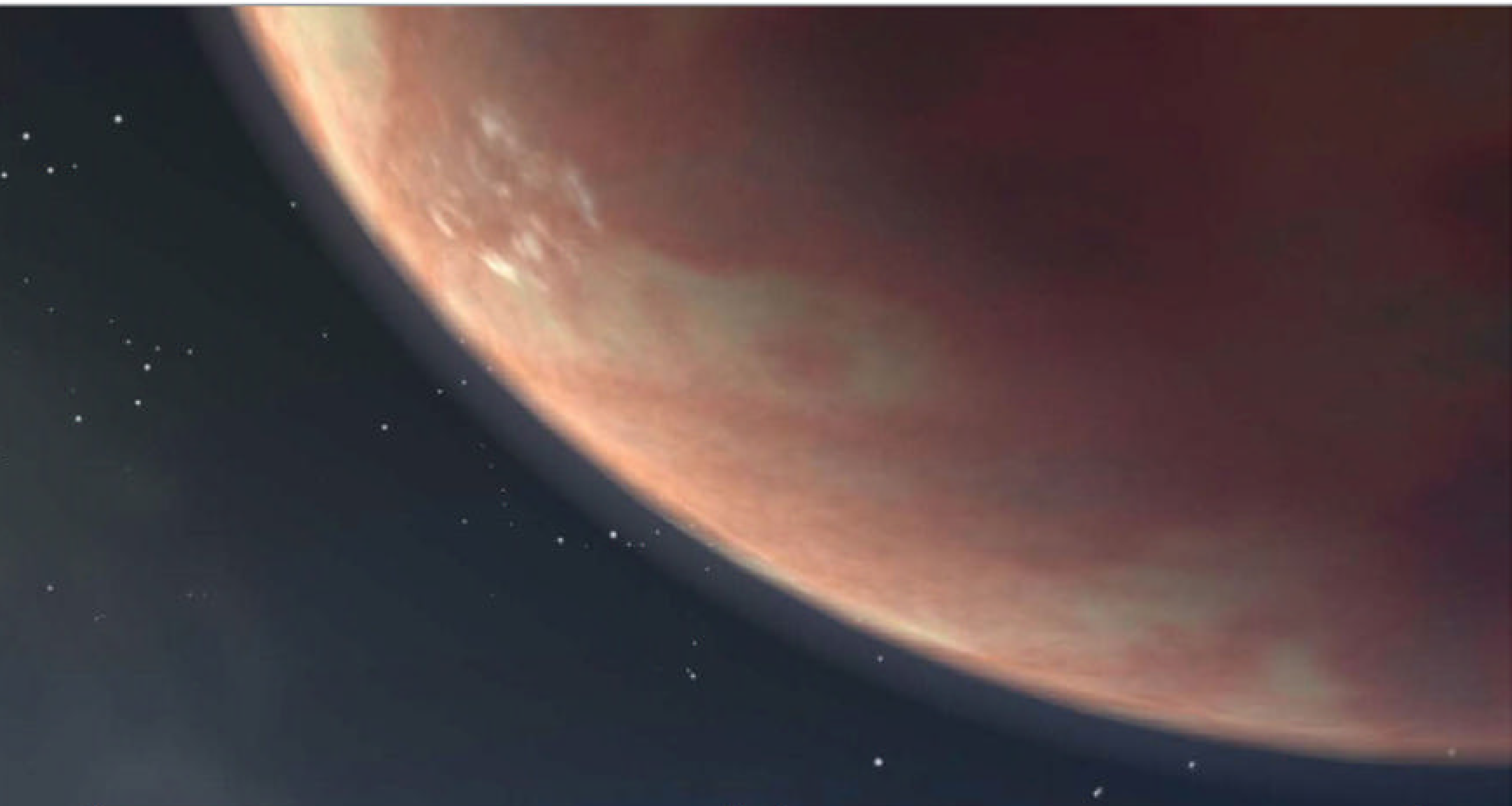
1999
The first measurements of the transit of an exoplanet, HD 209458b, were made by astronomers.

2005
The first rocky exoplanet, called Gliese 876d, was found in 2005 by astronomers led by Eugenio Rivera.

2009
NASA's Kepler Space Telescope blasts into space on a mission to discover thousands of exoplanets.

2012
Astronomers find evidence for a rocky, hot planet around one of the stars of the Alpha Centauri system.

DID YOU KNOW? *The first exoplanets found were not discovered around sun-like stars, but around dead stars called pulsars*



Exoplanet most like Earth

One of the great quests is to find a planet that is like Earth and could support life. Astronomers tend to categorise these planets as being found in the habitable zone, where temperatures are just right for liquid water on the surface. The best candidate so far is GJ 667Cc, which orbits a red dwarf in a triple star system. It is a super-earth, nearly four times the mass, and would be slightly hotter than Earth. It is unknown whether there is alien life.

The statistics...

GJ 667Cc

Distance: 22.7 light years

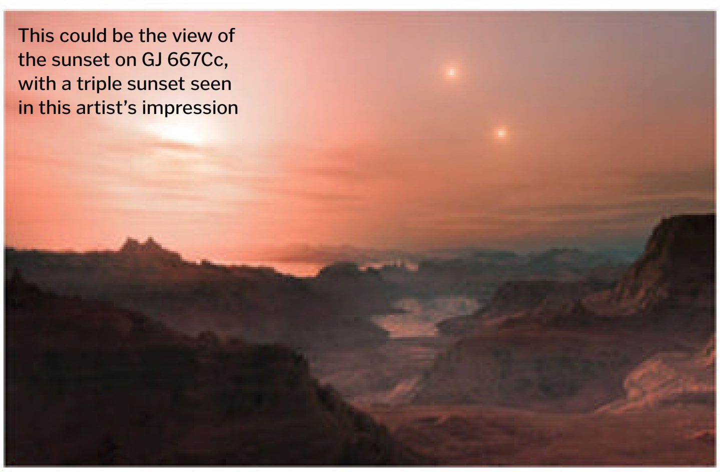
Mass: 2.26 x 10^{25} kg (3.78 Earth masses)

Diameter: 22,425 km

Length of year (orbital period): 28 Earth days

Discovered: 2012

Discovery method: Radial velocity



This could be the view of the sunset on GJ 667Cc, with a triple sunset seen in this artist's impression

The planet-sized hurricane

The strongest winds ever measured on Earth was 408kph (253mph), but this was just a breeze compared to the winds measured on HD 80606b, which reach 10800mph (17380kph)! The reason for these winds is the planet's egg-shaped orbit, which at times brings it just 4.5 million km (2.8 million miles) from the Sun. This causes the atmosphere to heat up rapidly each time it comes close. This heat drives a superstorm in its atmosphere.

The statistics...

HD 80606b

Distance: 190 light years

Mass: 7.6 x 10^27kg (4 Jupiter masses)

Diameter: 128,776 km

Length of year (orbital period): 111 Earth days

Discovered: 2001

Discovery method: Radial velocity

Hot Jupiters like HD 80606b can come incredibly close to their stars, the heat driving powerful winds

"CoRoT-7b is tidally locked, meaning it always shows the same face to its star like the Moon does to Earth"

The planet from hell

What happens though when a rocky planet finds itself in a similar situation to a hot Jupiter? CoRoT-7b is a molten world with a temperature between 1800 and 2600 degrees Celsius on its sun-facing side. It is tidally locked, so it always shows the same face to its star like the Moon does to Earth. The dayside's surface will be an ocean of lava, while the gravity from the nearby star will flex the planet's interior, causing the farside to be covered in giant volcanoes.

The statistics...

CoRoT-7b

Distance: 489 light years

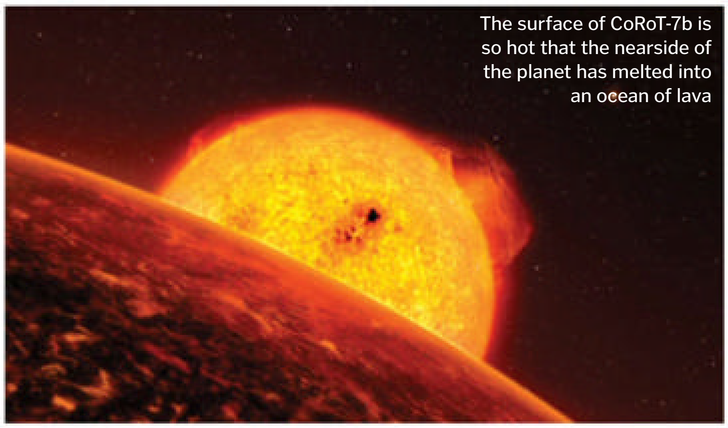
Mass: 5-9 times the mass of Earth

Diameter: 20,132km

Length of year (orbital period): 20 hours

Discovered: 2009

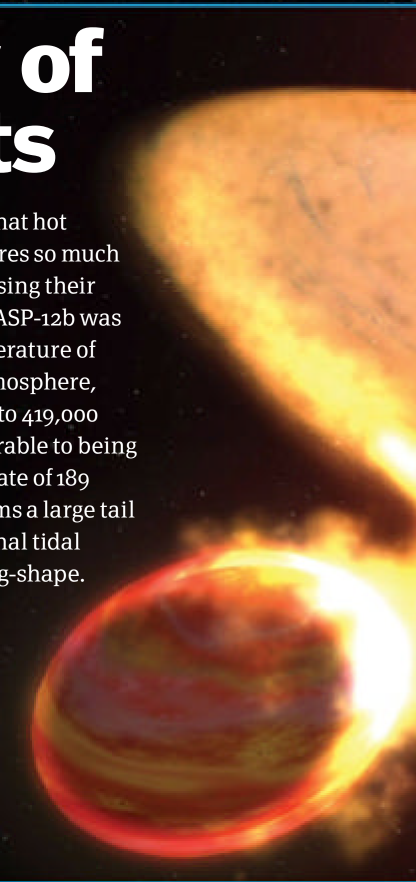
Discovery method: Transit



The surface of CoRoT-7b is so hot that the nearside of the planet has melted into an ocean of lava

Big daddy of the planets

Besides the powerful winds, the heat that hot Jupiters receive warms their atmospheres so much that their atmospheres expand, increasing their diameters. When it was discovered, WASP-12b was the hottest planet known, with a temperature of 2250 degrees Celsius. Its expanding atmosphere, which increases the planet's diameter to 419,000 kilometres (257 million miles), is vulnerable to being torn away by the gravity of its sun at a rate of 189 quadrillion tonnes per year, which forms a large tail of gas, a bit like a comet. The gravitational tidal forces also distort the planet into an egg-shape. This is one very messed-up planet.



WASP-12b's expanded atmosphere is being torn away into a long tail that forms a disk around its star

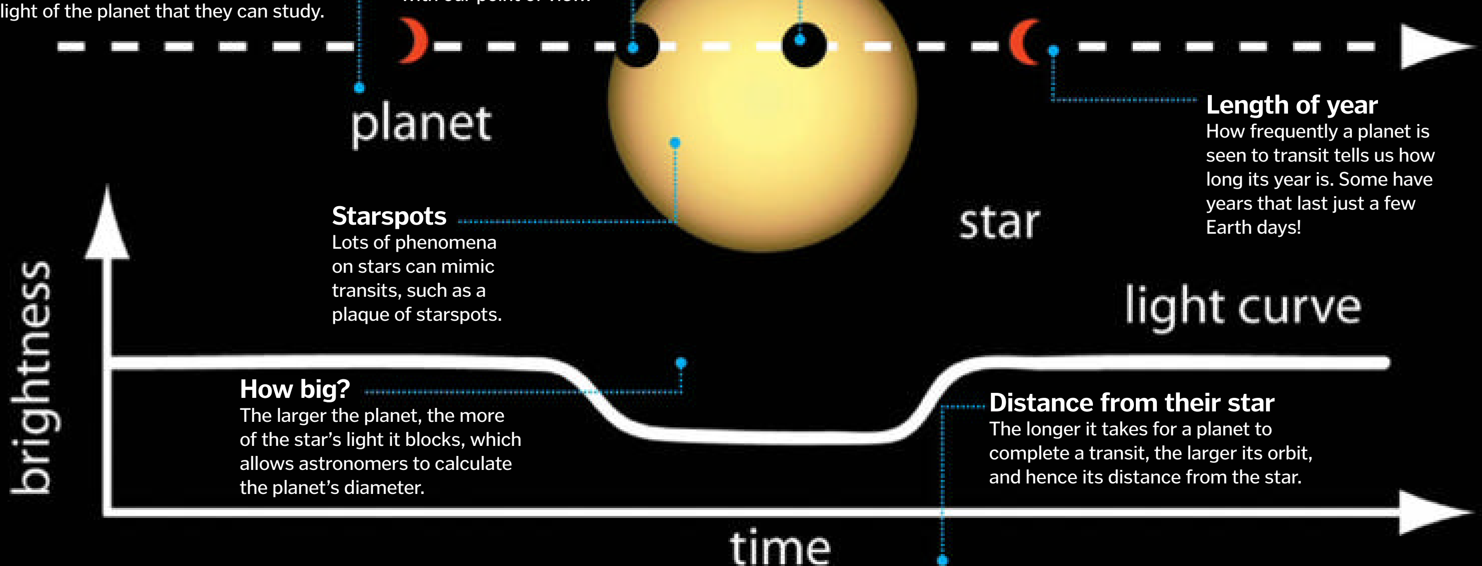
Understanding exoplanet transits

The Kepler Space Telescope discovers planets by watching for their transits as they pass in front of their stars.

Planet light
When a planet isn't transiting, astronomers are seeing the light of the planet and star combined. When the planet is behind the star, they can subtract the star's light, leaving just the light of the planet that they can study.

Line of sight
Astronomers can only see a transit if the equatorial plane of the star and exoplanet is exactly level with our point of view.

Invisible transit
Our telescopes are not powerful enough to see the planet transiting directly, but they can detect how much starlight is being blocked.



Length of year
How frequently a planet is seen to transit tells us how long its year is. Some have years that last just a few Earth days!

Starspots
Lots of phenomena on stars can mimic transits, such as a plaque of starspots.

How big?
The larger the planet, the more of the star's light it blocks, which allows astronomers to calculate the planet's diameter.

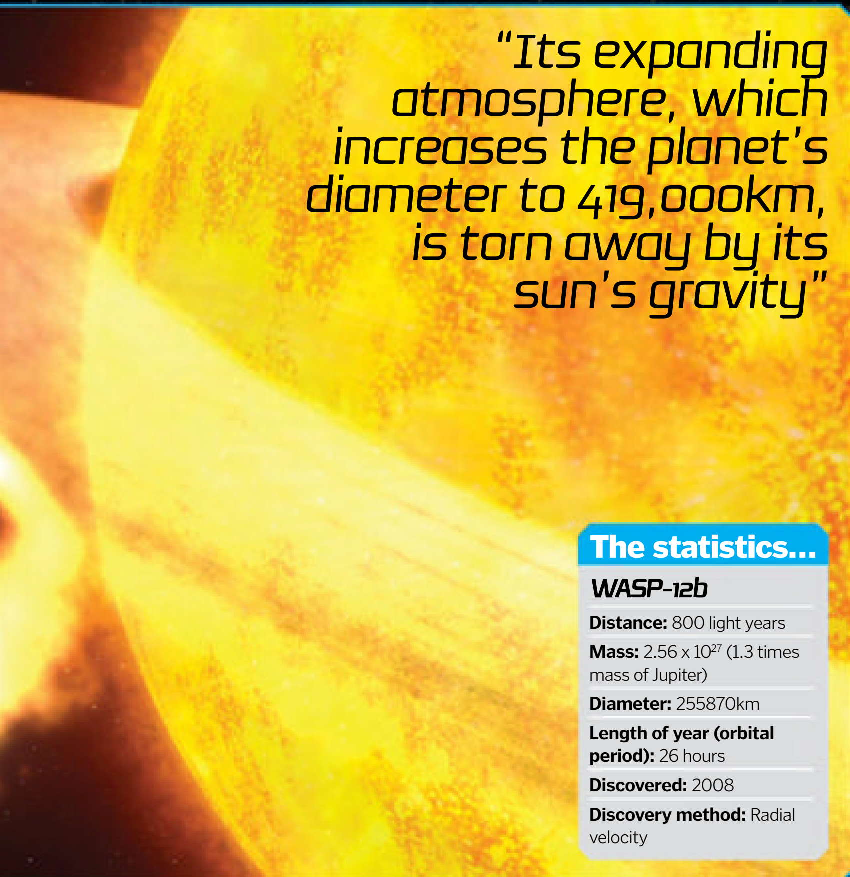
Distance from their star
The longer it takes for a planet to complete a transit, the larger its orbit, and hence its distance from the star.

8.5hrs

SHORTEST ALIEN WORLD YEAR

In the time it takes for humans to get a full night's sleep, a whole year has passed on the Earth-sized exoplanet called Kepler 78b, 700 light-years away. It's so close to its star that it orbits around it incredibly quickly.

DID YOU KNOW? Planets found by transits are named after the experiment that found them, eg. Kepler-22b



"Its expanding atmosphere, which increases the planet's diameter to 419,000km, is torn away by its sun's gravity"

The statistics...

WASP-12b

Distance: 800 light years
Mass: 2.56 x 10^{27} (1.3 times mass of Jupiter)
Diameter: 255870km
Length of year (orbital period): 26 hours
Discovered: 2008
Discovery method: Radial velocity

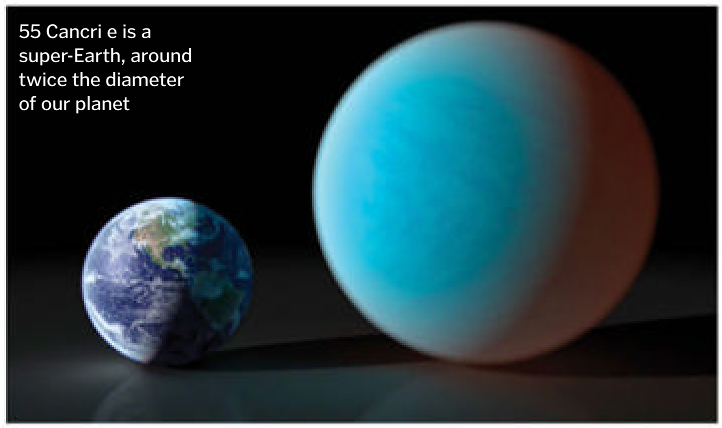
A diamond in the rough

Astronomers tend to focus on the surfaces, or cloud tops of planets, but sometimes what lies beneath is even more interesting. The planet known as 55 Cancri e is a huge 'super-Earth'. It is dry, with no chemical signature of water, and it is rich in carbon, amounting to a third of the planet's mass. In its core, all this carbon will be compressed under high pressures, to the point that deep within 55 Cancri e there is quite possibly a giant core of diamond.

