iPHONE 8

REVEALING THE TECH BEHIND THE SCREEN

WHY SHOULD WE EAT INSECTS?

HOW IT WORKS

EXPLORE A NUCLEAR BUNKER

The top-secret shelters built to withstand atomic warfare

SCIENCE | ENVIRONMENT | TECHNOLOGY | TRANSPORT | HISTORY | SPACE

TOMORROW'S TECH ON YOUR DOORSTEP

NEXT-GEN DRONES

HOW MAIL-BOTS WILL DELIVER IN RECORD TIME

+

RACING SUITS
COMETS
INTERNET
COOKIES
CROOKED FOREST

INSIDE A CARSCRAPER

Discover these innovative vehicle vending machines

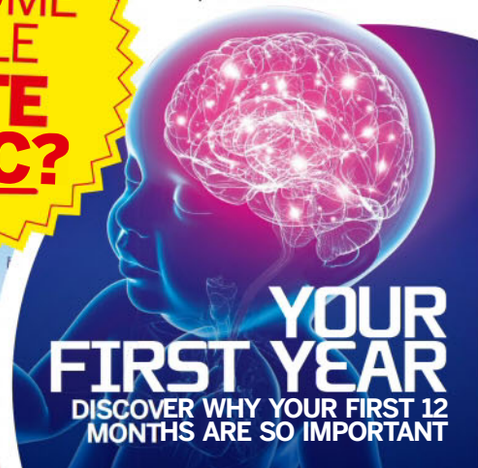
MISSION TO THE ICE GIANTS

Inside the frozen worlds of Neptune and Uranus

OXYGEN FROM THE OCEANS

Why phytoplankton are so important to life on Earth

WHY CAN SOME PEOPLE TASTE MUSIC?



YOUR FIRST YEAR

DISCOVER WHY YOUR FIRST 12 MONTHS ARE SO IMPORTANT

Future
ISSUE 107 PRINTED IN THE UK £4.99
Digital Edition
GreatDigitalMags.com

ALSO SAHARA DUST | TURTLES & TORTOISES | PUBS

VISIT THE SOUTH'S LARGEST MODEL ENGINEERING & MODELLING EXHIBITION

LONDON MODEL ENGINEERING EXHIBITION

FRIDAY 19th to SUNDAY 21st JANUARY 2018

A GREAT DAY OUT FOR ALL AGES

Why not come along & share your enjoyment of your favourite pastimes with fellow enthusiasts & friends?

Great Hall, Alexandra Palace, London

10am-5pm Friday & Saturday, 10am-4.30pm Sunday

Last entry Friday & Saturday 4.00pm Sunday 3.00pm.
The Model Active Zone will close at 3.30pm on Sunday.

Sponsored by ENGINEERING in Miniature

London Model Engineering Exhibition

@MeridienneEx

www.londonmodelengineering.co.uk

Book your tickets online at www.londonmodelengineering.co.uk

FREE PARKING for 1,500 cars & SHUTTLE BUS from local rail stations and main car park

LEADING SHOW OF ITS KIND • OVER 55 KEY SUPPLIERS TO SEE • OVER 45 CLUBS & SOCIETIES PRESENT • NEARLY 2,000 MODELS ON DISPLAY • EXCITING DEMONSTRATIONS • LIVE ACTION IN THE MODEL ACTIVE ZONE • IMAGINEERING FOUNDATION TO TALK TO YOUNG ENGINEERS • PASSENGER RIDES BEHIND THE 5" GAUGE STEAM LOCOMOTIVES

ISSUE 107

WELCOME

The magazine that feeds minds!

Sometimes, next-day delivery just isn't quick enough. That's where delivery drones come in, bringing goods direct to your door in a matter of minutes — at least, that's the idea. Beyond shopping, these mail-bots could also have plenty of life-saving applications, flying donor organs between hospitals or medical supplies to hard-to-reach disaster zones. But does reality live up to the hype? We find out on page 12.

We've got some exciting plans on the horizon and we'd like you to be a part of it! On **www.howitworksdaily.com** you will find a quick survey — we'd really appreciate it if you took 5–10 minutes to have your say. We value your feedback and read every response, so please let us know what you think about **How It Works**.

We hope you enjoy the issue!

Jackie **Jackie Snowden**
Editor

"How can we feed nearly 10 billion people? One possible answer is entomophagy — the eating of insects"

Why should we eat insects?, page 70

Meet the team...

Charlie G
Production Editor
With Kim Jong-Un and Trump trading threats, I'm starting to wish I'd thought to buy a nuclear bunker! Find out how they survive nuclear explosions on page 34.

Baljeet
Research Editor
We always hear about Mars and even Jupiter and Saturn, but what about the furthest planets from the Sun? Find out about NASA's plans to visit Uranus or Neptune on page 60.

Charlie E
Staff Writer
This month we learnt about agricultural engineering and the challenges it faces. From auto-steered tractors to crop sensors, there's plenty to find out on page 42.

Scott
Staff Writer
Imagine being able to see the colour of music or taste the flavours of words. Synesthesia mixes the senses to make some interesting combinations. Learn more on page 28.

Duncan
Senior Art Editor
Would a delivery drone safely leave your parcel with a neighbour when your not there, or just give up and throw it over the fence? Find out on page 12.

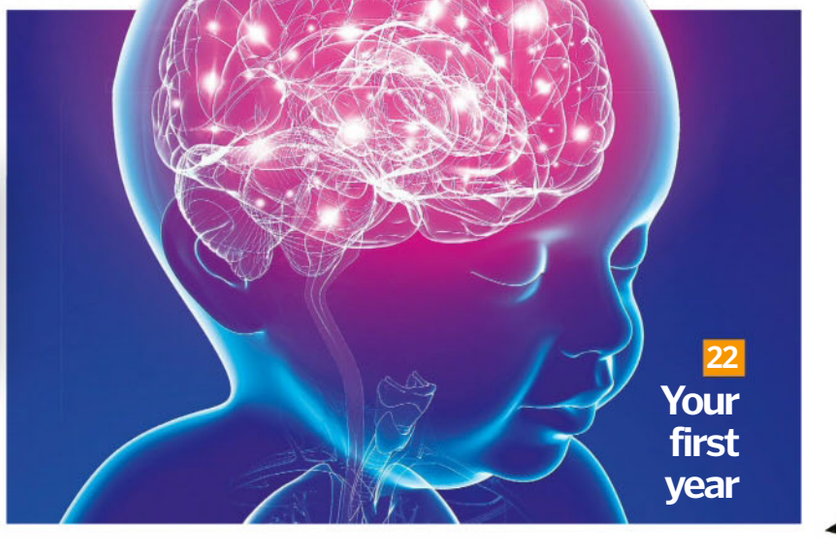
Laurie
Studio Designer
I'm all about nutrition and sustainability, but I'm not sure I could knock up a cockroach stir-fry! Is this the answer to feeding our planet? Turn to page 70 to find out.

FOLLOW US... How It Works magazine @HowItWorksmag

CONTENTS

+ **PULL-OUT POSTERS**
- Pond creatures
- Life in the pride
- Eye of a supernova

PAGES 48-53



Meet the experts...

Laura Mears
In this month's science section, Laura reveals just how much our brains and bodies develop in the first year of life. She also explains how turning forces work in 60-Second Science.

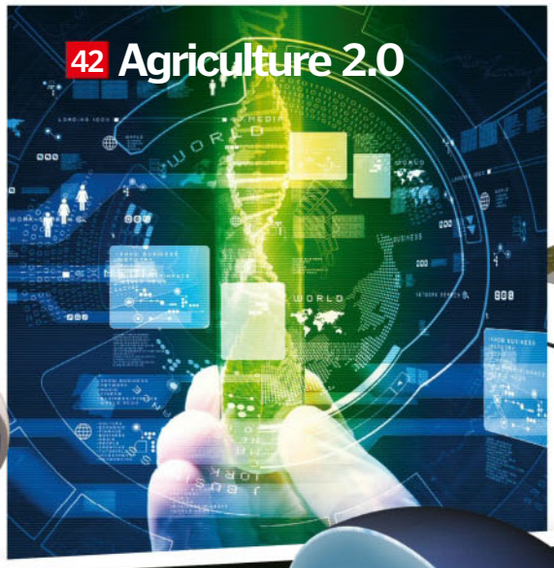
Jonny O'Callaghan
Jonny takes us on a tour of the outer Solar System this issue to explore the icy worlds of Neptune and Uranus. Find out more in the space section.

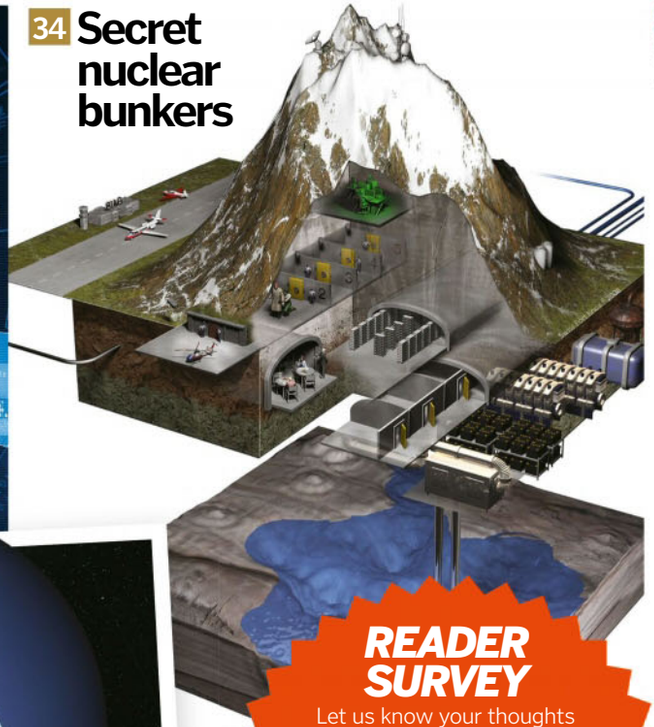
Marcus Leach
In our environment feature, Marcus explains why more of us should consider eating insects. Could it be the answer to how we will feed our growing global population?

Mike Bedford
This month, Mike goes underground to discover the secrets of some of the world's most secure shelters. Find out why they were built and how they could be put to use over on page 34.

Jodie Tyley
In the history section, Jodie uncovers the surprising history of pubs. Find out how Roman taverns evolved into our favourite locals over on page 41. We'll say cheers to that!

REGULARS





READER SURVEY

Let us know your thoughts about the magazine! We value your feedback and want to make sure we continue to create a magazine that you enjoy.

We would really appreciate it if you took part in our quick 5–10 minute survey. Head to **www.howitworksdaily.com** to find out more.

The awards ceremony was filled with exciting hands-on experiments, like these mentos rockets!

Young Imagineers

Statoil's competition challenged young minds to invent devices that will make tomorrow's world a better place

In September, Statoil and the Science Museum invited children from all over the UK to submit their ideas on how they would make the world a better place for the Young Imagineer's competition. The amazing inventors of tomorrow, aged between seven and 14 years old, submitted hundreds of creative, imaginative and inspirational entries, from devices that help you to find your lost dog to companion robots to assist the elderly, and even artificial legs for slugs!

Ten entries were shortlisted for the final, and each candidate was given the opportunity to work with designers to bring their ideas to life in a poster presentation. Our team attended the exciting day at the Science Museum, where the finalists presented their project ideas in front of an expert panel.

The day, hosted by broadcaster Dallas Campbell, celebrated some of the UK's most creative and inventive minds in Science, Technology, Engineering and Math (STEM). The Science Museum's enthusiastic Explainer staff demonstrated some fantastic hands-on experiments and workshops, from a messy guide of the journey your food takes as it passes through your digestive system, to an explanation of how an electric circuit is made.

We were so impressed to see the young inventors had invested so much time into really thinking about our planet's challenges. They had reflected on issues that were beyond their personal experiences, tackling big, real world problems that might never have affected them directly. Their projects were motivated by helping others with different lives to their own. They designed solutions to issues such as securing better accessibility for people with disabilities to cleaning the oceans or reducing air pollution. Well done from the team at here **How It Works** to everyone who entered the competition. Your ideas blew us away!

Finlay and his family alongside his winning presentation

Overall winner

And the winner is...

Finlay's hover wheelchair will make the world a better place for wheelchair users, as they'll be able to get up stairs and on to trains and buses without needing to ask for help. Finlay's idea was inspired by seeing his nan, who struggles with stairs and public transport, as well as his aunt, who uses a wheelchair.

His concept relies on the use of magnets to allow wheelchair users to hover up stairs or on to public transport. Finlay's thoughtful invention will now be made a reality and will be displayed outside Wonderlab: The Statoil Gallery, inside the Science Museum, so thousands of visitors can see his project brought to life. He will also be awarded the Children's Inspiration Officer position at the museum for a day, where he will be given an exclusive guided tour of the museum with a friend and lunch with some of the museum Explainers. Our team loved this idea! Well done Finlay, you really thought outside the box!

Darshini confidently presented her awesome idea to the panel

Runner up

Darshini's Flying Suit

Darshini's Flying Fuit is designed as an eco-friendly method of transport. It will mean less traffic and air pollution because people could just fly, and the feathers on the suit will clean the air as they go! The suit has a load of safety features, including an emergency parachute and a voice-controlled helmet that supplies oxygen when flying at high altitudes. Darshini really considered how she could make this invention good for the environment, including solar cells embedded into the suit to harness the power of the Sun.

Dorothy's fantastic starfish hair bows were made by her mum

Runner up

Dorothy's Starfish Sandbot

Dorothy was welcomed on to the stage and gave us a big drum roll before announcing her idea! Inspired by finding rubbish on the beach, Dorothy gave us some really startling statistics about how much plastic is clogging up our seaside spots. Her Starfish Sandbot — powered by bicycles — could be the solution to saving our seas. Once beach visitors have peddled on the stationary bikes for a few minutes, the robot has the power to scuttle around and pick up any rubbish that has been left behind. Dorothy's idea earned her the high commended award.

Sarah receives feedback from Steph and Tilly after explaining her concept of the Scaredy Sheep

The action-packed day was a treat for everyone to celebrate young people in STEM

Participants from around the UK presented their work in front of a live audience

Translator for Deaf – Jonathan, 11

The Translator for Deaf (TD) helps deaf people have a conversation with people that can hear. Jonathan recognised not everyone knows sign language, and wanted to make it easier for us to communicate. His simple device can help everyone get involved in conversations, whether they can hear or not.

Doctor of Giggles – Ben, 8

Doctor of Giggles (DOG) is a really creative robot designed by Ben, who wanted to make something to help comfort children in hospital. DOG is an intuitive bot that will make sure everyone is laughing and not worrying about upcoming procedures.

Scaredy Sheep – Sarah, 10

Sarah noticed that local farmers around her home have problems with sheep that lie down and aren't able to stand up again. Her invention, the Scaredy Sheep, is a tag worn on the animal's ear that will make a noise to scare them back on to their feet.

Dream Maker – Izzy, 10

Izz'y machine uses the power of sound to control our dreams. Just select something you'd like to dream about (maybe a beach holiday in Spain or flying over the Alps) and shut your eyes to be transported wherever you want!

Dolphin Warner – Grace, 10

Grace heard about the dangerous fishing nets that ensnare dolphins. Worried about their population, she wanted to make something that made the oceans safer, so she designed a clever warner that makes a noise to stop them approaching the nets.

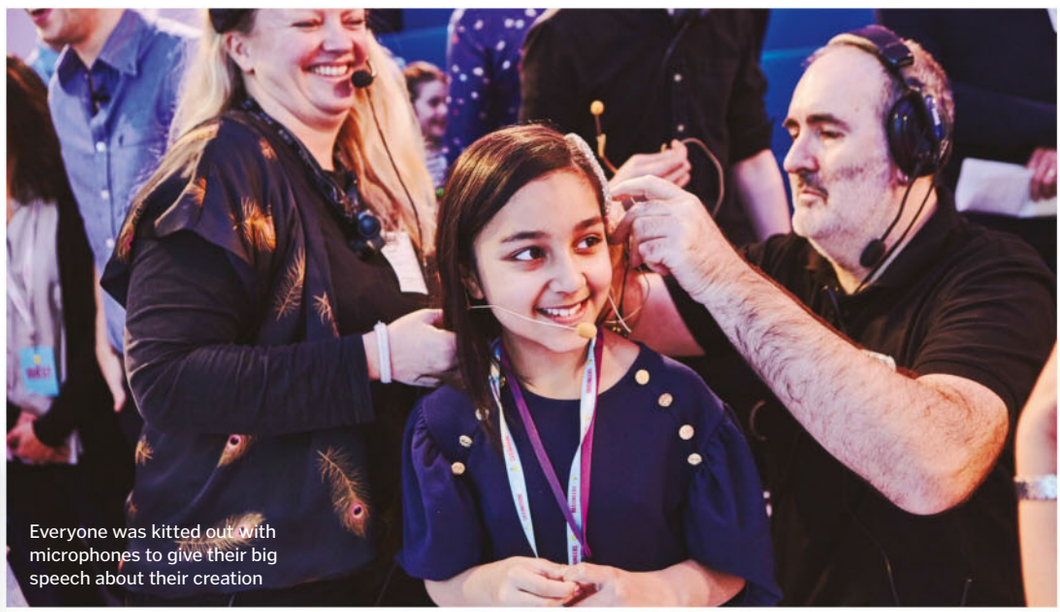
The expert panel of judges included Greg Foot from *Blue Peter*, Lopa Patel from Diversity UK, Steph McGovern from BBC Breakfast and Jill Tully from Statoil

Sound Converter – Lily, 11

Lily invented a device that could harness the sounds of cheering football fans and singing at festivals to generate electricity. Could Lily's idea be the next big source of sustainable energy?

Walking Sleeping Bag – Saffron, 8

Saffron's thoughtful idea was the Walking Sleeping Bag for the homeless. This would mean that everyone could always have a warm, dry and comfortable place to sleep.



Everyone was kitted out with microphones to give their big speech about their creation

Ben presents his invention — the Doctor of Giggles (DOG)

GLOBAL EYE

10 COOL THINGS WE LEARNED THIS MONTH

1 There's currently a hole in the Sun

With the use of extreme ultraviolet light, NASA has imaged a large hole in the Sun's corona from their Solar Dynamics Observatory. Find out more about the Sun's ultraviolet side on page 65.

3 Smartphone addiction causes brain chemistry imbalance

A study of young people diagnosed with internet or smartphone addiction revealed a significantly higher ratio of the neurotransmitters gamma aminobutyric acid (GABA) to glutamate-glutamine (Glx) within their brains. GABA slows down the signals within the brain, whereas Glx electrically excites the brain's neurons. This ratio between the two neurotransmitters significantly reduced once the patients underwent cognitive behavioural therapy.

Mussels can improve water quality

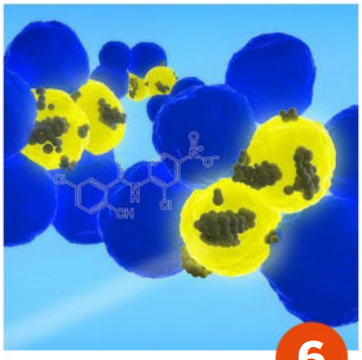
2 Researchers have found that ribbed mussels remove excess nutrients, such as nitrogen and phosphorus, in urban estuaries. This process is known as nutrient bioextraction, with samples taken from the Bronx River in New York. High levels of nitrogen and phosphorus can lead to harmful levels of algal blooms which deplete oxygen levels, and therefore results in the death of other organisms such as fish. Mussels are currently used in fish farms but may offer solutions for cleaning urban water.

4 Antibodies can help reduce migraines

Migraines affect 1 billion people globally and are most common in those aged 25–55. Research has shown that antibodies are able to neutralise the migraine-triggering molecules, calcitonin gene-related peptide (CGRP). In a study of 955 patients experiencing on average eight migraines per month, after treatment with the antibody erenumab 50 per cent of the patients found that they had half the number of migraine attacks.

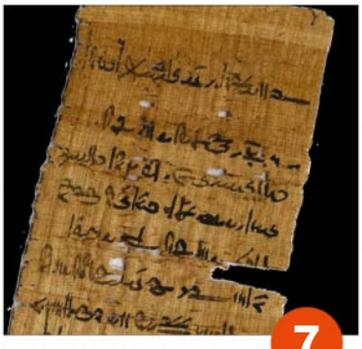
5 Julius Caesar invaded Britain via Kent

New evidence has unearthed the truth about Julius Caesar's invasion of Britain in 54 BCE. Archaeologists at the University of Leicester have found a defensive ditch during preliminary excavations for a planned road development at the hamlet of Ebbsfleet, Kent. Radiocarbon dating of artefacts suggested is was a Roman base dating to 1st century BCE, around the same time as Caesar's invasion.



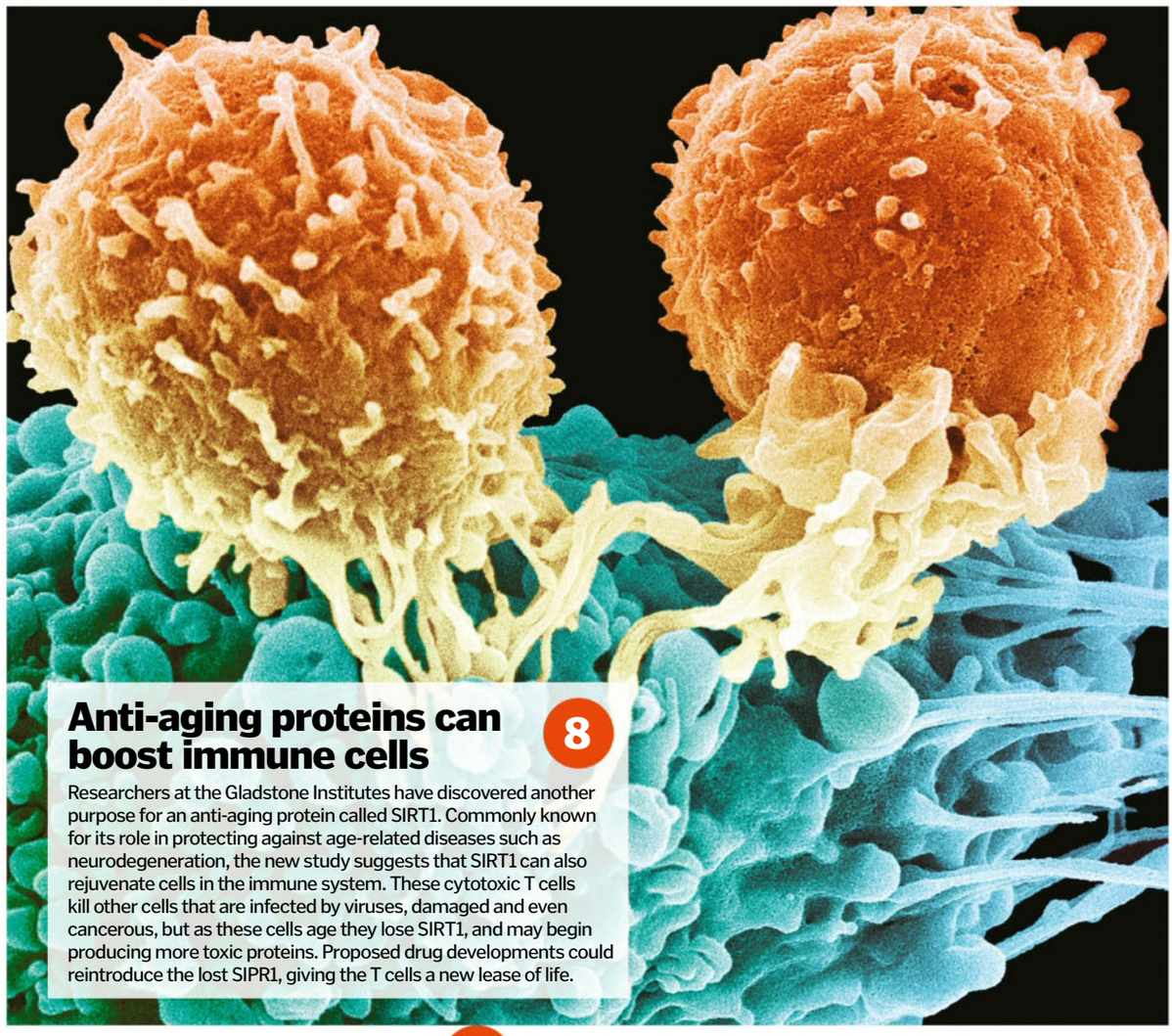
6 Nanoparticles can fight cancer

Tiny drug-laden nanoparticles have been developed by researchers at the University of Illinois to combat rare cancer stem cells. Loaded with the drug niclosamide, these particles bind to a specific protein, which only appears on cancerous cells, to prevent the stem cell from returning or spreading.



7 Egyptian papyri ink contained copper

A study of 2,000-year-old Egyptian papyri fragments analysed by the University of Copenhagen has revealed a surprising element: copper. Mixed in carbon ink, it was identified using synchrotron radiation-based X-ray microscopy. It is thought to be copper from sulphurous ores.

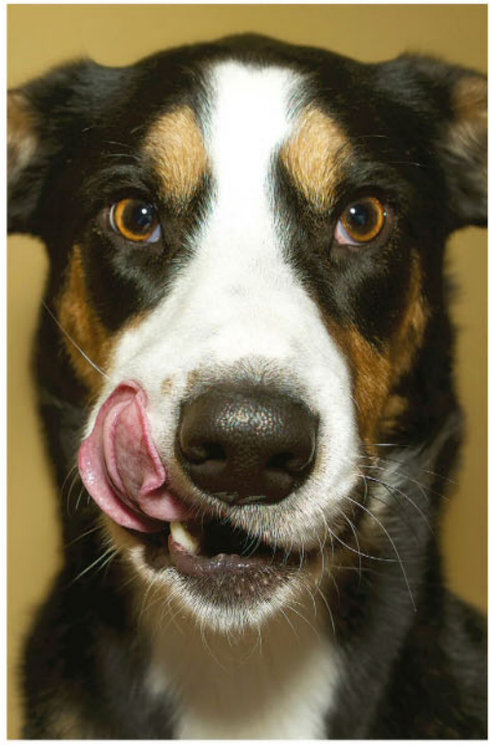


8 Anti-aging proteins can boost immune cells

Researchers at the Gladstone Institutes have discovered another purpose for an anti-aging protein called SIRT1. Commonly known for its role in protecting against age-related diseases such as neurodegeneration, the new study suggests that SIRT1 can also rejuvenate cells in the immune system. These cytotoxic T cells kill other cells that are infected by viruses, damaged and even cancerous, but as these cells age they lose SIRT1, and may begin producing more toxic proteins. Proposed drug developments could reintroduce the lost SIPR1, giving the T cells a new lease of life.

9 Dogs lick their mouths around angry humans

When exposed to simulations of angry humans, researchers have found that dogs respond by licking their mouths. Researchers from the UK and Brazil exposed dogs to both visual and audio cues of humans and other dogs expressing positive and negative behaviour. The findings showed that dogs predominantly displayed the licking behaviour in response to angry humans rather than dogs. The team suggest that this is a behavioural understanding of emotional information and can facilitate dog-human communication.



10 Lightning makes antimatter

Thunderstorms produce much more than a flash and boom according to a Japanese research team. Studying lightning bolts as they struck the northwest coast of Honshu, the team found a series of gamma radiation-releasing events. Due to a chain event involving the separation of neutrons, atmospheric nitrogen is left unstable, releasing the antimatter counterpart of electrons known as positrons.

HOW NEXT-GEN MAIL-BOTS WILL DELIVER IN RECORD TIME

DRONES TO YOUR DOORSTEP

COULD FLYING FREIGHT BE THE NEW WAY WE RECEIVE OUR ONLINE ORDERS?

Is it a bird? Is it a plane? No, it's your online shopping! Imagine a world where your shopping was literally dropped off on your doorstep by a buzzing delivery drone. Well, companies such as Amazon, UPS and even Domino's are working to make that idea a reality. Juggernauts in the delivery industry, Amazon and UPS are just some of the front-runners in the race to have the first ever commercial drone delivery service.

So far, Amazon's drones seem to be publicly leading the pack. Compact and light, the Prime Air drone has come a long way since its announcement back in 2013, achieving its first successful delivery to a customer in Cambridgeshire, UK, in late 2016.

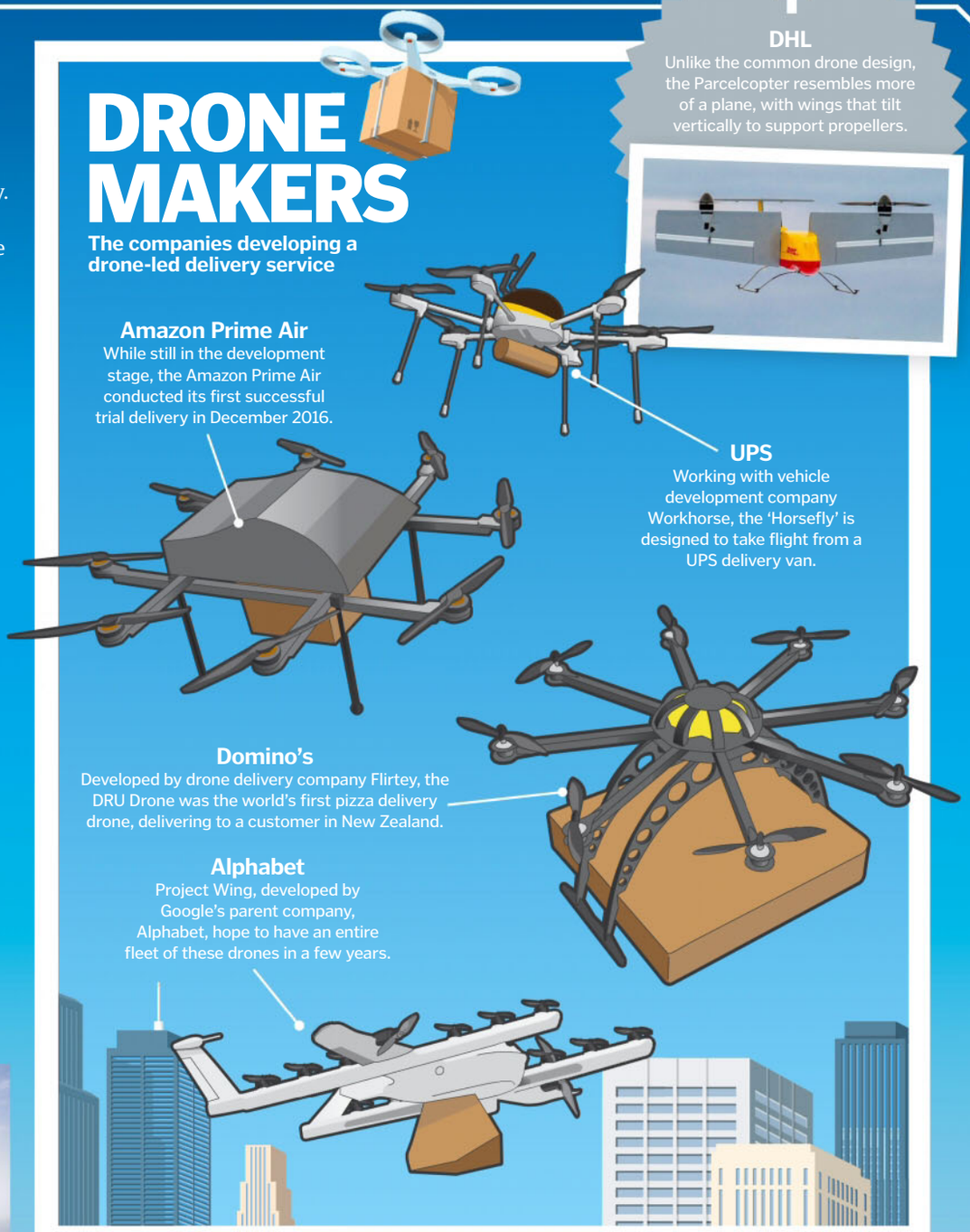
UPS, with its partner company Workhorse, aren't far behind; in February of this year the postal company saw the first successful test launch and delivery by one of their drones. Also entering the hi-tech air mail arena is Domino's, who made a delicious delivery first in New Zealand last year, dropping off two pizzas by drone. There is a wealth of companies such as DHL and Google who are also developing new drone delivery systems, so let the race begin.

Unmanned aerial vehicles/systems (UAV/S), now commonly known as drones, have actually been around since the First World War. Born from the battlefield, the first UAV was the Kettering Bug, an aerial torpedo (the earlier version of a cruise missile) taking to the skies in 1918. Today's commercial drones, however, are working hard to drop bargains rather than bombs.

A drone delivery could one day be just the tap of an app away

DRONE MAKERS

The companies developing a drone-led delivery service



Amazon Prime Air

While still in the development stage, the Amazon Prime Air conducted its first successful trial delivery in December 2016.

UPS

Working with vehicle development company Workhorse, the 'Horsefly' is designed to take flight from a UPS delivery van.

Domino's

Developed by drone delivery company Flirtey, the DRU Drone was the world's first pizza delivery drone, delivering to a customer in New Zealand.

Alphabet

Project Wing, developed by Google's parent company, Alphabet, hope to have an entire fleet of these drones in a few years.

DHL

Unlike the common drone design, the Parcelcopter resembles more of a plane, with wings that tilt vertically to support propellers.

"Built-in sensors and cameras will be able to identify and avoid a possible collision"

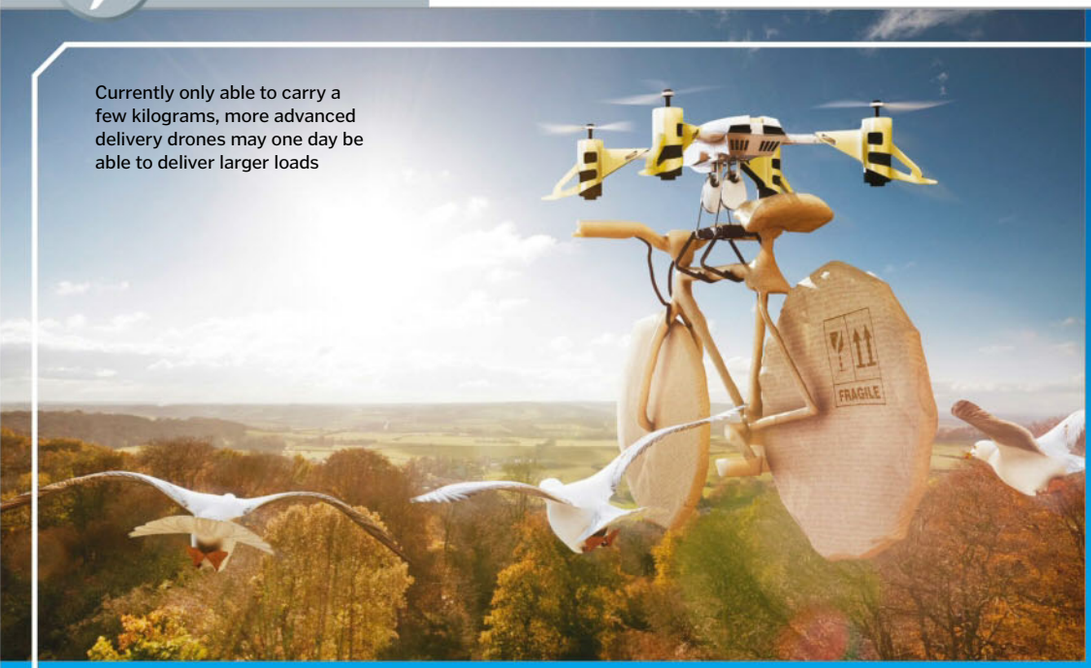
The sky really is the limit

Drone safety is of the utmost importance when attempting to commercially use drones, so what are the rules? Different countries have different rules, but there is a general agreement that drones should not exceed altitudes of 120 metres and must avoid 'No Fly Zones' near airports.

The UK's Civil Aviation Authority (CAA) has created the 'Drone Code', which sets out regulations for responsible drone use, highlighting where users can and cannot fly. Permits certificated by governing bodies such as the CAA or the US equivalent, the Federal Aviation Authority (FAA), need to be acquired in order to fly any new drone.

Current UK regulations state that drones should not be flown out of the sight of the operator, which poses a direct conflict with the proposal for autonomous commercial drones. As a new and not yet operational service, there is a lack of laws designated to outlining the allowances and restrictions of commercial delivery drones.

Delivery drones must pass a permit exam in order to be commercially viable



Currently only able to carry a few kilograms, more advanced delivery drones may one day be able to deliver larger loads

LIFT OFF

The driving force behind these delivery innovations is to cut down on the delivery time of products. Prime Air and UPS both promise to have products with their customers within 30 minutes. In order to meet the short delivery times these projects promise, how and where the drones take off is crucially important.

Two methods have been explored so far. The first option, being explored by Prime Air, is to release the drones from dispatch centres located around the country. Due to travelling speeds and built-in battery time, Amazon's drone has a range of around 16 kilometres. This means multiple dispatch bases would be needed for a nationwide fleet.

