323 AMAZING IMAGES & CUTAWAYS INSIDE

THE MAGAZINE THAT FEEDS MINDS

HOW IT WORKS

INSIDE

FORCES EXPLAINED
THE PHYSICS BEHIND EVERYTHING WE DO

SCIENCE ENVIRONMENT TECH SPORT HISTORY SPACE

AMAZING EXOSUITS
Inside the tech making us stronger, faster & better

SPACE BALLOONS
Discover why the future of space exploration has no rockets

SURVIVING EXTREME EARTH
REVEALED: THE SKILLS TO CONQUER ANY WILDERNESS

+ LEARN ABOUT
- MIGRAINES
- LAUNCH PADS
- HI-TECH RVs
- WWI DOGFIGHTS
- SUN TORNADOES
- SPACE SALAD
- THE CELL CYCLE
- BENJAMIN FRANKLIN

CRASH TESTING
WHY DESTROYING VEHICLES HELPS MAKE THEM SAFER

SUPERBUGS EXPLAINED
Find out how deadly bacteria are fighting back

ANGLE GRINDERS
How this DIY wonder can cut through any metal

BUTTERFLY BIOLOGY
Uncovering the anatomy of these colourful insects

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ISSUE 61

WELCOME

The magazine that feeds minds!

Page 14
How can you avoid getting hunted down by one of these? Find out the answer to that along with many more survival skills

Do we have what it takes to survive on ingenuity alone? If you've been watching Bear Gryll's TV series *The Island*, you might be doubtful. A group of men were left stranded in the Pacific like a real-life *Lord Of The Flies*. No one was sacrificed to the Beast, but it took two days to start a fire and even longer to catch a meal.

Even if you're not a born survivor, it's possible to master the skills. In our guide to conquering the most extreme terrains on the planet (page 14), you'll learn how to avoid man-eating animals, fight the thirst in the middle of the desert and the secret to building an indestructible igloo.

We also chat to explorer Ben Fogle, who's travelled to the ends of the Earth and lived to tell the tale (page 24). It's inspirational for this particular armchair adventurer, where the biggest challenge I have to face is surviving the summer when the air con is broken. But this month I've embarked on an exciting new voyage, as this is my first issue at the helm of **How It Works**.

Let's start the adventure!

Jodie

Jodie Tyley
Deputy Editor

Meet the team...

Marcus
Senior Designer
Since watching *Iron Man* I've found myself dreaming I could become Tony Stark. Our Exosuits feature shows why that dream may not be far away.

Erlingur
Production Editor
I'm scared of heights, which means I'm fascinated by heights. Therefore, the prospect of going into space in a balloon thrills/terrifies me.

Jamie
Staff Writer
Learning about surviving Earth's extremes has opened my eyes to the world as well as making me grateful I'll (hopefully) never have to do it!

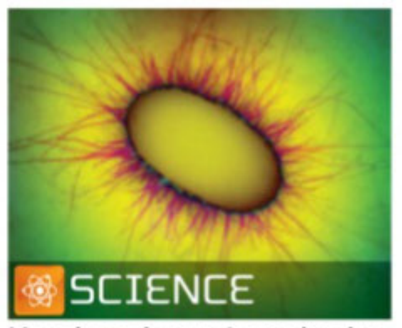
Jackie
Research Editor
I enjoyed reading about the Sagrada Família in Barcelona, which is still a work in progress after more than a century of construction.

Helen
Senior Art Editor
Learning how forces come into play in our everyday lives is fascinating. It makes bungee jumping less scary when you know what's going on.

Jack
Staff Writer
This month, I visited a crash test facility where I learnt just how important this process is to automobile and highway safety.

What's in store

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

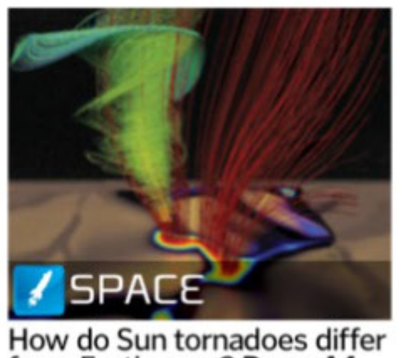


How have bacteria evolved to become superbugs? **Page 58**

How does a butterfly feed and fly? **Page 28**

How do heavy paramotors get off the ground? **Page 69**

Is *Iron Man* closer to real life than we think? **Page 30**



How do Sun tornadoes differ from Earth ones? **Page 44**

What's the story behind these creatures? **Page 77**

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WE HAVEN'T JUST MADE HISTORY.

WE'VE MADE AN INTELLIGENT HYBRID ENGINE THAT CHANGES THE WAY WE DRIVE.

With the new Mitsubishi Outlander PHEV, we haven't just made a car – we've made an intelligent hybrid that leaves other cars in the past. The fusion of electric and petrol technology can deliver a staggering 148 mpg[1] and creates a fraction of the CO_2 emissions of even a conventional small car - just 44g/km. As a result you'll pay no road tax or Congestion Charge. Business users will only pay 5% Benefit in Kind rather than the 25%+ that most business users pay[2]. If your commute is less than 30 miles your petrol consumption will be minimal too. That's because, in full electric mode, the Outlander PHEV has a range of 32 miles. Its combined petrol and electric range is an incredible 510 miles[3]. Plus its battery can be charged in a few hours via a domestic plug socket or a Charge Point[4] – which can be installed for free[5]. We've made history – you just need to make time for a test drive. **We call this Intelligent Motion.**

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1. Official EU MPG test figure shown as a guide for comparative purposes and may not reflect real driving results. 2. 5% BIK compared to average rate of 25%+. 3. 32 mile EV range achieved with full battery charge. 510 miles achieved with combined full battery and petrol tank. Actual range may vary depending on driving style and road conditions. 4. Domestic plug charge: 5 hours, 16 Amp home charge point: 3.5 hours, 80% rapid charge: 30mins. 5. Free British Gas plug-in vehicle charging package available – ask your dealer for more information. Offer ends 31st March 2015. 6. Prices shown include VAT (at 20%), exclude VED and First Registration Fee. Metallic paint extra. Model shown is an Outlander PHEV GX4h at £33,399 including metallic paint. Prices correct at time of going to print. For more information about the Government Plug-in Car Grant please visit www.gov.uk/plug-in-car-van-grants.

Outlander PHEV range fuel consumption in mpg (ltrs/100km): Full Battery Charge: infinite, Depleted Battery Charge: 48mpg (5.9), Weighted Average: 148mpg (1.9), CO_2 Emissions: 44 g/km.

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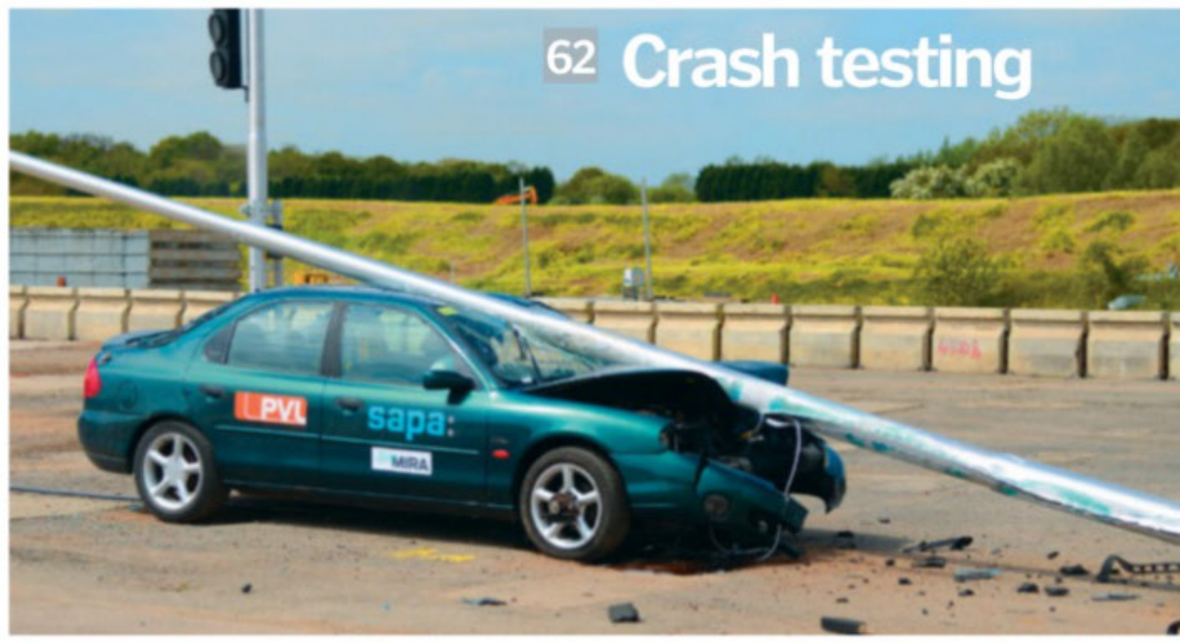
14 SURVIVING EXTREME EARTH

Take on jungles, deserts and mountains – our guide to conquering the planet's extreme terrains



Meet the experts...

Laura Mears
Forces explained
This month, Laura lays down the law (Newton's Law, that is) in the complete guide to forces and motion. You'll discover how these invisible powers come into play in your everyday life.

Luis Villazon
Sagrada Família
Why is Spain's most iconic church still not finished after 130 years? Luis finds out what's holding up the world's would-be tallest church and the controversial story behind its creation.

Giles Sparrow
Space balloons
High-altitude ballooning hit the headlines when a skydiver leapt from the edge of space in a record-setting free fall. Giles explores how balloons could be the future of space travel.

Lee Sibley
In a driver's seat
This month, Lee's got the best seat in the house – it's heated and comes with a DVD player and built-in stereo. He explains how driver's seats are designed to provide safety and comfort.

Aneel Bhangu
Super bacteria
Antibiotic-resistant superbugs can cause devastating epidemics. Aneel explains why and how these deadly bacteria are fighting back. He also reveals how dialysis machines can save lives.

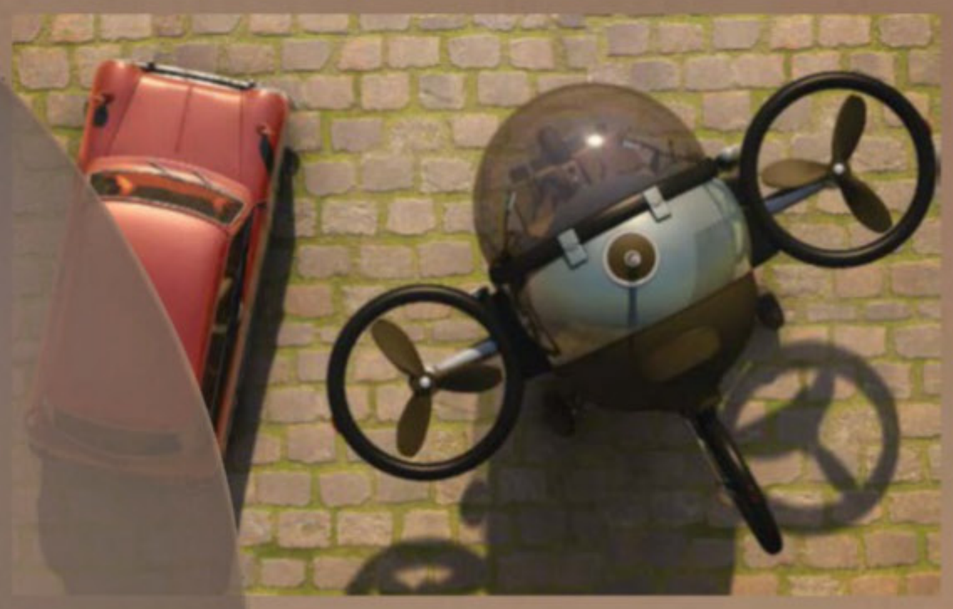
Is there any way to fight bugs that pay no mind to antibiotics?
Find out on pg 58

REGULARS

GLOBAL EYE

Showcasing the incredible world we live in

The Citycopter design is a bold concept to offer a glimpse into the future of transport methods



Solar-powered personal plane

The future of commuting?

These images showcase what could well be the future of transport, the Fly Citycopter. At a maximum speed of 193 kilometres (120 miles) per hour, it could take you from London to Paris in under two hours. The solar-powered Citycopter intends to provide a new and efficient way of transport. Designer Eduardo Galvani believes it will help relieve urban congestion and replace modes of public transport as the personal helicopter takes over. Still a design concept only, Galvani hopes the plans will inspire major players in the transportation industry to sit up and take notice.

Alien brain found

This deep-sea creature has the power to regrow its brain

Sounding like something out of a science fiction B-movie, the comb jelly has a brain like nerve net that can regenerate itself in just three and a half days. How does it do this? Scientists are claiming that this alien-like creature has a completely different chemical language and processes to any other animal. Unlike in humans where neurons are very difficult to replace, these organisms can regrow the nervous system very efficiently. Research is being undertaken to see if this can be harnessed to help with diseases such as Alzheimer's and Parkinson's, which harm the nerves and the brain.

Bizarre brains

Leeches
The blood-sucking parasites have 32 brain segments in their tiny bodies.

Sea squirts
Once they attach themselves to coral, they eat their own brain.

Cav King Charles Spaniel
Due to over-selective breeding, its skull is too small to accommodate the brain in a third of the dogs.

Diamond planets are forever

Space bling may be more common than first thought

The existence of stars and planets rich in carbon has been known for a number of years now. This month, experts at Yale University have revealed that these masses of crystallised carbon could be much more common than previously thought. Carbon forms the building blocks for life on Earth and scientists are looking into how these diamond dominated celestial bodies could possibly be habitable with carbon vastly outnumbering oxygen and nitrogen. The Earth's mass is 0.005 per cent carbon, compare this to diamond planets, which can be up to a massive 75 per cent. There are more stars with the right conditions for diamond planets to form than first thought, so they are bound to pop up again and again in the search for exoplanets.

USB post-it notes?

Discover the sticky notes that contain 32GB of data storage

Losing your most important files could be a thing of the past as the office essential takes centre stage. The concept has been put forward by company dataSTICKIES and each strip will be able to store up to 32GB of data. It will work by attaching to the Optical Data Transfer Surface (ODTS) around the computer screen and will be read by the computer. They will also be made more resilient with an injection of the supermaterial graphene to form a one atom thick protective layer. Better still, you will be able to write on the notes as usual to distinguish between them.

Just when we thought data storage couldn't get more compact and handy, we're getting dataSTICKIES

GLOBAL EYE

10 COOL THINGS WE LEARNED THIS MONTH

We can talk to dolphins

Conversations with dolphins have been all one-way, until now. Dolphin expert Dr Denise Herzing used an underwater translator while playing with a pod she had been tracking for 25 years when one of them suddenly said "Sargassum" – a type of seaweed. The device, known as Cetacean Hearing and Telemetry (CHAT), detects whistles and clicks that Herzing and her team invented for English words, such as 'seaweed' or 'bow wave ride.' If proven successful, this breakthrough could lead to the world's first inter-species dictionary. Click click (translation: flippers crossed).

First Battle of Hastings victim unearthed

The famous Battle of Hastings took place almost 1,000 years ago, but experts have only just found the first-ever recorded victim. The skull is believed to have belonged to a 45-year-old man in East Sussex, who suffered six sword blows to the noggin. The bones are believed to be from a Saxon soldier rather than Norman due to the way in which he was buried.

Zero gravity flights prepare for launch

If you think you have the stomach for zero gravity, start saving. In 2015, Swiss Space Systems will offer passengers the chance to board its modified aircraft for £1,600 ($2,700) per ticket. During the flight passengers will experience just over six minutes of complete weightlessness as the aircraft performs mid-air parabolas (u-shaped manoeuvres). It's similar to what astronauts are put through in their training, but much less extreme and will be open for anyone over eight years old. Only the brave need apply.

Suspended animation may become reality

Han Solo was frozen in suspended animation in *The Empire Strikes Back*, but it's not as far-fetched as it was in 1980. In the US, doctors are attempting to save patients by putting them into a state somewhere between life and death. They're not using carbonite like Darth Vader, however, but a cold saline solution. Surgeons at UPMC Presbyterian Hospital in Pittsburgh will replace all of a patient's blood with this liquid, which cools the body to ten degrees Celsius (50 degrees Fahrenheit) so blood cells need less oxygen. It's hoped this will buy doctors more time to save the lives of gunshot and knife-wound victims.

Octopus tentacles can't stick to themselves

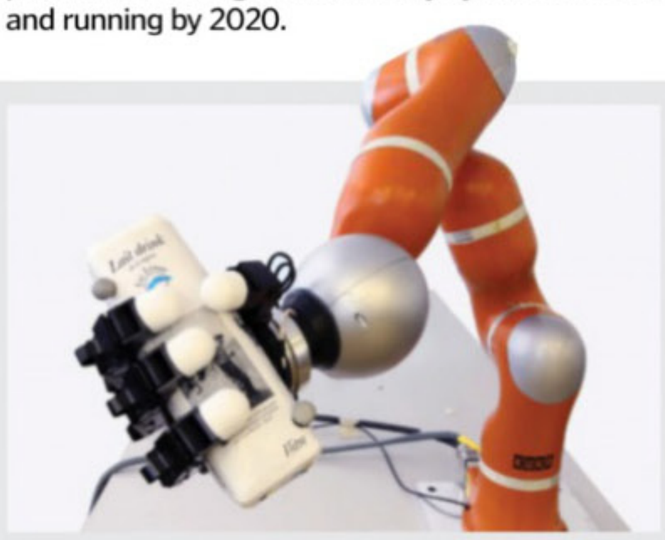
The eight arms of an octopus can stick to just about anything – except for themselves. If they did, the sea critter would get itself in a bit of a tangle since their brain has no idea what position the arms are in. Researchers at Hebrew University of Jerusalem found that the suckers temporarily shut down when they sense a chemical on an octopus' skin. They solved the mystery while testing amputated arms, which move and suck long after they've been detached. While the tentacles wouldn't grab onto other arms, they would if the arms had been skinned. They also found that octopuses can override this mechanism if they wanted to devour one of their own kind.

Windscreens of the future are intelligent

Looking much like a racing video game, this image is far from virtual reality. The screen produces an interactive visual display on the front of your car and shows essential information like speed and fuel consumption. The system will also help with satellite navigation and GPS technology, as well as predicting upcoming hazards on the road. Utilising technology already used in smartphones, it is predicted that augmented reality systems will be up and running by 2020.

Robots are learning from their mistakes

A new robotic arm was taught to catch objects in a similar way to how humans themselves learn: by imitation, trial and error. This technique called Programming By Demonstration doesn't give specific instructions, instead manually guiding the arm to the target and repeating the exercise over and over again. Soon the robot was swiping hammers, balls and rackets with immense accuracy. Researchers at the EPFL in Switzerland hope the robot arm will one day be able to protect humans by catching them or grabbing objects about to fall.



Virtual reality tech is game on

One year after the release of virtual reality platform Oculus comes the next-gen version: the DK2. The new and improved kit features a high-definition display that's designed to eliminate motion blur, which can cause simulation sickness. It also uses an external camera that allows users to peer around corners and lean in for a closer look during gameplay. "Virtual reality is going to continue to evolve rapidly in the coming years," say the developers at Oculus. "There's no cutting corners or 'good enough' when it comes to VR." The first batch is expected in July and prices will be $350 (£210) at launch.

Meditation makes you clever

Now we have an excuse for sitting still and relaxing, thanks to new research that says meditation boosts brain activity. It turns out there are two types of meditation: 'concentrative', where the person focuses on their breathing and specific thoughts; and 'nondirective', which allows the mind to wander. A team from the Norwegian University of Science and Technology and the University of Sydney studied brain activity with magnetic resonance imaging (MRI) and the results were unexpected. Dr Jian Xu says: "When the subjects stopped doing a specific task and were not really doing anything special, activity increased in the area of the brain where we process thoughts and feelings. Described as a kind of resting network, this area was most active during nondirective meditation."

Chubby cheeks + large eyes = cuteness

There's now an official scientific formula for determining how cute you are. Chubby cheeks, button nose, large eyes and a small chin all make a difference in how adorable children, and even adults, appear. The study at St Andrews University School of Psychology and Neuroscience analysed hundreds of faces and used computer software to identify the cutest facial features. It also showed that by manipulating face shapes in photos by as little as 20 per cent would boost an adult's cuteness rating, making them look younger.

You can see the 'cuteness' formula at play in Disney's *Frozen*

KEY DATES
ROALD AMUNDSEN'S EXPEDITION

Aug 1910
Amundsen and his team set off from Christiania, Denmark with nearly 100 Greenland dogs.

Jan 1911
The boat reaches the Ross Ice Shelf, sailing closer to the Pole than Scott's team, giving them an advantage.

Sept 1911
In their first bid to get closer to the Pole, bad weather forces them to race back to their base.

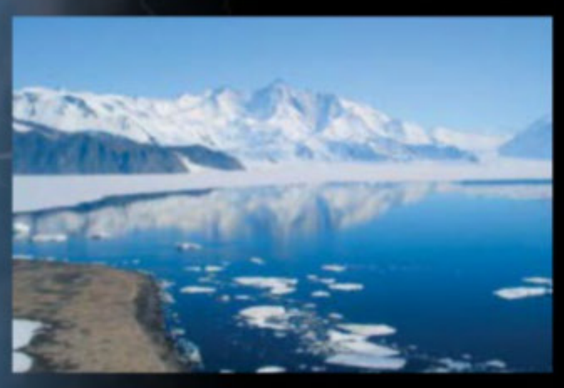
Dec 1911
By reaching 88°23'S, the team is further south than anyone has ever travelled before.

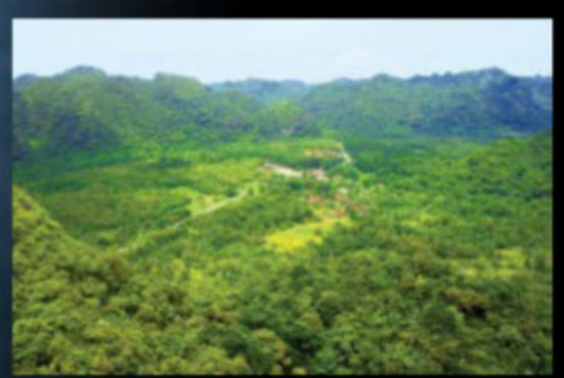
Dec 1911
Amundsen reaches the South Pole where he and his team place a Norwegian flag at the site.

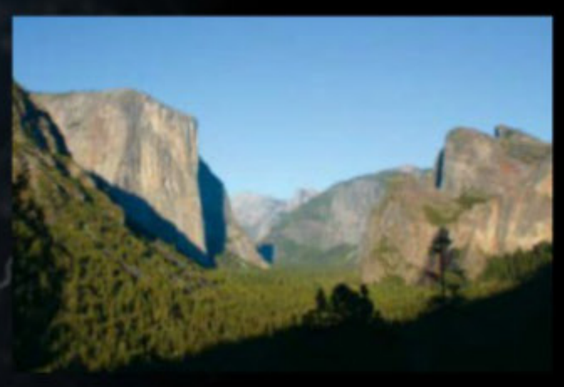
DID YOU KNOW? *Roald Amundsen beat Robert Scott to the South Pole by 34 days, despite Scott beginning eight weeks earlier*

SURVIVING EXTREME EARTH

The skills you need to journey into the wilderness and get out again alive







For many of us, the toughest conditions we'd ever have to face would probably be walking the dog in the bucketing rain. However, outside of the urban sprawl there are some places on Earth that aren't so hospitable to humans. While mankind has successfully populated large areas of the planet's land surface, there are still many places you wouldn't dare to venture unless you really enjoy a challenge or have just got horribly, horribly lost.

History is littered with people who have faced the biggest tests this planet has to offer, whether deliberately or accidentally, and lived to tell the tale, but many have fallen victim to frozen wastes or scorching plains. Even the best-prepared adventurers can come unstuck in the face of the amazing force of nature.

Over the next few pages we trek across deserts in search of water, dredge through jungles and scale icy mountains to uncover the dangers you're likely to come up against. Find out the equipment and skills needed to survive some of the most mind-boggling environments, where temperatures can plummet in hours, winds can reach breath-taking speeds and poisonous frogs can kill you where you stand.

We're not saying we will instantly turn you into the next Ranulph Fiennes, but it will hopefully give you a fighting chance should you find yourself in the depths of the Arctic Circle or in the middle of the Sahara. We still wouldn't recommend it though. ▶

"A word of warning, though: keep you eyes peeled. Polar bears are aggressive and masters of disguise"

Beat the freeze

How to stay alive when you're freezing to death

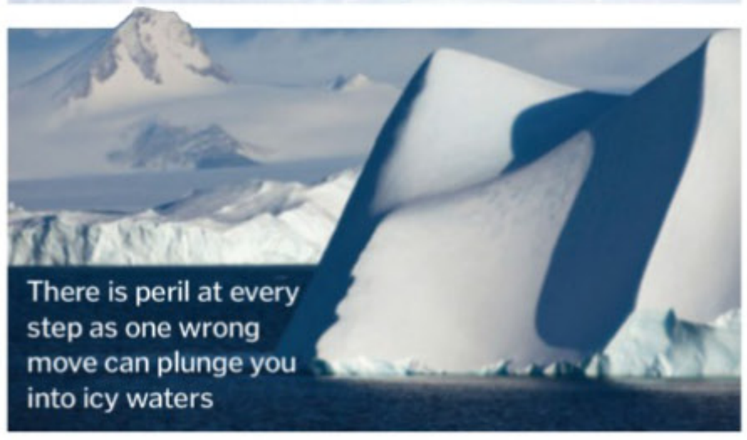
Earth's north and south extremities are among the most inhospitable on the planet. Even in the summer months temperatures are near freezing and winds can reach up to 327 kilometres (200 miles) an hour, so it's no wonder the cold is the biggest killer here. If you're trekking across snowy wastes, you better have packed your thermals. Shrug on multiple layers of breathable fleeces and keep them dry. Any water will instantly freeze, as will any exposed flesh. Even nose hairs and eyelashes start icing over in minutes, so covering up is key.

Your body will respond quickly to the heat loss by tightening blood vessels near your skin. This is the reason we look paler when we're cold and why our fingers and toes become numb. Meanwhile, your muscles will start moving involuntarily, causing you to shiver. It can boost heat production up to five times, but that uses up a lot of energy so you'll need to keep eating and drinking. Consume six to eight litres (10.6 to 14 pints) of water every day and around 6,000 calories, three times the typical recommended daily allowance. You can get this by melting butter into your food or munching on chocolate and bacon, so it's not all bad!

A word of warning, though: keep your eyes peeled. Hungry polar bears, particularly those with cubs to feed, can be aggressive and are masters of disguise. Flares and loud noises will often be enough to scare them away. You'll also need to watch your step, as slipping through a crack in the ice can send you plummeting into the freezing cold ocean. It's generally safe to walk on white ice, but grey ice is only ten to 15 centimetres (four to six inches) thick and prone to cracking, while black ice is to be avoided at all costs since it will have only just formed. Tread carefully, stay wrapped up and keep on the move if you want to have any hope of survival.


The snowy wastes of the polar regions are difficult to navigate


Polar bears are the Arctic's deadliest hunters


There is peril at every step as one wrong move can plunge you into icy waters


Little grows in this area so finding food is tough

Amazing animal

The arctic fox is an incredible little animal, well adapted to living in one of the harshest environments on Earth. Its furry feet and short ears are ideally suited to conserving heat in the unforgiving, freezing environment. Its coat is also adaptable; while its habitat is snowy its fur is brilliant white, hiding it from both prey and predators. However, as the ice melts, its coat turns brown or grey to hide among the rocks of the region. The arctic fox is an omnivore, feasting on rodents, fish and birds, but it will also eat vegetation when meat is difficult to find.

Life-saving kit

A rundown of what to wear to stay warm

Hat
A hat with ear flaps that covers the head and neck is vital. A strap to secure it on the head will be useful in high winds.

Thermal shirt
Your base layer should be a thin, thermal insulating top that wicks any sweat away from your body.

Jacket
Your jacket will need to be both wind and waterproof to keep you dry and warm. Wrist holes in the cuffs keep it secured.

Boots
Warmth is vital – literally – so fleece-packed boots are good. Straps are better than laces but don't fasten them so tight it cuts off the blood supply.

Goggles
The best goggles have a photochromic lens to help ward off glare from the ice and make sure you see cracks and holes.

Balaclava
You'll need to cover up as much as possible, so a woollen balaclava will keep the most heat in.

Mittens
Although gloves offer more dexterity with actions, mittens are better as they keep your fingers together and much warmer.

Trousers
Waterproof and windproof trousers are a must. Make sure they are also breathable, however, as you don't want your legs to become sweaty and lose valuable fluid.

-93.2°c

COLDEST PLACE ON EARTH

A bone-chilling temperature of -93.2°C (-135.8°F) was recorded in Antarctica in 2010 by satellite, making it the lowest temperature ever recorded on Earth.

DID YOU KNOW? *USA, Russia, Norway, Canada and Denmark all lay claim to territory in the Arctic, but none are allowed to own it*

Ice fishing

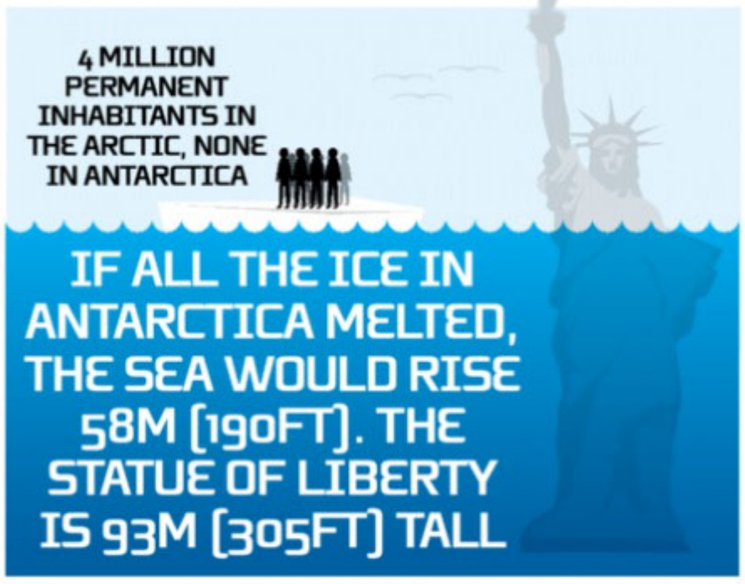
Make a hole in the ice with an auger – a kind of drill that bores large holes. The ice you bore on should be light grey and about 15 centimetres (six inches) deep. Produce a hole approximately 0.5 metres (1.5 feet) in diameter. Set up your chair one metre (three feet) away from the hole and hold your rod over the top of it, with the line dangling in the water. The rod should only be about a metre (three feet) long and made of a sturdy material. Drop the baited line down around two metres (seven feet) and wait for a bite. Reel it in and keep it chilled before cooking!

This simple tool can find you a life-saving source of food

AVERAGE DEPTH OF ICE IN ANTARCTICA – 2,126 METRES (6,975 FEET) EQUIVALENT TO 6.5 EIFFEL TOWERS

70%

ANTARCTICA'S ICE ACCOUNTS FOR 70 PER CENT OF THE WORLD'S FRESH WATER



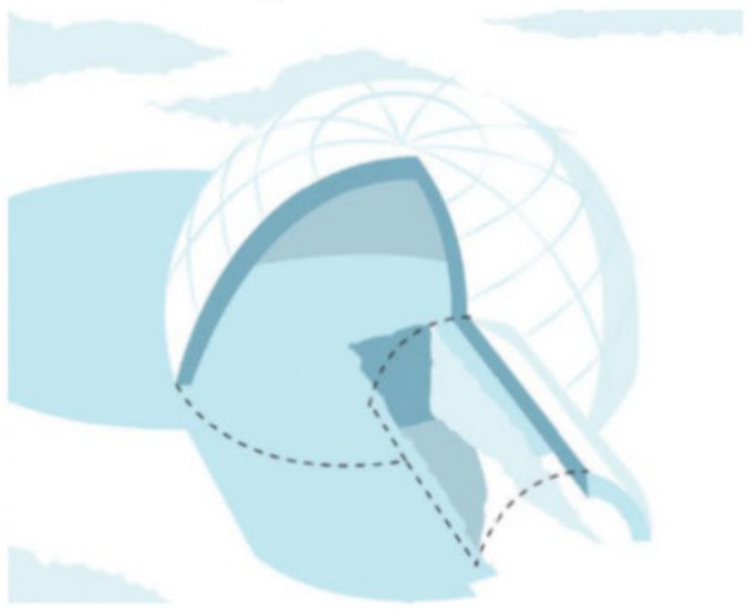
IF ALL THE ICE IN ANTARCTICA MELTED, THE SEA WOULD RISE 58M (190FT). THE STATUE OF LIBERTY IS 93M (305FT) TALL

Survive the night

Build an igloo for protection

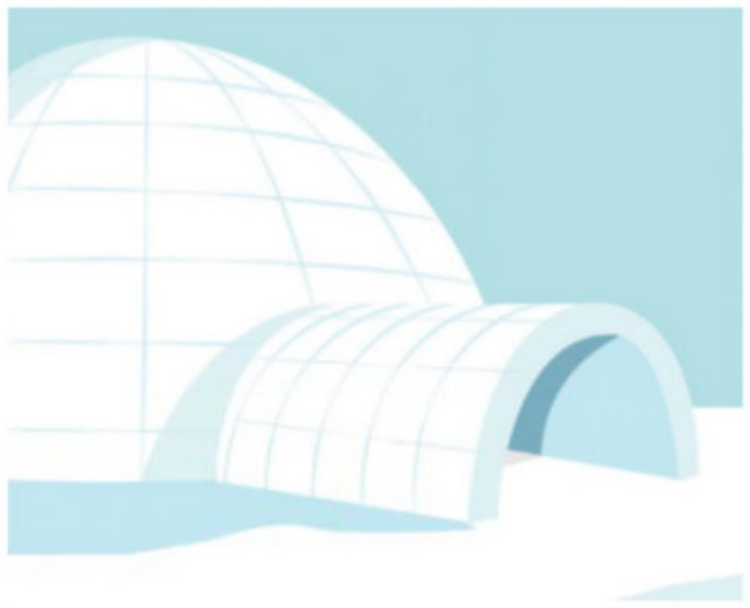
Find your spot

The first trick to making your igloo is to build it on the side of a slope. This will mean less building for you to do. Dig a trench in the snow around 0.6m (2ft) deep. Get in and slice out blocks of packed ice from either side of the trench to ensure they are nice and uniform.



Dig yourself in

Dig another trench into the side of the hill. It should be about 0.5 metres (1.6 feet) wide. This is the entrance trench. Leave a gap and dig another hole, but don't make it as deep as the entrance trench. This is your sleeping chamber, so make sure you fit in it!



Construct the walls

Stack the ice blocks in a circle around the sleeping trench, leaving a gap around the entrance trench. Over the entrance trench, stack the blocks in a semicircle. Make the entrance tunnel as small as possible to minimise heat loss. Rub water over the blocks to fuse them together.

"Your best bet for evading these huge predators is to stand still and hope you weren't seen, or run and hide"

Get out alive

Uncovering the dangers that lurk beneath the canopy of trees

Few places on Earth house quite as many things that can kill you in so many ways as the jungle. From snakes to poisonous frogs, berries to rivers, anyone walking through the jungle needs to have their wits about them at all times.

The most obvious threat will come from big animals like tigers and jaguars that inhabit the jungles of India and the rainforests of South America respectively. Your best bet for evading these huge predators is to stand still and hope you weren't seen, or run and hide. If you are spotted, make yourself as big as possible and shout loudly as this will surprise and intimidate them.

Don't be fooled into thinking the smaller critters pose less of a threat, though. Many can be deadlier than the big cats. The golden poison dart frog is particularly lethal to humans, as it has enough poison to kill ten adults. The poison is held in their skin, so eating or even touching one could have disastrous consequences. Add in the dangers of snakes, mosquitos, piranhas, crocodiles and bears, the jungle is not a place for the faint of heart. Take plenty of DEET-based insect repellent and make lots of noise as you travel so as to ward off creatures that would attack you out of fear or surprise.

While on your travels, be on the lookout for your next meal. On the menu will be fruit, plants, insects and fish, but you'll need a book to help weed out the edible from the poisonous. Avoid anything that's brightly coloured, because this is often an evolved defence mechanism to warn against eating that particular plant.

But while it's possible to survive for about 60 days without food in warm conditions, you'll last less than 72 hours without water. Always ensure you have a filtration device or water purification tablets to make the water safe, or catch rain before it has hit the ground to prevent catching diseases like cholera.

Although there are a multitude of things that can kill you in the jungle, being clued up on what you can and can't eat and how to avoid predator attacks will help enormously. If you're lost and ready to scream "Get me out of here!" then following water will take you out of the jungle to the end of the waterway. Ant and Dec almost certainly won't be there to meet you.

10
THE NUMBER OF ADULTS A GOLDEN POISON FROG COULD KILL IN ONE GO

Tigers in the jungles of India are deadly predators

Amazing animal

Bonobo monkeys are found in the jungles of the DR Congo and are one of our closest relatives. They share over 98 per cent of our DNA and have an astonishing ability to mimic human behaviour, including using tools and solving problems.

They have adapted superbly to life in the jungle, surviving on a varied diet of fruit, plant life small rodents, insects, and even soil. This flexibility means they will never go hungry.

They are extremely social animals, living together in groups of up to 100. The females move from group to group to prevent inbreeding and the males stay in their social groups for life.

STRANGE BUT TRUE

AGE TEST

What tells a sun bear's age?

A Rings on their teeth B Length of their tongue C Wrinkles on their forehead

Answer:
Much like you can do with trees, you can determine the real age of a sun bear by counting the rings on their teeth. Their jaws are incredibly strong and can break open nuts and coconuts quite easily, which also requires considerably strong teeth.

DID YOU KNOW? *Earth's largest rodent, the capybara, lives in South American jungles and can weigh as much as an adult human*

Avoid man-eating predators

Three steps to remaining undetected in the jungle

Cover your tracks

Predators like big cats are excellent trackers and they'll be keen to find you, especially if it's dinnertime. Walking in water will stop physical evidence of your movements, giving you a better chance of going undetected.

Camouflage

Hide yourself as you walk through the jungle using camouflage. If you don't have a specific outfit, coat yourself with mud and attaching leaves and foliage to your body will make you less likely to be spotted.

Cover your scent

Jackets lined with charcoal are excellent for preventing your natural odours from escaping into the environment. Otherwise, cover yourself in things like mud and strong smelling plants to mask your scent.

Jungle protection

The clothes and kit to keep you hidden, cool and safe

Sunglasses

The sunlight will be incredibly strong so you'll need some sunglasses with UV filters.

Long sleeve shirt

A light, breathable fabric will keep you cool, but make it baggy so mosquitos can't get to your skin.

Bug spray

Mosquitos carry a huge array of diseases, not least malaria, so 100 per cent DEET spray is vital.

LifeStraw

This device really could save your life. The filter inside the straw wipes out 99.99 per cent of bacteria in dirty water.

Trousers

Length is key here. You can't let your ankles get exposed because that's where mosquitos especially love to bite.

Hat

A large brimmed hat will protect you from bugs falling from the trees and keep you relatively hidden from animals above you.

Backpack

You'll need your hands free so a backpack is crucial. It needs to be waterproof, blend in with the environment and be comfortable.

Poncho

Sudden downpours are features of jungle and rainforest life, so a lightweight, quick-drying poncho is useful.

Machete

The jungle is a tough landscape to negotiate, so a large knife or machete will help you work your way through the thick and difficult undergrowth.

Boots

Your shoes don't want to be too thick and heavy because they'll wear you down. Sturdy trainers or Wellington boots will surprisingly be enough.

The edibility test

If you aren't a trained botanist, you might struggle to identify which plants are safe to eat. That's where the universal edibility test comes into play. Eat nothing and drink only water for eight hours before the test.

Your first task is to split up the plant you are testing into its individual components, such as the stem, root, leaf, flower and bud. Crush each part of the plant and, one-by-one, rub them on your skin to see if you have a bad reaction to it. If your skin blisters or forms a rash, it's unlikely to be good to eat.

If it's good, the next stage is to boil the plant, if possible. Hold the plant on your lip for a few minutes, removing instantly if it begins to burn. Finally, if the plant has passed the test so far, place it on your tongue. Again, if it begins to feel painful or look bad, spit it out and wash your mouth thoroughly. Remember though, tasting bad isn't the same as being poisonous!

Chew it for around 15 minutes and, if all still feels good, swallow it. Don't eat anything else for eight hours and see if you have any bad reaction to what you've eaten. If you're good, you've found a potentially life-saving food source!

"Even if it means burning another part of your body, wrap something around your head and neck"

Escape scorching heat

How to survive the extreme temperatures of the desert

While the polar regions are always bitterly cold no matter what time of day it is, one of the major challenges in surviving the desert is dealing with the ridiculous changes in temperature. In the midday Sun, the mercury can reach as high as 50 degrees Celsius (122 degrees Fahrenheit) in the Sahara, but drop to below freezing by night. Your best bet is to wear a loose-fitting robe. This will let air circulate around the body and you won't get nearly as hot and sticky. At night, when the temperature plummets, you can wrap it around you for warmth.

It is vital that you protect your head. If you think a touch of sunburn from staying by the pool on holiday is bad, that's nothing compared to the effects of walking all day in the parched desert. Even if it means burning another part of your body, wrap something around your head and neck so you don't succumb to sunstroke, which can lead to hallucinations and fainting.

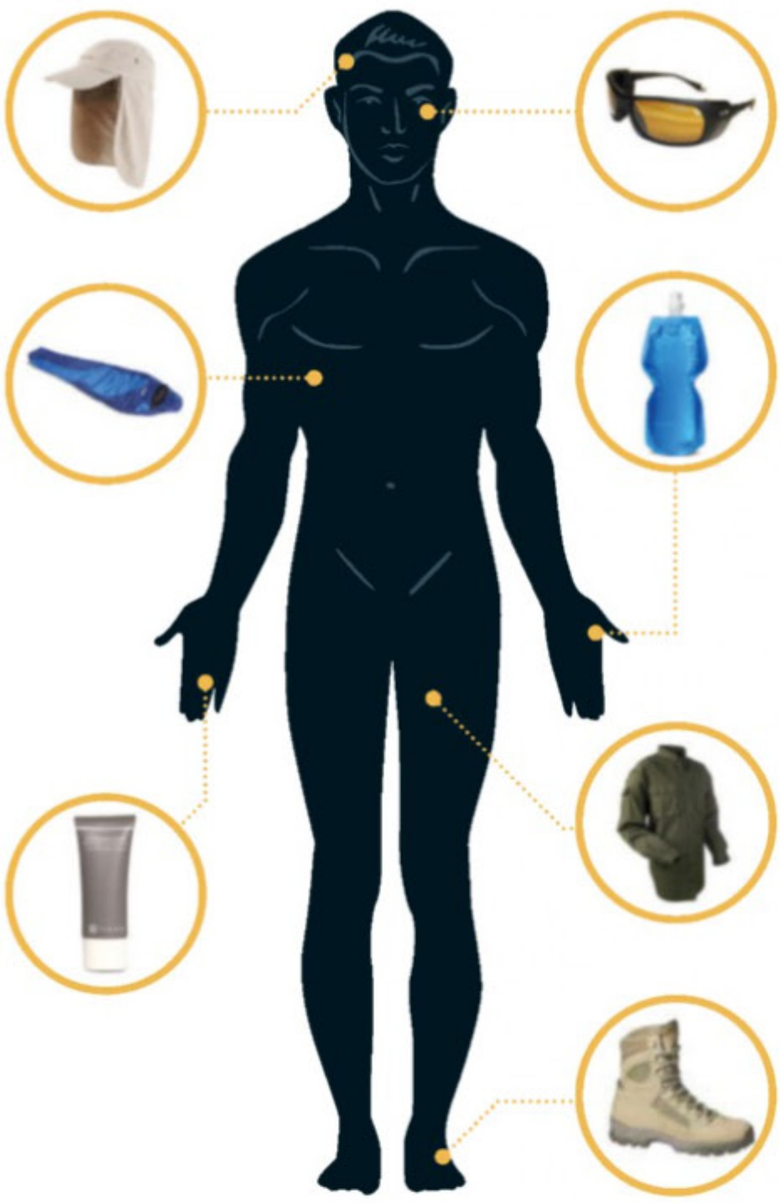
Other dangers in the desert will mostly come from scorpions. They hide in the sand and deliver a sting with their tail that can paralyse and eventually kill. Sturdy boots will protect you from these creepy crawlies, as well as making your travelling over sand much easier. While they don't make great pets, scorpions do provide a crucial source of nutrition. Picking them up by the tail just behind the stinger is the safest method and it will give you vital protein for your journey. Just don't eat the tail.

In the desert, you'll need to adjust your body clock. Aim to shelter during the day and travel at night. This has the dual benefit of avoiding the scorching sun and keeping you active during the freezing night. It also means you can keep on the right track easily by following the stars, hopefully leading to civilisation.

Shelter can come in the form of large rocks or cliffs. Alternatively, you can dig a trench down into the cooler sand and use clothing or some other material you have available to form a canopy over the top, secured by rocks or sand. As long as it is at an angle and not touching you, you'll be protected from the Sun's glare.

Desert dress

The essentials to surviving in the hottest places on Earth



Headwear
If you don't have any headwear, you could suffer with heatstroke, so protect your face and neck.

Sunglasses
The desert throws up an awful lot of sand and glare, so sunglasses will be absolutely vital.