The statistics...

55 Cancri e

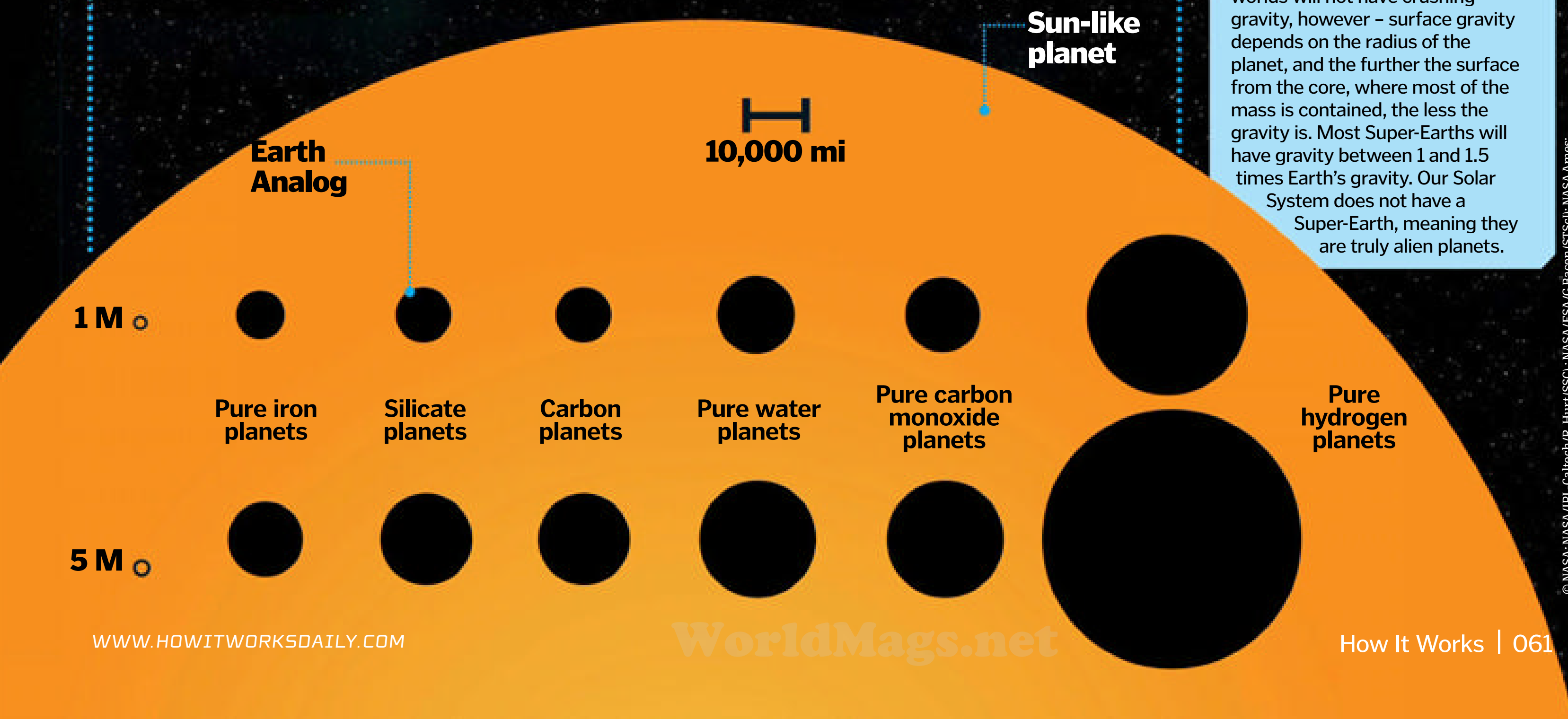
Distance: 41 light years
Mass: 4.7 x 10^{25}kg (7.8 Earth masses)
Diameter: 24,000km
Length of year (orbital period): 17 hours
Discovered: 2004
Discovery method: Radial velocity



55 Cancri e is a super-Earth, around twice the diameter of our planet

Predicting the sizes of exoplanets

The size of a transit – in other words, how much star light is blocked – tells astronomers how big the planet transiting is. This doesn't tell us its mass or what it is made from though, but we can work out its volume from its diameter. We can learn its mass by seeing how much its gravity causes its star to 'wobble'. Density is calculated by dividing the planet's mass by its volume, and knowing the density astronomers can figure out whether the planet is made of rock, gas or water.



Giant Super Earths

Super-Earths are rocky planets like Earth or Mars, but much, much bigger. They can be up to ten times the mass of our planet! These worlds will not have crushing gravity, however – surface gravity depends on the radius of the planet, and the further the surface from the core, where most of the mass is contained, the less the gravity is. Most Super-Earths will have gravity between 1 and 1.5 times Earth's gravity. Our Solar System does not have a Super-Earth, meaning they are truly alien planets.

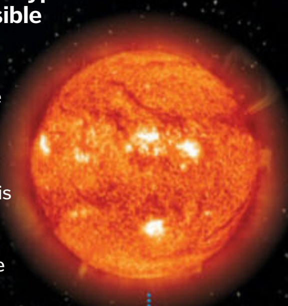
"We're able to arrange these waves into an order akin to notes on a piano keyboard"

Light waves in the universe

There's much more to the universe than what we can see with our own eyes

Wave types

Our universe is a concoction of all types of radiation – be it visible or invisible



Ultraviolet

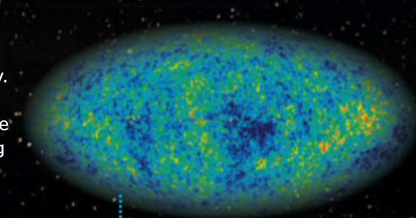
If you've ever had sunburn, then you have come into contact with radiation from space known as ultraviolet radiation. It's actually coming from our Sun, which also throws out many of the light waves on this list. Luckily we aren't often exposed to dangerous levels of ultraviolet radiation, since the ozone in the Earth's atmosphere catches the majority of it.

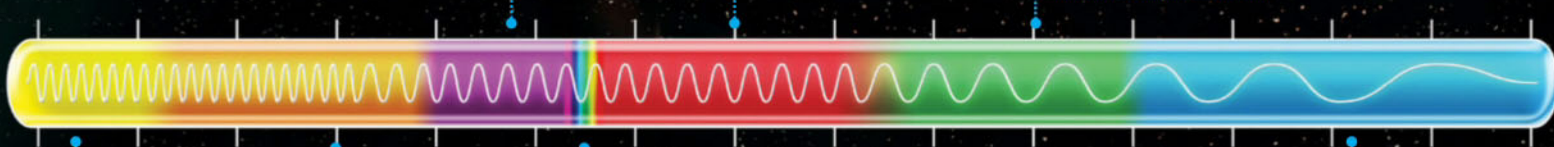
Infrared

Anything that gives off heat is throwing out infrared radiation – you even emit a small amount from your body. It's also in space, but is invisible to the human eye. We use telescopes, such as Spitzer, which are sensitive to the infrared part of the spectrum, to find out where it's being emitted. These waves are usually detected coming from nebulae, stellar nurseries where stars are born.

Microwaves

You are probably most familiar with microwaves, from using them to heat up your food in cooking appliances. Microwaves can be found throughout the universe – most notably in the Cosmic Microwave Background Radiation, left over from just after the Big Bang, which permeates the universe today and is a chilly -270°C (-454°F).



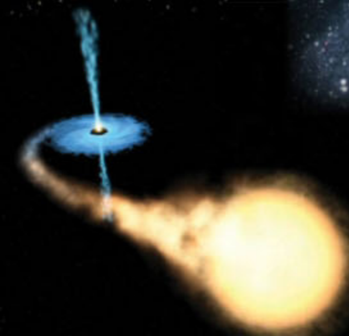


X-rays

X-rays are made when matter is heated to millions of degrees where magnetic fields, great forces and immense gravity have a strong influence. It is this radiation that helps us to learn more about black holes, neutron stars, dark energy and dark matter.

Radio waves

We use radio waves for communication and broadcasting, but they also occur naturally, emitted by lightning and objects in space such as galaxies, pulsars and quasars. These waves were first predicted by physicist James Clerk Maxwell and later discovered to be coming from our galaxy in the 1930s by physicist and engineer Karl Jansky.



Gamma rays

Gamma rays are so harmful to us that they can penetrate straight through the human body and can only really be stopped by several centimetres of lead. On Earth, gamma rays can be made in nuclear explosions, but in the universe, they are associated with great explosions in distant galaxies. These are known as gamma-ray bursts and are among the most energetic objects in the cosmos.

Visible

Visible light is the light we humans can see. It's because of this part of the electromagnetic spectrum that the human eye is able to detect the observable universe – that's the stars, planets and galaxies; we're able to see without the need for infrared, gamma ray or X-ray telescopes.

The electromagnetic spectrum

The different types of wave that can be found racing through space can be arranged together in what is known as the electromagnetic spectrum. Because of their characteristics, we're able to arrange these waves into an order akin to notes on a piano keyboard. The low notes of the electromagnetic spectrum, which contains waves with not a great deal of energy, start at radio and turn progressively to higher notes – through to gamma rays, which are extremely energetic.

Being called 'waves' it's easy to imagine the components of the spectrum as similar to sound waves, which vibrate air particles in order to reach your ear. With EM radiation, things are different – they don't need air to travel. They are the movement of magnetic and electric fields, so they don't need anything to help them move along. With the advent of a fleet of telescopes in space – such as the Chandra X-ray Observatory – and on the ground, we're able to see the universe in its many wavelengths.

Missions such as the Chandra X-ray Observatory are showing us the universe in different wavelengths

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What does the amplitude of a sound wave determine?

A Pitch B Volume C Tone

"Fragments from satellites that have been damaged or destroyed, and parts of rockets remain in orbit"

Earth's greatest threats

Hurtling above us are thousands of pieces of space junk

Since the launch of the first satellite, Sputnik 1, in 1957, the area of space near the Earth has been populated with countless pieces of debris. Fragments from satellites that have been damaged or destroyed, and parts of rockets and spacecraft remain in orbit, forming a true cosmic dump. The danger of these objects is due to the risk of collision: they can travel at speeds of up to 70,000 kilometres (43,496 miles) per hour. Even tiny chunks of debris can have a devastating effect on anything in their path when travelling at such speeds, as depicted in the 2013 blockbuster *Gravity*.

Space debris

Any artificial object without use that's orbiting around the Earth is considered space debris. Single-use rockets can remain in orbit, just like spaceship parts or machines removed unintentionally to prevent them from entering the wrong orbit. There is a wide range of objects; for instance, in 1965, Edward White lost a glove that kept orbiting at 28,000 kilometres (17,398 miles) per hour for a month!

Space debris size

Space junk comes in a range of fragment sizes, all capable of dealing some damage

30,000,000+

Less than 1cm
Very small particles that cause small surface damage.

100,000+

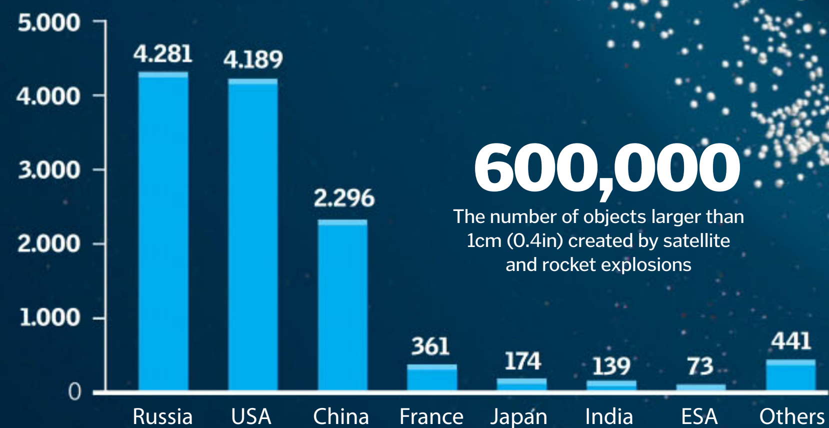
From 1-10cm
These particles can make holes in satellites.

13,000+

More than 10cm
These can cause damage beyond repair. These are the objects that are classified.

Classified objects in space by countries

There are over 25,000 objects that have been launched to the low Earth orbit since 1957. The United States and Russia have launched the most.



600,000

The number of objects larger than 1cm (0.4in) created by satellite and rocket explosions

5 TOP FACTS
RUBBISH TRIVIA

Particle problems
1 Several of NASA's Space Shuttles needed replacement windows after being struck by paint flecks less than 1mm (0.04in) in size.

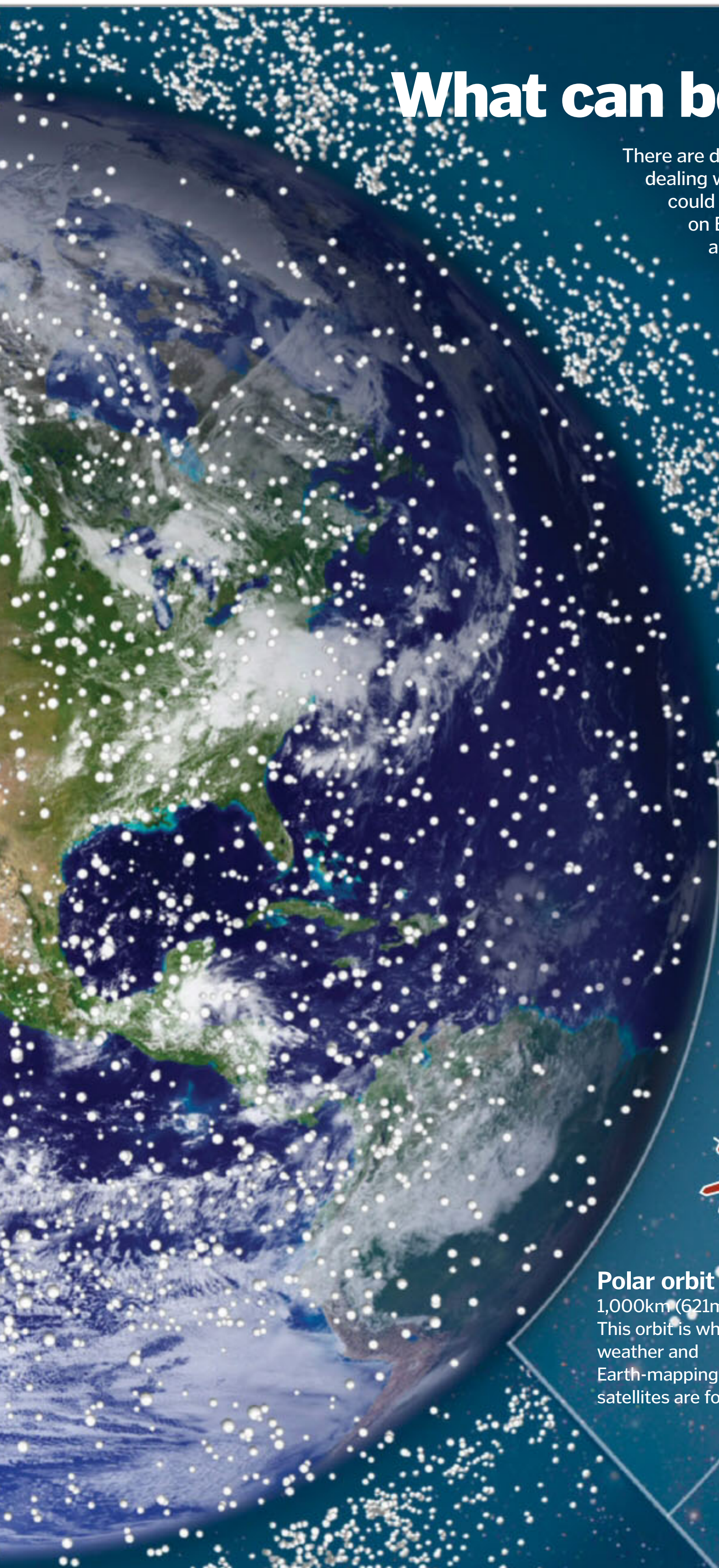
Burning up
2 The majority of debris that falls to Earth will burn up in the atmosphere. Any objects that make it to the surface are likely to end up in the ocean.

Astronaut safety
3 NASA keeps tabs on the location of larger debris so crews can stay clear of it by performing so-called 'debris-avoidance manoeuvres' of the ISS.

Bulletproof suits
4 Spacesuits help protect astronauts when they are outside the space station. The suits are made from the materials used in bulletproof vests.

High impact
5 If you were hit by a 1cm (0.4in) piece of debris travelling at 10km/s (6mi/s), it would be like being smacked with a bowling ball moving at 483km/h (300mph).

DID YOU KNOW? *The US Department of Defense keeps a catalogue of all space-debris larger than a tennis ball*



What can be done?

There are different methods of dealing with space junk. One could be that debris ends up on Earth and not orbiting around it, but the most effective way is to send satellite remains out of Earth's orbit.

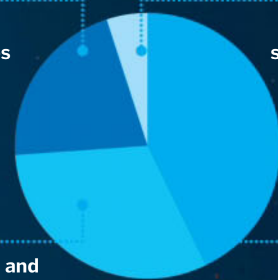
Sail
Like ships, the sail is unfurled when the satellite stops working and solar wind diverts it.