UPS have taken a different route for take off. Their iconic brown vans will act as the dispatch centre for their drones. Loaded from within the van, their drones will work with the road-bound vehicle's navigation system to deliver parcels to more rural areas while a human postal worker is delivering by foot. The company have predicted that this human-drone partnership will save them an estimated $50 million (≈£37 million) a year. In a press release, UPS senior vice president of global engineering and sustainability Mark Wallace said, "This test is different than anything we've done with drones so far. It has implications for future deliveries, especially in rural locations where our package cars often have to travel miles to make a single delivery."

UP IN THE AIR

Just like any aircraft, drones have to abide by the laws of physics and aerodynamics. The designs of delivery drones appear in all shapes and sizes. Some house an array of rotors on a compact body, while others only have two, more resemblant of a plane. The common factor, however, is the use of compact rotary blades. In a four-rotor drone such as the Prime Air, blades spin in time with their diagonal counterparts. The thrust generated by the blades' rotation, along with stabilisation technology, maintains the drone's position in the air.

However, for delivery purposes, the extra load carried by the drone needs to be accounted for. The bigger the package, the more powerful the drone has to be in order to carry it. The proposed maximum weight of a package to be carried successfully by drone is 2.3 kilograms. That's around the same weight as a couple of pairs of trainers with a little room to spare.

ON ROUTE

Once the delivery drone is in the air, current drone proposals describe these vehicles as autonomous (having the ability to not require a pilot), such as the Prime Air. In order for delivery drones to fly alone they will rely on beyond-visible line-of-sight technology. Guided by GPS systems, delivery drones will be able to travel directly to the customer's location.

While travelling, a prevailing concern among potential customers and development teams are the potential obstacles the drone may encounter. Whether it's a bird, tree or even another drone,

TO BE OR KNOT TO BE?

Drones promise to change the world, but there are hurdles to clear

PROS

✔ FAST

Commercial delivery drones can cut down the estimated time of delivery to just 30 minutes.

✔ ENVIRONMENTALLY FRIENDLY

Companies like UPS have stated that the use of drones would cut down on vehicle emissions.

✔ CHEAP

Though exact pricings for delivery drones aren't known, examples such as Amazon Prime Air suggest deliveries could be as cheap as $1.

✔ EMERGENCIES

There is a large scope for use in medical aid delivery. Without requiring roads, drones can fly straight to areas they're needed via the most direct route.

CONS

✖ WEATHER

Drones are not immune from the effects of the environment. Strong winds, lightning storms and heavy rainfall may impact deliveries.

✖ DISTANCE

In order to achieve some of the proposed delivery times, multiple dispatch centres will have to be built to accommodate demand.

✖ SAFETY

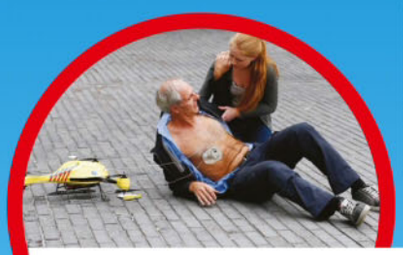
Measures will have to be taken in order to ensure the safety of the packages drones are delivering and of people walking below — although, as with any piece of technology, faults or malfunctions may occur.

✖ LANDING

Some of the most affluent areas are found in built-up cities, spaces where drones might be unable to land safely due to people living in high-rise apartments.

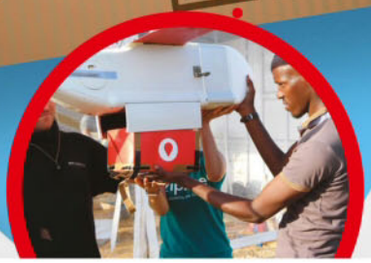
OTHER DELIVERY DRONE USES

Remote access
Not every medical centre in the world has access to roads all year round. Companies such as Matternet have developed drone technology and piloting software called 'Cloud' to deliver medical supplies to remote areas.



Emergency treatment
When someone is experiencing a cardiac arrest, time is of the essence. Rather than dropping off supplies, the TU Delft ambulance drone becomes the medical delivery. With a built-in defibrillator, this drone project aims to cut down response times to cardiac emergencies.

People carrier
Rather than delivering products or supplies, the Passenger Drone delivers people. Completely autonomous, this two-seated drone is set to allow people to fly to their destination, airspace safety permitting. 16 individual rotors propel the drone into the air, which can then fly for between 20–25 minutes.



Medical drop off
In Rwanda, blood delivery to hospitals often takes hours, but now with the help of the Zipline drone, blood and other medical supplies can be delivered in around 30 minutes. Launched in 2016, this life-saving drone delivers to 21 transfusing facilities.

"By 2021 we might see the beginnings of complex drone delivery systems in action"

automatic sense and avoid (SAA) systems will be needed to prevent in-air and ground accidents. Built-in sensors and cameras will be able to identify a nearby object's proximity and speed, enabling the drone to take a responsive action to avoid the obstacle. While each company working on this technology has their own version, the basics for the software appear to still be very much under development.

THE FUTURE OF FLYING FREIGHT

Though the delivery drone industry is alive with new technological advances, we are a long way from seeing fleets of post-bots zipping through the air. Factors such as flight legislation and sense and avoid technology appear to be just some of the obstacles that need to be overcome. But if these logistical hurdles are surmountable, delivery drones will revolutionise the freight industry

In 2019, NASA intends to submit recommendations for airspace use, offering a potential pathway for commercial drone activity. UPS, DHL and Amazon are continuing to develop new systems and strategies in order to perfect their drones. Amazon has even patented a beehive-style dispatch centre to house fleets of delivery drones within cities.

Over the coming years, test runs and pilot programmes will shape the future generation of drones. It is estimated that by 2021 we might see the beginnings of complex drone delivery systems in action. With some attempting Christmas delivery trials this year, it might not be long before we hear the hum of drones alongside the jingling of Santa's sleigh.

Fleets of delivery drones might be flying over our heads sooner than we think

© Passenger Drone: Getty; Thinkstock; Matternet

Order
Through shopping apps or websites, customers will select products available for drone delivery.

Dispatch
Products will be stored in warehouses nationwide, ready to be loaded into a designated drone.

FROM DISPATCH TO DOORSTEP

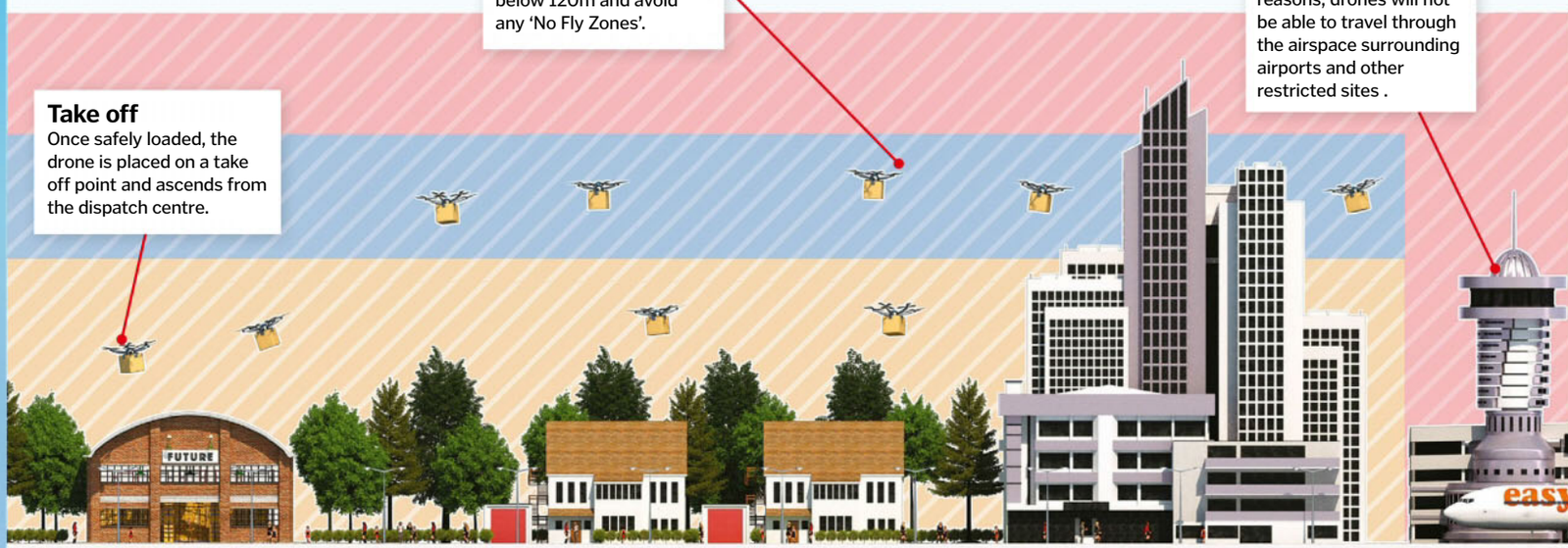
Discover how drones take to the skies and make their delivery drop off

"Test runs and pilot programmes will shape the future generation of drones"

Flight
Following airspace regulations, drones will fly below 120m and avoid any 'No Fly Zones'.

No Fly Zones
For safety and security reasons, drones will not be able to travel through the airspace surrounding airports and other restricted sites .

Take off
Once safely loaded, the drone is placed on a take off point and ascends from the dispatch centre.



Location
Once the customer's delivery location is programmed into the drone's mapping software, it's ready for take off!

Landing
Acting as a homing beacon, a landing pad will be placed in the customer's garden for the drone to register as its landing spot.

Fly away
Once the drone is relieved of its extra weight, it will proceed to take off and return to the dispatch centre.

Delivery
Sense and avoid technology will allow the drone to land in a clear space at the designated location before automatically releasing the customer's product.

DRONE DELIVERY BY NUMBERS

8–86 million
DRONE DELIVERIES ARE FORECAST IN THE NEXT 20 YEARS

$100
AVERAGE COST OF A DRONE BATTERY

250hrs
AVERAGE LIFESPAN OF A DRONE BATTERY

$1
AMAZON'S PREDICTED COSTS OF USING DRONES TO DELIVER A 2.3KG PARCEL WITHIN 16KM

DRONES COULD LEAD TO A PREDICTED INDUSTRY SAVING OF

$2 billion
COMPARED TO CURRENT DELIVERY OPTIONS

Race suits

Find out how these hi-tech overalls help to keep drivers safe

When your job involves speeding around racetracks at over 200 kilometres per hour, safety is paramount. In Formula series races an accident can be deadly, so the FIA (Fédération Internationale de l'Automobile, or the International Federation of Automobiles) enforces strict regulations to make sure drivers are well protected.

Drivers' clothing must be flame retardant to help shield them in the event of a fire. Materials are subjected to stringent open flame tests in laboratories. An artificial fabric called Nomex is widely used as it has excellent fire-resistant properties and is very lightweight. Modern drivers' suits are typically made from two to four layers of Nomex, and are thoroughly tested before use to ensure they can withstand temperatures of 600–800 degrees Celsius. To be suitable for use, the inside of the suit must not exceed 41 degrees Celsius for at least 11 seconds when exposed to such heat. Similarly, zips must also be able to withstand high temperatures so they do not melt or burn the driver's skin. Even the threads that stitch the suit together have to be fire resistant, as do any patches such as those of sponsors, although these tend to be printed on, which has helped to reduce the weight of race suits by over 500 grams. Making sure the suits are lightweight helps to keep drivers comfortable so they can perform at their best. Another important feature is breathability; due to the intense physical exertion, drivers can

In addition to safety, engineers have to consider the aerodynamic impact of the driver's helmet

How a race suit works

We take a look at the tech inside 2018 GP3 driver Callum Ilott's race suit

Shoulder epaulette

The shoulder epaulette construction provides an easy extraction system in the event of a crash.

Head and neck support (HANS)

The HANS device is integral while racing. It is used to protect Callum's neck while driving, being held in place by the shoulder belts of his car. The tethers link the sides of Callum's helmet to collar anchor points. When G-loads build during a forward impact, the HANS device ensures that Callum's helmeted head moves with his torso, so vulnerable neck and skull bones are protected. The collar is hollow, which substantially minimises weight and ensures maximum comfort, while engineered reinforcements ensure an exceptionally strong structure.

Race suit

Race suits are an oxymoron in a sense. They have to be breathable so that Callum is comfortable enough to be able to perform at his best. They must also possess heat- and flame-resistant properties to provide him with enough protection against a potential fire hazard. Special Nomex fibre technology ensures a highly breathable mid-layer for effective regulation of body temperature while ensuring the outer shell has exceptional heat- and flame-resistant properties.

Cuff closures

Ribbed wrist and foot cuff closures ensure a close fit, preventing unwanted movement of the suit that could have an impact on controlling the car.

lose several kilos of sweat during a race, therefore it's important for their comfort that this moisture can escape.

Drivers' suits are also specially designed to make sure their senses aren't too restricted, which could interfere with their ability to drive. Gloves are thin to make sure drivers can feel the steering wheel properly, and their rubber-soled boots have thin, slip-free soles to improve contact and grip with the car's pedals.

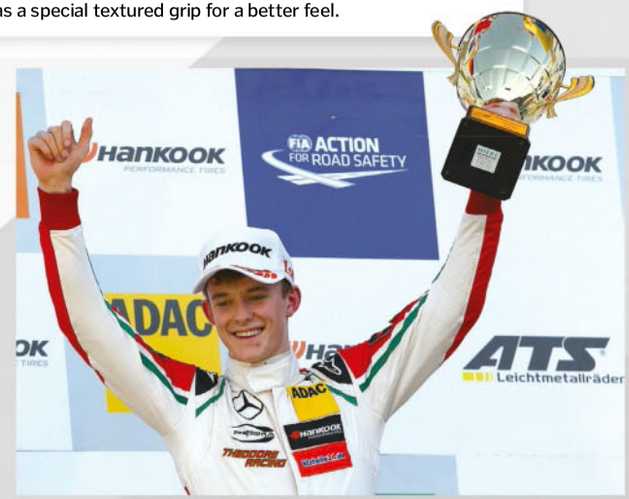
The helmet is incredibly important; head and neck trauma is the greatest injury risk among Formula racing drivers. They must be incredibly light, since the weight of the helmet contributes to the extreme G-forces on the driver's head when accelerating, braking or cornering. They also need to be very strong in order to absorb impacts and resist damage in the event of a crash. Most helmets are made from carbon fibre, polyethylene and aramid, combining the properties of high strength and fire resistance, while also being lightweight.

Stretch panels
Anatomical stretch panels in the lower back, sides, crotch, and knees provide increased flexibility.

Helmet
Without a doubt, Callum's helmet is his most important piece of race equipment. The Arai GP-6 RC helmet he uses meets all the high-end obligatory FIA standards. It is made from a proprietary weave of carbon fibre. This not only makes it incredibly strong, but also flexible and incredibly light at just 1,540 grams. All of this ensures that in the event of a collision it does not shatter. It also includes an emergency release system with special tabs for easy removal should Callum have an accident.

Race boots
Made from lightweight kangaroo leather, Callum's race boots provide him with the highest levels of comfort and abrasion resistance. The Nomex lining offers excellent heat resistance while the PU heel improves comfort and is fireproof. One of the most critical aspects for racing drivers is to be able to adequately control and feel the car. In order to aid this the heel and insole of the boots are equipped with microporous padding. This is coupled with a lightweight rubber sole, which has a special textured grip for a better feel.

Race suits first and foremost keep drivers safe, but can also improve comfort to allow them to perform at their best



In the 2017 Formula 3 European Championship, Callum Ilott won seven races, made 12 podium finishes and achieved more pole positions than any other driver in the Formula 3 category

"Drivers can lose several kilos of sweat during a race"

DID YOU KNOW? *In their 2017 season cars, Formula 1 drivers can experience G-forces of over 6G during corners*

The Autostadt Towers

Take a look inside Germany's car vending machine

Buying a new car usually involves heading down to a car dealership, selecting one and driving it home, but Volkswagen has revolutionised this tradition and brought it into the 21st century by automating the process of vehicle storage and delivery to the customer.

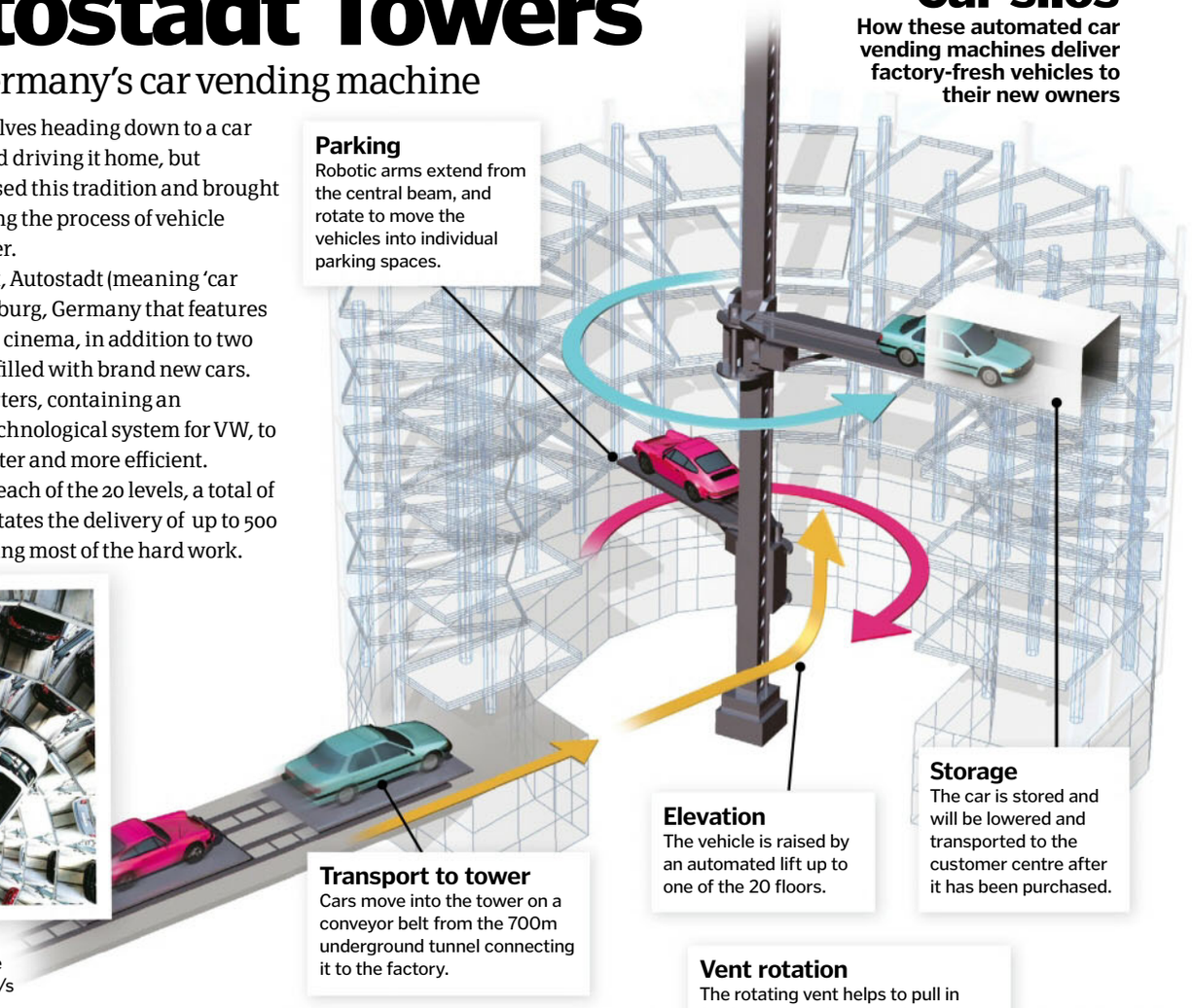
The company's VW-themed park, Autostadt (meaning 'car city'), is a visitor attraction in Wolfsburg, Germany that features a museum, exhibition spaces and a cinema, in addition to two iconic 48-metre-high tower blocks filled with brand new cars. Autostadt sits next to VW headquarters, containing an advanced, specifically-designed technological system for VW, to make the process of selling cars faster and more efficient.

The towers can house 20 cars on each of the 20 levels, a total of 400 each. This automated silo facilitates the delivery of up to 500 cars a day, with robotic systems doing most of the hard work.

The Car Towers are recognised as the "fastest automatic parking system in the world", moving vehicles at speeds of 2m/s

Car silos

How these automated car vending machines deliver factory-fresh vehicles to their new owners



Parking
Robotic arms extend from the central beam, and rotate to move the vehicles into individual parking spaces.

Transport to tower
Cars move into the tower on a conveyor belt from the 700m underground tunnel connecting it to the factory.

Elevation
The vehicle is raised by an automated lift up to one of the 20 floors.

Storage
The car is stored and will be lowered and transported to the customer centre after it has been purchased.

Rotating air vents

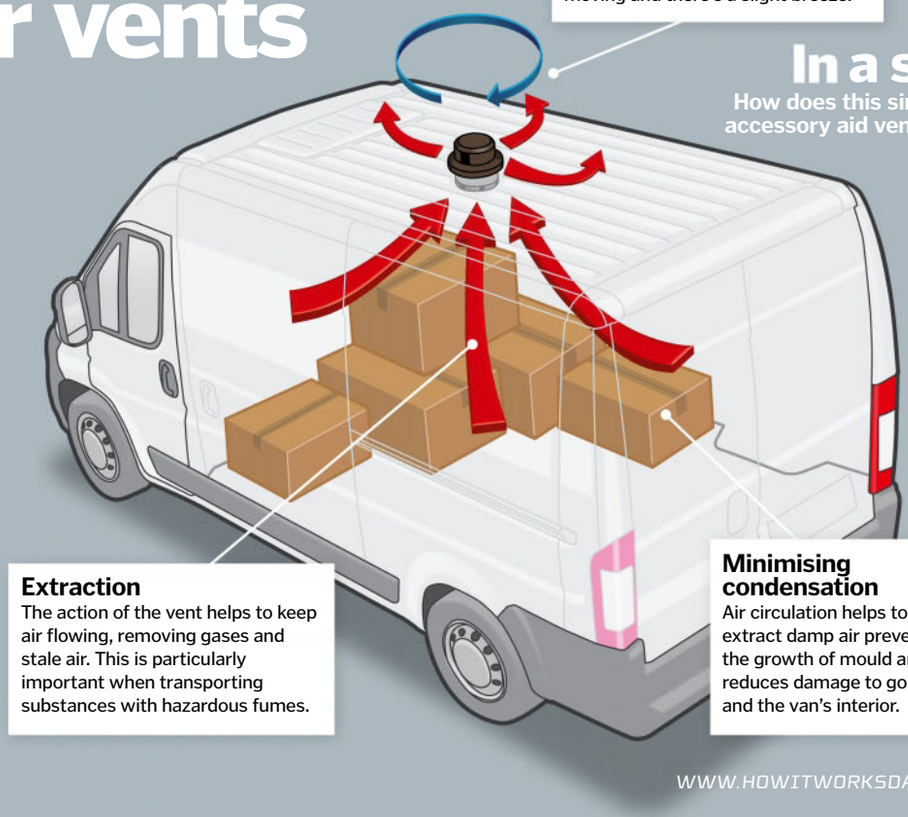
The tiny van accessory that makes a big difference

Have you ever wondered what the spinning objects mounted onto the top of vans are? Well, you're looking at a rotating air vent. They are moving due to the movement of the vehicle itself or because of the wind, and they circulate air inside the van. They are generally used in vehicles that have no windows, particularly if the van is transporting food (to reduce the temperature) or if they are carrying animals to make sure they have enough fresh air to breathe. They continually extract the warmer air from inside and draw in cool air from outside. It is also a way to help keep the vehicle dry and free from mould.

Though these vents might not look too spectacular they are considered vital across many industries and are a practical and cheap way to improve the safety and comfort of vans.

In a spin

How does this simple car accessory aid ventilation?



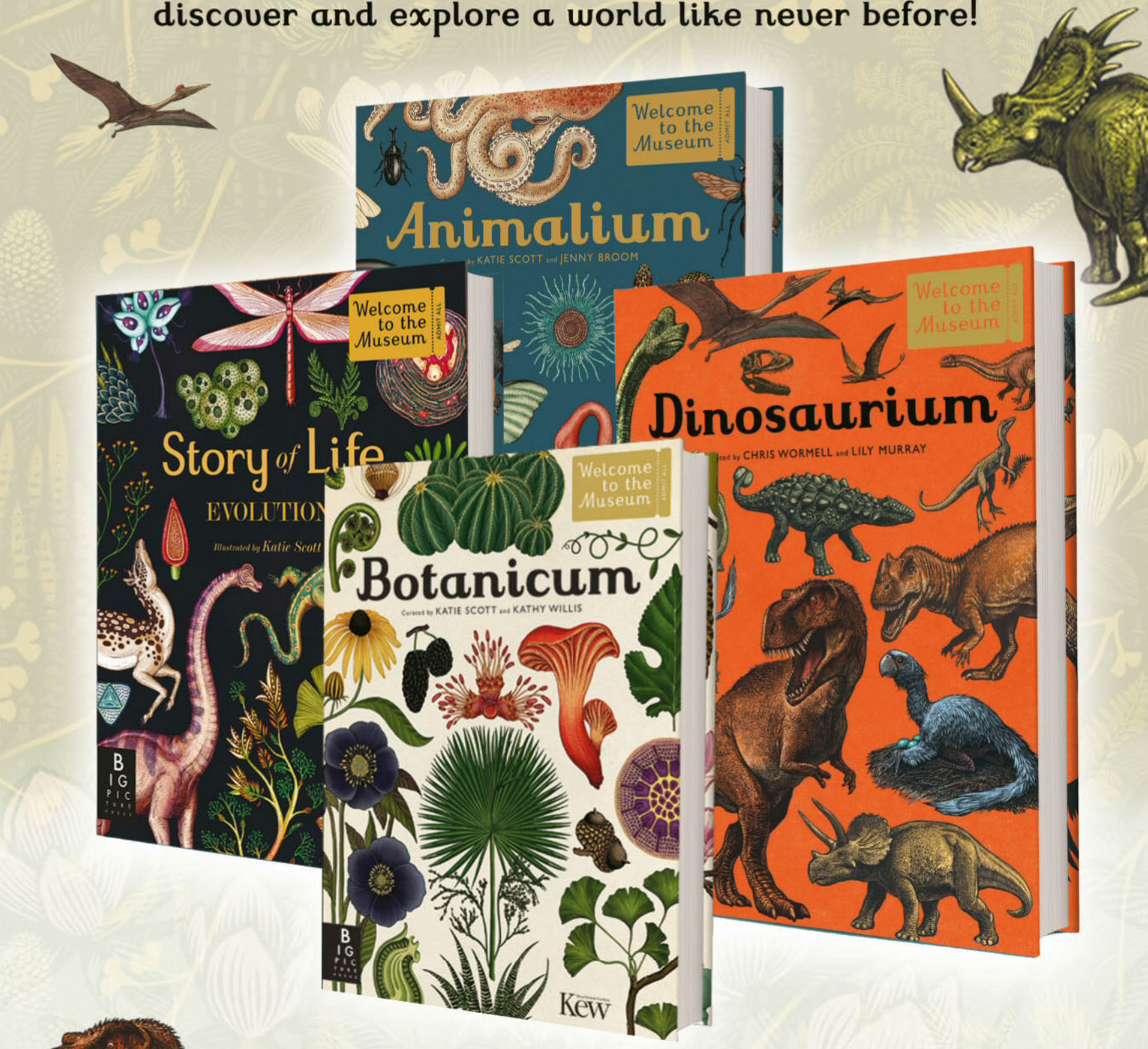
Vent rotation
The rotating vent helps to pull in fresh external air and replaces the internal air, even if the van is not moving and there's a slight breeze.

Extraction
The action of the vent helps to keep air flowing, removing gases and stale air. This is particularly important when transporting substances with hazardous fumes.

Minimising condensation
Air circulation helps to extract damp air preventing the growth of mould and reduces damage to goods and the van's interior.

Welcome to the Museum...

Step inside the pages of this beautiful series to discover and explore a world like never before!



From the Tyrannosaurus rex to the humpback whale and the Venus fly trap, these amazing books make the perfect gifts!

Available from

Waterstones

YOUR FIRST YEAR

What happens to the human body in the first 12 months of life

We are born well before we're ready to fend for ourselves, but we learn faster in our first three years than we will for the rest of our lives. So how do we get from vulnerable newborns unable to lift our own heads to walking, talking toddlers?

BIRTH

Babies enter the world with a lot of growing left to do. From around 35 weeks of pregnancy babies start becoming cramped. As the foetus gets bigger it demands more and more energy, and there's only so much that the mother can supply. Before they are born, their growth starts to slow.

Entering the world for the first time is a shock to a baby's system, and the first days of life are critical. Until the moment they emerge from the womb, their mother's body has supported every one of their needs. She maintains a constant temperature, digests food to supply nutrients and breathes to supply oxygen. She also deals with waste and fends off infection. Then suddenly the baby has to fend for itself.

As it hits the cold air of the delivery room, a powerful inward breath pulls its lungs open and fills them with air. In the safety of the womb, all the oxygen the baby needed came from the umbilical cord. The lungs were full of amniotic fluid and the heart diverted blood past them through a hole called the foramen ovale and a tube called the ductus arteriosus. Suddenly the baby needs to breathe. The hole in the heart slams shut and blood rushes into the lungs. Within hours or days after birth the tube, and another that carried blood from the umbilical cord to the heart (ductus venosus), closes too.

The other organ systems also spring into action. The baby has been practising breathing and swallowing in the womb, and the kidneys have already started working. Within 24 hours the gut starts moving, passing a dark green or black, tarry substance called meconium. It contains bile, mucus, amniotic fluid and anything else the baby has ingested in utero. Once this fluid is out of the way milk digestion can begin.

The newborn stomach is tiny — barely the size of a marble — so the baby needs to wake every few hours to feed. It can only take a few small mouthfuls at a time. The mother produces a thick, golden-yellow breast milk called colostrum. It's packed with energy but is lower in fat than normal breast milk, which newborns can find hard to digest. Instead, it's full of protein — perfect for a growing baby.

> "Babies are born with vital reflexes built in"

Colostrum has a mild laxative effect, which helps to get the baby's gut moving, and it comes with a secret weapon: antibodies. These neutralise bacteria and viruses, sticking them together and triggering their destruction. Throughout pregnancy they cross from mother to baby via the placenta, but this type of immunity is only temporary. The baby will be able to make its own, but this takes a few months. In the meantime, colostrum provides a boost, helping to stave off infection.

The newborn has some tricks of its own to help it survive this vulnerable time. Though they have a lot to learn, babies are born with some vital reflexes built in. These include simple things like blinking, swallowing and yawning, along with more complicated responses.

The rooting reflex makes the baby turn their head or open their mouth when something touches their cheek or lip, and the suck reflex makes them suck if something touches the roof of their mouth. These instincts help with feeding.

Then there are the Moro reflex and the palmar grasp reflex. The first happens when a baby feels as if they are falling. They extend their arms and legs and arch their backs before curling up. The second makes the fingers and toes curl if you touch the palm of their hand or the soles of their feet. Together they help the baby to survive.

FIRST WEEKS

Brand new babies can hear and respond to noises and are born with the beginnings of communication. They will turn their head towards light and sound, make out the face of the person holding them and cry when they are in need. It only takes a few weeks for these skills to start to improve. They rapidly start to recognise the voice of their mother, and soon they begin to make different noises, cooing and gurgling as well as crying.

For the first few weeks babies can only focus on objects right in front of their faces, and their eyes frequently cross. At this stage their hand-eye coordination is poor. Very young babies will investigate their own hands and fingers, but they can't yet use them properly, and they often keep their hands in fists.

Inside, their bodies are undergoing rapid change fuelled by milk. If the baby is being breastfed, normal breast milk has now replaced colostrum. It's higher in fat and contains enzymes that help the digestive system to access the nutrients. It's also packed with sugars. Not only do these provide energy, they also help friendly bacteria to colonise the large intestine.

Babies are ready to try their first meal at around six months old

Why do babies sleep so much?

Brand new infants spend around 16 hours a day in the land of nod. At first they wake often to feed, but by the time they are 12 weeks old and weigh on average 5.7 kilograms they begin to sleep for longer periods.

Like adults, babies cycle through four sleep stages. They begin with the lightest dozing before a gradual drop into the deepest slumber, and this rhythm starts when they are still in the womb. Between these cycles they go through phases of rapid eye movement (REM) sleep, spending up to half of their sleep time dreaming.

Early work suggests that sleep is important for consolidating learning and for brain plasticity. In other words, it helps with the strengthening and pruning of connections between different nerve pathways in the brain. Some studies suggest that inadequate sleep may cause problems in the refinement of nerve connections. However, it's still early days and scientists need to do more research to confirm these findings.

TWO MONTHS OLD

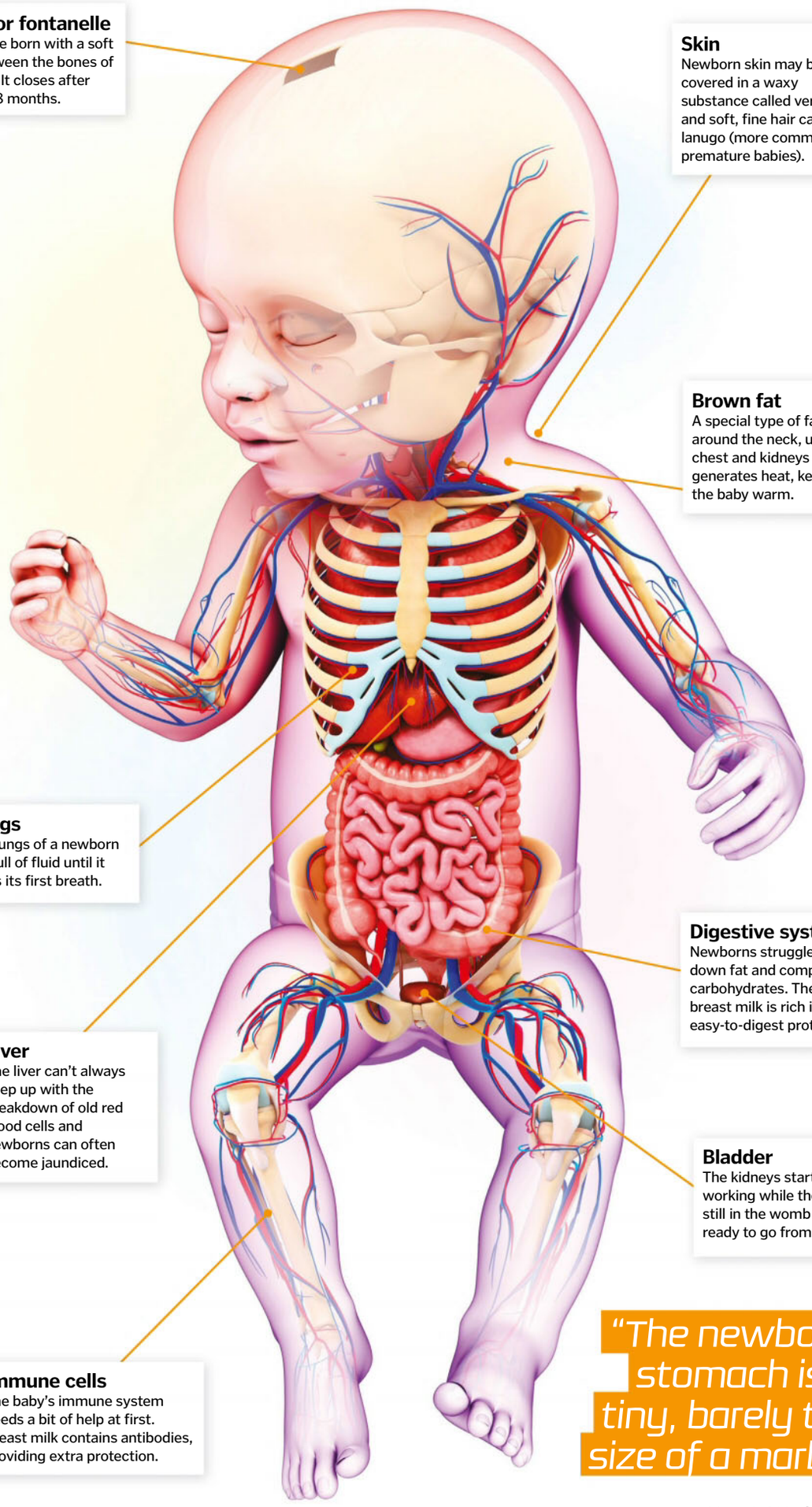
Babies spend much of their time eating and sleeping, and their bodies start to grow rapidly. In the womb, cells divide constantly to form tissues and organs, but after birth growth shifts. Rather than making new cells, babies increase the size of the cells they already have.

