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Why we'll leave Earth, and where we'll go next

DEADLY OCEAN PREDATORS AND THEIR FIGHT FOR SURVIVAL

SHARKS

AMAZING ADAPTATIONS

ENDANGERED SHARK SPECIES

OVER 200 TEETH

INSIDE THE SUN

WHAT POWERS OUR CLOSEST STAR?

+

iPHONE 7 TEARDOWN

MAKING MARBLES

POLAR DINOSAURS

HONEYPOT ANTS

ANCIENT STARS

• DR STRANGE
• JAMES BOND
• JURASSIC PARK

MOVIE FX EXPLAINED

BEHIND THE SCENES WITH HOLLYWOOD EXPERTS

SCIENCE OF HANGOVERS

Why alcohol can leave us feeling worse for wear

VERTICAL CABLE CARS

Inside the world's tallest moving observation tower

LOST CITIES

Discover the ruins of ancient civilisations

Future
ISSUE 094
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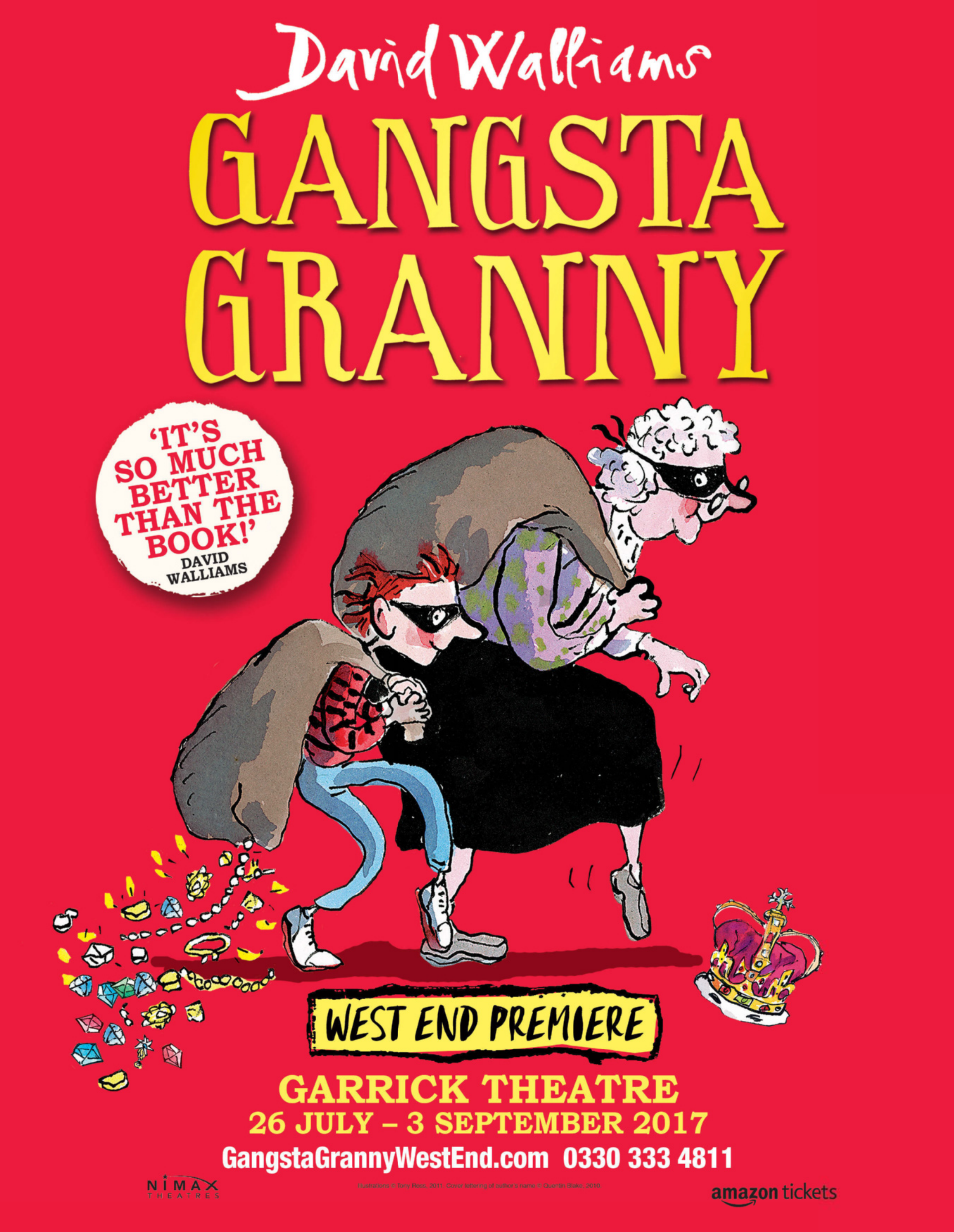
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ISSUE 94

WELCOME

The magazine that feeds minds!

> "As technology has improved, virtual creations in film have become more believable"

Special Effects, page 24

Meet the team…

Charlie
Production Editor
If you think sharks are just mindless man-eaters then think again. Immerse yourself in page 12 to find out why these prehistoric predators need our help.

Dave
Editor-in-Chief
Reading the extreme science article made me very grateful for my nice, safe desk job! It's quite amazing what people will go through for the sake of research and knowledge.

Jack
Senior Staff Writer
I've always thought of myself as a real-life Nathan Drake, so I enjoyed exploring the world's lost cities. Journey to some uncharted civilisations on page 74!

James
Research Editor
If you're burning with questions about our Sun, you've come to the right place. Head over to page 70 to delve inside our local star and discover the incredible power that lies within.

Duncan
Senior Art Editor
Colonising other worlds is totally my kind of thing. Now all I need to do is freeze myself for a few hundred years in order to get there! Find out more about life in space on page 64.

Laurie
Assistant Designer
As a lover of *Jurassic Park* it's fascinating to learn how they gave the T-Rex its scare factor. Learn more about the clever world of special effects on page 24!

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If films like *Jaws* or *The Shallows* left you wary of ever setting foot in the sea again, you're not alone. Hollywood has a long history of casting these fish as villains to strike fear into the audience. Peter Benchley, author of the novel that the film was based on, later expressed his regret at portraying sharks as bloodthirsty killing machines. Benchley had to remind people that his book was a work of fiction: "Sharks don't target human beings, and they certainly don't hold grudges"…but admittedly that would not have made such a thrilling screenplay. This month's environment feature explores the true nature of these fascinating fish.

What made *Jaws* so impressive was its use of cutting-edge robotic technology to build the finned foe. Our tech feature takes you behind the scenes with industry experts to find out how all manner of special effects are created, from CGI magic and Bond car chases to prosthetic make-up and animatronic dinosaurs. Enjoy the issue!

Jackie

Jackie Snowden
Deputy Editor

CONTENTS

Meet the experts...

Ella Carter
This month marine biology expert Ella explains why sharks get such undeserved bad press. Even these mighty predators are at risk, largely due to human activity. Find out how you can help on page 12.

Laura Mears
Laura goes to the ends of the Earth to explain why scientists work in such extreme environments, from the inhospitable Antarctic to deep underground laboratories.

Jo Stass
Jo takes a trip behind the scenes to bring you the secrets of special effects. Find out how they created *Dr Strange*'s magic, performed *Spectre*'s stunts and built *Jurassic Park*'s life-size T-Rex.

Sarah Bankes
This month, Sarah takes us on a tour of Earth's various land habitats. From the temperate regions' coniferous forests to the equatorial deserts, get to know these amazing biomes on page 20.

Jack Parsons
Could cargo ships of the future have sails? Editor of *Gadget* magazine Jack takes a look at the tech on board the latest generation of vessels that use wind power.

REGULARS

Virgin Galactic spaceplane completes first glide flight

Commercial suborbital journeys are now a step closer after a successful test run

Virgin Galactic plan to provide the first ever space tourism package, with passengers experiencing weightlessness during the journey

The 3 December was a turning point for Virgin Galactic's plans for space tourism. Lifting off from California's Mojave Air and Space Port, SpaceShipTwo – dubbed VSS Unity – and its carrier craft, the WhiteKnightTwo, flew for a total of one hour and 20 minutes. Flights using the WhiteKnightTwo carrier craft had been undertaken before, but this was the first where the VSS Unity flew for a period under its own control. The journey included ten minutes of free flight, where the spaceplane detached from the carrier and was piloted safely back to Earth.

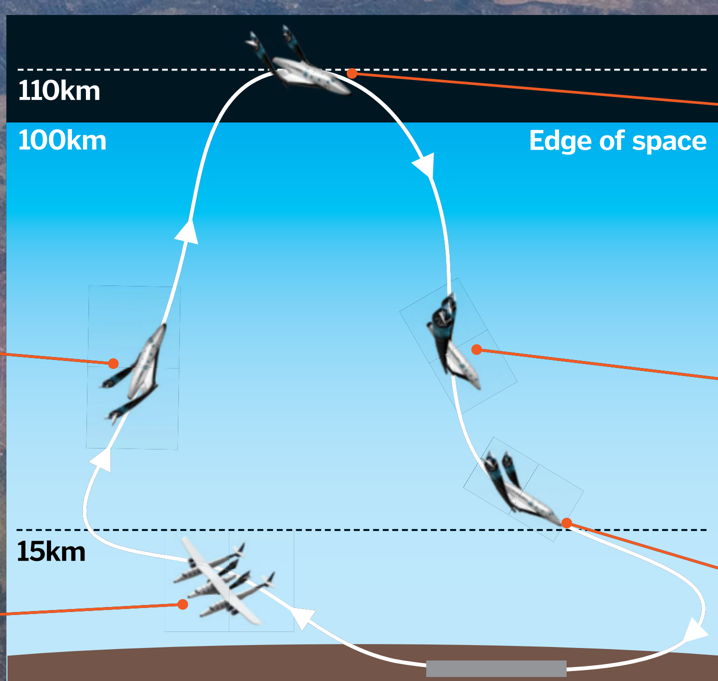
The success is great news for Virgin Galactic, who had seen their plans delayed after the VSS Unity's predecessor, VSS Enterprise, crashed in October 2014, tragically killing the copilot. The test is scheduled to be the first of many, and will eventually lead to ascents where the VSS Unity will climb even higher than the carrier craft.