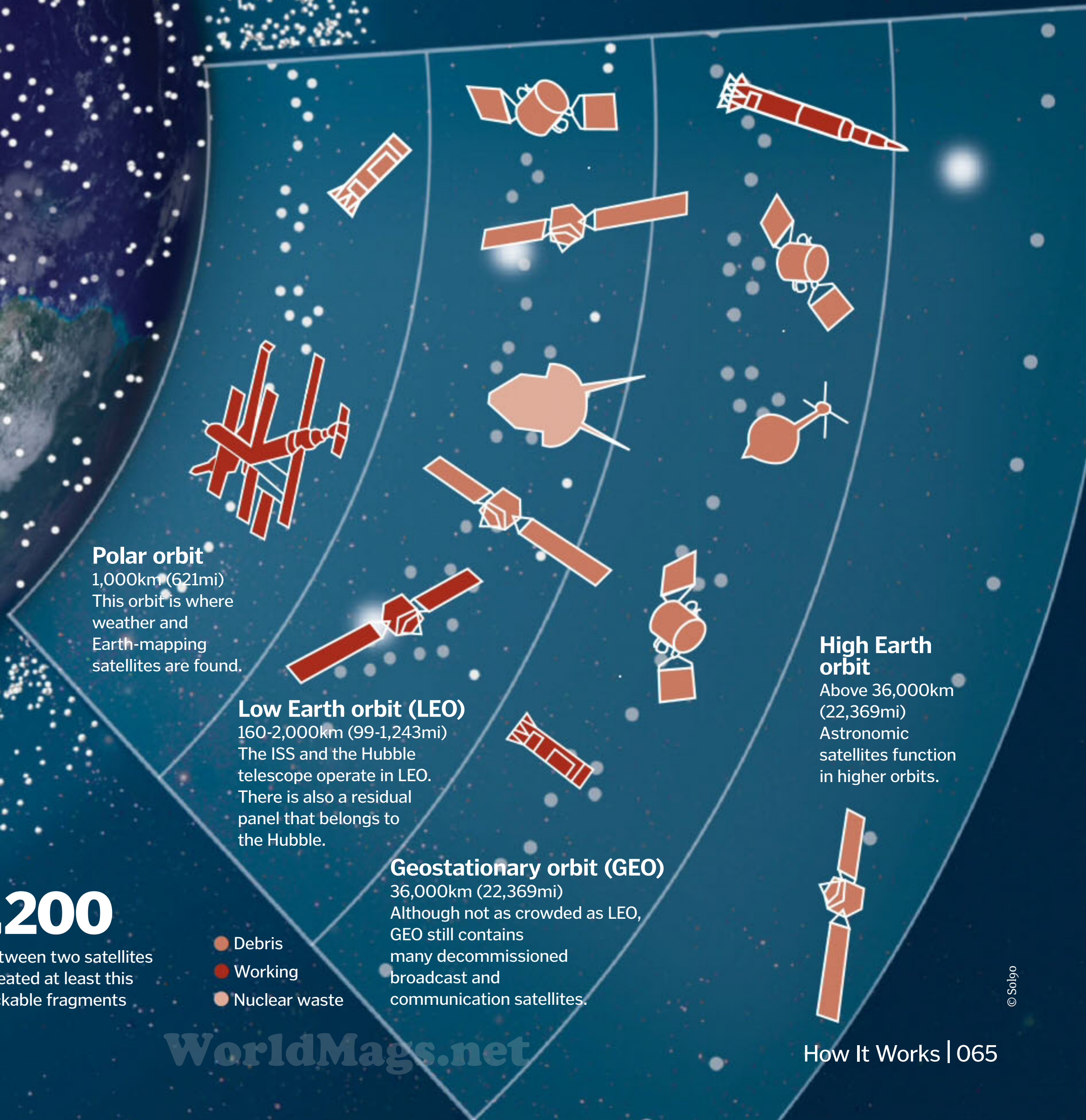
Space probe
A probe is set on a collision course with the satellite to propel it out of orbit.

Cable
A cable drags the satellite into a lower orbit. It disintegrates when entering the atmosphere.

Origin and location

Approximately 95 per cent of the objects shown orbiting Earth in this graphic are space debris, only five per cent are functioning satellites. Space agencies and private companies are developing reusable rockets to avoid generating more debris.





Polar orbit
1,000km (621mi)
This orbit is where weather and Earth-mapping satellites are found.

Low Earth orbit (LEO)
160-2,000km (99-1,243mi)
The ISS and the Hubble telescope operate in LEO. There is also a residual panel that belongs to the Hubble.

Geostationary orbit (GEO)
36,000km (22,369mi)
Although not as crowded as LEO, GEO still contains many decommissioned broadcast and communication satellites.

High Earth orbit
Above 36,000km (22,369mi)
Astronomic satellites function in higher orbits.

Debris
Working
Nuclear waste

2,200
A collision between two satellites in 2009 created at least this many trackable fragments

"These stars help us to measure distances farther and farther out into the universe"

Farming on alien planets

Mars and the Moon could be new places to grow food

Believe it or not, the soil found on the Moon and Mars could actually be much more fertile than some of the dirt found on Earth. If we are ever to go on to colonise other worlds – with the Red Planet being our number-one target – then this is very good news for astronauts.

It's thanks to a team of scientists in the Netherlands, who have braved volcanoes in Hawaii and Arizona to obtain material akin to Martian dirt and lunar soil, to provide us with the information that could help humans one day settle on an alien planet. Both soils have the essential ingredients plants need to grow – nitrates and ammonium.

The experts found – by using 'fake' minerals from Mars and the Moon to try and grow carrots, tomatoes, weeds and wheat – that untreated soil found on Mars was the plant's favourite. On the other hand, Moon dirt didn't agree with them completely, with some crops struggling to grow.

All's not lost for crop farming on the Moon, though – scientists think that pumping our natural satellite's soil with nitrogen-fixing bacteria could be the ticket for growing crops on our cratered companion.

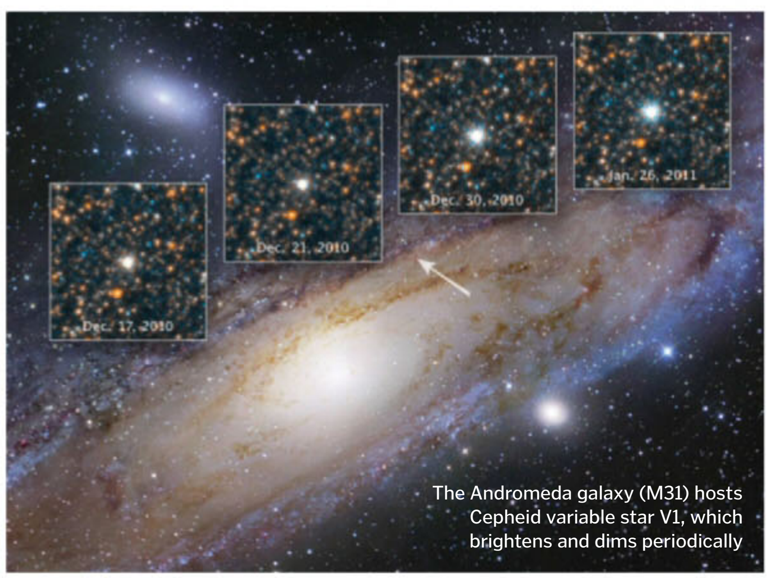
Growing food on Mars and the Moon could hugely benefit plans to colonise other worlds

The V1 star

A star that changed the entire universe

In a galaxy, not too far away, resides a star that changed how we saw the universe back in the early-20th century. Its name is Hubble variable number one, or V1 for short, and it told us that there were more galaxies beyond our own. At first it highlighted Andromeda – the star's home and the closest spiral galaxy to ours – soon dubbed 'island universes' beyond the boundary of our galaxy, the Milky Way.

It was soon realised that this star was no ordinary one. Because of its predictable brightening, caused by stellar gas heating and expanding before cooling and contracting in a cycle, this object was soon dubbed a Cepheid variable. These stars help us to measure distances farther and farther out into the universe. By working out how long it takes for a variable star to brighten and dim, we can work out how bright the star would be if we were up close to it.



The Andromeda galaxy (M31) hosts Cepheid variable star V1, which brightens and dims periodically

FINDING FOSSILS

How are prehistoric remains uncovered and what can scientists learn from them? How It Works digs up the facts…

Ever since Mary Anning first began piecing together the fossils of Jurassic beasts in the early-19th century, scientists have been learning more and more about the dinosaurs that ruled the world millions of years ago. Buried deep beneath the ground for aeons, the remains of countless extinct creatures are waiting to be unearthed by palaeontologists, who can gradually unlock their secrets.

Dinosaurs and other prehistoric fossils have been discovered around the world for thousands of years, with reports of 'dragon bones' found in China more likely indicating some of the earliest dino finds. However, it wasn't until the brilliant scientists of the Enlightenment in the late-18th and early-19th centuries that it became clear just how old these ancient skeletons really were. Before long, fossil hunting became an obsession for naturalists and amateurs alike, with the strange extinct 'lizards' being discovered at sites all over the globe.

5 TOP FACTS MOST IMPORTANT FOSSILS

Our lowly origin

1 Discovered in 2004, the Tiktaalik is one of the most important finds in evolutionary science, as it's seen as the transitional link between aquatic and land-based life, some 375 million years ago.

Was it a bird?

2 First found in Germany, specimens of Archaeopteryx lithographica indicate a transitional species between dinos and birds. There are signs the creature had feathers and was maybe able to climb trees.

A link in evolution

3 The missing link between primates and humans is thought be found in Homo ergaster, the first fossil of which was dubbed Turkana Boy. Homo ergaster walked around on two feet.

Colouring in the blanks

4 Studies of fossilised Sinosauropteryx feathers have revealed pigment-forming materials. Scientists determined the creature had a dark reddish brown tail.

A maternal instinct

5 The discovery of giant Maiasaura nests, including fossilised infant specimens, confirmed some dinosaurs possessed parental instincts and nurtured their young from the egg.

DID YOU KNOW? *A study in 2006 indicated that only around 28 per cent of dinosaur genera have been found so far*

Though ground-penetrating radar now helps archaeologists identify hidden underground remains, modern palaeontologists still often rely on the same methods their 19th-century predecessors did: plain luck. Of course, through a greater understanding of geology, as well as by searching in so-called fossil hotspots, it's possible to predict where fossils will likely be found. Once a fossil site has been identified, the long and delicate process of unearthing the dino remains begins.

Digging for fossils can be as simple as sieving through sand and silt in the search for tiny teeth, or cracking open large rocks with a hammer and chisel to see what may be lying within. Hills, quarries, mountainsides and ravines are often prime locations for fossil finds, as the deep layers of rock have become exposed by millions of years of erosion. In these cases heavy diggers and drills are crucial to reach the finds. Dozens of scientists, students and even enthusiastic volunteers are employed with brushes and trowels during the course of an excavation. However, because of the delicate nature of specimens that are millions of years old, it can often take what must seem like another million to safely uproot an entire dinosaur skeleton.

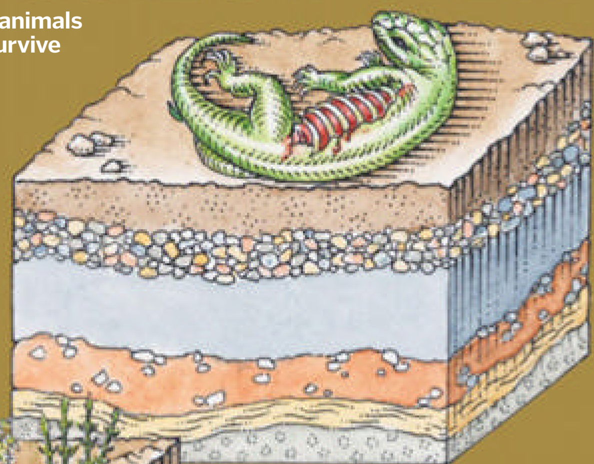
Of course, palaeontologists do much more than just dig up old bones. Mixing together the disciplines of geology and biology, palaeontology is the study of fossils to reveal the history of life on Earth. So, once the fossilised remains have been fully excavated, the real work can begin back in the lab. Here scientists painstakingly remove any residual earth and stone from the specimens in preparation for full analysis. Electron microscopes, CAT scanners and X-ray machines are all employed to gather as much information about the creature as possible.

By studying the shape, length and arrangement of each fossilised bone, palaeontologists have been able to determine not only what certain dinosaurs looked like and how they moved, but also what they ate. The discovery of indentations on fossilised arm bones similar to those found on modern birds has also indicated that many species of dinosaur were actually feathered.

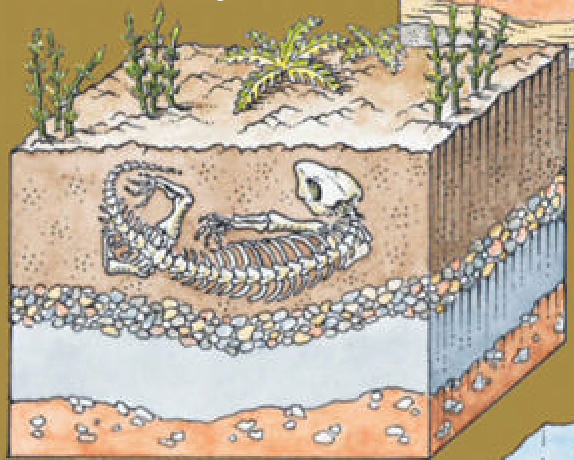
Bigger, stranger and ever-more unbelievable dino discoveries are being made all the time, each one challenging past theories and shedding new light on the distant land of the Mesozoic beasts. Thanks to the pioneering work of the scientists and enthusiasts of the past, each new fossil found could slot yet another piece of the prehistoric jigsaw into place. ▶

HOW FOSSILS FORM

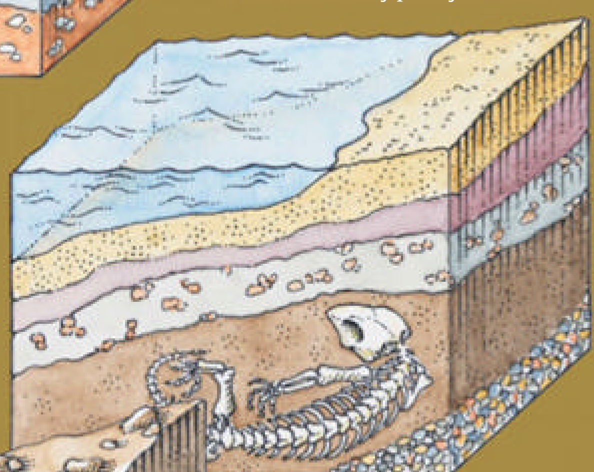
How do the remains of prehistoric animals become fossils, and why do they survive through the ages?



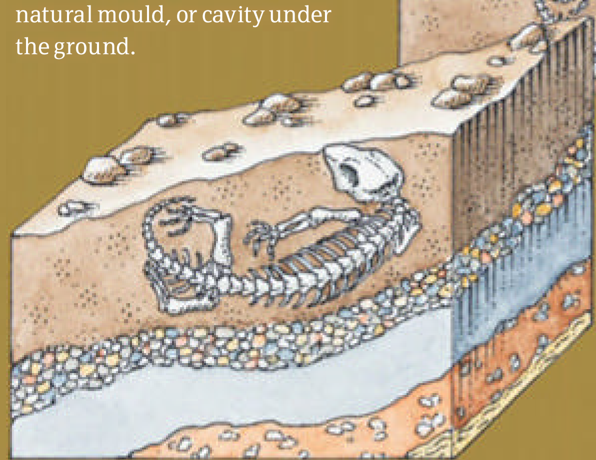
1 After death, a dinosaur's remains would often just rot and erode away completely, leaving not even a skeleton behind. However, in the right conditions, where the remains are kept safe from weather and hungry scavengers, the process of fossilisation can begin.



2 Over a long period of time, shifting sands, soil and sediment entirely cover the skeleton, encasing it in the ground. Any remaining soft tissue such as skin and organs, decays away entirely, leaving only the creature's bones. At this stage the remains are only partly fossilised.



3 As rising sea levels and shifting materials leave the skeleton further underground, the earth around the skeleton hardens under immense pressure. Eventually the bones entirely dissolve, leaving their shape behind in a natural mould, or cavity under the ground.



4 Over time, mineral deposits slowly gather in the creature's mould, chemically replacing the original bone. As sea levels recede away and materials shift around, the fossil draws closer to the surface. Eventually it can be found either entirely exposed or close to the topsoil.

"The process of excavating a dinosaur skeleton can take many years"

DIGGING FOR DINOSAURS

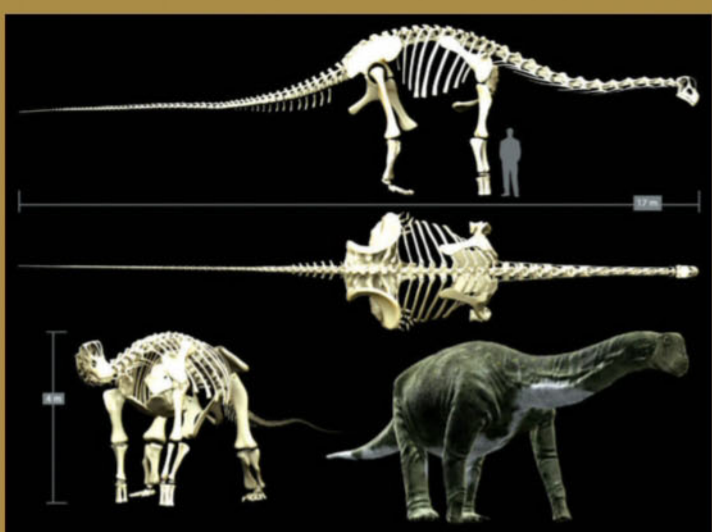
How palaeontologists discover and unearth prehistoric giants

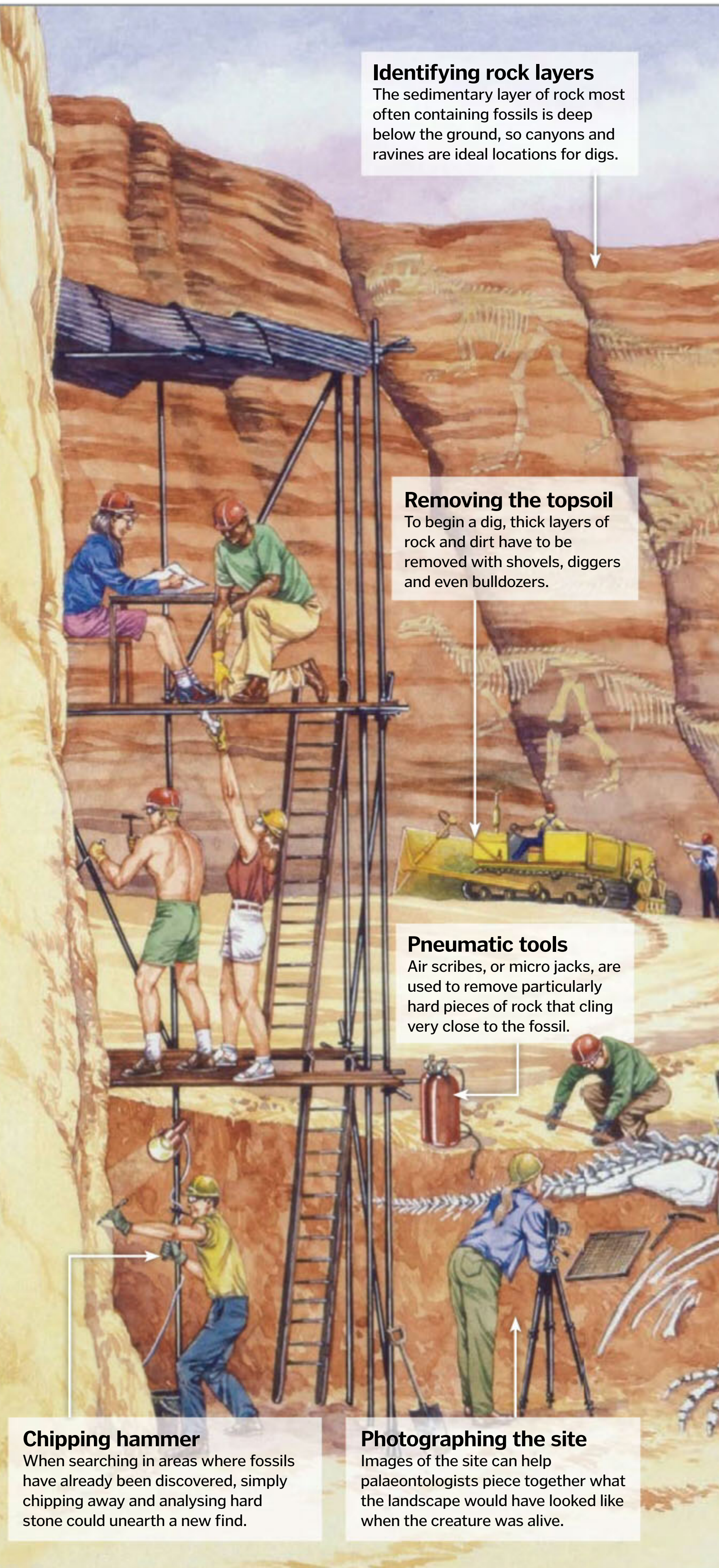
Bulldozers, hammers, chisels, drills and even dynamite – you'd be forgiven for thinking these were part of a construction-site inventory. In fact, they are the basic tools a palaeontologist will use to uncover the mysteries of the past. From removing tons of topsoil with diggers and other heavy machinery, to carefully clearing away clinging dust and debris with delicate brushes, the process of excavating a dinosaur skeleton can take many years.