The tissues of newborn babies are very different to those of children and adults. There is more fluid around their muscle and nerve cells, and they have less cytoplasm inside. As the baby develops this balance shifts. Muscle cells expand, filling with cytoplasm and molecules involved in contraction. Nerve cells extend, strengthening connections and making new ones, and the amount of fluid outside these cells starts to fall. With newfound strength, babies learn to push up with their hands when placed on their tummies and start to hold their head a little steadier, their movements becoming less jerky and more coordinated.

Fat continues to quickly build up under the skin, helping to keep the infant warm. By the

BABY ANATOMY

Babies are more than just miniature adults — they have their own unique anatomy



Anterior fontanelle
Babies are born with a soft spot between the bones of the skull. It closes after around 18 months.

Skin
Newborn skin may be covered in a waxy substance called vernix and soft, fine hair called lanugo (more common in premature babies).

Brown fat
A special type of fat around the neck, upper chest and kidneys generates heat, keeping the baby warm.

Lungs
The lungs of a newborn are full of fluid until it takes its first breath.

Digestive system
Newborns struggle to break down fat and complex carbohydrates. The first breast milk is rich in easy-to-digest proteins.

Liver
The liver can't always keep up with the breakdown of old red blood cells and newborns can often become jaundiced.

Bladder
The kidneys start working while the baby is still in the womb and are ready to go from birth.

Immune cells
The baby's immune system needs a bit of help at first. Breast milk contains antibodies, providing extra protection.

"The newborn stomach is tiny, barely the size of a marble"

two month mark babies are already starting to develop social skills. They begin to follow things with their eyes and recognise people at a distance, and they begin to smile and laugh.

HALFWAY THROUGH

Babies can finally hold their heads steady at around 16 weeks of age. They will also start to push down with their legs if they're held above a hard surface, and by six months they can roll over, push up to a crawling position and even stand with support.

At around this time babies also begin to use their hands and eyes together. They reach for objects and rake with their fingers to grab them, and they start to use their mouths to explore objects further. With all this extra strength and coordination, the grasp and Moro reflexes are no longer needed. These early fail-safes fade away. Babies start to learn to pass toys from one hand to the other.

Their eyesight improves too. By this stage they are becoming more perceptive to the subtleties of different colours, and they start to copy facial movements. They recognise and express emotion and begin to find their voice. They blow raspberries and start to make consonant sounds like 'ba', 'da' and 'ga', using noise to get attention and to express themselves. They will also start to recognise words, especially their own name.

To fuel all this progress, six-month-old infants often switch to solid food. As the baby grows, the fat content of breast milk has been increasing from about 2g/dL of colostrum (grams per decilitre, equivalent to 100 millilitres) to 4.9g/dL. It has provided energy and contributed to a growing store of fat under the skin. But now the digestive system is ready for more.

A newborn's digestive organs are not only smaller than an adult's, but they also work differently. They make different quantities of enzymes and bile and they operate at a different pH. But at six months old things are starting to change. The first teeth come through, starting with the bottom front teeth then the top. Swallowing improves and the digestive system will start to produce enzymes to break down complicated meals.

FIRST BIRTHDAY

By their first birthday, babies are starting to develop complex behaviours. They have favourite things and favourite people. They start to understand 'object permanence' — the idea that objects and people exist even though you can't always see them. They look for hidden objects and they begin to grasp the effects of gravity by learning to drop things and watching how they fall to the ground.

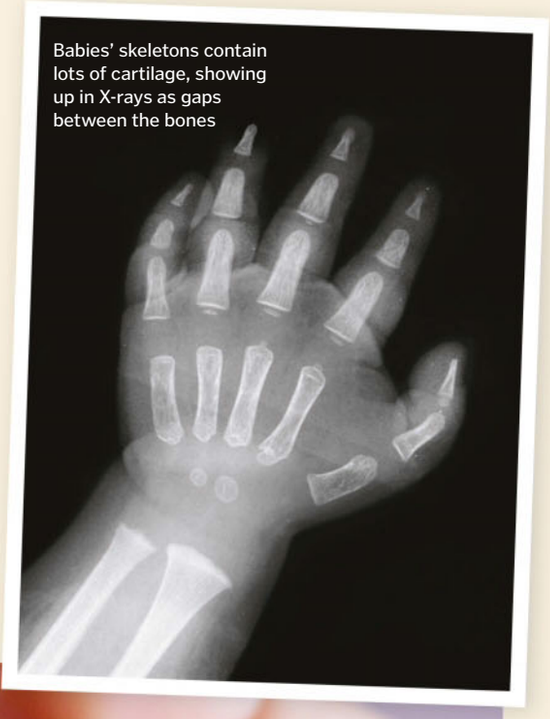
They also begin to respond to requests and make demands of their own. They will copy and use gestures like waving, pointing and head shaking. By now they will also understand familiar words and follow simple directions, as well as being able to help with tasks like dressing. Most importantly of all, they will start to communicate using 'babble'.

> "To fuel all this progress, six-month-old infants often switch to solid food"

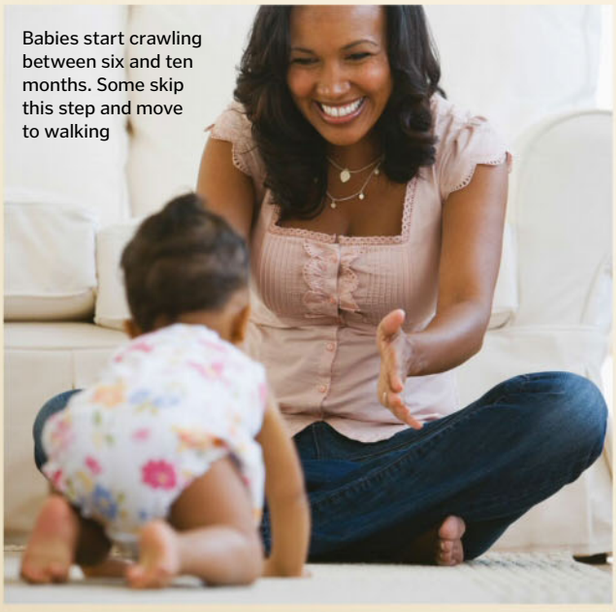
Their coordination has by now improved too. The grasp reflex is long gone, and they can move objects easily from one hand to the other. They can pick up small things between their thumb and forefinger and they will test new objects by shaking and banging. They will begin cruising, holding on to objects and moving around on two legs. Some may even take their first steps.

The hole that shunted blood through the heart when they were born is now fully healed over. Back teeth are starting to come through and the digestive system is processing full meals. The lungs have more air sacs, increasing surface area for gas exchange, and the brain has developed billions upon billions of new connections.

Over the coming months, babies transform into toddlers. As they begin to develop their understanding of the world, they start wanting to be more independent. They learn to walk, they start to talk and they even play games. Human babies are born tiny and vulnerable, but in a few short months they are already well on the way to growing up.



Babies' skeletons contain lots of cartilage, showing up in X-rays as gaps between the bones



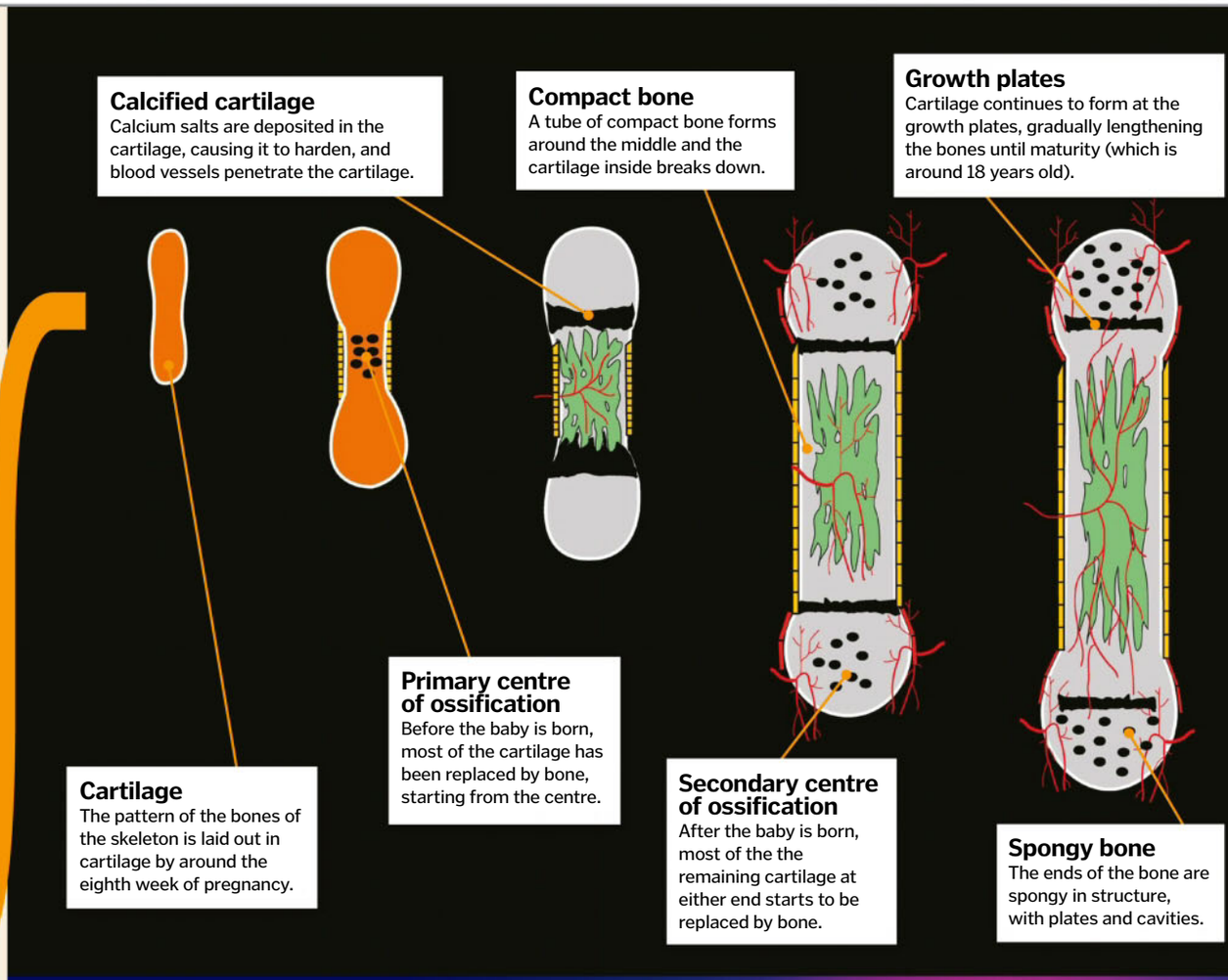
Babies start crawling between six and ten months. Some skip this step and move to walking

Babies are born with a grasp reflex. Their fingers close when something touches their palm

BRAIN DEVELOPMENT / HOW BONES GROW

HOW BONES GROW

Skeletons start out as cartilage and gradually turn to bone



Calcified cartilage
Calcium salts are deposited in the cartilage, causing it to harden, and blood vessels penetrate the cartilage.

Compact bone
A tube of compact bone forms around the middle and the cartilage inside breaks down.

Growth plates
Cartilage continues to form at the growth plates, gradually lengthening the bones until maturity (which is around 18 years old).

Primary centre of ossification
Before the baby is born, most of the cartilage has been replaced by bone, starting from the centre.

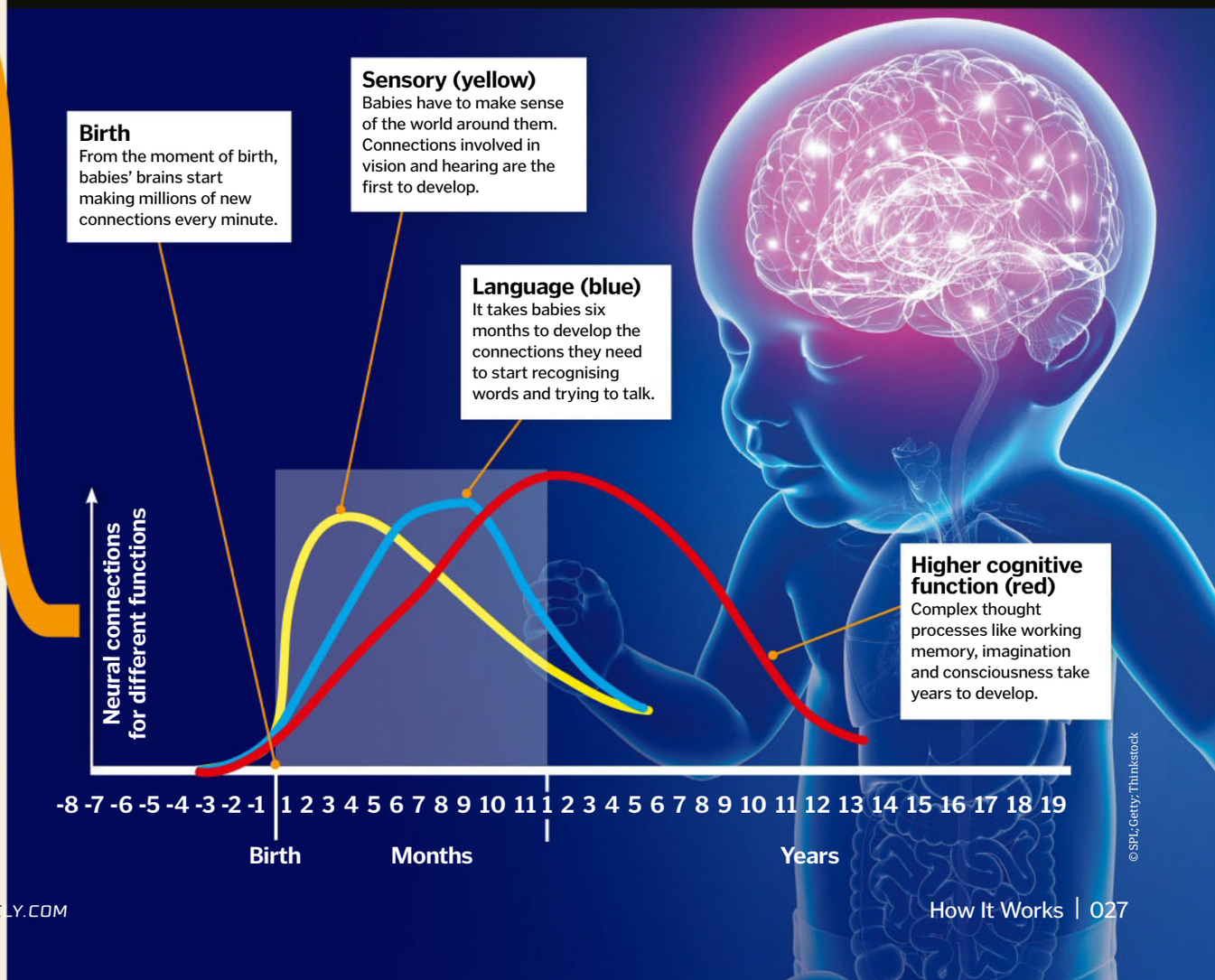
Cartilage
The pattern of the bones of the skeleton is laid out in cartilage by around the eighth week of pregnancy.

Secondary centre of ossification
After the baby is born, most of the the remaining cartilage at either end starts to be replaced by bone.

Spongy bone
The ends of the bone are spongy in structure, with plates and cavities.

BRAIN DEVELOPMENT

Newborn brains grow from 25 to 90 per cent of adult volume in just five years



Birth
From the moment of birth, babies' brains start making millions of new connections every minute.

Sensory (yellow)
Babies have to make sense of the world around them. Connections involved in vision and hearing are the first to develop.

Language (blue)
It takes babies six months to develop the connections they need to start recognising words and trying to talk.

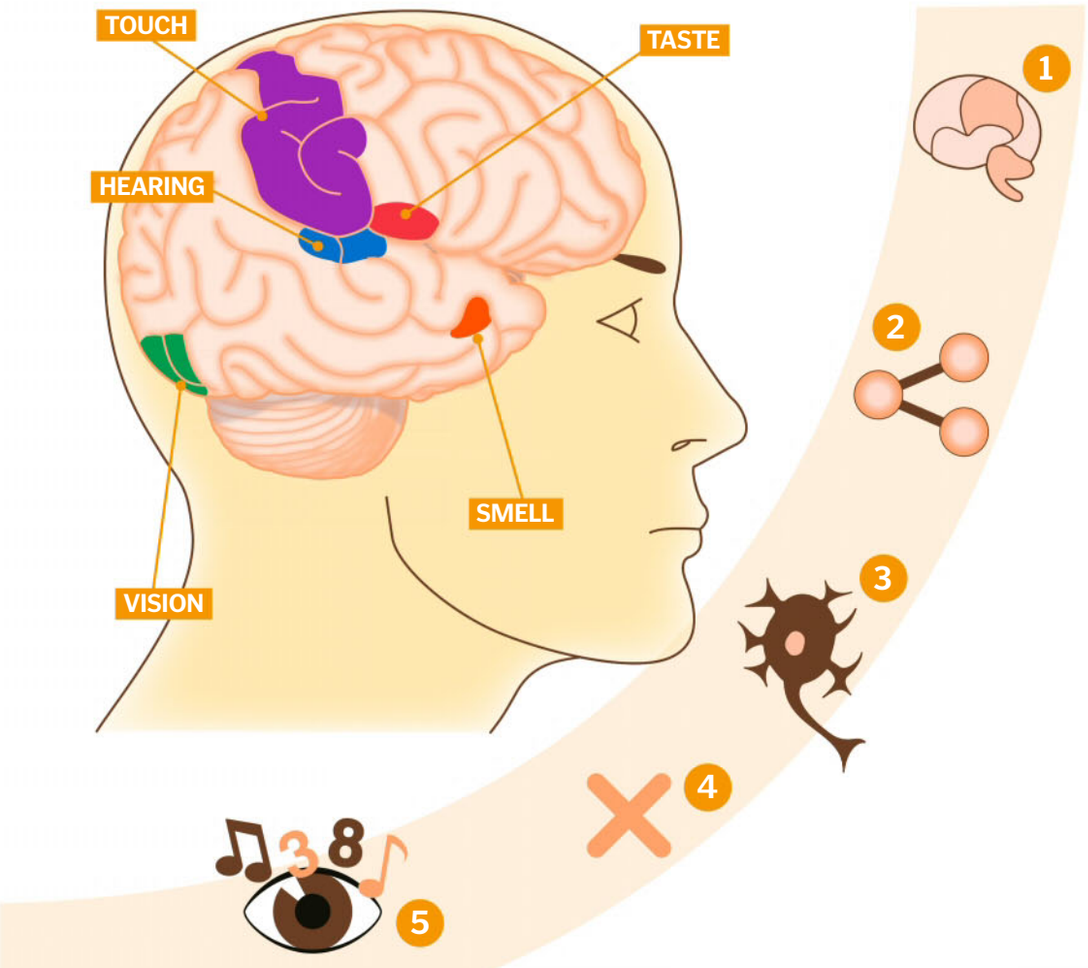
Higher cognitive function (red)
Complex thought processes like working memory, imagination and consciousness take years to develop.

What is synesthesia?

Why can some people see the colour of music or taste the flavour of words?

Synesthesia is a condition that affects around four per cent of the global population, and enables them to experience the world in a different way. During our infant development,the connections in our brains are held close together; areas in the brain that control taste, hearing, sight, smell and touch are overlapped. As we grow into adults those connections are pruned apart, but it is thought this process is interrupted somewhat for those with synesthesia. There have been over 60 forms of synesthesia reported, one of the most common being 'grapheme-colour' synesthesia. People with this type of the condition see colours in association with letters and numbers. However, there is no standard for this association; not every 'A' is red for everyone with the condition.

This blending of sensory information extends to other senses, such as seeing the colour of sound. One participant in a study of lexical-gustatory synesthesia (the ability to taste words) said they tasted Dutch chocolate when shown an image of a phonograph. Those with number-form synesthesia see numbers in physical space in varying forms and shapes. Many synesthetes may have more than one type of synesthesia, and quite often people aren't even aware they have the condition. So ask yourself, how do you see the alphabet, and what colour is it?



Crossed wires

Inside the brain of a synesthete

1. **Grey matter**
   Different sections of the brain are responsible for our perception of senses.
2. **Interconnected senses**
   At birth, neural connections between different senses overlap. In synesthetes some of this overlapping remains into adulthood.
3. **Neuronal pruning**
   In normal development, the connections to the neural regions that control vision and hearing, for example, grow apart by the age 4 months or so.
4. **A possible cause**
   The dominant theory on the cause of synesthesia is the lack of pruning and continual commutation between these connecting regions, known as cross-activation. It's thought to be hereditary.
5. **Multisensory experience**
   The cross-activation between two or more regions allows a synesthete to experience multiple senses at the same time.

Why do our limbs fall asleep?

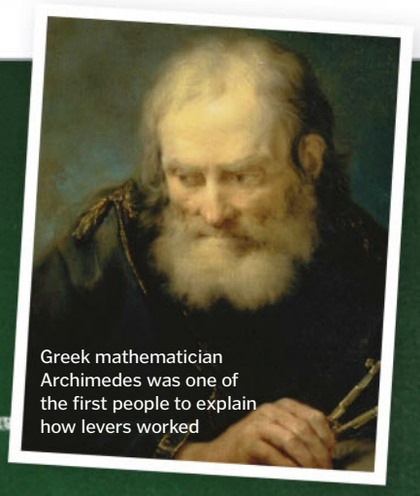
The science behind this weird numbing sensation

Have you ever woken up in the morning to your arm feeling tingly and numb? Normal sensation always returns, but it can take a while before you gain full control of your limb again. This feeling is referred to as a part of your body 'falling asleep'. It can happen when you cross your legs in an unusual position or if you accidentally spend some time sitting on your foot. When you apply direct pressure to a limb over a sustained period of time, you squeeze the nerves, which prevents electrical signals being transmitted through. At the same time you're also putting pressure on the blood vessels which supply these nerves. This means that information is not flowing correctly from your body to your brain, and the nerves are deprived of oxygen and nutrients. When the pressure is released the signal is still scrambled and it takes a while to adjust because the brain is misinterpreting the signals, meaning we feel odd things like warmness, numbness or the familiar 'dead leg' tingles.

After one of your limbs 'fall asleep' it can take a few minutes to regain sensation

Moments

GET STRAIGHT TO THE FACTS ABOUT THE SCIENCE OF PIVOTS AND LEVERS



Greek mathematician Archimedes was one of the first people to explain how levers worked

BACKGROUND

Moments come into play when forces act on an object that has a fixed point. For example, turning a door handle, sitting on a seesaw or closing a pair of scissors. When forces are applied to these objects they rotate around their fixed point, also known as the pivot or fulcrum. The 'moment' is the turning effect of the force. It tells us how much the object will rotate and in which direction. Put simply, a moment is a twist. It is also known as torque.

IN BRIEF

To calculate a moment you need to know two things: the force (which is measured in Newtons) and the perpendicular distance between the pivot to the line of action of the force (which is measured in metres). When you multiply these two numbers you get the moment, which is measured in Newton metres (Nm).

For example, a seesaw has a pivot at the centre. If a person sits on one end, the moment can be calculated by taking the force of their weight on the seat and multiplying it by the distance from the seat to the middle of the seesaw.

Moments also have a direction, either clockwise or anticlockwise. When no one is sitting on the seesaw, the moments in both directions are equal. But when one person sits down the seesaw moves. If another person joins them by sitting on the other end, their body weight creates a moment in the opposite direction.

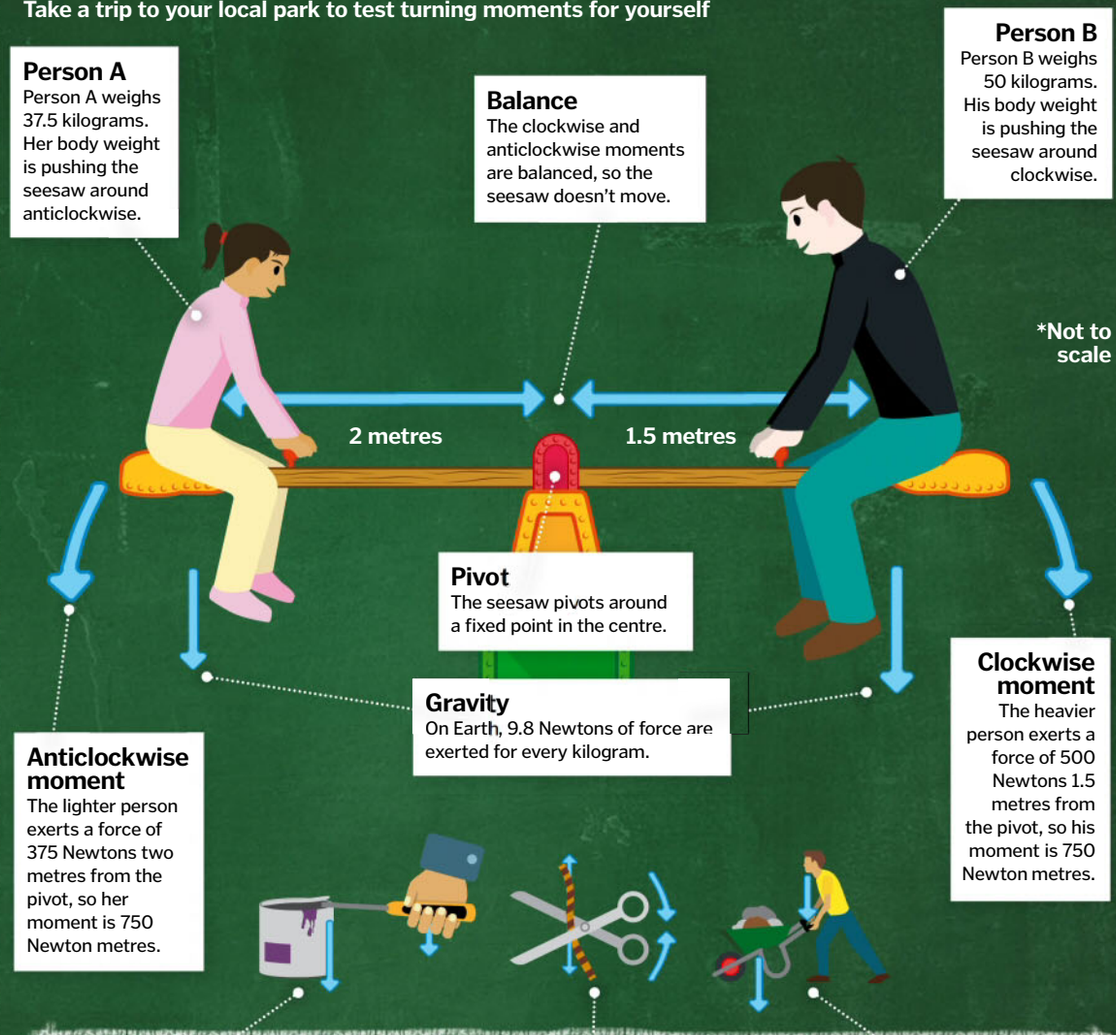
Moment (Nm) = Force (N) x distance (m)

SUMMARY

Moments are the turning effects of forces. They have a direction, either clockwise or anticlockwise, and they can be calculated by multiplying the force exerted by its distance from the pivot.

Moments in action

Take a trip to your local park to test turning moments for yourself



EVERYDAY MOMENTS

Moments are everywhere. Trying to undo a bolt with your fingers is almost impossible, but add a spanner and suddenly it becomes very easy to turn. This is because you're increasing the distance between the force and the pivot and therefore you're increasing the turning moment.

The same principle applies when using a screwdriver to pry open a can of syrup or paint, or closing the handles of a pair of scissors to slice through a sheet of card or a piece of string. The further away you apply the force from the pivot, the easier the task will become.

Moments don't have to be on opposite sides of the pivot, either. A heavy load in a wheelbarrow is close to the wheel, while the handles are further away. This means that you need less force in order to lift the contents. Understanding the simple principles of moments makes everyday tasks an awful lot easier to perform.


TIME TO STEP OFF
THAT TREADMILL
With so many demands from work, home and family, there never seem to be enough hours in the day for you. Why not press pause once in a while, curl up with your favourite magazine and put a little oasis of 'you' in your day.
PRESS PAUSE
ENJOY A MAGAZINE MOMENT
To find out more about Press Pause, visit;
pauseyourday.co.uk

Food Feuds

The world's most contentious culinary debates solved by science

CAN YOU SAFELY REHEAT RICE?

In a word, yes. Many people believe reheating rice causes food poisoning, but it's the cooling of the rice rather than the heating that affects whether or not it's safe to eat. Uncooked rice can contain spores of the bacterial species *Bacillus cereus*. They aren't a concern during the initial cooking and eating process, but if left cooling at room temperature these spores can grow into bacteria. These bacteria multiply, producing toxins which can cause food poisoning.

Don't be fooled into thinking you can kill the spores off by reheating the rice, as the hardy bacteria can easily survive temperatures of up to 100 degrees Celsius. The best thing to do is to cool the rice quickly and store it in an airtight container. This prevents the spores from growing into bacteria, so as long as you thoroughly reheat your rice to kill off any other bacteria, it's safe to eat.

WHY DO RED SWEETS TASTE THE BEST?

A surprising majority of sweets are red due to an inbuilt mental link with the ripeness of fruit. People are naturally drawn to red sweets because our brain links red with sweetness.

Duane Mellor explains, "We do seem to 'taste' colour, so lemon- or orange-flavoured things that are coloured green will be said to taste like lime and more sour. Red things are associated with ripe berries, so we think of strawberries and cherries, so that is often more pleasant than green or yellow ones."

So when choosing a sweet, your sensory organs are naturally drawn to the red ones as your brain has identified them as the sweetest.

HOW COME I ALWAYS HAVE ROOM FOR DESSERT?

You've stuffed yourself at dinner but suddenly find extra room for pudding. Luckily, science can explain this phenomenon. "This has been described as taste specific satiety," explains Duane Mellor. This is basically the idea of getting bored of one type of food and wanting another.

Habituation theory also suggests that exposure to a variety of foods act as a stimuli; unlike the main meal, dessert is offers different flavours and textures, so although you're full, you are not sated. Mellor continues, "Some have also suggested that it is so we get a range of foods and, in theory, a range of nutrients."

Thanks to our evolution, no matter how full you are, it seems there's always room for cake

WHY CAN STEAK BE EATEN RARE BUT NOT BURGERS OR CHICKEN?

Bacteria, such as salmonella and E coli, and other parasites live in the guts of animals and can be transferred to their flesh during the slaughter process. If ingested they can cause diarrhoea, vomiting and cramps. Cooking meat for 45 minutes, with the internal temperature reaching at least 60 degrees Celsius, should be enough to kill off those bacteria, so thoroughly cooking chicken (and other poultry) all the way through should be safe. Steak, however, is cut from the muscle of the cow, not the flesh so as long as the outside is seared to kill off any surface-lurking bacteria, rare steak should be safe to eat.

Burgers shouldn't be eaten rare as contamination could occur while the meat is being minced, so treat your burgers the same way you would a piece of chicken and cook them thoroughly.

WHY IS MELTED CHEESE SO DELICIOUS?

In 2011 Oxfam asked a cross-section of people from 17 countries what their favourite food was. Cheese made the list just once, coming in at 11th in the UK. However, pizza appeared on the list in 12 countries. Is it the dough? Is it the tomato? Or is it the melted cheese that makes pizza so universally popular?

The cheese begins to melt at about 32 degrees Celsius as the milk proteins liquefy. Then at around 54 degrees Celsius the milk proteins break down entirely, leaving a thick creamy, gooey substance. Creaminess is a soft texture our mouths love, while the warmth of the melted cheese also appeals, making melted cheese infinitely better than its hard, cold original form.

WHY DO KIDS HATE BROCCOLI?

Broccoli contains a glucosinolate compound that makes it taste bitter. The human gene TAS2R38 is responsible for sensing bitterness in food, and is more dominant in some people than others, so they're more sensitive to the bitter compound and more likely to dislike broccoli. Children have around twice as many taste buds as adults, so if they've got a version of the dominant TAS2R38 gene then broccoli can taste horrible.

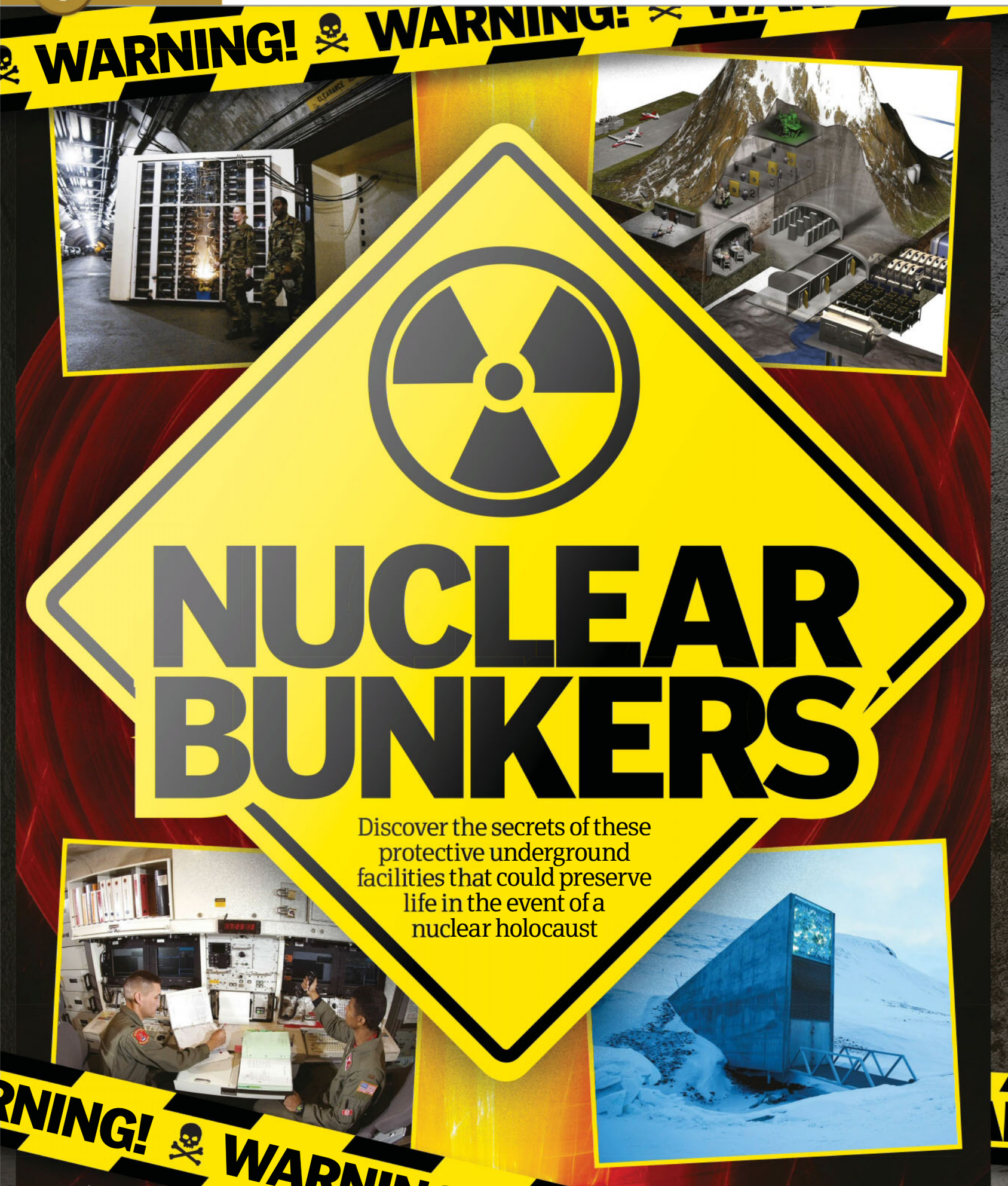
However, as they get older the number of taste buds on their tongue can reduce, and theoretically this bitter taste will be less potent. Duane Mellor, senior lecturer in Human Nutrition at Coventry University, also points out, "This bitter taste is thought to be protective. We are almost conditioned not to like bitter flavours as some bitter compounds can be toxic."

As long as the burger isn't rare, this meal choice is no contest for young taste buds

SHOULD SANDWICHES BE CUT INTO RECTANGLES OR TRIANGLES?

This debate has dominated lunchtimes for generations but, while a recent YouGov poll found 60 per cent of Brits cut their sandwiches into rectangles, it can be put to bed thanks to that champion of the triangle — Pythagoras. Cutting a 9x12-centimetre sandwich into two rectangles provides 21 centimetres of crust per half and nine centimetres of non-crust. Cutting it into triangles, however, still provides 21 centimetres of crust per half but 15 centimetres of non-crust, an increase of over 65 per cent.

Even if you aren't fussed by the amount of crust, cutting your sandwich into a triangle exposes much more surface area of sandwich filling right from the start, engaging more of your senses, stimulating more of your taste buds, improving the first bite and making for a better sandwich experience.