When these tests are completed, and the first commercial flights begin, the journey will become a unique public experience. Passengers will soar higher than any current commercial aircraft,experiencing several minutes of weightlessness in microgravity.

The carriers will be responsible for taking the spacecraft to 15,000 metres before releasing the rocket-powered SpaceShipTwo

Journey to the edge of space

Virgin Galactic's planned trajectory to give passengers an experience that is out of this world



The climb
The VSS Unity's ascent to 110 kilometres takes around 90 seconds as the craft reaches speeds of 4,000 kilometres per hour using its hybrid rocket motor.

Lift-off
WhiteKnightTwo carries the SpaceShipTwo – VSS Unity – to an altitude of around 15 kilometres before separation.

Microgravity
Now at its highest point, the SpaceShipTwo's passengers experience weightlessness, floating out of their seats for several minutes.

Descent
On the return back down to Earth, the SpaceShipTwo folds up its tailbooms to ensure a smooth descent.

Gliding to Earth
The final leg of the journey consists of an unpowered glide as the craft lands safely back at the spaceport.

NEW EXPLOSION-PROOF MILITARY VEHICLES

A 'memory metal' has been designed that will protect vehicles from blasts

In military operations, the threat of explosives disabling convoys of armoured vehicles looms large. Many army vehicles already have pretty formidable armour to protect them, but despite this, the suspension is often damaged or destroyed, which disables the vehicle.

To combat this, a new type of memory metal has been designed by BAE Systems that will make military machines tougher than ever before. The metal is a titanium alloy, and as well as being durable, it's very flexible. These bendable qualities mean that when struck by an explosion, the metal simply bounces back into shape. The alloy was first created in the US in the 1960s, but this is the first time that it will be used to build an entire suspension system.

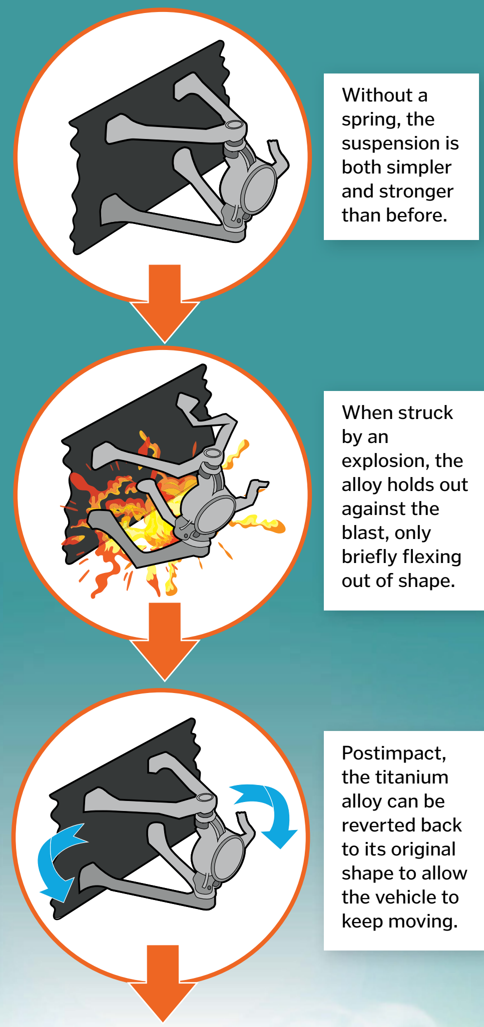
The technology is inspired by nature. The ironclad beetle has one of the hardest exoskeletons in the animal kingdom, and very flexible legs, something modern military vehicles want to replicate.

Memory metal is currently used in products such as bendable glasses, and is a type of shape-memory alloy. It will completely replace the spring normally used in a suspension system, making it even more durable. These resilient yet lightweight materials can be flexed in many directions but will return to their original shape. This is down to the molecules inside the material being able to move back into a set structure, which is designed by controlling the ratio of elements used in the alloy. The technology is currently only at the prototype stage, and is planned to be ready for use in the next decade.

> "When struck by an explosion, the metal simply bounces back into shape"

Memory metal

How the tough titanium alloy withstands battlefield explosions



The alloy has passed five explosive tests of increasing intensity

NEWS BY NUMBERS

$3.3 billion
The amount spent online in the US on Black Friday

€436 million
Recent payment agreed by ESA member states to finish funding the ExoMars Rover

40
The number of countries *Planet Earth II* was filmed in over four years

1,445
New viruses discovered in a recent study of invertebrates

A city powered by sewage

Aarhus is the first city to power its water with waste

Waste doesn't have to be wasted, and the Danish city of Aarhus has hatched a plan to have an energy-neutral water service. The city's water treatment plant has been completely renovated so it can now create a 50 per cent surplus of electricity. This has been achieved by feeding bacteria with wastewater then burning the biogas that's produced. The extra energy is used to distribute fresh water to 200,000 residents, as well as being sold back to the power grid. Cities that harness the power of waste to provide their populations with fresh drinking water could be the future, and Aarhus itself also wants to be completely carbon-neutral by 2030.


Aarhus is the first city to make full use of the scheme, and Copenhagen, Chicago and San Francisco are planning to follow suit


Bletchley Park was decommissioned by the British Government in 1987 but will reopen in 2018

National College of Cybersecurity to open

World War II code-breaking centre Bletchley Park is set to reopen

Famous for breaking the Nazi's Enigma code, Bletchley Park could once again help protect British shores. It won't be breaking secret codes this time though – instead, the government's plan is for a National College of Cybersecurity. Scheduled to open in 2018, the school will educate around 500 successful applicants aged 16-19, all selected based on their coding skills and other similar aptitudes. 40 per cent of the students' study will be devoted to cybersecurity, while the remainder will be based on standard qualifications within the national curriculum. It's hoped the course will enable people to develop the required skills to help defend against growing cybersecurity threats.

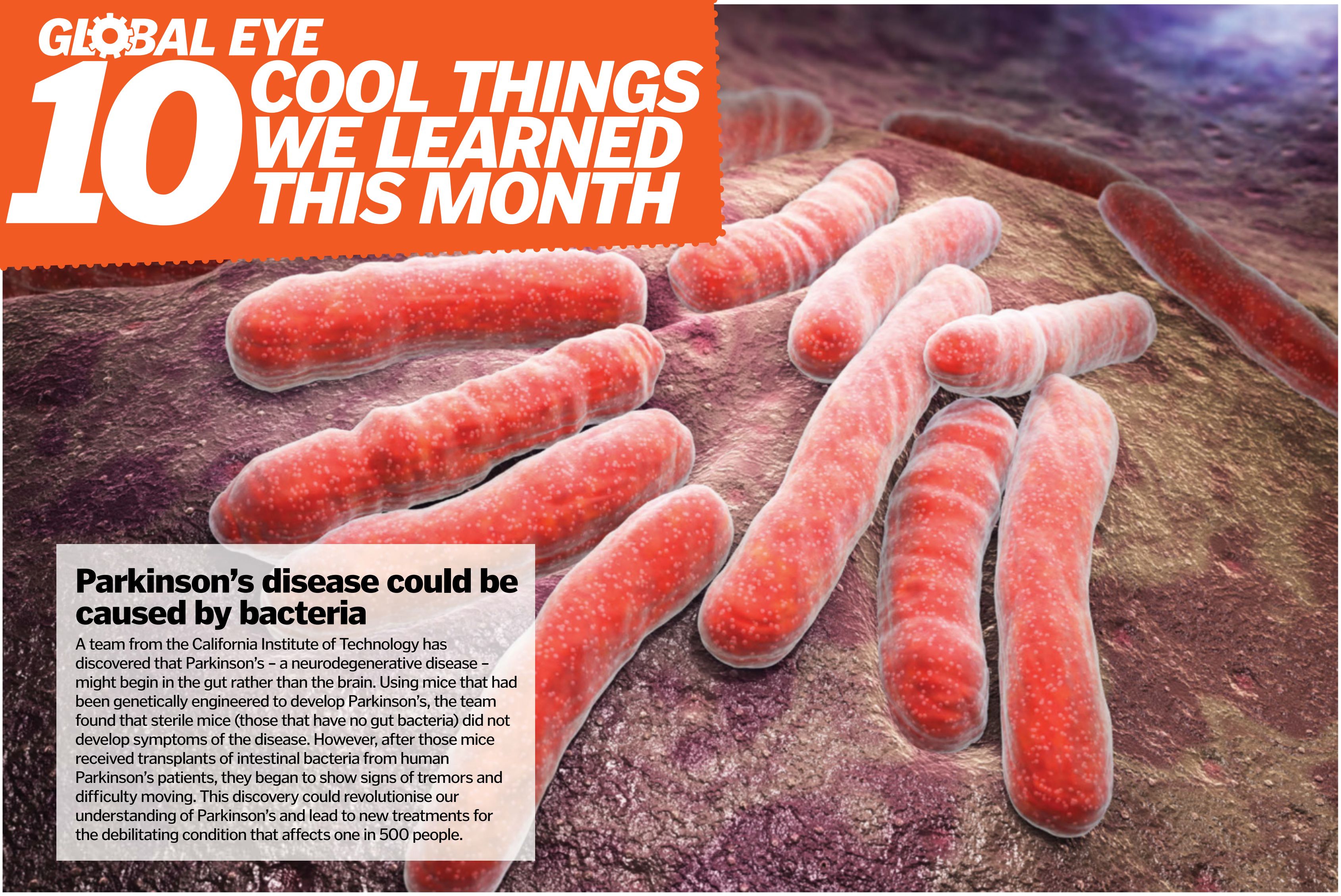
Diesel cars to be banned by 2025

In nine years, four capital cities will enforce a complete ban on diesel vehicles

Paris, Madrid, Athens and Mexico City have all agreed to clean up air pollution by prohibiting diesel vehicles. The plan is for all diesel-powered vehicles to be removed from the roads, and the cities' populations will be incentivised to use alternative transportation. The clean up movement was motivated by results published by the World Health Organization that linked three million deaths a year to air pollution. The decision is likely to have a massive impact on car manufacturers around the world, and will further encourage car companies to develop electric and hydrogen-powered alternatives.