Sleeping bag
A brightly coloured blanket will be useful as it would enable any search party to find you, will keep you protected in the day and warm at night.

Water bottle
This will be your greatest friend. Take small, regular sips and if you ever find a water source, fill it up as much as possible.

Sun cream
The baking temperatures will burn you in no time at all, so a high factor sun cream will provide at least some protection.

Shirt
Your clothes will need to be as loose fitting as possible to minimise sweating and dehydration.

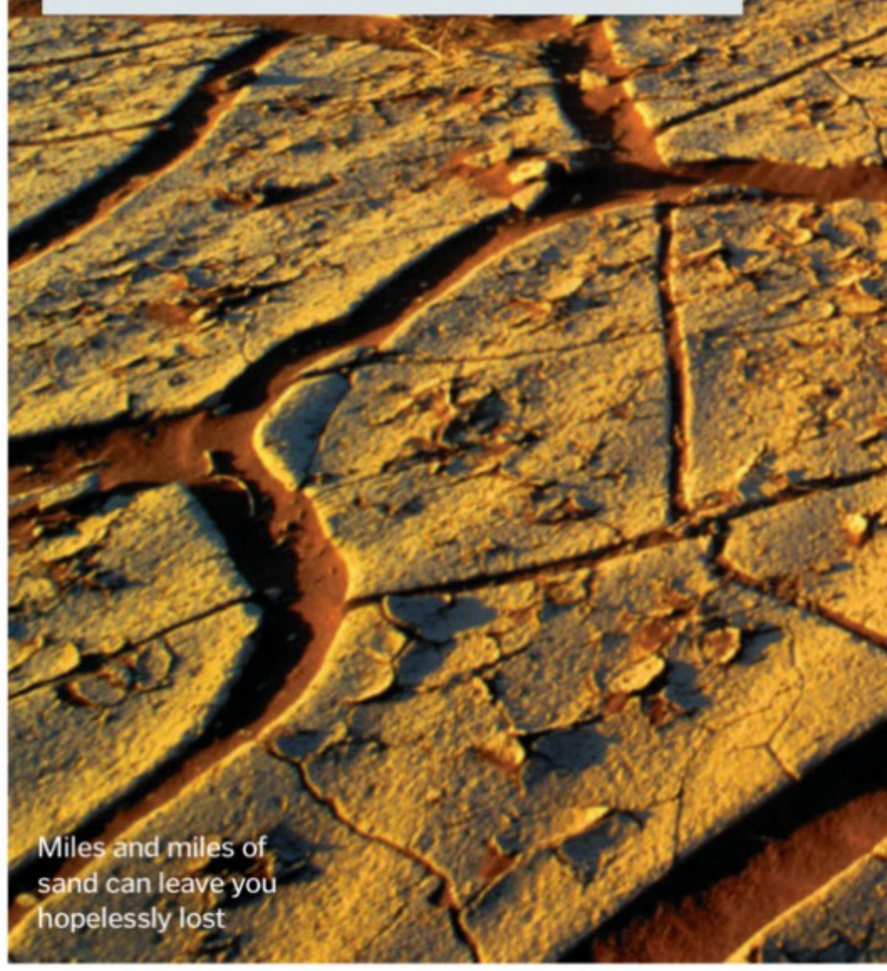
Footwear
Even though you'll be desperate for sandals, trainers or walking boots will give you grip and necessary protection.

Amazing animal

The camel is known as the ship of the desert, as this remarkable creature can travel without food or water for a long time.

Domesticated 3,000 years ago, camels have been an invaluable help to those who make their livelihood travelling the desert. They can carry 90kg (200lb) on their backs effortlessly and can travel up to 32km (20 mi) a day, with the added bonus of being able to last for at least a week without water and months without food.

Camels store fat in their hump to use as a food source and consume 145l (32gl) of water in one go, which they also store for later use. They have adapted wonderfully to the desert, developing a membrane across the eye and extra-long eyelashes to counteract sand storms. Their feet also are incredibly well protected with calluses and spread out for walking on sand.



Miles and miles of sand can leave you hopelessly lost

Finding your way around

The desert is not only barren and featureless, but it is also a moving entity. Therefore, finding your way around is tough. The easiest way to find your way around is with a compass, but if that isn't available, travel at night and use Polaris, the North Star, as your makeshift compass.

Even though they are always shifting, sand dunes can also provide useful navigation hints. They always build up at 90 degrees to the direction of the wind, as the wind pushes sand upward to form them, so even when there's no wind, if you know the wind is northerly, the dunes will go east to west and you can use that information to navigate.

If you are lucky enough to have any landmarks, try and make a straight path between them so you know you are going in a straight line.

HEAD 2 HEAD

LARGEST NON-POLAR DESERTS

1. BIG

Gobi Desert

This 1.3mn km² (502,000mi²) rocky desert covers a large portion of China and Mongolia, experiencing harsh and dry winters.

2. BIGGER

Arabian Desert

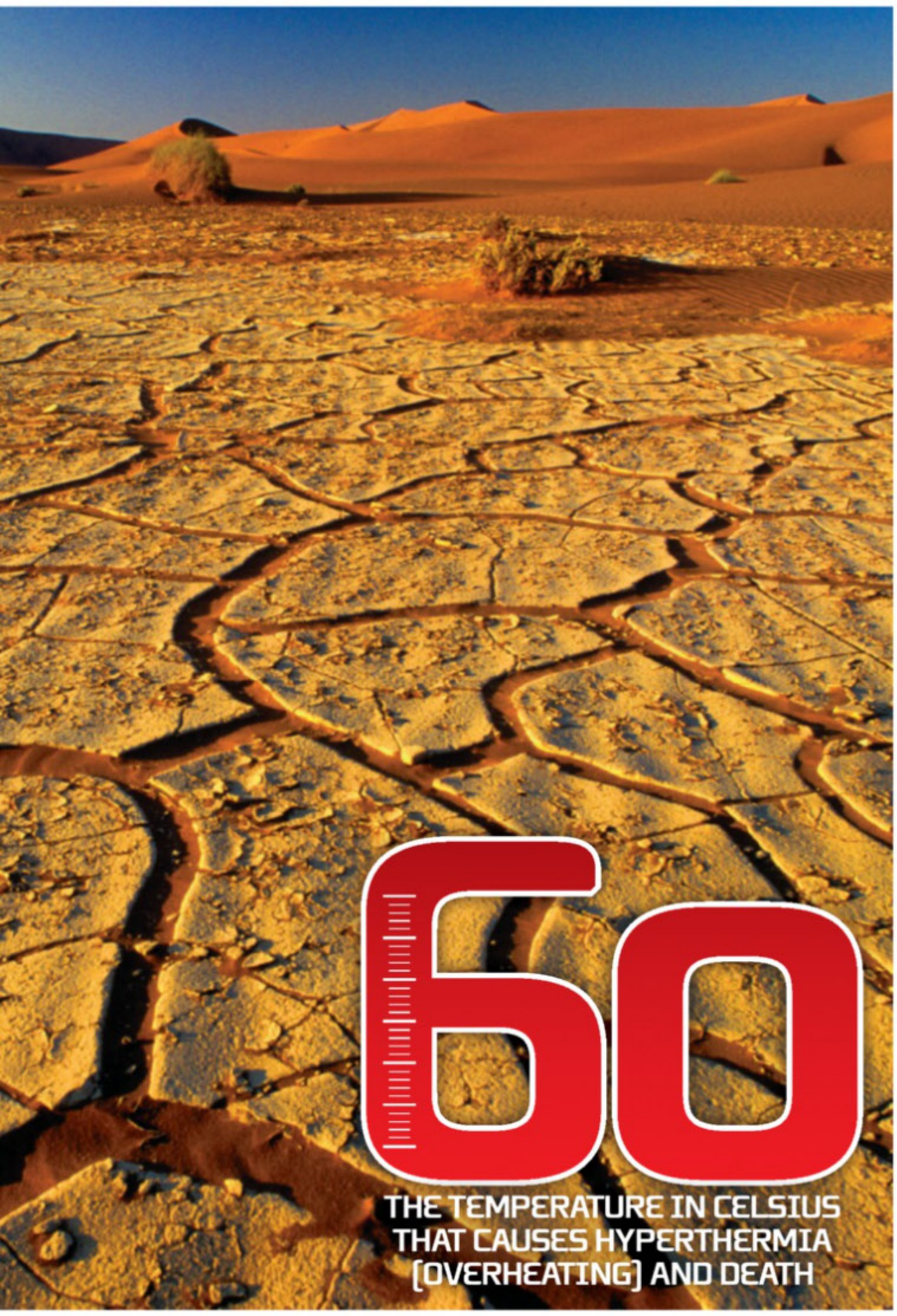
At a staggering 2.3mn km² (888,000mi²), the harsh Arabian Desert takes up most of the Arabian Peninsula.

3. BIGGEST

Sahara Desert

The most famous desert in the world measures 9.1mn km² (3.5mn mi²), making it over three times bigger than any other non-polar desert.

DID YOU KNOW? *Contrary to popular belief, drinking cactus water won't quench your thirst but make you very ill*



60

THE TEMPERATURE IN CELSIUS THAT CAUSES HYPERTHERMIA (OVERHEATING) AND DEATH

The plunging temperatures can leave you freezing cold without the right preparation

Fight extreme thirst

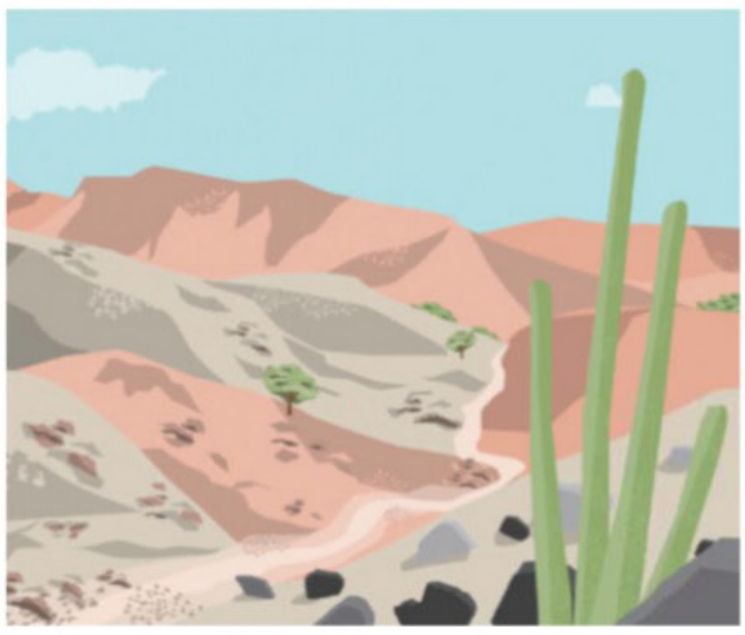
Locate the desert's most precious resource

Follow the wildlife

There are a number of birds and land animals that live in the desert and they all need water. Try and follow them wherever possible and hopefully they should lead you to a water source.

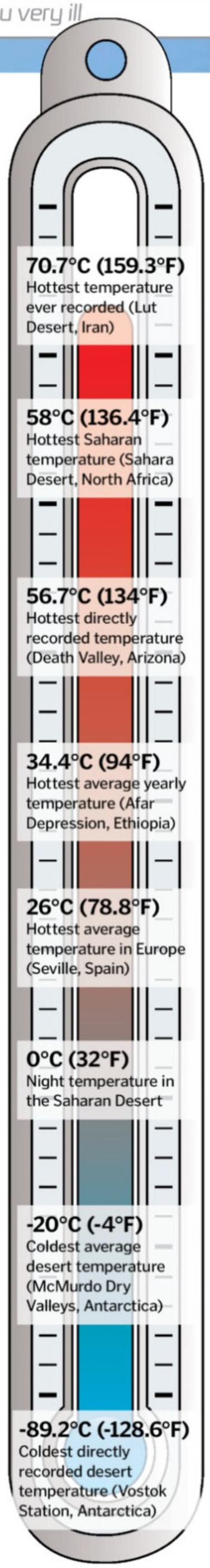
Shady cliffs

In your quest for precious shade, you might also be lucky enough to find water. Dips and ridges that face north could be housing puddles and pools in their shaded, cooler spots.



Grass is always greener

Plant life and vegetation means there is water around somewhere. Head down into valleys where there is plenty of greenery and even if there isn't a spring or pool around, you should be able to extract water from leaves or roots.



"As you climb higher, the air pressure reduces, meaning there is less oxygen for you to breathe"

Battle life-threatening altitude

How to cross the world's most treacherous terrain

Mountains are the ultimate test of survival. They're prone to rapid changes in weather and it's near impossible to predict. Even if the base is warm and sunny, by the time you reach the summit, low cloud can blind you, rain can make the terrain slippery and the cold can freeze you.

Good preparation is essential and you'll need a lot of kit. Pack a rucksack with a map, compass and a flashlight or headtorch, along with a brightly coloured emergency blanket, and dress in thermals and waterproof and windproof clothing. You'll also need to keep well hydrated. A lack of fluid at high altitude will result in dizziness, intense headaches and even frostbite. If you don't have any water to hand, try to find a stream or melt some snow or ice to drink.

The altitude is a real issue for many mountaineers. As you climb higher, the air pressure reduces, meaning there is less oxygen for you to breathe. This lack of oxygen will cause your brain to reduce activity in all but the most important organs, making your limbs heavy and head dizzy. The most important thing to do is rest and re-oxygenate your body.

If you are trying to escape the mountain, the best way is to head downward, but this isn't always possible. Mountains have complicated structures and often there isn't an easy path down. If possible, put markers along your route to show where you have already been, to avoid walking in circles. As well as being potentially confusing, mountains also hide dangerous crevices. Keep your eyes peeled for breaks in the snow or ice and if you are ever unsure, try to find rocks or stones to throw in front of you that could give away a hidden abyss.

If the visibility does become too poor, the safest thing might be to bed down. Find a spot out of the wind and protected from any snow or rainfall, like a cave or overhanging cliff. Even though it might sound strange, pack your surroundings with snow, because it does have insulating properties. Pile yourself with as many layers as possible and this should provide the warmth so you can make it through the night and try to find your way out in the light.

Amazing animal

The mountain goat is amazingly adapted to life on the mountainside. Their hooves are curved and flexible to provide them more grip and traction on the treacherous slopes. Despite looking spindly and thin, their legs are actually very strong and they can leap surprisingly large distances.

They have two coats, a warm, woolly undercoat and a thinner but longer overcoat, which keeps the insulating undercoat dry. This system is how they can stand the cold temperatures long after bigger animals have given up and descended down the mountain in cold weather.

GoPros are a great way to record your adventure

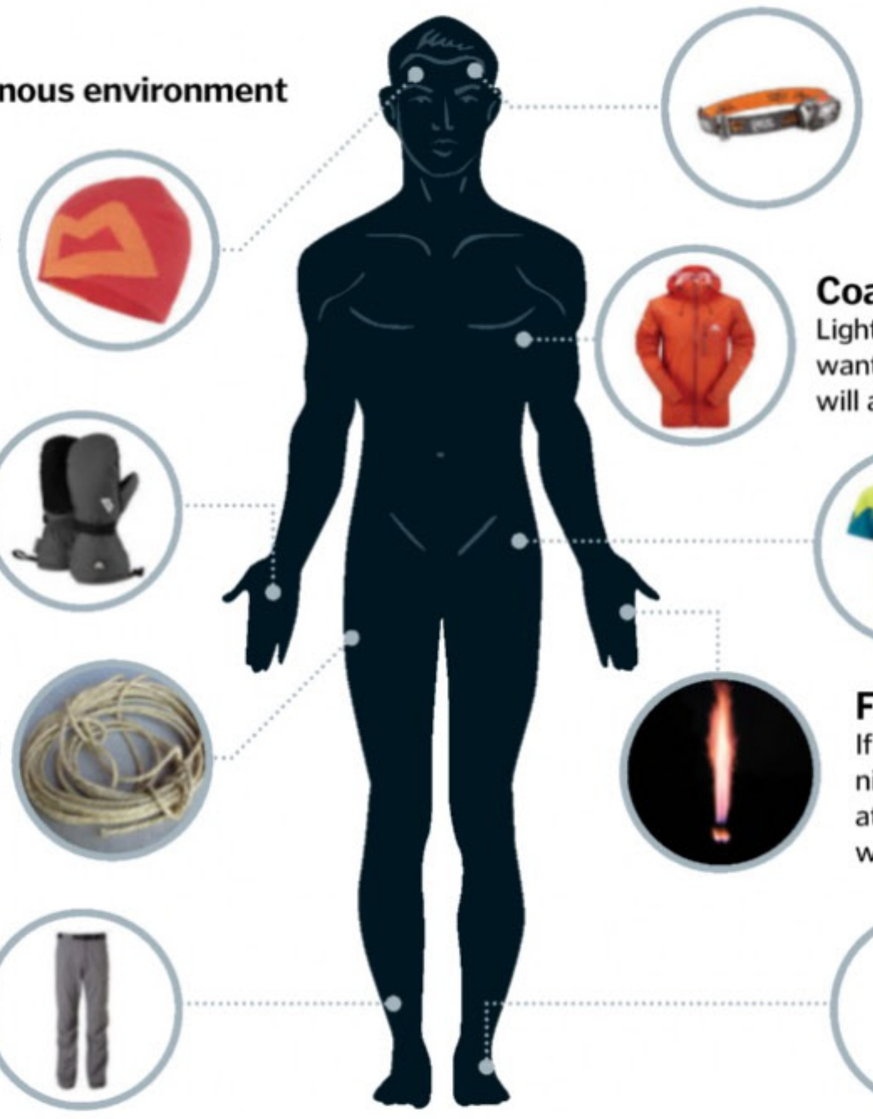
Keep a record

It's always handy to have a visual record of your travel by using a video recorder like the Hero3+ from GoPro. This camcorder is incredibly robust, lightweight and waterproof. It can also be attached onto helmets or bags, leaving your hands free to scale the treacherous mountainside.

Using a GoPro camera will also be useful as, once you get off the mountain to safety, you and a professional will be able to look over the footage, determine what went wrong and see how you could avoid getting stuck in the same situation again. The Hero3+ is available at **www.camerajungle.co.uk**.

Mountain gear

What you need to brave the harsh, mountainous environment



Beanie
A tight-fitting hat will keep lots of heat in as well as not being likely to fly away!

Headlight
A powerful headlight will be essential for finding your way around in darkness without wasting a hand on a torch.

Coat
Lightweight is key here because you don't want to be weighed down. Bright colours will also make you visible to rescuers.

Mittens
Although it would be useful to have fingers available for gripping ledges, it's more important to have your fingers warming each other.

T-shirt
A tight-fitting T-shirt made of breathable material will keep body heat in without making you sweat.

Rope
A strong and sturdy rope will help you protect yourself while asleep and also aid you in climbing or negotiating dangerous paths.

Flare
If you can send up a flare, do so at night. Not only will it attract the attention of rescuers, it might ward off predators.

Trousers
You need to keep dry and have items accessible, so a pair of waterproof trousers with zipped pockets will be the most useful.

Boots
A high-legged boot will keep the worst of the snow and water out, while the sole will need to be rugged and have tons of grip.

AMAZING VIDEO!

SCAN THE QR CODE FOR A QUICK LINK

See mountain goats take on near-vertical walls

www.howitworksdaily.com

DID YOU KNOW? *The tallest volcano is Mauna Kea, as it starts 6,000m (19,685ft) below sea level, making it 10,205m (33,480ft) tall*

Keep the fire burning

How to warm up on the mountainside

Find some wood

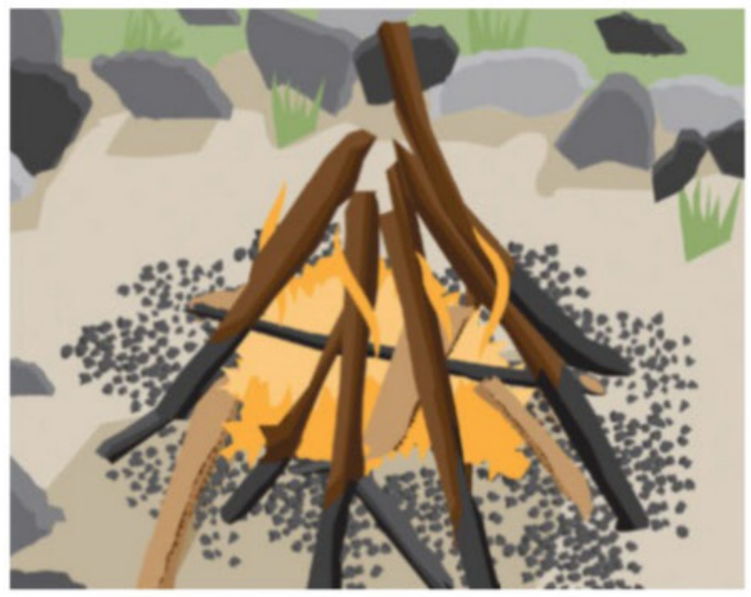
You'll want a variety of wood, from small sticks and twigs, all the way up to sizeable branches and logs. The smaller bits will light much more quickly while the bigger pieces will burn longer, hotter and form the bulk of the blaze.

Build your base

Dig a small pit in the ground. Surround it with stones so the fire doesn't get out of control. Place the smallest bits of wood at the bottom of the pile, but leave some gaps to keep the fire supplied with the oxygen it needs to burn.

Light the fire

Place the larger branches and logs at an upwards angle, allowing the air to circulate and ensuring all the wood is getting burned evenly. Make sure everything is connected so fire can transfer from one piece of wood to another.



Crevices and cracks await the unwary traveller

"We capsized and nearly drowned, but, as they say, what doesn't kill you makes you stronger"

Ben Fogle vs Mother Nature

TV's most charismatic survivalist has taken on ocean rows, desert marathons and polar expeditions. How It Works got the chance to ask him how and, more importantly, why

Ben Fogle first exploded onto the survivalist scene as the star of BBC series *Castaway 2000*. 13 years later, he's riding a camel, commando. "The desert is unforgiving; I wish I had worn pants", he laughs, recalling the time he followed in the footsteps of legendary British adventurer Sir Wilfred Thesiger, crossing a brutal stretch of Middle Eastern desert. "We did it authentically, wearing original clothes as worn by Thesiger. He didn't wear undergarments and neither did I. But chafing aside, the trek across the Empty Quarter of Oman was the most enjoyable thing I've ever done because it was a lifelong ambition."

The 40-year-old's rapid adjustment to the challenging environment shouldn't really have come as a surprise, considering his varied, outdoorsy early years. "I spent all my summers in Canada at the cabin my late grandfather handbuilt on a lake. It was an idyllic *Swallows And Amazons* childhood of tree houses, fishing and raft building. I did a degree in Latin American studies after spending two years living in the colourful continent. I loved it and wanted to learn more. My degree included a one-year overseas programme so I went to Costa Rica. I would recommend Central and South America to anyone."

A stint on *Castaway 2000* followed, in which Fogle and 35 other men, women and children tried to build a community on the Scottish Island of Taransay. It was a hotbed of disagreement, argument and drama but he managed to rise above it, becoming one of the stars of the show. "I applied for *Castaway 2000* because I was looking for an excuse for adventure", he says. "I liked the idea of spending a whole year marooned on a remote island. The experience was life changing in every sense. It taught me so many life skills that still serve me today."

The social experiment ended a year later and back in London, the TV presenting jobs came flooding in. But with adventuring clearly in his blood, Ben sought another challenge and decided to take part in the Marathon des Sables (MdS). This epic six-day race, known as the toughest footrace in the world, takes runners around 240 kilometres (150 miles) through the Sahara Desert. Those taking part have to contend with scorching heat, terrible blisters and sand storms. Despite this, Ben managed to finish the race in less than 60 hours. "Anyone who has raced the MdS will know there are points when you want to give up, but it's not so easy in the middle of the Sahara", he explains. "You can't just jump on a bus."

Ben struggled through one of the toughest foot races in the world

The Race to the Pole required a lot of hard work and calories

Having conquered the Sahara Desert, two years later Ben entered the epic Atlantic Rowing Race with former Olympic rower James Cracknell. The pair crossed the 4,717 kilometres (2,931 miles) in 49 days, 19 hours and eight minutes, finishing second overall in the pairs classification. "I was looking for a challenge to make me stronger", he says. "I applied for the Atlantic Rowing Race and then set about finding myself a rowing partner. We spent a year getting ready for it. It was a gruelling experience, we capsized and nearly drowned but, as they say, what doesn't kill you makes you stronger."

Not content with rowing all the way across the

5 TOP FACTS
THE LIFE OF BEN

The conservationist

1 While in South America, Ben Fogle worked on a turtle conservation project on the Mosquito Coast of Honduras, as well as volunteering in an Ecuadorian orphanage.

The driver

2 Fogle is a man of many talents, certified to skipper a variety of boats, yachts and dinghies as well as holding licenses for SCUBA diving and rally driving.

Famous mum

3 His mother is actress Julia Foster, best known for roles in *Alfie*, *The Loneliness Of The Long Distance Runner* and *Half A Sixpence*, among many others.

The boxer

4 He took on and beat *EastEnders*' Sid Owen in a charity boxing match in aid of Sport Relief back in 2004. He trained for six weeks for the fight.

Famous dad

5 Ben's father, Canadian-born Bruce Fogle, is also something of a celebrity, hosting many TV and radio shows in Britain in his role as a veterinarian.

DID YOU KNOW? *The Marathon des Sables was created by Patrick Bauer, who crossed the Sahara in 12 days*

Despite going to all corners of the globe, Ben still has more challenges to take on

second biggest ocean on the planet, the harsh Antarctic was Fogle's next challenge, once again teaming up with James Cracknell to take on the Race To The Pole, a team event that transports competitors to the southernmost tip of the planet. "Antarctica is the coldest, driest, windiest place on Earth," Fogle recalls. "It's a desolate, tough, unforgiving environment. We trained in Norway with the Marines and on a Swiss glacier with personal trainer Bernie Shrosbree. We had to bulk up before the race and take 5,000 calories of food per day for the race itself. The kit is essential to survival and we took advice from people who had previously trekked in Antarctica. The most important thing to remember is never sweat. Sweat and you die. It's difficult to race and not sweat."

In recent years there's been no avoiding a spot of perspiration, as his series *Extreme Dreams* took him to the jungles and mountains of South America and Africa, and his latest show *Storm City* investigates the effects of our planet's extreme weather. "One of the hardest things I have to face on my trips is disease and poverty", he says. "I still hate to see suffering in the world. It makes me feel guilty for what I have. Having said that, my job allows me to explore the world and meet incredible people. I wouldn't change it for anything."

As someone who's visited most of the hostile places on Earth, there aren't many options left for his next extreme expedition, but he's got a spot in mind. "The Moon. Watch this space."

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AMAZING VIDEO! SCAN THE QR CODE FOR A QUICK LINK

A beautiful music video of noctilucent clouds

www.howitworksdaily.com

DID YOU KNOW? *The biggest cloud is the cumulonimbus. They're dark and can contain millions of tons of water*

Clouds that shine at night

How do these glow-in-the-dark noctilucent clouds form high in the Earth's atmosphere?

How noctilucent clouds form

Observing
The light from the Sun that hasn't been scattered by the ice crystals reflects into our eyes, illuminating the noctilucent clouds.

Scattering
After dusk, sunlight can still reach the mesophere - the coldest part of Earth's atmosphere. The light hits ice crystal shards and is scattered, with the stratosphere absorbing red light, leaving only blue.

Nucleus
These ice crystals need to contain some kind of nucleus to effectively scatter the light. This could be either meteorite or volcanic dust.

Temperature
Ice crystal shards form when the temperature of the mesophere falls below -120°C (-184°F), but this only happens in the months either side of the summer solstice.

Sun sets
Once the Sun is more than six degrees below the horizon from the perspective of the viewer, it sends sunlight up into the mesosphere, 80km (50mi) up.

The sailing stones

Solving the mystery of the rocks that move by themselves

The Racetrack Playa in Death Valley, USA, has been a massively popular tourist spot for decades, mainly due to the incredible phenomenon in which huge rocks appear to move by themselves. Rocks as heavy as 318 kilograms (700 pounds) have travelled as far as 457 metres (1,500 feet), leaving a trail in the mud behind them. Everything from aliens to pranksters has been blamed for the phenomenon, while other researchers thought whirlwinds that suddenly kick up in the desert might be to blame. This theory was disproved, leaving us scratching our heads for years, until planetary scientist Ralph Lorenz from John Hopkins University cracked the mystery while working on a project with NASA. He discovered that in winter the Racetrack Playa gets extremely cold, allowing ice to form around the rocks. The ice makes even the heaviest rocks buoyant, allowing them to 'surf' along the standing water in only a slight breeze, creating a trail in the sand beneath it.

"A caterpillar can only travel a few metres in their lifetime, which is no good for finding a mate"

All about butterflies

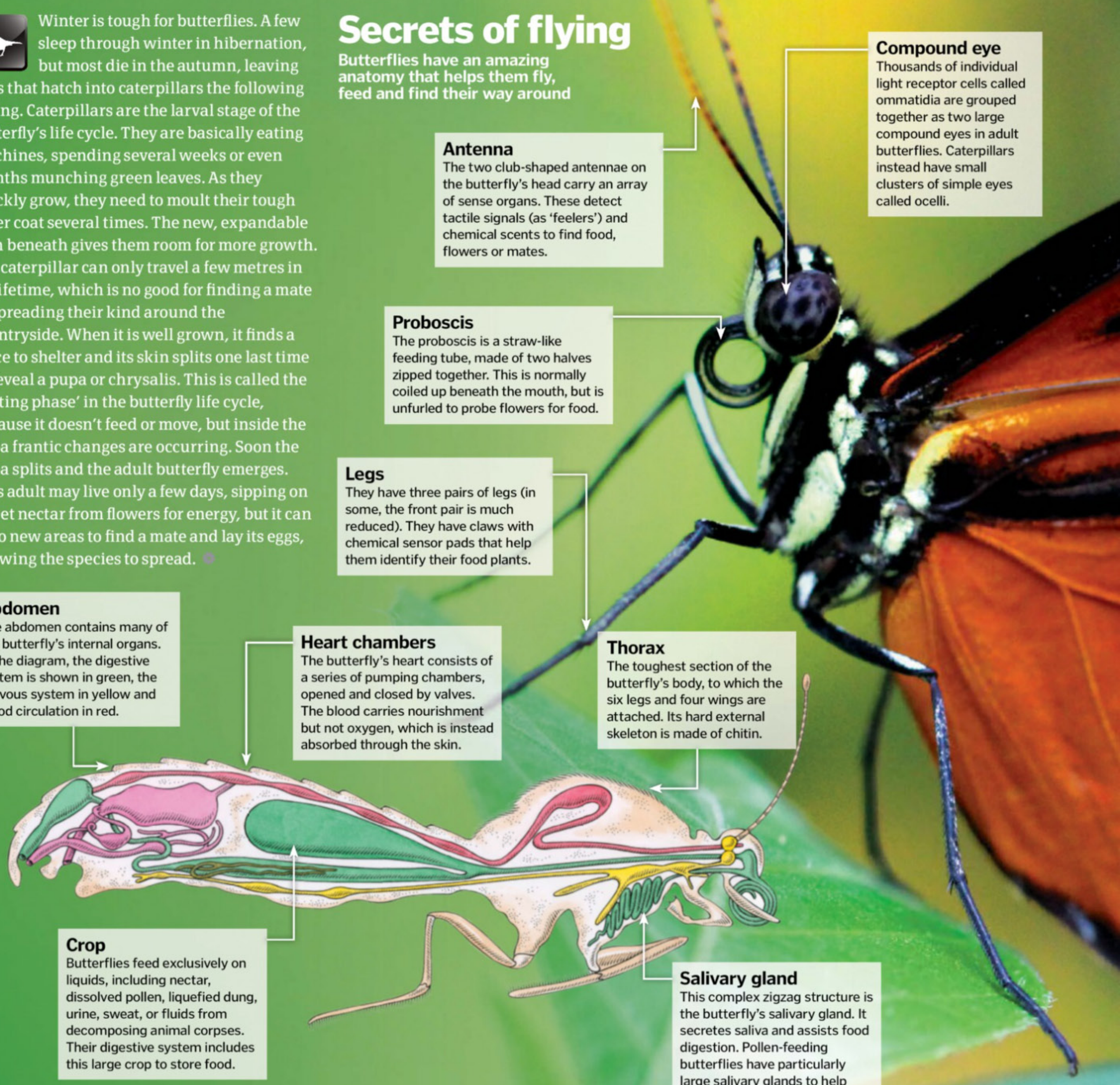
Get to know your garden visitor inside and out

Winter is tough for butterflies. A few sleep through winter in hibernation, but most die in the autumn, leaving eggs that hatch into caterpillars the following spring. Caterpillars are the larval stage of the butterfly's life cycle. They are basically eating machines, spending several weeks or even months munching green leaves. As they quickly grow, they need to moult their tough outer coat several times. The new, expandable skin beneath gives them room for more growth.

A caterpillar can only travel a few metres in its lifetime, which is no good for finding a mate or spreading their kind around the countryside. When it is well grown, it finds a place to shelter and its skin splits one last time to reveal a pupa or chrysalis. This is called the 'resting phase' in the butterfly life cycle, because it doesn't feed or move, but inside the pupa frantic changes are occurring. Soon the pupa splits and the adult butterfly emerges. This adult may live only a few days, sipping on sweet nectar from flowers for energy, but it can fly to new areas to find a mate and lay its eggs, allowing the species to spread.

Secrets of flying

Butterflies have an amazing anatomy that helps them fly, feed and find their way around



Compound eye
Thousands of individual light receptor cells called ommatidia are grouped together as two large compound eyes in adult butterflies. Caterpillars instead have small clusters of simple eyes called ocelli.

Antenna
The two club-shaped antennae on the butterfly's head carry an array of sense organs. These detect tactile signals (as 'feelers') and chemical scents to find food, flowers or mates.

Proboscis
The proboscis is a straw-like feeding tube, made of two halves zipped together. This is normally coiled up beneath the mouth, but is unfurled to probe flowers for food.

Legs
They have three pairs of legs (in some, the front pair is much reduced). They have claws with chemical sensor pads that help them identify their food plants.

Abdomen
The abdomen contains many of the butterfly's internal organs. In the diagram, the digestive system is shown in green, the nervous system in yellow and blood circulation in red.

Heart chambers
The butterfly's heart consists of a series of pumping chambers, opened and closed by valves. The blood carries nourishment but not oxygen, which is instead absorbed through the skin.

Thorax
The toughest section of the butterfly's body, to which the six legs and four wings are attached. Its hard external skeleton is made of chitin.

Crop
Butterflies feed exclusively on liquids, including nectar, dissolved pollen, liquefied dung, urine, sweat, or fluids from decomposing animal corpses. Their digestive system includes this large crop to store food.

Salivary gland
This complex zigzag structure is the butterfly's salivary gland. It secretes saliva and assists food digestion. Pollen-feeding butterflies have particularly large salivary glands to help liquefy the pollen.

5 TOP FACTS
BUTTERFLY TRIVIA

Rule breakers

1 Burnet moths contradict the stereotypes about moths and butterflies. They are brightly coloured, fly by day and even have club-shaped antennae, but are classified as moths.

Love dust

2 Some scales on male butterflies' wings are scent capsules. During courtship, males get close to females, then split open these capsules to release aphrodisiac 'love dust.'

Ultraviolet

3 Butterflies can see a wider colour spectrum than humans, into light invisible to us. Many flowers have ultraviolet markings on their petals to guide pollinating butterflies.

Diverse diets

4 While most butterflies sup flower nectar, blue morpho butterflies feed on the juices of rotting fruits and purple emperor butterflies enjoy the smelly fluids of rotting flesh.

Long-distance migrants

5 Painted ladies are one of several European butterflies that migrate from wintering grounds in North Africa to breed in Britain and Europe as far north as Iceland.

DID YOU KNOW? *Butterflies breathe through pores in their exoskeleton. Their movement allows oxygen in and carbon dioxide out*

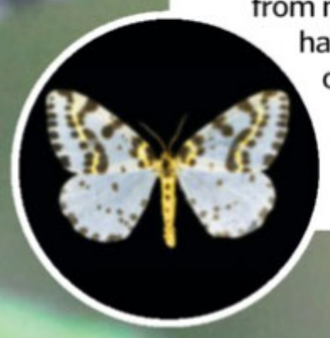
Life cycle of a butterfly

Butterflies undergo a remarkable transformation – or metamorphosis – during their development

Wings
Butterflies have two pairs of overlapping fore and hind wings. These consist of a thin double membrane, reinforced by a radiating network of tubular, blood-filled veins.

Butterflies vs moths

We generally think of butterflies as colourful and flying by day, while moths are drab and night flying, but zoologically there is no distinction. There are colourful, day-flying moths and some butterflies are dull-coloured and skulking. Butterflies only make up about ten per cent of the families in the order Lepidoptera. The other 90 per cent are moths, but they differ between themselves at least as much as butterflies differ from moths. It is true that most butterflies have club-shaped antennae, while moths often have feathery or hair-like antennae, but there are many exceptions. Butterflies and moths also tend to fold their wings differently when resting.



Butterflies in the UK

Things don't look great for butterflies in Britain, according to Dr Zoë Randle, surveys officer for the UK charity Butterfly Conservation. In the last ten years, three-quarters of British butterflies have declined in abundance or range. Common 'garden' butterflies have reduced in numbers by 24 per cent. Their wild habitats are destroyed by intensive agriculture and changes in traditional countryside-management practices. Climate change is also playing a part. Randle fears the specialist butterflies of isolated habitats will struggle to cope with the pace of change.

"Hard work by the Butterfly Conservation restoring wild habitats has helped increase populations of our rarest species, like the heath fritillary, but we need to think bigger", says Randle. "We need to manage remaining wild habitats more effectively and link them together by habitat corridors across the countryside. We need conservation sprawl, not urban sprawl."

We can all help by planting nectar-rich flowers in our gardens and leaving patches of wild grasses and stinging nettles for some caterpillars. And Randle encourages us to take part in the Big Butterfly Count, available online at www.bigbutterflycount.org, which runs from 19 July to 10 August 2014.

EXO SUITS

THE FUSION OF MAN AND MACHINE WAS THOUGHT THE STUFF OF SCIENCE FICTION, UNTIL NOW

Iron Man is no longer the sole domain of comic books and film superheroics. Thanks to advanced robotics and human-machine interfaces, mechanised exoskeletons are being adopted worldwide. From machines capable of turning men into super-soldiers to cyborg implants clever enough to make the disabled mobile, the concept of human augmentation is rapidly transitioning from pipe dream to power on, with a host of companies and developers producing systems to make humans quicker, stronger and more perceptive.

Why is this revolution happening now? It's a combination of advanced discussion regarding the ethics of such augmentations by the Earth's brightest minds and a ravenous, insatiable drive by science and technology corporations to take humanity into a glorious new age. Before, scientific developments such as these would have been stamped out by fanatics, now if a person is born without the use of their legs they will still be able to walk and live their life like they never thought possible.

Strap yourself in and power up your mind as **How It Works** takes you on a tour through some of the most groundbreaking advancements changing the world in the fields of robotics and bionics. Welcome to the human-machine fusion revolution.

1,000ft

DEEP DIVING SUIT

A 240kg (530lb) deep-sea diving suit called the Exosuit, a next-generation Atmospheric Diving System (ADS), has enabled scientists to explore the ocean as far as 305m (1,000ft).

DID YOU KNOW? *The first prototype for the Hybrid Assistive Limb (HAL) was built in 1997*

HAL

HUMAN LIMBS EVOLVED

One of the most useful developments in human augmentation right now is Cyberdyne Inc's Hybrid Assistive Limb, codenamed HAL. HAL is the world's first cyborg-type robotic system for supporting and enhancing a person's legs, giving them the ability to walk if disabled.

Attached to the user's lower back and legs, HAL works in a five-step process. The user merely thinks about the motions they want to undertake, such as walking. This causes the user's brain to transmit nerve signals to the muscles necessary for the motion to take place. At this stage, a disabled user wouldn't be able to receive these nerve signals correctly in their limb muscles, but with HAL attached, they can. HAL is able to read the user's emitted bio-electric signals (BES), faint subsidiary signals from the brain-muscle signals that extend to the surface of the user's skin. By detecting these signals, HAL is then able to interpret the motion intended by the user and execute it, allowing them to move.

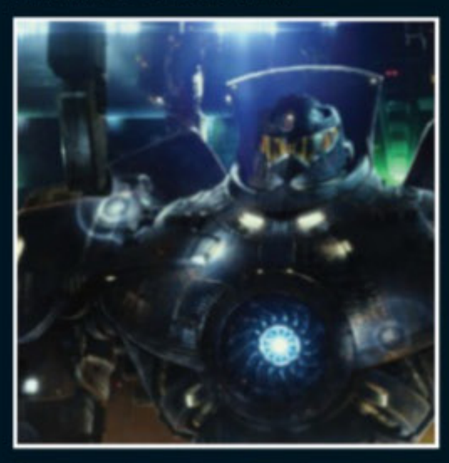
What is most exciting about HAL is its potential to train disabled individuals to move without its help. That is because every time HAL helps its user move, a natural feedback mechanism sees the user's brain confirm the executed movement, training the user's body to transmit those nerve signals correctly. While still some way off, continued development could eventually see HAL train a disabled person to walk unassisted.

Top 5 movie mechs

Gipsy Danger

Pacific Rim (2013)

One of the most important mechs from 2013's *Pacific Rim*, Gipsy Danger helps humanity combat inter-dimensional beasts bent on Earth's destruction.



Power Loader

Aliens (1986)

Piloted by Ripley in James Cameron's *Aliens*, the Power Loader mech helps Sigourney Weaver's feisty protagonist face off against the fearsome alien queen.

AMP

Avatar (2009)

Another hot mech from the mind of James Cameron, *Avatar*'s AMP plays a key role in the film's finale, with the baddie wreaking a whole lot of havoc in one.

Rhino

The Amazing Spider-Man 2 (2014)

Russian mobster Aleksei Sytsevich breaks out of prison and tears up Manhattan in a mech suit inspired by a rhinoceros.

APU

The Matrix Revolutions (2003)

Protecting the remnants of humanity against the sentinels of the *Matrix* universe, the APU deals huge damage with big guns.

"An untethered, hydraulic exoskeleton, the HULC allows soldiers to perform superhuman feats"

No longer the sole domain of comics and movies like *GI Joe*, exoskeletons are helping soldiers in the field

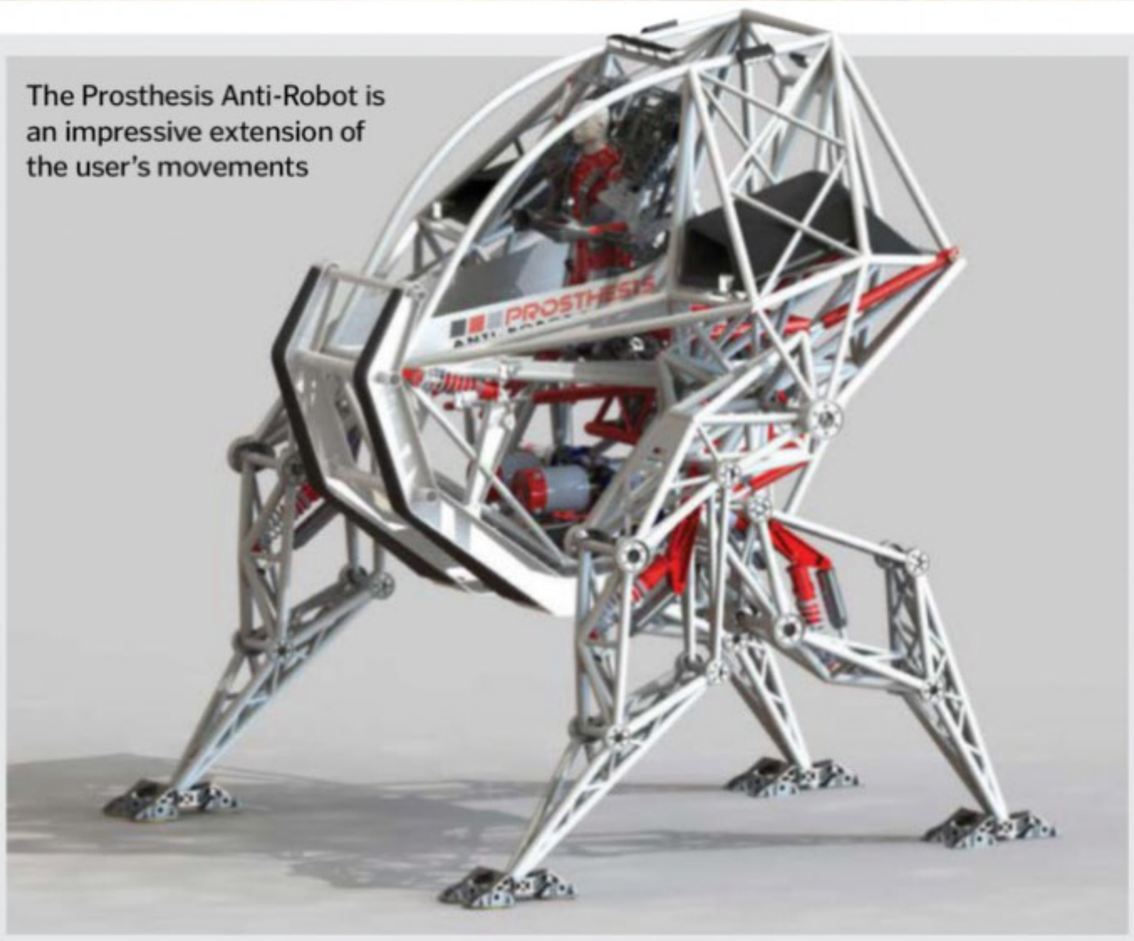
HULC

FASTER, STRONGER, TOUGHER

While Cyberdyne Inc's HAL is helping disabled people move once again, Lockheed Martin's HULC Exoskeleton is transforming able-bodied soldiers into mechanised warriors capable of feats of strength, speed and endurance never before seen by humans.