WARNING!
WARNING!
NUCLEAR BUNKERS
Discover the secrets of these protective underground facilities that could preserve life in the event of a nuclear holocaust
RNING!
WARNING!

Until recently, nuclear bunkers were considered relics of the Cold War, as indeed most of them are. But with increasing tension between North Korea and the US, perhaps these fallout shelters don't seem quite so irrelevant any more. Here we delve into the world of nuclear bunkers, with particular reference to those large facilities designed to provide military and governmental control centres in the event of conflict.

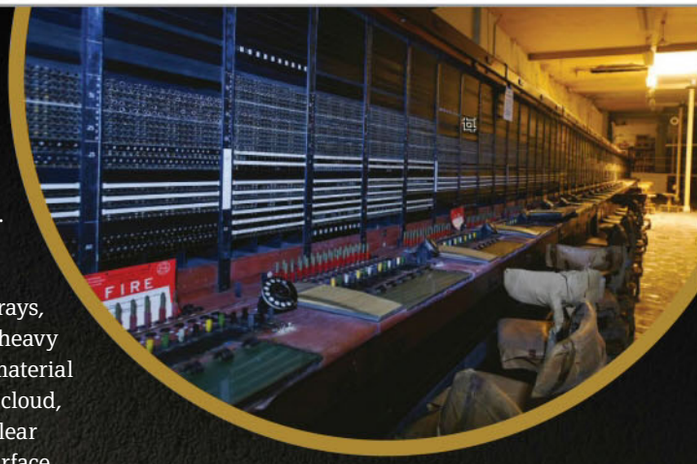
Although the threat of nuclear war tends to be associated with the period between the end of the Second World War and the breakup of the Soviet Union in 1991, nuclear bunkers can trace their heritage back to earlier conflicts. The phrase 'trench warfare' epitomises the First World War, but excavations in Flanders Fields also included underground bunkers that were used as command centres, shelters and stores for ammunition and food. However, it was due to the threat of bombing to the UK during the Second World War that underground defences really got a foothold. These sub-surface structures ranged from large facilities — such as Churchill's well-known Cabinet War Rooms — to the Anderson shelters that people were encouraged to bury in their own gardens to provide protection against air raids.

The design of a bunker capable of protecting its inhabitants from a conventional bomb isn't too demanding. Unless it suffers a direct hit, the protection afforded by a few metres of earth is generally adequate to prevent severe injury. As we turn our attention to a bunker capable of offering immunity from a nuclear attack, though, the requirements become a lot more stringent, as will become evident if we think about the result of a nuclear explosion.

> *"Perhaps fallout shelters don't seem quite so irrelevant any more"*

First of all there'd be an explosive force that would be much more powerful than that caused by a conventional bomb. A nuclear blast would result in a hugely powerful shock wave, effectively a blast of wind that could exceed 1,000 kilometres per hour, plus the risk of falling buildings and flying debris. Simultaneously with the physical blast, an intense flash of thermal radiation would be generated. This would result in fires over a wide area and could be capable of causing instantaneous severe burns to people to a distance of ten kilometres or more from ground zero depending on the size of the bomb. But the immediate effect of the nuclear blast is just the beginning.

A nuclear explosion releases gamma rays, alpha and beta particles, neutrons and heavy radioactive species, and it also carries material from the ground up into the mushroom cloud, where it becomes contaminated by nuclear material. This then drops back to the surface over a period of time in a phenomenon referred to as 'fallout'. The heavier, more dangerous debris falls back down within a matter of minutes whereas the smaller fallout particles, invisible to the naked eye, are small enough to be inhaled into a person's lungs, with the potential to cause serious injury. Because a detonation will typically occur at an altitude of several kilometres and such tiny particles could stay airborne for weeks, the result is that the region around the detonation (and perhaps up to many hundreds of kilometres) could be hazardous to human life for an extended period of time.



The telephone exchange at the UK's Cold War Emergency Government War Headquarters in Corsham, Wiltshire

The implication of this is that, while nuclear bunkers certainly need to offer protection against a powerful blast, they also need to provide protection from radiation and an isolated living environment for several months,

BBC radio broadcasting equipment in the Kelvedon Hatch nuclear bunker

BBC's Wartime Broadcasting System

To provide a service in the event of nuclear war, from the 1950s the BBC drew up plans for a Wartime Broadcasting Service. Around the country were 11 regional seats of government, housed in protected bunkers; the BBC had a studio in each, manned by staff from local radio stations. Overall control would have been from a bunker at the Engineering Training Department at Wood Norton in Worcestershire.

According to a recent BBC report following declassification of the service, the most recent recorded announcement by Radio 4 newsreader Peter Donaldson contained the statement, "This is the Wartime Broadcasting Service. This country has been attacked with nuclear weapons. Communications have been severely disrupted, and the number of casualties and the extent of the damage are not yet known. We shall bring you further information as soon as possible. Meanwhile, stay tuned to this wavelength, stay calm and stay in your own homes. There is nothing to be gained by trying to get away."

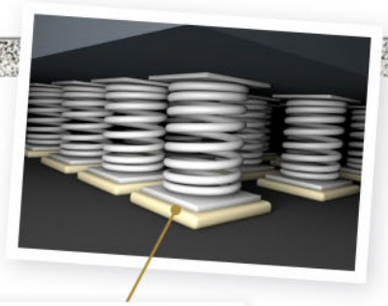
RNING! WARNING! WARNING! WA

perhaps up to a year, until the surrounding area recovers sufficiently to permit human habitation. Nuclear bunkers, especially those used for military and government purposes, also require communication capabilities. Among other things, a bunker would require protection from an EMP — that is a Electro-Magnetic Pulse that would shut down any electronic equipment unless it was properly protected against such an event.

Advice on the construction of a bunker capable of providing protection against nuclear attack was published in 1979 by America's Oak Ridge National Laboratory. Generally speaking, blast protection is achieved with adequate ground cover, perhaps by digging the shelter and then building an arched roof capable of supporting the weight of a mound of earth that covers the bunker. This cover of earth will also offer a good degree of protection against radiation risks. The advice gave particular attention to the door, which would otherwise undermine the protection. In particular, a blast door is needed to keep out blast waves, blast wind, over-pressure, blast-borne debris, burning hot dust and fallout. Some advice also suggested making tunnels as labyrinthine as possible as means of reducing the amount of radiation entering the shelter through them.

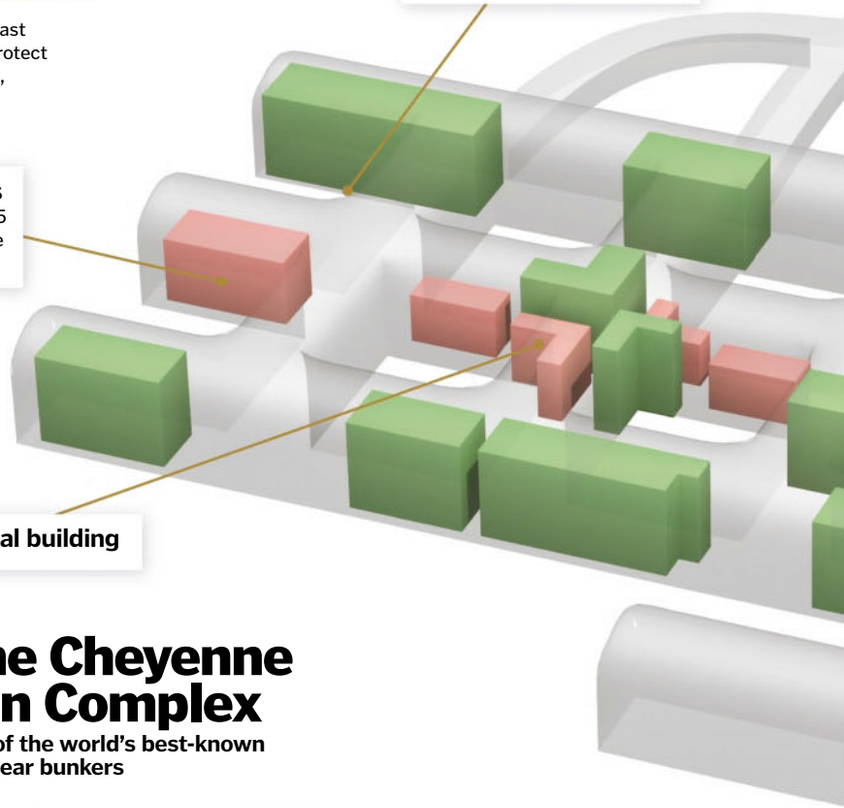
Moving beyond the immediate effect of the blast, advice was given on the provision of a living space for prolonged occupation. This meant stockpiling food that would last for months, perhaps even longer, and also providing an adequate supply of water. The air supply is also an issue, which means that an air pump and filtration system would have been required. Because of the uncertainty over the survival of power generation and mains distribution facilities, provision was required for manual operation.

Cheyenne Mountain's blast doors are designed to protect against a nuclear attack, among other threats



Spring mountings
The buildings are clear of the mountain walls, resting on 1,319 springs to absorb vibrations caused by an explosion.

Internal buildings
The complex contains 15 steel buildings, most are three storeys high.



Internal building

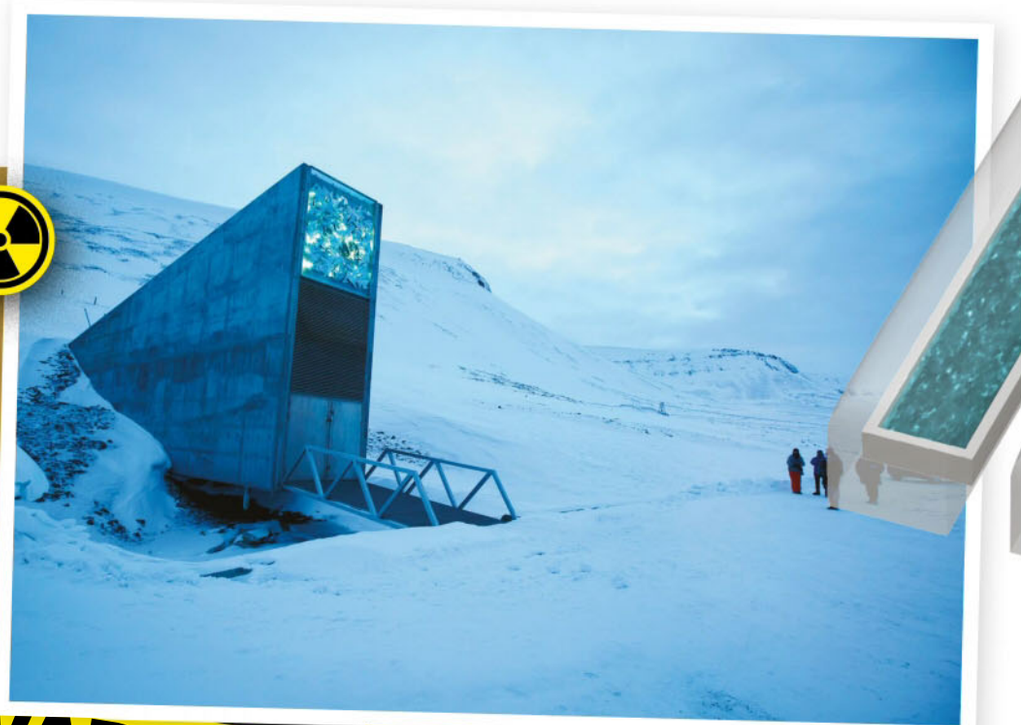
Inside the Cheyenne Mountain Complex

The secrets of one of the world's best-known highly-security nuclear bunkers

Svalbard Global Seed Vault

Way up above the Arctic Circle, in the Norwegian territory of Svalbard, is housed the Global Seed Vault. Built in an abandoned coal mine that burrows its way under a mountain, the facility is intended to protect the seeds of food crops, not only against natural catastrophes and war but also avoidable disasters, such as a lack of funding or poor management.

Its location just 1,300 kilometres from the North Pole takes it well away from likely nuclear targets, but that wasn't the main reason for picking this most remote island. The ambient temperature allows the seeds to be stored at the optimal temperature of -18 degrees Celsius without the expense of refrigeration. At the time of writing, the vault has 933,304 samples in storage, originating from almost every country in the world, and aims to offer options for future generations to overcome the challenges of climate change and population growth.



WARNING! WARNING!

Ground cover
Being built under a mountain ensured 610m rock cover, enough to withstand a 30-megaton bomb from 2km away.

The entrance to the Cheyenne Mountain Complex barely hints at its ultra-secure interior

Blast doors

Access tunnel

Internal building

Blast doors
The blast doors are not on the main tunnel, but a side tunnel, which reduces the impact of the blast by 80 per cent. Each door weighs over 22 tons.

Location
Being distant from either coast means missile flights would be longer, but the nearby Peterson Air Force base means it's close to a likely target.

Reservoirs
Four reservoirs contain 6 million gallons of water to support those living in the complex.

Access tunnel
The main access tunnel is open at both ends so any blast wave would pass straight through.

"Nuclear bunkers need to provide an isolated living environment for several months, perhaps up to a year"

While Second World War air raid shelters were intended to protect civilians, Cold War nuclear bunkers tended to be much larger facilities designed for military and governmental purposes. A list of over 700 disused establishments compiled by Subterranea Britannica reveals a broad range of purposes including national and regional war rooms, civil defence, communication facilities (including radio transmitting stations and telephone exchanges), water supplies, central and local government, fighter command and radar. A similar approach to providing protection for essential defence services was also taken in the US, the construction of the Cheyenne Mountain Complex being just one example.

It would be interesting to know how these large bunkers in the UK and the US would be used in the event of a nuclear threat, but needless to say, information is scant. Bearing in mind the furore following the recent discovery of a memory stick containing details of the route routinely taken by the queen from Buckingham Palace to Heathrow Airport, we can only imagine the level of secrecy surrounding such contingency plans. However, a few facts have come to light concerning the most recent use of a bunker at the White House during the terrorist attacks on New York, Virginia and Pennsylvania on 11 September 2001.

According to the reports, on realising the potential risk, Vice President Dick Cheney was taken by the Secret Service from his White House office to the Presidential Emergency Operations Center (PEOC) below the East Wing of the White House. This facility serves as a secure shelter and communications centre for the president and other essential personnel in an emergency. But this was an unusual situation since President Bush was travelling in Florida, so the response was not typical. Instead, George W Bush took to the skies aboard Air Force One, escorted by three F-16 fighters, from where he managed the response to the attack in the 'Airborne Oval Office'.

In the UK and many other countries, nuclear bunkers were intended mainly to permit military and government operations to continue. Elsewhere, though, bunkers are sufficiently plentiful to provide a safe haven for a significant proportion of the population. Switzerland is the ultimate example, with laws in place since the 1960s ensuring that all new buildings are equipped withfallout shelters. As a result, 100 per cent of the population is now catered for, either in their own bunkers or in large-scale facilities designed for civilian protection. In other countries this level of preparedness might not be guaranteed, but this hasn't stopped people from taking precautions.

Some companies offering private nuclear shelters are currently reporting more orders per month than they received during the whole of 2016. And some of these are pretty lavish, providing a bit of luxury during those months of isolation. For between $1.5 and $4 million you can buy an apartment in an underground facility protected against the effects of a nuclear attack, with amenities including a cinema, indoor pool and spa, medical centre, bar, gym and library. Now surely that's the ultimate status symbol.

Switzerland's Sonnenberg Tunnel was the world's largest civilian nuclear shelter, designed to protect 20,000 people

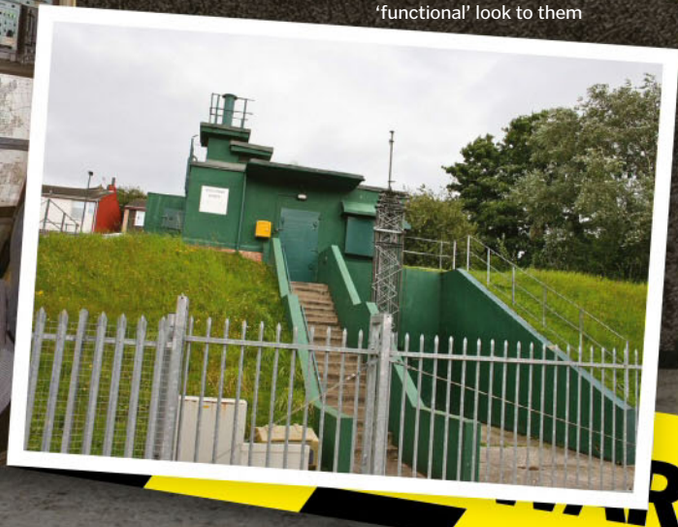
> "We can only imagine the level of secrecy surrounding contingency plans"

Swiss Fort Knox

Originally built as a Cold War nuclear bunker, a facility in the Swiss Alps is now home to a secure server farm designed to survive nuclear war. This is no official initiative, though, but the brainchild of two businessmen who offer their clients the ultimate in data security from risks as diverse as war, terrorism, environmental disasters and financial meltdown.

The so-called 'Swiss Fort Knox' is responsible for storing thousands of terabytes of data on behalf of 10,000 clients, including some of the world's largest corporations, such as Cisco Systems, UBS and Deutsche Bank. It also hosts data belonging to Planets, a project funded partially by the European Union with the aim of ensuring "long-term access to our digital, cultural and scientific assets".

Underground launch control centres still form a role in America's missile monitoring and launch capability



Cold War bunkers, like this one in York, had a most decidedly 'functional' look to them

Inside the Swiss Fort Knox

How a hollowed-out mountain provides the ultimate in data security

Maintenance staff
Service engineers are on site 24/7 to take action should a fault occur in the servers or associated equipment.

Airport
An airport is provided for visiting clients. Customs facilities permit direct international flights.

Communications
Secure communication is provided by a combination of terrestrial radio, satellite links and optical fibre.

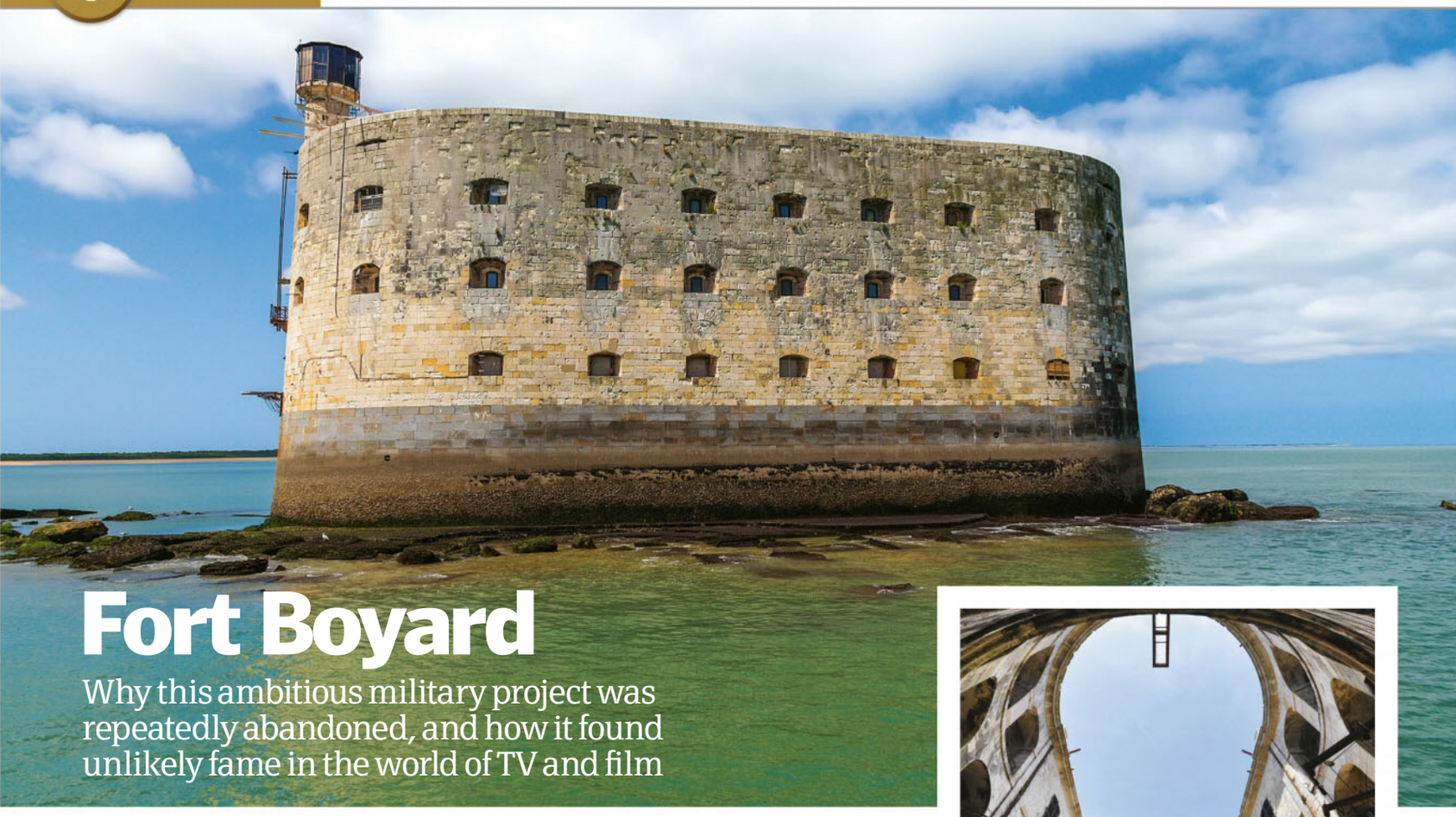
Security
Protection against intruders is provided by a CCTV system and guards.

Client facilities
Workspaces, a hotel and catering facilities mean the needs of clients on prolonged visits can be accommodated.

Power
Immunity from mains power failure is provided by a dual backup system comprising generators and batteries.

Servers
Servers are at the heart of the facility, but here the similarity to ordinary data centres ends.

Cooling
Cooling for the servers is provided by a sabotage-proof high-performance cooling system from an underground lake.



Fort Boyard

Why this ambitious military project was repeatedly abandoned, and how it found unlikely fame in the world of TV and film

Looming out of the sea off the west coast of France is an eerie stone fortress. Cut off entirely from the mainland, the small castle appears to be impossibly floating on the waves, keeping watch over the military port of Rochefort and the Charente Estuary. In fact, Fort Boyard is fixed to a rocky bank, which at high tide is hidden entirely from view — an incredible feat of engineering that has stood for over 150 years, against all the odds.

At the end of the 17th century, plans were drawn up for a sea fort that could protect the military base at nearby Rochefort from enemy raids. However, the project was abandoned in 1692 after the enormous financial cost was realised. Sébastien Vauban, a distinguished French military engineer, said of the planned fort, "It would be easier to seize the Moon with your teeth than to attempt such an undertaking."

During the Seven Years' War (1756-63) new plans for the structure were made, but once again these were abandoned, and it was not until 1804 that the first foundations of Fort Boyard were finally laid. Piles of rubble and stone were sunk into the natural sand and stone bank to form a firm, flat base on which the fort could be built. This process alone was painstakingly slow, as work could only continue during the short hours of low tide when the bank is revealed. In the winter of 1807-8, disaster struck when these foundations were washed away by a series of powerful storms, and in 1809 construction work stopped altogether.

It wasn't until 1857 that Fort Boyard was finally completed. Standing 20 metres high and armed with 74 cannons over three floors, the new fort resembled an impregnable battleship made of solid stone. Its oval design meant its guns could command a field of fire all across the surrounding area, protecting the harbour from any enemy incursions. It contained stores and living quarters to support an armed garrison of up to 250 soldiers.

> "The new fort resembled an impregnable battleship made from solid stone"

Ironically, in the time it had taken to be built, increasingly long-range cannons had quashed Fort Boyard's use as a credible naval defence. For a short time the building was therefore used as a prison, but by the turn of the century even this function was no longer required. The structure gradually fell into disrepair and ruin, until in 1990 it found an unlikely saviour. Fort Boyard became the filming location for a popular French game show of the same name, and received some much-needed restoration. Rendered redundant as a bulwark of France's defence, the fortress' newfound fame has, at least for now, secured its short-term future.

The fort is 20 metres high and has five separate floors, including a dungeon and open rooftop

After a British raid on the Island of Aix in 1757, Fort Boyard was intended to revolutionise French defences

Taverns were hubs of drinking, eating and socialising

The origin of pubs

Discover how foreign conquerors helped shape a British institution

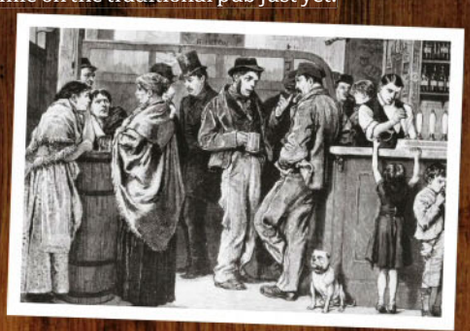
When the Romans invaded Britain in 43 CE, they brought with them all the trappings of civilised living: walled cities, literacy, sanitation — and pubs. Known as tabernae — the origin of the English word 'tavern' — these establishments sold wine to thirsty workers and soldiers. However, as the Romans left and the Anglo-Saxons settled in the British Isles, ale became the tipple of choice. Brewers opened up their homes as alehouses, which grew so popular that in 965 King Edgar I restricted them to one per village.

These taverns and alehouses continued to adapt. When the Normans conquered Britain in 1066, newly built monasteries began brewing their own beer to sell to weary pilgrims, while nearby inns offered refreshment and rest to travellers on the road to holy sites in Britain and beyond.

In 1393 King Richard II ordered that all drinking establishments must display a sign outdoors — normally an illustration as the majority of people were illiterate. These signs would usually have religious themes, with images of saints and angels, but this became taboo in the 16th century when King Henry VIII broke from the Roman Catholic Church. Cautious innkeepers were quick to show their loyalty to the monarch by changing the names of their premises, adopting royal names such as The King's Arms or The Greyhound — appealing to the Tudor tyrant's love of hunting.

In 1552, the Alehouse Act was passed by the monarch, which stated that a licence provided by the local Justice of Peace was needed in order to sell beer or wine. But this legislation didn't stop pubs from continuing to boom, with many later naming themselves The Red Lion in honour of King James VI of Scotland acceding to the throne of England in 1603.

Beer was often cleaner than water and cheaper than tea, with alcoholic drinking remaining widespread in Victorian Britain even after the temperance movement. These public houses — shortened to 'pubs' — featured new-fangled beer engines that could pump the liquid from underground cellars to customers' glasses in seconds. As drinking cultures changed during the 19th century, venues diversified into gin palaces, music halls and nightclubs, but the British public hasn't called time on the traditional pub just yet.



Victorian gin palaces were lavish, gas-lit establishments that Charles Dickens described as "dazzling"

Oldest inns

These are just some of the pubs claiming to have served for centuries

Ye Olde Fighting Cocks

St Albans, Hertfordshire

Reportedly dating back to the 8th century, this pub is perhaps named after the blood sport that took place here.

Ye Olde Trip to Jerusalem

Nottingham

This inn claims to have been established in 1189 CE — the year Richard the Lionheart became king.

Ye Olde Cheshire Cheese

Fleet Street, London

Rebuilt after the 1666 Great Fire of London, this slice of history hosted famous literary figures like Charles Dickens and Samuel Johnson.

Adam & Eve

Norwich, Norfolk

This ancient alehouse from the 13th century used to quench the thirst of workmen building the nearby cathedral.

The Clachan Inn

Loch Lomond, Scotland

Established in 1734, its name means 'a building of stone', as during this time most other buildings were made of turf.

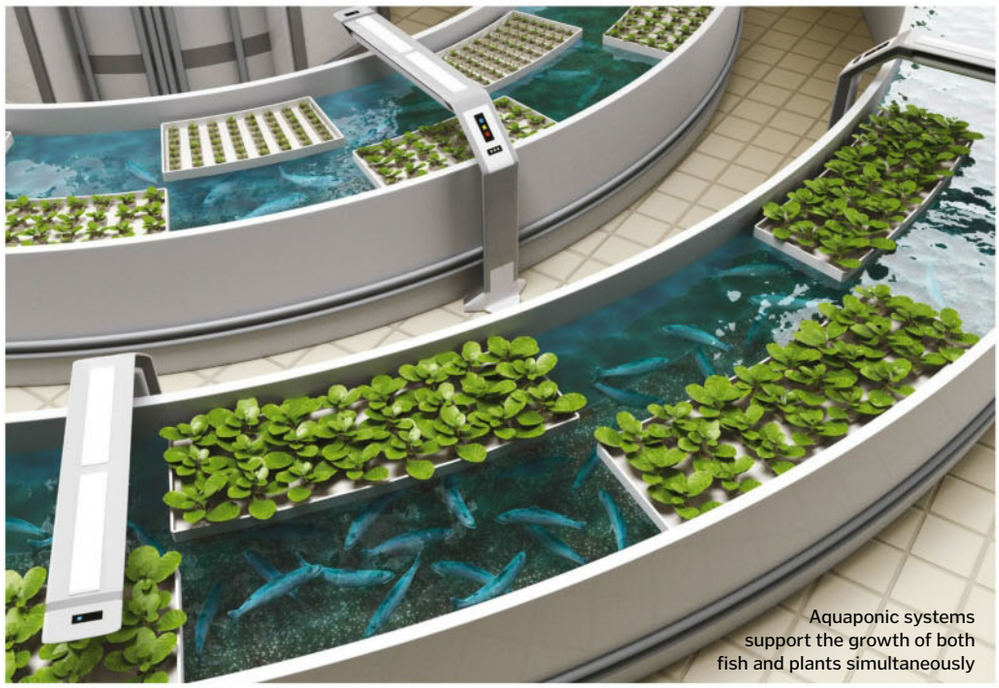
The FUTURE of FARMING

How are agricultural engineers using technology to help feed our ever-growing population?

Have you ever wondered how fruit and vegetables make it from crop to shop? Whether we're enjoying the tropical taste of papaya from Hawaii or savouring steamed spinach from west Asia, we have agricultural engineers to thank for being able to enjoy food from the opposite side of the planet. These specialists are responsible for tackling the massive challenges associated with feeding more people than ever before using limited land.

During the 1960s, each farmer produced enough food to feed approximately 26 people. Due to an increase in demand today's farmer feeds around 155 worldwide. However, by 2050 it is estimated that the global population could reach 9.8 billion, and food production will have to increase by around 70 per cent to feed all of these extra mouths. But when the going gets tough, agricultural engineers help farmers to get growing with creative solutions.

By 2050, it is predicted that advancements in agricultural technology will mean that each farmer will need to feed over 265 people. Work has begun to change the way we farm — from modernising growth substrates and designing new crop storage solutions to optimising conditions for indoor growth. It is hoped that these measures will make for a more sustainable future by increasing food security, reducing global farmland demands and decreasing deforestation.



Aquaponic systems support the growth of both fish and plants simultaneously

"It is predicted that advancements in agricultural technology will mean that each farmer will need to feed over 265 people"

PRECISION AGRICULTURE

Precision agriculture is a modern farming practice that aims to increase the efficiency of produce production through the use of technology, in order to provide more tailored crop treatments. This method makes use of satellite imagery, sensors to monitor crop health and variable-rate technology monitoring water and fertiliser applications.

The birth of the precision agriculture industry came with the introduction of GPS-guided tractors during the early 1990s. This enables the vehicles to navigate themselves according to the coordinates of a field, and also allows farmers to work during low visibility conditions. These systems have revolutionised how crops are planted and how fertiliser is distributed, as it results in less wasted seed, fertiliser, fuel, time and ultimately money.

Most modern farms now utilise GPS-steered tractors, along with a series of sensors to help measure the soil quality. By recording temperature, moisture and nutrient data, entire fields can be mapped out according to the crop yield, allowing farmers to adjust their practices to help improve struggling areas of produce. For example, additional water and fertiliser could be provided to sections struggling with growth, while lessening the supply to areas where the produce is already thriving.

The data processed in precision agricultural systems is being used around the world to optimise farms, from predicting the best time to harvest a crop to anticipating outbreaks of pests and disease before they impact the produce.

VERTICAL FARMS

The rapidly increasing human population brings a whole host of challenges for our planet. A major problem will be providing enough food for these additional people with the amount of farmable land we currently have available. Vertical farms are one of the engineered solutions that have been developed to help tackle this problem. By growing produce in space-saving stacked layers, we can make use of vertical space, growing upwards rather than outwards increasing the productivity of a farmed area by a factor of four to six. This innovative approach has been hailed

Hydroponic systems (right) are more efficient, productive and versatile compared to growing plants in soil

Hydroponic farming

Hydroponic growth methods are unique because they are performed without the use of soil. This modern approach utilises mineral nutrient solutions to provide nourishment to the plant via its roots. Plants can be cultivated by directly establishing their roots into liquid media, although most high-tech systems suspend the roots in a nutrient-rich mist (known as aeroponics). Both methods reduce the risk of disease from soil based organisms, and theoretically allow agriculturalists to grow any crop in any location.

As plants grown hydroponically do not require an extensive root network to extract minerals from soil, more energy can be diverted to leaf and fruit growth, resulting in a higher yield and improved growth of the crop.

as the 'third green revolution' and aims to produce fresh food in sub-optimal conditions, such as within high-altitude mountain towns, dry deserts and dense cities. The latter is particularly important, as experts predict that two-thirds of the global population will be living in urban areas by 2050. Vertical farming will be required to help provide fresh, local produce for the world's growing urban populations.

Typically, vertical farms use hydroponic systems, which involve growing plants without soil. Instead, their roots are suspended in a nutrient-rich water supply. Aeroponic methods — in which plants' roots are suspended in a nutrient-rich mist — further reduce water requirements as well as weight.

Vertical farms tend to make use of artificial light sources, increasingly using light-emitting diode (LED) lamps as a compact and energy efficient source. However, sizeable electricity bills can make vertical farming an unattractive option. These indoor, highly-controlled environments help farmers to establish optimum conditions for the rapid and healthy growth of produce in a way that would not be possible on a traditional farm.

GENETIC MODIFICATION

Genetic modification has been recognised as the innovation that could potentially solve world hunger. Drought, disease and pests affect crops around the globe. Currently, the rate of increase in crop-yield is less than 1.7 per cent, whereas the annual increase needs to be 2.4 per cent to meet demands of a growing population and nutritional standards. It is generally accepted that the solution to these obstacles could be the widespread introduction of genetically modified crops, made possible by engineering the plants to thrive in sub-optimal conditions.

Hydroponically growing crops suspended from the ceiling helps to make the best use of indoor space

"Vertical farming could provide fresh, local produce for growing urban populations"

Plants can have their genome edited to make them resistant to even the harshest of environments

Vertically stacked hydroponic farms are a promising future for sustainable food security

50%

Food production uses up almost half of Earth's land

4.5 billion

people gain 20 per cent of their daily protein requirement from wheat

33 metres

The depth of an abandoned WWII shelter beneath below the busy streets of Clapham, London, which is now used by urban farming company Growing Underground to cultivate sustainable crops with hydroponics

It is estimated that up to **40%** of the world's food would not exist without crop protection products

$9.9 billion

How much the global vertical farming market could be worth in 2025, according to projections

Q&A with agricultural engineer Andy Newbold

Andy Newbold is a chartered agricultural engineer and founder of FarmSmart Events. Previously the president of the Institution of Agricultural Engineers (IAgrE), he spoke to How It Works about the future of farming, the food challenges we face and how to overcome them

How would you describe the job of an agricultural engineer?
I often feel that the agricultural engineer is the Swiss Army knife of engineers because there are many facets to agricultural engineering. They have the tools to help society tackle some of the biggest challenges, be that mitigating the effects of climate change or ensuring food security.

What challenges are engineers facing, and what examples are there of overcoming them?
One particular challenge would be around what we call site-specific agriculture. Historically, we apply pesticides as a blanket across the crop — it's not particularly efficient but it works. But now there is a lot of work being done about applying agricultural chemicals specifically to the area of need — so by the use of cameras to identify maybe a black grass weed infestation or a fungus and applying the chemical directly to the problem. This reduces pollution and is much more efficient. You can scan a field, identify an area that needs treatment and only treat the problem rather than the whole field.

What do agricultural engineering solutions look like at the moment?
The technology is proven regarding auto-steer guidance, driverless tractors and things like that. The next challenge is to deal with public acceptance. So it's one thing in the prairies of Iowa or somewhere, but the moment you see a combine without a driver tootling around Guildford in England or somewhere where there is a population, I think the public have an issue with that, and that's a big challenge. One of the biggest challenges is not the technology — there are so many cases for that: business, environment and resource cases. The issue is a public understanding of why it's important.

Apart from public acceptance, what challenges will you face in the next decade?
I think that there has been an unexpected effect on the gathering of data. If you look at big data, the industry is trying to help farmers to help predict the weather, disease or the circumstances in which disease will occur and when to harvest, and they're trying to use technology. But the unexpected side-effect is the mushrooming, because there are loads of sensors, collecting information on weather, soil, pH, et cetera. As we are gathering mountains of data, we have much more data that we need to manipulate now. This in turn means there are practical problems with computers, storage, hard drives, things like that. I think there are real challenges around data farming and data processing, which is an unfortunate side-effect of what we're doing.