GLOBAL EYE

10 COOL THINGS WE LEARNED THIS MONTH



Parkinson's disease could be caused by bacteria

A team from the California Institute of Technology has discovered that Parkinson's – a neurodegenerative disease – might begin in the gut rather than the brain. Using mice that had been genetically engineered to develop Parkinson's, the team found that sterile mice (those that have no gut bacteria) did not develop symptoms of the disease. However, after those mice received transplants of intestinal bacteria from human Parkinson's patients, they began to show signs of tremors and difficulty moving. This discovery could revolutionise our understanding of Parkinson's and lead to new treatments for the debilitating condition that affects one in 500 people.

Whales send messages with water slaps

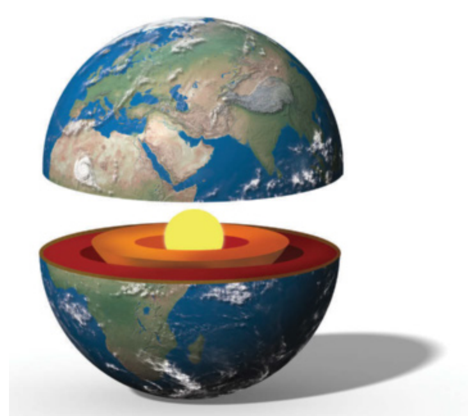
Humpback whales are sometimes spotted making a big splash by leaping up out of the water, but this isn't for show. Researchers have found they are more likely to perform these surface slaps when other whale groups are over four kilometres away, suggesting this behaviour is a form of long-range communication, as the sound of the body-slam travels through water. These whales also use repetitive tail and fin slaps for close-range communication.

You can suffer from nature deficit disorder

Urban life and more time spent indoors means that many of us rarely come into contact with nature in our daily lives. The term 'nature deficit disorder' was coined by an author in 2005, but it has recently become a buzzword for the negative effects this alienation from wildlife has on our mental health. The Royal Horticultural Society recommends that any exposure to nature, from a potted plant to a walk in a local park, can help improve wellbeing.

Earth's mantle may contain water

Water has been detected 1,000 kilometres beneath the Earth's surface, one-third of the way to the core. By studying a 90-million-year-old diamond, scientists discovered that it contained imperfections that indicated the presence of water during its formation in the lower mantle. There may be an ocean's worth of water in the molten-rock layers of our planet. Its presence could be the result of subduction, where two tectonic plates meet and the edge of an oceanic crust slips below another plate, sinking into the mantle.



Tornadoes are becoming more extreme

While the number of tornado events in the US is decreasing, outbreaks involving more than one twister are increasing significantly. These severe storms occur when multiple tornadoes form in an area over just a few hours or days, and can cause widespread destruction.

Platypus venom could help to treat diabetes

Researchers in Australia have discovered that platypuses and echidnas produce a hormone in their venom that helps to regulate blood glucose levels. These monotremes have a modified version of the hormone glucagon-like peptide-1 (GLP-1), which stimulates the release of insulin. Unlike the version found in humans, it's more resistant to degradation, which could help scientists develop treatments for type 2 diabetes.

Artificial dog noses can sniff out explosives

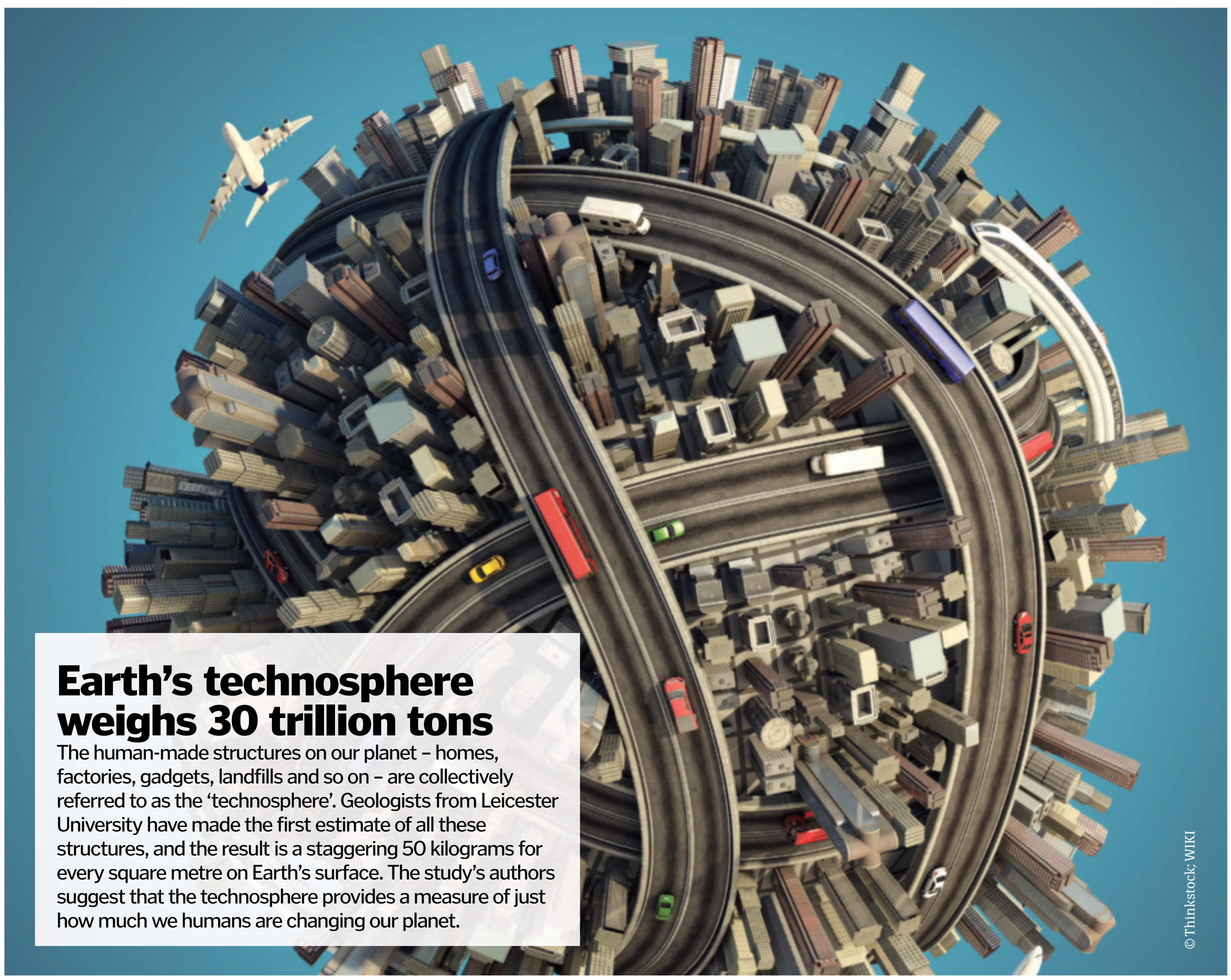
A team of engineers have developed a device that mimics the sniffing of a dog to help detect trace amounts of chemicals used in explosives, drugs and other banned substances. It is made using a 3D printer, and it can be fitted to standard explosives detectors, such as those used in airports, increasing odorant detection by up to 16 times.

Cold plasma helps produce fresher fries

International Space Station research can have some far-reaching applications, but who would have thought that plasma experiments on the ISS could help eliminate the unpleasant smells from deep-fat frying? Plasma is usually hot ionised gases, but it is possible to create this state at room temperature. Not only are these 'cold plasmas' antibacterial, antifungal and antiviral, they can also help to remove odours from the air by breaking down smelly molecules into harmless components. The German deep-fat fryer manufacturer Blümchen is looking to develop a prototype plasma-filter for fryers in the coming year.

Mystery mummified legs belonged to Queen Nefertari

Among the items found when Egyptologists rediscovered Nefertari's looted tomb in 1904 were mummified legs. It's long been assumed they were Nefertari's, and recent analysis suggests this is true. They belonged to a woman of between 40-60 years old at the time of her death, and she was embalmed using a method from the 19th and 20th dynasties, consistent with what historians know about Nefertari.