The largest dino fossil

Even in this ancient time when giants ruled the Earth, sky and sea, Dreadnoughtus schrani truly was a behemoth of a creature. Standing over two-storeys tall and weighing as much 60 tons, the remains of this beast were found by a team in Patagonia, Argentina, and have been dated back over 77 million years. A member of the titanosaur sauropod group of dinosaurs, Dreadnoughtus was a plant-eater and is to date the largest known land animal ever to have lived.

Two Dreadnoughtus titanosaurs were found at the site, and it's believed the pair died in a massive flash flood, which would explain why their remains were so complete. The preservation of the skeletons enabled scientists to take full advantage of 3D-printing technology, scanning in each individual bone into a digital format for even greater scrutiny. This 3D rendering of Dreadnoughtus provided even greater insight into how it likely looked and moved.





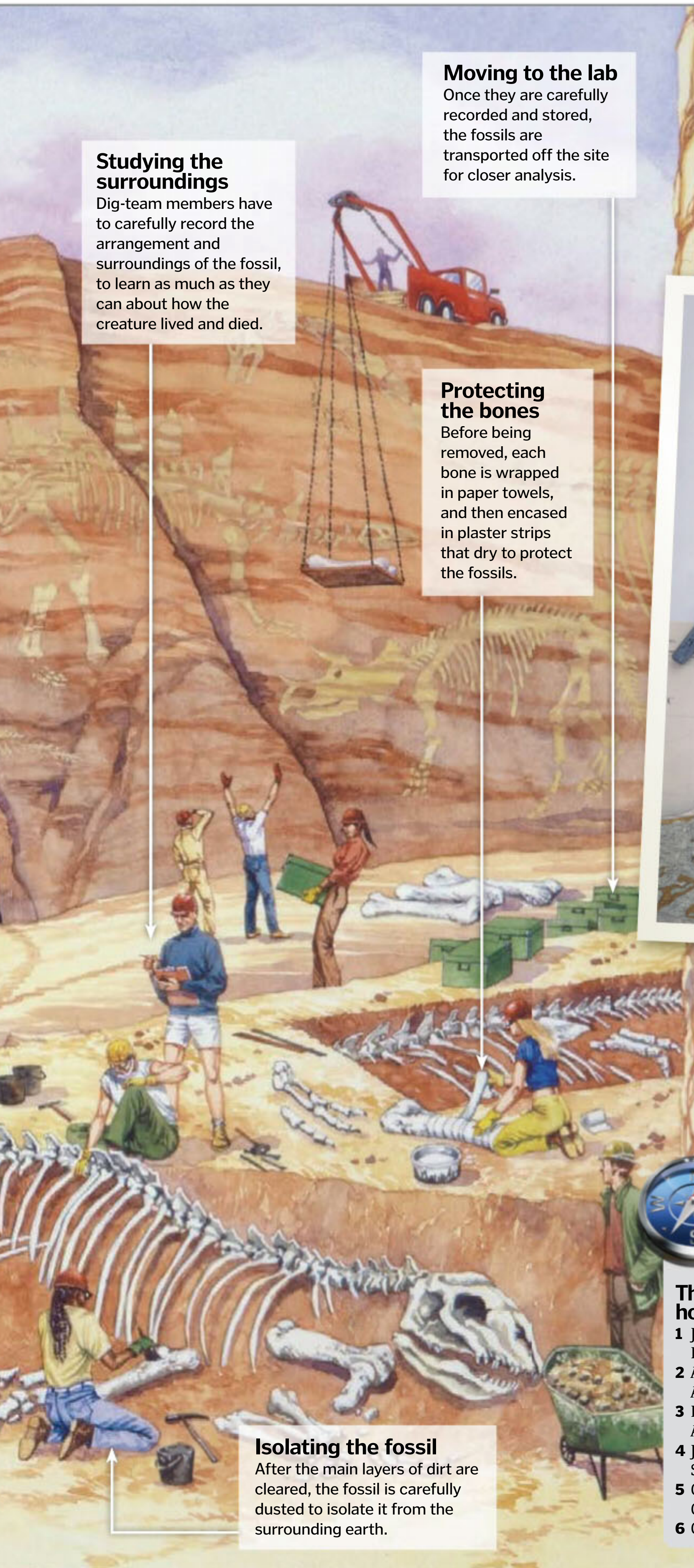
RECORD BREAKERS
BONA FIDE FACT

240 MILLION YEARS

OLDEST DINOSAUR FOSSIL

Nyasasaurus parringtoni has only been fully examined recently and was found to date back some 240 million years – nearly 15 million years earlier than dinosaurs were previously thought to have existed.

DID YOU KNOW? *English naturalist Richard Owen first coined the term 'dinosaur' in 1842*



Moving to the lab
Once they are carefully recorded and stored, the fossils are transported off the site for closer analysis.

Studying the surroundings
Dig-team members have to carefully record the arrangement and surroundings of the fossil, to learn as much as they can about how the creature lived and died.

Protecting the bones
Before being removed, each bone is wrapped in paper towels, and then encased in plaster strips that dry to protect the fossils.

Isolating the fossil
After the main layers of dirt are cleared, the fossil is carefully dusted to isolate it from the surrounding earth.

Tools of the trade

What do you need for a fossil dig?

Chisels
Chisel blades come in a range of sizes for either cracking apart larger stone or trimming away a rock face.

Hammers
Crack and chipping hammers are essential for carefully removing and trimming hard rock. They are also needed for working with chisels.

Sieve
Not all fossils come in huge sizes, so wire sieves are perfect for sifting through sand and silt for teeth and other small remains.

Maps
If travelling to more remote locations, as well as for making reliable notes for future reference, a good map and compass are a must.

Brushes
Small, soft bristles are ideal for working with delicate remains, while larger, harder brushes are best for removing thicker dust.

Journals and reference
Accurately recording everything you find, where it's found, as well as referencing what it could be, is vital for making new discoveries.

ON THE MAP

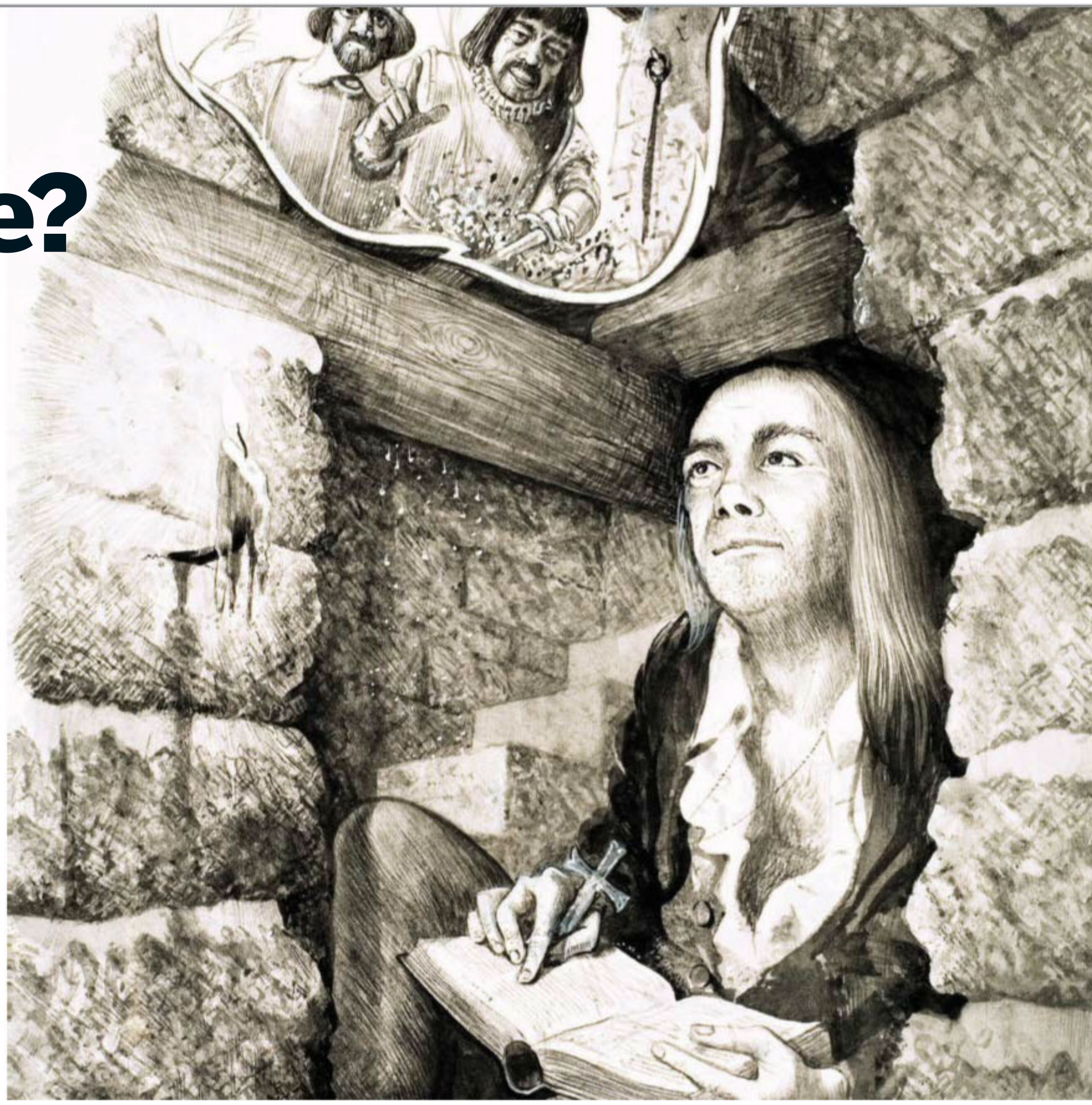
The world's fossil hotspots

1 Jurassic Coast, Devon and Dorset, UK
2 Auca Mahuevo, Patagonia, Argentina
3 Dinosaur Cove, Victoria, Australia
4 Joggins Fossil Cliffs, Nova Scotia, Canada
5 Chengjiang Fossil Site, Chenjiang County, China
6 Como Bluff, Wyoming, USA

"Many people who didn't want to give up their faith built priest-holes in their houses"

What is a priest hole?

The story behind 16th-century hiding places



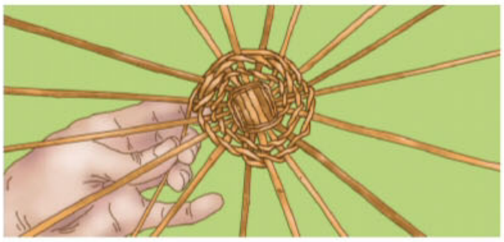
Priest-holes were built into many Catholic houses during the 16th century as a place for priests to hide. Britain was a Catholic country before Henry VIII formed his own church, followers of which became known as Protestants. Mary I reverted the national religion back to Catholicism, but Elizabeth I changed it back again and began a ruthless programme of retribution against Catholics. Many people who didn't want to give up their faith built priest-holes in their houses, which were recesses and hidden basements that Catholic priests could hide in during raids by priest-hunters.

Though often cramped and uncomfortable, these priest-holes allowed Catholics to meet and pray in secret as well as providing sanctuary to the priests who bravely held onto their faith during a time of great persecution. One of the most famous and skilled builders of priest-holes was Nicholas Owen, who created secret hide-outs that were incredibly difficult to spot. Famous priest-holes are found at Baddesley Clinton in Warwickshire and Naworth Castle in Cumbria.

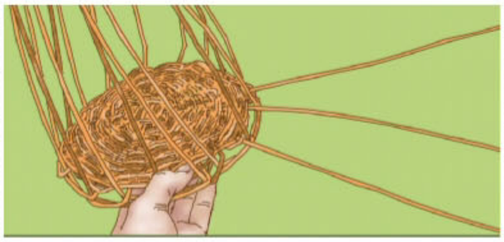
Weave your own basket

How ancient civilisations created their own carriers

Create your base
Select four fibres of equal length and cut a 5cm (2in) slit through the middle of each. Thread four fibres through them to create a cross. Bind the cross-section with thread and splay each fibre out so you have eight bicycle wheel-like spokes. Wind a thin, fibre around the cross-section and then weave it over and under the spokes, pulling it tight. Twine a new fibre around the end of the old one to continue.



Wind it up
Place longer fibres next to the spokes and bind them together in the weave. Once the base is big enough, bend the fibres upward at right angles to the base. Gather them and tie off at the top for a wigwam shape. Weave three fibres around upward strands and the base. Intertwine these and weave them around the bottom of the upward-reaching fibres to strengthen the bond between base and sides.



Weave the sides
Untie the top, releasing the fibres, which are called rods. Place a long, thin fibre to the right of a rod. Bend the rod and weave it in front of the new fibre, called a weaver, behind the next rod and in front of the next. Repeat all the way around. Weave the weavers in and out of the rods. Repeat, building upward by a layer each time until your basket is complete and snip off the ends to finish.

5 TOP FACTS
ABU SIMBEL

Great gods
1 Ra-Horakhty was a combination of the god of the Sun and sky. Osiris was the god of the underworld and Amun was the chief god and protector of the monarchy.

Light and shade
2 The temple is positioned so the light shines on Ra-Horakhty, Amun and Ramesses twice every year. Osiris is in perpetual darkness as he is the god of the underworld.

What's in a name?
3 It is thought that Abu Simbel was named after an Egyptian boy who showed the site to the Swiss explorer Johann Ludwig Burckhardt in 1813.

Four more years
4 With Burckhardt unable to uncover the temple in 1813, it was left to Giovanni Belzoni to find and excavate Abu Simbel, which he did in 1817.

Equal rights
5 The statues of Ramesses and Nefertari outside The Small Temple are the same height, a rarity in Egyptian culture. It was also the second temple dedicated to a pharaoh's wife.

DID YOU KNOW? *Abu Simbel is the second most popular tourist attraction in Egypt. It even has its own airport*

Abu Simbel

The incredible tale behind one pharaoh's tribute to himself

Egypt is no stranger to mind-blowing buildings and temples so it is a great compliment that the Abu Simbel rock temple at Nubia is one of the most visited sites in the country. Built during the reign of Ramesses II (circa 1279-1213 BCE), the construction of the two temples took 20 years to complete. The Great Temple is dedicated to the gods Ra-Horakty and Ptah, but it is Ramesses II that takes centre stage. The entrance to the temple is flanked by four 20-metre (65-foot) tall statues of Ramesses II that tower over the much smaller statues that depict the Pharoah's family as well as vanquished enemies such as the Nubians, Hittites and Libyans. Inside the Great Temple are statues of Ptah, Ra-Horakhty, Amun and Ramesses II as well as a number of reliefs that show Ramesses claiming great victories against his foes. A row of baboon statues line the façade as they were revered as Sun worshippers. The Little Temple was built to honour the memory of Ramesses' favourite wife Nefertari who later became known as the goddess of fertility and love. It is fronted by statues of Ramesses and Nefertari, while inside are reliefs that show the couple offering gifts to the gods. The location of Abu Simbel was very important as well. Nubia was already an important religious site and Abu Simbel, located at the Egyptian-Sudanese border, established it as definitively Egyptian.