Internet speeds are also a big problem, particularly in rural areas. UK agriculture is served by an old copper network that was designed for phone calls, not for data, so if you haven't got fibre optic (most UK farmers don't) you're reliant on the speed of data transport, which is often very poor.

And the solution to that would be?
Potentially going into the speed of 5G with wireless data, potentially getting a super-fast phone network. If you want to look at a fundamental, connectivity is key; the speed of data transfer, networks, how you get files between people. Improving the infrastructure that is required will enable an explosion in data-driven agriculture. What is holding everything back is we have got the technology, the sensors, cameras, drones, the ability to do all of this, but we can't shift, we are in the Stone Age. We need something a bit better. If you live in a town, everyone has fibre optic, but agriculture isn't in towns — it's distributed and it's away from the exchange on the old network systems.

What is the tech that has changed the face of farming in the last five to ten years?
Some of the game-changers are auto steer and guidance, where the tractor just drives in straight lines. It drives up and down by itself, reducing the overlap. By eye you can end up with a five to seven per cent overlap, but with GPS it can be reduced down to 1.5 to two per cent. That uses less fuel and reduces the strain on the operator, because you don't have to focus on that. There are a number of other great advancements, but that is one technology that has really enabled farmers to do a lot of things.

400-600%

The amount, on average, that crops farmed in indoor vertical farms in urban areas will yield compared to traditional seasonal agricultural yield

Over 9 billion

The estimated number of mouths to feed in 2050

Sensors

Sensors can be used in a variety of applications, and it's now possible for farmers to see that data as it is being recorded in the field. **How It Works** spoke to Nahuel Lavino of Pycno Sensors, who explained their importance to farming.

"Before sensors, farmers would use intuition to see how the plants' pattern and colour would change to suggest they were stressed. Now with sensors farmers can visualise in real time if their crops will be in stress or if there is a pest sprouting before it happens. Utilising the information about soil and air every few minutes means a decrease in the use of resources such as water, electricity, pesticides and fungicides. We can apply them when the plants really need them instead of depending on a set calendar."

Pycno sensors collect data on the condition of farms in remote locations, which is analysed and displayed to farmers directly onto their mobile device

We have a booming population, and we are running out of space to grow crops. It's time to start thinking vertically!

So how can genetic modification help boost the quality of the most important crops? The secret lies in editing the genome of an organism to improve its ability to photosynthesise. Corn and sugarcane are successful because they use a more efficient method called C_4 photosynthesis. This discovery has inspired research projects around the world to start investigating the feasibility of producing C_4 rice and C_4 wheat.

Genetic modification can also help increase the yield of a crop, which means more efficient land use. In addition, it can reduce the need for herbicides and other pesticides, as the produce itself can be modified to contain the genes needed to protect itself. Genetically modified organisms (GMOs) are already used around the world. For example, papayas in the US have been genetically engineered to survive the ringspot virus, which almost wiped out production of the fruit in the 1980s. The future of GMOs relies on widespread acceptance of their safety and importance so they can be further distributed to those in need.

ROBOTS AND DRONES

Machines have been integrated into almost every aspect of our lives, changing everything from the way we communicate to the way we travel, so it makes sense that robotics have shaped farming.

Agricultural robots, known as 'agbots', already play a role during the harvesting stage, and more recent developments have seen the introduction of this technology for weed control, seed planting and soil analysis. Some of these electronics are deployed to replace human labour, such as agbots programmed to pick fruit or spray crops, making the process faster.

The mechanical design of an agbot is highly dependent on its purpose, and defined by the end effector. For example, end effectors on a spraying agbot will be a spray nozzle whereas a robot at the end of the production line might have a bagging system. Drones can also play a role in precision farming, helping farmers to monitor crops by creating three-dimensional maps for soil analysis using ultrasonic echoing and lasers.

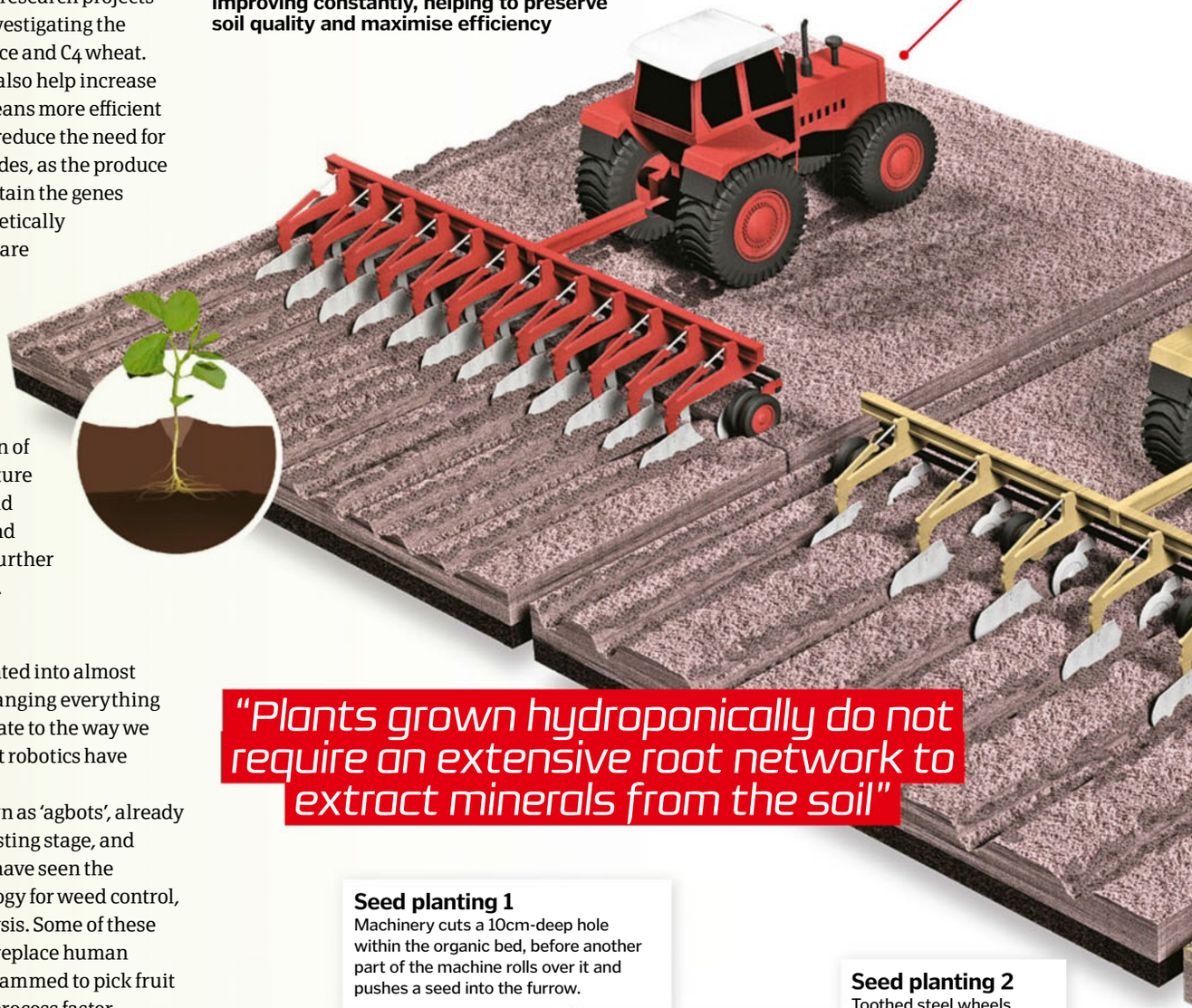
THE FUTURE

Engineering solutions have revolutionised agriculture, and with so many hi-tech tools at our disposal, ending world hunger may well be an achievable goal in the decades to come.

Farming methods

The ways in which farmers treat crops are improving constantly, helping to preserve soil quality and maximise efficiency

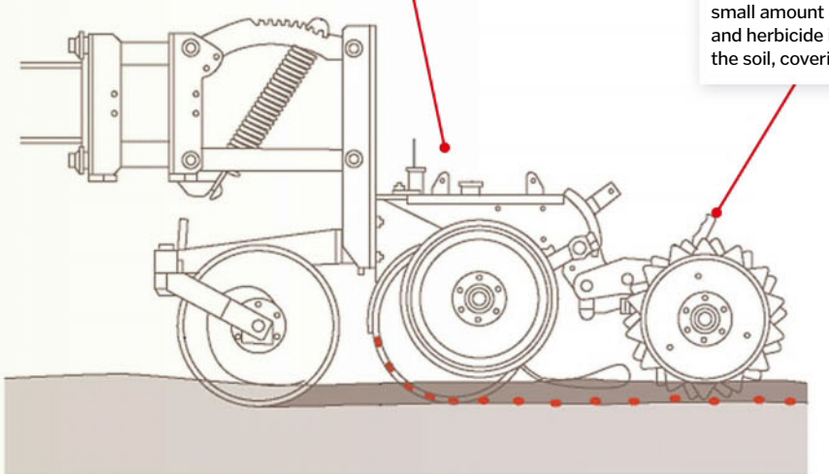
Conventional farming
Traditional field work involves ploughing and harrowing to turn up the earth to make the land more fertile and control weed growth, but over time the soil becomes exhausted and unusable.



"Plants grown hydroponically do not require an extensive root network to extract minerals from the soil"

Seed planting 1
Machinery cuts a 10cm-deep hole within the organic bed, before another part of the machine rolls over it and pushes a seed into the furrow.

Seed planting 2
Toothed steel wheels close the furrow before a small amount of pesticide and herbicide is applied to the soil, covering the seed.



Agricultural robots can be tasked with harvesting, spraying and planting

Precision farming
Recent decades have seen an increase in precision farming, improving the productivity of farmland by using global positioning systems (GPS).

Data analysis
Information gathered from field sensors and GPS trackers can help farmers evaluate the overall health of their crops and pinpoint any potential problems.

Minimal farming
Minimal farming methods are considerably less aggressive and use more widely spaced furrows in the ploughing process. However, this can destroy microfauna and becomes harmful to the land over the long term.

© Solop; Pixabay; Getty

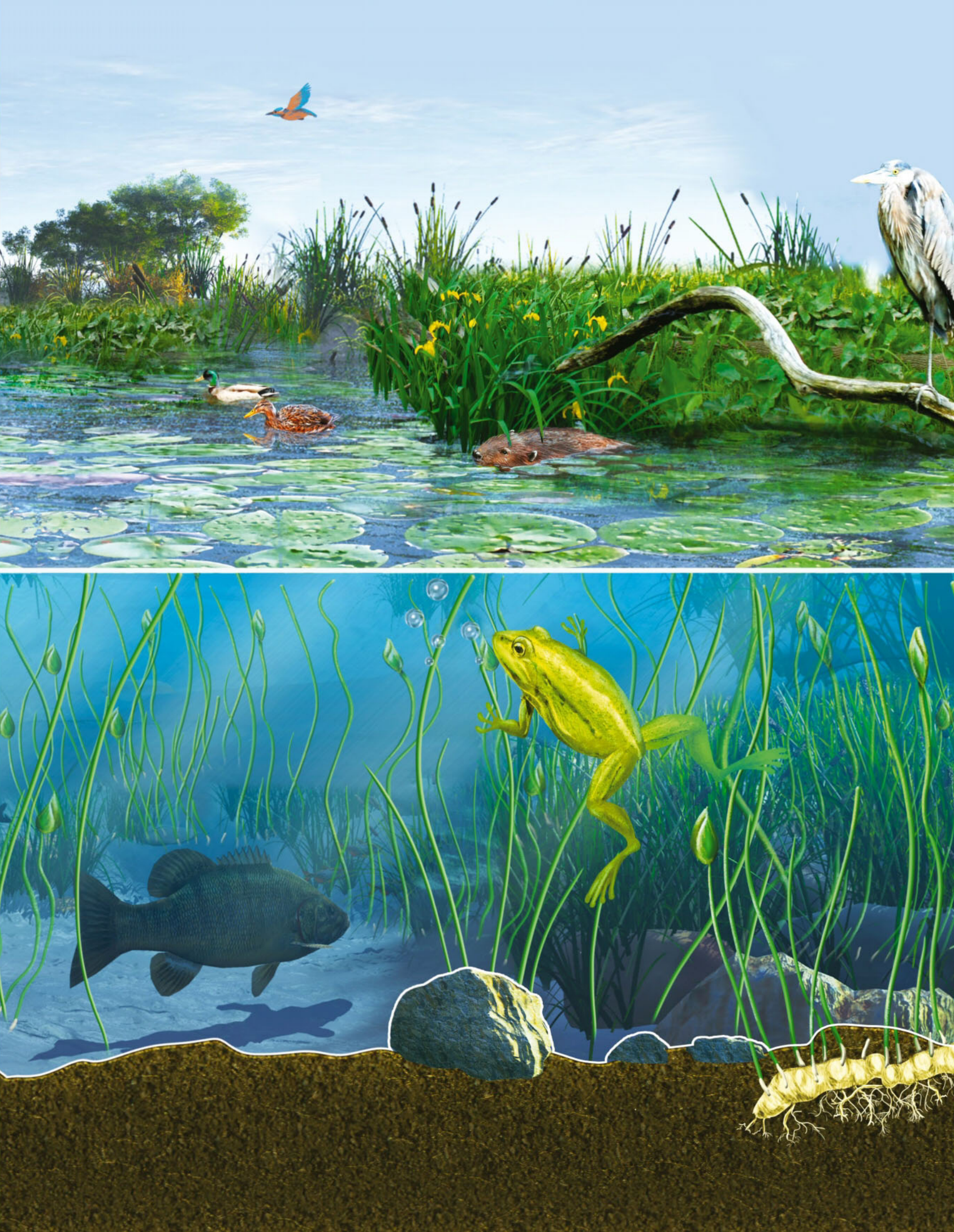
Mapping
A GPS system within a harvester can map crop yield to indicate areas of the crop that are thriving or struggling, so farmers can tailor the amount of fertiliser and/or water to the poorly performing areas.

Zero farming
This technique doesn't use any form of plough or harrow. Instead, seeds are placed in the remains of the previous crop, which over time forms a nourishing bed for the new crop, preventing soil erosion and increasing the land fertility. It doesn't destroy microfauna and flora, requiring a larger use of pesticides. This can pollute groundwater and rivers, but is required to keep weed growth under control.

Agricultural drones can use sensors and cameras to help increase crop production and monitor growth

HOW IT WORKS

POND LIFE



HOW IT WORKS

LIFE IN THE PRIDE

HOW IT WORKS

THE EYE OF A SUPERNOVA

Futureshocks

Discover the role of technologies in our future cities with the Museum of London

2018 marks the start of **Futureshocks**, a new series of panel discussions at the Museum of London. Curated by writer and urbanist Adam Greenfield and curator Lauren Parker, **Futureshocks** invites leading international writers, thinkers, technologists and cultural producers to discuss the role of technologies — from historical innovations to future speculations — in transforming and disrupting the city and the lived experience of our urban environments.

The first event, **Futureshocks: human** on 25 January, will examine issues around identity and the body in our changing cities, with a panel of speakers including Rachel Coldicutt, CEO of Doteveryone, Aimee Meredith Cox, scholar, dancer and author of *Shapeshifters: Black Girls and the Choreography of Citizenship*, and event co-curator Adam Greenfield.

Futureshocks: systems on 22 February will chart the power of data, networks and infrastructure in the city, from global migration and communication networks to designing for local systems. Contributors will include Greta Byrum (director of Resilient Communities at New America) and architect and artist Usman Haque.

The final event, **Futureshocks: civic** on 21 March, will explore topics including power, value, truth, community and collaboration in the future city, with speakers including community engagement and participatory design strategist Daisy Froud; designer, film-maker and co-founder of Superflux Anab Jain and speculative architect Liam Young.

Futureshocks is part of **City Now City Future**, a year-long season of more than 100 displays, commissions, festivals, workshops and talks at the Museum of London exploring the past, present and future of cities. January to April sees the final phase of the season as the museum imagines the future of architecture, politics and technologies in cities and explores what London could look like over the next century.

The **Futureshocks** talks series is supported by DLA Piper and developed in partnership with the *Guardian*.

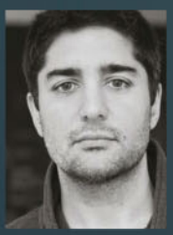
To book tickets or for more information about the season visit
www.museumoflondon.org.uk/citynowcityfuture

"Futureshocks explores the role of technologies in transforming and disrupting our cities..."

Meet the speakers

The Futureshocks lineup brings together technologists, writers, thinkers and cultural producers

Usman Haque



Usman Haque is founding partner of Umbrellium (*umbrellium.co.uk*) and Thingful (*thingful.net*) a search engine for the internet of things. Earlier, he launched the internet of things data infrastructure and community platform *Pachube.com*, which was acquired by LogMeIn in 2011. Trained as an architect, he has created responsive environments, interactive installations, digital interface devices and dozens of mass-participation initiatives throughout the world. His skills include the design and engineering of both physical spaces and the software and systems that bring them to life. He has also taught at the Bartlett School of Architecture, including the Interactive Architecture Workshop (until 2005) and RC12 Urban Design cluster, "*Participatory systems for networked urban environments*". He received the 2008 Design of the Year Award (interactive) from the Design Museum in London, a 2009 World Technology Award (art), the Japan Media Arts Festival Excellence prize and the Asia Digital Art Award Grand Prize.

Anab Jain

Anab Jain is a designer, filmmaker and co-founder of Superflux, a critically acclaimed foresight, design and technology innovation company. Superflux consistently produces inventive work in the realm of emerging technologies for business, cultural and social purposes. Anab's work has won awards from Apple Computers Inc, UNESCO, ICSID and Innovate UK. Her work has been exhibited at MoMA New York, the Victoria and Albert Museum, the Science Gallery Dublin and the National Museum of China, among others. She is a TED Fellow, co-founder of the IoTAcademy, curates the Long Now Foundation's London Meetup Group and sits on the boards of Broadway Cinema and London School of Economics Media. You can follow her on Twitter @anabjain.

Greta Byrum

Greta Byrum reimagines the way we design, build, control and distribute communications systems. As director of the Resilient Communities programme at the policy institute New America, Greta oversees Resilient Networks NYC, an initiative providing training, tools and equipment for storm-hardened local Wi-Fi to residents of six neighbourhoods impacted by Hurricane Sandy. Greta is also co-lead of PNK (Portable Network Kits), a sponsored project of the Allied Media Projects bringing standalone solar-powered communications kits and tech training to people recovering from Hurricane Maria. She was a 2017 Loeb Fellow at Harvard's Graduate School of Design.

Daisy Froud

Daisy Froud is a strategist specialising in community engagement and participatory design. She devises tools and processes that enable diverse voices to meaningfully contribute to design decision-making and to shaping the future of places in intelligent, imaginative and equitable ways. Having started her career in community-led regeneration and environmental campaigning, in 2003 Daisy co-founded the architecture practice AOC, which built a reputation for "a committed engagement with communities, clients and parts of the city" (FT, 2008) and was twice shortlisted for the Young Architect of the Year Award. In October 2014 she resigned in order to operate in a more fleet-footed way. Since 2007 she has taught on the history and theory of spatial politics at The Bartlett School of Architecture and in 2011 completed a visiting professorship at Yale. Daisy sits on the advisory design panel for High Speed 2 and design review panels for the London Boroughs of Lewisham, Hackney and Bexley. She is a design advocate for the Mayor of London, a built environment expert for Design Council CABE, an academician of the Academy of Urbanism, and in 2014 she was shortlisted for the prestigious AJ's Emerging Woman Architect of the Year Award.

Inside the iPhone 8

How does Apple fit everything inside the iPhone's tiny frame?

2017 year marked a significant change in Apple's iPhone release schedule — when Tim Cook took to the stage back in September, he actually announced two new models of the best-selling phone. This month, we took a closer look at the iPhone 8, with its all-glass design and a whole bunch of cool new tricks. Aside from a tweaked design, the phone also offers new sensors, an improved display, a better camera with more ways to take great photos, and wireless charging that lets you power up without needing to plug in.

The big news for this year, though, is the augmented reality tech that is being included with the new iPhone. A platform, AR Kit, was made available to app developers earlier this year, which allows them to create augmented worlds that can be viewed through the screen of the iPhone 8 — it's a little like *Pokémon Go* only bigger, better and easier to create. The iPhone 8 allows this to work seamlessly, and it's being used for everything from visualising furniture in your front room to fully interactive 3D games that appear on your tabletop at home.

Every year we are astonished by how much tech smartphones can pack into such a small space, so we've opened up the iPhone 8 to see how Apple fits it all in. Let's see what's inside...

Rear-facing camera
The 12-megapixel camera has a larger sensor to help you take better photos, and magnets inside to help stabilise images.

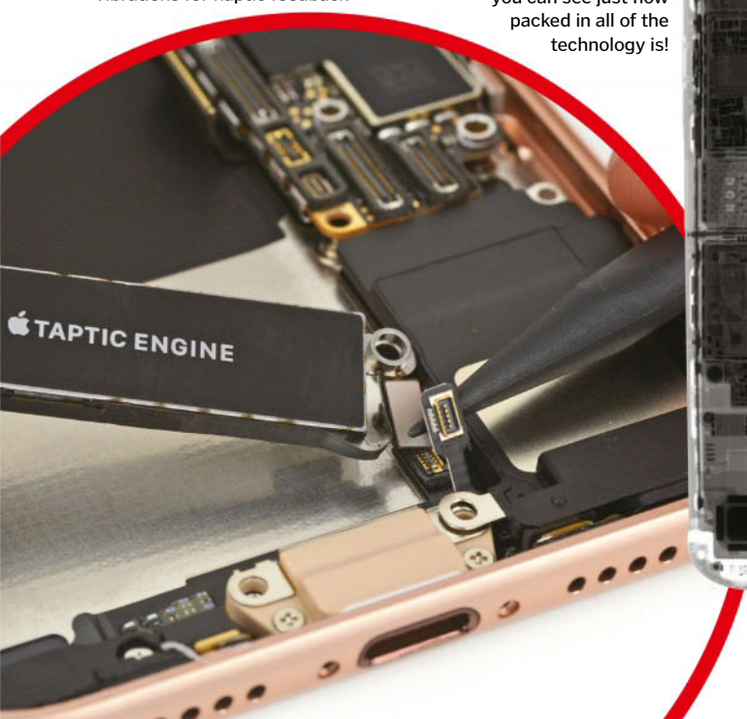
Front sensors
These sensors include the front-facing camera (for selfies), as well as light sensors to help adjust the display automatically.

Home button
The iPhone 8 still uses Touch ID for authentication and unlocking, and the fingerprint sensor is built into Home button.

Taptic engine
This tiny engine creates the vibrations you feel when you press the Home button on the iPhone's screen.

Apple's Taptic Engine generates vibrations for haptic feedback

With this X-ray image you can see just how packed in all of the technology is!



"The big news for this year is the augmented reality tech that is being included"

Opening up the iPhone 8

Take a look at the tech inside the latest Apple smartphone

The logic board
This is the brain of the iPhone, containing the bionic Apple A11 chip, as well as the flash storage where all your data is kept.

Reinforced frame
The front and back of the iPhone are both made of glass, but the rear frame of the phone is now reinforced with steel and copper.

Glass back
For wireless charging to work effectively, the back of the iPhone can't be made of metal. The iPhone 8's glass back, made using a seven-layer colour process, is the perfect solution.

The camera in the new iPhone has a bigger sensor with larger pixels that let in more light for better photos

Wireless charging
This black cover hides a coil of wire that will allow you to recharge the battery by simply placing it down on a compatible charging mat.

Battery
As always, the battery takes up the majority of space inside the iPhone. This one offers 6.96 Watt-hours of power — less than the iPhone 7.

The iPhone X

The second iPhone that was announced by Tim Cook in September 2017 was the iPhone X. This new model features a screen that extends right to the edge of the glass and includes Face ID, a new technology that scans your face to unlock the device and authenticate things like payments via Apple Pay. The new device doesn't feature a Home button either — it's the first iPhone without one. Instead, a section at the bottom of the screen can be swiped upwards to return to the main Home page. That huge display is an OLED (compared to the IPS display on more recent iPhone models), meaning that it can display deeper blacks and more vibrant colours. Of course, it's also waterproof, features wireless charging and takes incredible photos — just like the iPhone 8.

Glucometers

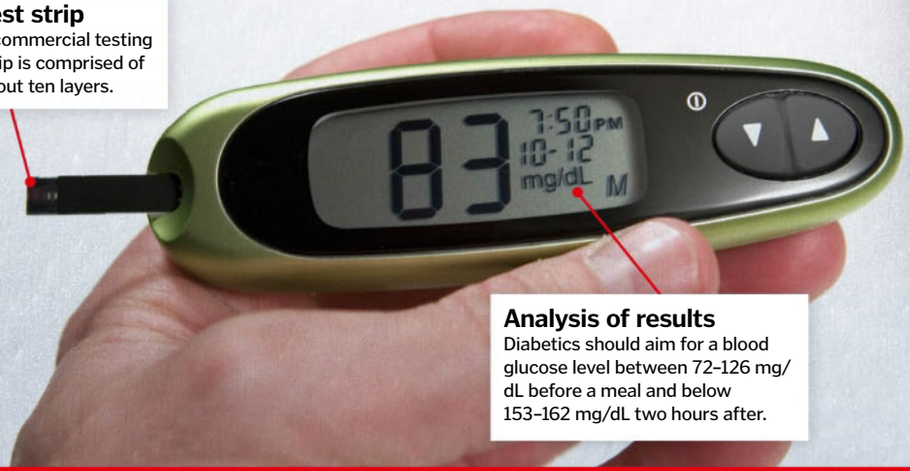
The devices that make monitoring the effects of diabetes more manageable

Monitoring blood glucose levels is incredibly important for those suffering with diabetes. Insulin regulates the amount of glucose in the bloodstream to try and keep blood glucose levels as stable as possible. But the bodies of diabetics either can't produce insulin (type 1), or don't produce enough or don't respond to it properly (type 2). By observing blood glucose fluctuations with a glucometer, diabetics can prevent excessively low or high blood sugar, known as hypo/hyperglycemia (respectively), and select the correct treatment.

In general, glucometers work using a drop of blood, usually from a pricked finger, which is then placed on a test strip inserted into the device. The enzyme glucose oxidase is housed on the strip and reacts with the glucose in the blood sample, becoming gluconic acid. As this acid moves through the layers of the strip it reacts with potassium ferricyanide to form potassium ferrocyanide. The electrode oxidises the ferrocyanide, which in turn generates an electric current, displaying a numerical value we understand. The more intense the reaction, the higher the glucose level and the greater the reading on the glucometer screen and visa versa.

There have been a number of developments made in glucometer technology in recent years. For example, researchers at Harvard University are developing a tattoo that will change colour depending on a person's glucose levels. Other, non-invasive methods are also being developed.

Glucometers help monitor glucose levels for those with both type 1 and 2 diabetes



Test strip
A commercial testing strip is comprised of about ten layers.

Analysis of results
Diabetics should aim for a blood glucose level between 72–126 mg/dL before a meal and below 153–162 mg/dL two hours after.

Internet cookies

The bite size messages that let your browser remember who you are

Internet cookies have a reputation for being more ominous than they actually are. Most websites use them in some way in order to recall your browsing habits to best serve your return visit. At a basic level, cookies are a file or string of text relaying information to a website from a web server.

There are two main types of internet cookie: the 'session cookies' that are erased when you leave a site, and the 'persistent cookies' that are stored on your computer with an expiry date. Cookies identify you as a unique user without knowing who you are, kind of like a fingerprint that doesn't belong to anyone. This allows sites to personalise their interfaces for their users with auto-login, give product suggestions or customise advertisements.

Cookies can only access information that you provide to individual sites, and they can't access other files on your computer. Managing options in browsers can allow you to control cookies, just in case you don't want to leave any crumbs.

Internet cookies have no software programs and can't deliver viruses

ICE GIANTS

Why are scientists so keen to send a mission back to Uranus or Neptune?

Travel to the edge of the Solar System and you might be in for a bit of a surprise. Along the way you'll find two so-called 'ice giants', worlds that fit somewhere between rocky planets and gas giants in size. Their simplistic names, however, belie their fascinatingly complex environments, which we're only now beginning to understand. Welcome to Uranus and Neptune.

Only one spacecraft has ever visited these two worlds: the enigmatic Voyager 2 probe in 1986 and 1989 respectively. Making use of a rare planetary alignment that only happens once every 176 years, Voyager 2 flew by the gas giants Jupiter and Saturn before briefly visiting Uranus and Neptune. Despite their status as two of the eight major planets in our Solar System, our knowledge of them is limited; mainly coming from this brief flyby, in addition to ground and space observations.

The distance of Uranus and Neptune from Earth — 2.7 billion and 4.3 billion kilometres on average — has made these two worlds decidedly difficult to explore. Right now, scientists at NASA are planning to return to one or both of these worlds. Both are interesting in their own right, but only one is likely to be selected for study, with a target launch date around 2030 or 2031. Of particular interest is to send a probe into the atmosphere of one of the planets, which we did with the Galileo probe that visited Jupiter back in 1995.

And there's good reason to go back, because both Uranus and Neptune — over 14.5 and 17 times the mass of Earth respectively — are still hiding plenty of secrets. For example, Uranus emits almost as much heat as it absorbs from the Sun, meaning it lacks a strong internal heat source, unlike the other outer planets. And we just don't really know why it's doing that. As for Neptune, its moon Triton is incredibly intriguing; possibly a dwarf planet stolen from further out in the Kuiper Belt. Looking at this moon up close could reveal its origins and offers an opportunity to explore a Kuiper Belt Object (KBO).

The name 'ice giants' is a little bit of a misnomer – there is relatively little solid ice in them today. These ice giants contain high levels of heavier elements including oxygen, carbon and nitrogen, which are the probably the next most abundant elements in the Sun. When the planets formed the elements were probably gathered up in their frozen form or contained in water ice. The gas giants, Jupiter and Saturn, are so named because of the large amounts of hydrogen and helium gas in their layers, likely gathered from the disc of dust and gas that surrounded our young Sun.

Inside each of the two ice giants we think there is a rocky core of iron and nickel that's anything from half to several times the mass of Earth. Surrounding their cores are thought to be icy oceans made of methane, water and ammonia. Even so, we're only just starting to understand what's happening in these regions.

Today you'd be hard-pressed to argue that Uranus and Neptune are icy in the traditional sense. The temperatures inside these planets can reach thousands of degrees, but the pressure is around 100,000 times or so that on Earth. The result is that water and other compounds are squashed into a 'superionic' phase, where they are neither a solid nor a liquid. Some atoms, like oxygen, are essentially frozen, whereas others, such as hydrogen, move at high speeds.

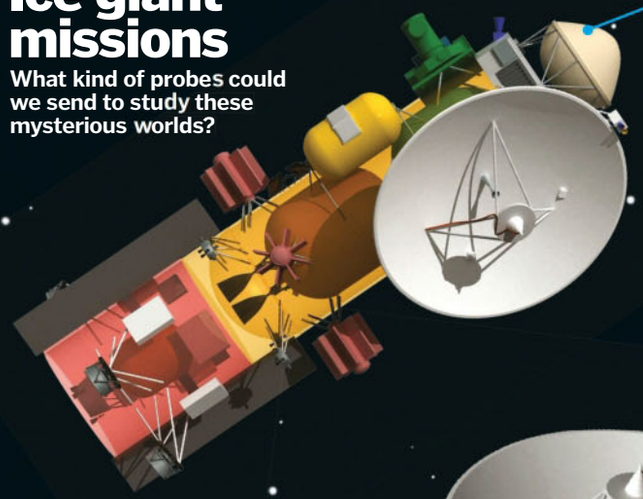
The results are some weird regions where a huge ocean of water, ammonia and methane churn. Scientists have proposed that the pressure and temperature is so intense that it may rain diamonds inside these planets. Researchers were able to mimic this process on Earth, producing diamonds a few nanometres across. But inside Uranus and Neptune the process can last millions of years, creating bigger diamonds.

Most of their mass is made up of hot, dense fluid of 'ices' whereas Jupiter and Saturn, by comparison, are essentially giant balls of hydrogen and helium gas. And it seems that ice giants must form in pretty exact circumstances after gas giants have swept up other material, and even then they must grow large enough to surround their rocky core with gas. Yet surprisingly, ice giants are one of the most common types of exoplanet.

Further studies of Uranus and Neptune are therefore not just important for our own Solar System. While we are interested to know what makes these worlds so different, we also want to know why so many other planetary systems have ice giants, or even planets that are a bit smaller (about ten times the mass of Earth), known as mini-Neptunes. A mission to one of these ice giants would produce a cavalcade of science. There will be plenty of people hoping such a mission happens soon.

Ice giant missions

What kind of probes could we send to study these mysterious worlds?



Neptune orbiter with probe

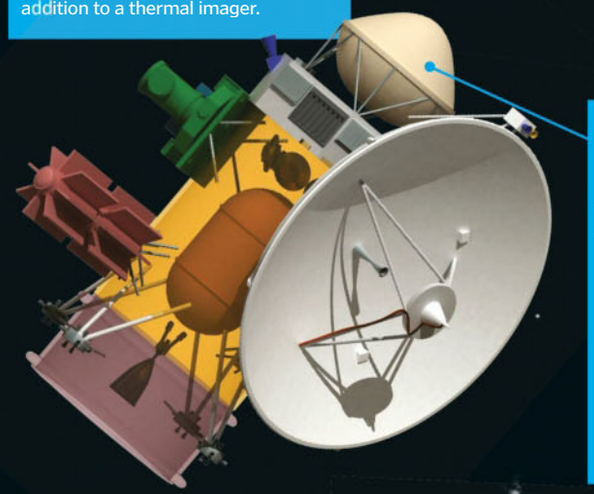
Provisional launch date: 2030
Mission duration: 15 years

This mission, one of several NASA ice giant proposals suggested, would involve sending an orbiter and an atmospheric probe to Neptune. The orbiter would be used to study the 14 known moons of Neptune, with a focus on Triton, thought to be an object captured from the Kuiper Belt. The probe, meanwhile, would be sent into the atmosphere of Neptune. It would measure how much hydrogen and helium is present, along with other elements.

Uranus orbiter only

Provisional launch date: 2031
Mission duration: 15 years

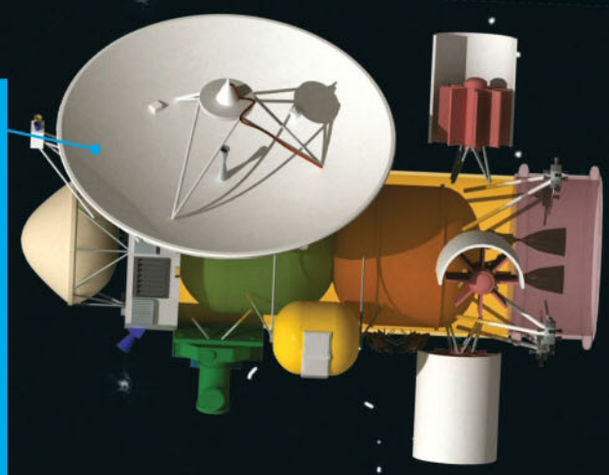
The other spacecraft here would carry just three instruments along with a probe, but this one, would be able to take a whopping 15 instruments. These would include a wide-angle camera to capture images of Uranus and its 27 known moons, in addition to a thermal imager.



Uranus flyby with probe

Provisional launch date: 2030
Mission duration: 10 years

This mission would be the cheapest of the bunch mentioned here. It would swing past the planet and into deep space, just as Voyager 2 did in 1986. A probe would be deployed into the atmosphere of Uranus, but the mission as a whole would have a limited time to observe Uranus, its ring system and its moons. This should still be enough to tell us what it's made of though.



Uranus orbiter with probe

Provisional launch date: 2031
Mission duration: 15 years

This mission combines the best of the other two Uranus missions, placing a probe into orbit for three years while also sending a probe into the atmosphere. It would have three instruments: a narrow-angle camera, doppler imager and magnetometer to allow study of the planet's composition, with the probe getting data from inside the planet. This would give us invaluable data on the moons and ring system of the ice giant.