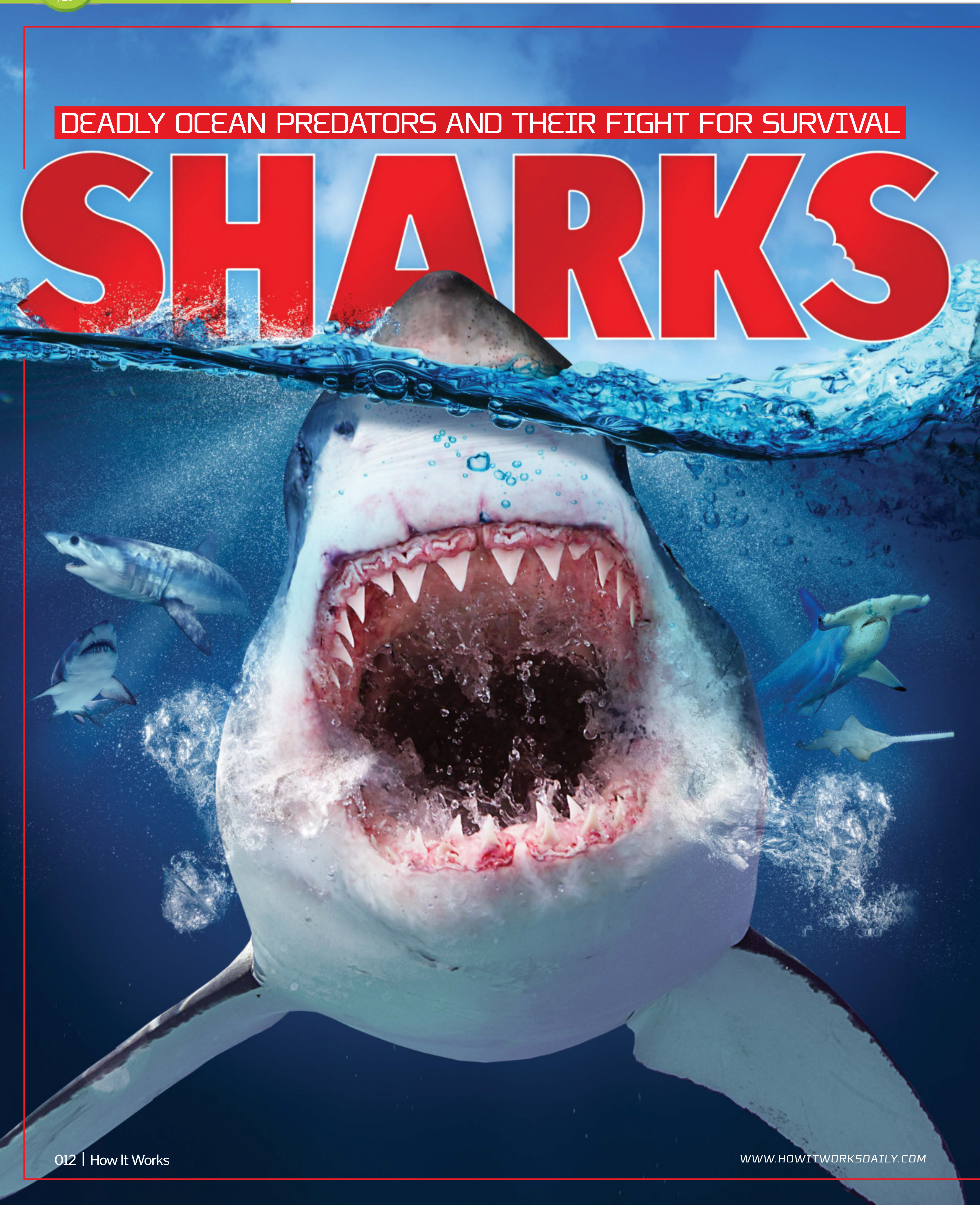


Earth's technosphere weighs 30 trillion tons

The human-made structures on our planet – homes, factories, gadgets, landfills and so on – are collectively referred to as the 'technosphere'. Geologists from Leicester University have made the first estimate of all these structures, and the result is a staggering 50 kilograms for every square metre on Earth's surface. The study's authors suggest that the technosphere provides a measure of just how much we humans are changing our planet.

DEADLY OCEAN PREDATORS AND THEIR FIGHT FOR SURVIVAL

SHARKS



Thanks to Spielberg's 1975 smash-hit *Jaws*, the great white shark is the poster animal for fear. As probably the most famous shark species out there, it's true that these fish are colossal chunks of muscle and teeth. But there's so much more to the great white shark – and indeed all shark species – than being the fictional man-eater of Amity Island.

All sharks belong to the class Chondrichthyes that also includes skates and rays. These critters all have cartilaginous skeletons (the same material that makes up the structure of our ears and noses), which makes them very light, enabling them to cut through the water. Their streamlined shape is of a pointed, tapered silhouette with angular fins and a strong tail.

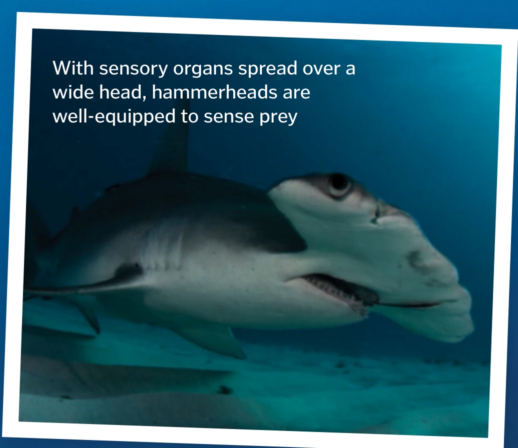
There are many different types of sharks that are found in oceans across the world, from colossal hunters to tiny little bottom-dwelling species. They are often organised into eight orders according to their body shape and other taxonomic factors. The great white, for example, is a member of the Lamniformes, or the 'mackerel sharks'. Along with others such as the basking, sand tiger and mako sharks, these fish are large and ferocious-looking, with mouths that extend behind their eyes, two spine-free dorsal fins and five gill slits, among other features.

> "Each shark has a killer set of adaptations for hunting, from nose to tail tip"

Each shark has a killer set of adaptations for hunting, from nose to tail tip. Even their skin is prepped for the cause – this is made up of a series of scales called dermal denticles, which act as an outer coating for easy movement.

Having conquered most of the oceans, specific shark species have evolved amazing ways of dealing with their environment. For example, the hammerhead's mallet-like skull is a direct adaptation for finding its favourite food – rays – on the ocean floor. Similarly, blue sharks have gills that have evolved a type of net across them, known as gill rakers, which prevent small prey from escaping from the gill slits. As food can be scarce, all prey is invaluable and therefore cannot be allowed to escape.

Sharks are portrayed all too often as public enemy number one, but it's important to realise that they don't see us as food. Read on to learn more about these amazing aquatic predators and find out how you can help save them from extinction in our oceans.



With sensory organs spread over a wide head, hammerheads are well-equipped to sense prey

Born survivors

Baby sharks are born with both a full set of teeth and all the instinctive knowledge that they need to survive. Straight from birth they are ready to take care of themselves. There's no parent-child bonding in this family; a newborn shark pup's fight-or-flight response kicks in immediately after birth, and they quickly swim away from their mother, who they perceive as a threat (she may well eat them!)

It's this instinct that guides them through life. Unlike many mammals, shark parents don't teach their young to hunt; they automatically know how to. But even innate abilities can be overruled. For example, the great white instinctively rolls its eyes back into its head to protect them when it attacks prey. However, these sharks have been witnessed taking chum meat without rolling their eyes back – indicating that they have learned that the chum is not a threat.

When a shark emerges from its egg, the baby is on its own and instinctively knows how to survive

Sharks by numbers

70 YRS

Life span of a male great white shark

50km/h

Speed of the shortfin mako shark

409 MILLION

Age in years of the oldest shark fossil ever discovered

21 kg

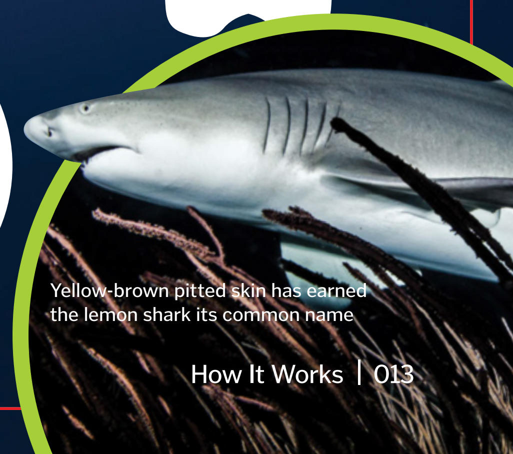
Amount of plankton a 6m whale shark can eat in a single day!

50%

Estimates of decline of Northwest Atlantic sharks since the 1970s

24hrs

Some sharks can replace teeth in this time



Yellow-brown pitted skin has earned the lemon shark its common name

SHARK ANATOMY

Powerful swimming muscles help great white sharks to charge at prey

This streamlined fish is built for hunting. Check out the specs on this killer model