A hydraulic exoskeleton, the HULC allows soldiers to perform superhuman feats such as carrying loads of 90 kilograms (200 pounds) over difficult terrain for hours on end, all the while retaining maximum mobility. It achieves this by augmenting the soldier with a pair of powered titanium legs and a computer-controlled exoskeleton with a built-in power supply. This mechanism transfers the weight carried by the soldier into the ground, while providing power for continued, agile movement in the theatre of war.

Due to the HULC's advanced composite construction and build materials, it also acts as armour for its user, protecting them from musculoskeletal injuries caused by stress from carrying heavy loads. Indeed, when you consider that HULC may also improve metabolic efficiency in its user, reduce oxygen consumption and improve the rate of muscle wear, its hard not to see the future of frontline combat becoming reliant on these mech warriors.



The Prosthesis Anti-Robot is an impressive extension of the user's movements

RACING BOT

THE ULTIMATE PROSTHESIS

The Prosthesis Anti-Robot is a towering machine operated purely by human body movements. If that doesn't impress you, how do you feel knowing the Anti-Robot weighs over 3,400 kilograms (7,500 pounds) and is 4.6 metres (15 feet) tall?

The pilot can move such a huge machine by their own efforts thanks to an interface that attaches to their arms and legs and translates the movements of their limbs into the robot's four hydraulic legs. This, along with positional and force feedback, means the pilot's limbs directly correlate to those of the machine and when the force on them increases, the limbs get harder to move. A suspension system also helps the pilot feel when the bot's feet connect with the ground.

The Anti-Robot clearly highlights the possibilities of exoskeletons, with human strength and speed not only dramatically increased but also transferred into a machine many times their size. It's not hard to foresee construction workers suited up and shifting huge crates with ease in the near future.

The rise of the mechs

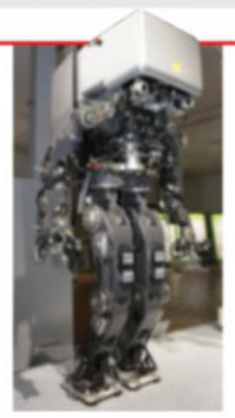
A timeline of real-life robotic tech

1961
Jered Industries in Detroit creates the Beetle, a tracked mech tank weighing 77 tons. The pilot is shielded by steel plating.

1968
General Electric creates the first cybernetic walking machine, a piloted mech with hydraulic hands and feet.

1989
MIT creates Ghengis, a small robot insect capable of scrambling over rough terrain while remaining stable.

1993
Honda unveils its first humanoid robot, the P1, which can walk around on two feet while tethered. It evolves into the now-famous ASIMO.



2000
DARPA, the US Defense Advanced Research Projects Agency, requests proposals for a powered military exoskeleton. It chooses the Sarcos XOS.

THE STATS
PROSTHESIS ANTI-ROBOT

HEIGHT **5m** | WIDTH **4.9m** | LENGTH **3.3m** | MASS **3,400kg** | STRIDE LENGTH **4.5m** | MAX SPEED **30km/h**

DID YOU KNOW? *The Prosthesis Anti-Robot project is a 100 per cent volunteer-staffed project*

BIONIC WALKER

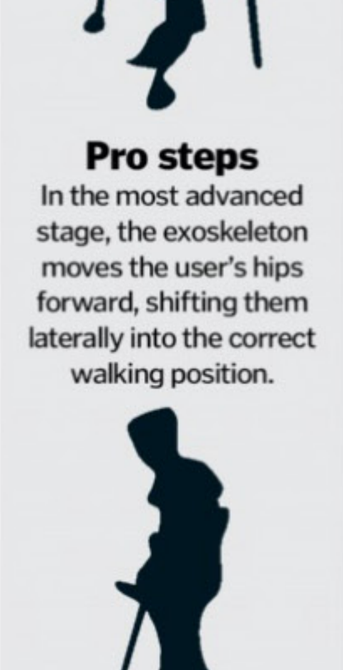
SUIT UP!

The most advanced gait-training exoskeleton currently in use, the Ekso Bionic Suit has been specially designed to grant people with paralysis a means of standing and walking. Once wearing the Bionic Suit, those who have suffered from neurological conditions such as strokes, spinal cord damage or traumatic brain injury can re-learn correct step patterns and weight shifts – things that able-bodied humans take for granted – all the while supported by a system that assists when needed and records every movement for later analysis.

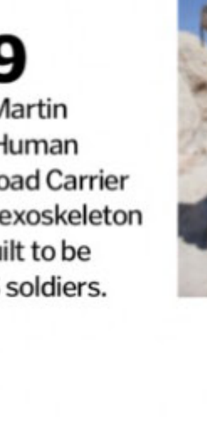
The Bionic Suit already has an shining record, with every medically cleared user walking in the suit in their first training session. Fitting the suit takes just five minutes so doctors can treat multiple patients, with the suit simply affixed over a user's normal clothes. Considering that it also offers multiple training modes, progressing its wearer from being unable to walk right through to various motor levels, and that Ekso has only been in operation since 2005, it's easy to see how the technology could transform lives.

Walking modes

First steps
A physical therapist controls the user's steps with button pushes, with the wearer supporting themselves with crutches.



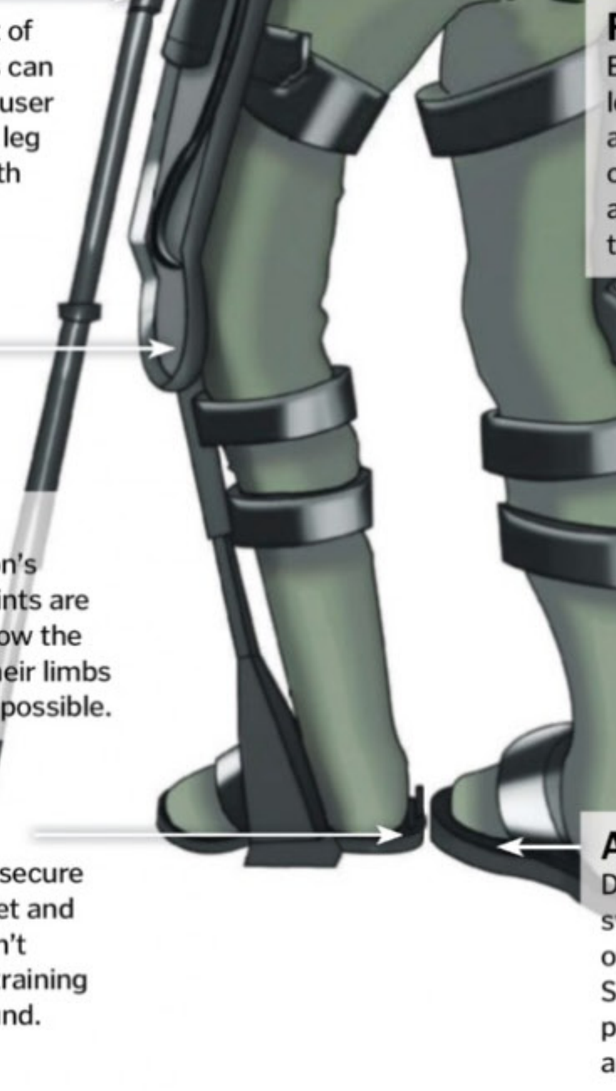
Active steps
In the second stage, the user takes control of their limb movements through button pushes on a set of smart crutches.



Pro steps
In the most advanced stage, the exoskeleton moves the user's hips forward, shifting them laterally into the correct walking position.

Anatomy of the Ekso Bionic Suit

Check out the core components and features of this revolutionary exoskeleton



Power plant
The Bionic Suit is powered by a brace of high-capacity lithium batteries that can energise the exoskeleton for up to four hours.

Computer
A central computer system receives data from the Bionic Suit's 15 sensors to fine-control the user's leg movements.

Motors
Four electro-mechanical motors drive movement at the user's hips and at each knee.

Crutches
If needed, a set of smart crutches can be used by the user to control their leg movements with arm gestures.

Fixed assist
Each of the exoskeleton's legs is fitted with a fixed assist system that can contribute a fixed amount of power to help the user complete a step.

Joints
The exoskeleton's mechanised joints are designed to allow the user to bend their limbs as naturally as possible.

Pegs
Heel pegs help secure the wearer's feet and ensure they don't stumble while training on uneven ground.

Adaptive assist
Depending on the strength and capability of the user, the Bionic Suit can be adjusted to produce various smooth and natural gaits.

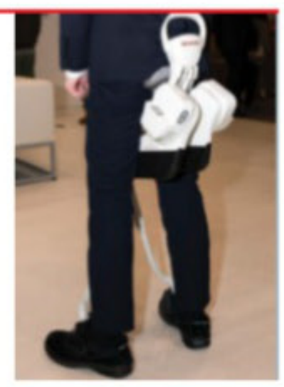
2004
TMSUK and Kyoto University reveal the T-52 Enryu, one of the first rescue robots to be used by Japanese emergency services.

2006
Japanese machinery and robotics manufacturer Sakakibara-Kikai produces the first genuine bi-pedal mech. The machine measures a huge 3.4m (11.2ft) tall.

2009
Lockheed Martin reveals its Human Universal Load Carrier (HULC), an exoskeleton purpose-built to be worn by US soldiers.

2011
Rex Bionics launches the Rex exoskeleton, a device that consists of a pair of robotic legs that can help people with paraplegia to stand and walk.

2013
Honda begins US trials of its Walking Assist Device at the Rehabilitation Institute of Chicago. The product aims to help stroke patients walk again.



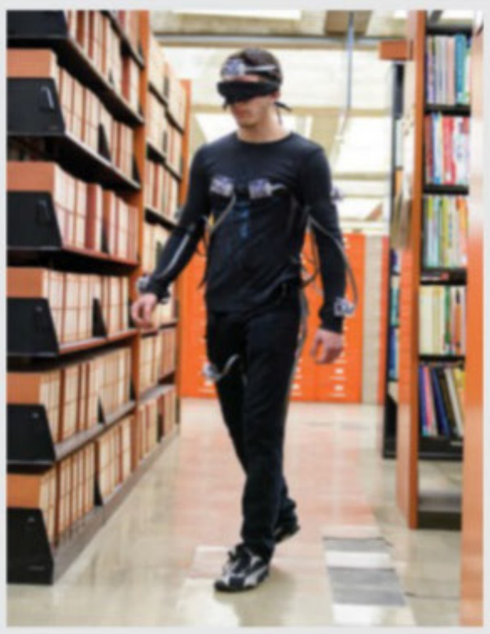
"The Land Walker is the world's first machine of its kind, capable of moving around on two feet"

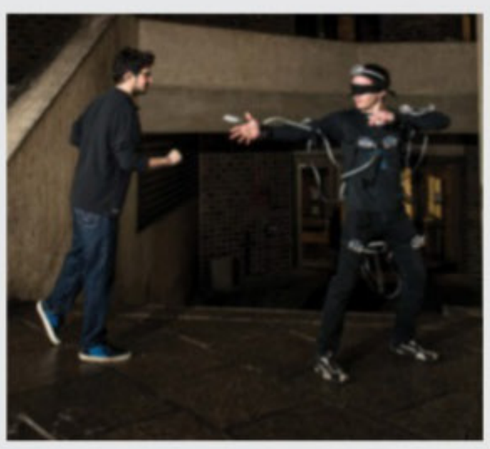
Real-life spidey sense

Ever thought it would be cool to have the 'spidey sense' of *Spider-Man* in real life? Well, now you can, thanks to a neat research project undertaken by the University of Illinois. SpiderSense is a wearable device that, by manipulating the some of the millions of sensory receptors located on human skin, can relay information about the wearer's environment to them. This clever tech means that despite being blindfolded, the user would know exactly where they were in relation to moving objects.

The system works thanks to the SpiderSense's wearable tactile display, which consists of a series of sensor modules affixed to the user's arms and legs. As the user moves about a room, distance information regarding its objects are relayed to the user through the pads via increases or decreases in pressure, with the skin's receptors relaying that information to the brain. The sensor modules scan the environment using ultrasound, repeatedly sweeping an environment for objects and barriers in the way.

In terms of applications, technology like SpiderSense could be used to compensate for a dysfunctional or missing sense, such as visual impairment, or to augment someone's fully functional senses.





LAND WALKER

BATTLEMECH POWER

On the most extreme side of the mech revolution sits Sakakibara-Kikai's Land Walker, a 3.4-metre (11.2-foot) tall, 1,000-kilogram (2,200-pound) bipedal exoskeleton. Designed to replicate the battle mechs of popular science fiction, such as the AT-STs of the *Star Wars* films, the Land Walker is the world's first machine of its kind, capable of moving around on two feet, thunderously plodding around under the command of its human pilot. The Land Walker is powered by a 250cc four-stroke engine, can walk around at 1.5 kilometres (0.93 miles) per hour and is equipped with an auto-cannon capable of firing squishy rubber balls. Unfortunately, the Land Walker currently retails for £210,000 ($345,000), so it might be some time before you can stomp to work in one.

While the Land Walker's current performance arguably leaves a lot to be desired, with more development funding, a machine such as this could easily become the future of law enforcement, with its intimidating physical presence and – if armed correctly – damage-dealing capabilities more than a match for any civilian vehicle.

The Land Walker is still a novelty device but has great future potential

AMAZING VIDEO! SCAN THE QR CODE FOR A QUICK LINK

See how the Kuratas mech can be operated

www.howitworksdaily.com

DID YOU KNOW? *A real, life-size Gundam mech statue has been built in Tokyo, Japan*

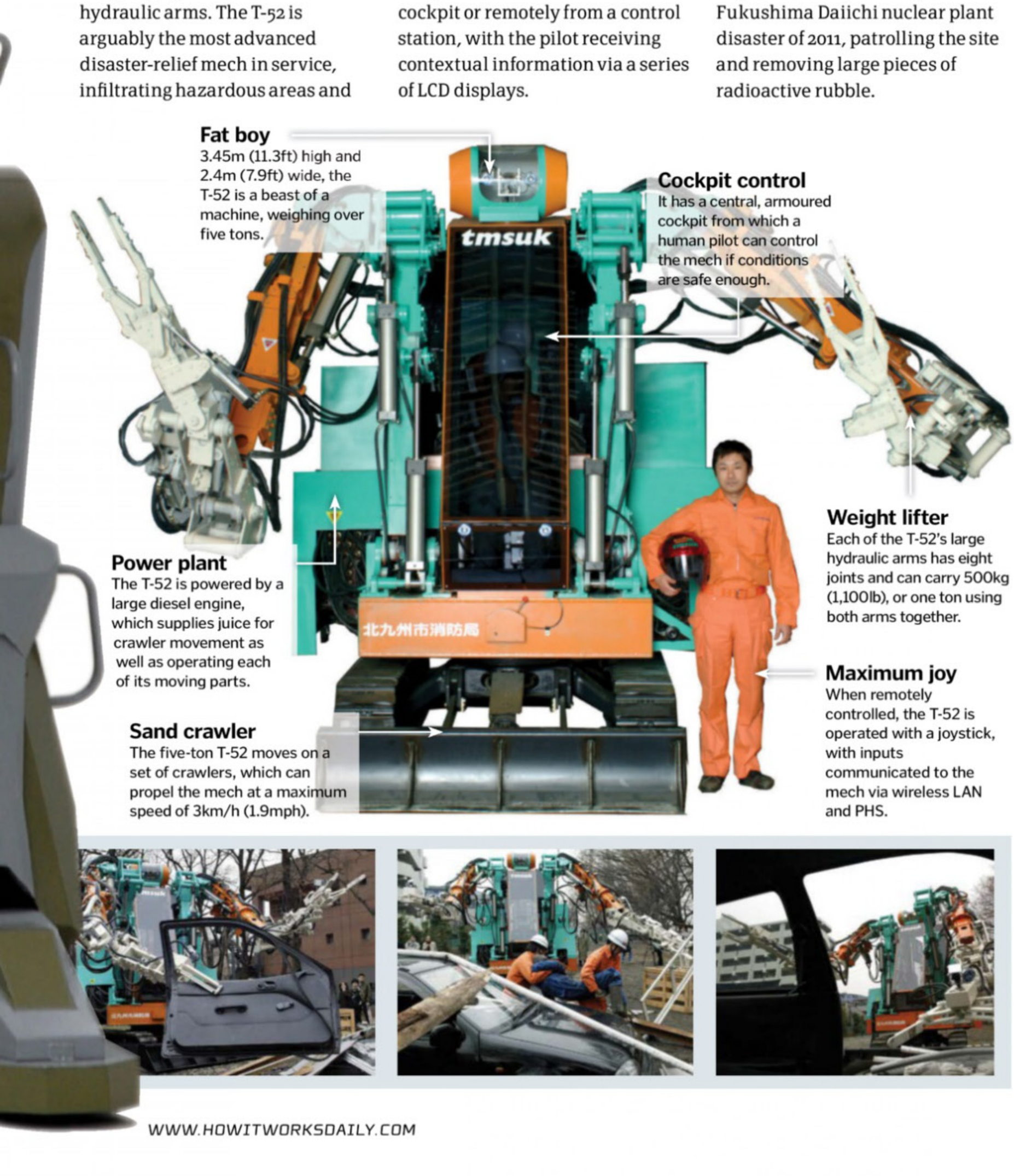
ENRYU

ROBOTIC RESCUE DRAGON

A large-scale, human-controlled robot for use in disaster sites, the T-52 Enryu (which translates as 'T-52 Rescue Dragon') is one heck of a piece of kit. At 3.45 metres (11.3 feet) tall and 2.4 metres (7.9 feet) wide, it's packed with seven 6.8-megapixel CCD cameras and the ability to lift objects weighing up to one ton with its hydraulic arms. The T-52 is arguably the most advanced disaster-relief mech in service, infiltrating hazardous areas and withstanding conditions a human never could.

The mech was built by the Japanese company TMSUK in partnership with Kyoto University and Japan's National Research Institute of Fire and Disaster for undertaking heavy-duty work in disaster areas. The T-52 can either be operated from its armoured cockpit or remotely from a control station, with the pilot receiving contextual information via a series of LCD displays.

The machine specialises in lifting large and heavy objects, meaning that it can easily help free people trapped in earthquake-generated building collapses. While the Rescue Dragon is still in its development phase, it has already passed a number of operational tests and was recently deployed to help clear up the Fukushima Daiichi nuclear plant disaster of 2011, patrolling the site and removing large pieces of radioactive rubble.



Fat boy
3.45m (11.3ft) high and 2.4m (7.9ft) wide, the T-52 is a beast of a machine, weighing over five tons.

Cockpit control
It has a central, armoured cockpit from which a human pilot can control the mech if conditions are safe enough.

Power plant
The T-52 is powered by a large diesel engine, which supplies juice for crawler movement as well as operating each of its moving parts.

Weight lifter
Each of the T-52's large hydraulic arms has eight joints and can carry 500kg (1,100lb), or one ton using both arms together.

Sand crawler
The five-ton T-52 moves on a set of crawlers, which can propel the mech at a maximum speed of 3km/h (1.9mph).

Maximum joy
When remotely controlled, the T-52 is operated with a joystick, with inputs communicated to the mech via wireless LAN and PHS.

The best of the rest

1 Kuratas
The ultimate executive toy, the Kuratas mech allows its owner to ride around in its futuristic cockpit while firing 6,000 BB rounds per minute from its dual, arm-mounted Gatling guns.

2 Cybernetic Anthropomorphous Machine
One of the first mechs ever built, the CAM was designed and built for the US Army in 1966 to move cargo and weapons across battlefields.

3 Sarcos XOS 2
An exoskeleton that grants its wearer superhuman strength, the XOS 2 is currently being trialled by the US Army, with a finished untethered variant set to enter service in 2020.

4 Body Weight Support Assist

Honda's Body Weight Support Assist from is a partial exoskeleton that, once worn, helps to support the user's upper body, taking some of its weight off their legs.

5 Raytheon Heavy Lifter
Designed to move large crates, containers and objects, the Heavy Lifter offers its user a high degree of freedom and agility.

6 Kid's Walker
The Land Walker's baby brother, the Kid's Walker – which costs about £12,000 ($20,000) – is designed to allow children to pilot their own toy mech while remaining safe.

"A dialysis machine can control which substances are removed and at what concentration"

How dialysis cleans blood

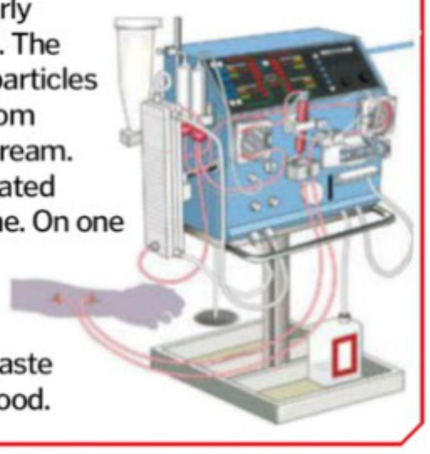
Discover how the amazing dialysis process rids your body of harmful waste

When kidneys fail to filter your blood of waste and unwanted water, we rely on dialysis. An artificial process, it takes the basic scientific principles of concentration gradients and diffusion to filter out harmful substances from the bloodstream, such as extra salt and excess fluids. A dialysis machine can control which substances are removed and at what concentration, allowing fine control of waste product removal and electrolyte balance, like sodium and potassium. Dialysis is needed when the kidneys' natural function is lost. Since you can live with one kidney, both need to be affected before dialysis is required. Common reasons for dialysis are severe diabetes and long-standing high blood pressure, while rare causes include genetic diseases.

Dialysis machines date back to the Second World War. The technology developed rapidly as it was proven to save lives and today there are two main types: haemodialysis, which filters the blood, and peritoneal dialysis, which filters fluid within the abdomen. While life-saving, dialysis needs to be performed up to four times a week and is not without complications. A kidney transplant offers the best chance of long-term cure, but the number of patients on transplant waiting lists far exceeds the number of donated kidneys, so dialysis remains a key part of keeping people alive around the world.

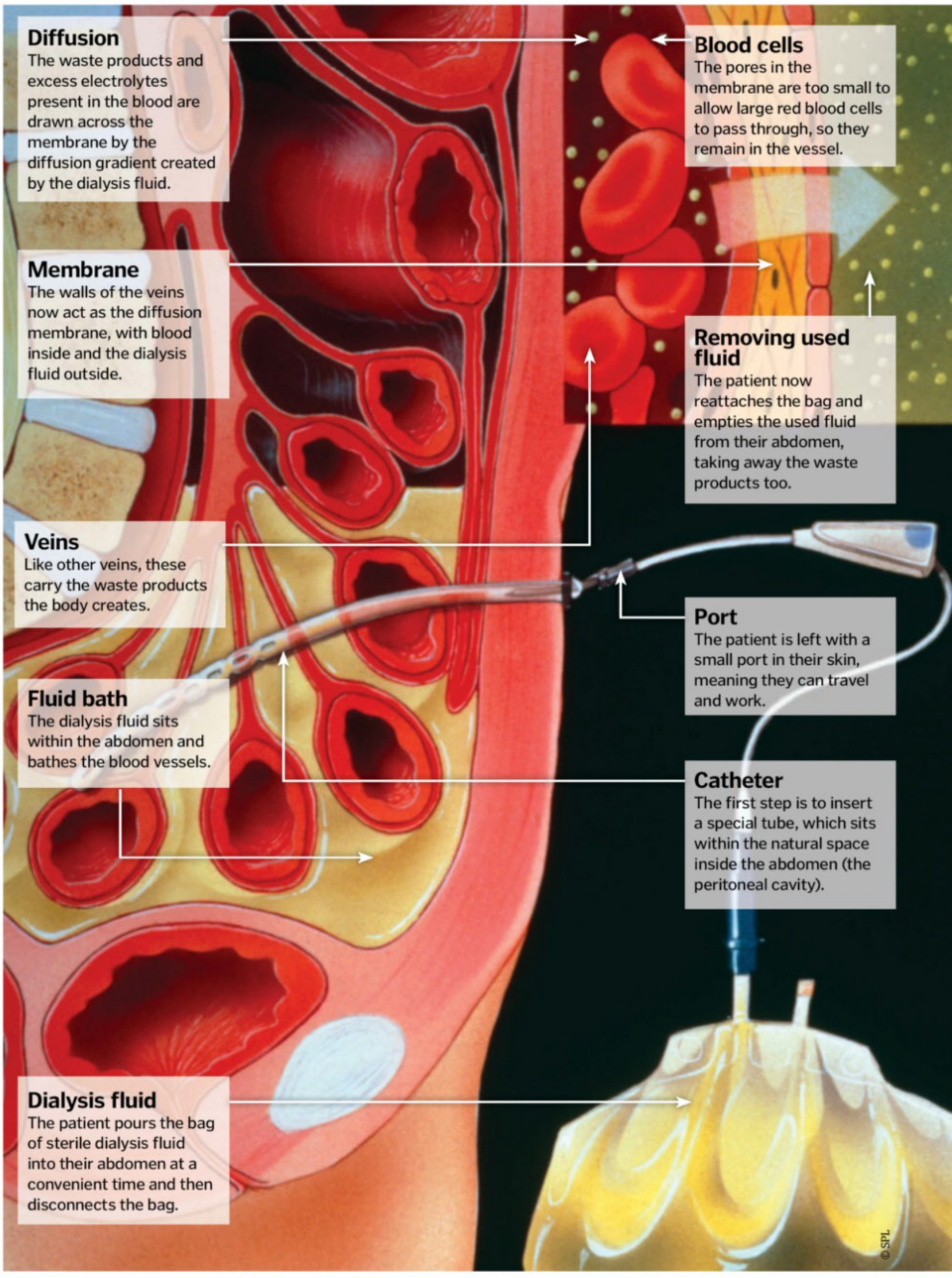
How a dialysis machine works

Sterile tubing is attached to a vein (to take blood away from the body) and an artery (to return cleaned blood) in the patient's arm. The process relies on a semi-permeable membrane, a thin sheet with tiny holes that only allows molecules under a certain size to pass through. On one side of the membrane is the blood, carrying nutrients and waste products. On the other side is the kidney, containing early components of urine. The pores prevent large particles like red blood cells from escaping the bloodstream. This process is replicated exactly in the machine. On one side is the removed blood and on the other is a solution that draws out the waste products from the blood.



How peritoneal dialysis works

Learn how a different type of dialysis can fit into your working life



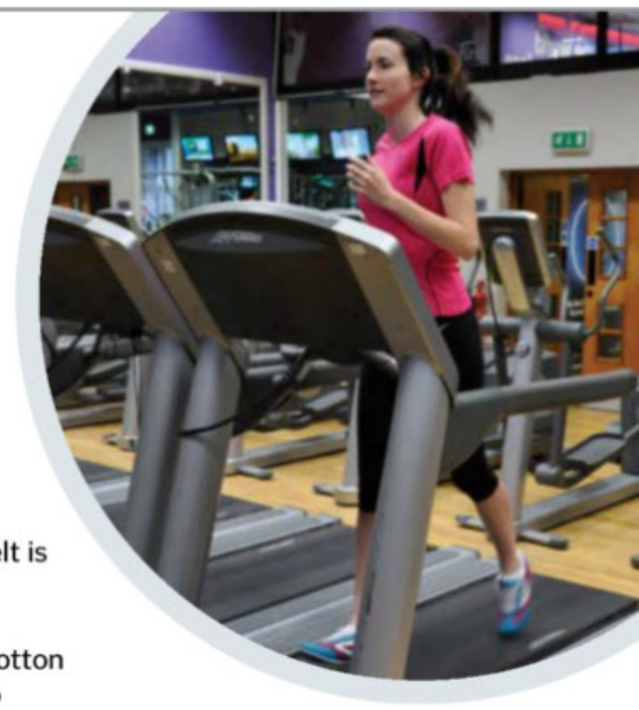
1.5m

LONGEST TREADMILL RUN

The longest distance run on a treadmill is 1,526,449 kilometres. It was achieved over 30 days by Ozden Tasdemir, a German runner who toured Germany to achieve his feat.

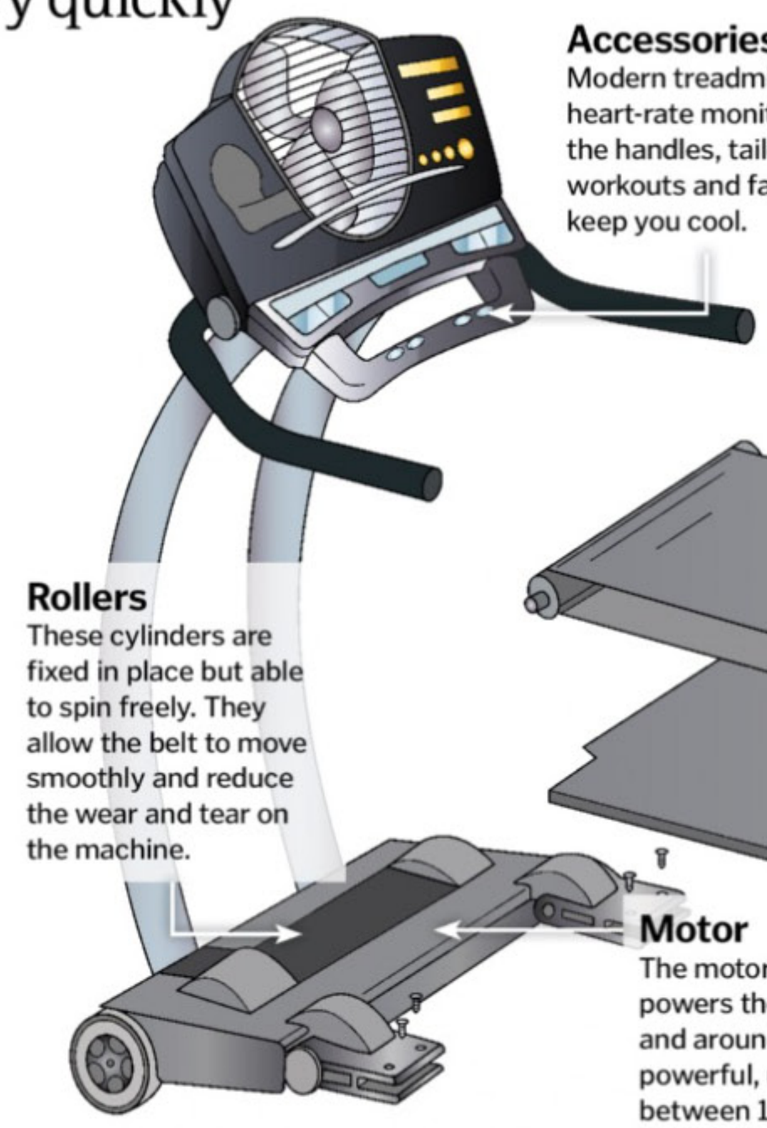
How treadmills work

How to go nowhere very quickly



In just 50 years, treadmills have evolved from a novelty item shown at trade shows to the staple of gyms and fitness rooms worldwide. Originally invented as a medical device for testing the cardiac health of patients, the treadmill was commercialised by William Staub, a Philadelphia-born engineer.

Staub was a fitness fanatic and developed the running machine in the late-1960s as a way of exercising without having to leave the house. Due to its practicality and relatively cheap price point he was selling 2,000 per year by the 1980s and 35,000 per year the following decade. The technology advanced, offering varied workout programmes, heart-rate monitors and emergency stop buttons.



Accessories
Modern treadmills have heart-rate monitors on the handles, tailored workouts and fans to keep you cool.

Belt
The top layer of the belt is made of PVC as it is springy yet durable. Beneath is a layer of cotton and polyester blend to reduce the sound of feet hitting the board.

Rollers
These cylinders are fixed in place but able to spin freely. They allow the belt to move smoothly and reduce the wear and tear on the machine.

Backing
Surrounding the belt is the deck. This will need to be of a sturdy material like steel to absorb the repeated pounding of feet.

Motor
The motor in a treadmill powers the belt around and around. It's not very powerful, usually only between 1.5 and 3hp.

Angle grinders are versatile tools – here's one serving as a power saw

Angle grinders explained

This DIY must-have can take on just about any job

Angle grinders are multi-purpose tools that can do almost everything, from polishing surfaces to shearing through steel. They can either be battery powered or work off the mains and consist of a powerful motor running a spinning disc, which is at a right angle to the handle.

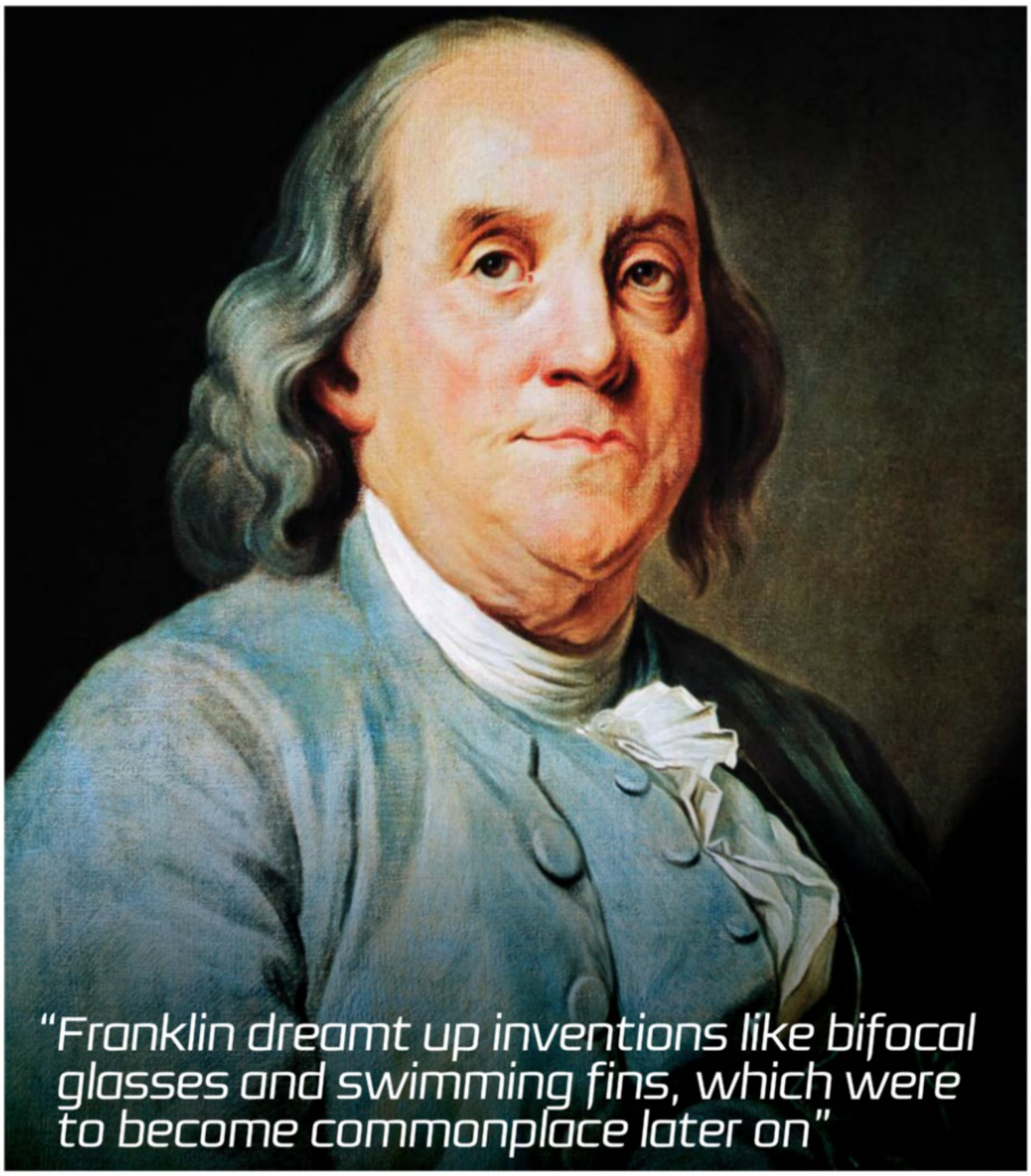
If a wire brush is placed on the spindle, it becomes an excellent tool for removing dried mud or cement from a spade, acting like a high-speed brush.

Alternatively, a sharp-edged blade whirring at high speeds can easily slice through metal or score through tiles and stone. The rapid movement of the blade means the cut will be clean and smooth, rather than jagged and coarse, like a hacksaw cut would be.

They can also be fitted with a grinding wheel that, when run up and down a blade, can sharpen it by shearing off tiny slivers of metal. Angle grinders rotate at around 10,000rpm – ten times the speed of a normal drill motor – and you'll probably find one in nearly every DIY lover's shed.

Benjamin Franklin

How the man on the $100 bill revolutionised technology just as much as American politics



Benjamin Franklin, one of the greatest minds of all time, had his first big break while pretending to be a woman. At 12 years old, he began an apprenticeship at his brother James' printing shop, which published the first independent newspaper in the colonies. But despite Benjamin's determination and hard work, James refused to print any of his articles. Instead, the young Franklin began writing under the pseudonym 'Mrs Silence Dogood', regularly sending letters to the paper for publication. 'Her' witty and insightful commentary became the talk of the town, but James was outraged when he discovered that true author was in fact his younger brother. Benjamin Franklin abandoned his apprenticeship and moved to Philadelphia, where he set up his own printing business and purchased *The Pennsylvania Gazette*.

The 1730s saw his prominence and success grow, especially with his publication of the *Poor Richard's Almanack*. Franklin bought properties and businesses, organised a volunteer fire department, established a lending library and was elected grand master of the Pennsylvania Masons, clerk of the state assembly and postmaster of Philadelphia. He also began to expand into entrepreneurship, and in 1741 he invented the Franklin stove – a heat-efficient fireplace that aimed to produce less smoke and more heat than the ordinary open fireplaces on the market. While the stove failed to take off, in 1749 he retired from business to concentrate more on his inventions, dreaming up things like bifocal glasses and swimming fins that were to become commonplace for centuries to come. Never one to rest on his laurels, Franklin then turned his attention to the study of electricity, and in 1752 conducted the famous kite-and-key experiment, which proved that lightning was made up of static electricity. He also developed the single fluid theory, which proposed that electricity was a 'common element' rather than two opposing forces.

A life's work

We travel through the key events in the famous polymath's career

1706
Franklin is born in Boston on 17 January to Josiah Franklin and his wife Abiah.

1718
At the age of 12, Franklin begins an apprenticeship at his brother's new printing business.

1723
After publishing work under a false name, Franklin runs away to Philadelphia.

1728
Franklin establishes his own printing company and purchases *The Pennsylvania Gazette* the following year.

1732
Franklin publishes the first edition of the *Poor Richard's Almanack*, which quickly becomes very popular.

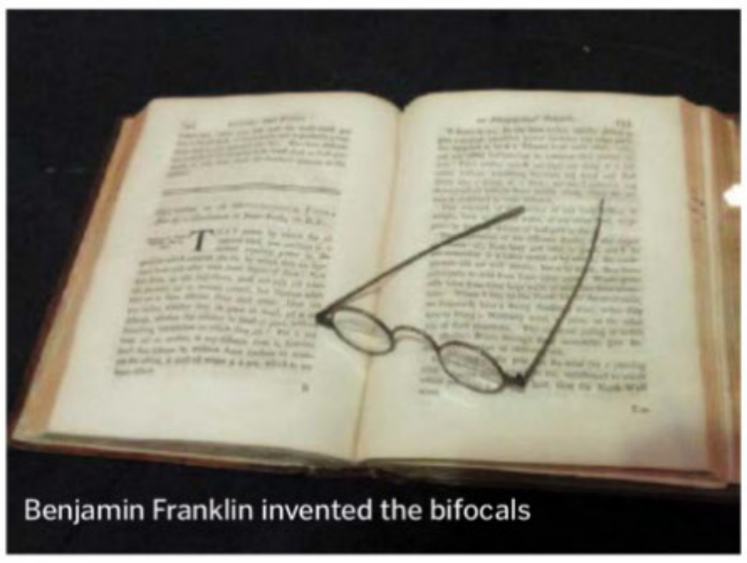
In their footsteps...

Michael Faraday

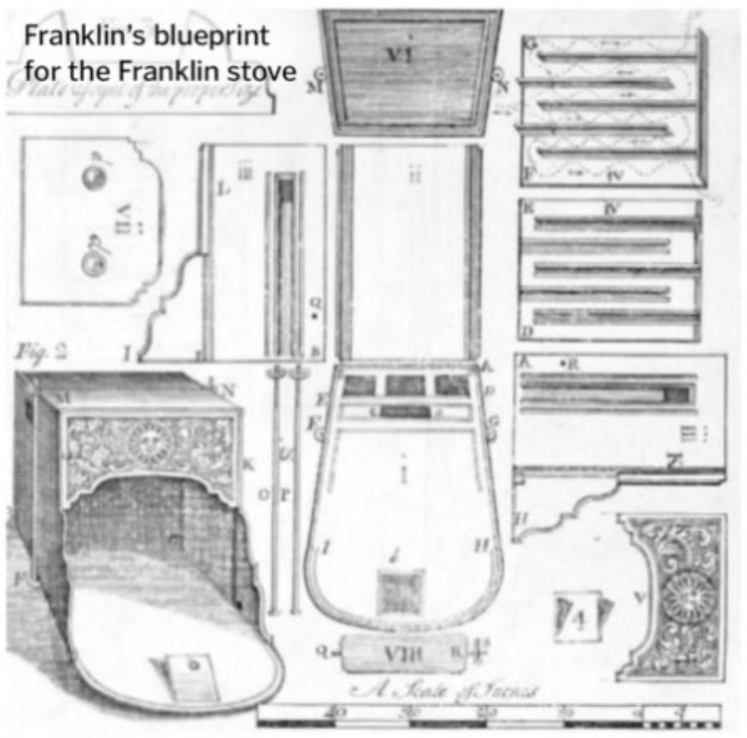
Born the year after Franklin died, he built on Franklin's work in his own experiments. He discovered electromagnetic induction and his Faraday cage, which blocks electric fields, was largely based on one of Franklin's experiments, where he dangled a cork ball into a metal cup to discover it was only attracted to the exterior, not the interior.

Thomas Edison

Edison was also devoted to the study of electricity. He discovered the 'Edison effect', or the heat-induced flow of an electric charge through space. This allowed for the invention of things like radios, TVs and other wireless products. Though he didn't actually invent the light bulb, he did develop a more practical incandescent bulb for use in the home.



Benjamin Franklin invented the bifocals

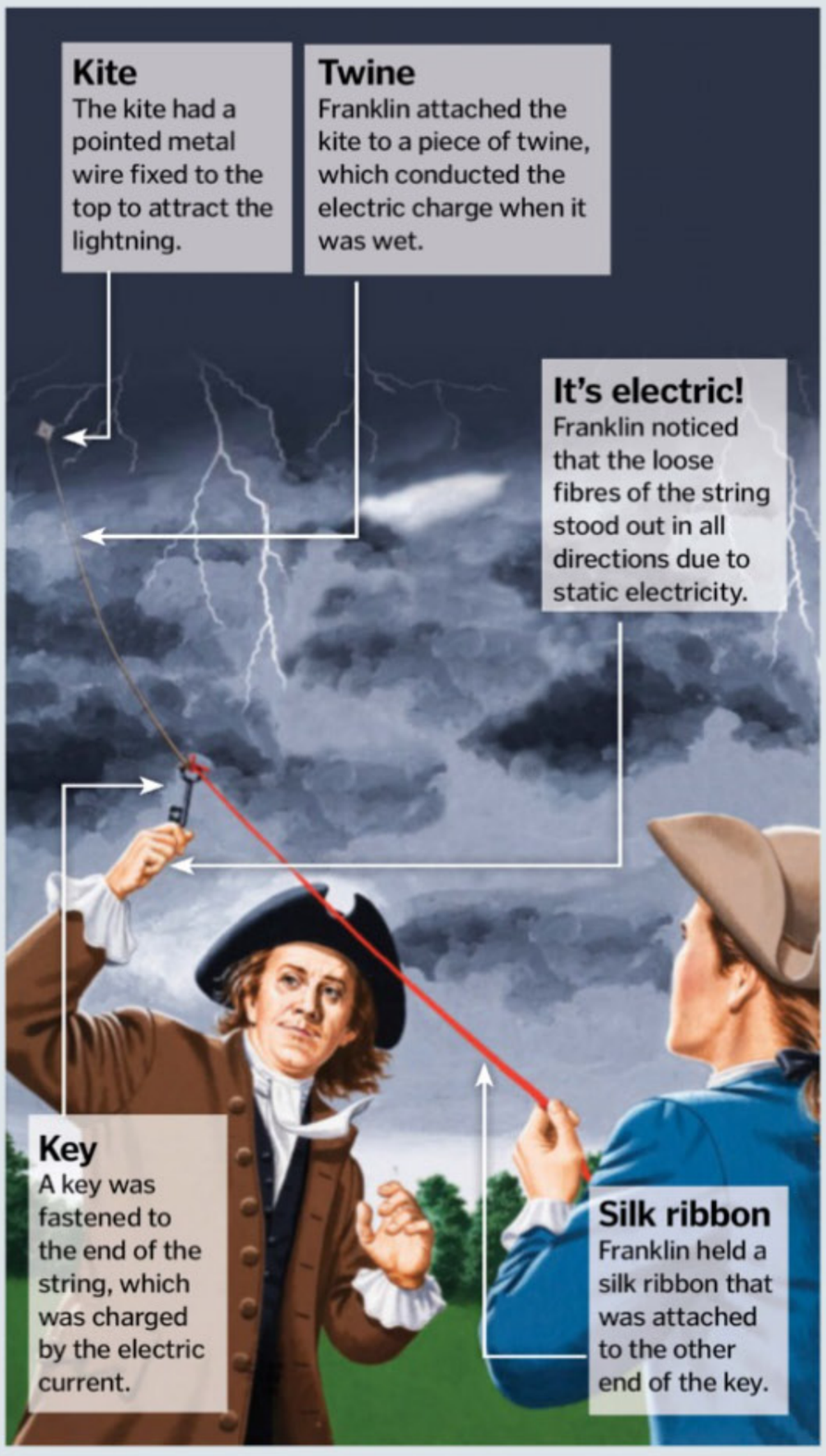


Franklin's blueprint for the Franklin stove

The 1750s saw Franklin become more involved in politics. In 1757, he travelled to England to represent Pennsylvania in its fight with the descendants of the Penn family over who should represent the colony. On his return almost 20 years later, he fought fiercely for American sovereignty, and was one of the five people who drafted the Declaration of Independence in 1776. Later that year he went to France as a diplomat for the United States where he became a much-loved figure, and it was largely because of him that the government of France signed a Treaty of Alliance with the USA in 1778. When Franklin died in 1790, he was dubbed 'the harmonious human multitude.' The legacy of his inventions and political work lives on to this day.