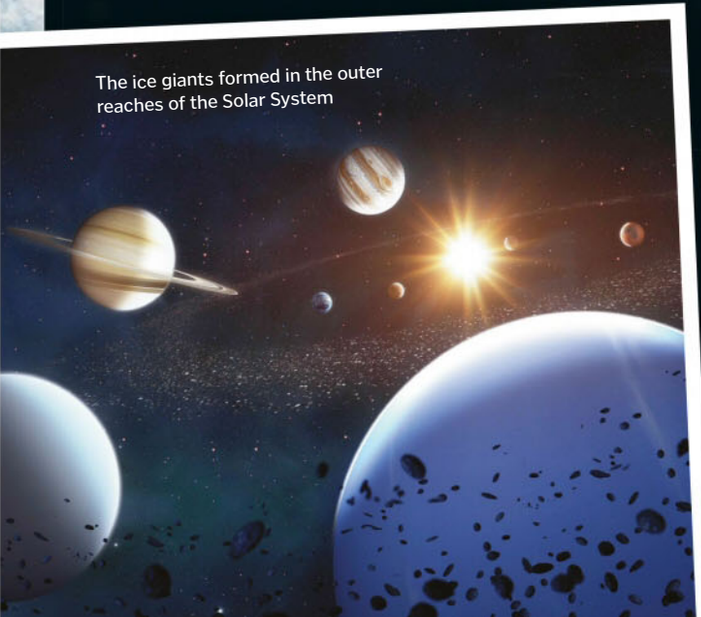
INSIDE THE ICE GIANTS

What do we think is hiding beneath the atmospheres of these two fascinating planets?

Core
A rock body made of iron and nickel at least 0.5 times the mass of Earth is thought to be hiding at the core of Uranus.

Mantle
The mantle of Uranus is thought to contain ammonia, water and methane ices, giving rise to its 'ice giant' title.

Composition
Uranus' outer atmosphere is thought to be composed of 82.5 per cent hydrogen, 15.2 per cent helium and 2.3 per cent methane.



The ice giants formed in the outer reaches of the Solar System

"Only one spacecraft has ever visited these two worlds"

NASA is considering sending a new mission to Uranus or Neptune

DID YOU KNOW? *Uranus was found by William Herschel in 1781, but Neptune wasn't spotted until 1846 by Urbain Le Verrier*

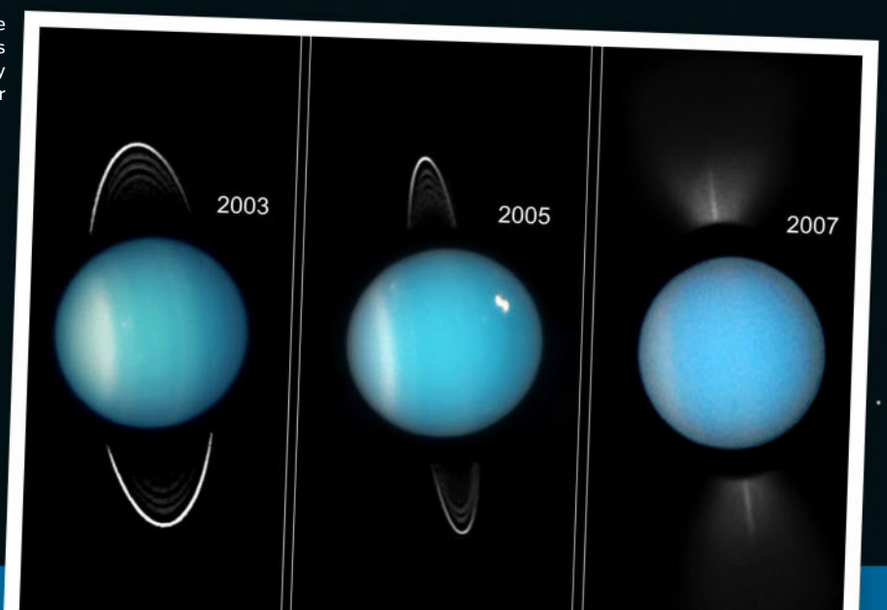
Composition
We think Neptune's outer atmosphere is made of 80 per cent hydrogen, 19 per cent helium and one per cent methane.

Mantle
Like Uranus, the mantle of Neptune is thought to consist of ammonia, water, methane and other ices.

> *"Scientists propose that it may rain diamonds on these planets"*

Core
Unlike Uranus, the rocky core of Neptune is at least the mass of Earth, but like Uranus, is thought to be made of iron and nickel.

The Hubble Telescope has helped us study Uranus from afar



DISCOVER THE PAST!

www.historyanswers.co.uk

ALL ABOUT HISTORY

Available from all good newsagents and supermarkets

ON SALE NOW

Viking Justice • Hitler vs the Mob • China's Dragon Empress • London's Lost Frost Fairs

BUY YOUR ISSUE TODAY

Print edition available at www.myfavouritemagazines.co.uk

Digital edition available at www.greatdigitalmags.com

Available on the following platforms

Print | Tablet | Phone | Desktop

facebook.co.uk/AllAboutHistory

twitter.com/AboutHistoryMag

Extreme ultraviolet Sun

Discover the different faces of the Sun when they are viewed at different wavelengths

SUNSPOTS
Wavelength: **Visible light, approx. 400–700nm**

These cooler, dark areas are the result of a disturbance in the magnetic field on the Sun's surface. They can reach temperatures of around 3,500 degrees Celsius and enormous diameters of up to 80,000 kilometres.

UPPER PHOTOSPHERE/TRANSITION REGION
Wavelength: **Ultraviolet, 160nm**

Here, the Sun's atmosphere appears somewhat granulated. The temperature of the photosphere can range from around 3,700 to 6,200 degrees Celsius; the temperature increases closer to the core.

TRANSITION REGION/ CHROMOSPHERE
Wavelength: **Extreme ultraviolet, 30.4nm**

Between 400 and 2,100 kilometres from the Sun's surface, the chromosphere can range from 3,700–7,700 degrees Celsius. Unlike the photosphere, the temperature increases further away from the surface.

CORONAL LOOP
Wavelength: **Extreme ultraviolet, 17.1nm**

Bright loops of hot plasma protrude from the surface as dominant magnetic fields. These charged flows appear as large curving lines and can extend several thousand kilometres above the photosphere.

ACTIVE REGIONS
Wavelength: **Extreme ultraviolet, 21.1nm (purple) and 33.5nm (blue)**

Under extreme ultraviolet light, bright regions of intense magnetic energy can been seen. These regions of very complex magnetic activty can give rise to solar flares and corona flare ejections.

CORONA/FLARE PLASMA
Wavelength: **Extreme ultraviolet, 19.3nm**

The corona is the outermost layer of the Sun's atmosphere and can only ever be seen with the naked eye during a total eclipse. Temperatures in this top layer exceed 499,727 degrees Celsius. Exactly why the corona is so much hotter than the photosphere and chromosphere below remains a mystery to scientists.

FLARE REGIONS
Wavelength: **Extreme ultraviolet, 13.1nm**

Electromagnetic energy builds up to a critical point before erupting and radiating from the Sun's atmosphere. Varying in degrees of severity and duration, most flares can last from minutes to hours.

Planetary nebulae

How the death of a star can create intricate cosmic gas clouds

Despite their name, planetary nebulae have nothing to do with planets. These gas shells are formed when smaller stars (those between around 0.8 to eight times the mass of our Sun) run out of hydrogen fuel for fusion. As fusion slows, the core becomes unstable and shrinks, becoming increasingly hot, allowing the fusion of helium into heavier atoms such as carbon and oxygen. The radiation pressure from this second cycle of fusion causes the star's outer layers to expand, transforming it into a red giant.

However, once the helium runs out, lower-mass stars are not hot enough to sustain further fusion of even heavier elements. The radiation pressure from the final throes of helium fusion pushes the red giant's outer layers away into space, creating cloud-like gas shells. The stellar core that remains at the centre of the cloud emits radiation, ionises the ejected gases, making the planetary nebula visible to us.

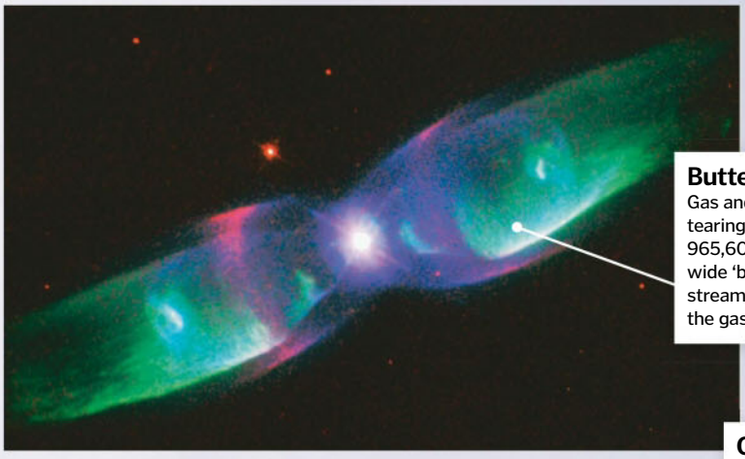
In cosmic terms, planetary nebulae don't last very long. After about 10,000 years, the remnant star cools to the point it no longer emits enough energy to ionise the surrounding cloud, rendering the nebula invisible to us.

The Cat's Eye Nebula

How did this swirling pattern of gas and dust form?

Massive shells
It is estimated that each of the Cat's Eye's gas shells contain as much mass as all the planets in our Solar System combined.

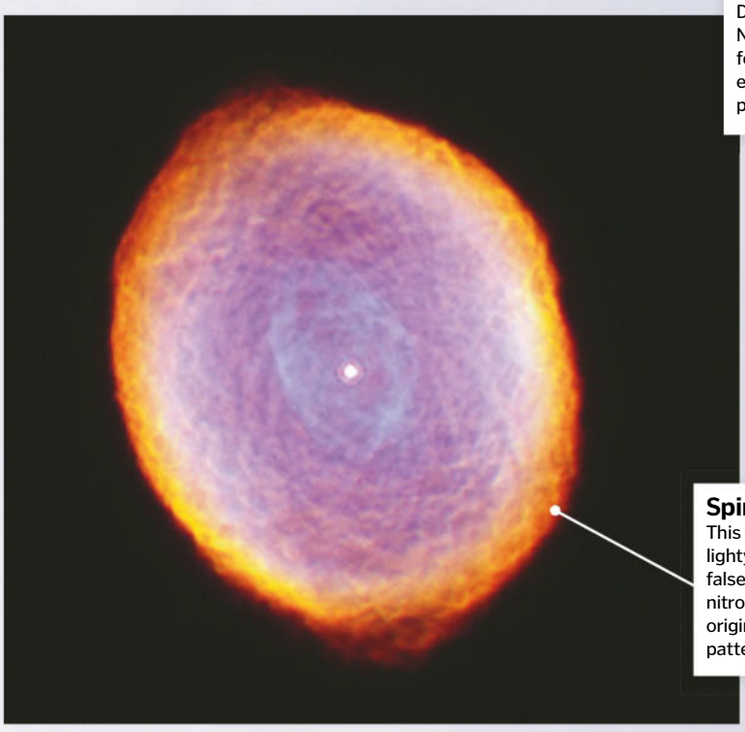
Stellar core
Planetary nebulae surround the remains of dying stars. Many of these remnants are incredibly hot as the former red giant's core continues to contract.



Butterfly Nebula, NGC 6302
Gas and dust ejected from a dying star tearing across space at over 965,600kph forms this two-lightyear-wide 'butterfly'. Ultraviolet radiation streaming off the stellar core causes the gases to glow.

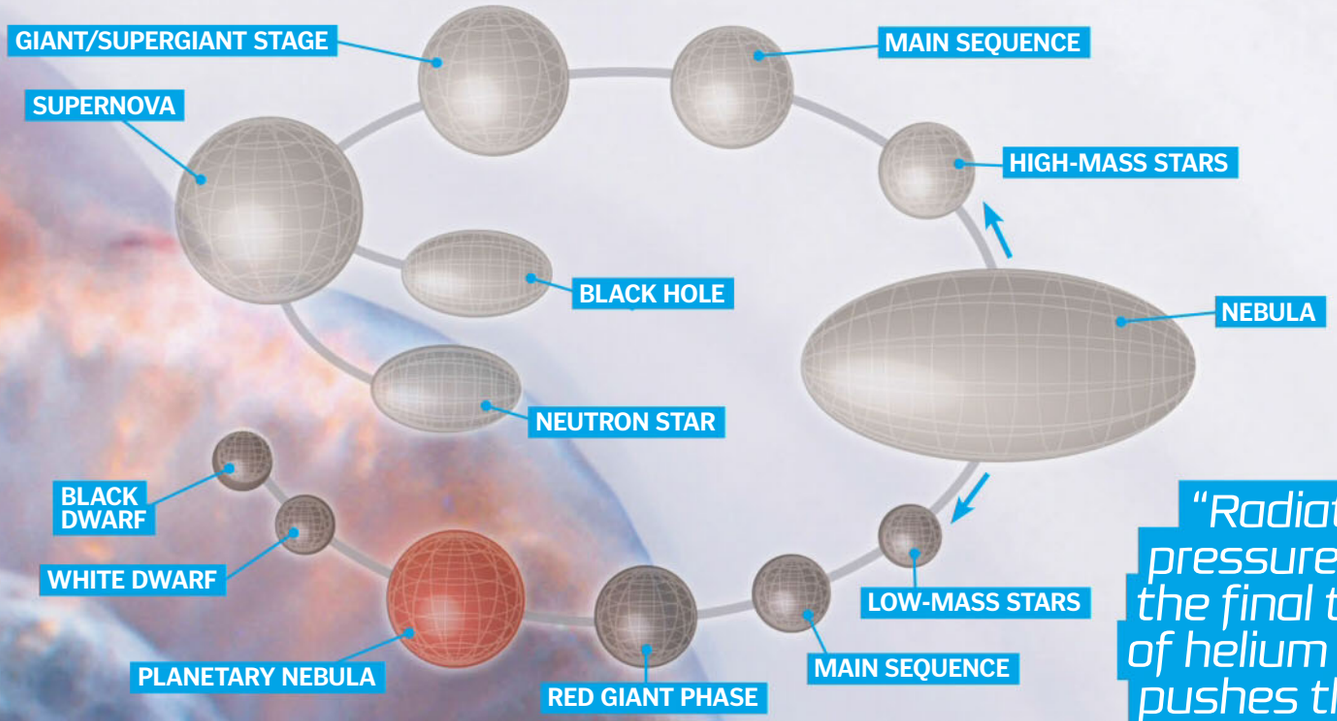
Concentric clouds
Distinct shells in the Cat's Eye Nebula are thought to have formed as the central star ejected its mass in a series of pulses 1,500 years apart.

Complex formation
The Cat's Eye Nebula was among the first planetary nebulae discovered by astronomers and is one of the most complex we know of.



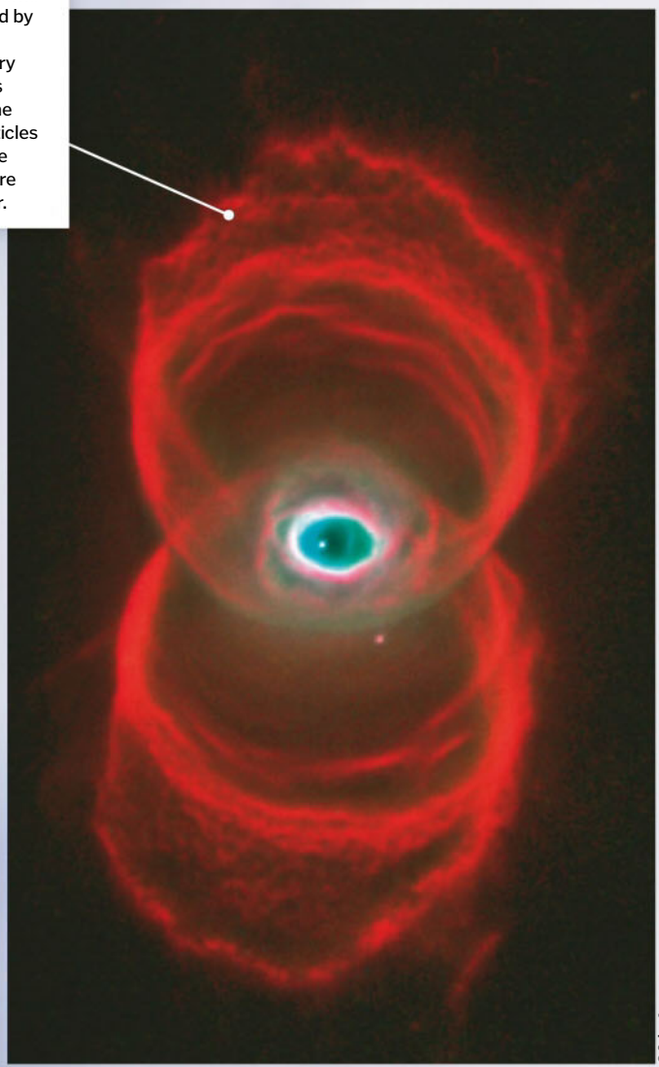
Spirograph Nebula, IC 418
This planetary nebula is around 2,000 lightyears away from Earth. This false-colour representation shows ionised nitrogen in red and oxygen in blue. The origins of its intricate spirograph-like patterns are not well understood.

Ionisation
Radiation from the stellar core transfers energy to gas molecules in the nebula, causing them to emit high-energy photons and glow in various colours depending on their constituent elements.

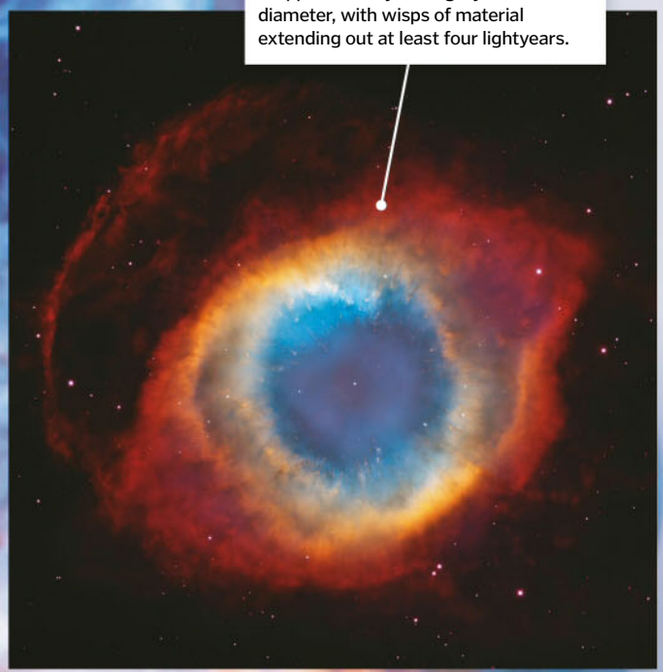


"Radiation pressure from the final throes of helium fusion pushes the red giant's outer layers away"

Engraved Hourglass Nebula, MyCn 18
It is thought that an extreme magnetic field generated by the stellar core of this relatively young planetary nebula contributes to its figure of eight shape. The rings are formed as particles become trapped in these fields, glowing as they are ionised by the dying star.



Helix Nebula, NGC 7293
At a distance of around 700 lightyears, the Helix Nebula is one of the closest planetary nebulae to Earth. Its main ring is approximately two lightyears in diameter, with wisps of material extending out at least four lightyears.



THE STORIES, STRATEGIES, HEROES & MACHINES

www.historyanswers.co.uk

HISTORY of WAR

Available from all good newsagents and supermarkets

ON SALE NOW

Hitler's Wolfpacks > Ia Drang > Spanish-American War > U-48 > Sparta's Nemesis > Butcher Cumberland

GREAT BATTLES

MILITARY MACHINES

HEROES OF WAR

SECRETS & INSIGHT

INCREDIBLE PHOTOS

BUY YOUR ISSUE TODAY

Print edition available at **www.myfavouritemagazines.co.uk**

Digital edition available at **www.greatdigitalmags.com**

Available on the following platforms

Print | Tablet | Phone | Desktop

facebook.com/HistoryofWarMag twitter.com/@HistoryofWarMag

The shape of the universe

Does the cosmos have a shape? And why does it matter?

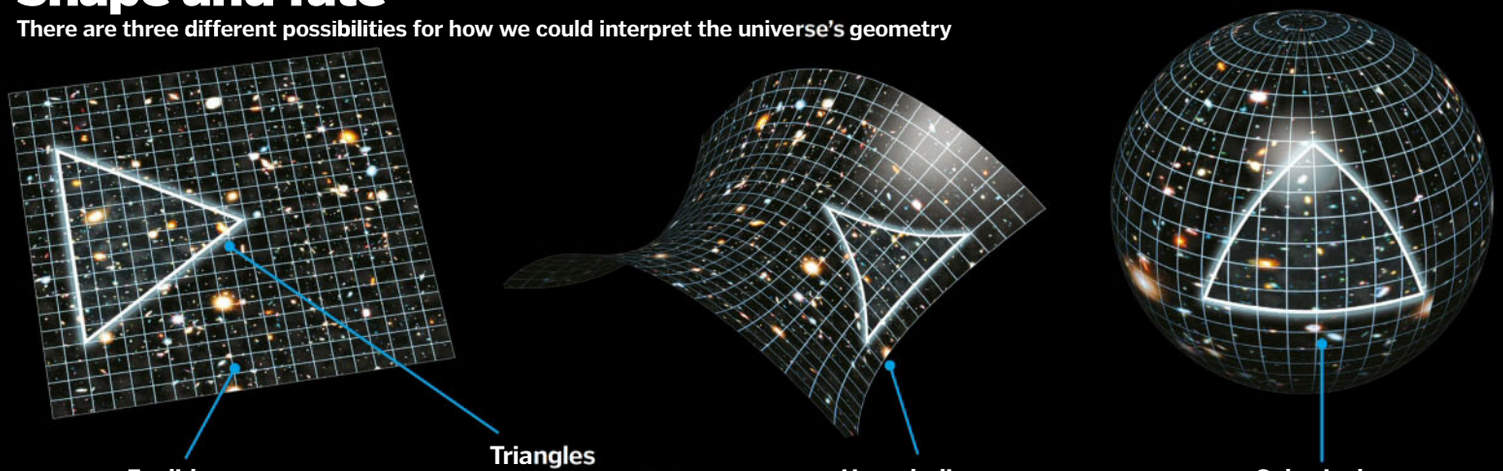
It is a concept that once divided the scientific community: do we exist in a spherical or flat universe? Einstein's theory of General Relativity suggests that space is curved by mass, and so the universe's density (its mass spread over its volume) determines its shape. We also know that the universe is expanding as a result of the Big Bang, and scientists have calculated a value known as the critical density — the minimum density required to prevent the universe from expanding indefinitely, while also stopping it from collapsing in on itself.

By comparing the universe's actual and critical densities, cosmologists can predict the shape of our universe and also its eventual fate. For example, if the actual density were greater than the critical density, the universe would look like a sphere. If this is the case, the universe is finite and will one day stop expanding and start to contract.

However, the concept of a flat (Euclidean) universe is now the most widely accepted theory. In this case, the actual density of the universe is equal to its critical density, without causing it to curve one way or another. If this theory is correct, the universe will continue to expand forever.

Shape and fate

There are three different possibilities for how we could interpret the universe's geometry



Euclidean
Space has zero curvature — in other words it doesn't curve positively or negatively and continues to expand forever.

Triangles
If we could physically draw a triangle in space connecting three points in the universe, the effective shape and angles of each triangle would change for each eventuality, remaining at a total of 180 degrees in a flat universe.

Hyperbolic
Space has a negative curvature, appearing as a saddle. The expansion of this open universe is infinite.

Spherical
Space has a positive curvature, curving to the point that it comes back on itself, forming a sphere. As a closed universe, the amount of expansion is finite.

Shoemaker-Levy 9

The comet that left scars on Jupiter so large they were visible from Earth

Comet Shoemaker-Levy 9 was discovered by astronomers Eugene and Carolyn Shoemaker and David Levy in 1993, a year before astronomers witnessed its spectacular collision with Jupiter. The gas giant's immense gravitational pull forced the comet to break apart into 21 smaller fragments, before plummeting to the planet's surface.

Individual fragments of the comet crashed down on Jupiter over the course of several days, creating visible bruises on the surface and ending its 4-billion-year journey through the Solar System. The impressive marks left on Jupiter were so clear that small telescopes on Earth could see them.

The scars left by Shoemaker-Levy 9 are no longer visible to us, having been erased by Jupiter's winds. The comet, however, did more than just make a mark on the surface: it caused the thin ring surrounding Jupiter to tilt by around two kilometres. As it struck the surface at 60 kilometres per second, the force of the impact and the dust expelled pushed the ring outward.

The impacts began on 16 July 1994 and ended on 22 July 1994, allowing astronomers to see the comet's fragments hitting Jupiter's surface

MEET THE EXPERT

Marcus Leach is an adventure athlete with a passion for food and creating a sustainable future. He started experimenting with edible insects as an alternative protein source and now incorporates them into his diet regularly, devising tasty recipes to encourage others to do the same.

SHOULD WE EAT INSECTS?

As the world's population continues to grow so too does the need for more food, but are insects really the answer?

We live in an exciting world, one full of promise, innovations and opportunities. But we also live in a world that has significant challenges, such as a rapidly growing population. If global population growth continues to increase at its present rate, then by 2050 there will be close to 10 billion people in the world.

Feeding a burgeoning and ever-more demanding population is going to require a dramatic increase in food production, with estimates suggesting we will need to increase food production by 70 per cent. Which presents us with the question of how? Can we not simply increase the scale of what we are already doing? No is the simple answer.

Resources such as land, oceans, water and energy are already limited, and the sheer quantity of land and water required by the global livestock industry is placing an enormous strain on the environment, not to mention the impact it's having in terms of pollution. The industry emits more greenhouse gases than planes, trains and automobiles combined.

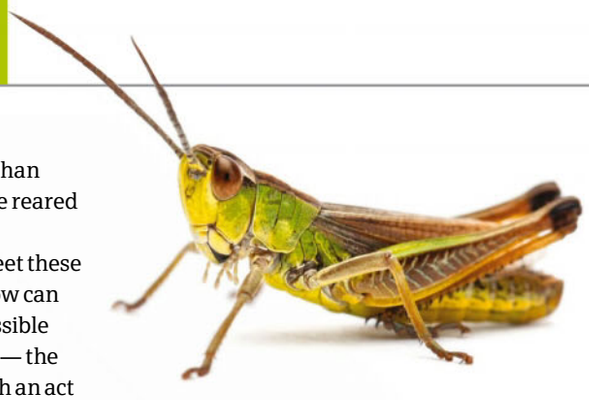
Then there is the degradation of natural resources as a result of crop production and land required to raise livestock, with the Amazon Rainforest being a prime example. Pasture now accounts for 70 per cent of its previously forested land, with feed crops covering a large part of the remainder. And last but by no means least is the animals' welfare. A quick internet search of

Today, 2 billion people across the world eat approximately 1,900 species of insects

'feedlots' is enough to highlight the less than satisfactory conditions many animals are reared in for mass meat production.

So what's the solution? How can we meet these ever-increasing demands for protein? How can we feed nearly 10 billion people? One possible answer to that question is entomophagy — the eating of insects. The very thought of such an act is enough to fill some people with a sense of repulsion, and yet our often common prejudgement towards entomophagy is not justified from a nutritional or environmental perspective. Insects are healthy, nutritious alternatives to mainstream staples such as chicken, pork, and beef. They are rich in protein, high in good fats and boast an array of micronutrients essential to the human body.

While an alien concept to many in the Western world, there are around 2 billion people worldwide for whom insects are a regular part of their diet. In most Western countries, however, people view entomophagy with a sense of disgust and associate eating insects with primitive behaviour. Such negative feelings do little to dispel the common misconception that people who eat insects in the developing world do so because of starvation. Many of those who eat insects do so not because there is little else



available to them, but instead due to the taste and the fact they have long been part of local food cultures; some are even seen as delicacies.

Delicacies or not, edible insects fit the mould from an environmental point of view. Research has shown that crickets are twice as efficient in converting feed to protein as chicken, at least four times more efficient than pigs and 12 times more efficient than cattle, and what's more, they require significantly less quantities of feed, and much less water, than livestock. However, a word of caution. On the face of it, given their nutritional content and the reduced resources required to rear them in comparison to meat, insects seem a viable solution to the need to produce more sustainable sources of protein. Yet it's hard to say what effect the mass production of insects would have on the environment, or if indeed it would be sustainable in the long term.

Many of the 2 billion people who already include insects in their diet do so having caught them in the wild, as opposed to buying them from the large-scale insect farms that would be required to produce the quantities needed for larger populations. That's not to say it's not viable, only that at this stage the full extent of such production is not yet known.

"Insects are healthy, nutritious alternatives to mainstream staples"

© Marcus Leach; Getty; Thinkstock

Insects are widely eaten in many countries

Comfort food with a twist: macaroni cheese with buffalo worms

Try a tasty insect recipe

For those still on the fence about eating bugs, try disguising them in these chocolate and cherry cricket brownies...

INGREDIENTS
- 125g of cashew nuts
- 250g of Medjool dates
- 75g of sour Morello cherries
- 50g of cricket flour
- 30g of raw cacoa powder
- 1 tablespoon of maple syrup

INSTRUCTIONS

Place the cashew nuts in a food processor and pulse them for 15 seconds until they are chopped into small pieces.

Now add in the dates, cherries and cacao powder and blitz for 20 seconds. Then add in the cricket flour and maple syrup and blitz until all of the ingredients form into a ball. This may take a few minutes but you will notice a sudden change in the texture and consistency of the ingredients.

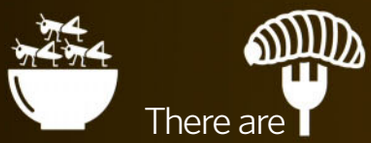
Roll the ball out on greaseproof paper until you have a neat rectangle and then place it in the freezer for 20 minutes to set. Once the mixture has set, remove it and cut it into squares, then keep it in the fridge in a sealed container.

Try converting cricket critics with this deceptively nutritious sweet treat

INCREDIBLE INSECT STATS

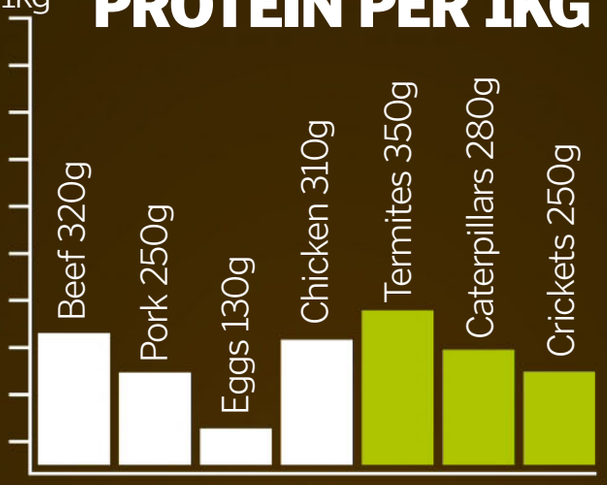
Insects are cold-blooded and do not require feed to maintain body temperature

80%
of plants rely on insects for pollination



There are
1,900
known different species of edible insects

PROTEIN PER 1KG

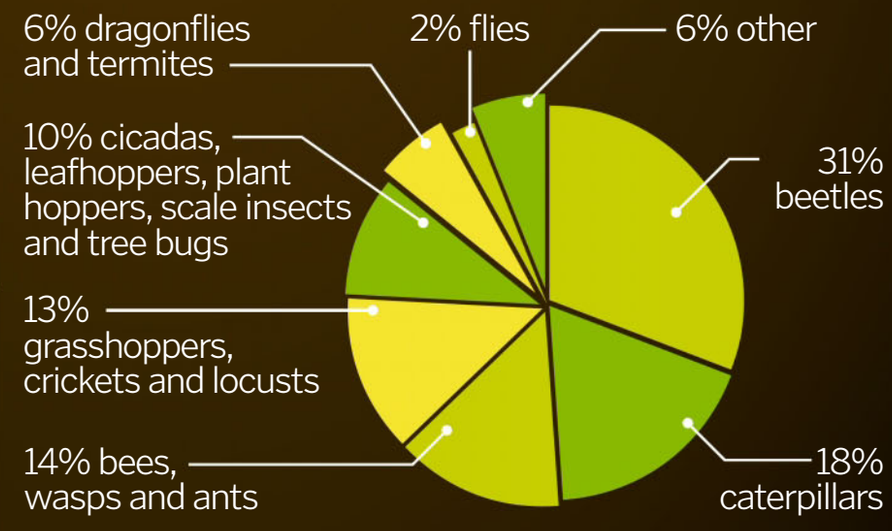


A cow takes **8kg** of feed to produce 1kg of beef, but only **40%** of the cow can be eaten. Crickets require just **1.7kg** of food to produce 1kg of meat, and **80%** is considered edible

1kg of crickets produce just **2g** of CO_2, while cattle produce **2,850g** of CO_2 per 1kg of meat

99%
of insects are not 'pests'

OF THE EDIBLE INSECTS...



36 African countries are entomophagous, as are **23** in the Americas, **29** in Asia and even **11** in Europe

100g of red ant provides: 14g protein (more than eggs); nearly 48g calcium; a nice hit of iron among other nutrients; and all that in less than **100 calories**

Encouraging more people to incorporate insect-based foods into their diets could help reduce pressures on agricultural land space

"By 2050 there will be close to 10 billion people in the world"

Sugar-free scorpion lollies are readily available from a host of online shops

Overcoming the Western aversion to insects would mean we could obtain protein from much more sustainable sources

With growing concern about sustainable agriculture, insect-based foods are becoming more widely available

And yet, while insects are commonly consumed as a food source in many regions of the world, Western societies are still largely averse to the practice of eating them because of the very fact they are insects. We have always seen insects as little more than pests, bugs, creepy crawlies, even objects of disgust — never as a food source. As American naturalist Joseph Charles Bequaert said, "What we eat is, after all, more a matter of custom and fashion than anything else. It can be attributed only to prejudice that civilised men of today show such a decided aversion to including any six-legged creatures in their diet."

Our prejudices are hardly helped by minor celebrities being forced to eat insects on trivial reality television shows, a practice that only serves to reinforce and exaggerate people's disgust towards bugs. We need to be actively educating people about the benefits of edible insects in a bid to try and change their perceptions and food preferences, which isn't always easy but by no means impossible. Lobsters and shrimp were once considered to be a mark of poverty, but are now considered luxury food items, and what's more, they belong to the same arthropod family as insects. So it begs the question, if we can change our thinking towards lobster, then why not insects?

While education surrounding the nutritional and environmental benefits of insects needs to play a part, there also needs to be a focus on creating attractive dishes that people actually want to eat. If we are to break down mental barriers and change people's mindsets then we need to do so with dishes that not only taste great — insects boast a wide variety of flavours — but appeal visually as well.

For someone not sure about eating grasshoppers, the last thing they want is to see one staring up at them from their plate. As with any change, it takes time, and at present the edible insect industry is still in its infancy, although it's growing rapidly as more people become aware of the benefits to the environment and also themselves.

As the world's population continues to swell so does the need to dramatically shrink agriculture's environmental footprint, meaning that we will need to look for more ethical and sustainable food sources very soon. Entomophagy isn't the only viable option available, but it is one solution, meaning insects have a valuable role to play in the future of our world and the people that live in it. And, with every year that passes, that role is only going to get bigger. Grasshopper stir-fry anybody?

How to add more grubs to your grub

Want to try insects but not sure where to start? The easiest way to incorporate insects into your diet is by using cricket flour (available from **www.eatgrub.co.uk**), which is incredibly versatile and can be used in all manner of recipes, especially when baking or making natural energy bars. For those wanting the 'whole bug' experience, you could try a fresh stir-fry with roasted grasshoppers tossed in.

"We need to be actively educating people about the benefits of edible insects"

Feeling peckish? How about tucking into a crispy beetle?

Insect skewers are a very popular snack in many parts of Asia, including China and Japan

BE INSPIRED BY NATURE

www.animalanswers.co.uk

World of Animals™

Available from all good newsagents and supermarkets

On sale now

ANIMAL VISION · ALL ABOUT THE CAMEL · REINDEER · CHRISTMAS CREATURES

BUY YOUR ISSUE TODAY

Print edition available at www.imagineshop.co.uk

Digital edition available at www.greatdigitalmags.com

Available on the following platforms

Print · Tablet · Phone · Desktop

worldofanimalsmag · @WorldAnimalsMag · animalanswers.co.uk

The Crooked Forest is near the western border of Poland, about 550 kilometres from Warsaw

Crooked Forest

The mysterious woodland where some trees appear to defy the laws of nature

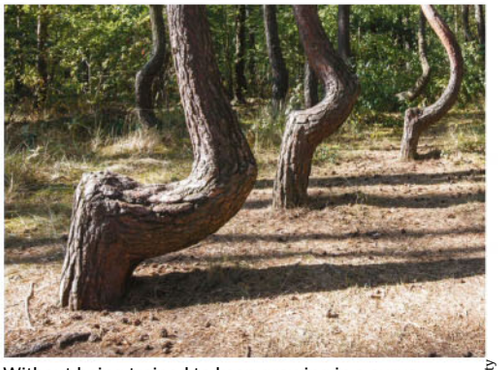
It is not uncommon to see trees curve and bend as they grow, but some of the pine trees in Poland's Krzywy Las are bizarrely deformed. Commonly known as the 'Crooked Forest', 400 pine trees protrude from the ground vertically until suddenly deciding to grow horizontally, creating an abrupt 90-degree bend. Most of the trees bend towards the north.