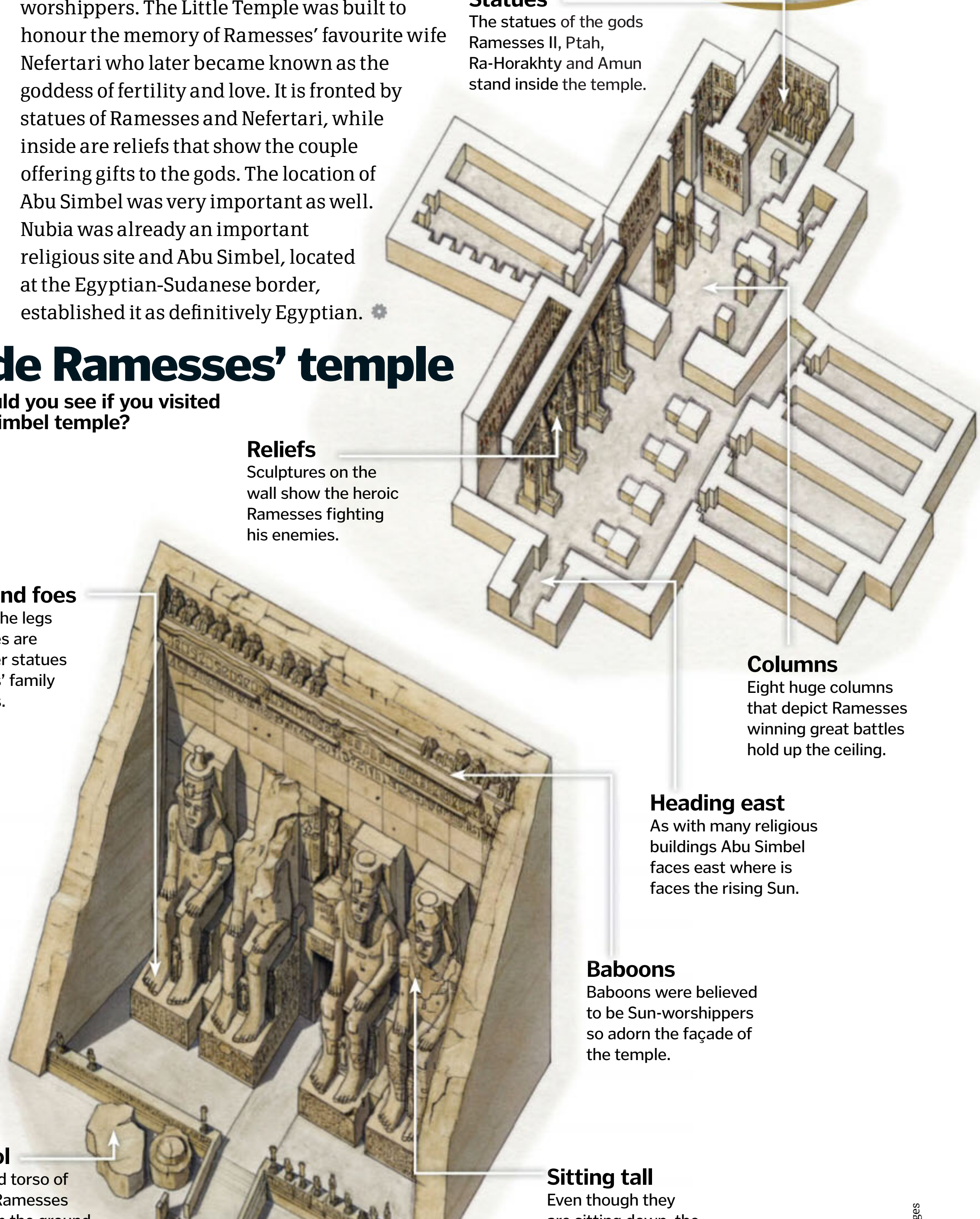
Moving on up

In 1952 the Egyptian Government made the decision to build a dam after the flood waters of the Nile got too high for the current one. However, this would have flooded the Abu Simbel temple so the decision was made to move the entire construction to higher ground. Between 1963 and 1968 the temple was cut into 10,000 blocks, each weighing between three and 20 tons. They were then moved 65 metres (213 feet) higher up the mountain and 180 metres (600 feet) to the west to keep it out of the soon-to-be-flooded area. The blocks were precisely re-assembled in exactly the same position as before and secured in place with concrete. The move cost $42 million at the time, which is around $288 million (£183 million) today, but was essential in preserving a key part of Egyptian history.

The task of moving the entire temple involved up to 3,000 people

Inside Ramesses' temple

What would you see if you visited the Abu Simbel temple?



Statues
The statues of the gods Ramesses II, Ptah, Ra-Horakhty and Amun stand inside the temple.

Reliefs
Sculptures on the wall show the heroic Ramesses fighting his enemies.

Friends and foes
In between the legs of the statues are much smaller statues of Ramesses' family and enemies.

Columns
Eight huge columns that depict Ramesses winning great battles hold up the ceiling.

Heading east
As with many religious buildings Abu Simbel faces east where is faces the rising Sun.

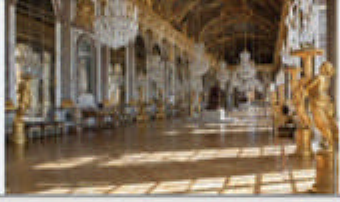
Baboons
Baboons were believed to be Sun-worshippers so adorn the façade of the temple.

Fallen idol
The head and torso of the second Ramesses statue lies on the ground having broken off following an earthquake.

Sitting tall
Even though they are sitting down, the entrance statues are 20m (65ft) tall.

How many mirrors are in the Hall of Mirrors?

A 137 B 357 C 579



Answer:
357 – As the main feature of French King Louis XIV's third building campaign of the Palace of Versailles, construction of the Hall of Mirrors began in 1678. Mirrors were expensive at the time, and so were a symbol of the king's wealth.

DID YOU KNOW? *Much of the talking heard from actor Al Jolson in The Jazz Singer was unscripted*

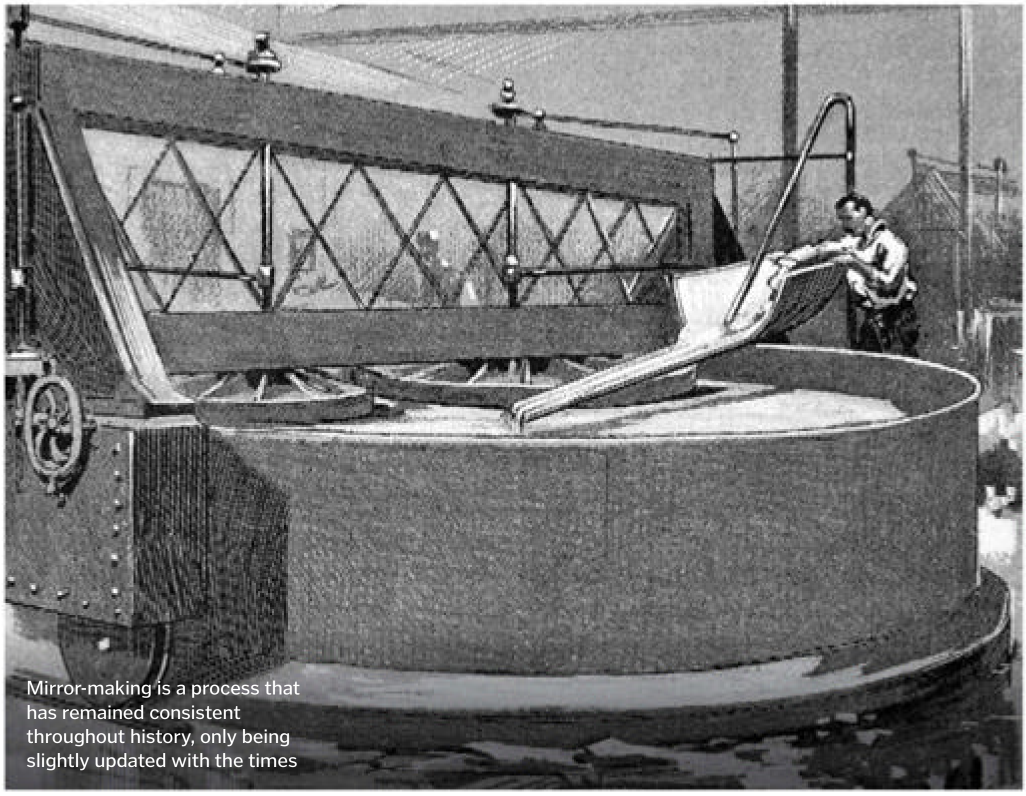
Mirror manufacturing

The process that allows you to look yourself in the eye

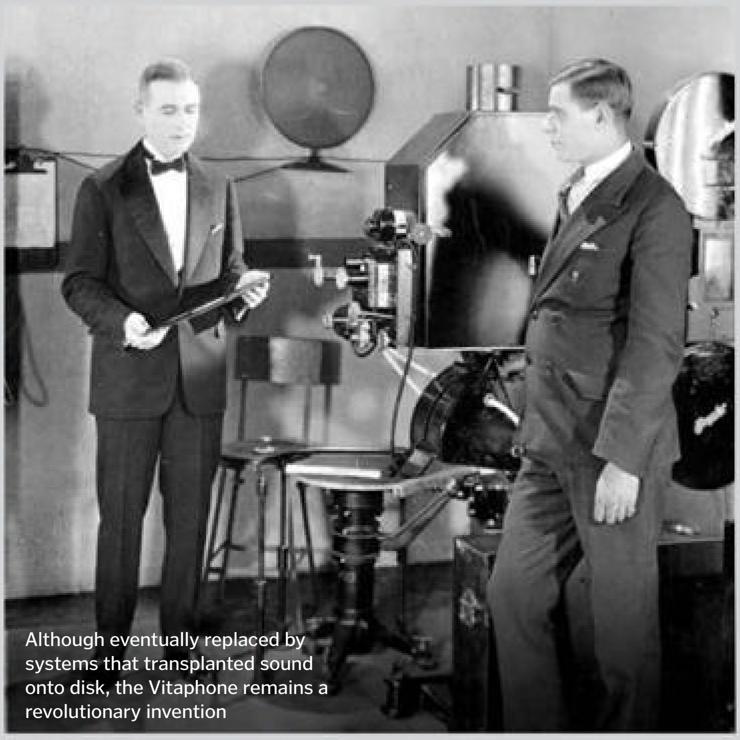
Throughout the ages, a great number of different materials have been used to create mirrors. Obsidian was used originally, with gold, silver, aluminium and bronze also being implemented at various times through history. At first, the stones were highly polished to create a reflective surface, but today the process is a bit more streamlined.

First, a reflective coating – usually silver or aluminium – is applied to a sheet of glass, which has to be polished to the highest possible standard, since any blemishes cause distortions in the image. The remaining solution is then poured off and the glass is dried. The back of the mirror is covered with a protective substance to safeguard the coating.

Depending on the type of mirror, they are created in different ways. Heavy-duty mirrors are created with thicker layers of glass in order to be sturdier, while in mass production, highly polished metal can be used. Some optical instruments use different coatings that better reflect certain types of light. For example, aluminium is better than silver at reflecting ultraviolet light.



Mirror-making is a process that has remained consistent throughout history, only being slightly updated with the times



Although eventually replaced by systems that transplanted sound onto disk, the Vitaphone remains a revolutionary invention

First sound in cinema

How movies made the step into the talkie revolution

Films have long represented a popular form of entertainment, but for much of the early-20th century, they were restricted to the silent format. Soon, however, this would all change.

Inspired by Thomas Edison's phonograph and Lee de Forest's Audion tube, the Vitaphone was created by Western Electric, and in turn was bought and developed further by Warner Bros. The Vitaphone comprised a film projector rigged up to a record player, with the sound being played over the footage of the film. In turn, the sound was amplified so that it was more audible to the audience, with a projectionist on hand to make sure the footage and sound were in sync.

The first sound movie to use the Vitaphone system was *Don Juan* on 6 August 1926 – although since there was no dialogue, the honour of the first 'talkie' is credited to *The Jazz Singer*, which was released on 6 October 1927.

"Washington National Cathedral is the world's sixth-largest cathedral and the second largest in the USA"

Washington National Cathedral

What makes the USA's second-largest church its most important?

With its roots stretching back to the birth of the United States of America and construction lasting 83 years, Washington National Cathedral – also known as the Cathedral Church of Saint Peter and Saint Paul in the City and Diocese of Washington – is the historical and spiritual heart of the nation.

A "great church for national purposes" was first proposed in 1791, 15 years after the American colonies declared their independence from Great Britain, during the ambitious construction of Washington, DC, as a purpose-built capital for the proud new nation.

Though proposed during the administration of the first US president, George Washington, the foundation stone (taken from Bethlehem) on the English-style neogothic cathedral was eventually laid down over a century later, on 29 September 1907 in the presence of the 26th US president, Theodore Roosevelt. It was only officially completed on 29 September 1990, when the last decorative finial stone was installed in the presence of the 41st president, George HW Bush (the father of George W Bush).

The end result is more than 152 metres (500 feet) long from west to east and its central tower is just under 92 metres (302 feet) tall, making Washington National Cathedral the world's sixth-largest cathedral and the second largest in the United States.

Although the cathedral remained unfinished for much of the 20th century, the central Bethlehem Chapel was opened in 1912 for services, including the state funerals for presidents Dwight D Eisenhower, Gerald Ford and Ronald Reagan, and memorials for several other US presidents.

Washington National Cathedral also held memorials for important figures such as the first man on the Moon, Neil Armstrong, and former South African president Nelson Mandela, as well as during moments of national mourning such as the 11 September terrorist attacks in 2001 and the end of the Vietnam War.

What to look out for

From *Star Wars* to World War II, you'll find it inside the Washington National Cathedral

Darth Vader
On the 'dark side' of the tower is a carved grotesque based on *Star Wars* villain Darth Vader, designed by 13-year-old Chris Rader in 1985.

Space window
This stained-glass window commemorates the Apollo 11 mission with swirling planets. A tiny piece of Moon rock is set in the glass.

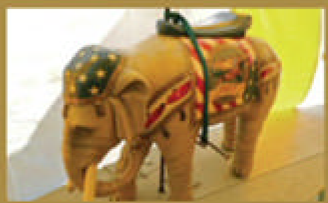
West facade
The cathedral's west facade shows the creation story from the Bible.

Cathedral Carousel

Not something you'd typically expect to find in the grounds of a church, the All Hallows Guild Carousel was built in the 1890s by the Merry-Go-Round Company of Cincinnati and was used in travelling county fairs across the States.

A rare all-wood carousel with a brass pipe organ, it has 24 hand-carved and brightly painted animals and two chariots for seating, which rise and fall as the carousel rotates around the centre pole, which is driven by a petrol engine.

It was purchased by the All Hallows Guild, the body that looks after the grounds of the Washington National Cathedral, in 1963 to bring a carnival atmosphere to open-air events. Now, the beautiful antique carousel is brought out only once a year and is on the National Register of Historic Places in its own right as one of only two all-wood carousels left in the United States.



A beautiful hand-carved elephant on the All Hallows Guild Carousel

KEY DATES
THE CONSTRUCTION OF THE CATHEDRAL

1791
French-born architect Pierre Charles L'Enfant sets aside space for a cathedral in his plan for Washington, DC.

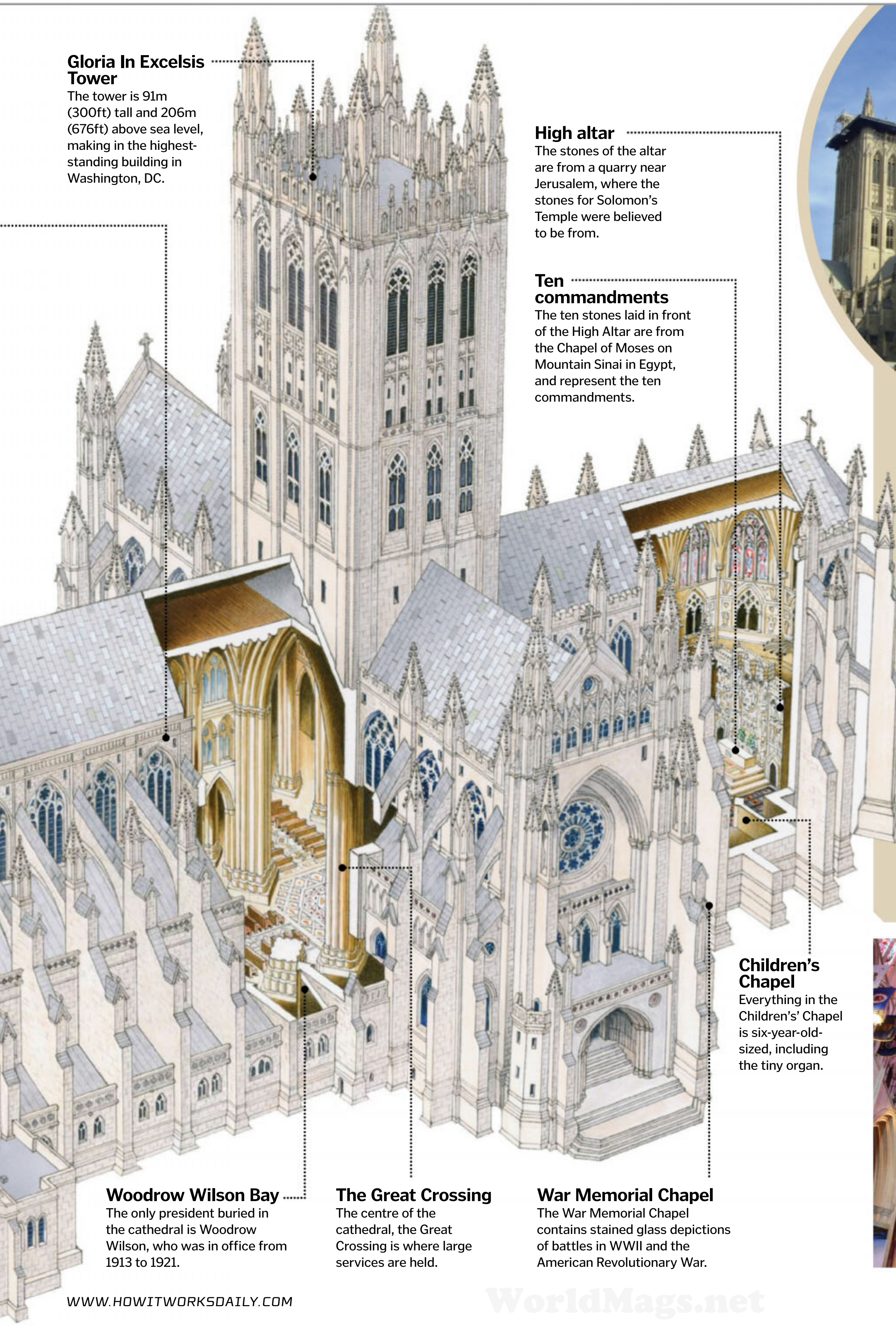
1906
George Frederick Bodley and Henry Vaughan are chosen to design it in Gothic Revival style.

1907
The foundation stone is laid down and construction begins following an address from President Theodore Roosevelt.

1921
With Bodley and Vaughan dead and building work paused during WWI, American architect Philip Hubert Frohman is brought on.

1990
After 83 years under construction, the final stone is added in a ceremony with President George HW Bush.

DID YOU KNOW? *Martin Luther King Jr delivered his last Sunday sermon at the cathedral on 31 March 1968. He was killed on 4 April*



Gloria In Excelsis Tower
The tower is 91m (300ft) tall and 206m (676ft) above sea level, making in the highest-standing building in Washington, DC.

High altar
The stones of the altar are from a quarry near Jerusalem, where the stones for Solomon's Temple were believed to be from.

Ten commandments
The ten stones laid in front of the High Altar are from the Chapel of Moses on Mountain Sinai in Egypt, and represent the ten commandments.

Children's Chapel
Everything in the Children's' Chapel is six-year-old-sized, including the tiny organ.

Woodrow Wilson Bay
The only president buried in the cathedral is Woodrow Wilson, who was in office from 1913 to 1921.

The Great Crossing
The centre of the cathedral, the Great Crossing is where large services are held.