The big idea

Before Franklin began his experiments in science, the popular belief was that electricity consisted of two opposing forces. Franklin proved that in fact it was a single element, imagining it to be like an invisible fluid. If a body had an excess of this fluid, it was positively charged. If it had a deficiency, it was negatively charged. He theorised that the body with more fluid flowed to the body with less fluid, or rather that electric charges flowed from positive to negative. However, it has since been discovered that electricity is actually the flow of electrons, which means it flows from negative to positive.



Five Franklin inventions

1 Bifocals
Franklin suffered from poor eyesight, but came up with the brilliant idea of creating glasses with a separate upper and lower half; the upper for distance and the lower for reading.

2 Lightning rod
After studying the behaviour of electricity, Franklin designed a metal rod that could be attached to the tops of buildings and connected to the ground through a wire to discharge lightning.

3 Glass armonica
A popular form of entertainment in the 18th century was playing music using wine glasses filled with water. Franklin invented a mechanised version consisting of 37 glass bowls.

4 Franklin stove
This metal-lined fireplace stood in the centre of the room, radiating heat in all directions. It provided more heat, used less wood and produced less smoke than open fireplaces.

5 'Long arm'
Franklin loved reading and established a number of libraries. His idea for a wooden pole with a grasping claw at the end helped visitors to reach books on the top shelves.

1741
The efficient Franklin stove is invented but fails to take off as a product.

1752
Through his kite experiment, Franklin proves lightning is an electrical phenomenon.

1776
Franklin signs the Declaration of Independence, signalling the United States' independence from the British Empire.

1783
The Treaty of Paris is signed, ending the American Revolutionary War.

1790
Franklin dies on 17 April aged 84. Over 20,000 mourners attend his funeral.

Space balloons

Could these high flyers be the future for space exploration?

For six decades, getting into space has been a messy business – rocket launches may be spectacular, but they involve a lot of noise, expense and pollution. But now, a new generation of spacecraft are carrying amateur and professional scientific instruments to the edge of Earth's atmosphere at a fraction of the cost of a rocket – and soon, paying passengers could be joining them. Welcome to the uplifting world of space balloons.

High-altitude ballooning hit the headlines around the world in October 2012, when Austrian skydiver Felix Baumgartner leapt from the Red Bull Stratos capsule to accomplish a record-breaking free fall and parachute descent. Stratos was one of the biggest balloons ever sent into the upper atmosphere, but in order to lift its 1,315-kilogram (2,900-pound) pressurised capsule, it had to be. The technology was evolutionary, not revolutionary, but the latest in a long line of balloons whose heritage stretches back well before the space age.

If you want to soar into the highest reaches of Earth's atmosphere, a traditional hot-air balloon won't be up to the job. These rely on the simple principle of heating the air in the balloon so it expands and becomes less dense than its surroundings and floats upward, but they can only go so far because the atmosphere itself gets rapidly less dense with altitude.

So high-altitude balloons (HABs) have long depended on the properties of 'lifting gases' that naturally weigh less than air. The first to be discovered was hydrogen, the lightest element in the universe. Although it does not exist naturally in Earth's atmosphere, it is relatively easy to manufacture and was used for test flights as early as 1783, the same year as the first manned hot-air balloon flight.

At any given pressure, a volume of hydrogen has just a fraction of the weight of the same volume of oxygen or nitrogen (the two major constituents of Earth's atmosphere). So a sealed balloon filled with hydrogen has a great deal of buoyancy or lifting power to carry any payload attached to it. Unfortunately, hydrogen is highly reactive and prone to catching fire and exploding, so many HABs – especially those carrying valuable equipment or human passengers – use the much safer) inert gas helium. However, this is rare and a lot mor expensive to use.

One major challenge faced by all HABs is the problem of expansion. As the balloon rises higher and the surrounding air pressure decreases, the lifting gas inside the balloon will expand to fill a larger volume. This is the reason why HABs usually look so unwieldy near the ground: they are launched with a relatively small amount of gas in a huge, mostly deflated envelope (usually made of a thin but strong plastic membrane such as polyethylene or neoprene). As the balloon rises higher in the sky, the gas sealed inside naturally expands, filling the balloon out into a spherical shape and stretching its material. ▶

This concept art for the World View balloon shows the stunning view the passengers would enjoy

1. HIGH

Boland Rover A-2

David Hempleman-Adams set a record for the highest hot-air balloon ascent at 6,614m (21,700ft) in December 2004.

2. HIGHER

Red Bull Stratos

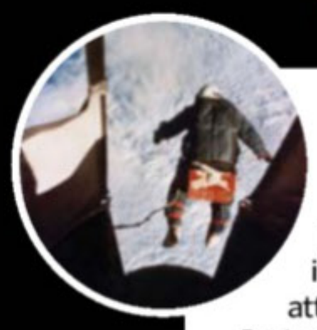
Felix Baumgartner's record-breaking ascent took him to an altitude of 38,969m (127,851ft) in October 2012.

3. HIGHEST

BU60-1

This Japanese research balloon reached a dizzying altitude of 53,000m (174,000ft) in May 2002, with the help of a new polyethylene film design.

DID YOU KNOW? *The 'UFO debris' recovered at Roswell, New Mexico in 1947 is now acknowledged as a crashed US Air Force HAB*



Leaping from space

Felix Baumgartner's space jump took its inspiration from earlier manned balloon attempts to reach the edge of space, like Project Manhigh and Project Excelsior in the late-1950s. At a time when manned orbital flights were still a dream, Manhigh used a pressurised capsule to test spacecraft design and see how pilots would perform in similar conditions to a true space mission. Excelsior involved a pilot in a pressure suit skydiving back to Earth. In 1960, Joseph Kittinger set a record for manned ballooning and the highest sky dive, reaching an altitude of 31,333m (102,800ft) aboard Excelsior III. The record stood until 2012 when Baumgartner, with Kittinger acting as his CAPCOM shattered it with a leap from 38,969m (127,851ft).

The statistics...

World View balloon

30,480m (100,000ft): Estimated cruising altitude

5,000m³ (176,573ft)³: Initial volume of helium used to fill the balloon on the ground

20 microns (0.001in): Thickness of the helium balloon's polyethylene material

1,132,674m³ (40mn ft³): Volume of the fully expanded helium balloon

5-6 hours: Estimated flight time, including two hours at maximum altitude

£45,000 ($75,000): The cost of a ticket

"Such altitudes put balloons firmly in 'near-space', high above the influence of weather systems"

Above a certain altitude, the pressure in the balloon can be so much greater than the thin air surrounding it that the envelope may give way and rupture – an abrupt ending some balloonists deliberately take advantage of to bring the balloon's payload back to Earth. Balloons intended to maintain a stable altitude, or gently return to Earth with its payload intact, contain vent systems that can release small amounts of lifting gas to reduce buoyancy.

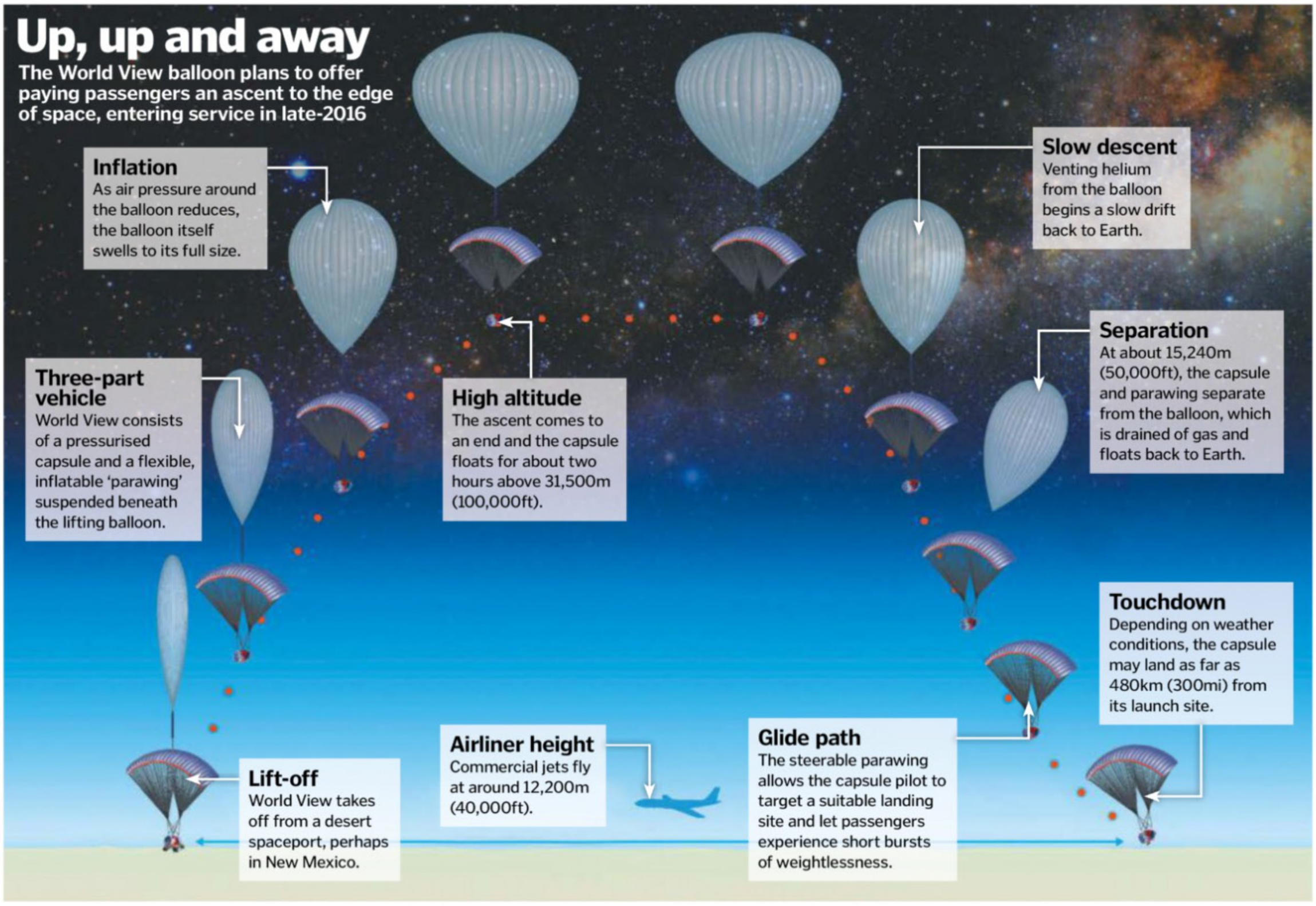
Another issue faced by most HABs is that they expand and contract as temperatures change from day to night. This alters their density and causes them to rise and sink instead of retaining a steady altitude. A reflective coating on the envelope can reduce the effects of the Sun's heat to some extent, but another alternative is the 'superpressure' balloon – one with a rigid outer shell that does not expand or contract. Since the lifting gas in this type of balloon has a constant density, it maintains a mostly constant height in Earth's atmosphere.

By their very nature, balloons need to rise through denser surrounding gases, so their uses are limited to Earth's atmosphere. But the larger a balloon can get, and the lighter its lifting gas, the higher it can rise. What's more, the atmosphere goes a long way up – Stratos set a manned altitude record of 38,969 metres (127,851 feet), but the highest altitude reached so far reached by an unmanned balloon is around 53,000 metres (174,000 feet), set by the Japanese space agency's BU60-1 mission in 2002.

Such altitudes put balloons firmly in 'near-space', high above the influence of weather systems in the lower atmosphere. This opens

Up, up and away

The World View balloon plans to offer paying passengers an ascent to the edge of space, entering service in late-2016



Inflation
As air pressure around the balloon reduces, the balloon itself swells to its full size.

Three-part vehicle
World View consists of a pressurised capsule and a flexible, inflatable 'parawing' suspended beneath the lifting balloon.

High altitude
The ascent comes to an end and the capsule floats for about two hours above 31,500m (100,000ft).

Slow descent
Venting helium from the balloon begins a slow drift back to Earth.

Separation
At about 15,240m (50,000ft), the capsule and parawing separate from the balloon, which is drained of gas and floats back to Earth.

Touchdown
Depending on weather conditions, the capsule may land as far as 480km (300mi) from its launch site.

Lift-off
World View takes off from a desert spaceport, perhaps in New Mexico.

Airliner height
Commercial jets fly at around 12,200m (40,000ft).

Glide path
The steerable parawing allows the capsule pilot to target a suitable landing site and let passengers experience short bursts of weightlessness.

Going global

The Global Space Balloon Challenge (GSBC) is an education project that aims to recruit teams from around the world to launch their own HABs. The revolution in small-scale manufacturing and the cheap availability of GPS units for tracking a balloon's position and altitude has brought near-space ballooning within reach of amateurs on a budget of a few hundred dollars, including enthusiasts and school and college groups. As part of Stanford University's Student Space Initiative, the first challenge event took place over the Easter weekend in April 2014. Almost 100 teams from around the world aimed to launch balloons into the upper atmosphere, from locations as far afield as Chile, India, Hawaii and Moscow, carrying payloads ranging from cameras and weather stations to radio transmitters. Prizes were awarded for the highest altitude reached, the best photographs and the most innovative designs and successful experiments.

KEY DATES
ONWARD AND UPWARD

1783 – The first manned hot-air and hydrogen balloon flights are made within months of each other in France.

1931 – Auguste Piccard and Paul Kipfer reach 15,781m (51,775ft) in a hydrogen balloon with a pressurised capsule.

1960 – Joe Kittinger sets altitude and skydive records with an ascent to 31,333m (102,800ft) aboard Excelsior III.

2012 – Felix Baumgartner sets new records for manned balloon flight and skydiving with a flight to 38,969m (127,851ft).

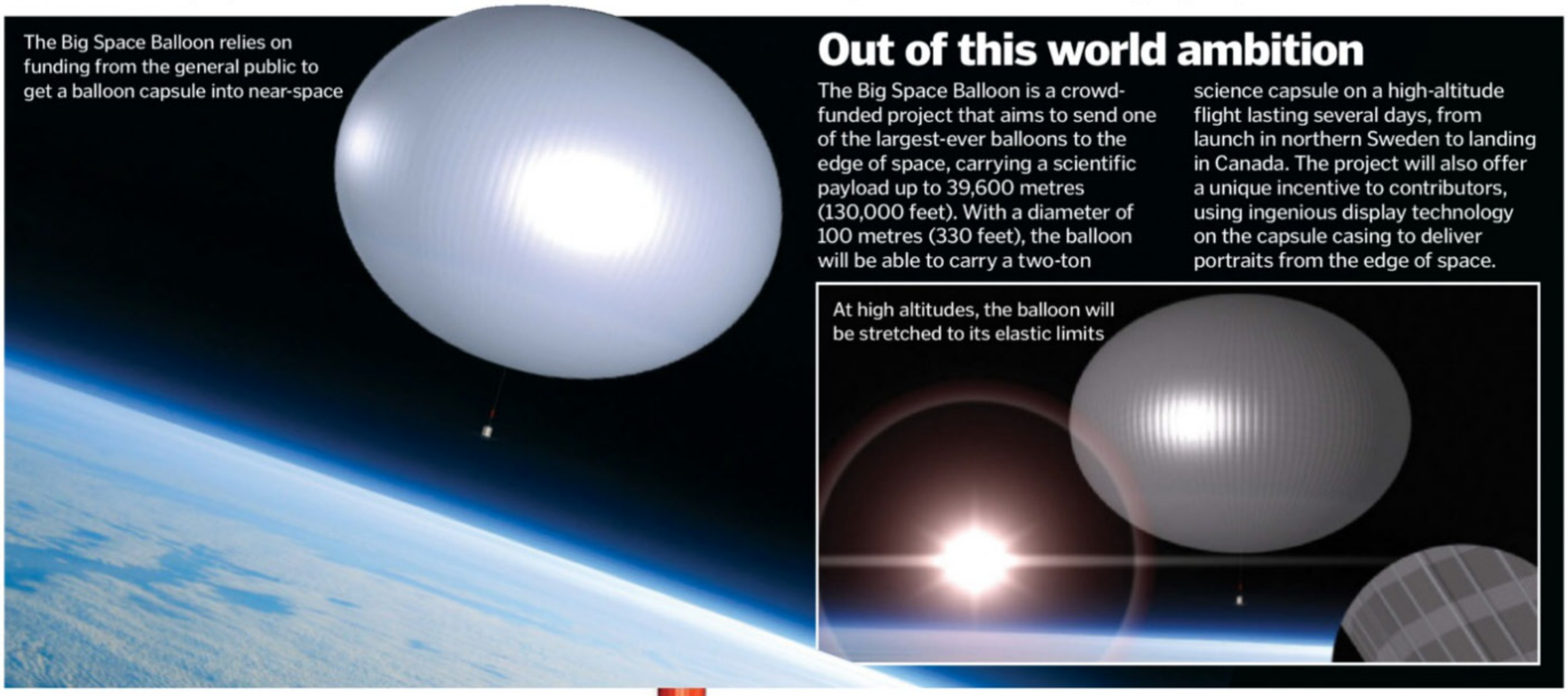
2016? – World View plans to offer pressurised balloon flights to near-Earth space to paying passengers.

DID YOU KNOW? *JP Aerospace hopes to combine low-thrust rockets with an airship design as a new way of reaching Earth orbit*

the way for a variety of applications. As well as studying weather conditions at high altitudes, these include aerial photography of wide areas, and radio communications. Google, for instance, is developing Project Loon, which aims to provide high-speed internet to remote areas or disaster zones via HABs floating at an altitude of about 20 kilometres (12.4 miles).

Balloons also offer a cheap way of putting telescopes above the vast majority of the atmosphere – particularly valuable for astronomers studying weak infrared and radio signals from the universe. BLAST (Balloon-born Large-Aperture Submillimeter Telescope) used a two-metre (6.6-foot) mirror to study some of the coolest objects in the universe from above the fogging effects of atmospheric heat – it made three successful flights between 2005 and 2011. BOOMERanG, meanwhile, was a balloon-borne telescope used to investigate the cosmic microwave background radiation left over from the Big Bang itself.

But for many, the most enticing aspect of high-altitude balloons is their potential to offer a relatively cheap human flight into near-space. Several companies are aiming to launch passenger services in the next few years, including World View and the Spanish zero2infinity. Critics argue that helium is such a limited and valuable resource that space tourism is a rather trivial way to waste it, but some balloon promoters also aim to offer 'atmospheric laboratory' services that would offer space-station-like facilities at a fraction of the cost. For the moment at least, it seems like the only way is up.



The Big Space Balloon relies on funding from the general public to get a balloon capsule into near-space

Out of this world ambition

The Big Space Balloon is a crowd-funded project that aims to send one of the largest-ever balloons to the edge of space, carrying a scientific payload up to 39,600 metres (130,000 feet). With a diameter of 100 metres (330 feet), the balloon will be able to carry a two-ton science capsule on a high-altitude flight lasting several days, from launch in northern Sweden to landing in Canada. The project will also offer a unique incentive to contributors, using ingenious display technology on the capsule casing to deliver portraits from the edge of space.

At high altitudes, the balloon will be stretched to its elastic limits

Big Balloon Capsule

The 2m (80in) tall science capsule's design enables it to carry up to 700kg (1,540lb) of scientific instruments

Landing parachute
During final descent, the science capsule detaches from the balloon and parachutes back to Earth.

Solar panels
Panels mounted around the top of the capsule generate electricity to power science instruments.

Telescope
The science payload within the capsule will include a telescope.

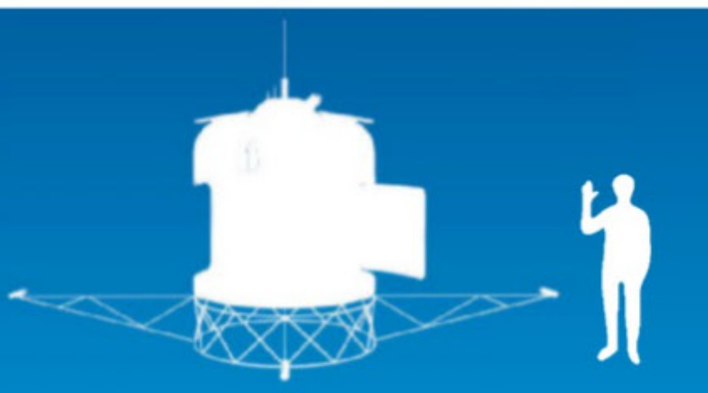
Science modules
The science modules will be constructed using 3D-printing technology for precise manufacture at minimal cost.

Battery cells
Additional batteries provide further electricity to on-board equipment.

Flight cameras
High-definition video cameras photograph the capsule itself, the portraits displayed around its casing, and the Earth below.

Capsule doors
Each door carries an OLED display showing thousands of individual portraits.

Landing base
A support structure ensures the capsule makes a cushioned landing.



"Solar tornadoes differ from Earth-based twisters because they are comprised of ionised gas"

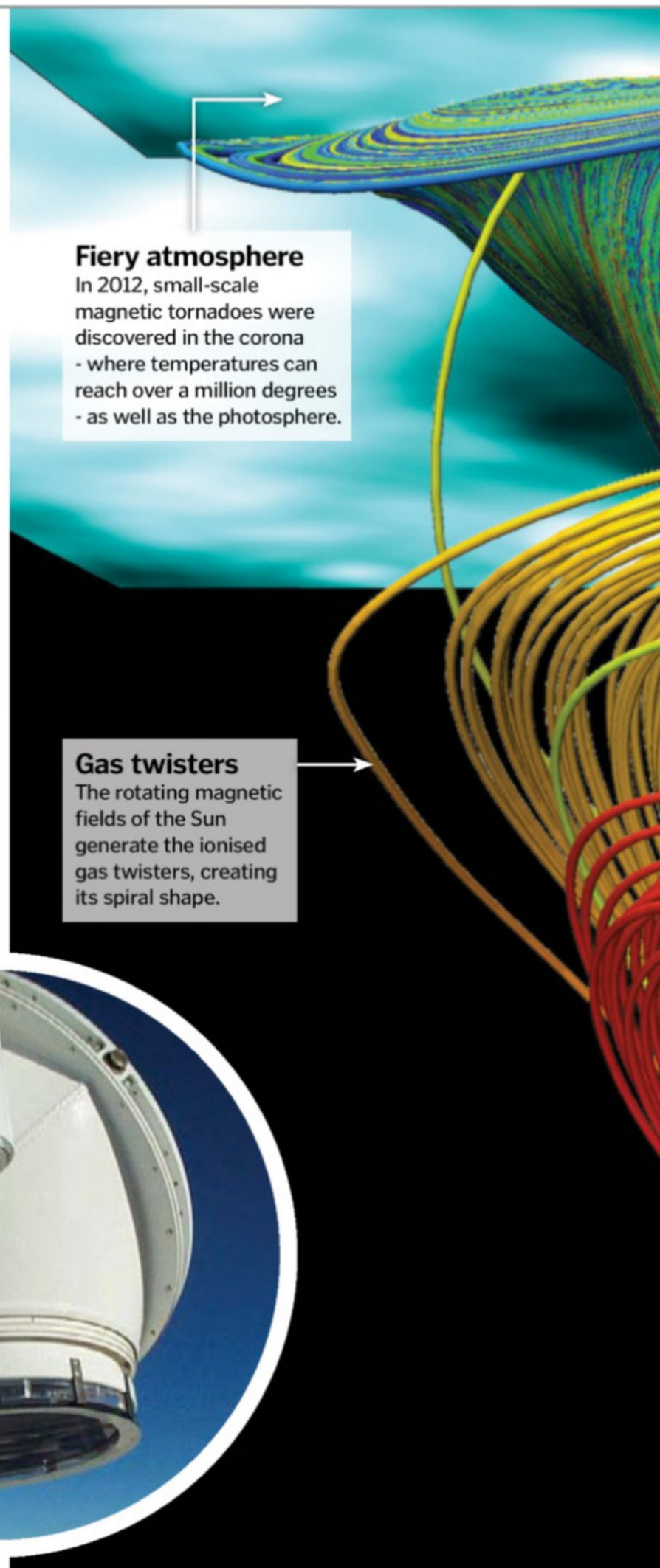
Solar tornadoes

The story behind twisters on the Sun, a thousand times larger than their Earthling counterparts

A gigantic sphere of hydrogen plasma (ionised gas), our Sun is by far the most dominant body in the Solar System and one of its most visually intense events is the solar tornado. These twisting magnetic fields are between 100 to 1,000 times larger than what we're used to on Earth and have been observed at a gigantic 70,000 kilometres (43,496 miles) tall. It has been calculated that over 11,000 of these phenomena are on the Sun's surface at any time and they are believed to potentially be the source of heating for the outer reaches of the Sun and could contribute to auroras on our planet.

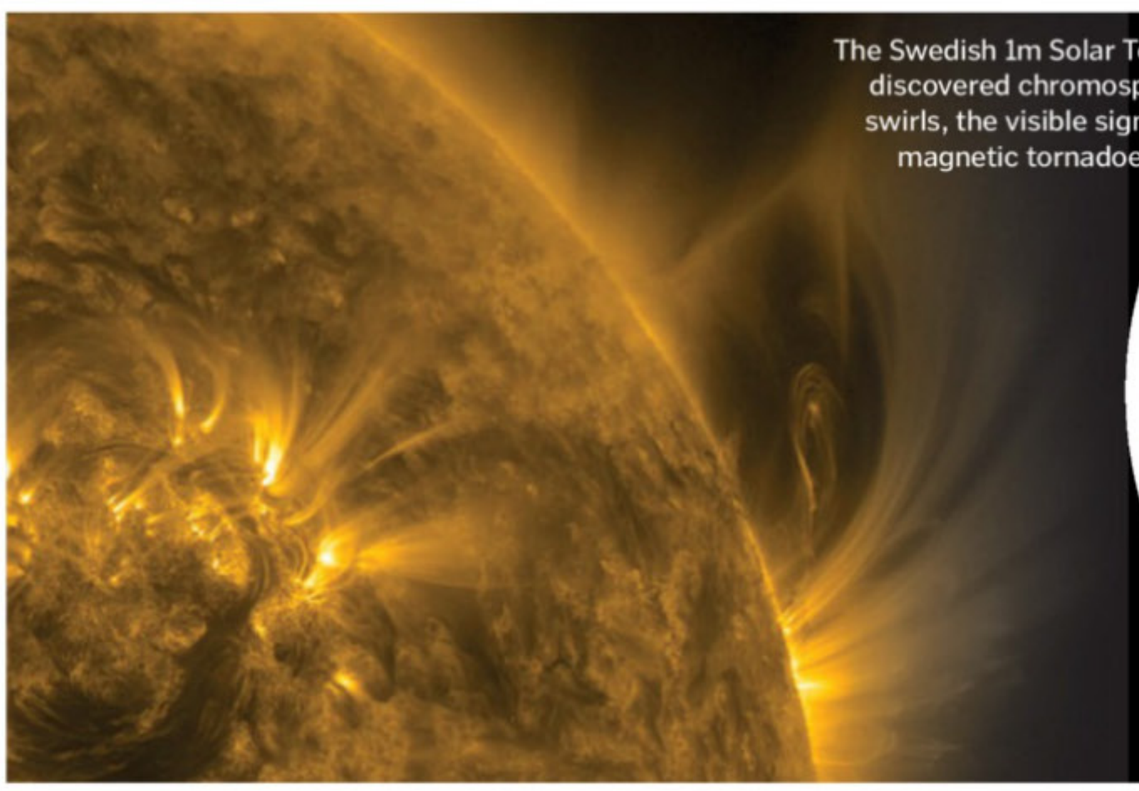
Solar tornadoes differ from Earth-based twisters because they are comprised of a magnetic field of plasma. They are more frequently spotted around the Sun's equator and poles, as this is where magnetism is most prominent. They exist on other stars as well as the Sun, burn at over a million degrees Celsius (1.8 million degrees Fahrenheit) and have swirling speeds of 10,000 kilometres (6,213 miles) per hour.

They appear in clusters and their main function is to heat the star's outer atmosphere by moving energy from the surface to the uppermost layer, the corona. They generate 100 to 300 watts per square metre (10.8 square feet) and are believed to be the reason for the corona's heat production, which has puzzled scientists and astronomers for generations. Observations from the Swedish 1m Solar Telescope in 2008 have increased our understanding of how nature heats magnetised plasma and how the 'chromospheric swirls' we can see are the result of the tornadoes.

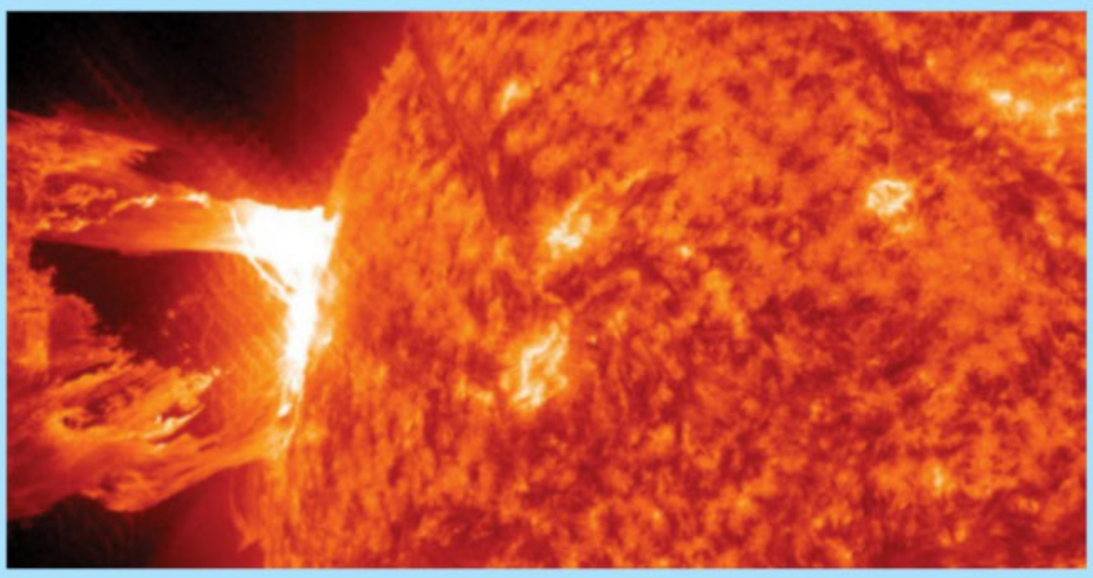


Fiery atmosphere
In 2012, small-scale magnetic tornadoes were discovered in the corona - where temperatures can reach over a million degrees - as well as the photosphere.

Gas twisters
The rotating magnetic fields of the Sun generate the ionised gas twisters, creating its spiral shape.



The Swedish 1m Solar Telescope discovered chromospheric swirls, the visible sign of magnetic tornadoes



Why is the corona so hot?

A curious anomaly of our nearest star is the fact that the corona, an aura of plasma surrounding the star, is hotter than many other areas of the Sun closer to its core. The corona can get up to two million degrees Celsius (3.6 million degrees Fahrenheit) while on the surface it is a measly 5,500 degrees Celsius (9,932 degrees Fahrenheit). Scientists and astronomers have long been perplexed by this but some new theories might explain why. Recent notions reason that heat is injected into the corona by wave heating from the core. As the corona is dominated by magnetic fields that are constantly connecting and engaging with each other, a convection zone is created, which releases high amounts of energy and heat. Solar tornadoes are linked to the plasma's astonishing heat levels as they contribute to coronal mass ejections (CME) and the solar winds in the Sun's atmosphere. To discover more, NASA has planned a mission known as the Solar Probe Plus, which is pencilled in for 2018.

5 TOP FACTS
SUN PHENOMENA

Solar flare
1 A massive magnetic energy release on the Sun's surface, a solar flare shows sudden concentrated brightness and emits huge amounts of radiation into the Solar System.

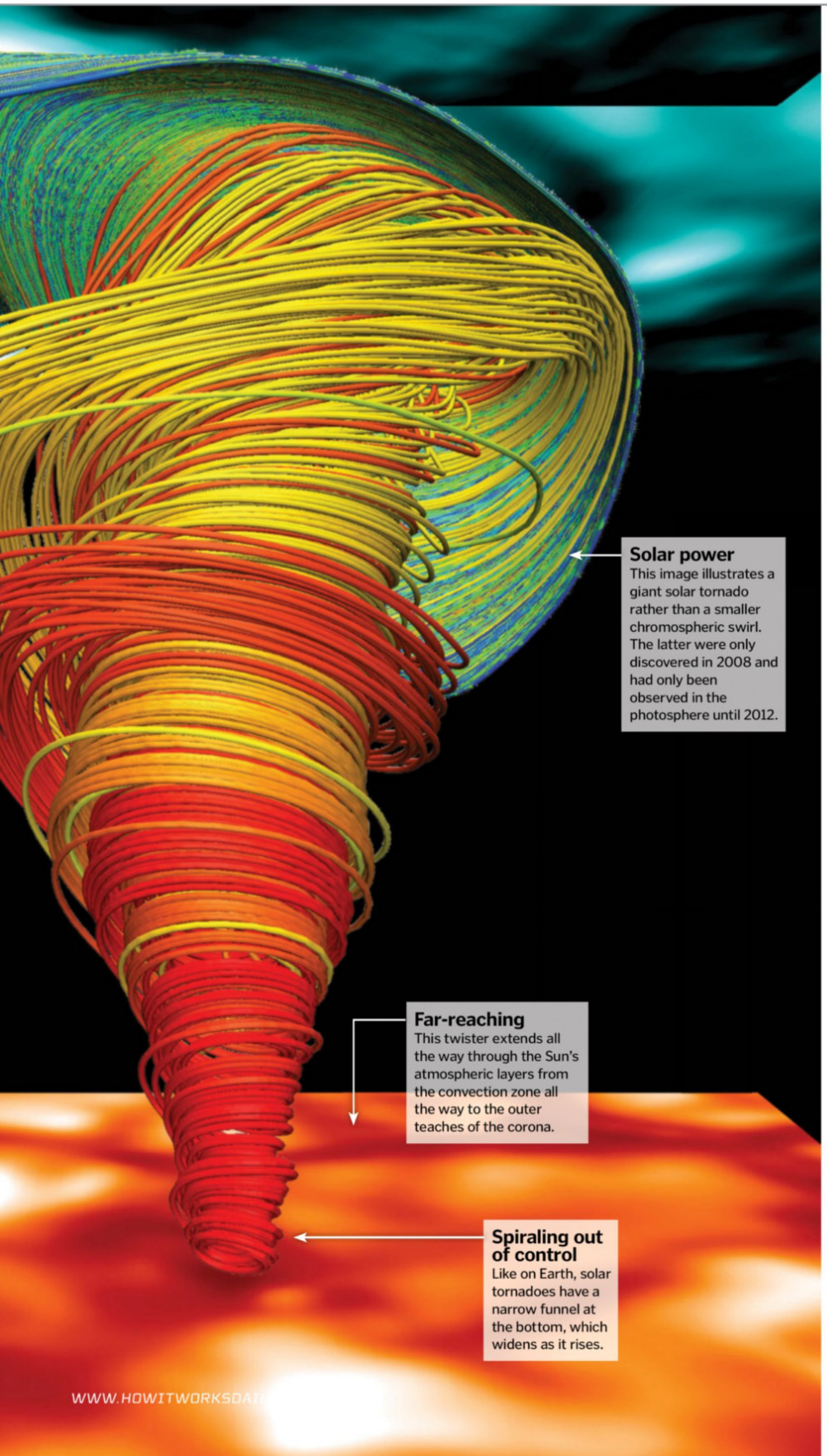
Coronal mass ejection
2 An eruption of solar wind caused by magnetic instabilities, CMEs can cause electrical problems to satellites and the Earth's magnetosphere.

Sunspot
3 A relatively dark and cool area of the photosphere, they have temperatures of around 3,500°C (6,330°F) and can reach over 50,000km (31,069mi) in diameter.

Geomagnetic storm
4 Caused by CMEs and solar flares, radiation-charged particles affect the Earth's magnetic field and cause auroras in the North and South Polar regions.

Solar prominence
5 Similar to a solar flare, solar prominences are loops of unstable plasma that extend from the surface to the corona, adding to the Sun's already vibrant appearance.

DID YOU KNOW? *There are two types of solar tornado: giant and small-scale magnetic. Experts are unsure whether they are linked*



Solar power
This image illustrates a giant solar tornado rather than a smaller chromospheric swirl. The latter were only discovered in 2008 and had only been observed in the photosphere until 2012.

Far-reaching
This twister extends all the way through the Sun's atmospheric layers from the convection zone all the way to the outer teaches of the corona.

Spiraling out of control
Like on Earth, solar tornadoes have a narrow funnel at the bottom, which widens as it rises.

Solar storm chaser

Dr Sven Wedemeyer-Böhm from the Institute of Theoretical Astrophysics explains more

How similar are solar tornadoes to tornadoes on Earth?
Aside from the visible appearance, tornadoes on Earth and on the Sun are very different phenomena. In both cases, the tornado funnel is narrow at the bottom and widens with height in the atmosphere. Particles inside tornadoes are forced to move in spirals. Tornadoes on Earth occur as a result of temperature and gas pressure differences and strong shear winds. Solar tornadoes are generated by rotating magnetic field structures, which force the plasma, ie the ionised gas, to move in spirals.

How do solar tornadoes contribute to auroras on Earth?
It has been speculated that giant tornadoes may serve as a possible trigger of solar eruptions, where they build up a magnetic field structure until it destabilises and erupts. As a consequence, ionised gas could get ejected towards Earth, which would then contribute to auroras. However, as of now, there's no direct connection confirmed.

Do you know about future planned missions to investigate this phenomenon?
There are missions such as Solar Orbiter and Solar-C, which may fly in foreseeable future. There will be also some major progress with ground-based observatories with the 4-m Daniel K Inouye Solar Telescope (DKIST, formerly the Advanced Technology Solar Telescope, ATST), which is currently built on Hawaii, and possibly the 4-m European Solar Telescope (EST), which may be built in the future. These new instruments will allow for an even closer look at our Sun and will enable us to answer the many open questions that we still have about solar tornadoes.

What is the primary difference between giant solar tornadoes and small-scale magnetic tornadoes?
It is currently not clear if these are different phenomena or not. Small-scale magnetic tornadoes have only been observed from the top so far, ie in the middle of the solar disk, whereas giant tornadoes are seen more towards the limb of the Sun, in other words: from the side. In general, magnetic tornadoes tend to have somewhat smaller diameters than giant tornadoes but it is too early to draw solid conclusions.

What is the primary difference between giant solar tornadoes and small-scale magnetic tornadoes?
There are still many questions concerning solar tornadoes and we hope to address some of the most important aspects during the next three years in a project, which has just started at the University of Oslo in collaboration with international experts.

5 TOP FACTS
LIFE ESSENTIALS

Temperature
1 For habitation, a celestial body must have a climate that allows the human body to exist. DNA, proteins and carbohydrate molecules need to be able to survive in the atmosphere.

Water
2 H_2O needs to be abundant for cells to function and reproduce. Too much water can be a hazard, though, if it restricts land space and chemical processes.

Atmosphere
3 The atmosphere must be thick enough to protect from space collisions and radiation but thin enough that it doesn't choke the surface and cause a 'runaway greenhouse effect.'

Energy
4 A balance of light and chemical energy is a must. Too little and organisms can't function. Too much and strong and harmful rays can make a surface uninhabitable.

Magnetic field
5 In the outer reaches of the atmosphere, the magnetosphere protects a planet from the radiation of its star and constantly protects from solar winds.

DID YOU KNOW? *The first exoplanet was discovered in 1992 orbiting the PSR 1257+12 pulsar in the Virgo constellation*

Can there be life on exomoons?

How humans could begin to colonise moons in other solar systems

Exploring the universe was once the stuff of science fiction, but exomoons could change that. Orbiting exoplanet gas giants similar to Jupiter or Saturn, these moons are comparable to the likes of Europa, Titan and Enceladus in our Solar System. These three natural satellites are believed to have the best chance of supporting life so scientists hold similar worlds in a very high regard.

Encouragingly, as they orbit gas giants, the exomoons are around the size of Earth. There are two main techniques in finding an exomoon. Firstly, if there is a slight dip in brightness this could show a celestial body crossing in front of a star. Secondly, the gravitational pull from a possible satellite can cause light to bend around it, momentarily magnifying it like a lens. None have officially been discovered yet but 250 potential exomoons have been located.

Currently, the HEK (Hunt for Exomoons with Kepler) project is in place and in 2018, NASA will launch the James Webb Space Telescope to study them further. To be habitable for humans they must have the correct conditions for carbon-based life forms to survive. Experts theorise that binary solar systems (systems with two stars) are more likely to have moons suitable for life. This is because binary stars dampen each other's solar radiation, which creates better conditions for life.

Eccentric orbits can put moons briefly out of the habitable zone but planetary illumination and tidal heating make them still momentarily sustainable. On the downside, even the nearest planets are still too far away for human expansion with current shuttle and rocket technology, so exomoons are still a pipe dream for the foreseeable future. Let's just stick to Mars for now...

The four states of a celestial body

All planets and moons have different life-span stages. These phases are known by scientists as 'habitable', 'hot', 'snowball' and 'transient.' The first sort has temperatures that stay more or less at the same average level, with more than ten per cent of the surface between the freezing and boiling point of water. The second, as its name suggests, has temperatures of a scorching 100 degrees Celsius (212 degrees Fahrenheit) minimum unlike snowball, which is constantly frozen. Transient is slightly different from the others as it has habitable conditions but varies in the amount of inhabitable surface area.

Farming in space

Growing intergalactic plants could be the key to living in space

One of the big hurdles to long-haul space flight and possible space colonisation is the absence of foodstuff in deep space. At the moment, astronauts are limited to dry processed food but methods are being developed to grow vegetation or 'space salad.'

The first forays into intergalactic farming are being pioneered by NASA tests at the ISS (International Space Station) and the Kennedy Space Center, as well as The International Laboratory of Plant Neurobiology. They all aim to devise ways for a terrestrial body to adapt to extraterrestrial conditions.

Initial tests have used lettuce as it can be eaten without being heated and is easy and simple to grow, but lack of gravity in space could be an issue. Artificial soil would float away and water wouldn't drain. Solutions to this include a 'plant pillow' which has grow bags to hold the soil in place and a permeable fabric to guide the water to the plant's roots.

For now, plants will be grown hydroponically – in nutrient solution instead of soil – with red and blue LEDs providing light for photosynthesis. As well as being a food source, plants will also help enrich alien worlds with oxygen and reduce toxic levels of carbon. The ultimate aim is to produce an artificial ecosystem, called bioregenerative, to sustain astronauts for long voyages and missions.

Plants grown in controlled conditions will form the nutritional requirements for astronauts on major expeditions

"Plans are being made for Skylon, a British spaceplane, to begin launching from the site"

ELS launch site

A look around the ESA's incredible, history-making launch pad

The sight of a rocket igniting and blasting off is one of the most awe-inspiring things anyone can ever watch. For the lucky people in Kourou, French Guiana, this is a regular occurrence, thanks to the European Space Agency's (ESA) multi-rocket launch pad. With the birth of the ESA, the French-built launch pad was selected as the place from where all European-funded missions take off.

The Ensemble de Lancement Soyouz (ELS) is made up of three specific sections. There is the preparation area, where rockets are put together, the launch control centre, a safe bunker, which houses the scientists and engineers involved in the launch, and finally the launch platform, the 53-metre (174-foot) high tower that holds the rocket steady and vertical until the moment it takes off. The site is fairly spread out, with the control centre one kilometre (0.6 miles) away from the launch pad, which is connected to the preparation area by a 700-metre (2,300-foot) long railway.

In 2011, history was made at ELS as a Soyuz rocket, the most famous Russian-made rocket, was launched from the site. It was a momentous occasion as it was the first of the flagship Russian rockets ever to be launched outside of Kazakhstan or Russia.