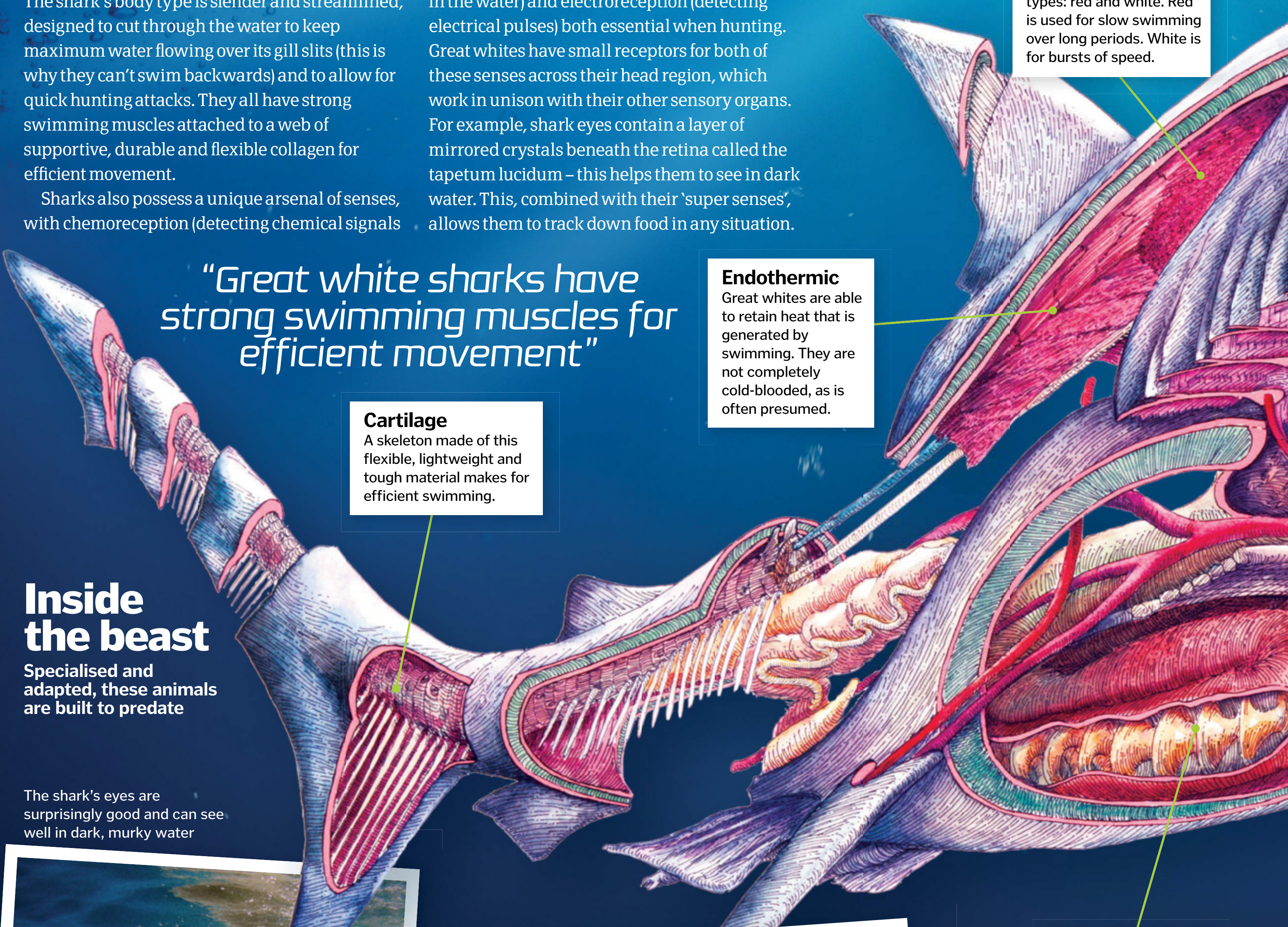
The shark's body type is slender and streamlined, designed to cut through the water to keep maximum water flowing over its gill slits (this is why they can't swim backwards) and to allow for quick hunting attacks. They all have strong swimming muscles attached to a web of supportive, durable and flexible collagen for efficient movement.

Sharks also possess a unique arsenal of senses, with chemoreception (detecting chemical signals in the water) and electroreception (detecting electrical pulses) both essential when hunting. Great whites have small receptors for both of these senses across their head region, which work in unison with their other sensory organs. For example, shark eyes contain a layer of mirrored crystals beneath the retina called the tapetum lucidum – this helps them to see in dark water. This, combined with their 'super senses', allows them to track down food in any situation.

"Great white sharks have strong swimming muscles for efficient movement"

Inside the beast

Specialised and adapted, these animals are built to predate



Muscular frame
There are two muscle types: red and white. Red is used for slow swimming over long periods. White is for bursts of speed.

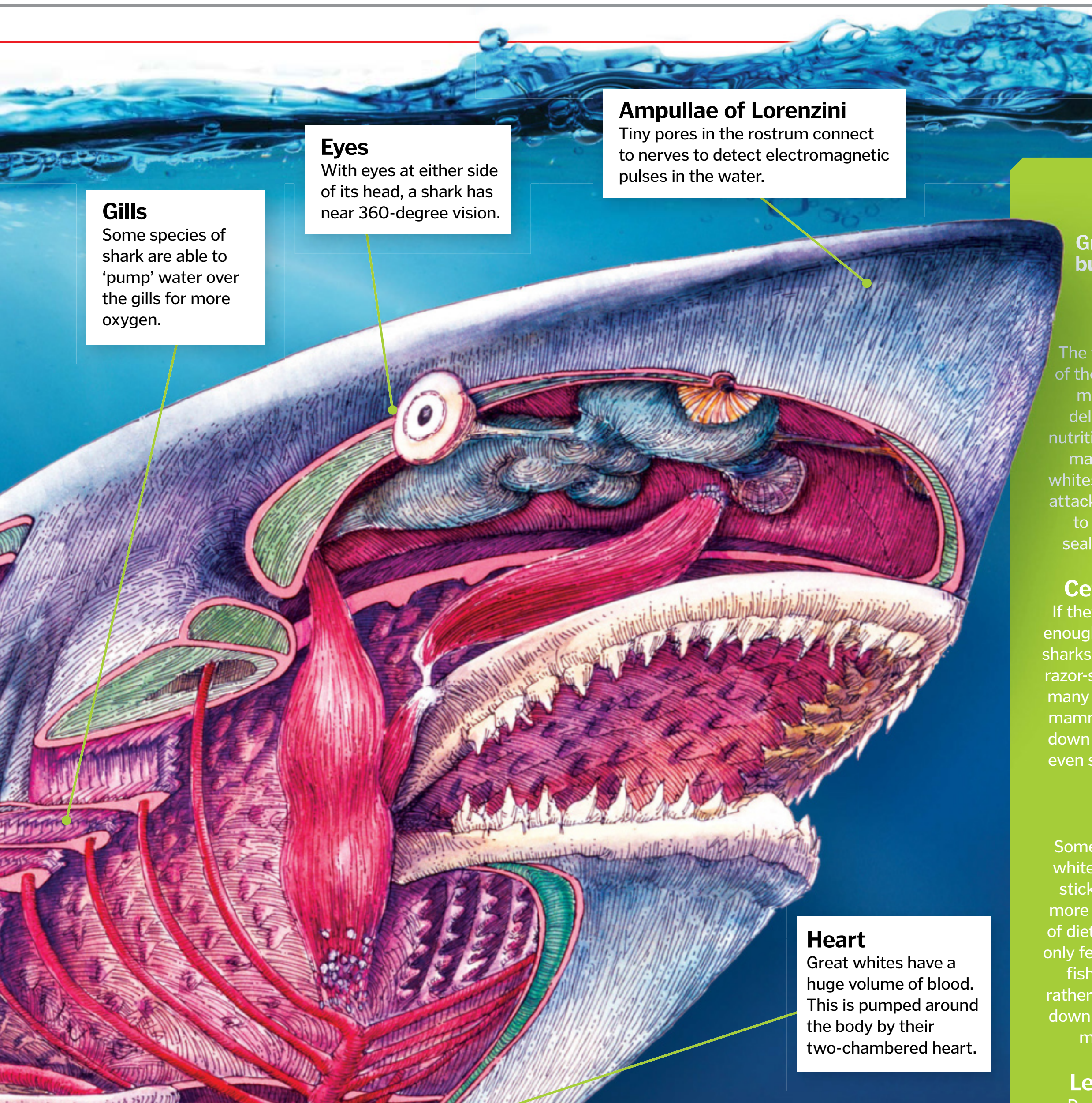
Endothermic
Great whites are able to retain heat that is generated by swimming. They are not completely cold-blooded, as is often presumed.

Cartilage
A skeleton made of this flexible, lightweight and tough material makes for efficient swimming.

Liver
A large, fatty liver aids buoyancy, and liver oil can provide fuel for long ocean swims.

The shark's eyes are surprisingly good and can see well in dark, murky water

All over the shark's rostrum (nose) are sensitive pores that help the great white to hunt

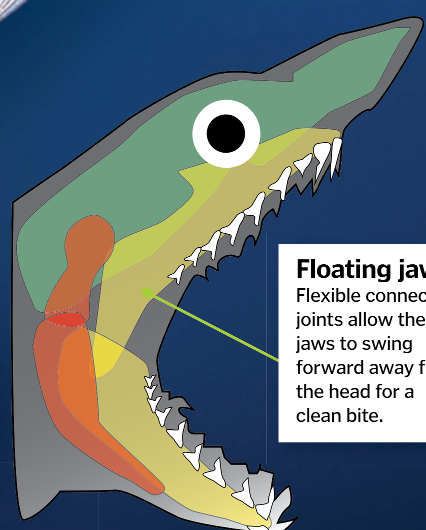


Gills
Some species of shark are able to 'pump' water over the gills for more oxygen.

Eyes
With eyes at either side of its head, a shark has near 360-degree vision.

Ampullae of Lorenzini
Tiny pores in the rostrum connect to nerves to detect electromagnetic pulses in the water.

Heart
Great whites have a huge volume of blood. This is pumped around the body by their two-chambered heart.



Floating jaw
Flexible connecting joints allow the jaws to swing forward away from the head for a clean bite.

Teeth
Arranged in rows, the shark's pointed and serrated teeth are continually replaced.

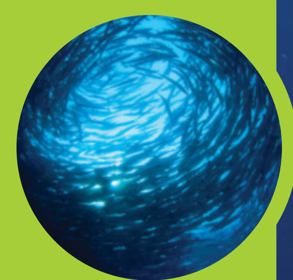
Shark menu

Great whites are known hunters, but what is the catch of the day?

Seals
The fatty blubber of these pinnipeds makes for a delicious and nutritious meal for mature great whites. They often attack from below to catch the seal unawares.

Cetaceans
If they are hungry enough, great white sharks will turn their razor-sharp teeth to many other marine mammals, hunting down dolphins and even small whales.

Fish
Some adult great white sharks may stick to eating a more juvenile type of diet, choosing to only feed on smaller fish and squid rather than hunting down large marine mammals.



Leftovers
Despite being skilled hunters, great whites will take a free meal. Individuals have been witnessed tucking into ocean carrion such as whale carcasses.

Great white teeth

The teeth of a great white shark are broadly triangular shaped, with serrated edges that come into play as the shark shakes its prey from side to side in order to take a bite. When tapered to an extreme point, these needle-like teeth are useful for impaling slippery prey like fish and blubbery seals.

Shark teeth routinely fall out and are replaced from rows growing behind the 'working' teeth

Sharks don't hunt people – we're not as nutritious as other prey

AMAZING SHARKS OF THE WORLD

Megamouth shark
This strange looking shark is a filter feeder. It has a blunt head with a very wide mouth for drawing in plankton-laden water. Apart from rising to the surface to feed, it is found in the deep waters of the Pacific, and is member of the mackerel shark group.