It has been estimated that the forest was planted in the 1930s in the hopes of harvesting the wood once they had grown. As an isolated portion of the woodland, various hypotheses have been proposed to explain the curvature of only some of the trees. Some have suggested that heavy snowfall over a lengthy duration flattened the trees while they were still saplings. Others suggest it may be the result of a genetic mutation, or due to sprout damage caused by tanks during World War Two.

However, the dominant theory to explain these wooden wonders, is one of human manipulation rather than natural defiance. It is thought that farmers restrained and manipulated the way some of the pines grew in order to later use the wood for curved furniture and the construction of boat hulls.

Manipulating trees to form desirable shapes is something we still see today. Pleaching, for example, is a method that trains trees like ash or beech to intertwine and form a curved canopy walkway. However, due to the German invasion of Poland in September 1939, farmers had to abandon this woodland, leaving a curious crooked wood behind.

It is estimated that these trees were seven to ten years old when the curves developed



Without being trained to keep growing in a curve, these pines will continue to grow vertically

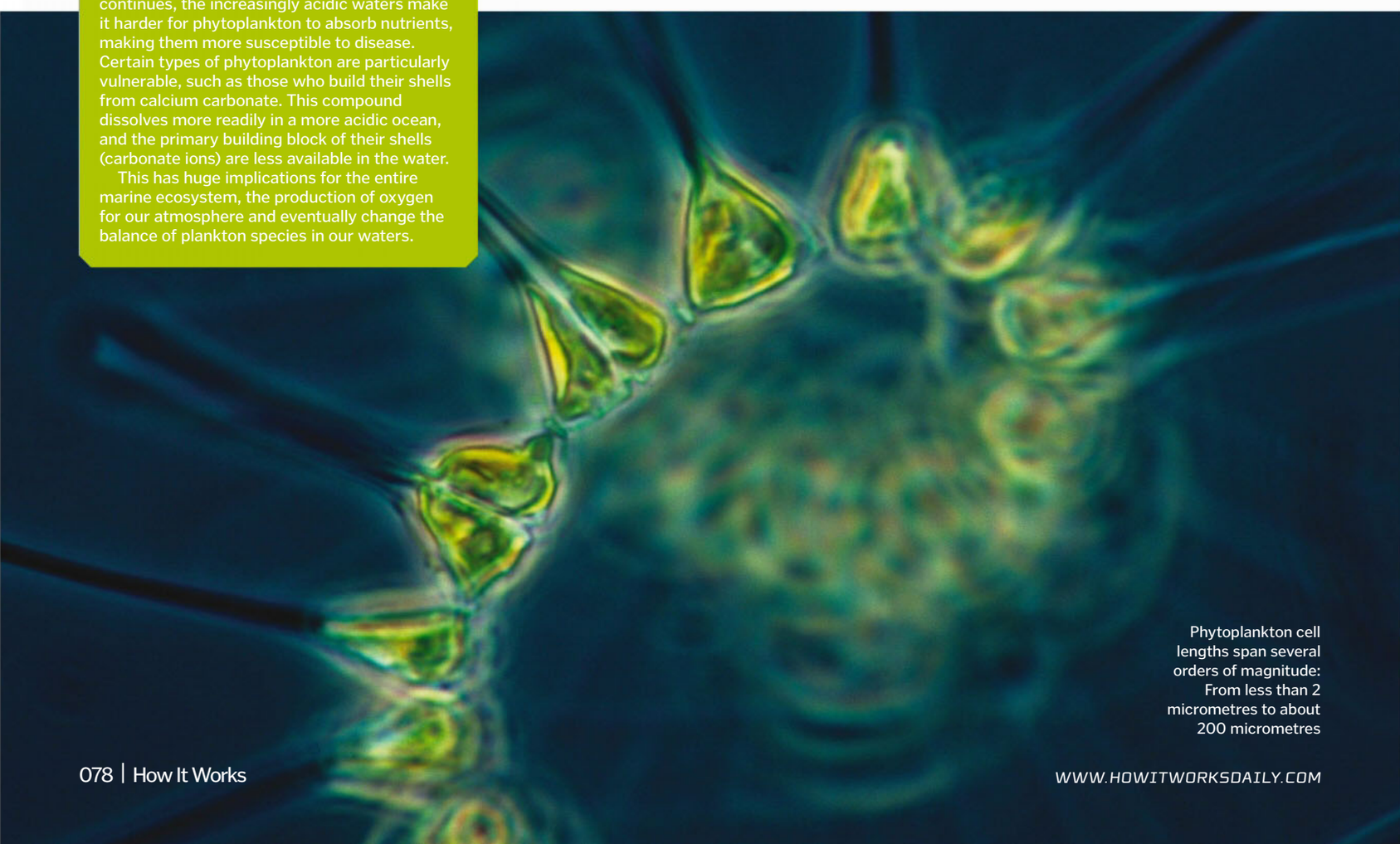
Diatoms are some of the largest and fastest-multiplying types of phytoplankton. Some can reproduce up to 100,000 times in a month!

The acid threat

Due to a higher level of carbon dioxide in the Earth's atmosphere, in part caused by the burning of fossil fuels, a higher level of carbon dioxide is absorbed into the oceans. This lowers the water's pH and causes the seas to become more acidic.

Since the Industrial Revolution, levels of carbon dioxide in the atmosphere have increased from 280 parts per million (ppm) to over 400ppm. As ocean acidification continues, the increasingly acidic waters make it harder for phytoplankton to absorb nutrients, making them more susceptible to disease. Certain types of phytoplankton are particularly vulnerable, such as those who build their shells from calcium carbonate. This compound dissolves more readily in a more acidic ocean, and the primary building block of their shells (carbonate ions) are less available in the water.

This has huge implications for the entire marine ecosystem, the production of oxygen for our atmosphere and eventually change the balance of plankton species in our waters.



Phytoplankton cell lengths span several orders of magnitude: From less than 2 micrometres to about 200 micrometres

The importance of phytoplankton

Forget whales, sharks and the giant squid: it's the smallest living organisms in the briny blue that keep life on our planet working as it should

Phytoplankton are the definition of the phrase 'all good things come in small packages'. Simply put, most of these little ocean drifters are microscopic, single-celled plant-like organisms that photosynthesise and can be found in both marine and freshwater and are present in all of the world's oceans. They live in the euphotic zone (the topmost layer of the ocean) where sunlight is plentiful. There are so many that if you scooped up a Coke can of seawater you'd probably have bagged yourself as many as 75–100 million individual phytoplankton.

Accompanying the phytoplankton in this heady mix of ocean soup are the zooplankton, which are tiny animals — some are the larval stages of much bigger creatures, others will remain as just tiny beasts. All plankton are unable to swim against the ocean currents and so they float at the mercy of the waves. However, there are areas where more phytoplankton occur, usually where upwelling (deep, cold water rises up to the surface) brings essential nutrient-rich water to the surface.

Phytoplankton are crucial for life on Earth — it's almost unimaginable to think of a world without them. The tiny organisms form the basis of the entire oceanic food web, photosynthesising to turn sunlight into energy and providing food for small filter-feeders and grazers, which in turn are food for larger animals, including the fish on our own plates.

The phytoplankton also have a huge impact on our atmosphere as they are responsible for producing at least 50 per cent of Earth's oxygen. They are also an important carbon sink, taking in carbon dioxide from the atmosphere that is then pulled to the bottom of the ocean when the phytoplankton dies. Over millions of years these plankton (along with other marine creatures and organic matter) build up in layers on the seabed, which, under intense pressure and heat, can form oil or natural gas.

Some species of phytoplankton are bioluminescent — they emit light when they are disturbed

Tracking the blooms

When ocean conditions are right, the plankton population can boom very quickly. In just a few days (or sometimes even hours) a stretch of clear blue ocean can be transformed into a soupy green liquid — this happens to such an extent that great swathes of plankton blooms are easily visible from space.

This ability to watch the plankton from afar has allowed scientists to build up a comprehensive study of plankton blooms over many years, which in turn can be used as an indicator of global climate changes. Satellite imagery shows where the blooms are occurring, along with the size, rate and density of the bloom. They can also identify the type of plankton and even track the development of harmful algal blooms. While most phytoplankton blooms are non-toxic, there are some species that can cause harmful or toxic effects in marine animals and humans.

Blooming in the lakes, seas and oceans, plankton can clearly show the whirls and tracks of currents

"The tiny organisms form the basis of the entire oceanic food web"

Common types of phytoplankton

Not to scale

There are around 5,000 types of phytoplankton. Here are five of the most common ones

Cyanobacteria

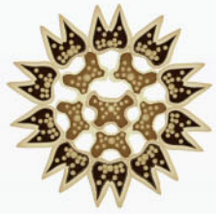
Not actually algae, these bacteria were the first organisms to produce significant volumes of oxygen via photosynthesis some 2.4 billion years ago — changing the Earth's atmosphere forever.

Diatom

A common type of phytoplankton, the diatom's cell wall is made of silica (which is the main component of glass) and the many beautiful perforations allow nutrients to enter and remove waste.

Dinoflagellate

Some dinoflagellates are bioluminescent while others produce toxic 'red tides' that are lethal to marine life. They have 'flagella', tiny whip-like structures that allow for movement in the water.



Green algae

Members of this huge, informal group of algal types (which contains about 8,000 species) are the ancestors of land plants. They live as single cells as well as forming large colonies in marine and fresh water.

Coccolithophore

The single cell of the coccolithophore is covered in minuscule discs made of calcite, or chalk, which accumulate on the seabed when the cell dies. Billions of coccolithophores created the white cliffs of Dover.

Special offer for readers in **North America**

4 FREE issues

When you subscribe*

"The action-packed science and technology magazine that feeds minds"

Order hotline **+44 (0)344 848 2852**

Online at **https://www.myfavouritemagazines.co.uk/hiwusa**

OFFER EXPIRES 31 Jan 2018

***Terms and conditions** This is a US subscription offer. 4 free issues refers to the USA newsstand price of $9.99 for 13 issues being $129.87, compared with $87.08 for a subscription. You will receive 13 issues in a year. You can write to us or call us to cancel your subscription within 14 days of purchase. Payment is non-refundable after the 14 day cancellation period unless exceptional circumstances apply. Your statutory rights are not affected. Prices correct at point of print and subject to change. Full details of the Direct Debit guarantee are available upon request. UK calls will cost the same as other standard fixed line numbers (starting 01 or 02) are included as part of any inclusive or free minutes allowances (if offered by your phone tariff). For full terms and conditions please visit: bit.ly/magtandc. Offer ends 31 January 2018

Saharan dust

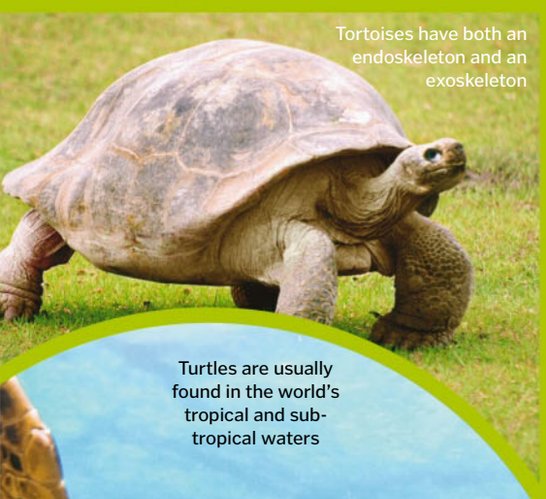
Discover how weather conditions can whip up sand from the Sahara Desert and carry it around the world

Saharan dust sweeps across the globe to South America, where it covers the Amazon Rainforest

Saharan dust is a mixture of dust and sand from the Sahara Desert. When very strong winds pass over the desert, this mixture blows up into the sky to form clouds, which can reach astonishingly high altitudes. Winds in the upper part of the atmosphere then transport these dust clouds, also known as the Saharan Air Layer, towards the UK.

The particles are capable of travelling thousands of kilometres on these dust-laden winds, crossing land and entire oceans where they even become visible on other continents. But you need something to wash it out of the sky. As rain falls from the atmosphere it collects the dust particles on the way down. When the raindrops land on a surface they evaporate, leaving behind a layer of dust. Not only does this dust layer result in hazy skies, but sometimes it also causes shorter-wavelength 'blue' light to be scattered away, leaving behind longer-wavelength 'red' light to shine through. This gives the appearance of orange-red skies.

Hurricane Ophelia transported dust from the Sahara Desert back in October 2017, creating orange skies over London



Tortoises have both an endoskeleton and an exoskeleton

Turtles are usually found in the world's tropical and sub-tropical waters

Turtles versus tortoises

They certainly look alike, but just how similar are these creatures?

The most obvious distinction between tortoises and turtles is where they live: tortoises are land dwellers, whereas most turtles reside in or around water. While both are reptiles from the order of Testudines, they are in different classification families and therefore have differing features.

Although both have bodies protected by a shell, a turtle's shell is lighter and flatter to prevent it from sinking and more streamlined to help it swim, while a tortoise's shell is larger and heavier and shaped like a dome to protect it from predators. Turtles also have webbed feet to aid swimming, while tortoises possess stubby feet for walking across various terrains.

Their habitats inevitably mean their diets differ too. Tortoises tend to be herbivores, whereas turtles are omnivores, feasting on vegetation as well as small fish and insects. However, a key similarity is that both species lay their eggs on land. A female turtle will leave the safety of the water to lay her eggs before quickly returning to the sea: her hatchlings have to make the dangerous journey to the sea alone. Tortoise hatchlings, however, stay with their mother for about 80 days.

The lifespan of a common turtle is around 20–40 years, but green sea turtles can live for around 80 years or more. A tortoise's lifespan is longer, averaging 80–150 years.

BRAIN DUMP

Because enquiring minds need to know...

MEET THE EXPERTS

Who's answering your questions this month?

Laura Mears

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

Alexandra Franklin-Cheung

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

Tom Lean

Tom is a historian of science at the British Library where he works on oral history projects. He published his first book, *Electronic Dreams: How 1980s Britain Learned To Love The Home Computer,* in 2016.

Katy Sheen

Katy studied genetics at university and is a former **How It Works** team member. She now works for a biomedical journal, where she enjoys learning about the brilliant and bizarre science of the human body.

Joanna Stass

Having been a writer and editor for a number of years, **How It Works** alumnus Jo has picked up plenty of fascinating facts. She is particularly interested in natural world wonders, innovations in technology and adorable animals.

Angular momentum has 'flattened' most galaxies in our universe

Why aren't galaxies spherical like planets and stars?

Shelly Midsummer

Angular momentum leads most galaxies to flatten out over time, with all their planets, stars, asteroids and other objects existing roughly on a single plane. While the trajectories of individual objects within a galaxy may change, their collective angular momentum as they spin around their centre of mass remains constant. Picture a plane that is perpendicular to the galaxy's axis of rotation with objects initially moving above and below the plane. As these objects collide any upward or downward motion is progressively cancelled out, while the conservation of angular momentum dictates that they must keep spinning around the same axis, resulting in a flat, disc-like shape. **AFC**

Do carrier pigeons still exist?

Alice Orson

The English Carrier pigeon is a breed of domesticated pigeon that is descended from the rock dove. They are now bred as ornamental birds by pigeon fanciers. Carrier pigeons can be identified by their wattle, a fleshy white growth on their bill, and they are still around today.

Other specialist breeds include homing pigeons, which were used to carry messages, and racing pigeons, which were selectively bred for their enhanced speed and homing instinct for use in racing. **JS**

Carrier pigeons are fancy pigeons bred for show – not a bird used to deliver messages

Want answers? Send your questions to...

How It Works magazine | @HowItWorksmag | howitworks@futurenet.com

The ancestors of modern whales had four legs and lived on land

How did marine mammals evolve to return to the water?

Ella Dias

Mammals have gone back into the sea at least seven times. This has given us whales, porpoises and dolphins (Cetacea), sea cows and dugongs (Sirenia), seals, sea lions and walruses (Pinnipedia), polar bears, sea otters and two extinct groups: Desmostylia and aquatic sloths (Thalassocnus). Only Cetacea and Sirenia became fully aquatic. Around 50 million years ago, the ancestors of these two groups started to adapt to feeding and hearing in the water. They could still walk on land, but as they spent more and more time in the water their bodies began to change; their front legs became flippers and they started to grow tail flukes. By the end of the Eocene about 35 million years ago, both were living in the water full time. **LM**

Why are police officers' hats so tall?

Rachel Oliver

Wearing a tall custodian helmet makes a police officer look taller, adding to their authority. It also makes them easier to see, helping the public to find them and deterring criminals. **TL**

What was Ceefax?

Valerie Dawning

Ceefax was the world's first teletext information service launched by the BBC in 1974. So-called because it enabled viewers to 'see the facts' at their fingertips; it provided quick updates on news headlines, sports scores, weather forecasts and TV listings in the pre-internet era. It was developed by BBC engineers who, while exploring ways to provide subtitles on TV programmes, discovered that they could transmit full pages of text information in the spare lines at the top of pictures transmitted on the analogue TV signal. However, after 38 years on air, it was turned off when the digital switchover was completed in 2012. **JS**

How do vehicle speed limiters work? Kirsty Ennis

When a car's electronic sensors detect that it has reached the predetermined top speed, the engine's computer restricts air flow and fuel supplied to the engine, limiting its speed. **AFC**

Why are Martian sunsets blue? Kerry Newsom

Martian sunsets owe their blue tinge to fine particles of dust in Mars' atmosphere that scatter red light very uniformly and scatter blue light at slight angles. As the Sun sets, it shines through a thick slice of the atmosphere. Most red light is scattered away, while most blue light reaches the planet's surface. **AFC**

How is Queen Elizabeth II related to Queen Victoria?

Nathan Carver

Queen Elizabeth II is the great-great-granddaughter of Queen Victoria, great-granddaughter of Edward VII, granddaughter of George V, niece of Edward VIII and daughter of George VI. **JS**

Which city has the highest proportion of cycling commuters? Sigourney Marshall

According to the Copenhagenize Bicycle Friendly Cities Index, Copenhagen comes out on top with 62 per cent of its citizens riding a bike to work or education in the city every day. More people enter the city centre on bikes than in cars, and over €134 million (approximately £120 million / $160 million) has been invested in bicycle infrastructure in the last ten years. **JS**

BRAIN DUMP

Away from Earth, astronauts can be exposed to dangerous levels of cosmic radiation

Is Earth protected from cosmic rays?

Jerry Reed

■ Our planet's atmosphere and magnetic field protect us from cosmic rays — high-energy particles hurtling through space. Before even reaching Earth, some of the charged particles are deflected by the planet's magnetic field. Upon entering the atmosphere, the remaining particles collide with nitrogen and oxygen atoms, producing showers of lower-energy secondary particles that rain down on the Earth but are mostly harmless. Very few primary particles make it to the Earth's surface. **AFC**

How fast can a standard electric car charge?

Max Fischer

■ How fast an electric car charges depends on several factors, including the size of the battery and how you charge it. Cars can be plugged into a charger at home, but the lower-power electricity supply means it can take six to eight hours to fully charge. More powerful roadside charging points can fully charge many cars in just three to four hours, but the very fastest can provide an 80 per cent charge in just half an hour. **TL**

Electric car charging points are becoming an increasingly common sight on our streets

Why are koalas known as 'koala bears'? Nadine Ali

Koalas are marsupials, not bears, but they seem to have been given the name due to their big ears, rounded nose and cuddly body — similar to the classic teddy bear. **KS**

Who decides the collective nouns for things? Tina Sanchez

There isn't an academy or governing body that decides these nouns. Like all new terms or phrases, they simply become more popular over time. Although a 'parliament of owls' and a 'murder of crows' still sound peculiar, a 'pride of lions' and a 'school of fish' have steadily become everyday language. **KS**

What is 'biodynamic' farming? Delia Cross

It's a farming method based on the work of Dr Rudolf Steiner that emphasises the role of the farm as an ecosystem. It combines principles of organic farming with social responsibility and spirituality. **LM**

What was the Illuminati?

Dennis Warner

It was an 18th-century secret society set up by Bavarian professor Adam Weishaupt. He opposed the Roman Catholic Church and wanted to create a free and equal society based on reason rather than religion. They disappeared after a Bavarian government ban in 1785 but reappeared in conspiracy theories in the 1960s. **LM**

Why don't humans have as much hair as other primates?

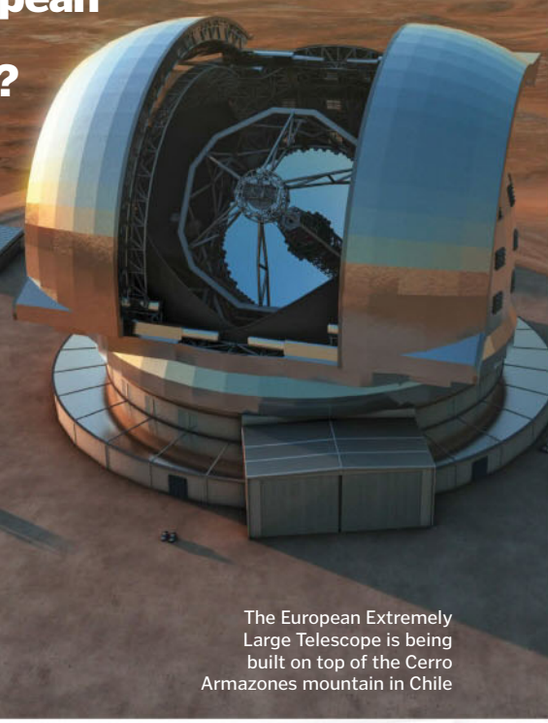
Lisa Preston

Humans evolved from apes, so our earliest human-like ancestors, known as hominins, were ape-like in appearance. Around 3 million years ago, it is thought that these early hominins would have been covered in fur, but between 2–3 million years ago they started to inhabit open savannahs where they were exposed to the glare of the Sun. They also started to hunt large animals, which required running over long distances. A hairy coat would have kept the hominins too warm for this new lifestyle, so it is thought that they gradually evolved to have less hair in order to keep cool. **KS**

What will the European Extremely Large Telescope look for?

Maria Hernandez

Due for completion in 2024, the Extremely Large Telescope (ELT) will be the largest optical and near-infrared telescope in the world. One major use will be to search for distant planets. Stars with planets orbiting them 'wobble', and by indirectly measuring how distant stars wobble the ELT will be able to discover new planets around them, possibly allowing astronomers to understand how new planets form. The ELT will also be used to help us understand how galaxies evolve, study black holes, probe the nature of the elusive dark matter and dark energy and perhaps even measure the continued expansion of the universe. **TL**



The European Extremely Large Telescope is being built on top of the Cerro Armazones mountain in Chile

Why are gargoyles used on churches?

Gargoyles are rooftop gutters, helping to divert rain away from buildings

Ryan Forger

Gargoyles are ancient drainage systems designed to funnel water away from buildings. They are often carved in the shape of a human, animal, or mythical creature with a channel cut throughthe throat. When it rains, water spills out of the gargoyle's mouth, preventing damage to the stone walls. They became more popular during the Gothic period, but not all examples are true gargoyles. Decorative statues without a waterspout are called 'grotesques'. **LM**

Is sleeping on a harder mattress really better for your back?

Izzy Truman

A soft mattress can cause back pain by allowing you to sink into a unnatural position, resulting in bad posture during sleep, which may cause pain later on. However, an extremely hard mattress can also leave you aching, as it will place too much pressure on the muscles in your back. The ideal mattress is firm rather than hard, so that your spine can relax in its natural position. **KS**

What is the furthest distance humans have travelled from Earth?

Kieran Hemsworth

In 1970 an accident forced Apollo 13 to abandon its mission of landing on the Moon. To get the damaged spacecraft home its crew ended up travelling 400,171 kilometres above the Earth's surface, the furthest distance that humans have ever travelled. **TL**

Natural Wonders of the World

Amazing facts about the most incredible and unique places in the world

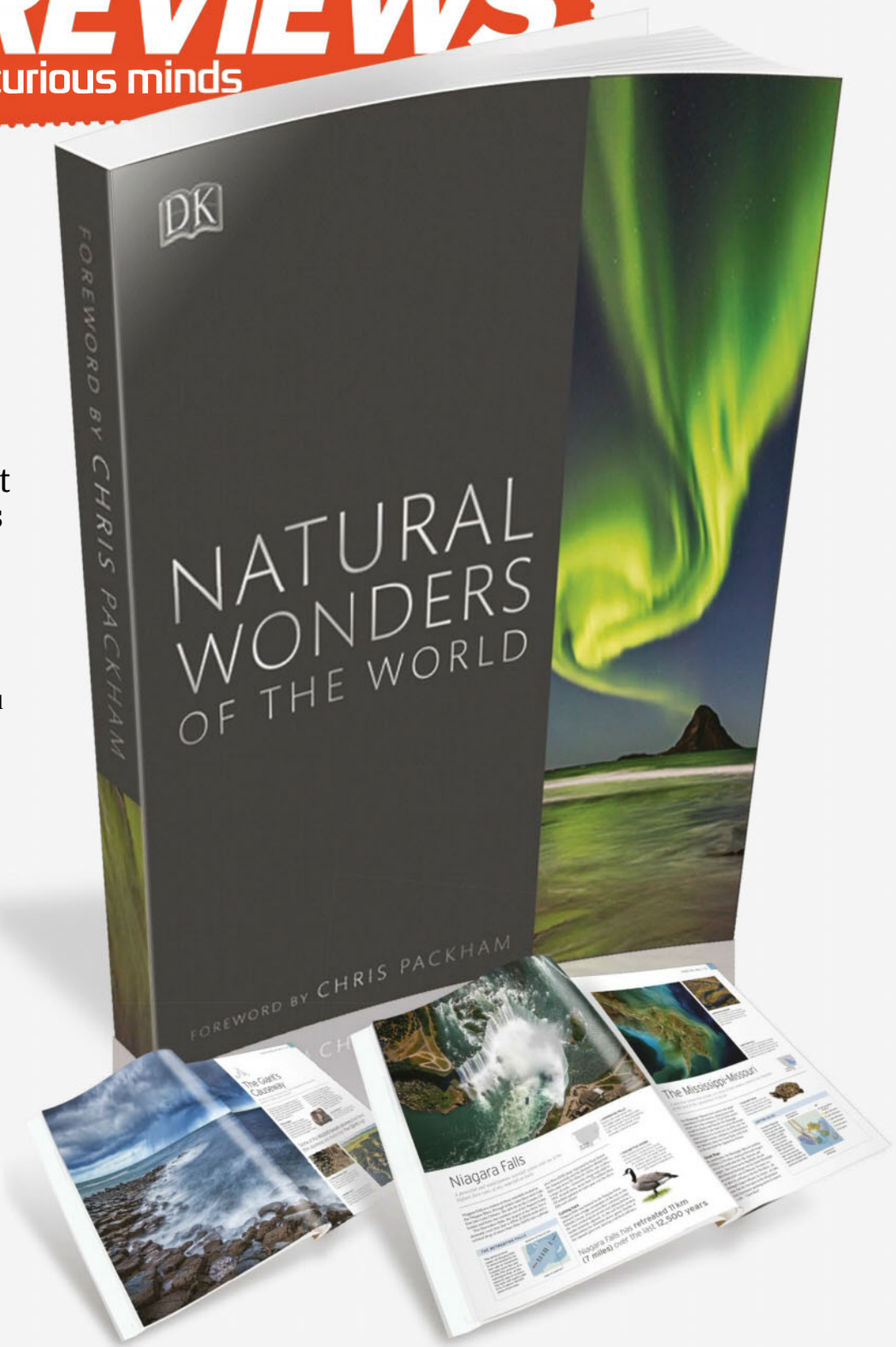
- Author: **Various**
- Publisher: **DK**
- Price: **£30 / $50**
- Release date: **Out now**

The world in which we live is an exceptional place. This planet is home to places of incredible beauty, astonishing locations that will leave you speechless, and views that once seen, can never be unseen. Some people are lucky enough to explore the world and see these captivating places, but for those of us that can't, this book will help to fill in the gaps.

While there are officially just seven Wonders of the Natural World, this book proves the real number is far greater. From huge, flowing glaciers that cascade down from Mount Blanc to magnificent rock formations in the middle of an Australian desert, these pages prove that there are wonderful sights all around us.

Divided into chapters that focus on continents (and two separate chapters for the oceans and extreme weather) this book covers the entire globe. These chapters are sub-divided into smaller sections, such as Rivers & Lakes and Tundras, which each contain a selection of examples from every continent. What's so brilliant about this layout is that even within the same continent all of the entries are so different, offering a new perspective on a country or landmass that you perhaps thought you already knew everything about.

> "This book will give you serious wanderlust — we're already planning our next trip"



Each of these locations is shown off with some truly stunning photography, often taken from locations that appear difficult to access and offer awe-inspiring views. Alongside the photography you'll find diagrams, illustrations and yet more magnificent images, all with clear and interesting explanations. There is plenty of information packed into the pages here, including geographical and geological insights into how some of these bizarre structures came to be, but it is the photography that is the star from start to finish.

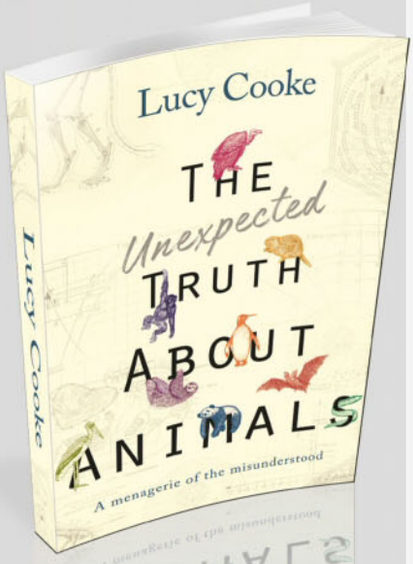
We have been fortunate enough to travel to a few of the locations listed in the book, and yet it has still provided us with new information about the areas that we otherwise wouldn't have known and gave us more insight into places we thought we already knew about. If there's one downside to this book, it's that it will give you serious wanderlust — we're already planning our next trip to visit some of the incredible locations that we've read about. On second thoughts, maybe that's not a downside after all.

★★★★★

The Unexpected Truth About Animals

Nature, but not as we know it

- Author: **Lucy Cooke**
- Publisher: **Doubleday**
- Price: **£16.99 (approx. $22)**
- Release date: **Out now**



Think of a particular member of the animal kingdom and certain traits spring to mind: the sloth is lazy; the vulture is a garish carcass-picker; and the penguin is utterly comical. Renowned zoologist Lucy Cooke attempts to turn these myths (and many others) on their heads in this book, which delves headlong into the truth behind some of the planet's most misunderstood inhabitants.

Encompassing chapters devoted entirely to the eel, beaver, frog, hippo, panda, moose, and many more, Cooke moves quickly to dispel myths that have attached themselves to various unfortunate recipients (like — for some reason — moose being alcoholics), while expounding others, such as the night-time activities of the panda. It turns out much of what you've heard about them is true.

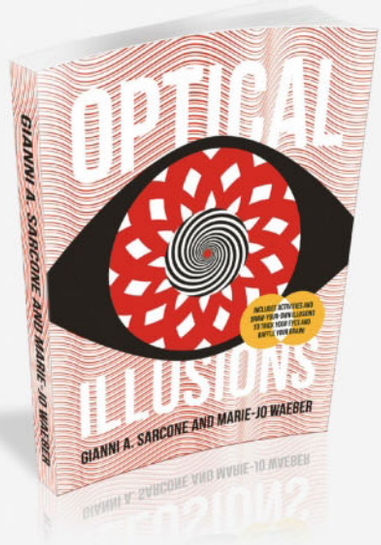
Intended to embellish the keen naturalist's existing knowledge set, *The Unexpected Truth About Animals* provides many additional pieces of trivia and achieves its mission statement in replacing untruths with some decidedly left-field truths.

★★★★☆

Optical Illusions

Look into my eyes

- Author: **Gianni A Sarcone, Marie-Jo Waeber**
- Publisher: **QED**
- Price: **£11.99 / $16.95**
- Release date: **Out now UK / 15 March 2018 US**



Do you enjoy being unsure of what's in front of your eyes, or even of yourself? Do you like interrogating perceived wisdoms, even if the truth is seemingly staring you in the face? If so, then this could well be what you're looking for, with this book seemingly tailor-made to make you question your perception of reality.

Containing such psychedelic gems as the pulsing star, sparkling squirrels and expanding Gothic heart (don't ask), the optical illusions contained within its pages are generally of a high standard. Inevitably, there are some that aren't (the illustrations that pose questions are generally the easiest to decipher), but reading this book will definitely leave its mark on you, one way or another.

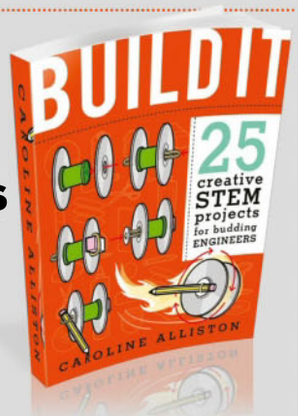
We challenge you to get through this in one sitting — after a few pages we had to go for a quiet lie-down in a darkened room. This book even tells you how to create your own optical illusions, should you so desire. Realistically, this has 'passing fad' written all over it, but it's one that you surely won't forget. Which has to be the point, surely?

★★★☆☆

Build It! 25 Creative STEM projects for budding Engineers

Can you make it? Yes you can!

- Author: **Caroline Alliston**
- Publisher: **QED**
- Price: **£10.99 / $12.95**
- Release date: **Out now**



Any attempts at encouraging the younger generation to apply their minds should always be welcomed, and such is the case with *Build It!*, which contains 25 practical exercises for children to tackle and in the process develop their skills in science and tech.

Containing detailed yet accessible guides to making items like clocks, catapults, periscopes, and traffic lights from such everyday objects as beads, elastic bands and cardboard, everything is made simultaneously crystal clear and educationally focused, with the instructions accompanied by detailed illustrations and noteworthy facts.

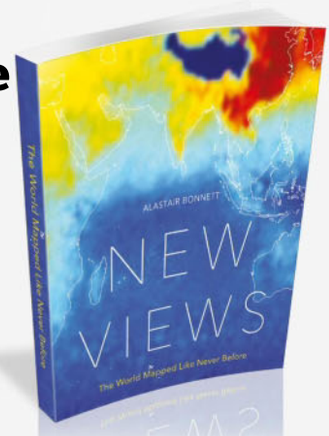
Depending on the age of the reader, some projects will inevitably require adult supervision, and some of the building materials will undoubtedly need to be obtained beforehand, but ultimately that doesn't really matter. All in all, this is a great little guide to encourage budding scientists.

★★★★★

New Views: The World Mapped Like Never Before

See the Earth in a different way

- Author: **Alastair Bonnett**
- Publisher: **Aurum Press**
- Price: **£25 / $35**
- Release date: **Out now**



With Google Earth just a few taps of your phone away, it's reasonable to ask whether there is a place left for the humble atlas. Judging by this book, the answer appears to be yes — although inevitably it has had to alter itself in order to stay relevant.

Gone are the mammoth indexes dedicated to showing you where to find specific locations. Instead, *New Views* maps out the world in an entirely different way, colour-coding Earth according to such factors as linguistic diversity, ecological footprint, the amount of energy used and the concentration of fast-food franchises. It's safe to say that you've probably never seen the world like this before.