Looking to the future, plans are being made for Skylon, a British spaceplane, to launch from the site. The exciting thing about Skylon is that parts are reusable and can be turned around in hours, making huge savings. Although the runway at Kourou would need strengthening, the ESA has already shown active willingness to pump money into the site, having already spent €1.6 billion (£1.3 billion/$2.2 billion) on improving and upgrading the site. There is also the option to store liquid hydrogen at the site, as there are plans to use it as a fuel for future Soyuz rockets.

KEY DATES

TIMELINE OF KOUROU

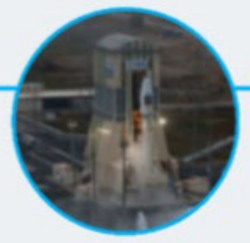
1964
France commissions the building of Kourou. Completed four years later, it costs 25 million francs.

1970
The Diamant-B rocket is launched, carrying the DIAL satellite. It is Kourou's first rocket launch.

1986
Ariane 3 is the first rocket to set off from ELA-2, the second launch pad at the site.

2003
An agreement between France and Russia paves the way for Soyuz rockets to launch from Kourou.

2011
A Soyuz rocket is successfully launched from the site, with more launches planned for the future.



DID YOU KNOW? *French Guiana was the seventh country to launch a satellite after the USSR, USA, France, Japan, China and Britain*

The remote location at Kourou on French Guiana makes it perfect for space launches

What makes Kourou perfect?

Kourou is an ideal site for a range of launches. French Guiana is one of the northernmost countries in South America. It sits at latitude 5°3', which means it's only 500km (311mi) north of the equator, ideal for geostationary orbit launches as the rocket won't need to make many adjustments to get the satellites into their planned orbit.

Other pros to being near the equator include the slingshot effect. As the equator is the widest point of the Earth, it has the largest distance of rotation of any part of the planet. Spacecraft can use this rotation to vastly increase the speed of the rocket and save fuel on launch.

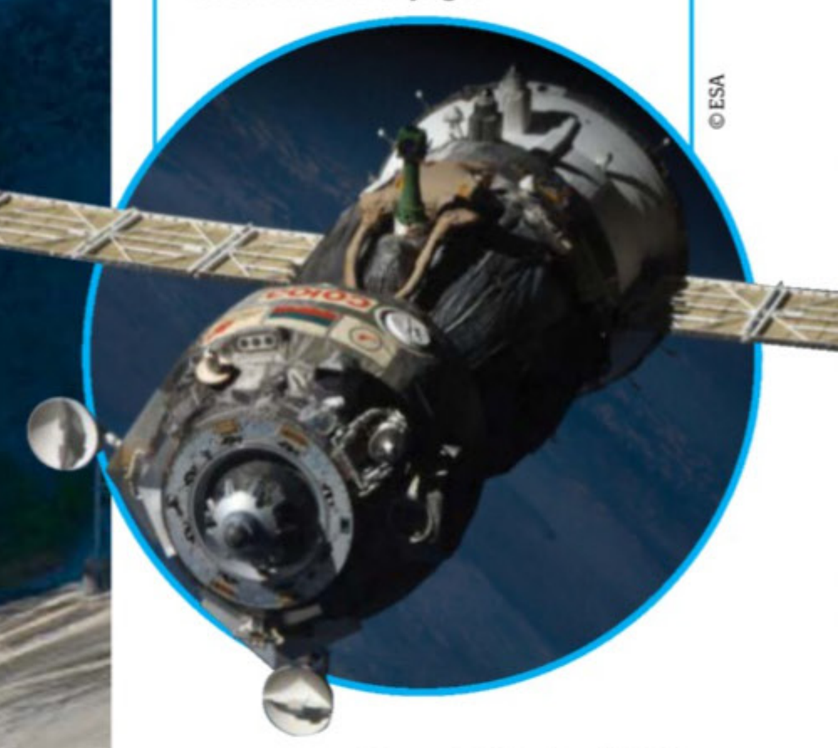
French Guiana is ideal because 90 per cent of the land is covered in uninhabitable forests so the population is low. This means disruption to the locals is minimal.

Ready for Soyuz

A huge coup in the history of ELS was in 2003 when the Russian and French governments came to an agreement to begin launching Soyuz rockets from Kourou.

Updates were required to make it suitable for the Soyuz rockets to launch there. One of the key changes was the construction of a moveable tower, which could be placed next to the launch pad, providing access for engineers up to a height of 36m (118ft). However, the tower itself rose 53m (174ft) high and was the cause of delays to the programme.

The first rockets scheduled for launch arrived in November 2009 and in October 2011 the first Soyuz rocket ever to be launched outside of Kazakhstan and Russia took off on its maiden voyage.



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FORCES EXPLAINED

Understand the invisible powers that govern everything we do

Isaac Newton was the first to point out that without forces, objects would not move – thereby describing the concept of inertia. From the smallest atoms to the largest stars, everything is governed by four fundamental forces: gravitational force, electromagnetic force, nuclear weak force and nuclear strong force. If any one of these were taken away, with the possible exception of the weak force, the universe as we know it would be unrecognisable.

Gravity keeps our feet firmly on the floor and tethers the planets into orbits around the stars. Wherever there is matter there is gravity, and without it, the universe as we know it could not exist. Matter would never have condensed to form the first stars after the Big Bang.

The weak force governs nuclear fusion and radioactive decay and is the only force capable of changing the types (or 'flavours') of subatomic particles, which are known as quarks. These particles make up the protons and neutrons that come together to become the nucleus of an atom. There is a hypothetical model of a 'weakless universe', but without the weak force to mediate the fusion reactions that power the stars, it is not known if the model would work.

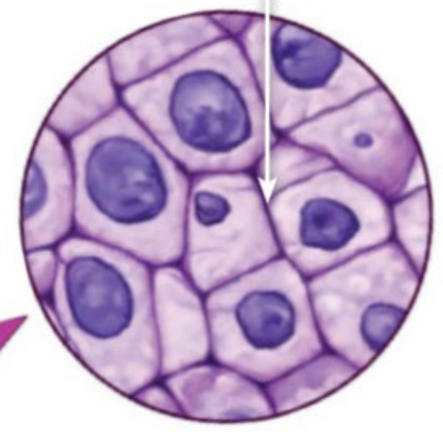
The electromagnetic force is responsible for the sticking force of friction, and is the reason that solid objects don't move through one another when they collide. It creates the pull of a magnet, and is responsible for the upward force of buoyancy in water. Most importantly, though, the electromagnetic force holds negatively charged electrons in orbital shells around the nucleus of every atom and allows those atoms to come together to form molecules. The nucleus itself is held together by the nuclear strong force, so if one of these forces were missing, atoms could not exist and neither could the universe that we live in.

Fundamental forces of physics

Uncovering the four forces that rule the entire universe

Elementary particles
The strong force and weak force are transmitted by heavy elementary particles, and can only travel short distances, while the electromagnetic force is transmitted by massless photons and can travel much further.

Molecular interactions
The electromagnetic force keeps atoms and molecules together.



Gravitational force
All matter has a gravitational pull but at the atomic level, the force is very weak. The bigger the object, the greater the force, and the effects of gravity can be clearly seen in space.

Electromagnetic force
This long-range force is the result of interactions between positively charged protons and negatively charged electrons.

Beta emission
A neutron decays into a proton and an anti-neutrino and an electron are ejected from the nucleus of the atom.

Weak force
The weak force is responsible for radioactive decay.

5 TOP FACTS
MAGNET TRIVIA

Magnetic elements

1 Iron, nickel and cobalt are the only three magnetic elements. Some of the others, like oxygen, react to magnetic fields, but the interaction is barely detectable.

Hot magnets will break

2 Magnets are made by applying an electrical current to metal, forcing the magnetic domains to align. Heating the magnet allows the domains to fall out of alignment.

Shark repellant

3 Sharks sense electromagnetic fields in the water and use this ability to locate their prey, but faced with a strong magnet, their senses are overwhelmed and they back away.

Levitating trains

4 Strong magnets keep maglev trains levitating a few millimetres above the track, minimising friction. They can also provide thrust that drives the trains forward.

Weak magnetic field

5 Earth's magnetic field at the surface is around 100 times weaker than a fridge magnet. Despite this, it's still strong enough to protect Earth from solar wind.

DID YOU KNOW? *Some physicists believe gravity is transmitted by hypothetical particles known as gravitons*

The science of impacts

A frame-by-frame look at the forces at work

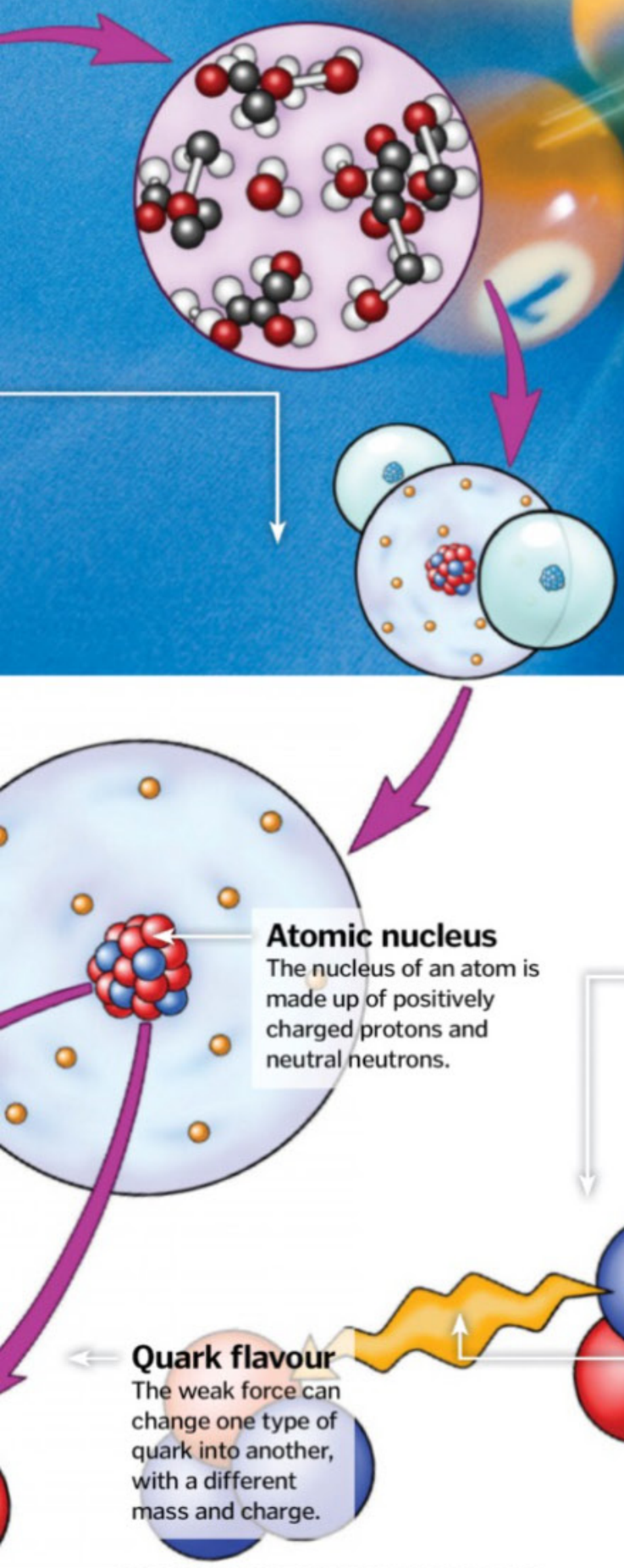
Inertia
Moving objects, like the balls on a billiard table, resist changes in motion and tend to travel in a straight line.

Conservation of momentum
As one ball hits the next, almost all of the energy is transferred and the first ball comes to a stop.

Energy transfer
As balls collide, energy is transferred from one to the next.

Acceleration
The more force applied to the balls, the faster they will move.

Friction
As the balls roll across the surface, electromagnetic forces between the molecules of the plastic ball and the felt of the table slow their progress.



Atomic nucleus
The nucleus of an atom is made up of positively charged protons and neutral neutrons.

Strong force
The strong force only acts over an extremely short range, but is able to overcome the repulsion between positively charged protons, holding the nucleus of each atom together.

Quark flavour
The weak force can change one type of quark into another, with a different mass and charge.

Quark
Protons and neutrons are made up of elementary particles known as quarks. They come in six flavours – up, down, strange, charm, bottom and top.

How to measure the invisible

Forces cannot be seen, but the effects they have on matter can be used to measure them. When a spring is stretched by a force, it lengthens in proportion to the force applied: if there is twice as much force, the spring will lengthen twice as much. By measuring the length of the spring, the relative magnitude of the force can be determined.

Force is measured in comparison to a standard benchmark; one newton (N) is equal to the amount of force required to accelerate a mass of one kilogram by one metre (2.2lb by 3.3ft) per second every second. For example: on Earth, for every 1kg (2.2lbs) of mass, the force of gravity is 9.8 newtons (N), so (ignoring the effect of air resistance), if dropped from the roof of a supermarket, a 1kg bag of sugar would accelerate toward the ground at a rate of 9.8 m/s^2.

"Terminal velocity is reached when the downward force of gravity is matched by air resistance"

How fast can you fall?

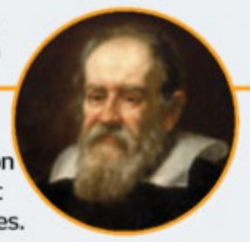
As a skydiver drops from a helicopter, they accelerate toward the ground due to the force of gravity. But they do not continue to speed up indefinitely. The molecules in the Earth's atmosphere block their path and as they collide with them, the interaction creates drag. The amount of drag generated is directly related to the speed of the skydiver and as they fall toward the ground, the resistance increases, opposing the downward pull of gravity, in turn slowing their acceleration.

Terminal velocity is reached when the downward force is matched by air resistance: at this point, the skydiver cannot fall any faster. It is a myth that everyone falls at the same speed. Terminal velocity is not a constant and is affected not only by the weight of the skydiver, but also by their body position. In a face-down freefall position, the average terminal velocity is 193 kilometres (120 miles) per hour, but head first, a skydiver can exceed 322 kilometres (200 miles) per hour.

KEY DATES
THE DISCOVERY OF FORCES

1452-1519
Leonardo da Vinci studies friction and makes hundreds of observations in his journals.

1564-1642
Galileo notes that moving objects are affected by friction and that heavy objects don't accelerate faster than light ones.



1687
Isaac Newton publishes his three laws of motion, laying the foundations for classical mechanics.

1831
Michael Faraday discovers that electricity can induce a magnetic field in an iron ring.

1932
James Chadwick discovers the neutron, leading to the discovery of the nuclear strong and weak forces.

DID YOU KNOW? *The strongest naturally occurring magnet is lodestone. It is just strong enough to lift a paperclip*

Why do we sink?

When a diver drops into the sea, their body fills the space once occupied by water molecules, so an equal volume of water must move out of the way to make room – a phenomenon known as displacement. The water exerts pressure on the diver, pushing upward with a force equal to its weight.

Objects of the same volume displace the same amount of water, therefore experiencing the same buoyant force. Why then, does a basketball float, while a bowling ball sinks? This is down to density. The bowling ball has more matter crammed in to the same volume, so the pull of gravity, or its weight, is higher. When the weight of an object is greater than the weight of the water it displaces, the object sinks.

Pressure gradient
The water below the diver is more compressed than above, compacting the molecules and increasing the pressure.

Displacement
Water molecules move out of the way to make space for the diver.

Buoyancy
The buoyant force is equal to the weight of the water displaced.

Mass
In general, the heavier the skydiver, the faster they will fall.

Balanced forces
When the force of gravity matches the upward drag force, the skydiver stops accelerating and achieves terminal velocity.

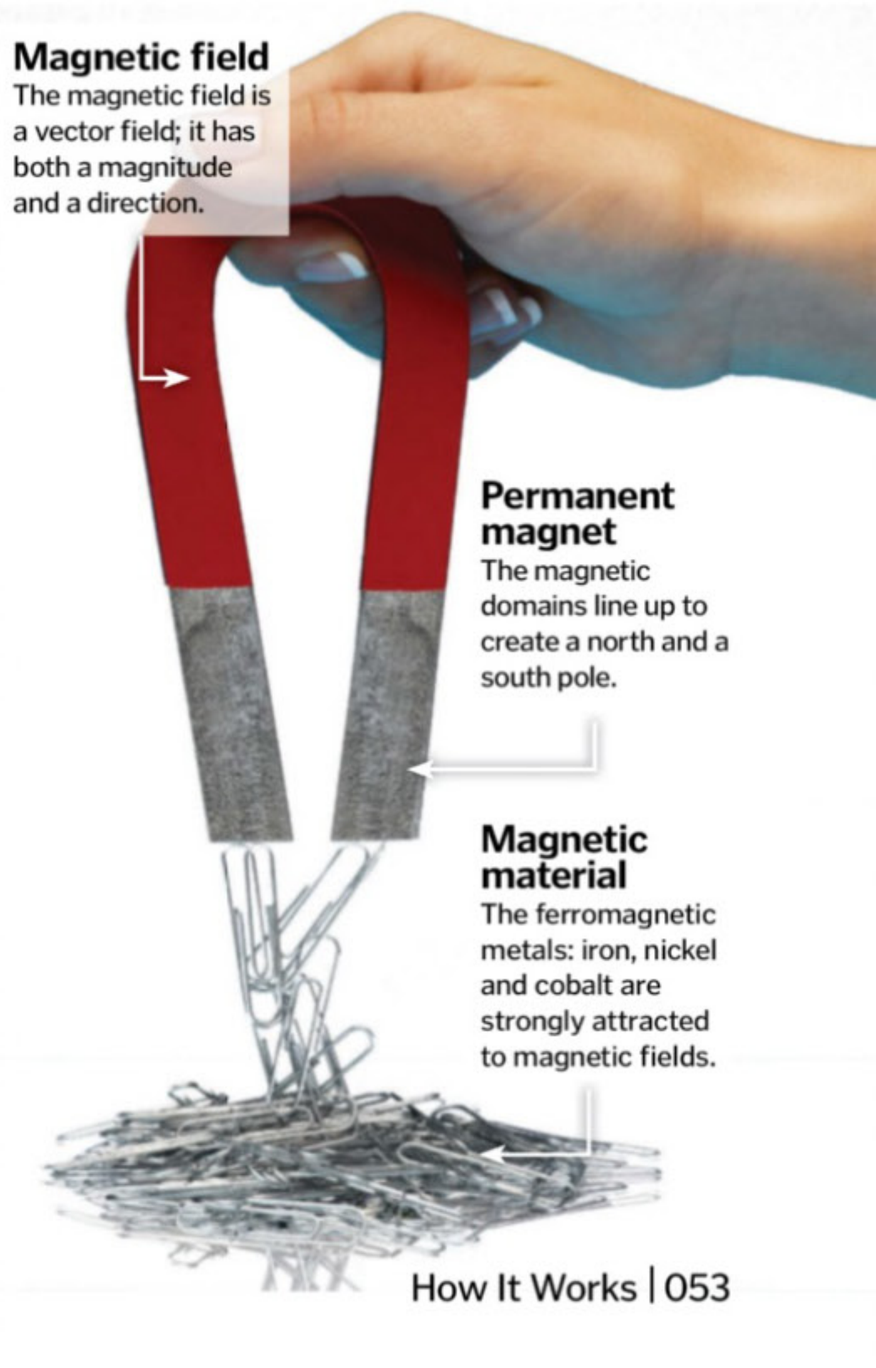
Parachute
The huge surface area of a parachute creates additional drag, slowing the skydiver's acceleration.

Magnetism

Magnetic fields are generated by attraction and repulsion between electrons. The electrons around the nucleus of an atom are not only negatively charged; they also act like miniature magnets. According to quantum mechanics, each electron has a 'spin', creating a tiny magnetic dipole.

In nonmagnetic materials, most of the electrons are arranged so that their magnetic moments cancel each other out, but in ferromagnetic metals like iron, there are unpaired electrons in the outer orbitals. On their own, the forces are small, but when aligned with billions of others, the cumulative magnetic field can be felt.

The fields generated by adjacent atoms of magnetic metals naturally come together to form miniature magnetic domains. In natural magnetic materials, these domains are randomly orientated, but if an electrical current or a magnetic field is applied, they can be forced into alignment, creating a magnet.



Magnetic field
The magnetic field is a vector field; it has both a magnitude and a direction.

Permanent magnet
The magnetic domains line up to create a north and a south pole.

Magnetic material
The ferromagnetic metals: iron, nickel and cobalt are strongly attracted to magnetic fields.

"Elastic materials, like steel and bungee rope, deform under tension and compression"

Tower
The support towers at either end of the bridge are under compression, bearing the load of the bridge.

Cable
Tension is spread across the braided steel support cable, distributing the load to the towers.

Anchorage
The bridge is anchored into the rock, which directs tension from the cables into the ground.

Suspender cable
Vertical cables extending downward from the main cable support the load of the bridge and are under constant tension.

Deck
The load-bearing portion of the bridge is suspended from above.

Elastic recoil
As the jumper pauses at the bottom of the jump, the potential energy in the rope is converted to kinetic energy, flinging them back up into the air.

Air resistance
Friction is generated as the bungee jumper rushes through the air, slowing their acceleration.

Gravity
The force of gravity acting on the bungee jumper pulls down on the bungee cord, deforming its shape.

What makes materials stretch?

Stress inside a material can be caused by a number of forces, like gravity, friction or pressure. There are two types: tension and compression. Elastic materials, like steel and bungee rope, deform under tension and compression, altering their shape to accommodate the force, and recoiling again when it is removed. In contrast, brittle materials like concrete are only elastic over a small range and rapidly reach their breaking point when stress is applied.

400ft

HIGHEST BUNGEE JUMP

72-year-old Ray Woodcock holds the record for the highest-ever bungee jump into water after plunging a terrifying 121.92m (400ft).

DID YOU KNOW? *One of the most common injuries from bungee jumping is damage to eyes due to the increase in pressure*

Energy storage
The elastic fibres of the bungee cord store elastic potential energy, slowing the bungee jumper to a stop.

Bungee rope
The long chains that make up elastic bungee cord can stretch and deform in response to stress, and then recoil back to their original position.

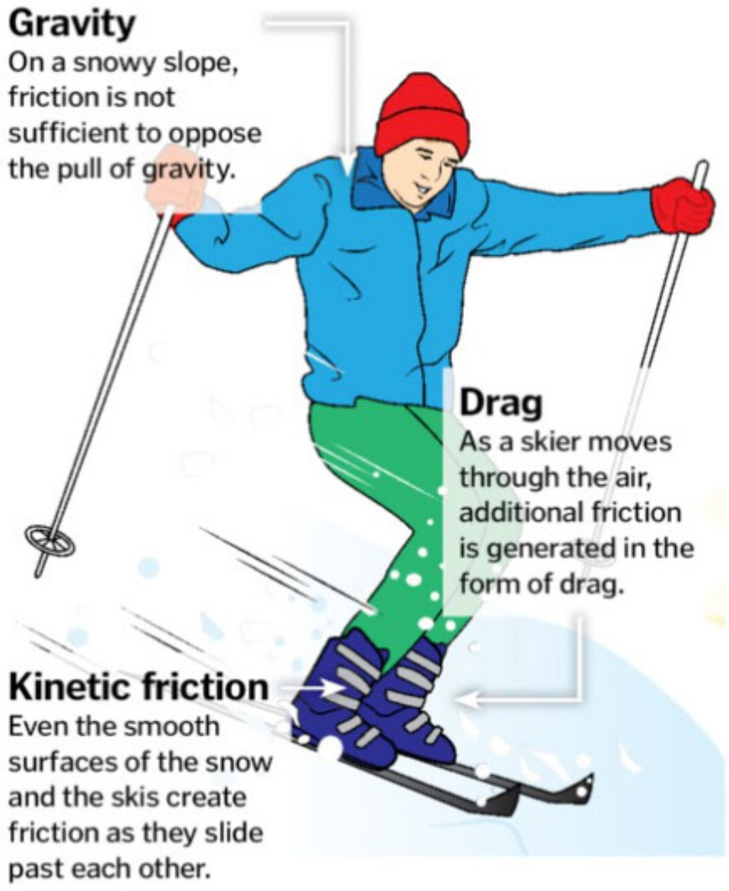
Bouncing back

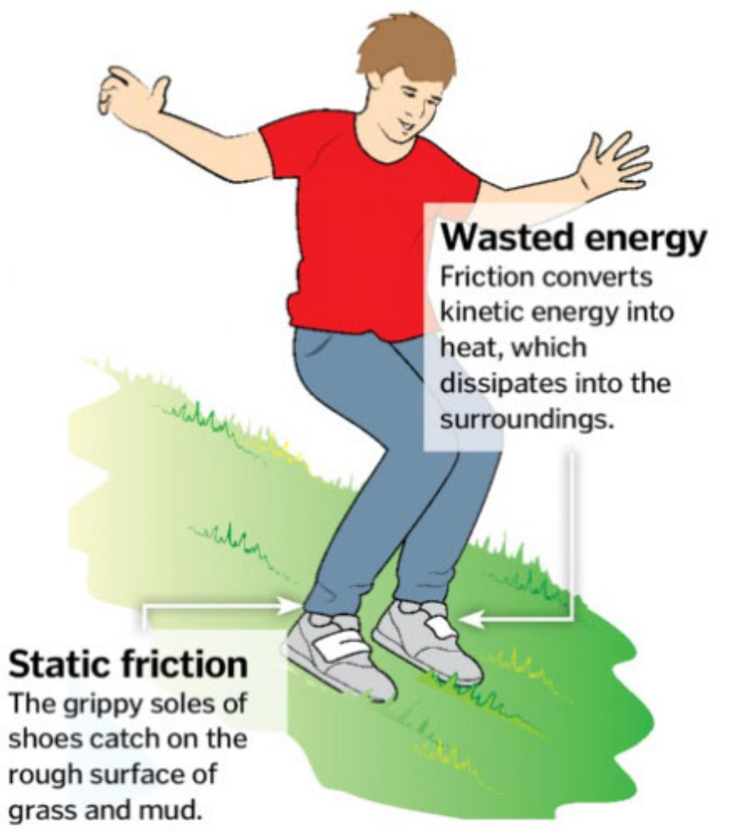
The stress of a bungee jumper pulling on a bungee rope causes it to stretch and deform, but it does not snap. The force is resisted by strain. The forces generated during a bungee jump are within the elastic limit of bungee cord and strain increases proportionally to stress. When the force is removed, the length of the rope returns to normal. Beyond the elastic limit, in the plastic region, the cord can stretch further, but will not fully bounce back, and at very high stress forces, it will reach breaking point and snap.

What creates and controls friction?

Friction is the force that resists the movement of one object relative to another. It can be static where neither object is moving – or kinetic – when one or both of the objects are in motion. Friction is the result of a combination of factors. Rough surfaces, like sandpaper, catch and drag as they move past one another because of irregularities in their surface, but, some of the most highly polished surfaces, like glass, create lots of friction too.

A mirror might look smooth, but touch it and your finger will cling. Slide your hand over rough-ground glass and it will move much more easily. This is thought to be down to a fundamental force – electromagnetism. As two objects move relative to one another, interactions between electrical charges in the molecules cause the surfaces to stick together. Individually, these interactions are weak, but across a large contact area, like a smooth pane of glass, they quickly add up.





"To explain the physics of what happens if you jump in a lift, fake forces must be used"

Fake forces

Newtonian mechanics work fine when we are standing still, but what happens when the reference frame is moving? To explain the physics of what happens if you jump in a lift as it travels between the floors of a building, or what happens if you throw a ball while spinning on a merry-go-round, fake forces must be used.

If a rider on a merry-go-round throws a ball to a person waiting on the ground, to any onlookers, the ball follows Newtonian physics and travels in a straight line toward the catcher, dropping in an arc as it is pulled down by gravity. But to the person who threw the ball, it appears to curve away. The ball does not actually curve, but because the thrower is accelerating, the ball looks like it is changing direction. This is known as the Coriolis effect.

Spinning around

From the ground, it is clear how a merry-go-round works; the chains pull the chairs inward, forcing them to travel in a circle. But from the perspective of the riders, an additional force seems to be at play; as the chairs spin round, it feels like something is pulling them outward.

According to the law of inertia, the accelerating riders should travel in a straight line, but the chains attached to the central spindle of the ride prevent forward motion. Instead, the chairs change direction, rotating around the spindle in a circle. As this happens, the bodies of the riders continue to try to move in a straight line, and the pulling feeling as the chairs twist them around is centrifugal force.

Coriolis effect
For the people sitting in the chairs, the accelerating reference frame makes objects appear to curve as they move relative to the ride.

Gravity
The faster the ride spins, the higher the chairs go as the centripetal force exceeds the downward pull of gravity.

Inertia
Without centripetal force, the chairs would continue to move in a straight line, catapulting away from the merry-go-round at a tangent.

Centrifugal force
An outward pull is felt by the riders as centripetal force opposes inertia.

Centripetal force
The chains hold the chairs firmly to the merry-go-round, pulling them inward and forcing them to follow a circular path.

AMAZING VIDEO! SCAN THE QR CODE FOR A QUICK LINK

Learn more about the four fundamental forces

www.howitworksdaily.com

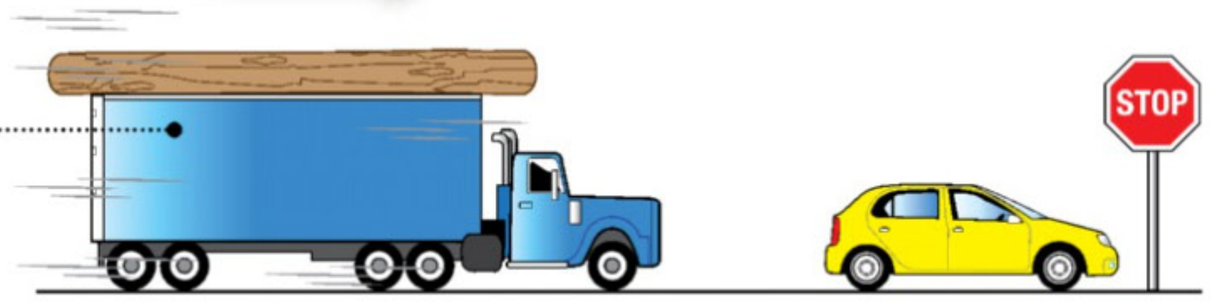
DID YOU KNOW? *The gravity on Mars is 3.71m/s², around a third of the gravity on the surface of Earth*

What are the three laws of motion?

Newton's laws of motion explain how things move and interact. The first law essentially describes inertia; the tendency of objects to resist changes in motion. It is the reason a ball doesn't roll along the floor until you kick it and why spacecraft continue to drift through the Solar System even after their fuel is spent. The second law describes how the force required to move an object is related to the mass of the object and explains we can push a bike much faster than we can push a car. The third and final law explains what happens when two objects interact. As your feet push down on the floor, the floor pushes back.

Newton's first law

A body in motion tends to stay in motion

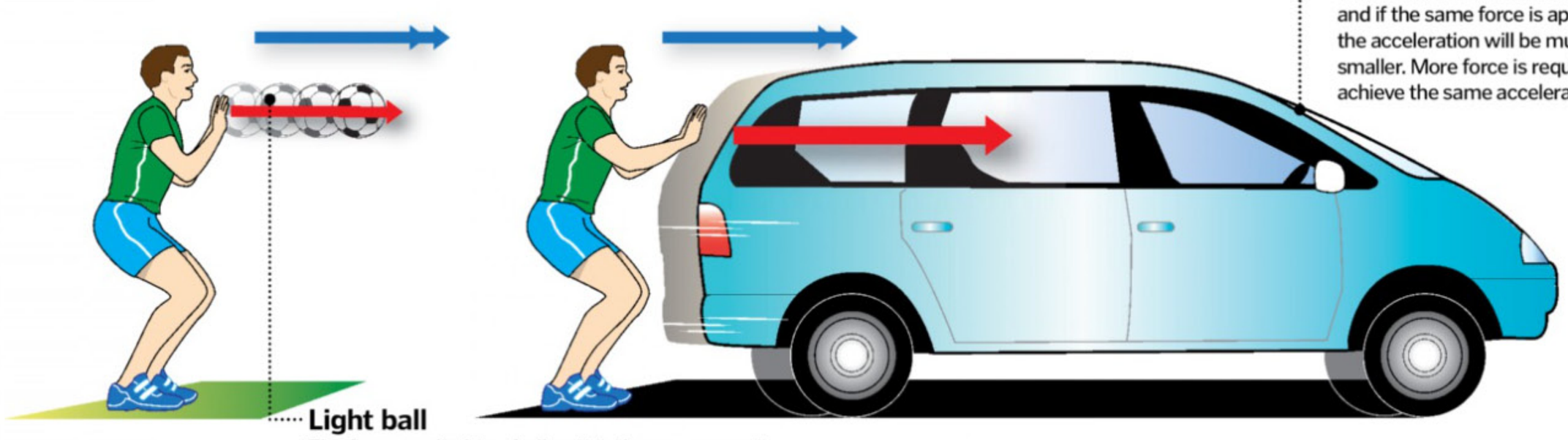


Inertia
Once an object is moving, it will continue to move in a straight line unless a force is applied.

Collision
As the truck strikes the stationary vehicle, the normal force at the point of contact causes it to stop. The log on top of the truck does not hit the car, so it continues to move forward.

Newton's second law

Force is equal to mass times acceleration (F=ma)

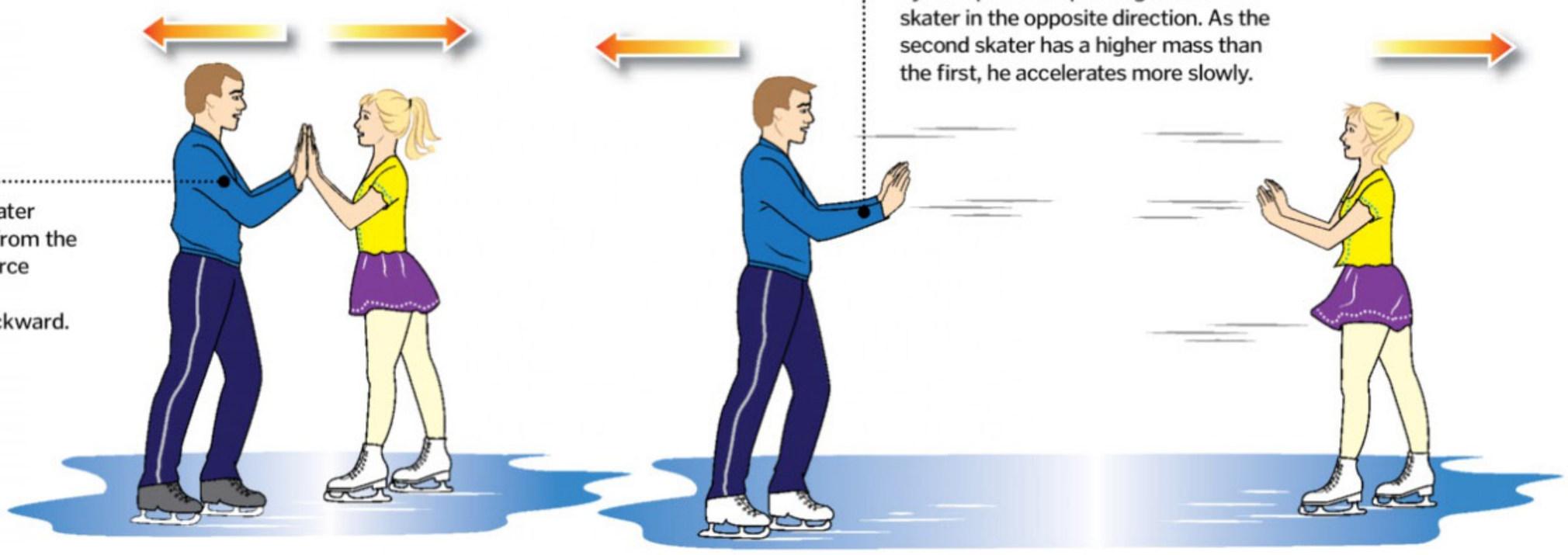


Heavy car
The car is heavier than the ball, and if the same force is applied, the acceleration will be much smaller. More force is required to achieve the same acceleration.

Light ball
The force applied to a ball as it is thrown causes it to accelerate through the air. The acceleration is equal to the force divided by the mass: the ball has a low mass, so it accelerates quickly.

Newton's third law

For every action, there is an equal and opposite reaction



Reaction
The push of the first skater is matched by an equal force pushing the second skater in the opposite direction. As the second skater has a higher mass than the first, he accelerates more slowly.

Action
As the first skater pushes away from the second, the force causes her to accelerate backward.

"After an attack from antibiotics, the few bacteria left over are the strongest of the bunch"

The war against superbugs

Learn how bacteria will hide, change, lie and cheat to evade antibiotics and secure their survival

Bacteria are vital to our survival. They help us digest food, keep our skin clean from more harmful organisms and help develop our advanced immunity while we're young. However, they can also cause disease, which ranges from simple eye infections to life-threating illnesses.

Antibiotics were discovered in 1928 and almost overnight they changed what were once fatal diseases into trivial infections. But despite effective medication, bacteria are smart and know how to fight back. They can change their shape, hide in plain sight and alter their surface appearance. After an attack from antibiotics, the few bacteria left over are the strongest of the bunch and are resistant to the current crop of antibiotics; this is true survival of the fittest. The lasting bacteria then multiply, become stronger and are able to survive attacks from other antibiotics. This is known as 'multidrug resistance' and has led to certain bacteria being ominously called 'superbugs.'

Over the last 30 years, it's been stated that too many antibiotics have been prescribed, which has contributed to this resistance. This is why doctors no longer give antibiotics for simple colds; they have no effect on viruses but contribute to antibiotic resistance.

The revenge of the superbug

How the toughest bacteria are taking over

Bottom of the food chain
Modern farming techniques mean animals are given antibiotics to keep them healthy. They subsequently develop resistant bacteria in their guts.

Entering our food chain
The resistant bacteria in food and vegetables can remain in the human gut once we've eaten them.

Realm of the superbug
The remaining bacteria are now resistant to even the strongest antibiotics and are called superbugs. They spread as patients move and on healthcare staff who go between patients.

Resistance in humans
Antibiotics given for simple illnesses lead to resistance in healthy people.

Entering hospitals
As patients enter and leave hospitals, these tough bugs start growing in wards and nursing homes.

Community resistance
Community resistance gradually develops, helping the toughest bacteria to establish and spread.

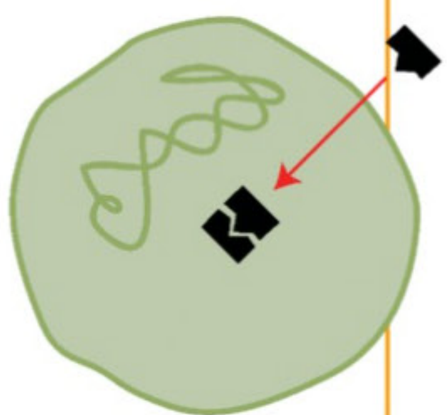
Crop circles
Fertiliser used on crops contains animal matter, which also contains the resistant bacteria, increasing their spread.

Weak targets
They cause infections, secondary to the main reason the patient is in hospital. Doctors treat these, but some bacteria still remain.

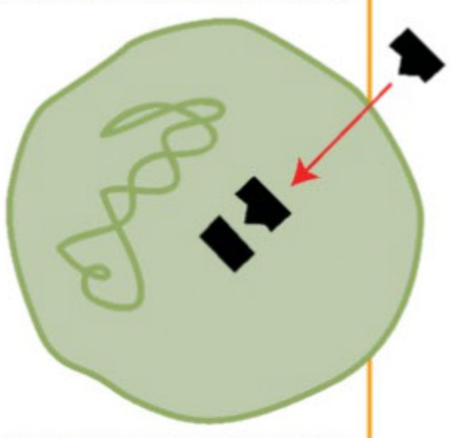
Future strategies
Doctors only prescribe antibiotics for as short a time as possible. New and smarter antibiotics tackle even the toughest of resistance.

How antibiotic resistance develops

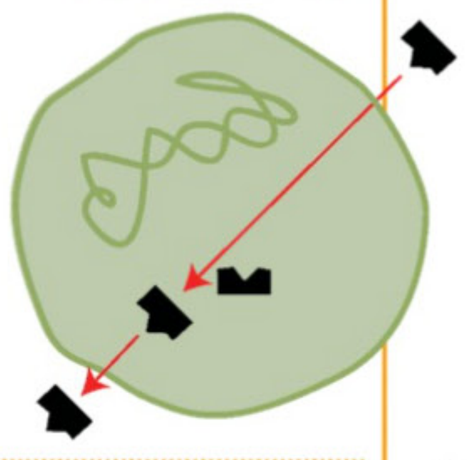
Normal function
Antibiotics target bacterial cells, by changing the signals of their outer wall, their membrane shape, impairing DNA function in the cell or by blocking protein synthesis.



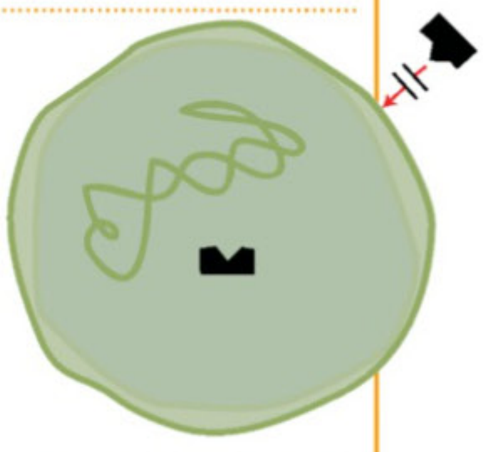
Changing the landing zone
Bacteria can change the shape and structure of the molecules that antibiotics target, meaning they can't recognise them and rendering them useless.



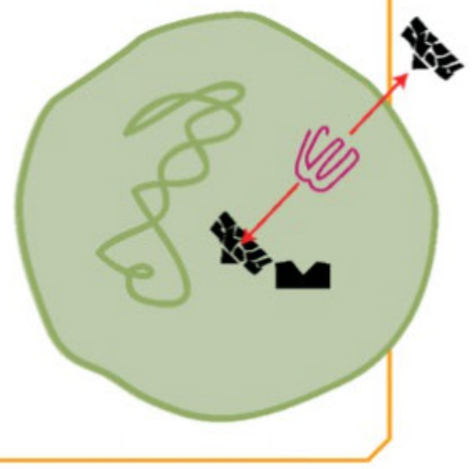
One in, one out
Antibiotics enter bacterial cells via special pumps. The bacteria can develop more exit than entry pumps, meaning the antibiotic is exited faster than it can enter.



Entry policy
Bacteria can stop antibiotics entering: they can change the shape of entry pumps and reduce the size of pores in their surface, meaning the antibiotics are too large to enter.



Inactivation
The strongest bacteria develop special enzymes, which can destroy the key parts of an antibiotic before they have a chance to take effect.



AMAZING VIDEO! SCAN THE QR CODE FOR A QUICK LINK

See artificial photosynthesis in action

www.howitworksdaily.com

DID YOU KNOW? *Some people get early signs of migraine, like flashing lights. This early-warning system is called an aura*

Man-made photosynthesis

How plants are leading the way in cheap and clean energy

Earth's plants have been utilising the Sun's abundant energy for millions of years. This pure and free source of energy is one that scientists have been trying to harness for a long time, now technology is finally catching up with nature.

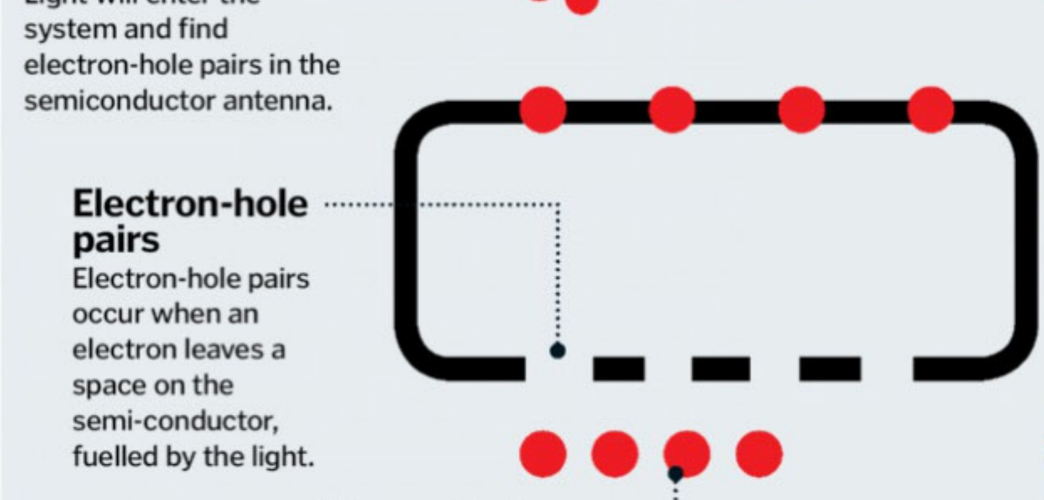
To trigger the process of photosynthesis, plants absorb light energy through the chlorophyll in their leaves (the green pigment). The plants then take carbon dioxide, which is what humans breathe out, along with water and turn this into sugar for food. The waste product of this process is oxygen, which is delivered back into the atmosphere, as the plant only needs the hydrogen to create the sugar to provide it with energy.