Far from being just a tropical fish, sharks have conquered a surprising array of habitats

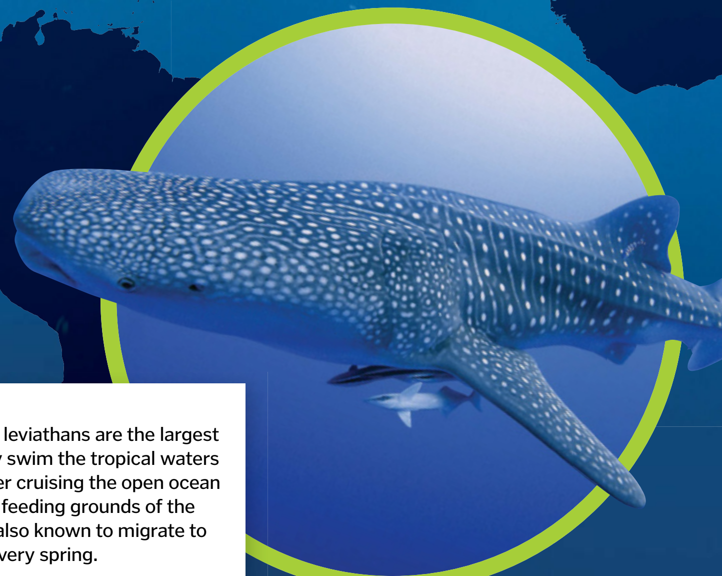
There are sharks in all oceans of the world. These predators are very adaptable – species such as the blue shark have made their home in deeper waters both cool and warm. At one end of the temperature chart, the tropical seas are home to species such as black-tipped reef sharks. Sharks inhabit both the shallows (such as the mighty hammerhead) and the deep ocean, which is the home of the curious cookie-cutter shark. There are even species like the bull shark that are known to swim in brackish, estuarine water.

Sharks of many varying species are also present throughout the water column, with some crossing open oceans, while others, such as the wobbegong, prefer to lurk on the seafloor and hunt for food. There are even migratory species – the hardy critters that cross entire ocean basins such as Nicole, the great white shark that was tracked swimming an incredible 11,100 kilometres in 99 days, from South Africa all the way to Australia!

"Thresher sharks execute a 'handbrake turn' to unleash their tail whip"

Sharks on the map

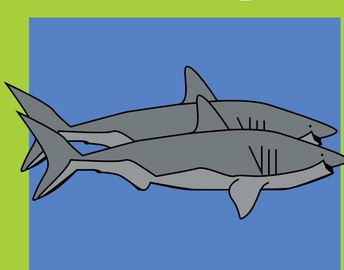
There are over 400 known shark species in the world. Here are just a few of them



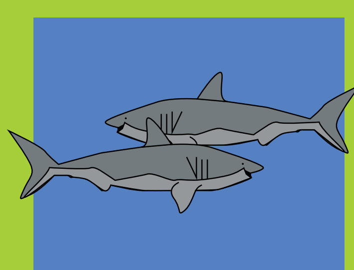
Whale shark
These filter-feeding leviathans are the largest fish in the sea. They swim the tropical waters of the equator, either cruising the open ocean or enjoying the rich feeding grounds of the shallows. They are also known to migrate to Australian waters every spring.

Shark signals

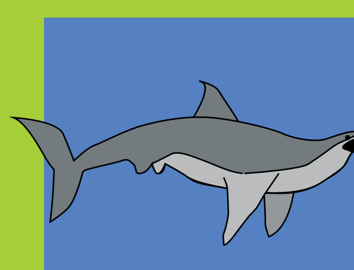
Here's how body language plays a key role in the lives of great whites



Parallel swimming
Swimming side by side can be a way of sizing up the competition and figuring out rank between sharks. The less dominant will swim away.



Swim-by
Sharks swim directly towards one another and pass close by. This behaviour may be used to identify the other shark and also to establish their rank.



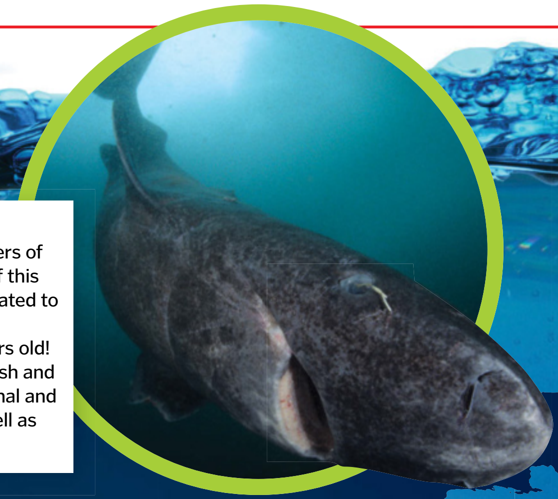
Hunch displays
When the shark hunches its dorsal fin, this is often seen as a confrontational sign to either attack or flee from a more dominant shark.

Arctic Ocean

Mediterranean Sea

Indian Ocean

Northern Australia and New Guinea

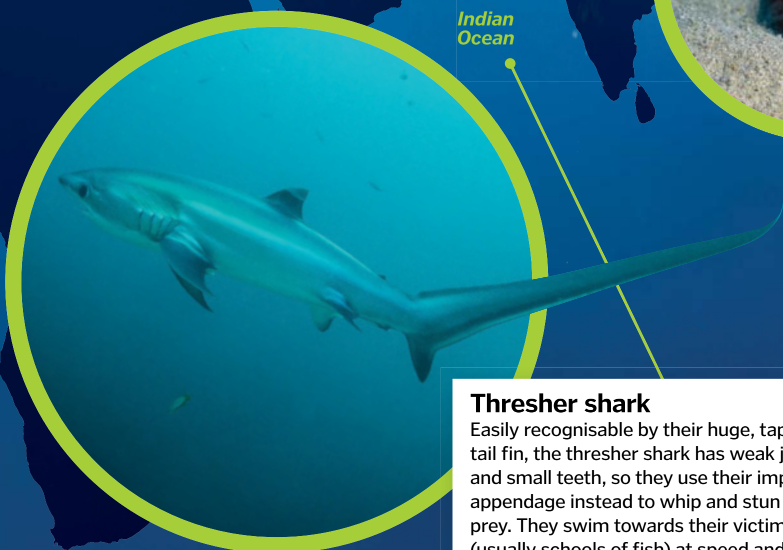


Greenland Shark
Swimming the cool, deep waters of the Arctic Ocean, a member of this extraordinary species is estimated to be the world's oldest living vertebrate, at almost 400 years old! This large shark is quite sluggish and so is believed to feed on narwhal and beluga whale carcasses, as well as hunting other fish.

This flattened, fancy-looking Australian shark has specially adapted jaws for feeding on the seafloor

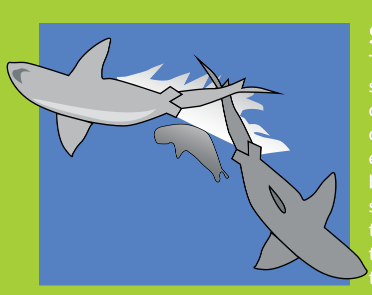
Atlantic sawtail catshark
This small shark measures around 45 centimetres long, and can be found lurking on the seabed of the Mediterranean and Northeast Atlantic coasts. Catsharks typically have an elongated, tapering body, and feed on fishes, squid, crustaceans and marine worms.

Speartooth shark
So called due to the sharp, spiky teeth that run along their lower jaw, the speartooth is one of the few sharks that live in brackish water. They cruise murky mangrove swamps and use the cover of the silty water to hunt for fish.

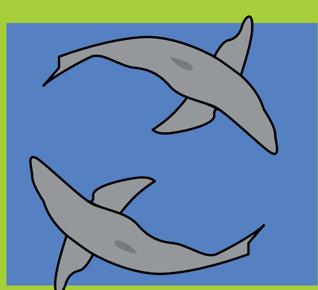


Thresher shark
Easily recognisable by their huge, tapered tail fin, the thresher shark has weak jaws and small teeth, so they use their impressive appendage instead to whip and stun their prey. They swim towards their victims (usually schools of fish) at speed and use pectoral fins to execute a 'handbrake turn' before unleashing the whip.

Bull sharks can adapt their ability to process salinity, allowing them to live in more freshwater habitats

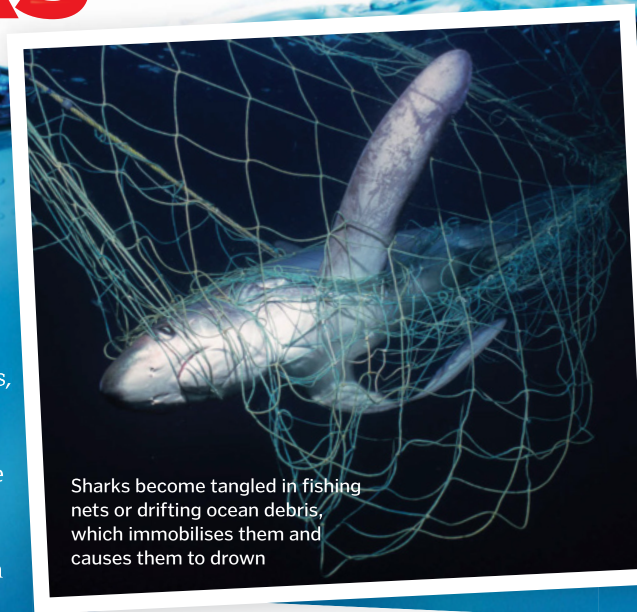


Splashing
This may be a stand-off to claim ownership of a kill. The executor of the biggest tail splash will win the right to claim the prey from their opponent.



Circling
Like the swim-by or parallel swim, the purpose of this behaviour could be to establish rank, or for the sharks to identify one another as friend or foe.

WHY ARE SHARKS IN DANGER?