War Memorial Chapel
The War Memorial Chapel contains stained glass depictions of battles in WWII and the American Revolutionary War.

Cathedral vs quake

On 23 August 2011 the Washington National Cathedral was damaged by an earthquake. The 2011 Virginia Earthquake measured 5.8 on the Richter scale – the largest seen on the US east coast since 1944 and felt by more people than any other quake in US history.

Cracks appeared in the supporting buttresses surrounding the church, while three of the four stone spires on the central tower twisted out of alignment or broke off altogether and crashed through the roof.

The cathedral was closed until 7 November 2011 and repairs – expected to cost $26 million (£17 million) and not covered by the building's insurance – are ongoing.

"Plate armour fell out of use on the battlefield in the mid-17th century as firearms became more powerful"

How armour was made

Plate armour changed the nature of Medieval warfare, but how was it created?

Although armour made from strips of metal had been worn as far back as Ancient Greece, the use of fully enclosed suits of plate armour began in the early-15th century. Associated with European knights charging into battle on horseback, plate armour was worn by whoever could afford it – regardless of their status – as it could easily deflect sword and spear blows. Plate armour fell out of use in battle in the mid-17th century as firearms became more powerful, but it continued to be worn for jousting.

Specialist armourers – not blacksmiths – made plate armour in workshops and many of the best could be found in southern Germany and northern Italy, close to where iron was mined. First, a hammer man – often an apprentice – would heat up iron bars in the forge until they were soft. Then the iron would be hammered into shape over an anvil. Each segment of the armour, from the tip of the helmet to the toe of the boot, had a different anvil in a different shape that worked as a cast.

The completed piece would then be given to a polisher, who would smooth it down to the correct thickness with a grinding stone powered by a water mill. The finisher, often the master armourer as this was the most complex job, would then assemble all of the individual pieces. He would also add the padding that let it sit comfortably on the body and the leather buckles that held it together.

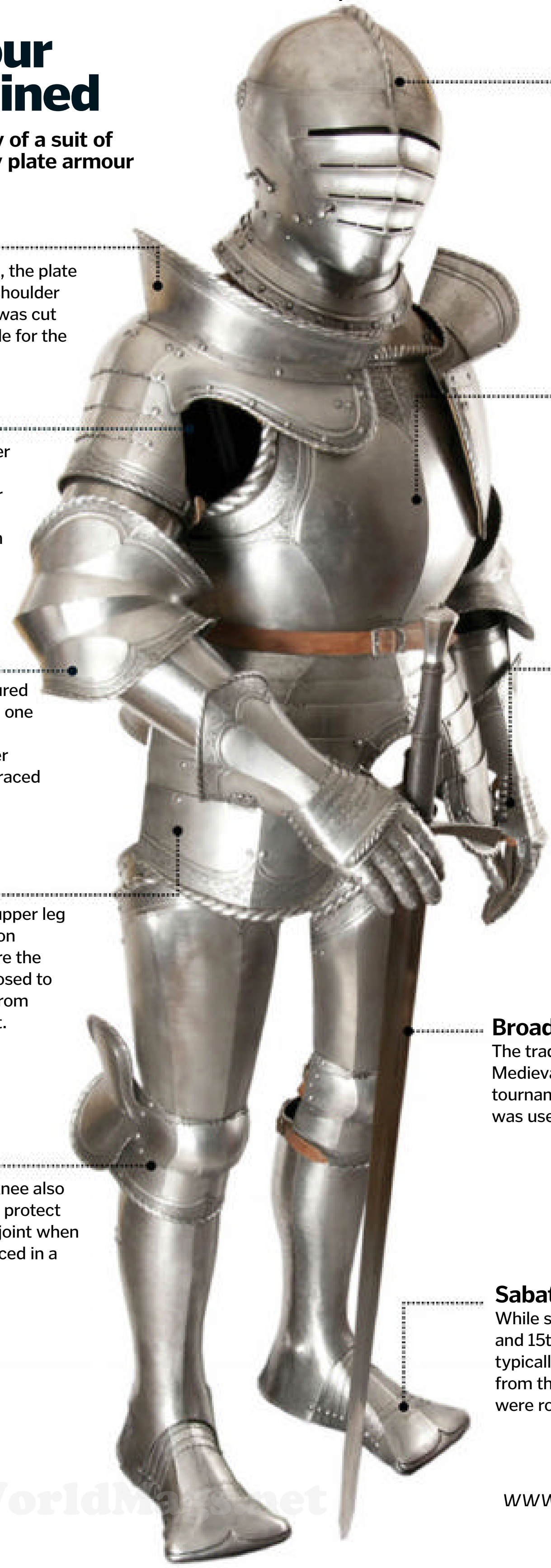
Piercing armour

Just as plate armour was developed to protect against swords and spears, new weapons were developed to find a way around these awesome new suits of steel. These included swords called estoc that were over a metre (3.3 feet) long and tapered to a single point, along with heavy poleaxes and halberds, which were effectively axes mounted on poles. While slashes from blades struggled to damage plate, blunt force could be conducted through sheet metal with devastating results, and so war hammers and maces became more common.

Medieval martial arts also came into their own with the 'Kunst des Fechtens' (meaning 'art of fighting') – a style of swordsmanship taught in the Holy Roman Empire – which focused on weak spots such as unprotected necks, armpits and joints.

Armour explained

The anatomy of a suit of 16th-century plate armour



Close helm
The close helm completely covered the head and neck, while the visor could be lifted if needed.

Pauldron
In jousting suits, the plate protecting the shoulder and upper arm was cut away on one side for the lance to rest.

Cuirass
The cuirass rested on the hips, not on the shoulders, as the weight was too great to press down on the body for long.

Doublet
A padded leather or cloth doublet was worn under the armour for extra protection and comfort.

Couter
A heavily armoured elbow joint, this one has 'wings' to protect the inner arm when it's braced while jousting.

Gauntlet
Effectively a metal glove, special jousting gauntlets were also available. These were more heavily armoured but fixed in position to hold a lance.

Tasset
Protecting the upper leg was important on horseback where the knight was exposed to upward blows from warriors on foot.

Broadsword
The traditional weapon of the Medieval knight in both battle and tournaments, the broadsword was used for slashing.

Poleyn
The armoured knee also has 'wings' that protect the back of the joint when the legs are braced in a riding position.

Sabaton
While sabatons of the 14th and 15th centuries typically ended in a point, from the 16th century they were rounded.

BRAIN DUMP

Because enquiring minds need to know...

Want answers?

Send your questions to...

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howitworks@imagine-publishing.co.uk

MEET THE EXPERTS

Who's answering your questions this month?

Luis Villazon

Luis has a degree in Zoology from Oxford University and another in Real-time Computing. He has been writing about science and technology since before the web was invented. His sci-fi novel *A Jar of Wasps* 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 videogames.

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!

There are fewer than 400 Sumatran tigers left in the wild

How do we know the number of tigers left in the wild?

Faye Lomas

■ The International Union for the Conservation of Nature (IUCN) keeps records of the population sizes of thousands of threatened species. Like all their figures, the number of wild tigers is an estimate, based on surveys from lots of regional conservation bodies. This is a mixture of direct observation, cameras set up near watering holes, and droppings or paw prints found on trails. IUCN figures are subject to peer review, like any other scientific data, to ensure they have the most accurate figures. The most recent figures, which are from 2011, suggest there are around 3000 tigers left in the wild. **LV**

What does 1080p mean?

Jack Holt

■ This is the most common of the high-definition TV standards currently available. The 1080 refers to the number of pixels in the vertical direction. On a normal widescreen TV with an aspect ratio of 16:9, the screen resolution is 1920 by 1080 pixels. The p stands for *progressive*, which means that the entire 1920x1080 picture is displayed on each frame. This is better than 1080i or *interlaced*, which displays the even numbered horizontal lines on one frame and the odd numbers on the next frame. 1080i alternates between them fast enough that your eye sees a solid image, but it's not as sharp as 1080p. **LV**

The latest 4K TVs have four times the resolution of 1080p

Out-of-date milk may contain much more bacteria

Why does milk go lumpy when it goes off?

Fiona Calloway

■ Milk that's gone off becomes slightly acidic, causing it to curdle as its proteins clump into lumps. Milk is composed of mostly water, sugar, fat and protein. In fresh milk, protein molecules are uniformly distributed and move around freely in the solution. But as bacteria digest lactose – the sugar in milk – they produce small quantities of lactic acid. The resulting acidic conditions cause the milk proteins to attract each other, forming lumps. Curdling can be caused intentionally during the production of cheese, when vinegar, lemon or enzymes are used to separate milk solids from whey. **AC**

How do banana trees move?

Anthony Gillard

■ Over time, banana plants do appear to move. They are not trees, but are giant herbs with trunks (pseudostems) made from tightly wrapped leaf stalks. Under the ground, these stalks are supported by an underground stem known as a rhizome. The rhizome travels horizontally, forming suckers that can produce new pseudostems. Most of these are harvested and planted elsewhere to grow new banana plants, but as the first stem dies back, a second is allowed to grow, making it seem like the plant has moved. **LM**

Plants seem to move when one stem dies and another replaces it

Why do drains smell so bad if only toothpaste and soap go down them?

James Hoare

■ It's not just sweet-smelling soap and minty-fresh toothpaste that travel down household pipes and into drains. Each time you flush the toilet or empty the kitchen sink, this waste matter joins them. The used water that carries these substances exits the building via a private drain, which connects to a pipe that serves several properties. The bacterial breakdown of organic matter where oxygen is not present produces the chemical compound hydrogen sulfide, a gas that gives off a foul smell. Since the drainage system consists of various components, blockages will inevitably occur, particularly if items have been flushed away or put down the sink that shouldn't have been. This means the smell can linger. **SB**

FASCINATING FACTS

How long can the human body survive without food?

It depends on many factors but some experts estimate up to two months without food. However, death will occur in less than a week without water.

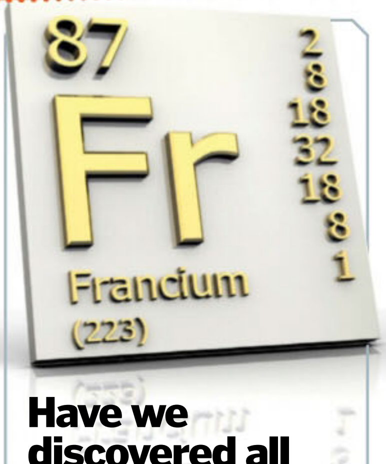
How deep down can a person dive before the pressure gets too much?

Anthony Gillard

■ Experienced scuba divers can dive to about 40 metres (140 feet), where the pressure is five times that of the surface. The real danger is the drop in pressure as the diver resurfaces. At high pressures, nitrogen from the air tank dissolves into the diver's bloodstream. Ascending too quickly causes bubbles of nitrogen to dissolve out: a potentially lethal condition called decompression sickness (the bends). Divers are therefore limited by the time it takes to decompress safely. The deepest ever scuba dive was to 332 metres (1090 feet). It took Ahmed Gabr 12 minutes to descend, but 14 hours to come back up. **AC**

Resurfacing can be the most dangerous part of deep diving

How powerful was the first airplane? Find out on page 82



Have we discovered all the elements?

Michael MacDonald

Most experts believe that we have found all the naturally occurring elements on our planet, reaching a total of 94. We haven't found a new element in nature since 1939, although many have since been synthesised in the lab. The periodic table can be used to predict what elements could theoretically exist, and those remaining are super-heavy elements with over 104 protons. It is unlikely that conditions on Earth could ever produce such atoms. In the lab, they can be synthesised by using particle accelerators to smash atoms together, causing their nuclei to fuse. Many such elements are radioactive and decay very rapidly. **AC**

How does vacuum-packing work?

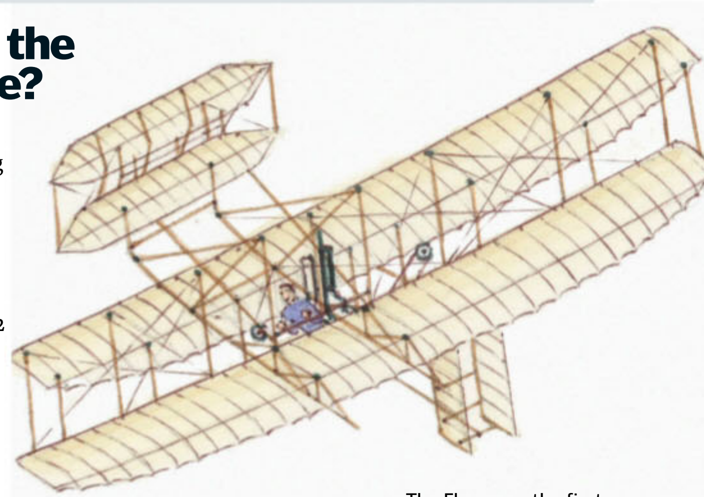
Leanne Chesterton

Vacuum-packing removes air from packaging before it's sealed for two reasons: to preserve and to reduce volume. Taking out the environmental oxygen limits the ability of bacteria and fungi to grow, so food packed this way lasts much longer. It's typically used to store dry foods for long-term storage, like cereals, nuts and coffee, but fresh foods like meats are also vacuum-packed. Some people vacuum-pack both food and non-food items at home, but it's important to know that some bacteria actually prefer low-oxygen environments, and cooks have to take special safety precautions when vacuum-packing food at home. **SF**

How many horsepower did the Wright Brothers' plane have?

Colin Edgerton

In December 1903, after years of studying, designing and inventing, American brothers Orville and Wilbur Wright finally invented and built the first successful airplane. Known as the Flyer, it had a simple motor without a fuel pump, carburettor, throttle or spark plugs. Yet astonishingly, it was capable of producing 12 horsepower. This was pretty impressive, considering their minimum requirement was only 8 horsepower. The first flight lasted for 12 seconds and covered a distance of 37 metres (120 feet). The Flyer's water-cooled, gasoline engine had four cylinders that were enclosed in a cast aluminium crankcase. It weighed less than 91kg (200lb) and powered two propellers. **SB**



The Flyer was the first successful airplane and produced 12 horsepower

Why do returning space ships land in the sea?

Liam Day

Not all returning spacecraft land in the sea. The Russian Federal Space Agency's Soyuz craft – which transports astronauts and cosmonauts to the International Space Station – lands on the flat steppes of Kazakhstan. In fact, Russian space programs have always used ground-based landings, while NASA used splashdowns until the Space Shuttle program. Because it launches from Cape Kennedy (formerly Cape Canaveral) in Florida, there was plenty of surrounding water safe for astronauts to land in and open their capsule. The Russian program launches from the Baikonur Cosmodrome, located in the land-locked country of Kazakhstan. A splashdown in the closest Russian waters would freeze any exiting cosmonauts, and landing in international waters could be politically tricky. However, there's plenty of sparsely populated, flat land in Russia. Recovering astronauts from the sea ultimately presented NASA with many challenges, and that's part of why the design for the Space Shuttle program incorporated landing on a runway. **SF**

FASCINATING FACTS

Which country gets the highest amount of rainfall?

According to The World Bank, Colombia has the highest annual rainfall, receiving around 3,240mm of rain each year. In contrast, the driest country, Egypt, receives just 51mm per year.

Rain is collected and measured in a rain gauge

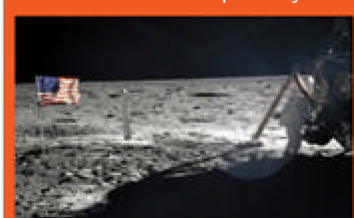
What is the world's longest straight road?

At 260km (162 miles) long, the world's longest straight road is the Highway 10 in Saudi Arabia, which was built to connect Haradh with the UAE border.

Saudi Arabia's Highway 10 is the longest straight road in the world

What were Neil Armstrong's second words on the Moon?

According to the official NASA transcript, after stepping off the ladder, Armstrong looked at the soil his boots had touched and said, "Yes, the surface is fine and powdery."



Bullet-resistant glass is made from heat-bonded layers of glass and plastic

How does bulletproof glass work?

Hosun Cho

Although no manufacturers claim their glass to be truly bullet-proof, there are many types of bullet-resistant glass, capable of stopping a variety of different high-speed projectiles.

When a normal pane of glass is struck, there is nothing to absorb the energy, and the weakly-bonded particles break apart, cracking open and allowing a bullet to travel straight through.

To prevent this from happening, sheets of tough, flexible plastic, often polyvinyl butyral (PVB), are sandwiched in between, and repeatedly heated and cooled to bind the two together in a process known as lamination.

When a bullet hits, the layers of glass shatter as normal, but as they break, the force is absorbed and spread by the strong and flexible PVB sandwiched in between. This slows the bullet down, preventing it from passing through. The fragments of broken glass remain firmly stuck to the plastic, stopping them from flying away and causing injury. **LM**

Hair growth is affected by a variety of factors, from diet to the seasons

Why does some people's hair grow faster than others?

Louise Green

There are so many different factors that affect hair growth, so it is difficult to pinpoint just one reason. Genetics and ethnicity are thought to play a role; Asian hair reportedly grows the fastest. Diet and lifestyle also have an impact; iron deficiency and smoking, which reduce blood supply to the scalp, can cause hair growth to slow down. There also seems to be a seasonal component, with an increased rate of hair growth in winter. Trimming the ends of the hair regularly can help to prevent breakage, preserving the existing length, but will not make the hair grow any faster. **LM**

How do computers play chess? Find out on page 84

Why does the date of Easter keep changing?

Sammy Robertson

According to the Bible, the events surrounding Easter occurred on or around the Jewish festival of Passover. The Jewish calendar is based on the lunar cycle, and Passover begins on the date of the first full Moon after the spring equinox, where the length of the night is equal to the length of the day. The date of Passover therefore changes every year.

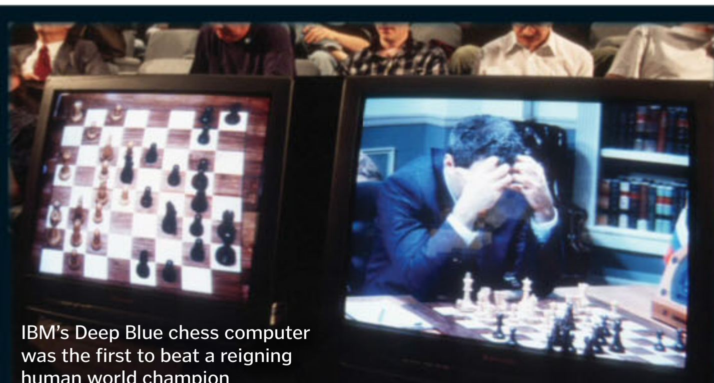
Easter should, in theory, occur on the first Sunday after Passover, but in practice it is slightly more complicated than this. In 325AD, the Christian Council of Nicaea fixed the date of the spring equinox to the 21 March, and drew up tables that predicted the dates of the full Moons. The modern dates are based on these ancient writings. **LM**

The date of Easter changes because it is tied to the cycles of the moon

FASCINATING FACTS

What were the first domesticated animals?