However, hydrogen itself is a fuel that humans find very useful, so a way of mass-producing that would be a technological and environmental leap forward as the need for the finite resources of fossil fuels would be drastically reduced. The key to replicating the success of photosynthesis is in the splitting of water molecules. The newest technique involves artificial light entering a semiconductor. This sucks oxygen atoms out of the water, creating hydrogen, which can then be used to fuel cars and rockets alike.

How artificial photosynthesis occurs

Storage
This hydrogen can now be stored and used as fuel for transport.

Light
Light will enter the system and find electron-hole pairs in the semiconductor antenna.



Electron-hole pairs
Electron-hole pairs occur when an electron leaves a space on the semi-conductor, fuelled by the light.

Combination
The electrons and protons come together to make molecular hydrogen.

Spare electrons
Those holes in the semiconductor suck the oxygen atoms from the water molecules.

Why do we get migraines?

Discover how these mega-headaches strike

Those who suffer from migraines know they are a constant concern as they are liable to strike at any time. Essentially, a migraine is an intense pain at the front or on one side of the head. This usually takes the form of a heavy throbbing sensation and can last as little as an hour or two and up to a few days. Other symptoms of a migraine include increased sensitivity to light, sound and smell, so isolation in a dark and quiet room often brings relief. Nausea and vomiting is also often reported, with pain sometimes subsiding after the sufferer has been sick.

It is thought that migraines occur when levels of serotonin in the brain drop rapidly. This causes blood vessels in the cortex to narrow, which is caused by the brain spasming. The blood vessels widen again in response, causing the intense headache. Emotional upheaval is often cited as a cause for the drop in serotonin in the brain, as is a diet in which blood-sugar levels rise and fall dramatically.

"In mitosis, the membrane surrounding the nucleus breaks down, exposing the chromosomes"

The cell cycle

Inside one of the body's most vital processes

The continuous cycle of cell division and growth is essential to all life on Earth. Without it, no organism would be able to reproduce or develop. The cycle consists of three main stages: interphase, mitosis and cytokinesis.

During interphase, the cell expands and makes the new proteins and organelles it will need for division. It then makes copies of its chromosomes, doubling the amount of DNA in the cell and ensuring the conditions are right to begin the next phase.

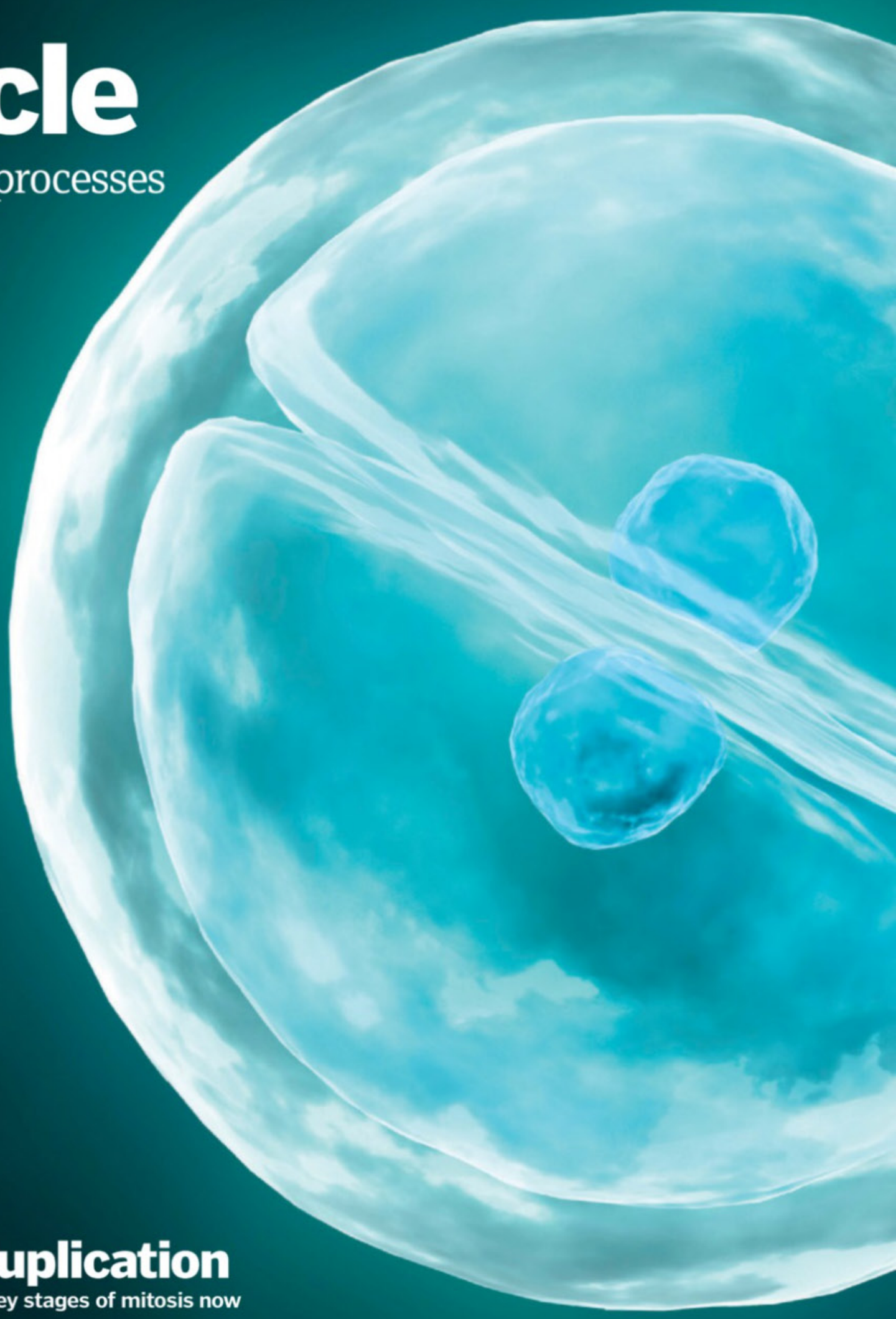
In mitosis, the membrane surrounding the nucleus breaks down, exposing the chromosomes, which are pulled to opposite sides of the cell by tiny spindle fibres. A new nuclear envelope then forms around the chromosomes at each end of the cell. During cytokinesis the cytoplasm splits in half to create two 'daughter' cells, each with their own nucleus and organelles.

The cycle is managed by regulating enzymes known as CDKs (Cyclin-dependent kinases). These effectively act as a checkpoint between the phases of division, giving a go-ahead signal for the next stage in the cycle to begin.

The cell cycle of prokaryotic cells (those without a nucleus) is slightly different. Bacteria and other prokaryotes divide via a process called binary fission, in which the cell duplicates its genetic material before doubling in size and splitting in two. Meiosis is another type of cell division and is concerned with sexual reproduction as opposed to the asexual organic growth of tissue in mitosis.

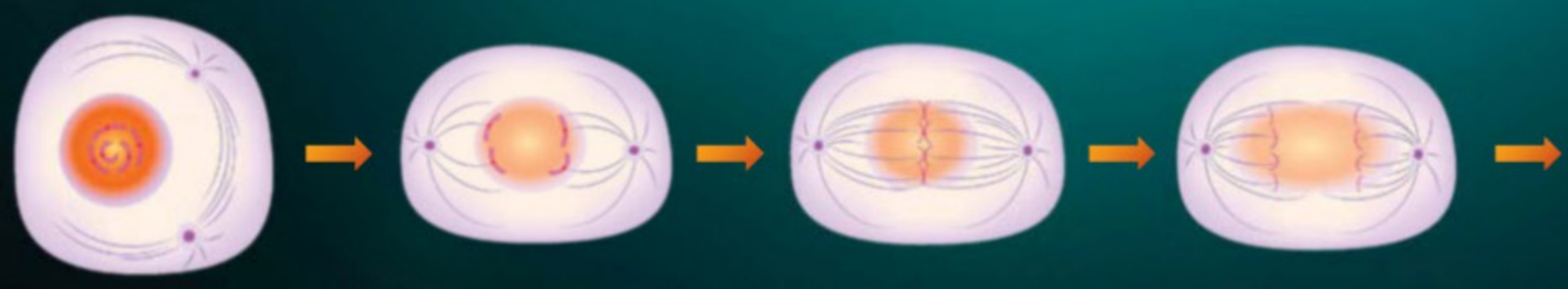
Cancer and the cycle

If the cell cycle goes wrong, cancerous tumours are a possible consequence. It all depends on the levels of proteins in the cycle. A protein called p53 halts the process if DNA is damaged. This provides time for the protein to repair the DNA as the cells are then killed off and the cycle begins anew. On the rare occasions this process fails, cells can reproduce at a rapid rate and tumours can form. Chemo- and radiotherapy work by destroying these mutated cells. A p53 mutation is the most frequent one leading to cancer. An extreme case is Li Fraumeni syndrome, where a genetic defect in p53 leads to a high frequency of cancer in those affected.



Cell duplication

Explore the key stages of mitosis now



Prophase

Chromosomes condense, becoming thicker and shorter. Sister chromatids form when the chromosomes replicate themselves.

Prometaphase

The nuclear envelope breaks down and spindle fibres extend from either side of the cell to attach to the middle of each chromatid.

Metaphase

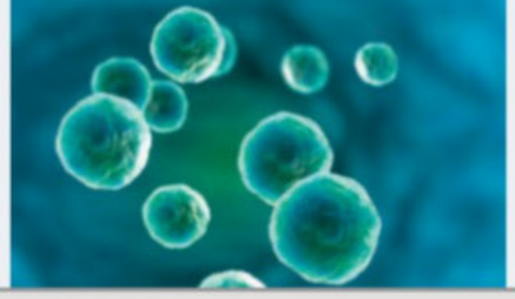
In this phase, all the spindle fibres are attached and the chromosomes are arranged in a line along the equator of the cell.

Anaphase

Now, the spindle fibres pull the chromosomes apart, with the chromatids moving to opposite ends or 'poles' of the cell.

What is apoptosis?

A Another type of cell division B Programmed cell death C A new type of soft drink



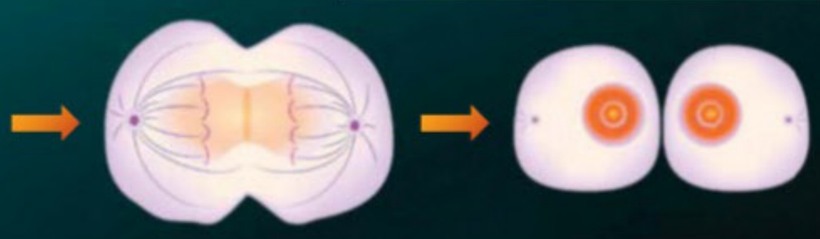
Answer:
Essentially a cell committing suicide, apoptosis is a controlled biological system that kills off unneeded or excess cells. One example is the removal of webbing in between your fingers and toes before you are born.

DID YOU KNOW? *A common theory is that every living cell is descended from a single ancestral cell from 3-4bn years ago*

Every step of the cell division cycle is vital for life as we know it

Learn more

For more on the cell cycle and other science topics, check out the British Science Festival, which will be held from 6 to 11 September all around Birmingham. Head to **www.britishsciencefestival.org** for more information.



Telophase
The two new sets of chromosomes form groups at each pole and a new envelope forms around each as the spindle disappears.

Cytokinesis
The cytoplasm divides and two or more daughter cells are produced. Mitosis and the cell cycle have now reached their end.

An expert's view

Paul Nurse, Nobel Prize winner and director of the Francis Crick Institute, chats to How It Works about cell cycle

What is the cell cycle?
The cell is the basic unit of life for all living things. One of its many properties is the ability to reproduce. The cell cycle is a series of processes that occur between the birth of the cell and its division into two.

What is mitosis?
Mitosis describes what happens near the end of the cycle. The replicated chromosomes are separated from each other into opposite ends of the cell just before the cell divides.

What are the different parts of the cycle?
The other major part occurs before mitosis and is the process in which the DNA that makes up the chromosomes replicates itself. This is called the S-phase or DNA synthetic phase [part of interphase]. The S-phase replicates and mitosis separates and divides.

What is the difference between mitosis and meiosis and does cell division occur in both?
Meiosis is usually considered to be the mitotic full cycle and also leads towards cell reproduction. However, in meiosis there are two M-phases or divisions so the number of DNA and chromosomes are halved. Meiosis uses gametes for fertilisation in diploid cells in animal and plants.

Does it occur in eukaryotic or prokaryotic cells?
Only in eukaryotic cells. In prokaryotic cells there is a cell cycle but it is not mitosis. This [process] is simply the copying of DNA and then a much less obvious separation of the copied DNA into the two divided cells.

Why did you use yeast in your experiments?
Yeast is a very simple eukaryote, which reproduces in much the same way as more complex cells in us. It only has 5,000 genes compared to our 25,000. It simplifies cell division so is extremely convenient to study. It's got fantastic genetics and genomics, which allow you to investigate complicated processes like the cell cycle.

Why do skin cells divide so quickly and nerve cells so slowly?
Cells change at varying rates and some nerve cells barely divide at all. This is one reason why it is difficult to regenerate the nervous system when it becomes damaged. Because the body has to deal with cuts and abrasions, it is much easier to get skin cells to divide.

What is tissue culture and why is it important?
It is simply a way of growing cells from animals and plants in test tubes. They will divide under these circumstances so you can study the cell cycle away from the complexities of an animal or plant.

What are the differences between plant and animal cell cycles?
Fundamentally, not very much. They both undergo the same processes but are subject to different overall controls.

What is proteolysis and how does that mechanism help the cell cycle?
It is a biochemical mechanism that breaks down protein. It takes away certain proteins as part of a regulatory system for a variety of biological process such as the cell cycle. It is used at the end of the cycle to destroy excess protein and prepare for the next cycle.

You discovered CDK (Cyclin-dependent kinase). How do they contribute to the cell cycle?
CDK is a type of enzyme and my research group was involved in discovering that they were the major regulators in the cycle. CDK brings about the S-phase and mitosis and controls them.

How can the cycle help understand potential cures for cancer?
To understand cancer, you have to be able to understand the cell cycle. Crudely blocking the cell cycle is a problem as a therapy as our body is full of other cells that have to divide.

Paul Nurse is also the former director of Cancer Research UK and president of the Royal Society

CRASH TESTING

We go behind-the-scenes at one of the world's most advanced crash testing facilities to witness the destruction first-hand

Crash testing is a lot more varied than simply flinging cars into walls – it now incorporates almost all aspects of the driving environment, including lampposts

HEAD 2 HEAD
TOP 2013 NCAP RATINGS

1. SAFE

BMW i3

The dinky electric BMW managed four stars out of five, impressing the NCAP with its innovative BMW Assist Advanced eCall emergency feature.

2. SAFER

Honda CR-V

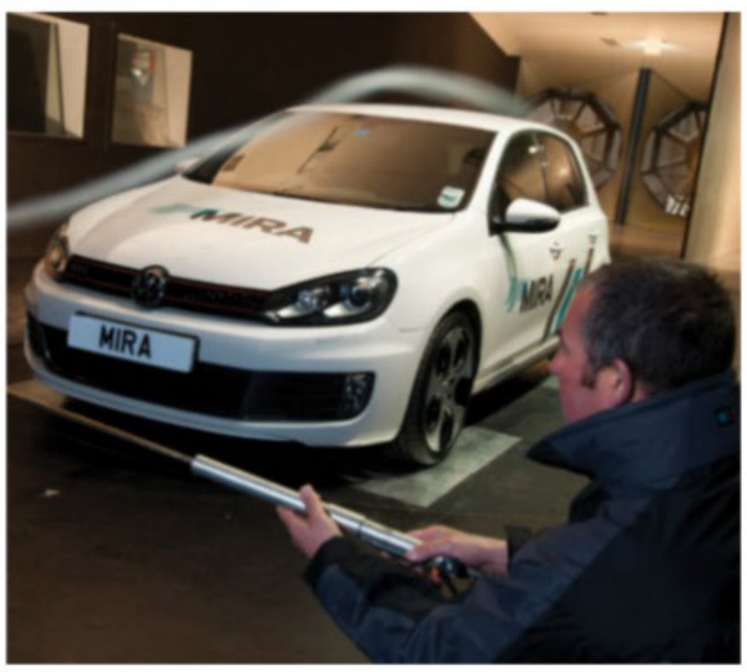
The Japanese motor giant's flagship 4x4 scored a mighty 93 out of a possible 100, excelling in adult passenger and driver safety in particular.

3. SAFEST

Qoros 3 Sedan

The best of our selection with a full five stars, the fledgling Chinese company recorded excellent results across the board.

DID YOU KNOW? *Crash test dummies are made from plastic skin and metal bones – to mimic the movements of a human body*



Before a new car rolls off the production line, it must be smashed to pieces to determine whether it's roadworthy. Safety is at the forefront of the automobile industry and procedures like crash testing evaluate the vehicles and the roadside environment. To find out exactly what goes into the process, we travelled to Nuneaton in Warwickshire to visit MIRA (previously known as the Motor Industry Research Association) for the National Crash Demonstration Day.

Expecting to find a line-up of vehicles with a one-way ticket to smash city, we discover the agenda is to test the mettle of traffic lights, barriers and posts instead. But that's not to say cars weren't harmed in the process.

Before we got to witness some twisted metal, however, we chatted to business development manager for safety development, Lee Thompson. He explained that although today would focus on roadside furniture barriers and traffic signals, the facility also supports heavy goods vehicles (HGVs) and high-speed tests. Both interior and exterior crashes are undertaken here but while inside is geared toward approving different vehicle types, outside is where roadside products are put to the test. "If a vehicle leaves a highway and makes contact with a lighting column, the job of the column is not to cause any serious damage or injury to the vehicle or the occupants," he says. Today, these 'columns' were a lamppost and a set of traffic lights.

The first crash demonstration saw a 1500-kilogram (3,307-pound) saloon car launched at 70 kilometres (43.5 miles) per hour into a 12-metre (39-foot) lighting column. The test, like all of them on the day, was more concerned with the infrastructure rather than the vehicle. In this case, the column passed with flying colours and acted exactly like it was designed to, illustrating its life saving capabilities. As the car hurtled into it, the aluminium column was uprooted and landed on the car, helping to constrain the vehicle and grind it to a halt.

On closer inspection the car's bonnet was completely crumpled, but the occupant area was only lightly scathed as the front of the car took the brunt of the damage. As for the lamppost, it was taken clean out of the ground and only the base remained. It was bent and dented but there was very little debris, with most of the structure intact. The electrical disconnection system also worked perfectly, disengaging and isolating all volts within 0.2 seconds of impact. This was an ideal result because in a real-life situation, any clean up operation would take much less time. Also, as the lamppost was easily uprooted it meant there was less force exerted on the car, as it spun over the bonnet and onto the roof.

As the streetlight was carted away, the next victim was prepped for destruction: a traffic signal post. The difference with this crash was that the traffic lights were not embedded into the car like the lamppost, but it still left a similar dent before it came to a rest on the road by the side of the car. The traffic lights portrayed a pedestrian crossing, so it was imperative that shards of material did not fly off the structure and strike potential pedestrians. The company who produced the post had made sure of this and the pole remained relatively intact. Recently developed roadside objects are termed 'passively safe' and there is a huge push to use inventive technology to make the roadside as safe as possible.

HIW's day at MIRA consisted of four outdoor crash tests but there is much more to it than just the High Energy Facility. Formed in 1946, the site was originally a Royal Air Force base during the Second World War. The area is an ideal secluded location to undertake discreet and essential testing for not just commercial cars, but military, aerospace and rail vehicles as well. Over 40 crash dummies are at the centre and the results are recorded through the use of high-speed camera filming technology. The site also contains high-speed performance circuits, cross-country and off-road surfaces and a climatic wind tunnel.

The National Crash Demonstration Day was based solely outside, but there is also an indoor crash laboratory. This facility has five bays, which include state-of-the-art load cell walls, crash walls, a transparent pit for underside filming and a roll over rig. Every crash imaginable is thoroughly tested and captured by high-speed camera technology that records every detail.

When the subject of crash testing comes up, the image associated is more often than not, the crash test dummy. The first dummy was known as 'Sierra Sam', which was created in the United States in 1949 for use in aircraft ejector seats. After 'Sam', the mannequins became specialised for use in cars. In 1971, the Hybrid I formed the first template for the current crash test dummy as we know it. The Hybrid III was the longest-serving dummy, first used way back in 1976. ▶

"We use different dummies for frontal and side impacts [...] to record different types of forces"

An updated edition is used today, which includes force, torque and acceleration sensors and can accurately simulate how a real body would respond. Each one has 130 sensors in their body and each dummy costs approximately £100,000 ($170,000). The dummies are made of an aluminium structure with a flexible PVC skin. Thompson said the dummies at MIRA were "several different kinds. They represent different occupant sizes from a one-and-a-half-year-old-child to 95 percentile male. We use different dummies for frontal and side impacts as the instrumentation is set to record different types of forces on the occupant during the crash. Dummies also vary by region and the legislation required."

A chat with senior certification engineer Mitesh Chauhan found that the world of crash testing is constantly expanding. He explained that it is now compulsory for all manufacturers to have a CE mark and a declaration of performance on their cars. This mark has to be submitted to any customer on request. This will ensure all companies adhere to strict guidelines set by authorities so standards won't slip. Chauhan explained that MIRA's role is to "carry out a factory production controlled audit to see if the product meets the criteria and can be awarded a CE mark." The firms are then, and only then, free to retail their products.

Safety assessment

MIRA's safety engineer Roy Quinney takes us through the anatomy of a crash

Air bag
"When most people have an accident, they see a lot of damage and expect the restraints to deploy. It's actually based on whether you, the occupant, receive high enough local deceleration to require the restraints to deploy."

Bumper beam and bonnet
"We've had a central impact from a pole aimed at the middle of the vehicle. It has deformed the bumper beam, a load path into the engine bay, and the bonnet's been crumpled."

5 TOP FACTS
TYPES OF DUMMY

1 SID
Specialising in side impacts, this dummy measures the effects on organs in the chest and spine area. This version is used in the US while Europe uses the EuroSID.

2 BioRID
This type is designed to combat whiplash trauma and aid neck restraints from a rear impact. It has 24 vertebrae to assess the effects on the back as clearly as possible.

3 THOR
The successor to the Hybrid III is equipped with an improved spinal and pelvic structure. Additional sensors also measure the effects of an impact on the face.

4 THUMS
An acronym for 'total human model for safety', this is a computer simulation developed by Toyota and incorporates detailed virtual models of humans.

5 CRABI
A child test dummy that comes in six-, 12- and 18-month-old versions. It tests the effectiveness and suitability of different types of child restraint devices.

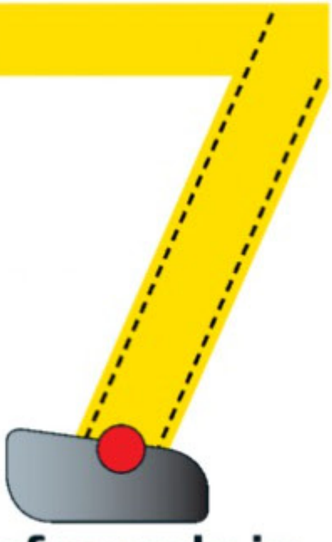
DID YOU KNOW? *Human cadavers and even animals were used as crash testers before dummies were introduced*

Roy Quinney is MIRA's senior safety engineer. When watching the crash tests, it was surprising to see that the air bags didn't always deploy. However, Quinney quashed the idea that they didn't activate because they were faulty: "Many people see a lot of damage and expect the restraints to deploy. That's not what it's based on. It's based on whether there is enough local deceleration to require the restraints to deploy." The air bag measures the forces impacting on the occupant and specific points of the vehicle to determine whether deployment would be advantageous or not.

The rigorous crash assessments are held in a high regard by manufactures and MIRA works alongside various bodies to achieve the best results. The two biggest organisations in the world are undoubtedly the European-based NCAP (New Car Assessment Programme) and the US-centred NHTSA (National Highway Traffic Safety Administration). If a car is to be put on sale, they have to pass stringent tests put forward by the bodies. Since a revaluation by NCAP in 2009, there are now four key areas: adult protection, child protection, pedestrian protection and safety assist (Seat Belt Reminders (SBR), Electronic Stability Control (ESC) and Speed Assistance Systems (SAS)). These results are then plotted together to reach an average star rating out of five. ▶

Absorbing the impact
"We start off from the front. We have a cross member known as the bumper beam. That then ties in to the longitudinals as another load path. Combine these with the engine as a third load path of resistance. So, the impact will go from the bumper beam to the longitudinals, to the A-pillar, through the header rail, down the back, into the sills and through chassis members under the floor."

Windscreen, door and A-pillar
"If you take a look around the rest of the vehicle, there is no contact whatsoever to the A-pillar, the windscreen and the doors. So, in terms of passenger safety, it is intact and there is no intrusion."

87

Percentage of people in the US who wear seatbelts regularly. The figure is 95 per cent in the UK.

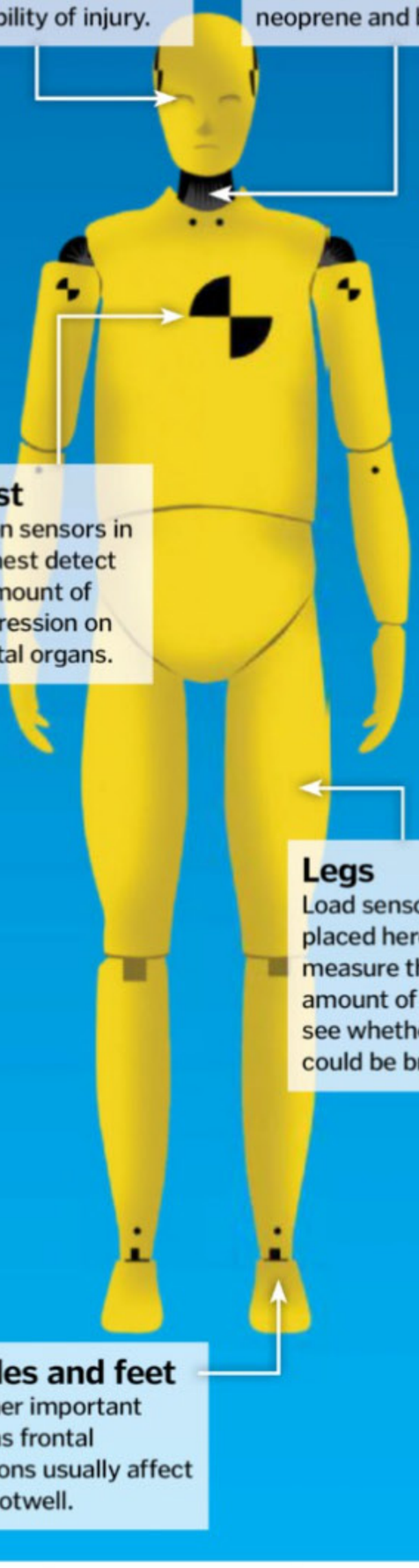
718
The most crashes endured by a human crash test dummy, W.R. Haight.


6in
The ideal distance you should be from an airbag to prevent injury.


58
The number of data channels in a Hybrid III dummy.

1.78m
The height of the most commonly used dummy.

Anatomy of a dummy
The main parts of a crash test dummy



Head
Accelerometers measure the force of acceleration to the head to determine the probability of injury.

Neck
A vital area to test, it is made of a mixture of natural rubber, polyacrylates, nitriles, neoprene and butyl.

Chest
Motion sensors in the chest detect the amount of compression on the vital organs.

Legs
Load sensors are placed here to measure the amount of force to see whether bones could be broken.

Ankles and feet
Another important area as frontal collisions usually affect the footwell.

"Primarily used in racing cars, roll cages are now also making their way into production vehicles"

Despite all these efforts, it's estimated that over a million people worldwide die in car crashes every year. Therefore, many state-of-the-art devices are being developed to provide a safer future. In a crash, the first hour after impact is the most important. Quick reaction times are essential to begin CPR or prevent brain swelling on the casualty. To combat this, a type of advanced telemedicine is currently in development to beam a screened image of a surgeon or doctor to the crash site, who will relay important information to help the injured before emergency services arrive.

Similarly, measures are being made to develop an in-car system that alerts the emergency services when the driver is unable to do so themselves. Already in use in some US cars, the Urgency Algorithm programme will send the exact location and type of collision to available help. Meanwhile, another system emphasises the role of the public rather than doctors. Known as Driver First Assist (DFA), these courses have been set up across the UK and the scheme aims to train drivers and passengers in first aid so they are ready to help at a crash scene before the emergency services arrive. For truck, bus and coach drivers, the course will now be a compulsory part of their Driver CPC Periodic Training.

Primarily used in racing cars, roll cages are now also making their way into production vehicles. As the name suggests, if the car rolls the cage will protect the occupants by keeping the vehicle much more structurally sound. Crumple zones, as well, are imperative to the modern car. They specialise in dissipating impact energy and decreasing the rate of deceleration. By crumpling in a collision, the majority of the impact is absorbed and the force is reduced, giving greater safety to the occupants and other areas of the car.

The visit to MIRA was fascinating to see that roadside furniture goes through the same rigorous processes that vehicles do. Many do not realise that a lot of time and effort goes into ensuring that what we are crashing into is made as safe as possible. Whether it's a particular material used or an innovative engineering technique, crash testing is not just about dummies and seatbelts, it concerns the whole spectrum of motoring and transport. With MIRA and transport infrastructure companies working together, all areas of transportation are constantly being made safer and our roads, streets and lanes are much better off because of it.

Crash test dummies are designed to best represent real-life humans

Safer cities

75 per cent of all crashes happen at speeds under 30 kilometres (18.6 miles) per hour, so Volvo's City Safety technology looks to combat this extraordinary statistic. Using an optical lidar system, the device kicks in when a vehicle is rolling toward another vehicle or obstacle due to human error, distraction or misjudgment. With the commute ever-more stressful, this system will be important to the demands of long haul and tough driving. A similar system is Subaru's EyeSight, which uses 3D imaging to give the driver warnings to upcoming dangers and can supply automatic braking if required.

KEY DATES
HISTORY OF MIRA

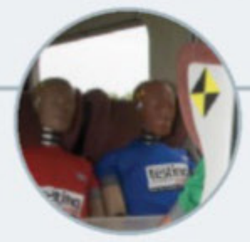
1945
Shortly after the end of WWII, MIRA is established at a meeting on 11 December.

1950
The first purpose-built track and laboratory facilities are constructed as the site starts to expand.

1968
Former minister of technology Tony Benn opens up the new crash laboratory.

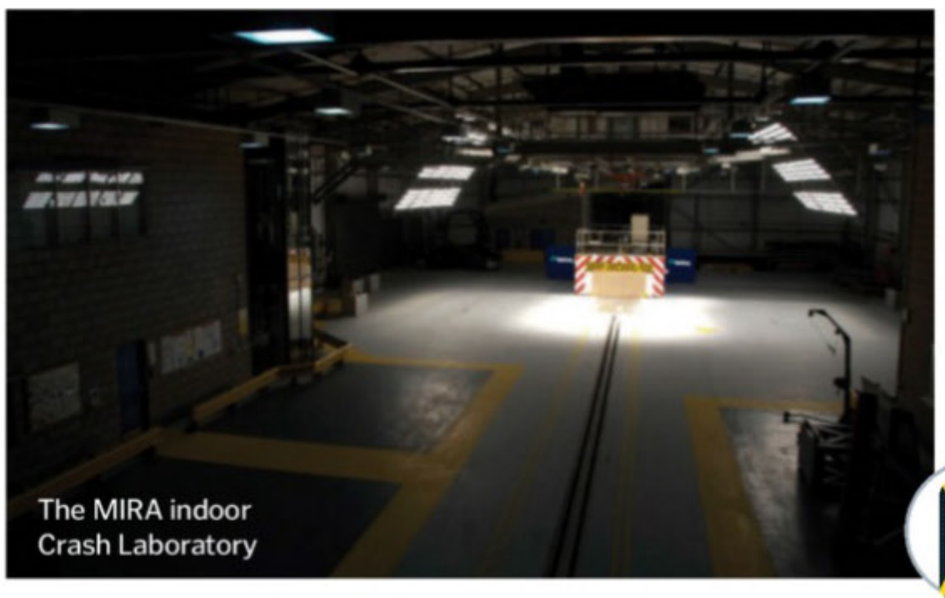
1993
The first crash test is conducted on 19 November. A climatic wind tunnel is also built.

2009
MIRA performs Britain's first full-scale rail crash test for over 20 years.



DID YOU KNOW? *The Tesla Model S holds the NHTSA record for the best safety rating with five stars in every subcategory*

MIRA's business development manager, Lee Thompson


The MIRA indoor Crash Laboratory

After a test crash, the results are immediately screened to evaluate what has happened and what can be improved

The Intellicone

The final test of the day promoted a new innovation that is being designed to combat jams and motorway gridlocks as well as improving responses to accidents. The Intellicone safety platform is an alarm built in to traffic cones and barriers that will signal a chain reaction when hit. Real-time information will then be utilised to locate where, when and how the collision happened. Temporary roadwork sites will now be better suited to responding to accidents and congestion, making Britain's and the world's infrastructure more efficient and safer.

Safety inventions through history

Tyres

Initially wooden wheels on carts and wagons, tyre technology grew as the world began to embrace petrol and tarmac. The first air filled tyre was created in 1845 on bicycles but was not entrusted to cars until 1895 when they replaced the solid rubber versions. The next advancement was radial tyres, which popularised in Europe in 1948 by French manufacturer Michelin. These tyres are made stronger by steel belts and a fabric casing and showed that tyres could be made to be very durable. They specialise in longer tread life, better steering but are more expensive than standard tyres.

Seatbelts

Beginning in both military and racing, seatbelts worked their way into commercial cars in 1955 when the Motor Vehicle Seat Belt Committee was set up. Still optional, they were only included in cars by law in the 1960s. The first type was a two-point model made in 1955 but by 1959 they had been improved upon by the three-point model invented by Volvo. Since then, the main crux of the belt has been retained with various bills and acts passed to improve their manufacture and implementation. The invention has proved to be extremely effective, improving chances of survival by 50 to 75 per cent.

Air bags

The idea of the air bag first came from an incident in 1952 when industrial engineer John W Hetrick was involved in a road accident. Using his knowledge of torpedo canvas covering, Hetrick devised a way of storing compressed air in a car. Despite initial interest from Ford and General Motors, the idea was not realised until 1971 when it was incorporated into several Ford models. After more setbacks, air bags soon became the norm for all production cars and were installed in other parts of cars as well as just the driver's seat. The National Highway Traffic Safety Administration ordered air bags to be fixed onto both driver and passenger sides in all new vehicles by 1998. Recently, a new invention called the smart airbag has been produced. The airbag inflation speed of 320 kilometres (200 miles) per hour has been known to cause injury if a child or baby is subjected to them. As a consequence, the smart airbag has been developed. This new system uses sensors to monitor the size of the person in the seat and the ferocity of the impact. As a result, the deployment will not cause injury to the passenger.

Virtual Dummy

With 30,000 sensors in the neck alone, the virtual crash test dummy is a marked improvement on the physical version. Designed to predict the exact moment when crash forces become too much, this new generation of dummies will be detailed computer-based models of the human body. Despite being computer generated, the dummies will show much more realistic affects than their physical counterparts with lifelike details of ligaments, vessels, muscles and organs. This virtual version will also cost much less than a standard dummy and use up less material as it can be used again and again.

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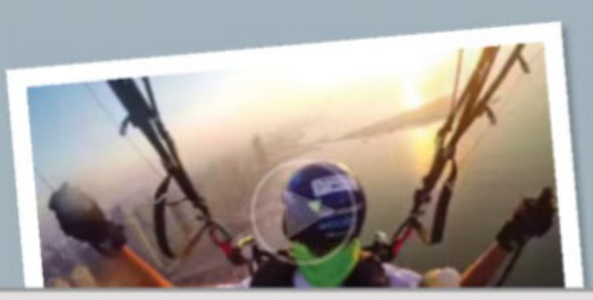


DID YOU KNOW? *Adventurer Bear Grylls set a world record paramotoring over the Himalayas at 8991.6m (29,500ft)*

High-flying paramotors

The secret to soaring on an engine-powered glider

The latest craze that's literally taking off is paramotoring. These powered paragliders are the cheapest and most compact form of flying, offering mere mortals the chance to explore the heavens where the sky is literally the limit!

It's remarkably simple: combining a backpack engine attached to a ram-air parafoil wing so you wear the engine itself. Variations include a tandem flown by two people and a trike, which has wheels attached to increase the device's ground adaptability. It is usually foot launched so there is no need for a long airfield or runway to ascend and with the powerful two or four-stroke propelled engine in tow, there is no reliance on wind assistance.

The engine can be stopped and restarted mid-air to easily change direction and altitude. The steering controls work via brake lines that increase or decrease the drag on each side of the wing. But perhaps its most appealing feature is the low carbon footprint, with minimal emissions coming from a paramotor. Costing between £3,500 and £12,000 ($5,900 and $20,200) each when brought from a constructor, many people also make their own and combine it with a second-hand paraglider wing. The pilots must also wear the appropriate safety gear including a flying suit, boots and a helmet.

In many countries paramotoring does not require a special licence, but pilots must learn and obey airspace regulations in order to avoid commercial airline flight paths.

Paramotors give the pilot an almost-unique sensation of free flight

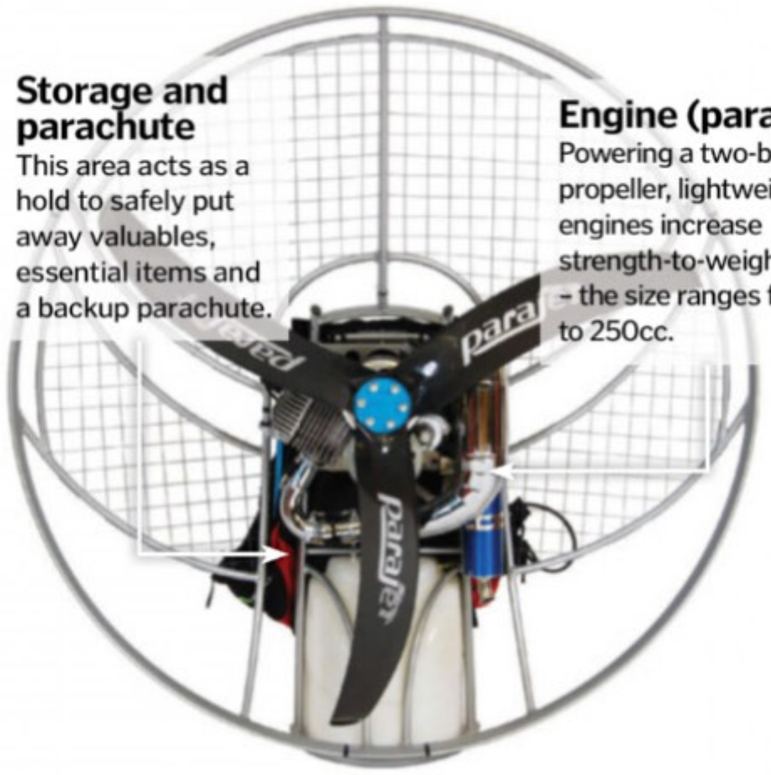
The SkyRunner

UK-based Parajet International is designing a paramotor-vehicle hybrid known as the SkyRunner. Designed to be all-terrain, it has been described as the 'ultimate recreational sports vehicle.' The first prototype emerged in 2009 when a design of attaching a paraglider to a buggy appeared. Through continual modifications it has morphed into its current incarnation.

The SkyRunner is a lightweight, high-strength construction intended to tackle demanding landscapes and be road legal. As well as its impressive specs, the vehicle takes the pilot's comfort seriously with new paraglider wing technology, which absorbs turbulence, and a flywheel design that counters uncomfortable engine vibration without affecting performance.

Anatomy of a paramotor

The technology, aerodynamics and safety features explained



Storage and parachute
This area acts as a hold to safely put away valuables, essential items and a backup parachute.

Engine (paramotor)
Powering a two-blade propeller, lightweight engines increase strength-to-weight ratio – the size ranges from 50cc to 250cc.

Seatboard
Paramotoring is often done in a seated position to lessen fatigue and new versions are self-deployable for easier landing.

Pivot arms
Locks your arms into the mechanism and allows you to fly safely and comfortably.

Hangpoints
These can be placed in a high or low position. The first restricts movement and is for beginners while the second feels more like free flight and is for expert flyers.

Harness
Using air-mesh tech, this straps the body tight onto the paramotor and acts as a 'backpack' giving the pilot ideal weight distribution for flight.

© SkyRunner\Nick Wilson Photography: Parajet

"Electric circuits hidden underneath the cushion in seats means even greater adjustability is possible"

In the driver's seat

How the seats in your vehicle are designed to provide the utmost in safety as well as comfort

The seats in your vehicle have come a long way in terms of development since the car's early days. From humble beginnings as merely a bench running parallel with the dashboard, seats have since become an individual focal point of comfort and safety, customised for each occupant of a car, with manual operation ensuring adjustability of the base, lumbar and headrest supports. Between the metal frame and durable cushion fabric in a seat you'll find an abundance of ergonomically moulded foam specifically shaped to enable a human being to sit comfortably upright.

But that's not all. Numerous electric circuits hidden underneath this ergonomic cushion in seats mean even greater adjustability is possible. Seats can now be electrically adjusted in up to 18 different ways at the push of a button, providing greater support than ever before. These adjustments can include side bolsters, for example, which feature cushioned pads on small arms underneath the fabric. They can move in and out to provide good lateral support for the occupant when the car is cornering.

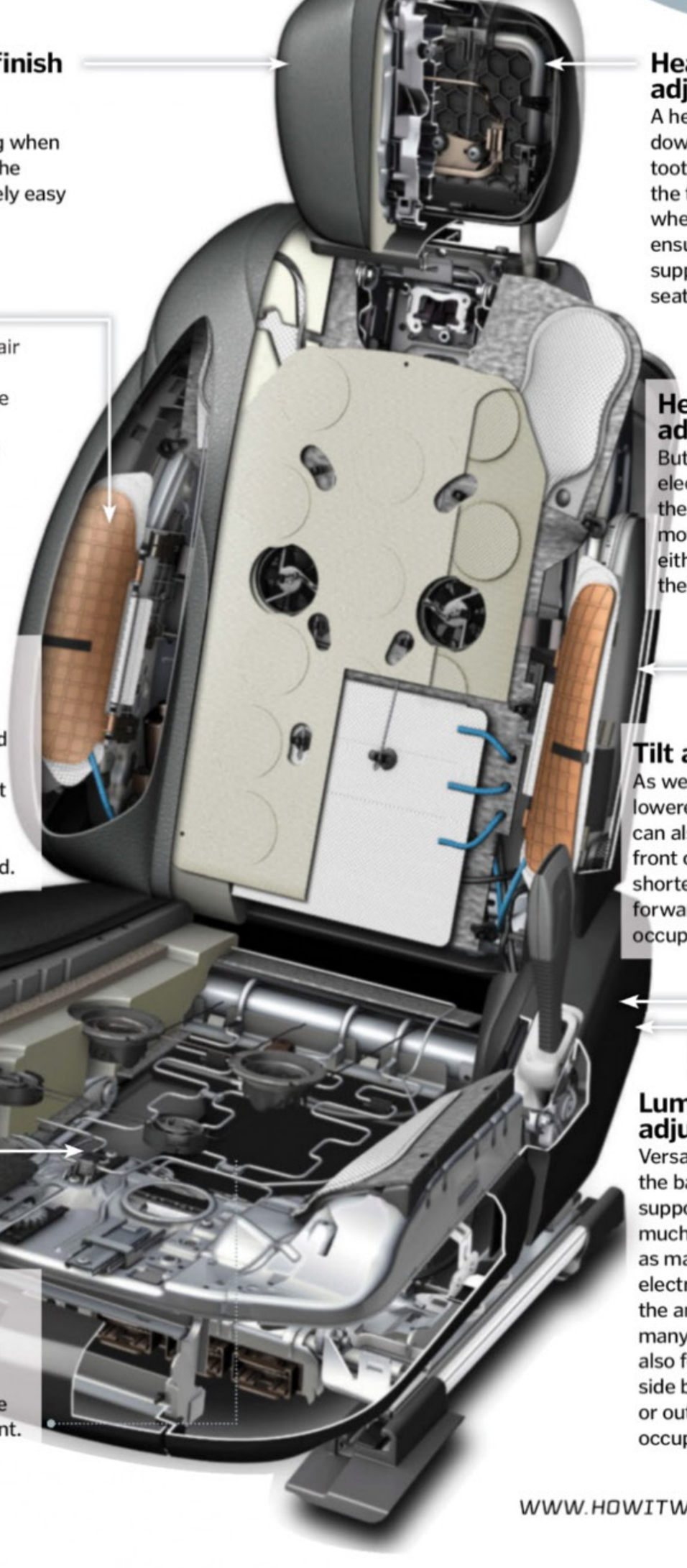
Many more exotic car manufacturers use seats that have evolved even further, with heated seats commonplace in executive saloons and sports cars. These work thanks to a heating coil hidden in the seat that gets hot under an electrical current. Similarly, vibrating elements in chairs can provide a massage effect, should they wish.

Seats can also house music speakers and television screens in the headrests, though be warned: the more electric circuits and hardware fitted to a seat, the heavier your car will become, which will have an adverse effect on your fuel economy.

However, there's one final – and absolutely vital – feature stowed away that can save your life: air bags. These deploy outward to protect the driver from colliding with the B-pillar in a side impact. Most modern car seats have been designed to be the perfect marriage of safety and comfort.