Sharks become tangled in fishing nets or drifting ocean debris, which immobilises them and causes them to drown

Despite being ice-cold predators, sharks are under threat

Unfortunately, as is very often the case with endangered species, human activity is the biggest threat to many of the shark species in our oceans – it's thought that overfishing puts one-third of all oceanic shark species at risk of extinction. The main issues arise from both direct and indirect fisheries of these ocean creatures.

In 2014 it was estimated that a staggering 100 million sharks are removed from the ocean each year, mainly as a result of the demand for shark-fin soup. In many Asian countries this is considered a delicacy and can reach staggering prices of over $1,100 (£875) per kilogram of fin. As a result of this high demand for a luxury dish, illegal, unreported and unsustainable pirate fishing is a common occurrence and incredibly damaging to fragile shark populations.

Practices such as finning are exceptionally cruel, as fishermen illegally catch the sharks, de-fin them and toss them back into the ocean. The fin trade, where just two to five per cent of the shark is used, affects a huge range of shark species and is one of the biggest threats they face.

Sharks are also very susceptible to getting caught in the nets intended for other fish species, known as bycatch. Due to many sharks' need to have a constant flow of water over their gills, becoming ensnared in a net and unable to move means certain death by drowning for these creatures. If this shark is young and has not reached sexual maturity, not only has the ocean lost one shark, but also the potential for many more sharks is wiped out with it. As sharks are fished more and more, smaller specimens are being removed from the water and the species' chances of survival dwindle with the haul-out of every net.

Many fisheries don't report their bycatch of sharks, and this lack of data adds to the plight of shark species as researchers are not able to properly monitor both the fishery activity and the shark population. Pirate fishing causes the same problem. When sharks are illegaly removed from their ecosystem it's impossible to gauge their conservation status accurately, often before it is too late.


Researchers tag and monitor shark species to learn more about their biology and movements to aid conservation

Most endangered

These sharks are some of the most threatened shark types in the ocean

VULNERABLE

Porbeagle
This coastal-dwelling shark is found across the world, and is highly fished for its meat and fins. Illegal fishing, as well as finning and bycatch, are the main threats.

VULNERABLE

Basking shark
Previously hunted for their cartilage and liver oil, and now also targeted for their giant fins, the slow-growing and infrequent breeding nature of these sharks makes them very vulnerable and numbers have declined dramatically.

VULNERABLE

Oceanic whitetip
With their distinctive white-tipped dorsal fin, these sharks are fished for their fins and are very susceptible to being taken as bycatch. This species was reported to have significantly declined in at least one region.

ENDANGERED

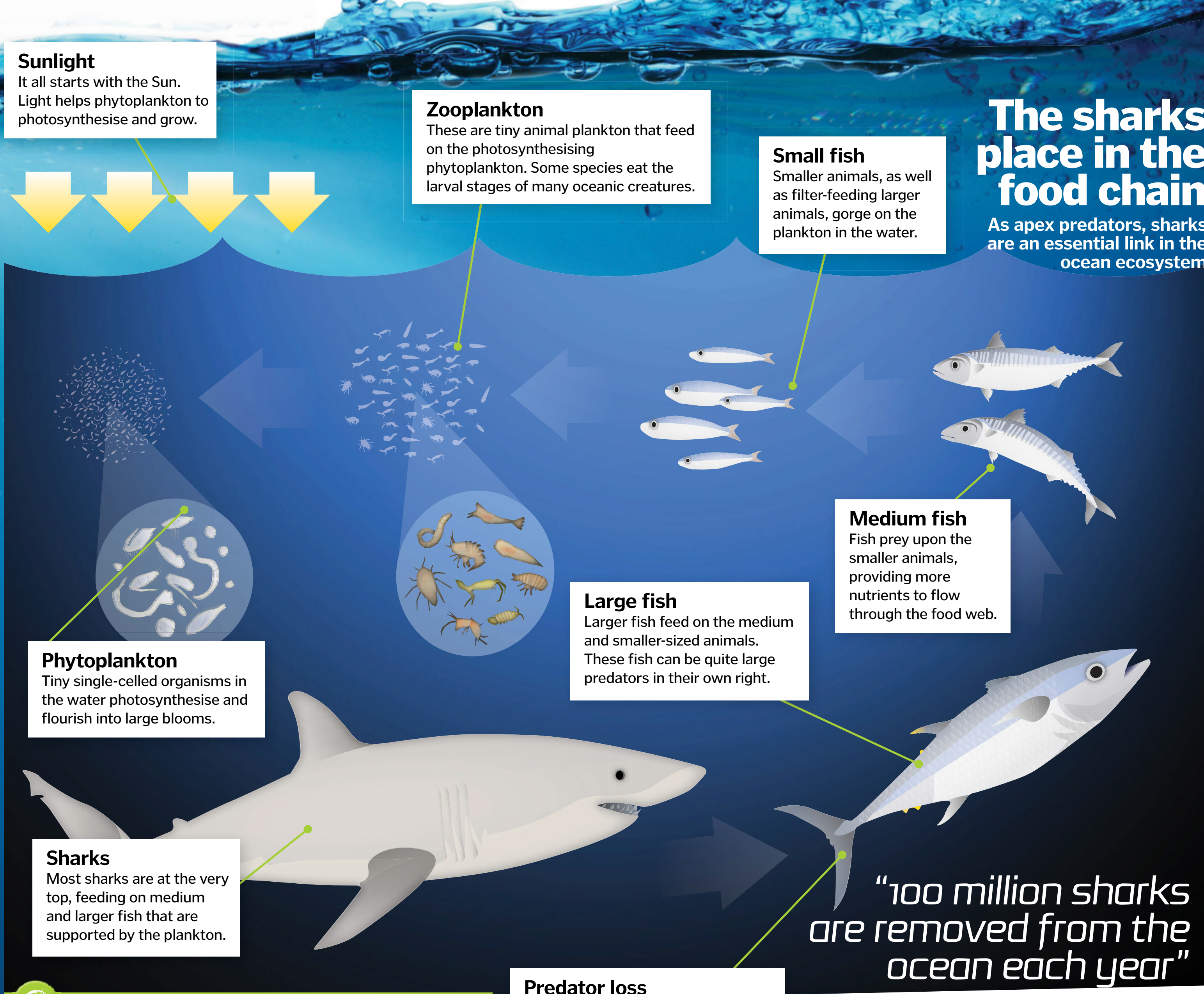
Scalloped hammerhead
This species' fins are highly valued in Asian markets and they are targeted heavily throughout their range of temperate and tropical seas. Fisheries are taking young and juvenile sharks, decimating population numbers.

ENDANGERED

Great hammerhead
These sharks are heavily fished as they have a high number of fins on their body, making them highly attractive to the shark-finning industry. They live in shallow coastal waters, making them vulnerable to becoming bycatch.

The sharks place in the food chain

As apex predators, sharks are an essential link in the ocean ecosystem



"100 million sharks are removed from the ocean each year"

Learn more

To find out more about sharks and other amazing marine creatures, get your copy of the World of Animals' *Book Of Sharks & Ocean Predators* special edition bookazine. Available to buy or download now from **www.imagine-shop.co.uk** and **www.greatdigitalmags.com**

Close encounters with sharks can prove that they're not human hunters and they need our protection

What you can do

There are various things you can do to help save shark species across the world. To learn more about the challenge facing sharks, you can watch documentaries such as *Sharkwater*, which shows the real extent of the issues.

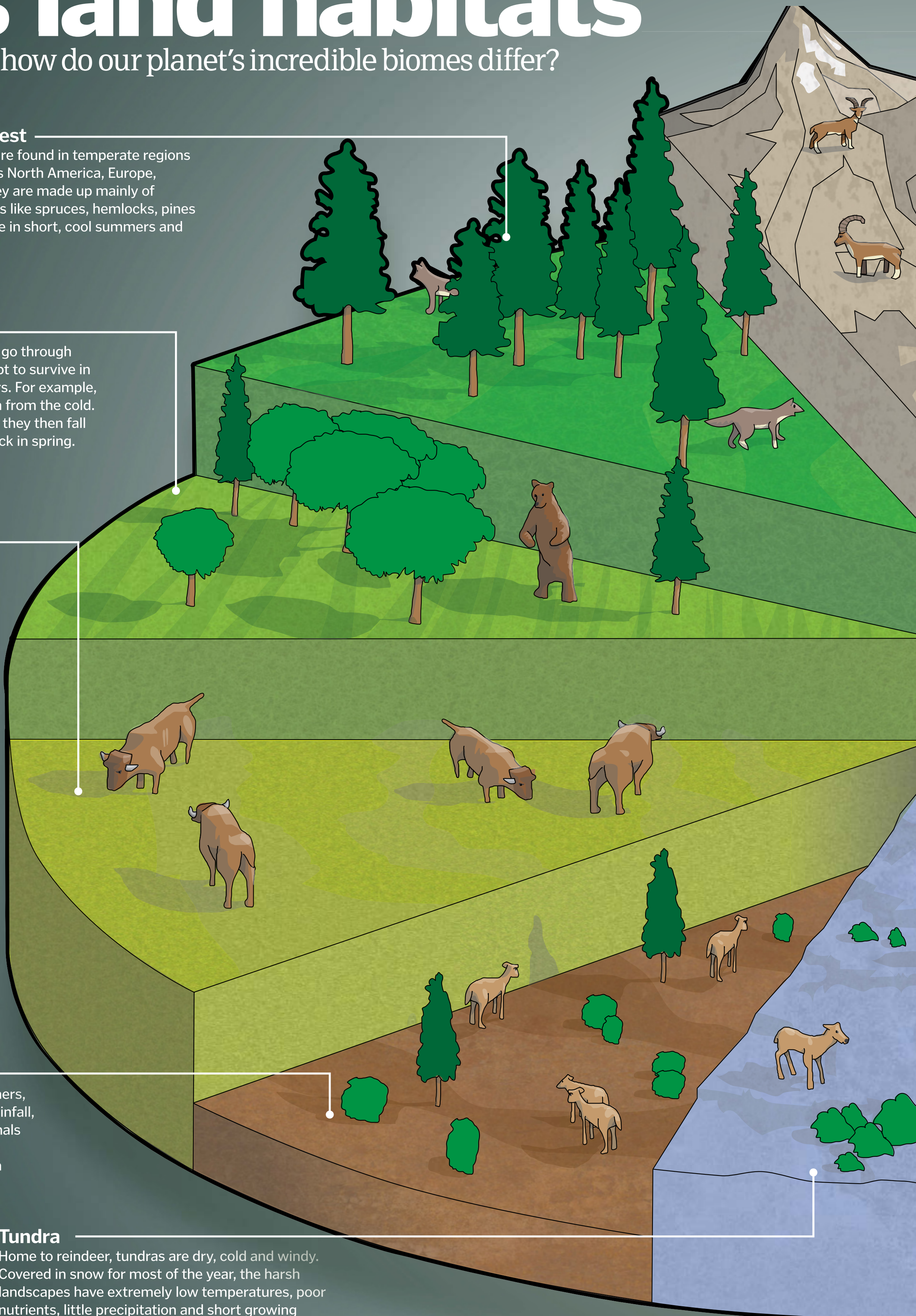
Another key action is to help to raise awareness – you can do anything from fundraising to public speaking to get as many people as possible interested. If you live in a country where shark-fin soup is a delicacy, stop eating it and avoid restaurants that serve it. You can even write to the authorities to demand the sale or importation of shark fins is stopped. The more people that speak up and show their support the better the situation will be for sharks.