Dogs, by a wide margin. Archaeological evidence suggests that domesticated dogs existed at least 15,000 years ago. Sheep were the second animals to be domesticated, but it took another 4,500 years.



IBM's Deep Blue chess computer was the first to beat a reigning human world champion

How do computers play chess?

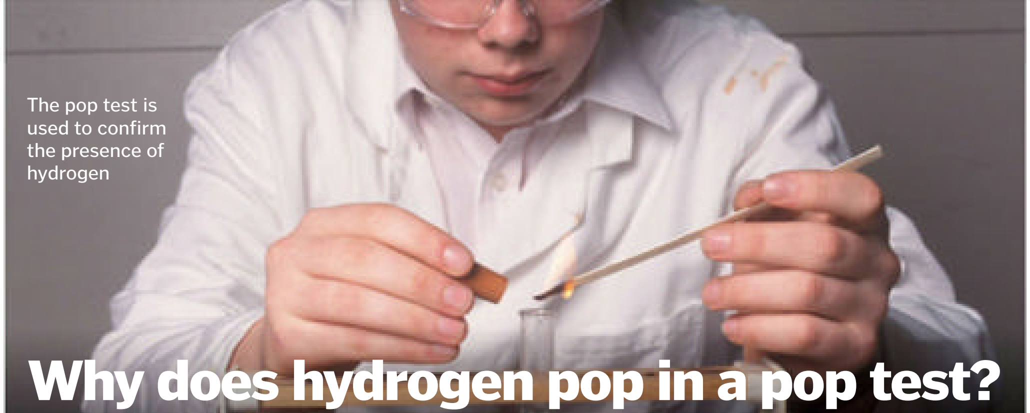
Sandra Key

Humans and computers play chess in essentially the same way. Both start with a large selection of memorised opening gambits and then plan their move by imagining the consequences of each possible move. The difference is that computers are more methodical. On each turn, they build a tree of all the possible moves branching off. They score each move according to certain rules and focus on the sequences with the highest tactical scores. IBM's Deep Blue chess computer first beat a reigning world champion in a 1997 match against Gary Kasparov, but even today, computers aren't guaranteed to win. In particular they can be weak at assessing strategies that involve sacrificing some pieces early on, in order to gain an advantage later in the game. **LV**

If you fell down a hole, would you reach the centre of Earth or the Moon?

Lauren Smiley

If you fell down a hole that went all the way to the centre of the Earth – falling about 13,000km (8,078 miles) – you'd die. End of story. But assuming that's not an option, you'd pick up speed quickly and reach the centre of the Earth in about 20 minutes. If the hole went all the way through, a really interesting thing would happen. Once you got past the centre, you'd start falling up for 20 minutes, decelerating on your way up. And once you came up above the surface? You'd fall again. And again, and again. Forever. **SF**

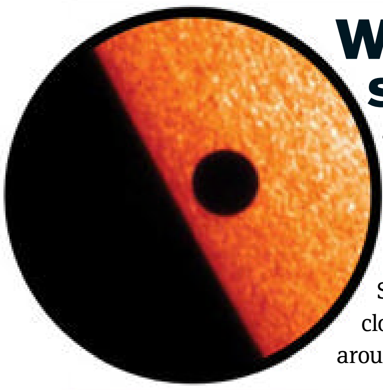


The pop test is used to confirm the presence of hydrogen

Why does hydrogen pop in a pop test?

Glenn Durant

■ The characteristic pop that you hear when you ignite a test tube containing a mix of air and hydrogen is the sound of the hydrogen combusting and exploding. Hydrogen is extremely flammable, and when ignited by a burning matchstick, reacts with oxygen in the air to produce water. This exothermic reaction releases energy as heat, light and kinetic energy. The rapid release of energy causes a pressure shockwave to form in the air around it, creating an explosive pop. If enough hydrogen is present, it can produce a bang with flames. Air containing anywhere from 5 to 75% hydrogen will produce an explosion, but for the loudest bang, go for a ratio of two volumes of hydrogen to one volume of oxygen. The pop test is often used to identify hydrogen since most other common gases are not as flammable. **AC**



What are the fastest and slowest-moving planets?

Jessica Christie

■ The planets travel faster along their elliptical orbits when they're at their perihelion, or closest to the Sun. The inner planets – the four closest to the Sun – travel faster around it than the outer planets. The closest planet to the Sun is Mercury, and at its perihelion it travels at a velocity of 56.6 kilometres per second (126,611 miles per hour). The most distant planet, Neptune, has a mean velocity of 5.43 kilometres per second (12,146 miles per hour). **SF**

Capsaicinoids give chillies their varying degrees of heat

What makes chillies so hot?

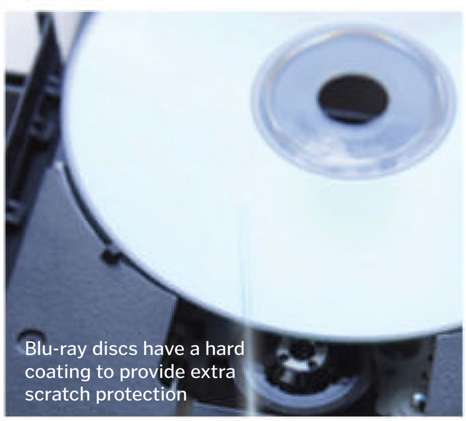
Kevin van Huyten

■ The ingredient that makes chillies so hot is a chemical called capsaicin. It is the most common compound in the complex chemical compound family known as capsaicinoids. When eaten, capsaicinoids bind to a pain receptor in the mucous membrane of the mouth. This pain receptor registers pain from heat, which is why some chillies feel like they are burning. Of course, the heat of a chilli depends on the number of individual capsaicinoids it contains, and the heat level can be measured on the Scoville Scale; a widely respected scale developed by Wilbur Scoville in the early 1900s to measure the pungency level of a chilli pepper. **SB**

Why do CDs skip?

Terry Braithwaite

■ Dust and small scratches on the clear side of a CD are usually fine because the laser focuses past this to the aluminium data layer beneath. However, a deep scratch, especially one that runs around the circle, rather than outwards from the centre, can cause enough read errors to overwhelm the digital error correction in the CD player, so it skips the laser ahead to the next section of valid data. Scratches on the label side of the CD are actually worse because the aluminium data layer is much closer to the surface on that side and can be permanently damaged. **LV**



Blu-ray discs have a hard coating to provide extra scratch protection

Medium wave radio stations pick up static and lose signal in tunnels

Why do you lose radio signals in a tunnel?

Henrik Svensson

■ When you are travelling in a vehicle listening to a radio station that broadcasts on medium wave (AM), the signal will weaken or cut out when you go through a tunnel. However, when you are listening to a radio station that broadcasts on high frequency (FM), the signal remains strong. This is because many tunnels have what is known as a relay system that maintains the high frequency channels but not the medium wave ones. The higher frequency of an FM radio station allows the wave to pass through most solid matters with little or no interference, thanks to its wide bandwidth. On the other hand, AM radio stations are unable to prevent solid structured matters from blocking the wave. **SB**

New Brain Dump is here!

■ Don't miss issue 21 of **Brain Dump**, the digital sister magazine to **How It Works**, when it lands on the virtual newsstand on 1 February. You'll learn all about chaos theory, the answer to why silverbacks have silver backs, and what Uranus' rings are really made of. Every issue is jam-packed with incredible photos and loads more trivia snippets for you to get stuck into, giving you the knowledge hit you need without having to lug an encyclopaedia around! Download the new issue of **Brain Dump** on the first day of every month from iTunes or Google Play. If you have a burning question, you can ask at **www.facebook.com/BraindumpMag** or Twitter – the handle is @BrainDumpMag.

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Home science gear

Delve into the world of science with state-of-the-art kit

Learning about science shouldn't just be reserved for the classroom. As the equipment is becoming more and more affordable, you can expand your knowledge of physics, chemistry and biology in the comfort of your own home too. These clever gadgets and fun kits provide a hands-on learning experience that everyone can enjoy, from young children to older science enthusiasts.

Checklist

- ✔ Portable microscope
- ✔ Desktop microscope
- ✔ Chemistry set
- ✔ Biology kit
- ✔ Programmable robot
- ✔ Electronics kit

Personal assistant
The Recon 6.0 rover can be programmed to tell jokes, bring you snacks, and patrol your room.

1 Biology lab

Thames & Kosmos Genetics & DNA
£24.99 / $36.95
www.thamesandkosmos.co.uk
Understanding the building blocks of life and what makes you unique is easy with this great-value kit. It features equipment for completing 20 different exercises and an illustrated guide to take you through each one. However, some tasks require additional household items and equipment, as well as items of food to experiment on.
Verdict:

2 Personal robot

ReCon 6.0 Programmable Rover
Approx. £46 / $69.99
www.smartlabtoys.com
Programming is a useful skill to have in this computer-led age, and this robot companion will help you learn the basics. The illustrated manual helps get you started, with step-by-step instructions for getting your robot to move and talk, then you can invent your own missions. A camera is all that's missing.
Verdict:

Electronic creations
As well as creating travelling machines, you can also build an alarm or power a bulb.

Biology basics
Discover how we inherit genes, build your own DNA model and more with this kit.

3 Understand electronics

Cars and Boats 2
£24.99 / approx. $38
www.cambridgebrainbox.co.uk
Have fun building your own car or boat whilst learning the basics of electronics with this complete kit. Discover how circuits work by fitting together simple components to power your creations. Although aimed at young children, following the simplistic instructions may require assistance from an adult.
Verdict:

EXTRAS Get inspiration for your experiments

BOOK

How It Works Book Of Science Experiments

Price: £9.99 / $15
Get it from:
www.imagineshop.co.uk
Tired of hearing 'don't try this at home'? This book contains incredible science experiments that you can do yourself, from making mega bubbles to building a matchbox microphone. There's even a foreword from the brilliant Professor Robert Winston.

APP

Home Science Experiments

Price: £2.29 / $3.49
Get it from:
iTunes / Google Play
All you need to set up your own science experiments is a few household items and the simple guides in this app. Turn a lemon into a battery, make your own pinhole camera and even create your own slime.

WEBSITE

Home Science Tools

www.hometrainingtools.com
As well as selling lots of home science gear, this website also has a science projects section, with all sorts of fun chemistry, physics, biology and even space experiments to try.

4

LCD monitor
The rotating LCD lets you and others view the slides in real time.

5

Compatible app
The free Micro Fi app is available from the Apple App Store and Google Play.

6

Professional quality kit
The set contains safety equipment, test tubes, an alcohol burner, a range of chemicals and more.

4 Digital microscope

Celestron LCD Digital Microscope II
£249 / $280
www.celestron.uk.com
This reasonably priced desktop microscope features up to 1600x magnification and comes with a set of pre-prepared slides. You can record stills and videos onto the supplied SD card or use the supplied cables to view a live stream on your computer or TV. It's simple to operate but focusing accurately takes a bit of practice.
Verdict:

5 Handheld microscope

Celestron Micro Fi
£290 / $219.95
www.celestron.uk.com
This travel-sized microscope is a fun but expensive gadget. It's Wi-Fi enabled and connects to your smart device via a free app, letting you live stream and record video, as well as take photos. It's easy to set up, but difficult to keep steady without a tripod and only features 80x magnification.
Verdict:

6 Chemistry set

Thames & Kosmos Chem Lab C3000
£160 / $250
www.thamesandkosmos.co.uk
You can conduct over 333 different science experiments with this complete chemistry kit. It contains 103 components to help you get hands on with chemical equations, atomic structures and more. The accompanying manual gives detailed instructions that are easy for novices to follow, but young science enthusiasts will need to be accompanied by an adult.
Verdict:

GROUP TEST
Putting products through their paces

Telescopes for astronomy

A must-have piece of kit for an astronomer, but which gets our vote?

1 Visionary Mira Ceti 150 1400

Price: £299.99 / $N/A
Get it from: opticalhardware.co.uk

Setting up the Mira Ceti is very straightforward. There's no need for a toolkit and with a weight of 12 kilograms (26 pounds), it is easy to pick up and take outside for observing. Polar aligning the mount – the process of aiming the telescope at part of the sky that doesn't move (the north celestial pole) – is a speedy process, although holding the telescope into position involves tightening the locking screws to a fairly high degree.

We relied on the 25mm eyepiece – thus not pushing the magnification of the telescope too high – throughout our review of this Newtonian, since the additionally supplied 6.5mm produced fuzzy images. Views of the Moon were good, although anywhere beyond 70 per cent of the field of view saw a degree of distortion. With the help of a 2x Barlow lens, though, we were able to pick out two major bands of Jupiter.

Turning our attention to the Orion Nebula, we were keen to try out the Mira Ceti on deep-sky targets. Views of the Trapezium star cluster at the star-forming region's heart were fair and the reflector drew in faint light well when we observed the ghostly Merope Nebula in the Pleiades star cluster.

The Mira Ceti is a good, affordable telescope for the beginner and, although the flimsy mount and finderscope let this reflector down, its ability to pick out a good selection of targets will please the novice astronomer.

Verdict: ✪✪✪✪✪

Low magnification is best
The Mira Ceti struggled when pushed to high magnifications, so we advise using eyepieces of around 10mm upward for low magnifications.

2 Celestron NexStar 6SE

Price: £999/$1,359.95
Get it from: www.celestron.uk.com

The NexStar 6SE is an all-rounder that's suitable for both beginners and astronomers who have very good night-sky knowledge. It's quite difficult to outgrow this telescope, given what it can offer and how easy it is to accessorise with extra eyepieces and other kit.

Setting the telescope up took next to no time and we were very impressed with the quality of its many components. Its robust build promises years of observing sessions, provided it is treated with care. A dew shield should be purchased for the NexStar, though, since it will succumb to moisture.

When we took the telescope out to test, we were pleased to discover that the SkyAlign technology – which polar-aligns the telescope – is impressively simple to use. It wasn't long before we were touring the winter-night sky and made the Orion Nebula our first target. The NexStar slewed smoothly into position but vibrated slightly while bringing this star-forming region into focus. Thanks to the excellent StarBright XLT optical coating, our view of the nebula and its stellar members as well as the Moon's surface were very crisp, bright and clear. What's more, there were no defects in the optics to speak of. Many might be put off by the hefty price tag but we thought that this telescope model is good value for money – given the stunning views and little to no maintenance required in the telescope's upkeep.

Verdict: ✪✪✪✪✪

Built to last
The NexStar's robust build promises years of superb observing sessions, provided it is treated with care.

3 Meade ETX 90EC

Price: £430.00/$699.00
Get it from: www.harrisontelescopes.co.uk

What the Meade ETX 90EC may lack in stature is certainly made up for with great optics and an easy-to-use GoTo system, with an AutoStar hand controller that has over 30,000 objects in its database. Aligning the telescope requires the AutoStar controller to lock onto two bright stars and triangulate from there – the best results come when polar-aligning on Polaris in the constellation Ursa Minor.

Like the Sky-Watcher Skymax, there's no dew shield, which means that as this is also a Maksutov-Cassegrain telescope, its corrector plate also becomes fogged up with condensation. The mount drive's gears are also plastic, which makes you wonder how long they will last before wearing down. The high focal ratio (f/13.8), which means a narrower field of view, makes the Meade ETX90 better suited to planetary work than expansive deep-sky studies – particularly with the smaller aperture/lower light grasp, but you can still use this for observing the brighter deep-sky objects. There are also larger aperture models in the range that increase the range of celestial objects you can see, but at greater cost.

Verdict:

ON THE HORIZON

Take the next step up to a larger full-frame

Celestron NexStar Evolution

An that instrument brings the latest technology to the already comprehensive GoTo, the NexStar Evolution promises to make finding your way around the night sky simple and provides a gateway into astrophotography.

Sky-Watcher Star Discovery 150P

An ideal instrument for the beginner, the Star Discovery 150P is packed with technology and excellent light-gathering ability to observe a wide variety of objects at a low cost.

A good planetary telescope
The Meade ETX 90EC's narrower field of view makes it better suited to planetary observations.

A database of 40,000 objects
Similar to other telescopes in this group test, the SkyMax holds a database of thousands of objects.

4 Sky-Watcher SkyMax-127 SynScan AZ GoTo

Price: £360.00 / $N/A
Get it from: www.sherwoods-photo.com

This five-inch, 127mm Maksutov-Cassegrain telescope, which uses a lens and a mirror to prevent distorted star images at the edge of the field of view, provided excellent views of the full Moon, especially through the 25mm eyepiece and the 2x Barlow lens, which put the entirety of the full Moon in the field of view. We did find that the telescope's corrector plate fogged up a bit, so we recommend that you purchase a dew shield. The finderscope is also positioned in such a way that makes it awkward to use when tilting the telescope at a high angle in the sky. Comet Lovejoy, which was visible during our test, looked impressive through the 10mm eyepiece, with its fuzzy coma.

The telescope is attached to the SynScan mount by a single arm. The mount's computer database contains over 40,000 deep-sky objects such as galaxies and nebulae that it can take you to. In order to do this, the telescope must be aligned so it knows where it is in the sky. You just direct the mount to point the telescope toward any of the brightest stars, which it is able to recognise by double-checking the stars around it.

Verdict:

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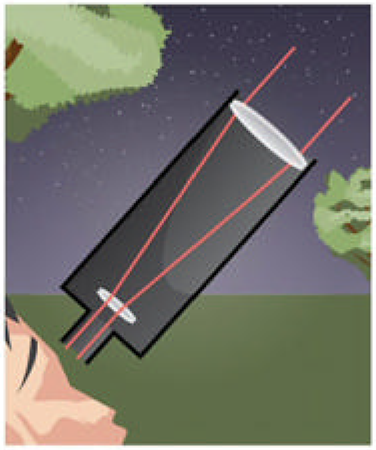
Use a telescope

A few steps to help you get to grips with looking at the stars



1 Reflective or refractive?
The first stage for any budding astronomer is to decide what kind of telescope they need. Refractor telescopes use a lens to bend light into the eyepiece and are good for seeing planets and stars. Reflector telescopes use two mirrors to capture light and magnify it so you can see incredible nebulae and distant reaches of the galaxy. Catadioptric telescopes can see both planets and deep space, but are pricier.