Driver's seat dissected

Go inside a Mercedes S-Class driver's seat to uncover today's vehicle technology



Cloth/leather finish
These are durable materials that can withstand stretching when an occupant sits in the seat, and are relatively easy to keep clean.

Air bags
Some seats even have air bags fitted to them, usually found in the side of the seat to protect from a side impact to a car's B-pillar.

Cushioned base
Foam padding is strategically placed at the base of the seat and in the upright back to ensure an ergonomic fit for the occupant, also helping to soften the vibrations from the road.

Heat
An electrical current passes through several wire coils in the seat, heating them to provide warmth for the occupant.

Head height adjustment
A headrest moves up and down on a slightly toothed aluminium rail at the top of the backrest, where clips lock to ensure the perfect support height for the seat's occupant.

Height adjustment
Buttons on the side can electrically raise or lower the aluminium subframe, moving the whole seat either up or down to suit the occupant.

Tilt adjustment
As well as being raised or lowered, the subframe can also be tilted at the front or rear, helping a shorter occupant to sit forward, or a larger occupant to sit back.

Lumbar adjustment
Versatile adjustment of the backrest helps support the spine as much as possible. As well as manually or electronically adjusting the angle of the backrest, many modern day seats also feature adjustable side bolsters that move in or out to 'hug' the occupant in the seat.

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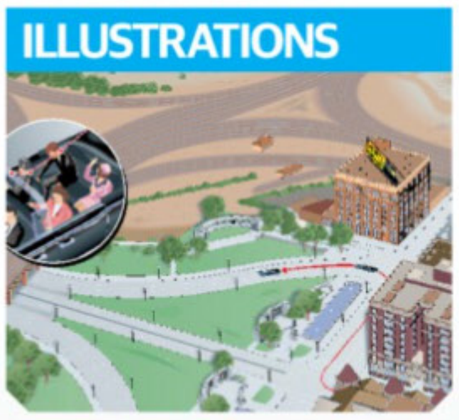

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Inside the ultimate RV

This camper van has everything you need for an adventure

Most fathers want to show their children the world, but American inventor Bran Ferren took that dream a step further. He designed his camper van with an office, kitchen and bedroom, and even a pop-up tent on the roof for his four-year-old daughter Kira, who the KiraVan is named after.

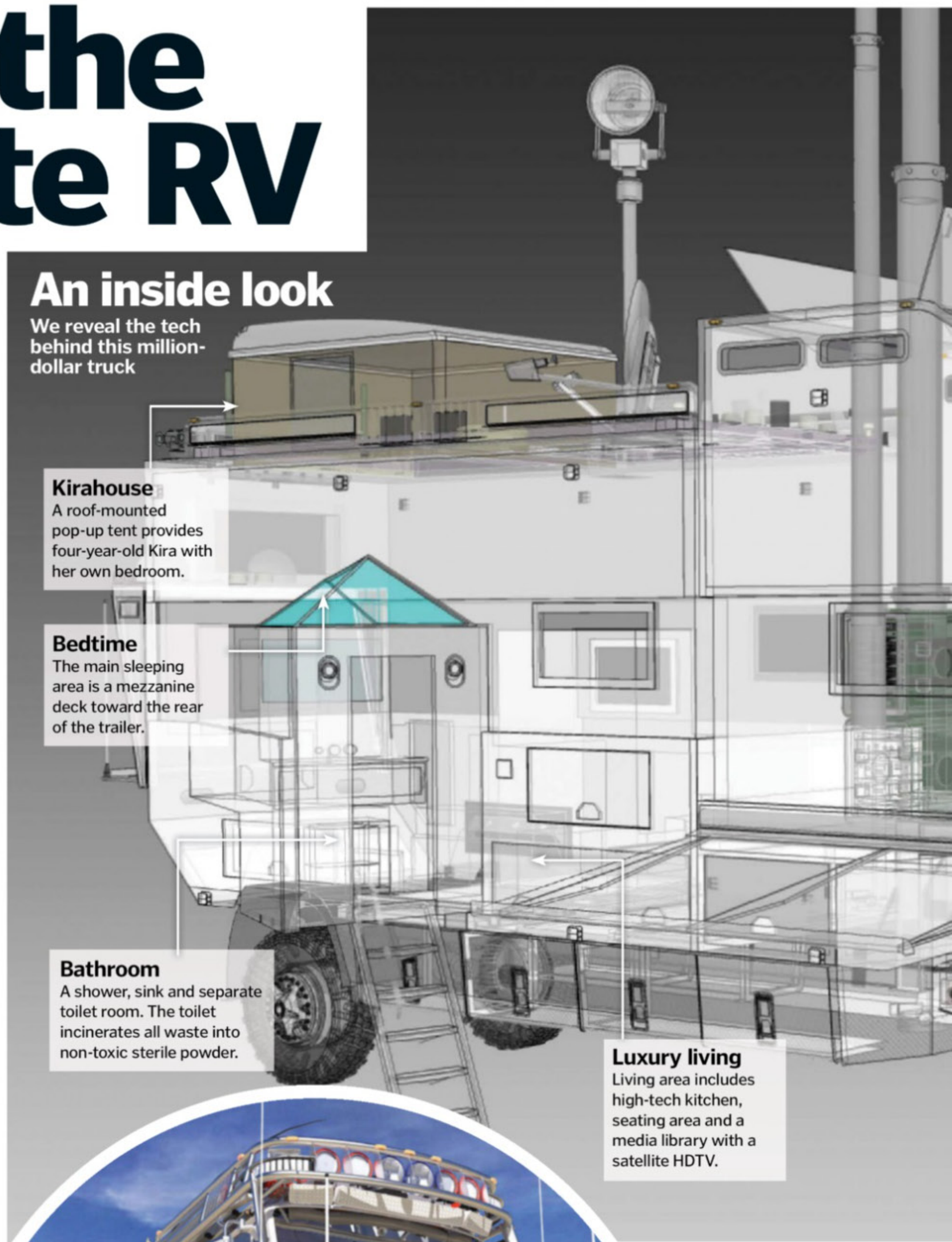
It can travel 3,220 kilometres (2,000 miles) without resupply, powered by a modified Mercedes-Benz Unimog chassis, renowned for their reliability and cross-country performance. The diesel engine has been fitted with sensors to monitor temperature, vibration and torque so the driver has a constant picture of how the engine is performing. A heated fuel tank ensures the diesel won't freeze in low temperatures and also filters the diesel so only clean, pure fuel is fed to the engine for optimum performance.

It's comfortable for the driver too, thanks to the special vibration-reducing chair. The cockpit is surrounded by screens that display road conditions, GPS mapping and weather details. Drones even fly ahead to check on traffic. At 15.8 metres (52 feet) long and over three metres (10 feet) high, the KiraVan uses a tractor-trailer design like an articulated lorry. This gives the trailer off-roading capability by adding a hydrostatic drive system, enabling six-wheel drive at speeds up to 40km/h (25mph). Hydrostatic drives use pressurised fluid to drive a motor, negating the need for a drive shaft, which would restrict movement between the two units.

The insulated trailer unit has a bedroom, office, kitchen, living quarters and an eco-friendly bathroom. Slide-out compartments and a motorised rising roof section doubles the internal living space when deployed. You'll find home comforts such as a media library, flat-screen TV and seating area, and enough supplies for to last three people three weeks before having to restock.

An inside look

We reveal the tech behind this million-dollar truck



Kirahouse
A roof-mounted pop-up tent provides four-year-old Kira with her own bedroom.

Bedtime
The main sleeping area is a mezzanine deck toward the rear of the trailer.

Bathroom
A shower, sink and separate toilet room. The toilet incinerates all waste into non-toxic sterile powder.

Luxury living
Living area includes high-tech kitchen, seating area and a media library with a satellite HDTV.

KEY DATES

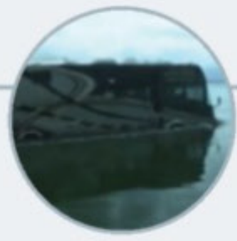
DRIVE BACK IN TIME

1914
Charles Kellogg builds the world's first motorhome. It has living quarters made from a single redwood tree.

1969
A modified Ford RV 'Debbie' is driven in the Baja 1000 race. It finishes last but is the world's first off-road RV.

2001
KiraVan's predecessor, the Unimog-based MaxiMog, is built for Bran Ferren in Germany.

2004
Terrawind, the world's first (and last) amphibious motorhome, takes to the water in the Unites States.



2010
The world's biggest off-road RV, an eight-wheel drive, 30-ton Desert Challenger is built in Austria.

DID YOU KNOW? *In the Gulf War, the British SAS used the Unimogs, using them as 'motherships' to resupply Land Rover patrols*

Sunshine
Roof mounted solar panels are attached to a bank of batteries, combined with an alternator to keep the van powered.

Engine power
Engine monitors help the driver to keep an eye on engine performance.

SOS
A rescue beacon can transmit a distress signal if the KiraVan is stranded.

Info screens
Dashboard screens linked to on-board cameras give the driver a view of the KiraVan's surroundings.

Software
While many displays are based on those used in aircraft, all software is unique to the KiraVan and designed for land use.

Communications
Various radios ranging from CB to satellite ensure the KiraVan keeps in contact with the rest of the world.

Flexibility
Two units connected with an off-road fifth wheel, which is more flexible than a road version.

Power
The tractor unit is powered by a 260hp Mercedes turbo-diesel engine.

Custom suspension
Standard Unimog suspension has been replaced with nitrogen-hydraulic suspension, allowing for variable ride height.

Tyre tech
Tyres can be inflated and deflated from the cockpit to give better traction on soft ground. This is a system standard in military Humvees.

©Rex Features; KiraVan

WWI dogfights

How fighter aircraft engaged in epic sky battles to win air supremacy

The plane hadn't long been invented when it was pulled into war. At first they were used as scouting devices, spying on the movements of enemy troops, but as technology progressed, so did their role. As rival forces came into conflict in the First World War, fighters would try to seize an advantage for bombing raids and aerial support. As a result, so-called dogfights would often break out between the opposing sides. There were two main ways to gain an advantage in this type of warfare: have the best modern tech or be the greatest pilot around.

Weaponry was initially very primitive in dogfights, with grenades dropped from the planes, but this was soon replaced by the first aircraft gun, which was a multi-directional turret on the plane. They were later improved to rapid-fire machine guns shooting through the propeller, developed by French pilot Roland Garros who added a steel plate to stop the bullets striking the blades. This was developed further by German Anton Fokker who introduced an interrupter gear that allowed the rounds to fire in between the propeller's revolutions. Soon after came the invention of tracer ammunition, which aided the accuracy of fire.

As well as having top-notch firearms, expert flying ability was also required. The British opened the Central Flying School in 1912 and taught advanced air combat manoeuvres such as barrel rolls, dives and spirals to outwit the enemy. For example, the defensive split was when a pair of fighters with the enemy on their tail would turn rapidly and place themselves behind their attackers, gaining the upper hand. Now the roles were reversed and the opponent would be in the crosshairs.

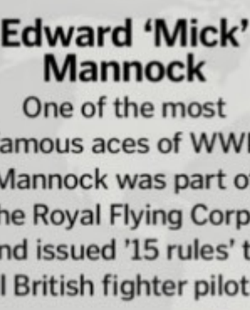
The first-ever dogfight was an engagement involving British Royal Flying Corps Lieutenant Norman Spratt, who downed a German fighter on 28 August 1914. It was dubbed 'dogfighting' because of the way the planes would chase each other in tight circles so the enemy aircraft struggled to fire back.

Bloody April

The war on the Western Front was still raging in April 1917. In an attempt to gain an upper hand in the stalemate, Allied forces advanced toward the French city of Arras. To do this effectively, they would have to rely on sufficient air support. The Fokker E.I and the German Albatros D.II and D.III had bettered the British Airco DH.2 and the Factory F.E.8 in what was known as the 'Fokker Scourge.' 'Bloody April' saw the Brits' shortcomings magnified, as over 200 aircraft were lost compared to 66 German ones. The German air force was led by the 'Red Baron', Manfred von Richthofen, but the British were to have the last laugh. Despite heavy losses, significant gains were made by the Allies who completed many recon missions and prevented German bombers from hitting important targets. Subsequently, with the introduction of the Sopwith Pup and Camels, the German forces had to operate much more defensively from then on out and the Battle of Arras became a turning point in the war.

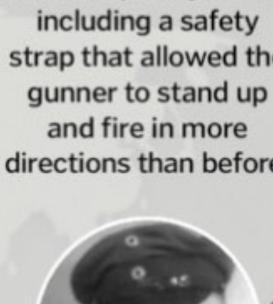
Top 5 flying aces

The pilots who personified the dogfight



Edward 'Mick' Mannock
One of the most famous aces of WWI, Mannock was part of the Royal Flying Corps and issued '15 rules' to all British fighter pilots.

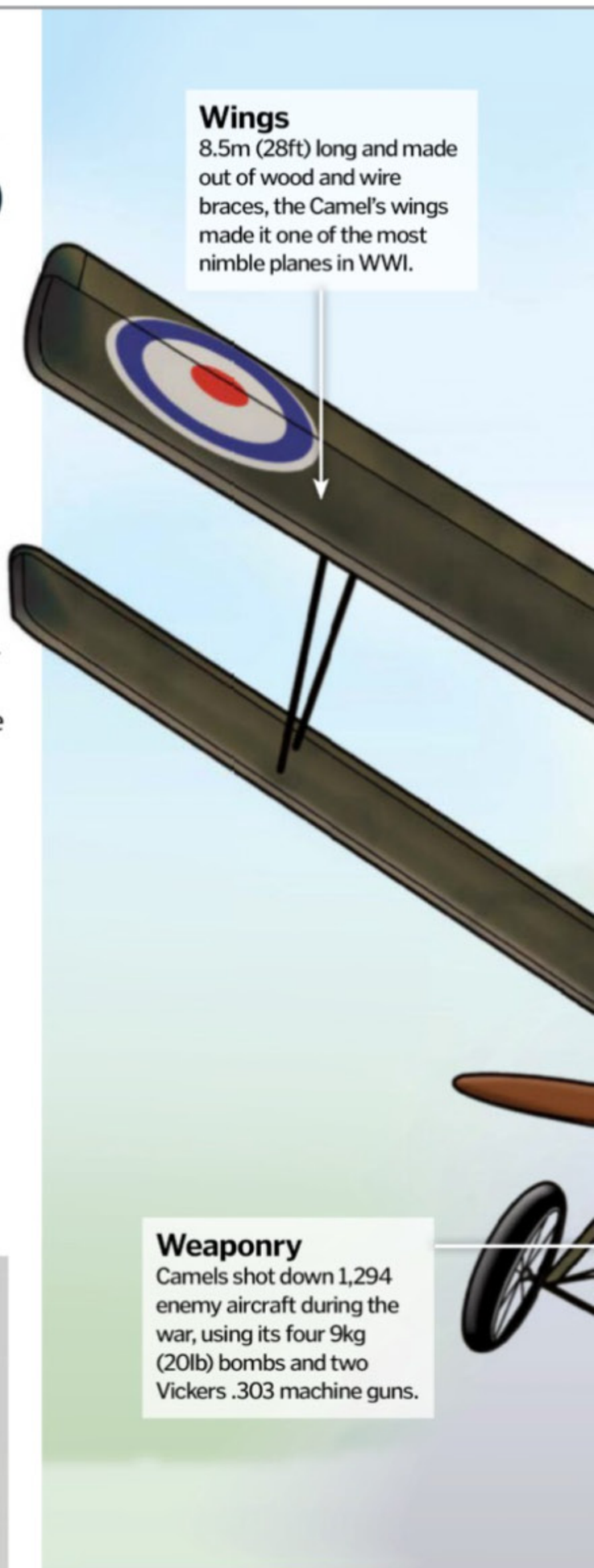
Petr Nesterov
Along with Frenchman Adolphe Pégoud, Nesterov was described as the first-ever pilot to complete the 'loop the loop' manoeuvre.



Louis Strange
He developed many new weapon systems, including a safety strap that allowed the gunner to stand up and fire in more directions than before.

Albert Ball
Downing 45 planes in WWI, Ball was Britain's top fighter ace and was posthumously awarded the Victoria Cross.

Manfred von Richthofen
Nicknamed 'The Red Baron', The German ace reportedly shot down 88 Allied aircraft in WWI despite not training to be a pilot at the start of the war.



Wings
8.5m (28ft) long and made out of wood and wire braces, the Camel's wings made it one of the most nimble planes in WWI.

Weaponry
Camels shot down 1,294 enemy aircraft during the war, using its four 9kg (20lb) bombs and two Vickers .303 machine guns.

The statistics...

Sopwith Camel

Total built: 5,490
Entered service: 1917
Length: 5.7m (18.8ft)
Height: 2.6m (8.5ft)
Top speed: 185km/h (115mph)
Range: 485km (300mi)

Types of fighter

The different roles of fighter planes in WWI

RECORD BREAKERS

BIGGEST VICTORY

86

THE BLACK FLIGHT DIVISION

In the summer of 1917, this Canadian division painted their Sopwith Triplanes black and shot down 86 enemy planes in the German JG 1 unit while only losing three of their own fighters.

DID YOU KNOW? *During WWI, a British pilot's training lasted a measly 30 hours*

Start of the descent
As the manoeuvre begins, the pilot purposely stalls the aircraft and enters a state of free fall.

Choice of direction
The first wing to stall falls first and the pilot fully engages the rudder to allow the descent.

The spin
The rotation begins and eventually reaches a set rate as the vertical drop continues on.

Recovery
When the procedure finishes, the rudder is placed back into neutral and then forward to regain forward momentum.

Back to normal
The engine and flight are back to normal as the manoeuvre is now completed.

Markings
Rather than use union flags, the British Royal Flying Corps used a roundel to mark planes, which is still used today.

Engine
Using a Clerget 9B rotary engine to power the flight, the Camel could generate 96.9kW (130hp) of output.

Propeller
One man could be both pilot and gunner as the twin guns shot through the propeller using a synchronisation gear.

Interceptor

Key aircraft: Sopwith Pup

This particular type of aircraft was intended specifically to destroy bombers to protect key areas and battlegrounds.

Night fighter

Key aircraft: B.E.2

As Zeppelin raids ravaged cities, Britain responded with night fighters who used incendiary bullets to attack the airships.

Day fighter

Key aircraft: DFW C.V

Not as technical as the night fighter, the day fighter relied on being swift and nimble for recon and dogfighting missions.

Fighter bomber

Key aircraft: Sopwith Salamander

Near the end of WWI some planes had the dual role of maintaining air supremacy and bombing ground targets.

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TRILOBITE-SIZED

20,000 DIFFERENT SPECIES

5,000 GENERA
10 **ORDERS**

150 FAMILIES

70cm LARGEST FOUND

1mm SMALLEST FOUND

DID YOU KNOW? *Trilobites' eyes were made of crystal – mineral calcite (calcium carbonate). Talk about a stony gaze!*

How to make bells

The process of chime creation explained

Originally a basic percussion instrument created in China as early as 3,000 BCE, bells now come in all sorts of shapes and sizes. They are made in a foundry (a metal casting factory), where the bell's design must be calculated precisely in order to strike the right pitch.

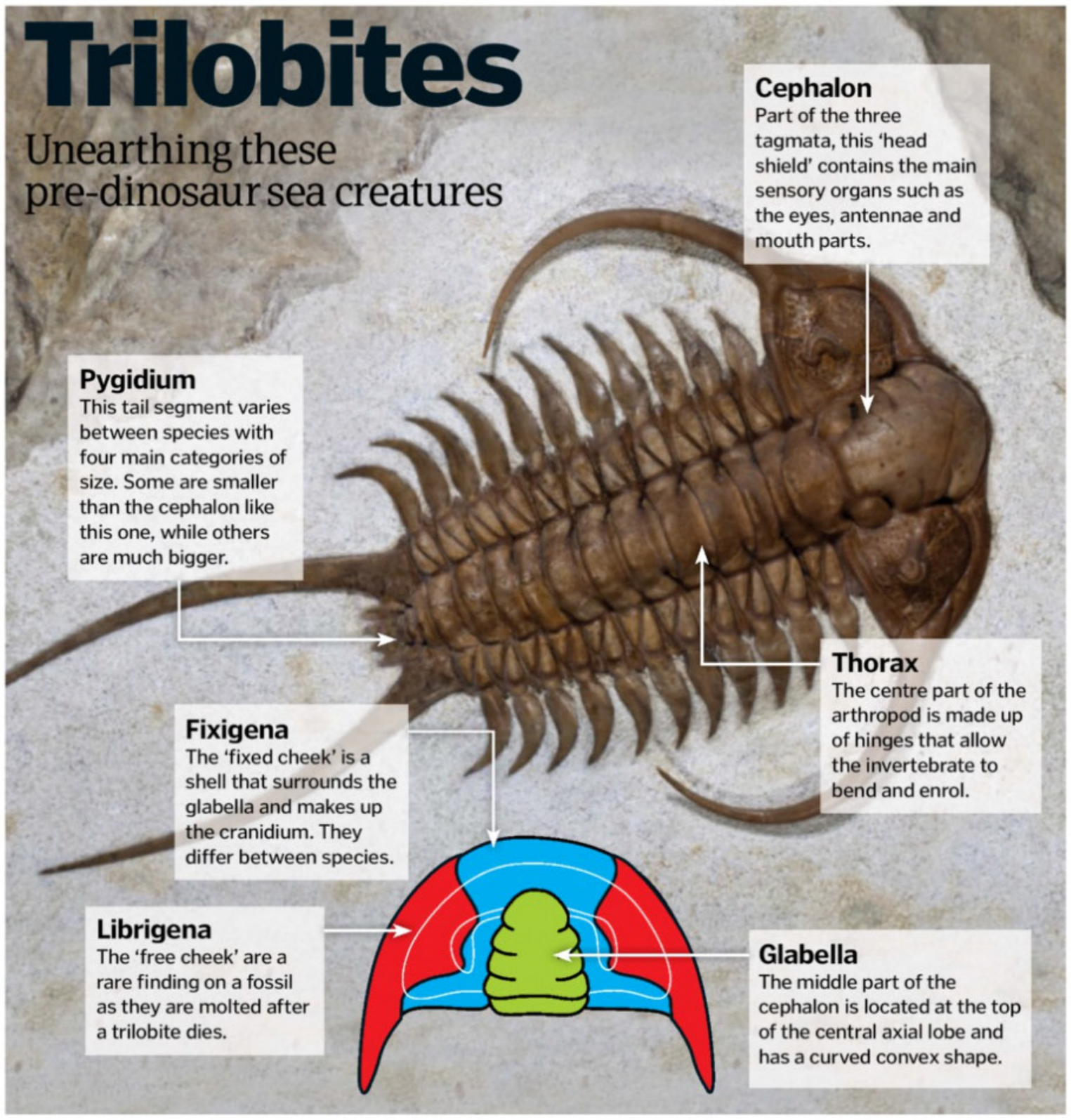
First, the bell pattern is cut out in two wooden templates called strickle boards as the basis for the moulds. Two moulds are made: inside (core) and outside (cope). They are made out of clay and sand to make a material known as loam. The loam core and cope are then clamped together to make the mould case and a runner box is used to act as a funnel for liquid metal to be added. The furnace is heated up to 1,150 degrees Celsius (2,102 degrees Fahrenheit), which is above the melting point of the copper and tin used in the bell. Once this process is finished, the metal's impurities or 'slag' have to be removed and the bell can now be cast. The liquid metal is poured into the mould case and takes about two days to cool into place.

All that's left to do now is to skirt (smooth) the edges to ensure the aesthetic design is correct and tune it so the desired sound will be produced. Every bell can produce five chime tones: the octave, the fifth, the minor third, the prime and the hum. They were originally measured by a tuning fork but now a computer is used.

The most famous bell foundry is in Whitechapel, London. It was established during the reign of Elizabeth I in 1570, making it Britain's oldest manufacturing company. It constructed the Liberty Bell in 1752 and Big Ben in 1858 and is still in business today.

Trilobites

Unearthing these pre-dinosaur sea creatures



They look like something out of Ridley Scott's *Alien*, but trilobites existed long before 1979. Exclusively marine animals, they swam in the Earth's oceans around 520 million years ago. Lobsters and crabs count them as their distant relatives because, like them, trilobites were anthropods (invertebrates) that scuttled around inside armoured shells.

These strange sea creatures are believed to have existed from the Cambrian Period all the way to the Permian Period, around 250 million years ago. Both of these periods were within the Paleozoic Era, which oversaw great change on Earth as huge supercontinents divided and more complex animals and ecosystems evolved in what is known as 'the Cambrian explosion.'

Trilobites were one of these animals and became extremely widespread in this era. Their appearance varied with some being blind while others had eyes on stalks. We understand that they were predators whose main diet consisted of plankton. They were long extinct before dinosaurs roamed the Earth and are the most diverse class of extinct organisms available to contemporary palaeontology research.

Trilobite fossils are important in understanding Earth's development. They back up the theory of punctuated equilibrium, which suggests evolutionary change happens in short periods of time and is linked to events like the division of continents. For instance, trilobites have been found in the Pacific and Atlantic Oceans, supporting the idea that all of Earth's continents were once joined together but have drifted apart over millions of years.

Trilobites died out at the end of the Permian Era in a mass event known as the Permian extinction, when global temperatures rose as huge volcanic eruptions released methane and caused an intense greenhouse effect. Over ninety per cent of marine life died and life on Earth only began to recover during the Triassic Period, with the dawn of the dinosaurs.

"Gaudí himself was not concerned with the slow progress and famously said: 'My client is not in a hurry'"

Sagrada Família

Why is Spain's most iconic church still not finished after 130 years?

The statistics...

Sagrada Família

Length: 90m
Height: 170m
Area: 4,500m2
Spires: 18
Seats: 8,000
Visitors: 2 million per year

Sagrada Família is not a cathedral, because it doesn't have a bishop. But it was intended from the outset to be cathedral *sized*. The design calls for 18 spires, seven side chapels and three grand facades. The raised choir space has room for 1,100 singers and the six separate organs will be playable from a central console to give a single instrument with 8,000 pipes. When it is completed, Sagrada Família will be the tallest church building in the world. But the extraordinary gingerbread architecture has divided opinion from the very beginning. George Orwell called it "one of the most hideous buildings in the world."

The church was commissioned by a pious bookseller called Josep Maria Bocabella and the first stone was laid in 1882. The Spanish architect Antoni Gaudí took charge of the design a year later. Because it has never received money from government or the Catholic Church, the pace of building work has always depended on the money that could be raised privately. During Gaudí's lifetime only the crypt, the apse above it and one of the spires had been completed. Gaudí himself was not concerned with the slow progress and famously said: "My client is not in a hurry."

Today, Sagrada Família is a UNESCO World Heritage Site and one of the most popular tourist attractions in Spain. The admission charge and other fund raising generates more than €25 million (£20 million), which now allows an extraordinary level of craftsmanship and detail on the construction. But Sagrada Família is not a museum piece. Modern construction techniques and materials are used wherever possible, including reinforced concrete, computer-aided design and 3D-printing of plaster decorations. Even though Antoni Gaudí lies buried in the crypt at Sagrada Família, a team of engineers, artists and craftsmen remain dedicated to finishing the work he began.

Construction ahead

The road toward completion of the Sagrada Família has been long and arduous – and there is still some way to go...

1882
Work begins under the architect Francisco de Paula del Villar y Lozano. It is originally designed as a Gothic revival church.

1883
Gaudí takes over after the original architect disagrees with the project promoter and resigns.

1894
More than a decade later, the crypt and apse (the semi-circular area behind the altar) are the first parts of the church to be finished.

1926
Gaudí dies, aged 74. He has spent over 42 years working on Sagrada Família, but more than 75 per cent of it is still unbuilt.

1. LONG

Ryugyong Hotel, North Korea

Begun in 1987, it took 20 years to finish the exterior of this 105-storey hotel and it still hasn't opened.

2. LONGER

Ajuda National Palace, Portugal

The official residence of the Portuguese royal family was begun in 1796 but wars and a revolution stalled construction indefinitely.

3. LONGEST

Siena Cathedral, Italy

A massive extension to this ancient cathedral was commenced in 1339 but was halted by the Black Death and never finished.

DID YOU KNOW? *The Jesus tower will be 1m (3.3ft) lower than Montjuïc Hill – Gaudí believed his creation should not exceed God's*

Inspiring architecture

Every tower and entrance represents a different part of the *New Testament*

Jesus tower
Work on this tower has not even started, but it will eventually be the tallest of the spires at 170m (558ft).

Vaulted roof (not shown)
The ingenious double roof space is angled so that light from the side windows is directed down into the church below.

The Mary tower
Currently missing the top half of the spire, this tower will be 123m (404ft) high when finally completed.

Apostle towers (not shown)
One for each of Jesus' 12 apostles. The four at the south end represent Andrew, Peter, Paul and James the Greater.

Evangelist towers
These will be topped with a statue to represent each of the four canonical gospel writers: Matthew, Mark, Luke and John.

Nativity facade
The earliest facade and the only one with sculptures designed by Gaudí himself. His original vision called for all the statues to be brilliantly painted.

Sacristy
A private chamber where the priest prepares for the service. There is another on the opposite side.

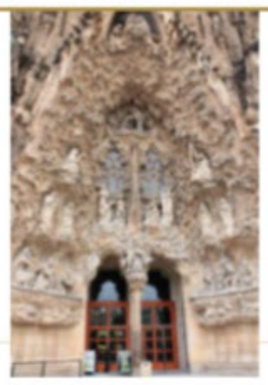
Gloria facade
Construction of this facade only began in 2002. It represents humanity's ascension to heaven and will eventually be the grandest of the three facades.

Passion facade
The three facades depict different parts of Christ's story. The Passion facade shows his crucifixion and is more austere.

Modern interior

Sagrada Família uses elaborate branching internal columns to direct all the weight of the building downward. This allows it to have a durable stone roof, instead of the traditional wooden design, and avoids the need for flying buttresses (which Gaudí called 'crutches') to prop up the walls on the outside. The shapes of the columns are modelled on twisting plant stems. At their base, each column begins as a polygon or star, and the number of sides or points doubles at intervals as the columns rise, until they all become cylinders at the top. The stained glass windows are another deliberate departure from traditional Catholic church design. Normally, the panes at the bottom are in lighter colours than those near the top, to give even illumination. At Sagrada Família it's the other way around. The windows at the top of the central nave are completely clear, to flood the vaults with light.

1933
The Nativity facade is finished. It is intended to set the standard for the structure and decoration of the rest of the church.



1936
The Civil War interrupts construction. Catalan anarchists burn down Gaudí's workshop. His models are destroyed.

1978
The four towers of the Passion facade are built and work starts on the facade itself.

1992
The Barcelona Olympics speed up funding by bringing in millions of extra tourists to the city.

2010
The roof of the central nave is completed and Pope Benedict XVI consecrates the basilica so it can be used for religious services at last.

2026
The aim is to have the church completed in time for the centenary of Gaudí's death – 144 years after work began.

BRAIN DUMP

Because enquiring minds need to know...

Want answers?

Send your questions to...

How It Works magazine @HowItWorksmag

howitworks@imagine-publishing.co.uk

MEET THE EXPERTS

Who's answering your questions this month?

Luis Villazon

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

Mike Simpson

Michael has a doctorate in moss and teaching awards from the University of Alberta. While not working as a botanist or environmental consultant, he writes for magazines and online media.

Alexandra Cheung

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

Rik Sargent

Rik is a science communicator who has a background in physics and public engagement, having worked at the Institute of Physics. Pastimes include experimenting with sound, baking cakes as well as the complex science of brewing coffee.

Shanna Freeman

Shanna describes herself as somebody who knows a little bit about a lot of different things, which comes of writing about everything from space travel to how cheese is made. Her job comes in very handy for quizzes!

How do astronauts prepare for a spacewalk?

Shelley Waltham

■ Preparing for a spacewalk takes about a day. Before astronauts step out, they need to go through a process called decompression. As there's no air pressure in space, spacesuits are pressurised at about a third of the air pressure inside the spacecraft. This both protects the astronauts and allows them to manoeuvre outside. Before they don the suit, the air pressure in the cabin is lowered and the oxygen levels slightly raised. If an astronaut just stepped outside, he could suffer serious illness or even death due to decompression sickness. Also called 'the bends', this occurs when nitrogen bubbles expand and quickly escape in the bloodstream due to a rapid decrease in air pressure. The decompression process allows the nitrogen to dissipate. A few hours before the spacewalk, the astronauts begin pre-breathing pure oxygen, which is what they'll breathe inside their spacesuits. They step into the airlock, put on their full suit, and the pressure inside slowly decreases until it's time to step out for their spacewalk. **SF**

Do animals get sunburn?

Stan Innes

Some do. Pigs, for example, have sparse hair and will sunburn easily. Wild pigs spend most of their time in forests so it isn't a problem for them but elephants and rhinos don't always have somewhere to shelter and can get sunburned. That's why they wallow in watering holes to give their skin a protective coat of mud. Hippos secrete their own sunblock, in the form of a pink liquid that oozes out of the pores in their skin. Sperm whales can spend hours resting and breathing at the surface and researchers in 2009 found that most of them had sunburn. **LV**

What puts the 'super' in superfood?

Fran Beckmann

This term is used to describe foods with high concentrations of nutrients, but the science behind their health benefits is not clear-cut. There is no scientific definition of superfoods and many dieticians feel the term is misleading. Many of them aren't really superior to their counterparts. Kale is often labelled a superfood due to its high levels of vitamin A, K and calcium – yet other dark leafy vegetables such as spinach contain almost as much. Other superfoods such as blueberries boast high anti-oxidant counts, but not all research supports the claim that these are good for our health. Also, the marketing of superfoods may lead consumers to believe that these 'miracle foods' can compensate for the damage done by unhealthy eating. Instead, dieticians suggest that following a balanced diet rich in fruit and vegetables is more beneficial than focusing on individual foods. **AC**

COOL FACTS

Your brain actually has a favourite part of the day

Everyone is different, but most people's brains perform best at the end of the morning. Body temperature increases after we wake up, leading to a peak in concentration and memory from around 11am to noon.

Do our eyes grow?

Christopher O'Hennessey

Contrary to popular myth, our eyes do grow during infancy and childhood. At birth, a baby's eyes average 16 millimetres (0.63 inches) in diameter, growing rapidly to about 23 millimetres (0.91 inches) by the age of three. When we hit puberty, our eyes reach their adult size, measuring 24 millimetres (0.94 inches) from front to back. Like their heads and brains, babies' eyes grow far less than other body parts. While eyes increase in size by about 50 per cent, feet typically grow to triple their original size during childhood, for example. These disproportionately large eyes are one reason why we find babies so cute. **AC**

Was T-rex the biggest carnivorous dinosaur?

Lauren Dafis

Judging the size of dinosaurs is difficult based on the limited evidence available from the fossil record. Remains uncovered in North Africa, however, suggest that the beast that took on *King Kong* and brought down *Jurassic Park* would have been dwarfed by Spinosaurus aegyptiacus. This fish-eating theropod, which lived about 100 million years ago during the Cretaceous Period, might have weighed as much as 21 tons, or more than twice the weight of a Tyrannosaurus rex. With an elongated head like a crocodile's, Spinosaurus could also have reached 18 metres (59 feet) in length. That is about six metres (20 feet) longer than the estimated span of a typical 'tyrant lizard.' Other contenders for the title of biggest prehistoric meat eater are Giganotosaurus carolinii and Carcharodontosaurus saharicus. Extrapolations based on fossilised skull dimensions put these giants at up to 13 metres (43 feet) in length with a weight approaching 14 tons, about as heavy as a school bus. **MS**

What causes blood moons?

Callum MacDonald

All total lunar eclipses can be 'blood moons.' Filtering and refraction of sunlight entering the Earth's atmosphere can cause the full Moon to appear anywhere from coppery to a deep 'bloody' red. In 2014 and 2015, we will see a lunar tetrad, or four successive total lunar eclipses separated by six lunar months (six full Moons). The first occurred on 15 April 2014 and was visible across most of North America. The next will occur on 8 October this year and in 2015 we can witness them twice, on 4 April and 28 September. **SF**

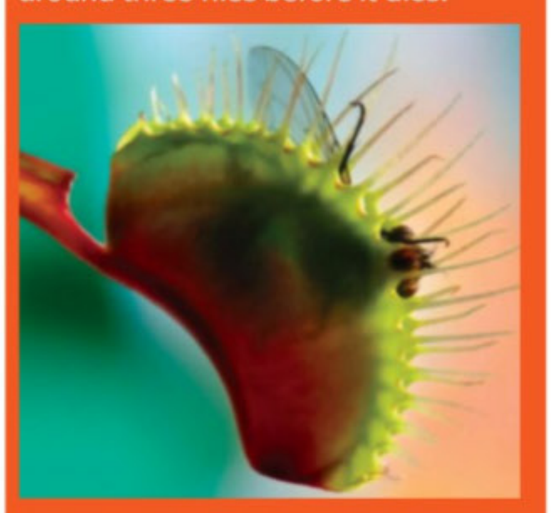
Can water alone cure diseases? Find out on page 82

BRAIN DUMP

COOL FACTS

Venus flytraps can only eat a limited amount of flies

This number depends on the size of the plant and how many working traps it produces. Some estimates suggest that a leaf can only trap around three flies before it dies.



The Pacific hosts the biggest tectonic plate

The largest tectonic plate is the Pacific plate, covering 103mn km² (40mn mi²). The gigantic layer of the Earth's crust reaches from North America to as far as New Zealand.

The cannon was made in China

Cannons – like gunpowder – were invented in China during the late Song Dynasty, which lasted from 960 to 1279. One of its earliest iterations was a cast iron or bronze tube that shot lead balls.

For how long did Homo sapiens and Neanderthals live together?

Mei Gao

The latest research suggests our species coexisted with Neanderthals for almost 15,000 years, a much shorter period than was once thought. Neanderthals, our closest extinct relative, appeared in Europe 250,000 years ago and disappeared about 30,000 years ago. Homo sapiens emerged in Africa, spreading to Europe some 43,000 years ago. In some regions, the two species may therefore have coexisted for up to 15,000 years.

It is thought that Homo sapiens outlasted their Neanderthal relatives thanks to their more powerful brain capacity. **AC**

Is it true drinking water is a cure for certain illnesses?

Josh Walker

While drinking water is undoubtedly a necessary function for survival, there is no scientific evidence that drinking it will cure you of specific diseases. Perhaps the most extreme falsehood related to water therapy is that it can cure cancer, diabetes and asthma. This idea was popularised by Dr Fereydoon Batmanghelidj, who became convinced that water had miraculous healing properties while detained at Evin Prison in the 1979 Iranian Revolution, after he 'cured' a fellow inmate suffering from a chronic ulcer with two glasses of water. Rather than assuming it could be a coincidence and testing his theory within the confines of science, Dr Batmanghelidj reinforced his beliefs using only this anecdotal evidence, convincing a large number of people in the process, ultimately causing more harm than good. **RS**

Why is glass transparent?

Billy Rooke

Light travels through glass due to how its electrons are arranged. Electrons orbit an atom's nucleus at different energy levels. For an electron to move up a level, it must receive a packet of energy of the right size. When light strikes most solids, its photons excite the electrons, pushing them up to the next energy level, causing the light to be absorbed. In glass, however, the energy levels occupied by electrons are much farther apart. As a result, visible light photons don't have enough energy to excite the electrons. They travel straight through glass, making it transparent to visible light. **AC**

Do all bats use ultrasound?

Steven Hood

No. All of the mouse-sized microbats use ultrasound calls for echolocation but fruitbats and flying foxes (megabats) have lost this ability. Although we can't hear it, echolocation requires bats to scream at 130 decibels! That takes a lot of energy but the microbats are able to harness some of the muscular effort from their wingbeats to generate the air pressures needed for their calls. Megabats flap their wings too slowly for this to work and considering that flying is already more tiring for them because they are heavier, it makes echolocation too exhausting to be worth it. **LV**

How does anti-climb paint work?

Robyn Thompkins

Anti-climb paint is based on non-drying oil that keeps a surface slippery and greasy, preventing anyone from climbing something which has been coated in it. In addition, it will rub off onto clothes helping to identify intruders. As it is an extremely messy and oily substance, there are usually rules about the minimum height anti-climb paint can be used. Commonly it is applied from 2.4 metres (8 feet) above the ground and up, and is especially effective on walls and lampposts. The adhesive will work in hot and cold weather conditions alike and has a lifetime of around three years on average, before a fresh coat is needed. **RS**

Why is fire orange?

Pat Rosenberg

The colour of fire is determined by the chemical composition of the fuel and the temperature at which it is burning. We see fire because energy is given off in the form of light as well as heat. Fires are commonly hydrocarbons burning in the presence of oxygen, giving rise to fine soot particles that emit yellow light when they burn at around 1,000 degrees Celsius (1,832 degrees Fahrenheit). Some materials produce different-coloured flames when they burn, such as lithium and copper, which produce pink and green flames respectively. This is because the wavelength of emitted light for burning materials is characteristic of each element involved. **RS**

Will we be able to clone humans one day? Find out on page 84

BRAIN DUMP

Is there a giant reservoir of water in space?

Joe Bulger

■ Yes! In 2011, astronomers announced they had found the largest known reservoir of water in space in the form of water vapour. Located around a type of energetic active galactic nucleus (AGN) called a quasar that surrounds a black hole, the reservoir contains the equivalent of 140 trillion times the water in Earth's oceans. This quasar, called APM 08279+5255, spews as much energy as a thousand trillion Suns and its black hole is 20 billion times more massive than the Sun. The black hole 'eats' the dust and gas around it, and the gas includes water vapour. APM 08279+5255 is about 12 billion light-years away, which means the water reservoir has been there since our universe was just 1.8 billion years old. **SF**

COOL FACTS

The hardest wood on Earth is in Australia

The Australian Buloke is a species of ironwood. The wood from this tree is 57 per cent harder than ebony and seven and a half times harder than Douglas fir.

Which was worse: bubonic or pneumonic plague?

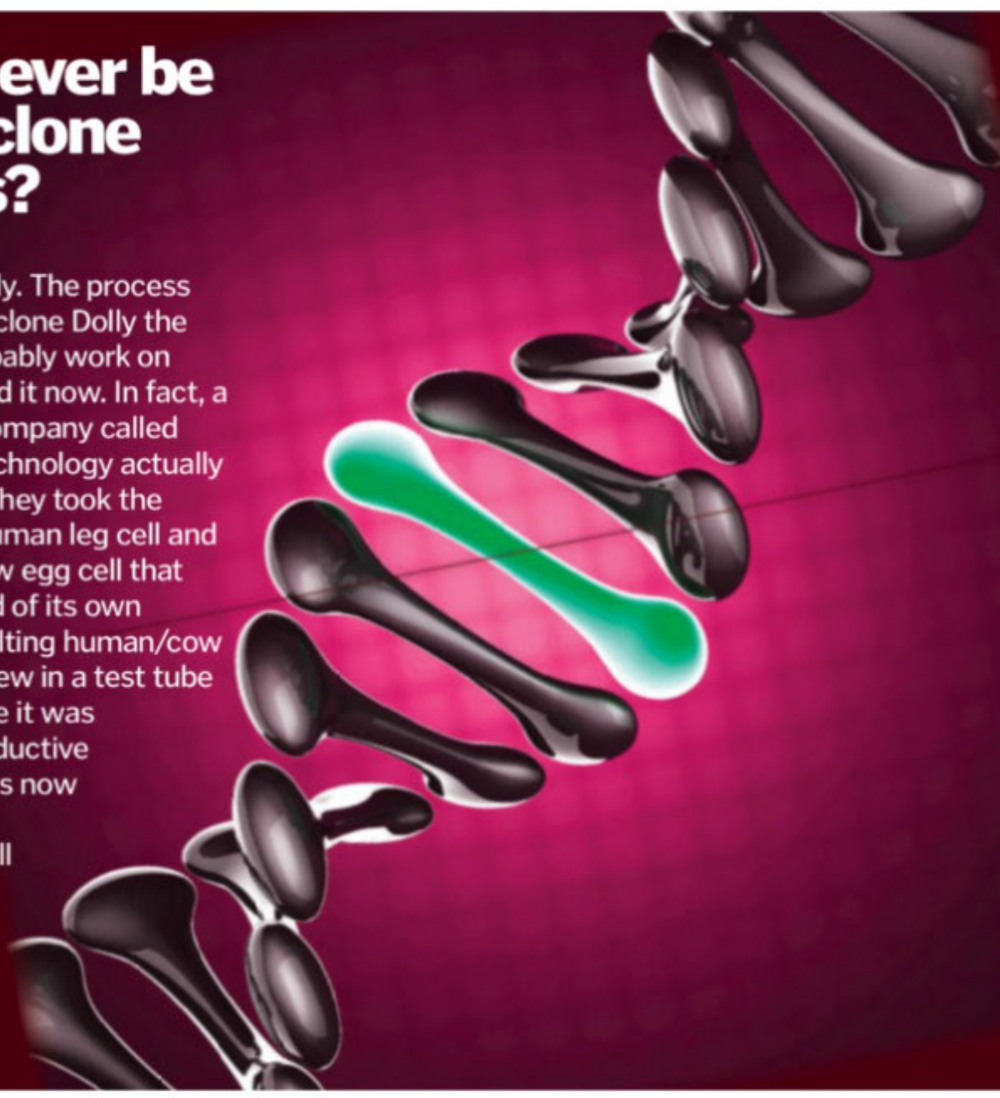
Beverley F

■ Both are caused by the bacterium Yersinia pestis and result in fever and pain. Whereas pneumonic plague affects respiratory organs, bubonic plague is an infection of the lymphatic system. They can now be cured if diagnosed within 24 hours. The severe symptoms produced by pneumonic plague and the fact that it can be spread person-to-person make it especially dangerous. The chances of surviving it in the 14th century would have been almost zero because no medical intervention was available. **MS**

Will we ever be able to clone humans?