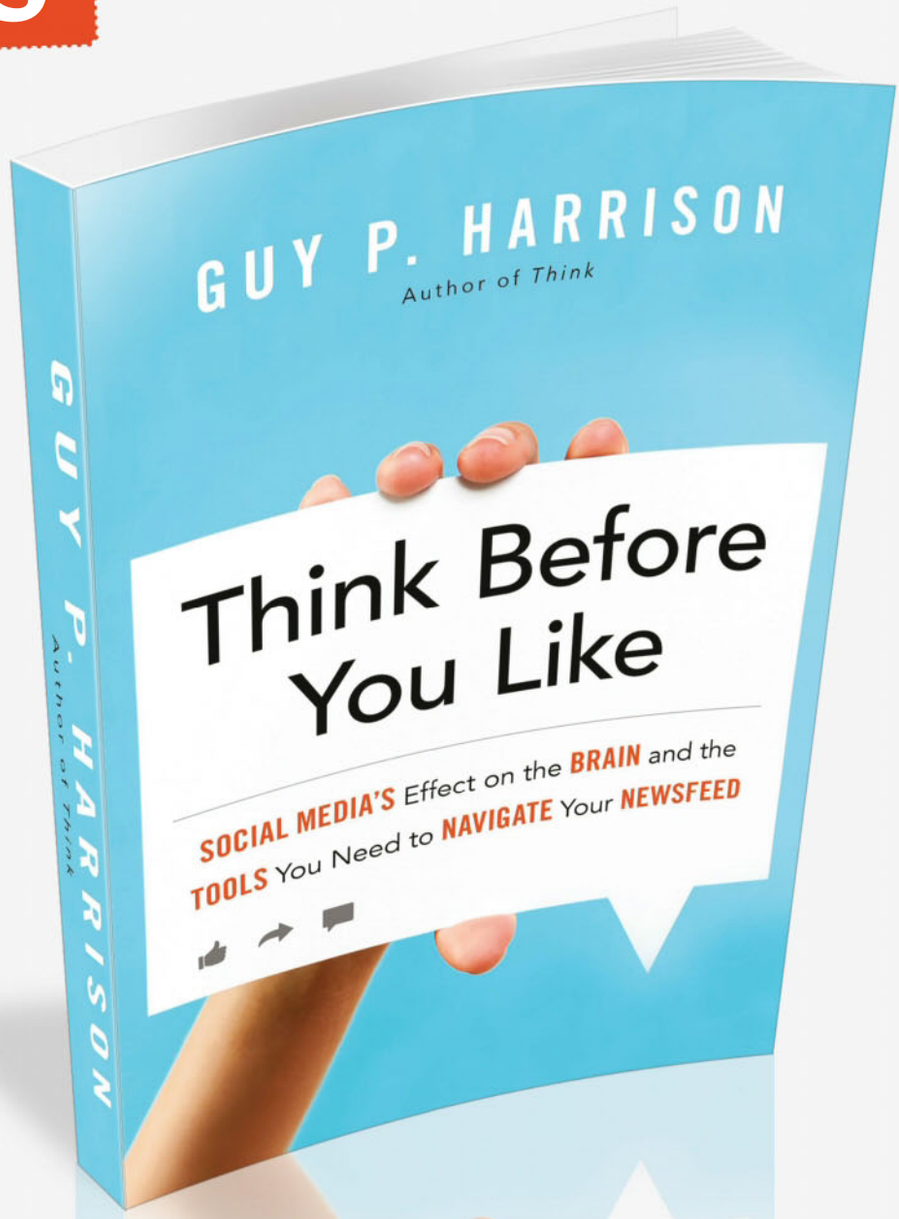
New Views does its very best to earn a place on your coffee table, including alongside its maps insightful and thought-provoking descriptions of certain trends. This book won't be what you're expecting, and ultimately it is all the better for it.

★★★★☆

Think Before You Like

A controversial look at the effect of social media on our brains

- Author: **Guy P Harrison**
- Publisher: **Prometheus Books**
- Price: **£15.99 / $18**
- Release date: **Out now**



Whether we're posting photos of our cats, scrolling through our newsfeed or reaching out to professional contacts, social media has become an integral part of our lives. Humans are deeply social creatures with a fundamental desire to connect, and the digital age has reshaped our culture and the way we communicate, enriching our lives in many ways. But are there unseen dangers in this new digital world that we haven't educated ourselves about?

Guy Harrison seeks to delve into the digital realm to explore the controversy around technology platforms that exploit our brains to manipulate how we spend our time online. His book highlights the critical thinking skills needed to navigate social media through a series of studies, discussions and observations, providing information about how social media exploits our brains, which are hard-wired to respond to reward mechanisms, and gives practical advice such as how to cut down on social media and how to utilise technologies to make us more aware of our online habits.

The reader is challenged to consider how social media notifications work in a similar way to slot machines to draw us in — sometimes we receive a lot of likes, sometimes we receive nothing, and Harrison describes the intermittent variable reward system that keeps us posting.

Throughout the book the reader is invited to start considering how to use social media in a smarter and more self-enriching way, which includes methods to break out of your own bias bubble, information on data law and a look at social media addiction. While Harrison raises concerns about the dangers of social media and internet use, he also raises some positive and thought-provoking points.

He points out that privacy has been an alien concept to our species for most of human history. Small bands of hunter-gatherers would have lived in such close quarters that there would have been little room for privacy. It's only in the last two centuries that privacy has become desirable, and it's likely that generations of the future will look back at privacy as a fanciful relic of the past.

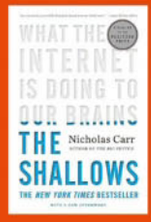
The message within *Think Before You Like* is clear. We have a digital footprint that can't be deleted, but we can educate ourselves to understand how our brains work and how social media works so we can take charge of our own lives away from handheld technology.

★★★★★

YOU MAY ALSO LIKE...

Alone Together: Why We Expect More from Technology and Less from Each Other
Author: **Sherry Turkle**
Publisher: **Basic Books**
Price: **£13.99 / $17.99**
Release date: **Out now**

Mind Change: How Digital Technologies are leaving their mark on our Brains
Author: **Susan Greenfield**
Publisher: **Rider Books (UK)**
Price: **£9.99 / $28**
Release date: **Out now**



The Shallows: What the internet is doing to our Brains
Author: **Nicholas Carr**
Publisher: **Atlantic Books (UK) /WW Norton & Company (US)**
Price: **£9.99 / $15.95**
Release date: **Out now**

How Language Began

A sweeping history of the origins of humanity's greatest invention

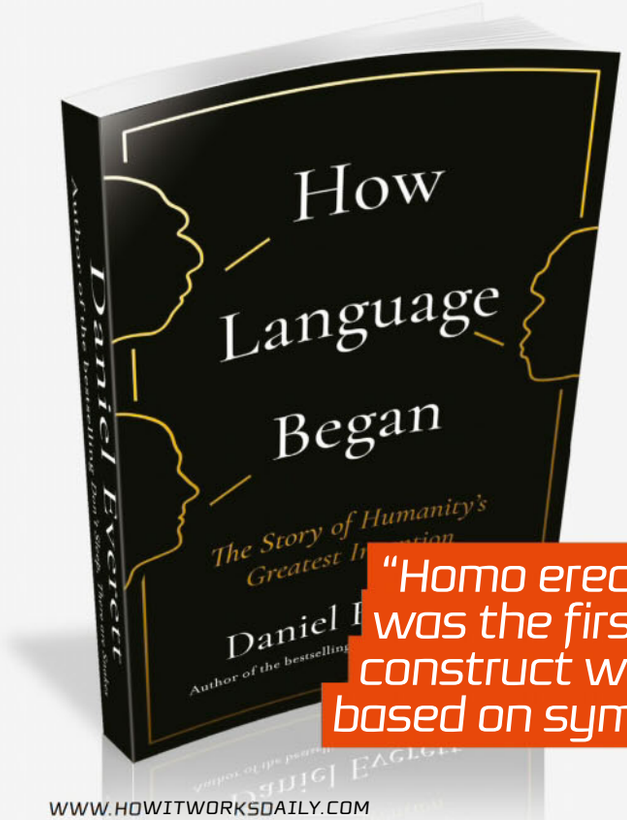
- Author: **Daniel Everett**
- Publisher: **Liveright**
- Price: **£25 / $28.95**
- Release date: **Out now**

Daniel Everett has uprooted the commonly accepted foundations of language theory and challenged the leading explanations for the development of language. His engaging and extensive investigation into early language pushes a culturally driven motive for its development into the spotlight for the first time.

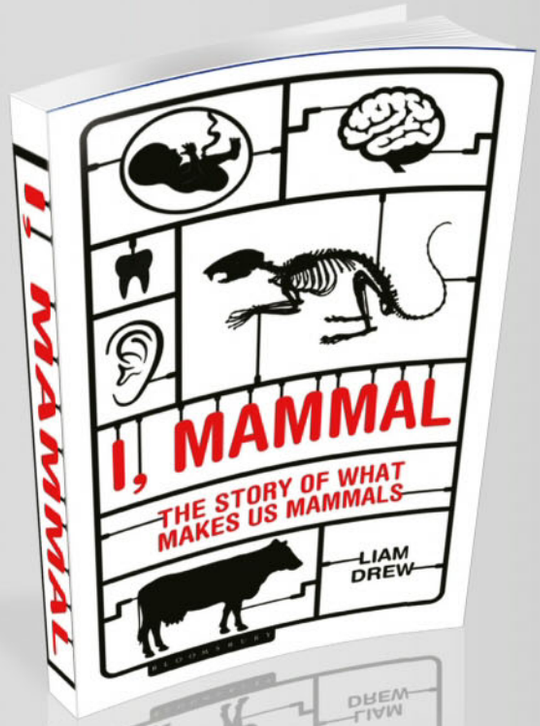
Rejecting the theories that language was a genetic 'on' switch or a result of a random evolutionary mutation, Everett puts forward an alternative approach to the subject that fossil hunters and linguists have speculated upon across decades. His carefully formulated theory suggests that *Homo erectus* was the first to construct words based on symbols that had been developed within the culture, which were further built on by early humans to include gesture and intonation for more precise communication.

He describes how language gradually progressed over 60,000 generations, methodically breaking down each part of the biology required to speak, from how we mastered using our tongue to how the larynx functions, before explaining the intricacies of how we further refined language to include grammar and our helpful ability to tell stories.

★★★★★



"Homo erectus was the first to construct words based on symbols"



I, Mammal

Discover exactly what it means to be a member of club Mammalia

- Author: **Liam Drew**
- Publisher: **Bloomsbury Sigma**
- Price: **£16.99 / $27**
- Release date: **Out now UK / 16 January 2018 US**

More often than not, we humans separate ourselves from other species, ignoring the fact that we are related to them. But what does it mean to be a mammal, and do we have more in common with an aardvark than an alligator? In his new book, Dr Liam Drew answers these very questions and encourages us to celebrate our inner mammalian-ness.

From the evolution of senses to the mammalian production of milk, Drew calls upon Darwinian principles in order to paint the picture of what makes us a mammal. As a former neurobiologist and with a PhD in sensory biology, Drew provides an analytical yet conversational approach to a range of topics, making *I, Mammal* both an entertaining and informative read. Suitable for older readers, there are plenty of humorous anecdotes from Drew's own life — such as the birth of his daughters and sustaining a particular sports injury — making the exploration of his mammalian heritage engaging and relatable.

Not only comparing the features of present-day mammals, Drew also explores our prehistoric cousins that brought fur to the forefront, such as the 255-million-year-old Therapsids. We also discover why mammals' brains are so advanced, the benefits of being warm-blooded and how evolution shaped our senses. Drew also uses evolutionary peculiarities, such as the platypus, as case studies.

Overall, *I, Mammal* is an excellent combination of scientific principle and comedic wit that will appeal to biology fans and non-scientists alike. An excellent read.

★★★★★

To read more about what makes us mammals, check out Liam's feature in issue 106 of How It Works, available now from www.myfavouritemagazines.co.uk

BRAIN GYM

GIVE YOUR BRAIN A PUZZLE WORKOUT

Wordsearch

G	P	L	A	N	K	T	O	N	N	X	B	Z	A	V
P	R	I	O	L	A	D	V	W	E	W	H	L	E	S
U	R	K	L	B	T	R	G	S	W	E	V	N	U	A
B	O	X	I	P	H	O	N	E	B	C	T	X	F	H
S	P	E	Q	Z	H	N	G	X	O	S	N	B	R	A
C	A	R	T	O	W	E	R	D	R	I	F	W	R	R
T	S	J	A	N	X	S	F	A	N	V	K	E	Y	A
O	T	U	R	T	L	E	X	T	N	Y	K	J	T	W
R	N	F	L	X	S	T	C	E	S	N	I	L	F	N
T	A	U	T	F	R	X	V	I	U	S	C	O	U	G
O	I	I	S	Y	O	C	L	B	N	O	F	T	X	A
I	G	N	X	T	E	L	O	I	V	A	R	T	L	U
S	E	J	I	F	A	C	G	U	L	S	F	Y	I	N
E	C	A	G	R	I	C	U	L	T	U	R	E	S	C
V	I	T	N	A	I	S	E	H	T	S	E	N	Y	S

FIND THE FOLLOWING WORDS...

PUBS
VENTS
ICEGIANT
IPHONE
DRONES
BUNKER
SAHARA
INSECTS
TURTLE
TORTOISE
NEWBORN
PLANKTON
CARTOWER
ULTRAVIOLET
AGRICULTURE
SYNESTHESIA

Quickfire questions

Q1 When did comet Shoemaker-Levy 9 hit Jupiter?

- 1991
- 1994
- 2001
- 2004

Q2 Which is NOT a type of plankton?

- Phytoplankton
- Zooplankton
- Bacterioplankton
- Osteoplankton

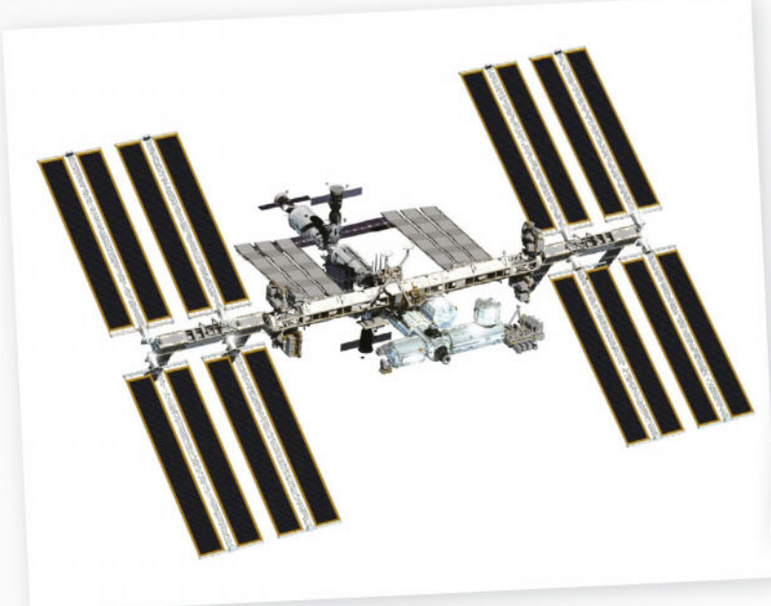
Q3 What is the word 'pub' short for?

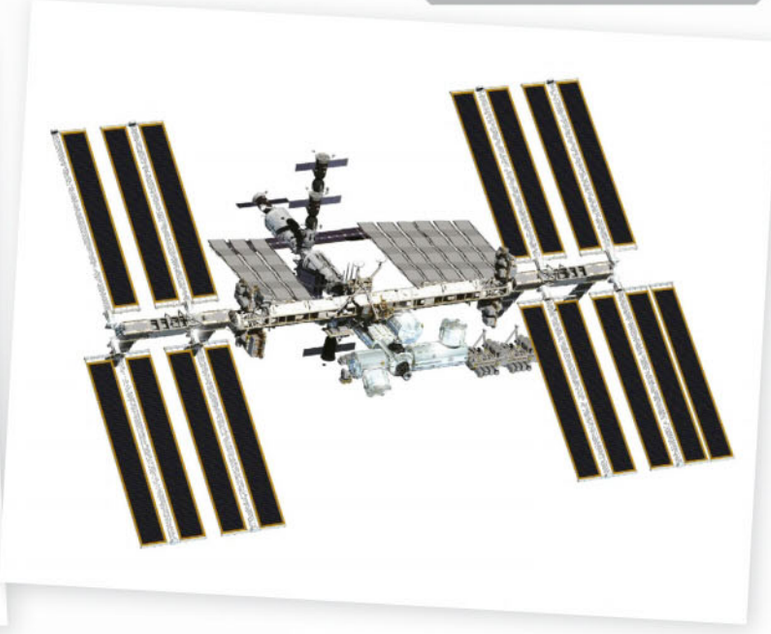
Q4 What is Amazon's proposed drone delivery service called?

- Prime Air
- Prime Where
- Prime Here
- Prime Now

Spot the difference

See if you can find all six changes we've made to the image on the right





Sudoku

Complete the grid so that each row, column and 3x3 box contains the numbers 1 to 9. See if you can beat the team!

What is it?

A .....

7	8				1			
	2			5		6	3	1
5	1	6	4		3	9	8	7
4				8			7	
	9		3	7	2	8	4	
		8		6			1	
		7	2					
2		5	9	4				
1		9	8	3			5	2

BEAT THE TEAM...

- Jackie 02m 17s
- Charlie 02m 48s
- Scott 03m 30s
- Baljeet 02m 29s
- Charlie 02m 58s
- Laurie 03m 14s
- Duncan 03m 54s

▶ Visit our website at **www.howitworksdaily.com** to check your answers!

Subscribe and save 20%*

Every issue, delivered straight to your door

Never miss an issue
13 issues a year, and you'll be sure to get every single one

Delivered to your home
Free delivery of every issue, direct to your doorstep

Get the biggest savings
Get your favourite magazine for less by ordering direct

What our readers are saying about us…

"I've been a subscriber to this magazine for a couple of years now and I have never been bored once. The variety every month is just endless and I love that."
Daniel Scott (aged 15) via email

"@HowItWorksmag Best magazine ever!..."
@LeaSavoy via Twitter

"Just started reading @HowitWorksmag about #tech #science & #space. Where have you been my whole life? :) #GeekAndProud"
@DeputyDCooper via Twitter

Pick the subscription that's right for you

MOST FLEXIBLE

Subscribe and save 20%

✔ Automatic renewal – never miss an issue

✔ Pay by Direct Debit

Recurring payment of £26 every six months, saving 20% on the retail price

DIRECT Debit Instruction to your Bank or Building Society to pay by Direct Debit

Originator's reference 7 6 8 1 9 5

Name of bank

Address of bank

Postcode

Account Name

Sort Code

Account no

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

Signature

Date

GREAT VALUE

One year subscription

✔ Great offers, available worldwide

✔ One payment, by card or cheque

A simple one-off payment ensures you never miss an issue for one full year. That's 13 issues, direct to your doorstep

☐ UK £51.90 (saving 20% on the retail price)

☐ Europe €78.64 ☐ USA $87.08 ☐ Rest of the world $96.75

Pay by card or cheque

Pay by Credit or Debit card

☐ VISA Visa ☐ Mastercard ☐ Amex

Card number

Expiry date

Pay by Cheque

I enclose a cheque for £

Made payable to *Future Publishing Ltd*

Signature

Date

Your information

Name

Address

Telephone number

Mobile number

Email address

Postcode

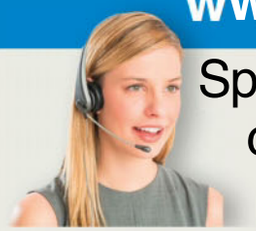
☐ Please tick if you want to receive any communications from Future and its group companies containing news, special offers and product information.

Please post this form to

Future Publishing Ltd, 3 Queensbridge, The Lakes, Northampton, NN4 7BF, United Kingdom

Order securely online

www.myfavouritemagazines/HIW/PS17



Speak to one of our friendly customer service team

Call 0344 848 2852

These offers will expire on Wednesday 31 January 2018

Please quote code **PS18**

Prices and savings are compared to buying full priced print issues. You will receive 13 issues in a year. You can write to us or call us to cancel your subscription within 14 days of purchase. Payment is non-refundable after the 14 day cancellation period unless exceptional circumstances apply. Your statutory rights are not affected. Prices correct at point of print and subject to change. Full details of the Direct Debit guarantee are available upon request. UK calls will cost the same as other standard fixed line numbers (starting 01 or 02) are included as part of any inclusive or free minutes allowances (if offered by your phone tariff). For full terms and conditions please visit: bit.ly/magtandc Offer ends 31 January 2018.

Get in touch

Want to see your ideas on this page? Send them to...

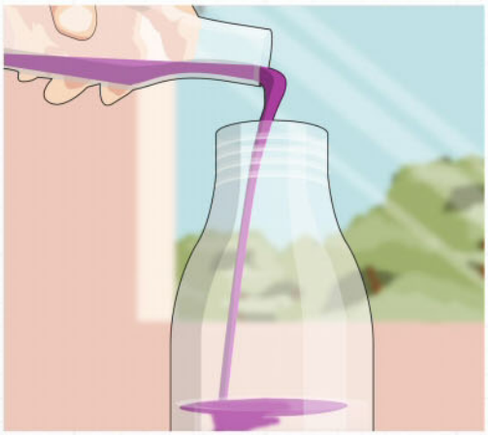
How It Works magazine @HowItWorksmag

howitworks@futurenet.com

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

Make a bubble bottle

Create a simple lava lamp at home using household ingredients



1 Make it bright

First take a clear plastic bottle. You can use a small bottle or a large two-litre bottle, any size works, but large bottles will require more materials! Fill the bottle around one-third of the way with water, and then add some food colouring; around ten drops should do for smaller bottles. You can use whichever colour you want, but orange and blue work well.

2 Add some oil

Fill the rest of the bottle almost to the top with vegetable oil. You'll notice the water and oil don't mix; the oil sits on top of the water because it is less dense. They don't mix because water molecules are attracted to each other and the oil molecules are attracted to other oil molecules, so they will not combine and you should be able to see a clear line of separation between the two.

3 Make it bubble

Now drop a fizzy vitamin tablet or an Alka-Seltzer tablet into the bottle to start the fizzing. This will work better if you break the tablet into smaller pieces first. The tablet is made from a mixture of chemicals that react with each other in the presence of water to form carbon dioxide gas. These bubbles are lighter than the liquids, so they rise to the top of the bottle.

4 Light it up

As these bubbles rise they will pull some of the coloured water up with them, making streaks of colour burst through the oil. Put the lid tightly onto the bottle (otherwise it might bubble out of the top) and tip the bottle over a couple of times to make the blobs move even more. If you put a bright flashlight underneath the bottle, it will light up like a real lava lamp!

5 Add more stuff

When the bubbles stop appearing, open the lid again and drop in another broken up tablet to start the process all over again. You can also try dropping some raspberries or other small and light fruits into the bottle — they'll float between the layers of water and oil. When you add the tablet into the bottle how does the fruit react to the bubbles?

"If you put a flashlight under the bottle, it will light up like a real lava lamp!"

In summary...

The fizzing tablets create carbon dioxide gas in the water, and these bubbles carry some of the coloured water with them as they rise. When they reach the top of the oil, the bubble burst, allowing the gas to escape and the water sinks through the oil. This creates streaks and balls of coloured liquid in the oil, just like a lava lamp!

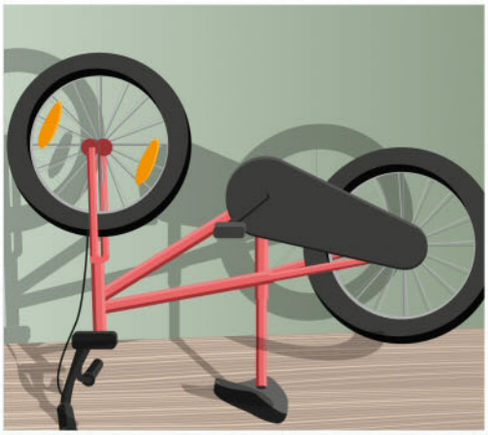
Make your bike tyre sing

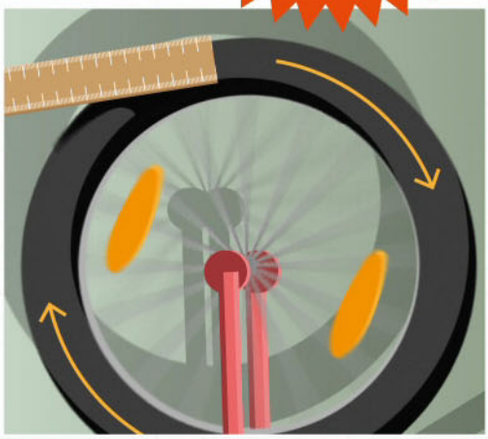
Create music with a tyre and a ruler

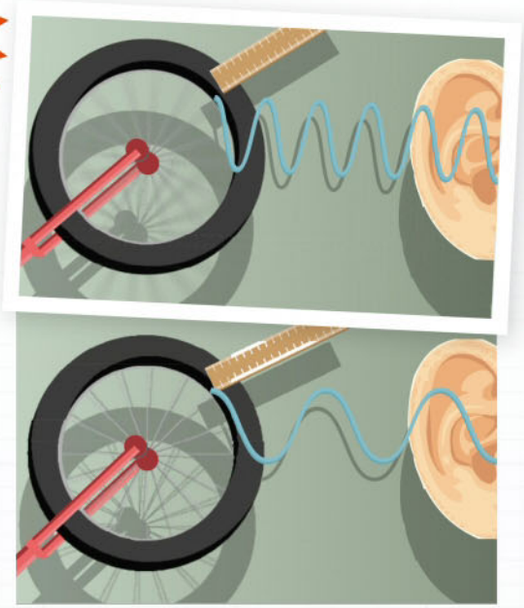
NEXT ISSUE

MAKE A STICKY NOTE WATERFALL

MAKE A TEABAG ROCKET







1 Turn and spin

The first thing you need to do is turn your bike over — rest it on the seat and straighten the handlebars to make sure it doesn't fall over. Make sure ask an adult to help you if you need a hand. You need to spin the tyre in order to start making music. The easiest way to do this is to turn the pedals as if you were riding the bike. This will cause the back wheel to spin round really fast.

2 Make music

Take a plastic ruler and press it against the side of the spinning bike tyre. You should hear a humming noise. The sound is created as the ruler hits the bumps in the tread of the tyre and the air between the tyre and the ruler is squeezed out. It's the same effect as when you clap your hands, only with the spinning tyre it happens over and over, creating a humming noise that goes on for as long as the ruler is held to the tyre.

3 Speed it up

Turn the pedals faster to speed up the tyre, then hold the ruler there again. You'll find that the note that is played is higher than when the tyre spins slower. This is because the impacts come more quickly on the tyre, so the vibrations are closer together and the sounds reach your ears as a higher note. Try pressing the ruler onto different parts of the tread too — does the tyre create a different note depending on where you touch it?

"Take a plastic ruler and press it against the side of the tyre"

In summary...

As the ruler impacts on the tyre it creates vibrations that form sound waves. The quicker the vibrations occur, the higher the note that you hear. This is how musical instruments work too — guitar strings vibrate at different frequencies to create different notes.

INBOX
Speak your mind...

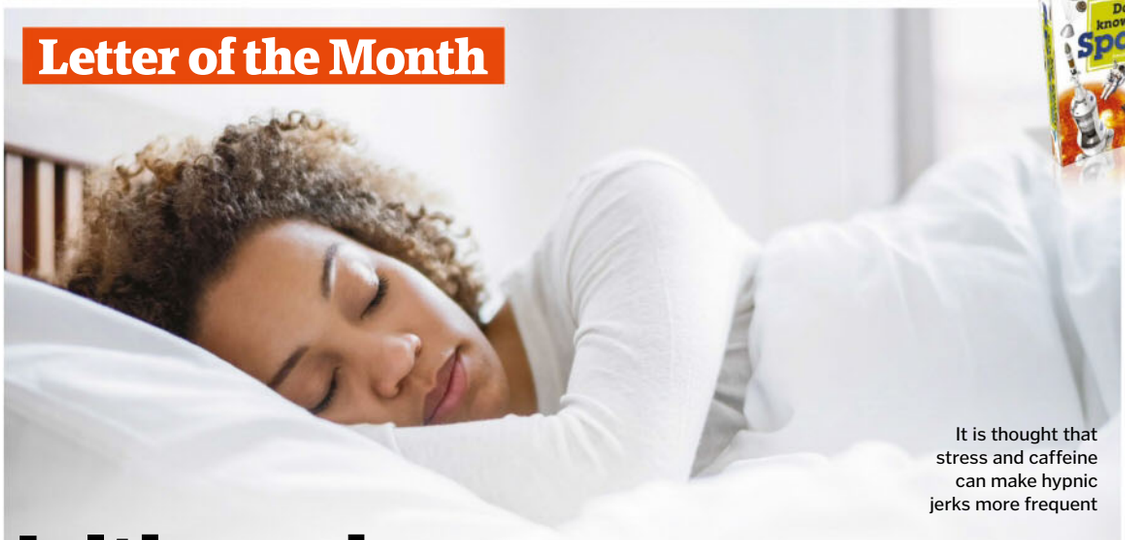
Get in touch
Want to see your letters on this page? Send them to...

How It Works magazine @HowItWorksmag

howitworks@futurenet.com

WIN!
AMAZING PRIZE FOR LETTER OF THE MONTH!
DO YOU KNOW ABOUT SPACE?
Discover the answers to over 200 cosmic questions in this fantastic book from DK. You'll learn plenty of fascinating facts as you explore the universe

Letter of the Month



It is thought that stress and caffeine can make hypnic jerks more frequent

Jolting when you fall asleep

Dear **HIW**,
Why is it that when I go to bed, when I shut my eyes and I am about to go to sleep, sometimes I get the sudden feeling that I am falling or lurching into the air and then I immediately wake up? I've heard that it happens to other people too. I hope that you can answer it for me and keep on making quality magazines!
Oliver O'Brien, aged 11

Hi Oliver, thanks for such a fantastic question. You're describing something known as a hypnic jerk. This is a term for when your body involuntarily spasms before sleep. It feels really weird, but it actually happens to almost 70 per cent of us.

Scientists are not exactly sure why humans do this, but it is thought that it could be an ancient reflex. Before some hominin species started sleeping on the ground around 1.8 million years ago, our ancestors slept up in trees. In response to our muscles relaxing while we drift off, our brains could be trying to stop us from falling out of a tree.

Researchers have found that the jerks often occur at the same time as the start of symptoms like a fast heartbeat, quick breathing and sweating, and they can be made worse when you are stressed, not sleeping properly or have taken a stimulant like coffee.

Shivering is an important evolutionary mechanism to keep us warm by involuntarily contracting our muscles

Shivering

Dear **How It Works**,
I have to say I absolutely love reading your magazine each month! It has so much information packed into each issue that it always makes my day when I get it through the mail. With the weather getting increasingly colder, I was wondering what happens when we shiver? And do any other animals shiver too? I am looking forward to your reply and the next issue! Thank you!
Christopher Egan, 14

Hi Christopher. As you probably already know, our bodies need to keep warm in order for us to stay alive; we need to maintain a core temperature of about 37 degrees Celsius. When we get cold, sensors in our skin signal our brain to start some 'warming up' tactics. Shivering is one of these instinctive responses.

When you shiver the muscles in your body contract and expand in quick bursts that produce heat by expending energy, hopefully helping to warm up our core temperature again. And yes, nearly all mammals and birds shiver, as do some snakes and insects.

Lots of animals can handle the cold much better than we can (mostly because they have fur), such as the Arctic fox, which will only start shivering once the temperature hits -70 degrees Celsius! Thank you for writing to us and make sure you keep warm this winter.

Dolphin naps

Hi **HIW**,
If dolphins are mammals and can't breathe underwater, how do they sleep? Also, why do we get bags under our eyes when we are tired? Thank you
Oscar, aged 12

Hi Oscar! You're right that dolphins can't breathe underwater. When they rest, half of a dolphin's brain is actually 'awake' and the other side is asleep (unihemispheric sleep). This allows them to stay alert enough to surface when they need to breathe, and also to scan their environment for any dangers.

As for why we have bags under our eyes, this is usually because a lack of sleep often causes the blood vessels in the more delicate skin under your eyes to dilate (expand).

Dolphins can sleep and swim at the same time for around eight hours per day

What's happening on... social media?

This month we asked you...

Do you think we will use delivery drones in the future?
How it Works

"100% yes! Virtual reality, 3D printing and drone delivery are going to change the retailing game forever. #TripleThreat #Retail"
@Max Kingsley Hannon

"Love the idea of things getting to me quicker but slightly concerned that deliveries will never make it to my front door"
@Katharine Marsh

"They are a really cool idea, although I think it will take some time for drones to be rolled out everywhere!"
@Jessica Leggett

"We're probably lazy enough as a species to let this happen."
@Erlingur Einarsson

"Won't people shoot them down and nick the stuff?"
@Kev Trueman

HOW IT WORKS

Future Publishing Limited
Richmond House, 33 Richmond Hill
Bournemouth, Dorset, BH2 6EZ

Editorial
Editor **Jackie Snowden**
jacqueline.snowden@futurenet.com
Senior Art Editor **Duncan Crook**
Research Editor **Baljeet Panesar**
Production Editor **Charlie Ginger**
Staff Writer **Charlotte Evans**
Staff Writer **Scott Dutfield**
Group Editor-in-Chief **James Hoare**
Photographer **James Sheppard**

Contributors
Stephen Ashby, Sarah Bankes, Mike Bedford, Ella Carter, Ed Crooks, Liam Drew, Nicholas Forder, Alex Franklin-Cheung, Jamie Frier, Marcus Leach, Tom Lean, Adrian Mann, Laura Mears, Laurie Newman, Jonathan O'Callaghan, Alexander Phoenix, Katy Sheen, Jo Stass, The Art Agency, Jodie Tyley, Tim Williamson, Steve Wright

Cover images
Getty Images; Thinkstock; Wikimedia Commons

Photography
Alamy, Getty Images, NASA, Science Photo Library, Shutterstock, Thinkstock, Wikimedia, © & ™ Lucasfilm Ltd. Used under authorization
All copyrights and trademarks are recognised and respected.

Advertising
Media packs are available on request
Commercial Director **Clare Dove**
clare.dove@futurenet.com
Group Advertising Director **Mark Wright**
mark.wright@futurenet.com
Media Sales Executive **John Butters**
john.butters@futurenet.com
01225 687170

International
How It Works is available for licensing. Contact the International department to discuss partnership opportunities
International Licensing Director **Matt Ellis**
matt.ellis@futurenet.com

Print subscriptions & back issues
Web www.myfavouritemagazines.co.uk
Email contact@myfavouritemagazines.co.uk
Tel 0344 848 2852
International +44 (0) 344 848 2852

Circulation
Head of Newstrade **Tim Mathers**
01202 586200

Production
Head of Production US & UK **Mark Constance**
Production Project Manager **Clare Scott**
Advertising Production Manager **Joanne Crosby**
Digital Editions Controller **Jason Hudson**
Production Controller **Vivienne Calvert**

Management
Managing Director **Aaron Asadi**
Editorial Director **Paul Newman**
Art & Design Director **Ross Andrews**
Head of Art & Design **Greg Whittaker**
Commercial Finance Director **Dan Jotcham**

Printed by
Wyndeham Peterborough, Storey's Bar Road, Peterborough, Cambridgeshire, PE1 5YS

Distributed by
Marketforce, 5 Churchill Place, Canary Wharf, London, E14 5HU
www.marketforce.co.uk Tel: 0203 787 9001

We are committed to only using magazine paper which is derived from responsibly managed, certified forestry and chlorine-free manufacture. The paper in this magazine was sourced and produced from sustainable managed forests, conforming to strict environmental and socioeconomic standards. The manufacturing paper mill holds full FSC (Forest Stewardship Council) certification and accreditation

ISSN 2041-7322

recycle
When you have finished with this magazine please recycle it.

NEXT ISSUE

Issue 108 on sale 25 January 2018

YOU USE 10% OF YOUR BRAIN

+ "THE EARTH IS FLAT!" CONSPIRACIES DEBUNKED

+ 50 OTHER MYTHS BUSTED

Meet the real-life Kermits: glass heart frogs

Under the bonnet of the latest Ford Mustang

Inside Fort Knox: the hi-tech fortress protecting US gold

+LEARN ABOUT

■ 2020 ROVER ■ GRAPHICS CARDS ■ GONDOLAS ■ TIGHTROPE PHYSICS
■ CORFE CASTLE ■ TUBE MAPS ■ HUMPBACK WHALES ■ BREATHPRINTS

FAST FACTS

Amazing trivia to blow your mind

TORTOISE SHELLS ARE MADE FROM KERATIN, THE SAME MATERIAL AS YOUR NAILS

IN 2014 ASTRONOMERS DISCOVERED THE FIRST ICE GIANT EXOPLANET

APPLE'S IPHONE X SOLD OUT IN UNDER

10 MINUTES

NEPTUNE TAKES ALMOST

165

EARTH YEARS TO ORBIT THE SUN ONCE

50°C

TEMPERATURE THE COCKPIT CAN REACH DURING A F1 RACE

THERE ARE

40 TONS

OF INSECTS FOR EVERY HUMAN

THE EMISSION NEBULA NGC 604 SPANS NEARLY

1,500 LIGHTYEARS

EACH OF THE AUTOSTADT CAR TOWERS HAS SPACE FOR

400 VEHICLES

AMAZON PRIME AIR WILL AIM TO DELIVER SMALL PACKAGES IN LESS THAN **30 MINS**

SINCE THE 1950S, THE POPULATION OF PHYTOPLANKTON IN THE WESTERN INDIAN OCEAN HAS DECLINED BY AROUND

20%

BY THE AGE OF 12 MONTHS BABIES WILL HAVE TRIPLED THEIR BIRTH WEIGHT

OVER

400 MILLION

ADULTS GLOBALLY HAVE DIABETES

45 MILLION REMEMBRANCE POPPIES ARE BOUGHT IN THE UK EACH YEAR

AliveColors

IMAGE EDITOR

ALL-IN-ONE

alivecolors.com


LOSE YOURSELF IN A WORLD OF
Vinyl
FIND YOURSELF IN
OXFAM'S ONLINE SHOP
oxfam.org.uk/shop
COLUMBIA
TIME ON MY HANDS
OXFAM