2 Choose your mount
As with the telescope, there is more than one kind of tripod. Alt-azimuth tripods swing left to right and up to down so are easy for beginners to control. Equatorial mounts need to be aligned to the North Star where they track the stars across the sky as the Earth rotates. This is especially useful for astrophotography but because of the added tech, an equatorial mount will be more expensive.

3 Setting it up
Find a flat, stable surface on which to stand your tripod and extend the legs evenly so there's no risk of the telescope overbalancing. If you are in an area with lots of light pollution, maybe find a high place to stargaze from, providing it's safe, of course. Follow the instructions for attaching the telescope to the mount extremely carefully, making sure everything is screwed on tightly.

4 Research the sky
The easiest and most common way to get discouraged when using a telescope for the first time is to not know what you're looking for. Go online, download a mobile app or get some stargazing books to learn more about the skies you are going to be looking at. Once you've got a solid idea of what is out there and established landmarks in order to help you find your targets, you can begin to stargaze with more confidence.

5 Practice makes perfect
Start out simple. Instead of trying to focus on tiny pinpricks of light many light years away, search for items a little closer to home such as trees and buildings. Once you've managed to get the hang of finding items on Earth, turn your telescope up toward the sky and start searching for easy objects such as the Moon before trying harder-to-spot bodies such as particular planets or nebulae.

In summary...
The key to starting out with telescopes is patience and making the right choices for what you want to achieve. Selecting the correct telescope, mount and position takes careful planning, so you need to take your time in working your way up to checking out the most incredible sights in the galaxy.

NEXT ISSUE
- How to make compost
- Make your own lava lamp

Blow bubbles inside bubbles

Create an incredible double bubble using the science of hydrogen bonds

1 Create your bubble

Fill a glass with 260 millilitres (nine fluid ounces) of cold water, a tablespoon of granulated sugar or glycerine and two tablespoons of washing-up liquid. Mix it together with a few brisk stirs until the sugar has dissolved into the water. Next, carefully snip part of the bulbous end off a pipette. Dip your hand in the bubble mixture and wipe it over a surface, such as a table or worktop, to create a thin film of mixture. This will form the base of your bubble.

2 Blow those bubbles

Dip your pipette in the solution, bulb first. When the end is coated in mixture, blow gently through the thin end until you've created a half-sphere bubble on the table. Make sure it is at least ten centimetres (four inches) in diameter. This mixture should be strong because of the sugar content. The sugar molecules hold the water molecules in the bubble, forming hydrogen bonds and stopping it evaporating and bursting the bubble.

3 Multi-bubbles

Now for the fun part! Dip your pipette in the solution again and push it smoothly but firmly into the bubble. The hydrogen bonds around the edge of the bubble have pushed the soap molecules apart so the pipette can enter without disturbing the soap and water bonds. Blow gently and create a new bubble inside that one. Dip the pipette again and repeat. The elasticity of the hydrogen and soap bonds allow each bubble to expand as another is blown inside it.

In summary...

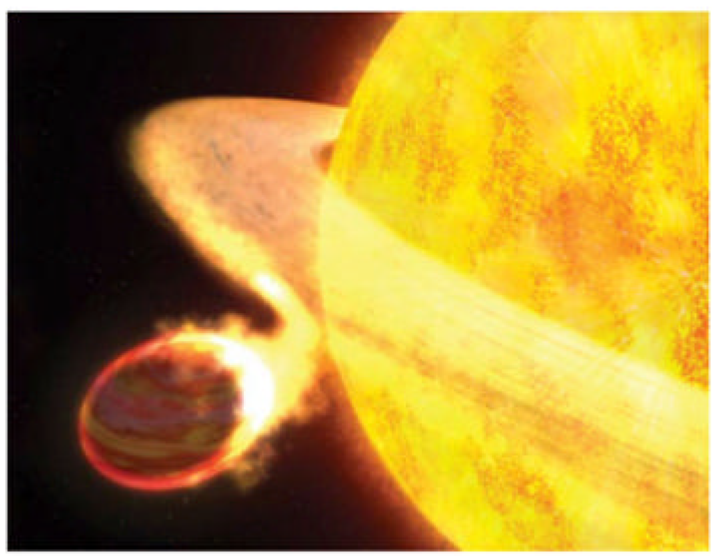
This experiment is made possible thanks to the bonds formed by the sugar or glycerine. By stopping the water evaporating they prolong the life of the bubble and by pushing the soap molecules apart they enable the pipette to enter. See how many bubbles you can get inside the original.

QUICK QUIZ

Test your mind with ten questions based on this month's content to win an amazing Airfix RAFBF Supacat Jackal model!

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

1. What is Kevin Fong's profession?
2. What is the dark area between two rainbows called?
3. Which hormone's levels are lowered when you fall in love?
4. Which types of white blood cell first signals an infection?
5. Who was president when the Washington National Cathedral was officially completed?
6. What is the name of the first exoplanet to be discovered orbiting a main-sequence star?
7. Which galaxy did the V1 star first highlight?
8. How much did the Dreadnoughtus schrani dinosaur weigh (in tons)?
9. Which animal is depicted on the façade of the Abu Simbel Great Temple?
10. Which protein enables skin to stretch?



ISSUE 68 ANSWERS

1. Abu Dhabi **2.** Binary fission **3.** 1954 **4.** Winston Churchill **5.** Active site **6.** 15 **7.** Cumulonimbus **8.** 160 **9.** Juist **10.** 4S

INBOX
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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!

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Enjoy your favourite tunes in superb quality with Musical Fidelity's MF-100 headphones. The memory-foam ear pads ensure excellent acoustics and the closed design prevents noise leaking in or out.

Letter of the Month

Flying car regulations

Dear **HIW**,
This was the first time I have read your magazine (issue 67) and I must say I found it absolutely fascinating, with numerous subjects including anatomy, space, environment and history to name a few. A couple of things stood out to me and they were the articles on driverless taxis, but especially flying cars. You stated that flying cars are already on the way, however I couldn't help wonder how it will work regarding airspace?

Yours sincerely,
Susan King

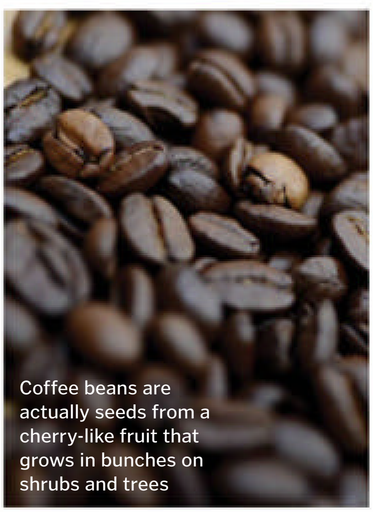
Much like drones, flying cars are a bit of a grey area when it comes to aircraft regulations. Most aviation authorities are still trying to catch up with new advancements in technology as updating their rules takes a lot of time. It's most likely these vehicles will be classed as 'light sport aircraft', and so will come with the same restrictions. Therefore, you will need a sport pilot's licence in order to fly one, and will be restricted to flying within certain areas of airspace, depending on the country. You will also have to take off and land from an airport, so you won't simply be able to glide off of your driveway. However, it will solve the problem of getting to and from the airport, allowing you to avoid those expensive parking or taxi charges.

The AeroMobil 3.0 prototype's weight and performance classes it as a light sport aircraft

© AeroMobil

Caffeine query

Dear **HIW**,
I'm a huge fan of your magazine. I love impressing people with my weird knowledge that comes from the magazine. There is one question that has been bothering me. How do they make decaf coffee? Does coffee grow caffeinated and, if so, how do you remove it? I would be grateful if you could answer this question for me.
Peter Betts



Coffee beans are actually seeds from a cherry-like fruit that grows in bunches on shrubs and trees

Coffee is naturally caffeinated so it has to be extracted. When the bean is still green it is pumped with water or steam so it swells. A mixture of water and solvents such as ethyl acetate or methylene chloride is then added. This action washes out the caffeine. The process is repeated until less than 0.1 per cent of the caffeine remains in roasted coffee beans and less than 0.3 per cent in instant.

Winter colds

Dear **HIW**,
Why do we get colds more often in the winter? I'm now on my fourth this winter and I rarely get them in any other season. I've always assumed this is to do with the temperature, but have never been sure.
Nikolai

Until recently, there were many potential theories about why colds are more common in winter. The most popular being that people tend to stay together indoors in poorly ventilated rooms in winter, providing the virus with the perfect conditions to spread. However, a recent study has revealed that temperature does have an effect on the phenomenon. The human immune system was found to be weaker when the nose temperature is cooler, giving the virus more opportunity to replicate. Therefore, the best way to avoid infection is to keep your nose warm.

Rhinovirus, one of the main causes of the common cold, thrives in temperatures of 33°C (91°F)

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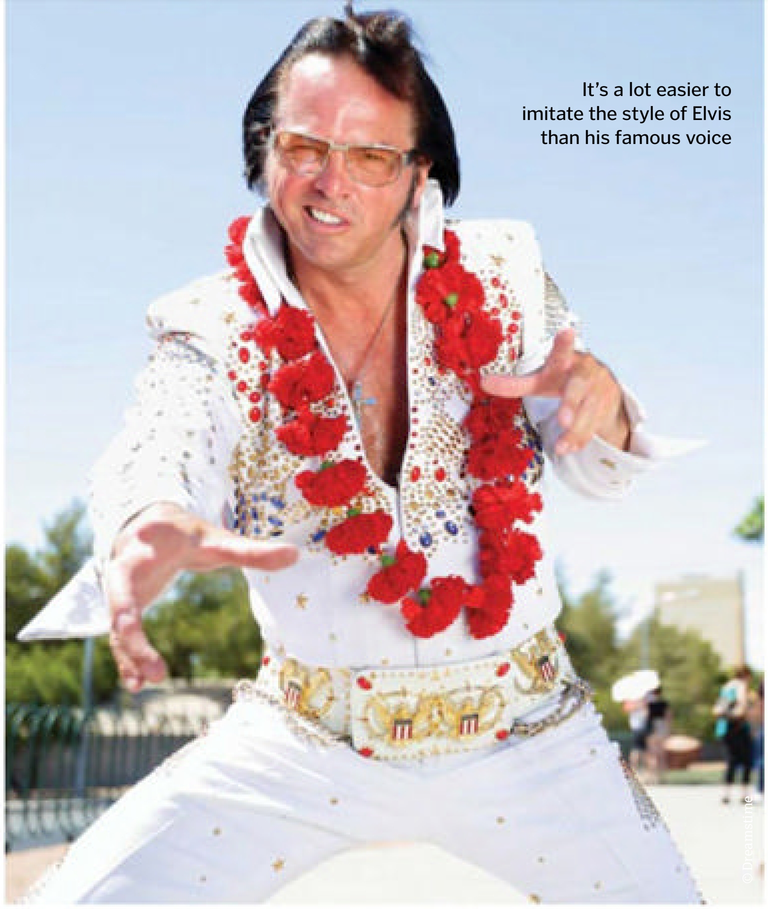

It's a lot easier to imitate the style of Elvis than his famous voice

"A lot of impressionists rely on mannerisms and physiological traits rather than the actual voice itself"

Making a good impression

Dear **HIW**,
Most of us are aware that our voice sounds unfamiliar when we hear a recording of it. This, I understand, is because we normally hear our voice both through our ears and through vibrations inside our skull initiated by our vocal chords. My question is: how do top-class impersonators such as Alistair McGowan manage to produce such accurate impersonations when they cannot be hearing what we, as an audience, hear?
Many thanks,
Chris Stratford

You are completely right, Chris. Sound is created through vibrations so extra vibrations, such as those that occur in our jaw or cheekbones, alter how we hear our own voices. Impersonators combat this by listening to recordings of their impressions so, although it might eventually sound wrong to them, it will sound right to the listener. A lot of impressionists rely on mannerisms and physiological traits rather than the actual voice itself.

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...

Freya Burrow
@HowItWorksmag Got a subscription to HIW for Christmas!!!

DJI Phantom Vision+
@HowItWorksmag Discover drones that will change your life in How It Works Issue 68.

Tom R
@HowItWorksmag Making a database of all my How It Works magazines and what information they contain so I can easily find information.

Aditi Rawal
"Family flight" – Five A350 XWBs together in flight via @Youtube **@HowItWorksmag** beyond love this!

Ian Burrell
As **@HowItWorksmag** enters Taiwan market, interview with its Bournemouth based creators, Imagine Publishing. http://www.independent.co.uk/news/media/opinion/ian-burrell-the-publisher-of-bookazines-hopes-his-reliable-unstuffy-medium-will-appeal-to-parents-everywhere-9947433.html

Barrd
Seasons greetings and a HUGE thank you to all **@HowItWorksmag** – fantastic read with eclectic articles covering very interesting topics.

Neil Clarke
@HowItWorksmag Garmin Fenix watch. Brilliant piece of tech for my outdoor hobbies.

Robert ALAI
Full page ad of #Olpejeta on **@HowItWorksmag**. Splendid!!!

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Imagine Publishing Ltd
Richmond House, 33 Richmond Hill
Bournemouth, Dorset, BH2 6EZ
☎ +44 (0) 1202 586200
Web: www.imagine-publishing.co.uk
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Magazine team

Editor **Jodie Tyley**
jodie.tyley@imagine-publishing.co.uk
☎ 01202 586274
Art Editor **Andy Salter**
Editor in Chief **Dave Harfield**
Research Editor **Jackie Snowden**
Senior Art Editor **Helen Harris**
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Production Editor **Erlingur Einarsson**
Photographer **James Sheppard**
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Contributors
Sarah Bankes, Ed Crooks, Ella Carter, Peter Kavanagh/Art Agency, Alexandra Cheung, Tom Connell/Art Agency, Barry Croucher/Art Agency, Marcus Faint, Shanna Freeman, Jamie Frier, Jack Griffiths, James Hoare, Ian Jackson/Art Agency, Gemma Lavender, Adrian Mann, Laura Mears, Larissa Mori, Hannah Parker, Hayley Paterek, Peter Scott/Art Agency, Lee Sibley, Luis Villazon, Tim Williamson, Steve Wright

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hang.deretz@imagine-publishing.co.uk
Account Manager Jennifer Galvin
jennifer.galvin@imagine-publishing.co.uk
Sales Executive Luke Biddiscombe
luke.biddiscombe@imagine-publishing.co.uk

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13 issue subscription (Europe) – £50
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Circulation
Head of Circulation Darren Pearce
☎ 01202 586200

Production
Production Director Jane Hawkins
☎ 01202 586200

Founder
Group Managing Director Damian Butt

Printing & Distribution
Wyndeham Peterborough, Storey's Bar Road, Peterborough, Cambridgeshire, PE1 5YS

Distributed in the UK, Eire & the Rest of the World by: Marketforce, Blue Fin Building, 110 Southwark Street, London, SE1 0SU
☎ 0203 148 3300
www.marketforce.co.uk

Distributed in Australia by: Network Services (a division of Bauer Media Group), Level 21 Civic Tower, 66-68 Goulburn Street, Sydney, New South Wales 2086, Australia
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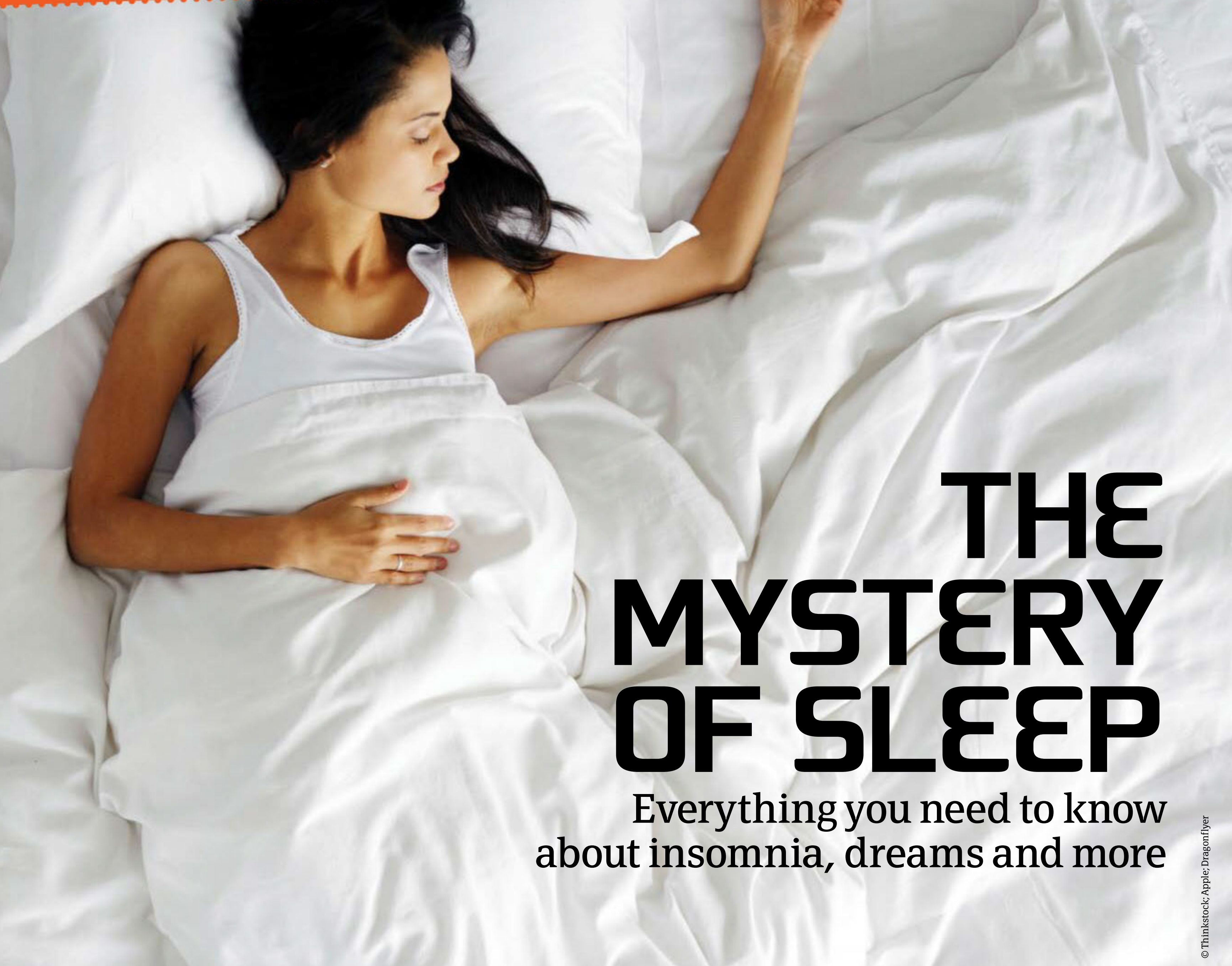

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