Sven Bohm

■ Almost certainly. The process that was used to clone Dolly the sheep would probably work on humans if we tried it now. In fact, a private biotech company called Advanced Cell Technology actually did this in 1998. They took the nucleus from a human leg cell and injected into a cow egg cell that had been stripped of its own nucleus. The resulting human/cow hybrid embryo grew in a test tube for 12 days, before it was destroyed. Reproductive cloning research is now illegal in most countries. This will slow progress in the field but probably not halt it altogether. **LV**



What percentage of Earth's forests have we cut down?

Sasha Bialkowski

■ At the end of the last ice age 10,000 years ago, forests covered about 45 per cent of the Earth's land area. Today it's about 31 per cent. That's a drop of almost two billion hectares (4.9 billion acres) – an area larger than Russia. Felling for timber and to clear land for agriculture is the biggest cause. Before 1900, most of the felling was in the temperate forests of Europe, North America and Russia. Now it's almost all tropical forest as they are the largest reserves in the fastest-growing countries. As population has expanded, the rate has increased. It took humans about 8,000 years to cut down the first billion hectares of forest but just 160 years to cut down the second billion. **LV**

How did the famous pirate Blackbeard die?

Adam S

■ Blackbeard's death on 22 November 1718 came at the hands of British sailors who were sent on a mission to end his piracy by Virginia's Governor Alexander Spotswood. To appease local merchants who were complaining about Blackbeard's attacks, Spotswood hired the sailors under the command of Lieutenant Robert Maynard. He then sent them on two fast ships to the pirate's refuge on Ocracoke Island off the coast of North Carolina. The story goes that in the ensuing battle Maynard was almost killed by Blackbeard but was saved at the last moment when a sailor slit the villain's throat from behind. **MS**

What was the first global empire?

Nathanial Featherstone

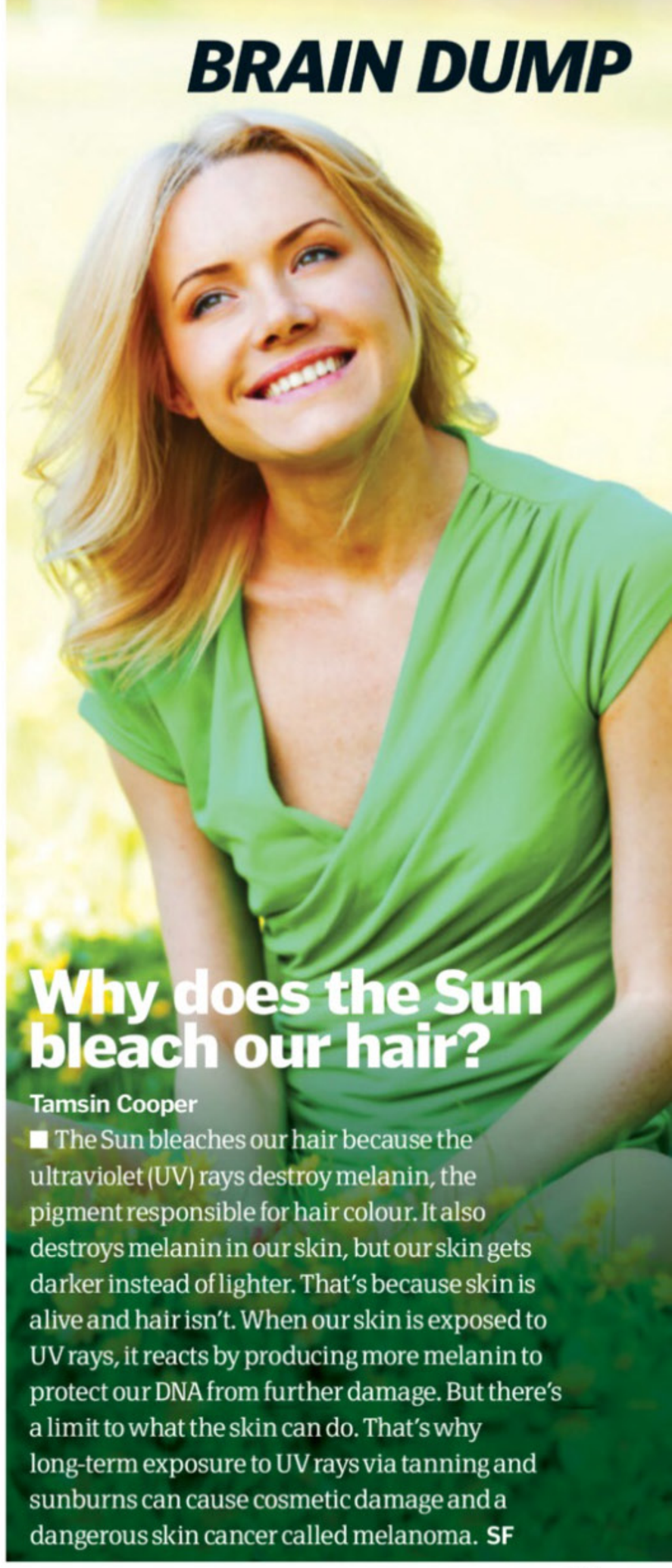
■ The Portuguese Empire was the first empire to expand globally, with the capture of Ceuta on the coast of North Africa in 1415, and the last to fall, with the return of Macau to China in 1999. The empire established colonies in territories that now belong to 53 different sovereign states. The expansion was initially led by Prince Henry, later known as Henry the Navigator, who possessed a thirst for exploration and had plenty of money to inject into seafaring expeditions. A desire to improve the declining economy of Portugal were also driving factors.

Key events include Bartolomeu Dias becoming the first European navigator to sail around the Cape of Good Hope in 1488 and Pedro Cabral reaching Brazil in 1500 – Portugal's largest colony. **RS**

Why were canaries used in mines?

Adrian Combe

■ Canaries were used by miners as a warning system for poisonous gas. Canaries were chosen because the small size of these birds made them easy to carry and quick to succumb to poisonous gas. Canaries have a relatively high basal metabolic rate and breathe more rapidly than humans. Therefore, any atmospheric toxins they inhale will circulate quickly through their bodies and could be harmful at concentrations lower than those that would affect an adult human. These real-life Tweety Pies would give miners early warning of carbon monoxide – a deadly, colourless and odourless gas. If the bird suddenly fell off its perch, the miners knew they needed to get out sharpish. **MS**



Why does the Sun bleach our hair?

Tamsin Cooper

■ The Sun bleaches our hair because the ultraviolet (UV) rays destroy melanin, the pigment responsible for hair colour. It also destroys melanin in our skin, but our skin gets darker instead of lighter. That's because skin is alive and hair isn't. When our skin is exposed to UV rays, it reacts by producing more melanin to protect our DNA from further damage. But there's a limit to what the skin can do. That's why long-term exposure to UV rays via tanning and sunburns can cause cosmetic damage and a dangerous skin cancer called melanoma. **SF**

21st-century encyclopaedia

■ Find out why kangaroos are so good at jumping in the latest edition of **Brain Dump – How It Works'** digital sister magazine. In issue 13 you'll also receive a tour around a ship's engine room, as well as finding out how coffee is decaffeinated, why we laugh, five cool things you never knew about jellyfish and many more trivia snippets. **Brain Dump** is a mini encyclopaedia, packed with incredible facts and jaw-dropping photos. You can get each new issue on the first day of every month from iTunes or Google Play. If you have a burning question, you can ask us on Twitter @BrainDumpMag or www.facebook.com/BraindumpMag.

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Computer gadgets

Devices to make laptop life a lot easier

Computers mean well but tangled wads of cables, poor battery life and unreliable Wi-Fi connection can make you want to rip out the hard drive in frustration. Fortunately, there are gadgets out there that are designed to ease your computing woes, so we've put them to the test.

Checklist

- ✔ Multi-purpose charger
- ✔ Portable Power Bank
- ✔ Wi-Fi booster
- ✔ Bamboo pad
- ✔ HDMI switch
- ✔ Remote control switch
- ✔ Plug in mic
- ✔ USB TV

1 Power up

QDOS PowerMax Dual
£29.99/$NA
Qdossound.com
Rather than having a nest of cables to power up your different devices, getting in each other's way and frequently getting lost, try this neat charger. It's USB on one side and Micro-USB and Lightning Connector for Apple devices on the other.
Verdict: ✪✪✪✪✪

2 Banking on power

Portable Power Bank
£29.99/$NA
www.maplin.co.uk
If you ever run out of juice and you're nowhere near a power supply, this handy little gadget will charge you up in a flash. Lightweight and stylish, once fully charged, the Power Bank will work with a range of devices. It's compact and gets the job done.
Verdict: ✪✪✪✪✪

3 Boost your Wi-Fi

dLAN 500 WiFi Network Kit
£124.99/$NA
www.maplin.co.uk
If you're frustrated with poor Wi-Fi signal in one part of the house, this easy-to-install kit will help. All you need to do is plug one adaptor into your router and another where signal is weak and it will boost the signal. Easy to set up and effective, if not lightning fast.
Verdict: ✪✪✪✪✪

4 The new keyboard

Bamboo pad
£59.99/$79.00
www.wacom.com
If you aren't a fan of the traditional mouse-and-keyboard, this wireless touchpad could prove very useful. Extremely sensitive to pressure, the Bamboo Pad is very responsive and easy to master, but you do have to have a very steady hand to use it.
Verdict: ✪✪✪✪✪

It is ideally set up for interviews as the multiple pattern selection can pick up sound from a variety of different angles.

The TV can pick up Freeview channels and store up to 256 channels.

The remote control isn't totally necessary. It automatically responds to whatever HDMI device has just been turned on.

EXTRAS

Some more computer fun

BOOK

USB Complete

Price: £43.49 / $54.95
Get it from: amazon.com
If you have been inspired to make some USB gadgets of your own, then this may be the perfect book to send you on your way, with plenty of tips and code.

APP

USB Disk

Price: Free
Get it from: iTunes
The USB Disk is a handy app that lets you transfer documents and photos onto your phone and view them in a range of formats. It will read PDFs and MS Office too, which is really useful.

WEBSITE

everythingusb.com

You like USB gadgets? Not as much as these guys! as the name suggests, this website is a roundup of all the maddest USB gadgets on the market, from USB coffee stirrers to USB-powered hairbrushes.

5 Cable tidy

5-Way HDMI switch
£39.99/$NA
www.maplin.co.uk
Instead of with switching your HDMI inputs around every time you want to play the Xbox, you can now plug all HDMI cables into this one stylish device and switch between them using the remote control. It looks cool, works efficiently and saves a lot of scrambling around.
Verdict: ✪✪✪✪✪

6 Remote power

LightwaveRF remote control socket
£23.99/$NA
www.maplin.co.uk
It can be frustrating to have to reach over furniture and other obstacles to turn a plug on or off, so these remote control plug sockets are fantastic. Quick and easy to install, you can turn them on and off with the press of a button. Not intrusive, with good range and response.
Verdict: ✪✪✪✪✪

7 Plug in popstar

Blue Yeti USB Microphone
£114.99/$N/A
www.maplin.co.uk
This handy USB microphone is great for recording a range of sounds, vocals and instruments alike. Put together in seconds, it looks cool, but is a bit larger and heavier than expected. The mute button is very handy and the sound quality you can get from it is superb.
Verdict: ✪✪✪✪✪

8 USB TV

7-inch LED television
£59.99/$NA
www.maplin.co.uk
Plug into your computer via USB and watch this miniature television while you work (if the boss allows it, of course). The crisp LED screen delivers an excellent picture and you can watch camcorder videos and play MP3s on the device as well.
Verdict: ✪✪✪✪✪

GROUP TEST

Putting products through their paces

Up close
A 5x optical zoom brings you closer to life under the sea.

Find your photo
Can't quite place a certain snap? Built-in GPS on the D30 can tell you exactly when and where a photo was taken.

Underwater cameras

We delve deep to find the best waterproof compacts

1 Fujifilm FinePix XP200

Price: £189.98/$229.95
Get it from: www.fujifilm.eu / www.shopfujifilm.com
The FinePix range is a popular one and you can see why. Fujifilm has developed a robust range of cameras that function perfectly as an everyday snapper, but excel in outdoor conditions. You can submerge it in water to 15 metres (50 feet) with no problems and it's both shock- and freezeproof, so it's the ideal travel companion. What's more; it comes with built-in Wi-Fi so that you can transfer your images to your smartphone or PC while on the move.

Set-up is quick as there's only the main menu to contend with. It's straightforward to use thanks to the clear icons, which is exactly what you need when underwater. There are 19 scene modes for just about every scenario, from Snow and Beach to Party and Underwater. The last comes with two variations: one for shooting clear images of the ocean and another for capturing close-ups of underwater subjects.

While it might not be the prettiest camera, the tech inside more than makes up for it. There's the opportunity to shoot 3D images, 360-degree panoramas and a bunch of creative filters to experiment with, making the XP200 a solid all-rounder, whether for a newbie or a more sea-tested veteran.
Verdict: ✪✪✪✪✪

2 Canon PowerShot D30

Price: £259.99/$329.99
Get it from: www.canon.co.uk / www.canon.com
If you're a serious diver, then Canon PowerShot D30 is well worth a look. Waterproof to 25 metres (82 feet), no compact digital camera can go deeper. It's suited to other expeditions too, since it's shockproof up to two metres (6.6 feet), freezeproof to minus-ten degrees Celsius (14 degrees Fahrenheit) and dust-proof. There's GPS on board for tagging the location of your photos and videos, which is handy for keen travellers.

This an ideal match for beginners and those who don't want to fiddle around with settings underwater, as there are 32 automatic scene modes. As well as stills, users can record full-HD (1080p) movies with optical zoom and the camera's built-in image stabiliser for keeping shots sharp. On top of this, Movie Digest mode will record four seconds of video before your photo is taken, making sure you don't miss anything incredible.

It looks great; it's lightweight and simple to get to grips with. The 12.1-megapixel resolution is more than enough for the casual user and its six image stabilisation modes make sure your images don't suffer from motion blur. The D30 is a serious player in the underwater photography market.
Verdict: ✪✪✪✪✪

Wide shots
A simple press of a button can widen or narrow the area that will be captured by the camera, meaning you can adapt your shot to the situation at hand.

Pick your shot
The Slow View mode allows you to capture video and select the perfect shot from a slow-motion replay to turn into a photograph.

ON THE HORIZON

What breakthroughs are next in the photography world?

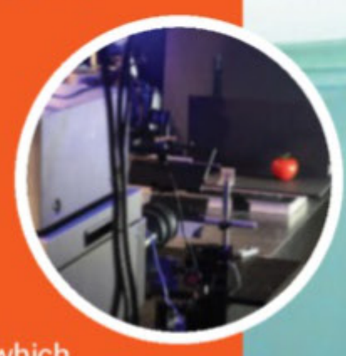
AWARE-2

This epic 50-gigapixel camera can photograph subjects using 98 mini-cameras, resulting in a picture that sees better than a human eye.

WVIL

If you don't want to take a ton of cameras with you wherever you go, take this Wireless Viewfinder Interchangeable Lens. It attaches onto your phone, so you can take amazing pictures without lugging a load of equipment on your holiday.

One Trillion FPS camera



You might think cameras are pretty snappy (pun intended) now, but that's nothing compared to the one trillion frames per second camera developed by MIT, which can capture light moving. Unfortunately, it still probably won't get a group shot where no one is blinking.

3 Nikon 1 AW1

Price: £749.99/$799.95
Get it from: store.nikon.co.uk / www.nikonusa.com
The AW1 is part of Nikon's adventure range and is a seriously impressive machine. With a resolution exceeding 14 megapixels, the camera is capable of taking crystal-clear photographs wherever you like, using its interchangeable lenses.

It looks by far the most professional of all the underwater cameras we tested, with smooth silver casing and the ability to swap lenses making this very much the professional's choice.

One of the AW1's key selling points is the fact it has the fastest continuous shooting frame rate of any digital camera with 15 frames per second. That's extremely useful for when you are shooting a cool action shot, capturing multiple images in one burst so you can pick the best one.

In terms of shooting underwater, it is excellent. You can go down to 15 metres (50 feet) without any problems and with its rapid shutter rate, it can snap shut in 1/16,000 of a second, means you should be able to manage to avoid underwater blurring with ease.

It is very comfortable to use, has a lot of features experienced photographers will enjoy playing with, but it's accessible enough for amateurs too.
Verdict: ✪✪✪✪✪

4 Ricoh WG-4

Price: £309.99/$379.95
Get it from: shop-uk.ricoh-imaging.eu / www.us.ricoh-imaging.com
The Ricoh is waterproof to the shallowest depth of the four cameras we tested, but as it's still a good 14 metres (46 feet) it's not the end of the world.

It has a very interesting design, which is brave but doesn't quite work. It's not the most comfortable to hold either, and the buttons on the main control centre aren't easy to access without accidentally pressing another. Its specifications are pretty solid, with a 16-megapixel resolution providing detailed shots for printing big, and 4x optical zoom that enables you to get closer to the action.

The WG-4's main selling point is its anti-blur and anti-shake feature. The super-bright f2.0 aperture helps shed more light on your underwater shots, capturing clear images even in the dimly lit ocean. The dual-shake reduction system means that even the unsteadiest hands shouldn't distort the picture. In practice this works very well and even when deliberately shaking the camera, there is only a marginal loss of focus.

Physically it doesn't look amazing and it doesn't quite have the technological wizardry of the others, but image quality is impressive.
Verdict: ✪✪✪✪✪

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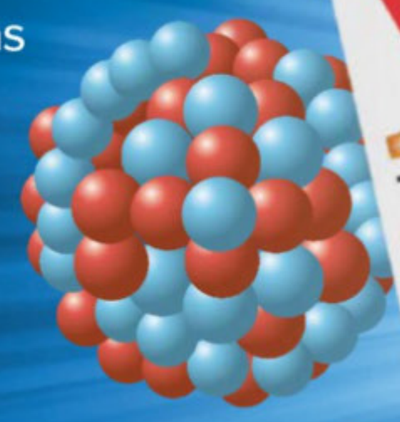

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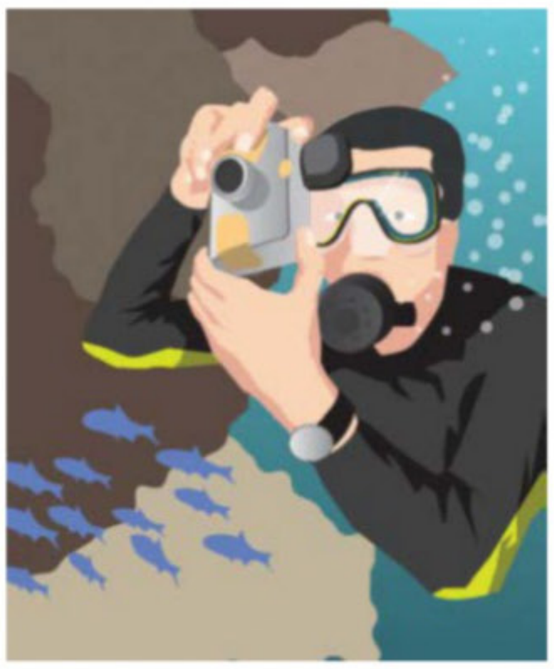
Take photos underwater

Dive into the deep and discover how to capture amazing underwater images

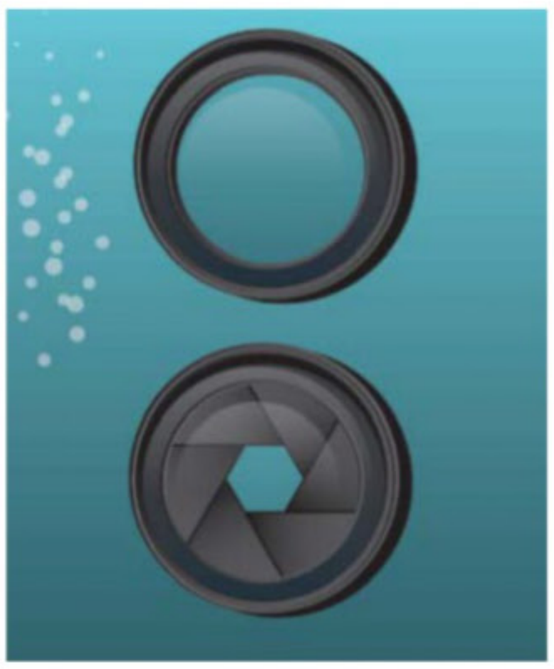


1 Use underwater mode

There are many good waterproof cameras on the market. They usually have an underwater mode that automatically makes any colour corrections, so consult your manual and adjust your settings. Choose your underwater camera well, depending on your plans. Many of them are only waterproof to a certain depth, so if you're going on a scuba-diving trip, make sure your camera can cope with deeper water.

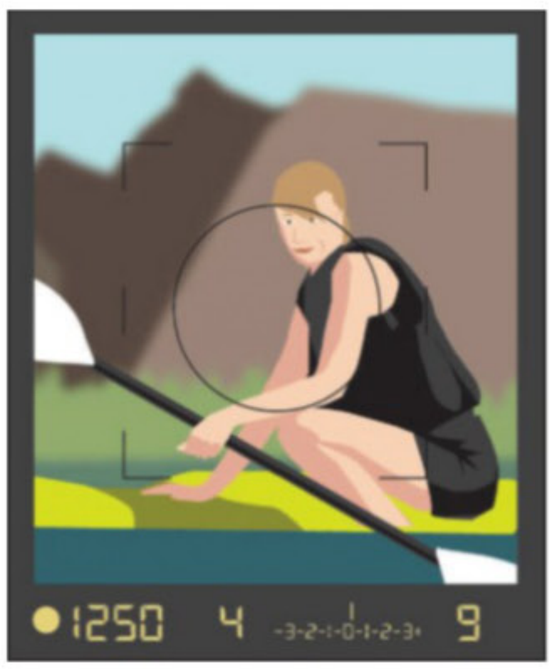
2 Set your shutter speed

Cameras that don't have an underwater mode require a little more work to achieve the perfect shot. The first thing to consider is shutter speed. As there is so much movement in the water, a fast shutter speed is required. This will mean as little movement as possible will be captured, resulting in a pin-sharp shot, while a slow shutter speed would produce a blurry image. A speed above 1/125 seconds should do the trick.



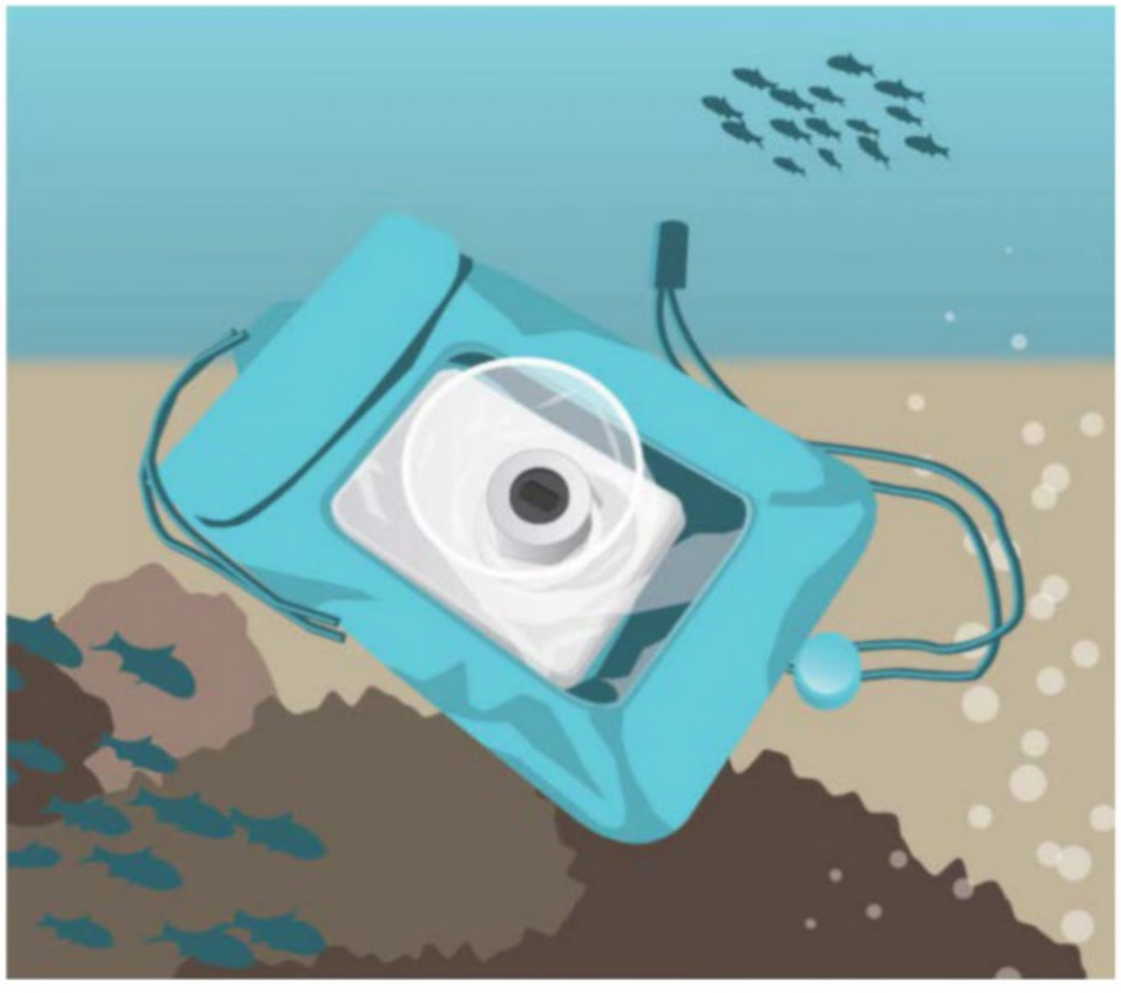
3 Open the aperture

In water, light is refracted and scattered all over the place, which can confuse your camera. To create true-to-life photos that aren't too gloomy, you'll need to set the aperture of your camera as wide as you can in order to capture the most amount of light possible. The rule is the lower the f-number, the wider the aperture, so select a setting such as f4. Raising the ISO and boosting the exposure would also brighten up images.



4 Switch to autofocus

This might be considered cheating but autofocus will be invaluable underwater, especially if you are photographing moving objects. Most cameras are already set to autofocus, so unless you have changed it to manual yourself, you won't need to do much. If your camera has this function, choose continuous autofocus so your camera repeatedly checks whether the subject of your underwater snap is the clearest image possible.



5 Waterproof it

There is a wide range of bags you can buy that will fit your camera in. These are usually see-through and plastic, meaning you can safely carry your camera underwater, see what you are shooting and have a decent range of control over the results. Subtle focus changes will be tricky to achieve but if all you want to do is take some basic underwater shots with a digital camera, a waterproof bag is all you'll need.

In summary...

Basic underwater shots can be taken fairly easily, but if you want sharp, clear images, you will need a waterproof camera and adjust your shutter speed and aperture settings. This will require a lot of trial and error as the water is an ever-changing environment, but perseverance should give you some unique holiday photos to treasure.

NEXT ISSUE
- Pamper your pet
- Master the perfect swallow dive

Cook the best barbecue

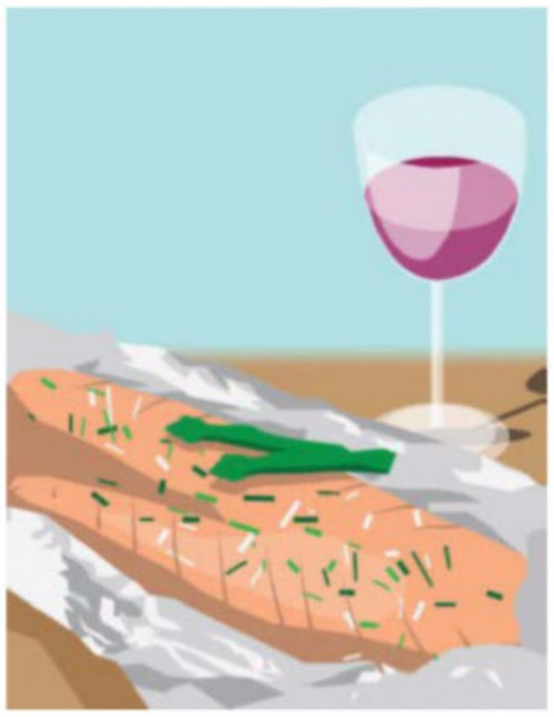
The summer's biggest challenge is the classic barbecue. Here's how to avoid getting grilled

1 Be prepared

Make sure you have all side dishes prepared in advance and all meat defrosted so that when the day eventually comes, you can concentrate solely on the cooking. To save even more time, clean the barbecue thoroughly beforehand. Make sure the coals are lit a good half an hour before you plan to begin grilling the food. Only when the coals are glowing red hot with a white or grey layer on top is the barbecue ready to cook.

2 Cook carefully

The best meats to cook are thin and boneless, which is why burgers and chicken fillets work well, while chicken drumsticks often end up still raw on the inside. Cook the meat steadily, not too close to the coals. You should only have to flip the meat once, so it's evenly cooked throughout. Make sure the juices run clear before serving. If you have a food thermometer, the meat should be fully cooked when the internal temperature reaches 75°C (167°F).



3 Touch of class

To really make your barbecue a cut above the rest, try cooking fish in foil. This keeps the juices in, prevents burning and stops the grill smelling like fish, potentially spoiling the flavour of other food. Wrapping potatoes in foil will also create fluffy-on-the-inside, crispy-on-the-outside baked potato. If you really want chicken drumsticks, try part-oven cooking them to give them a fighting chance of being cooked all the way through.

In summary...

Preparation is key to creating the ideal barbecue. So often they are spoiled by people rushing or trying to do too much at once. If the cook is alert, turns the meat in good time and is confident enough to try something a little different, summer food poisoning could become a thing of the past.

QUICK QUIZ

Test your mind with ten questions based on this month's content to win an Airfix model of a Hawker Hurricane Mk.1 aeroplane.

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

1. Which part of a butterfly's body holds most of its internal organs?
2. By what sci-fi-related name is Cyberdyne Inc's mechanical leg called?
3. How high (in km) was Felix Baumgartner's space jump?
4. In what year were antibiotics discovered?
5. What event wiped out over 90 per cent of Earth's marine creatures?
6. Which adventurer set a record after paramotoring over the Himalayas?
7. Which telescope was used to discover chromatic swirls on the Sun?
8. What was German fighter ace Manfred von Richthofen's nickname?
9. Which chemical is responsible for migraines?
10. In which year was the ELS in French Guiana completed?

ISSUE 60 ANSWERS

1. Toadstools **2.** Hungary **3.** 1876 **4.** Xenon **5.** 17%
6. Vredefort, South Africa **7.** Roman **8.** Pitot tube
9. Poly-PicoSatellite Orbital Deployer **10.** £600 ($1,000)

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Next issue's letter of the month will win some Battroborg motion-controlled battling robots. Use a wireless controller to control your cyborg and enter the arena to do battle with your rivals!

Letter of the Month

Are soft drinks safe?

Hi,
I understand that when rain falls it absorbs small amounts of carbon dioxide to form very dilute carbonic acid, H_2CO_3. When I open a bottle of carbonated water thousands of bubbles of CO_2 fizz into the water. Am I then drinking carbonic acid? If not, why not?
Geoff Andrews

Carbonic acid is present in rain and is used in the development of fizzy drinks. Don't worry though, it dissolves in water and the amounts used are very small so it's just what makes your drink look and taste fizzy. In fact, the acid is used in the blood where it acts as a catalyst increasing the efficiency of respiratory gas exchange and helps keep your pH levels stable.

Carbonic acid is used to make soft and sparkling drinks 'fizzy'

Wear and tear

HIW,
Watching aircraft landing I'm alarmed at the amount of smoke generated by tyres contacting concrete. Has anybody thought about somehow making the wheels revolve prior to contact? The mechanism could have a 'freewheel' action similar to a bicycle, to prevent any swerving. This idea would prevent the colossal wear on the tyres.
Great mag,
Dennis

This is a question that has had many different theories over time. Simple ideas include inflating the tyres to a set amount and using belt plies but some experts claim that built in aerofoils could use the surrounding airflow to make the wheels rotate upon landing. Physics dictate that this method of spinning would prevent wear but it is more complex than that. The incredible amount of downforce on the tyres and speed of the aeroplane would make it extremely difficult to maintain the correct 'freewheel action.' Therefore, mechanisms are still in the early days of planning and production.

Teleportation – real or a hoax?

Hi HIW,
I have heard various theories about this, but my question is: can Nikola Tesla's magnetic wall experiment really act as a teleporter? Or is it just a hoax?

Experiments to reduce the stress on aircraft wheels during landing are still in early stages

"In the Industrial Revolution, horses saw their role decline as new machines took over"

Thanks,
Harry Moses (13)

Nikola Tesla's magnetic wall experiment put forward the idea of using highly charged electromagnetic fields and waves that could create a 'wall of light', which could manipulate and control energy and matter. The idea of 'teleportation' wasn't exactly a hoax, but rather an incorrect term. Tesla found ways to produce wireless energy transfer and contributed to electrical engineering but not a way to teleport humans or solid matter. Films like *The Prestige* and various online videos show a fictional version of this but as far as we know, no device has been made to teleport anyone yet!

If you want to know more about Tesla and his inventions, check out issue 30 of our mag when he was the star of our Heroes of Science feature. Also, for more on teleportation, we answered a question on it in last month's Brain Dump section.

Nikola Tesla's magnetic wall experiment has fired the human imagination for over a century

Just how important are horses to human civilisation?

Horsing around

Dear Editor,
Would the Industrial Revolution have happened without the domestication of horses? Where would civilisation/society be now? I hope you can help!
Kate Ireland (13)

The horse was domesticated in ancient times and has been used in warfare, manufacture, agriculture and transport. In the Industrial Revolution, horses saw their role decline as new machines such as the train and automobile took over. If horses were never domesticated or even never existed, human civilisation would still be here and the Industrial Revolution would have happened, but it would have progressed at a much slower rate. Or maybe we'd have just used cows?

What's happening on... Twitter?

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

Nattie
@Nat__moores
I LOVE **@HowItWorksmag** – sinkholes, light speed, life in the boreal forest, science of happiness, quantum mechanics, Chernobyl. Best mag ever!

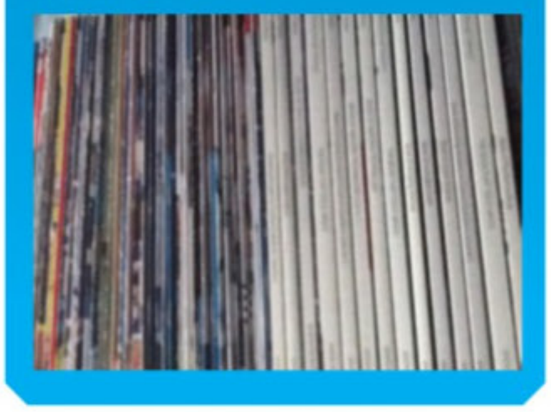
Angie Brooks
@MissAngieBrooks
Did anyone else know this is how silk is made?! **@howitworksmag** #shocking – poor silk worms! Never wearing silk again!

Colin Bowett
@MonkeyMan16
@HowItWorksmag Ducks quacks don't echo! #HIWFacts #WatchingCosmos

Michael Aars @michael_aars
Whoa **@HowItWorksmag** There's only 5,055 black rhinos left! Join **@WorldAnimalsMag** & **@olpejeta** to stop poachers

Phillip Davies @phdzx
The star Lucy in the constellation Centaurus is a Cosmic Diamond of 10 billion trillion trillion carats. #WatchingCosmos

Jake Savage @JakeSavage99
I actually think I've got to be the biggest fan of HIW!



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Distributed in the UK, Eire & the Rest of the World by: Marketforce, Blue Fin Building, 110 Southwark Street, London, SE1 0SU
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Distributed in Australia by: Network Services (a division of Bauer Media Group), Level 21 Civic Tower, 66-68 Goulburn Street, Sydney, New South Wales 2086, Australia
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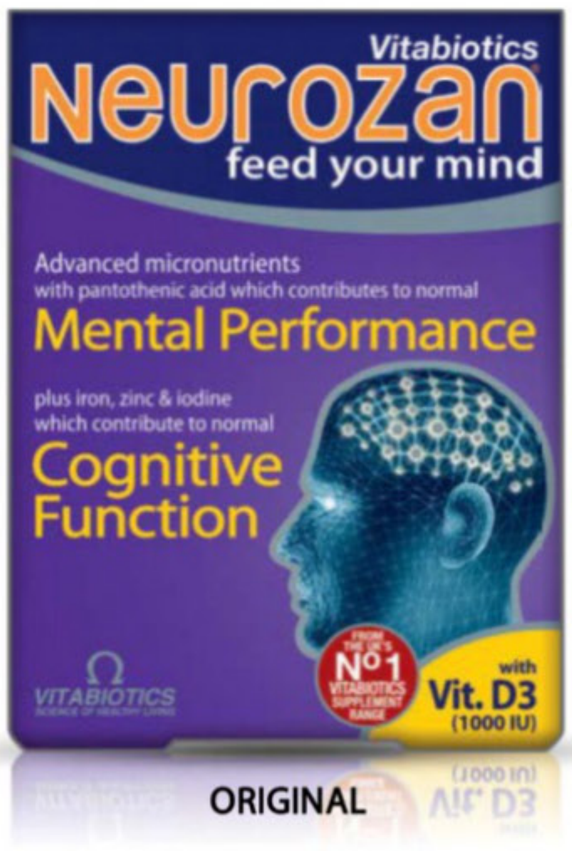

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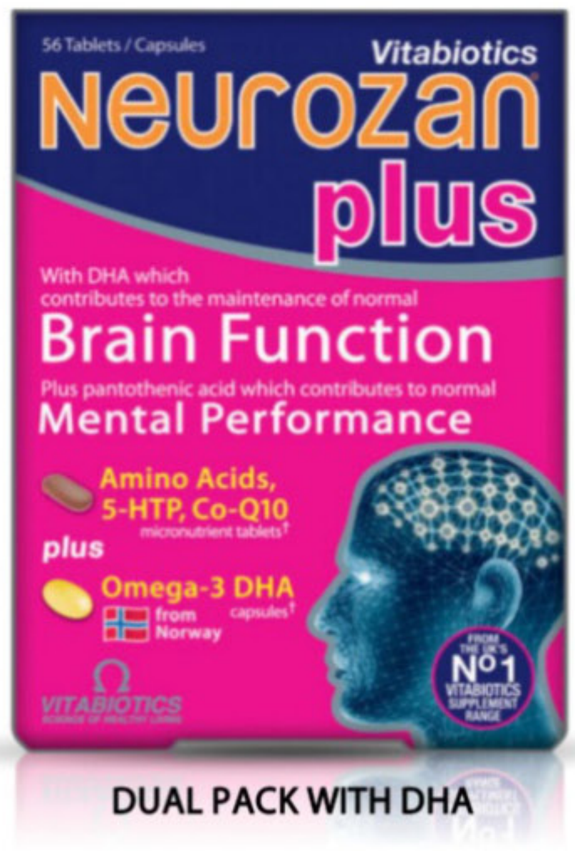

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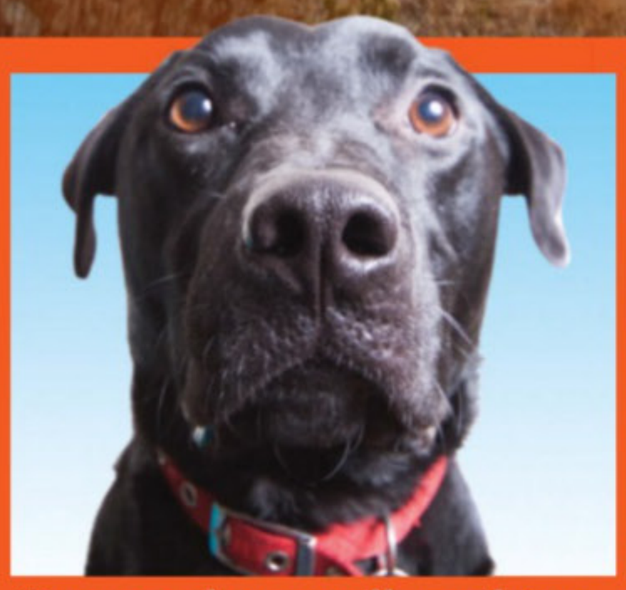
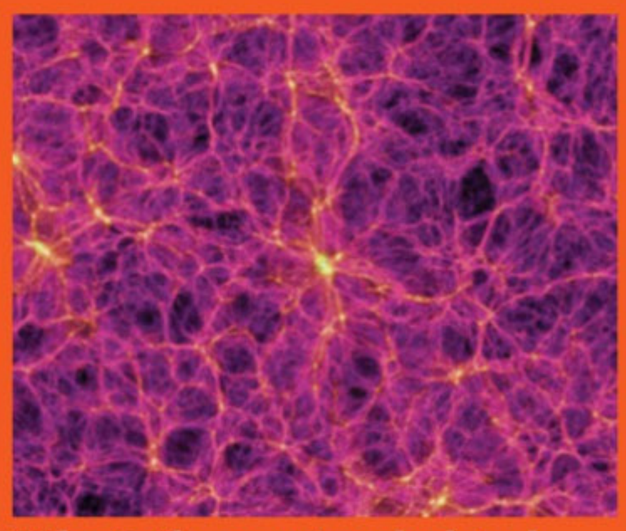
How do super submarines take us to hidden depths?



How can dogs smell anything from drugs to cancer?



What's the mystery behind dark matter in the universe?

How are snakes covered in scales and why?

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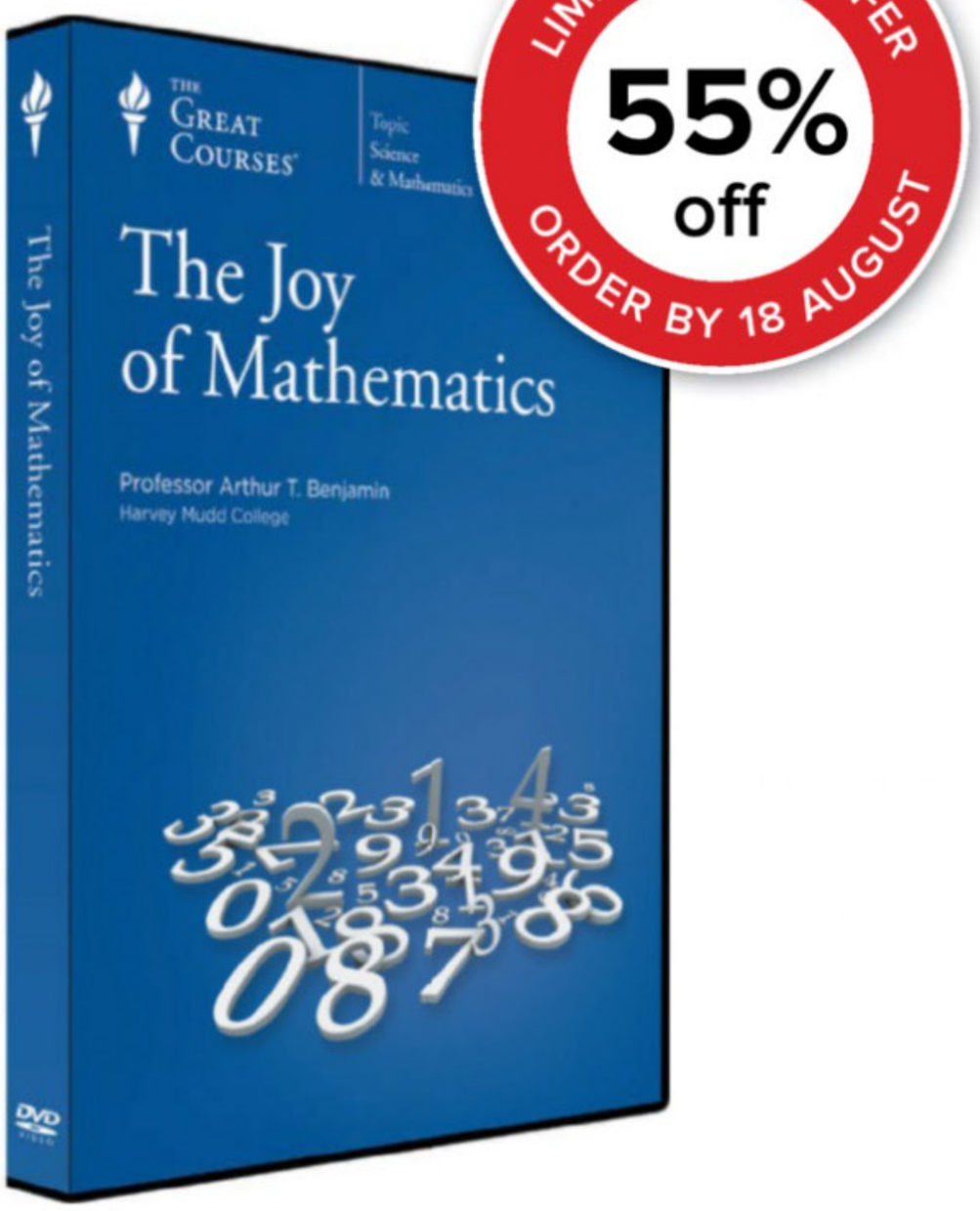

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Iceland. Captured by Tim Nunn.

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