You can also help sharks by taking a trip to see them – responsible tourism really helps because the more people that go to see sharks and realise that they need our help, the better the chance that the sharks have to survive.

It's also important to support shark conservation charities through fundraising, or even by adopting sharks and contributing towards the essential research and conservation projects that these organisations undertake. Check out WWF, The Shark Trust and Bite Back for more details.

Earth's land habitats

From climate to wildlife, how do our planet's incredible biomes differ?



Coniferous forest

Coniferous forests are found in temperate regions of the world, such as North America, Europe, Russia and Asia. They are made up mainly of evergreen cone trees like spruces, hemlocks, pines and firs, which thrive in short, cool summers and long, harsh winters.

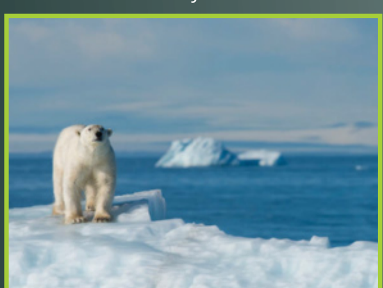
Deciduous forest

Deciduous forests exist in areas that go through four distinct seasons, so wildlife adapt to survive in both warm summers and cold winters. For example, trees have thick bark to protect them from the cold. In autumn, the leaves change colour; they then fall from the trees in winter and grow back in spring.

Temperate grassland

Lacking in trees and shrubs, the dry grasslands of Africa (veldts), North America (prairies), South America (pampas) and Eurasia (steppes) have nutrient-rich soils that are ideal for grazing animals. Although home to many animals, such as bison and antelope, there is little diversity in terms of wildlife.

Polar ice habitats are covered in ice for most of the year

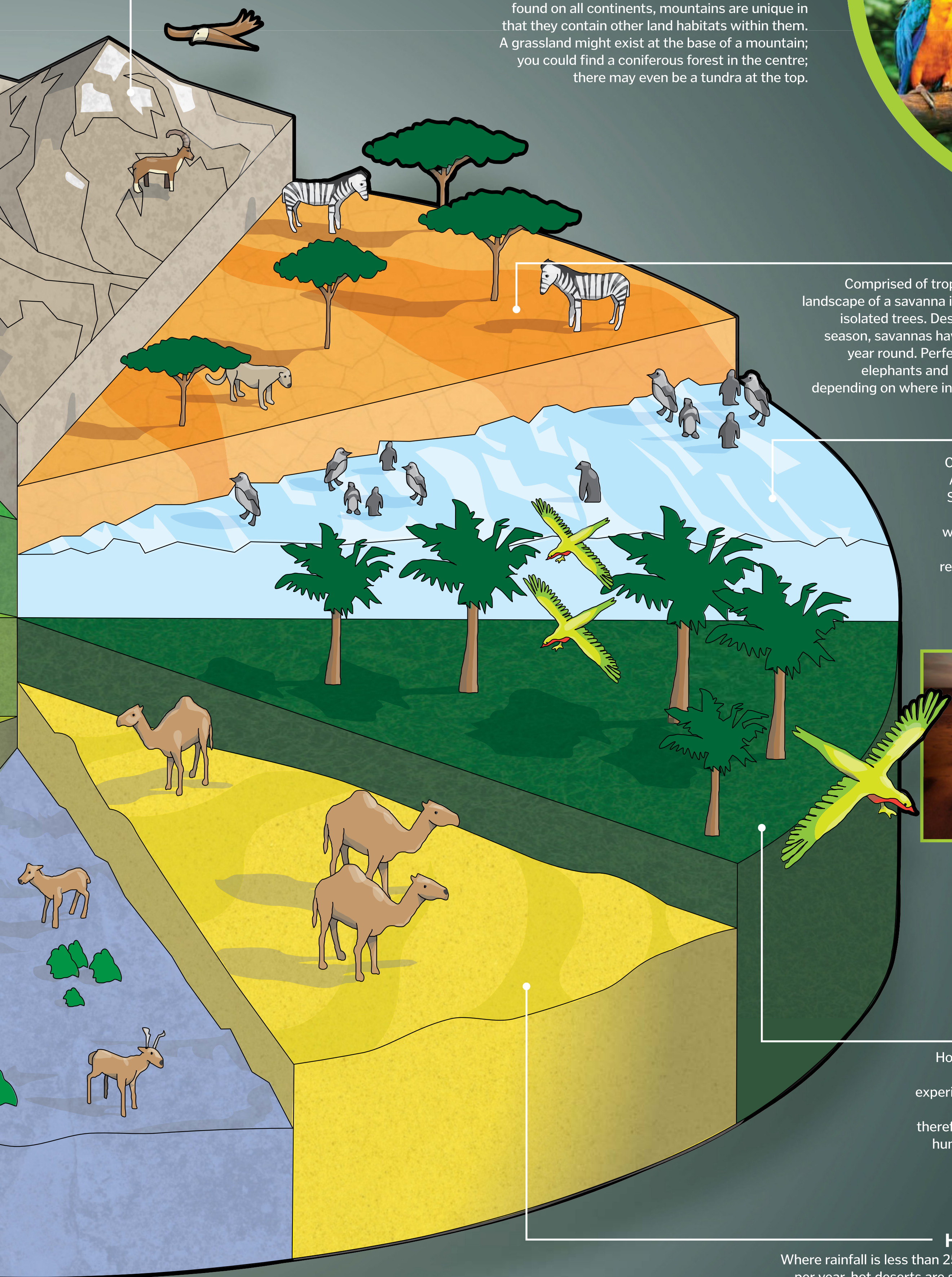


Mediterranean

Mediterranean habitats have hot and dry summers, but cool and moist winters. Experiencing low rainfall, but still more than in desert regions, many animals and plants have adapted to survive in these conditions. These ecosystems are teeming with insect species, and home to plants that have adapted to conserve water.

Tundra

Home to reindeer, tundras are dry, cold and windy. Covered in snow for most of the year, the harsh landscapes have extremely low temperatures, poor nutrients, little precipitation and short growing seasons. The few plants and animals that live there are well adapted to the long, cold winters, though.



Mountain

Rising above the surrounding landscape and found on all continents, mountains are unique in that they contain other land habitats within them. A grassland might exist at the base of a mountain; you could find a coniferous forest in the centre; there may even be a tundra at the top.

Savanna

Comprised of tropical grasslands, the open landscape of a savanna is littered with shrubs and isolated trees. Despite having a wet and dry season, savannas have warm temperatures all year round. Perfect for herbivores, such as elephants and zebras, animal types vary depending on where in the world the savanna is.

Polar ice

Covered in ice for most of the year, the Arctic and Antarctica in the North and South Poles are the coldest regions on Earth. Marine animals populate the waters, while polar bears and penguins live on land, in the north and south respectively. The only plant life is algae.

There is little in the way of biodiversity in the desert

Tropical rainforest

Home to more animal and plant life than any other habitat, tropical rainforests experience a constant hot temperature and high rainfall. Near to the equator and therefore exposed to plenty of sunlight, the humidity and dense vegetation provide a unique water and nutrient cycle.

Hot desert

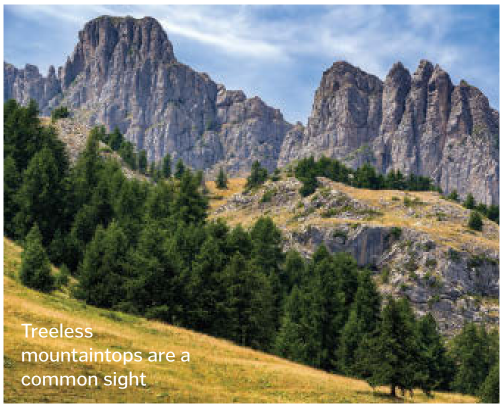
Where rainfall is less than 25 centimetres per year, hot deserts are so dry that it's difficult for plant life to grow. Reaching temperatures of up to 50 degrees Celsius during the day but turning very cold at night, there is a low level of biodiversity.

Tree lines

The clear divide in the landscape where tree growth comes to a sudden halt

Many sweeping mountain landscapes are marked with an interesting feature that often goes unnoticed. A clear, distinct line often separates the dense forest of trees that grow in abundance on the slopes and the near-lifeless barren landscape near the peaks. And interestingly, the 'tree line phenomenon' is still something of a mystery.

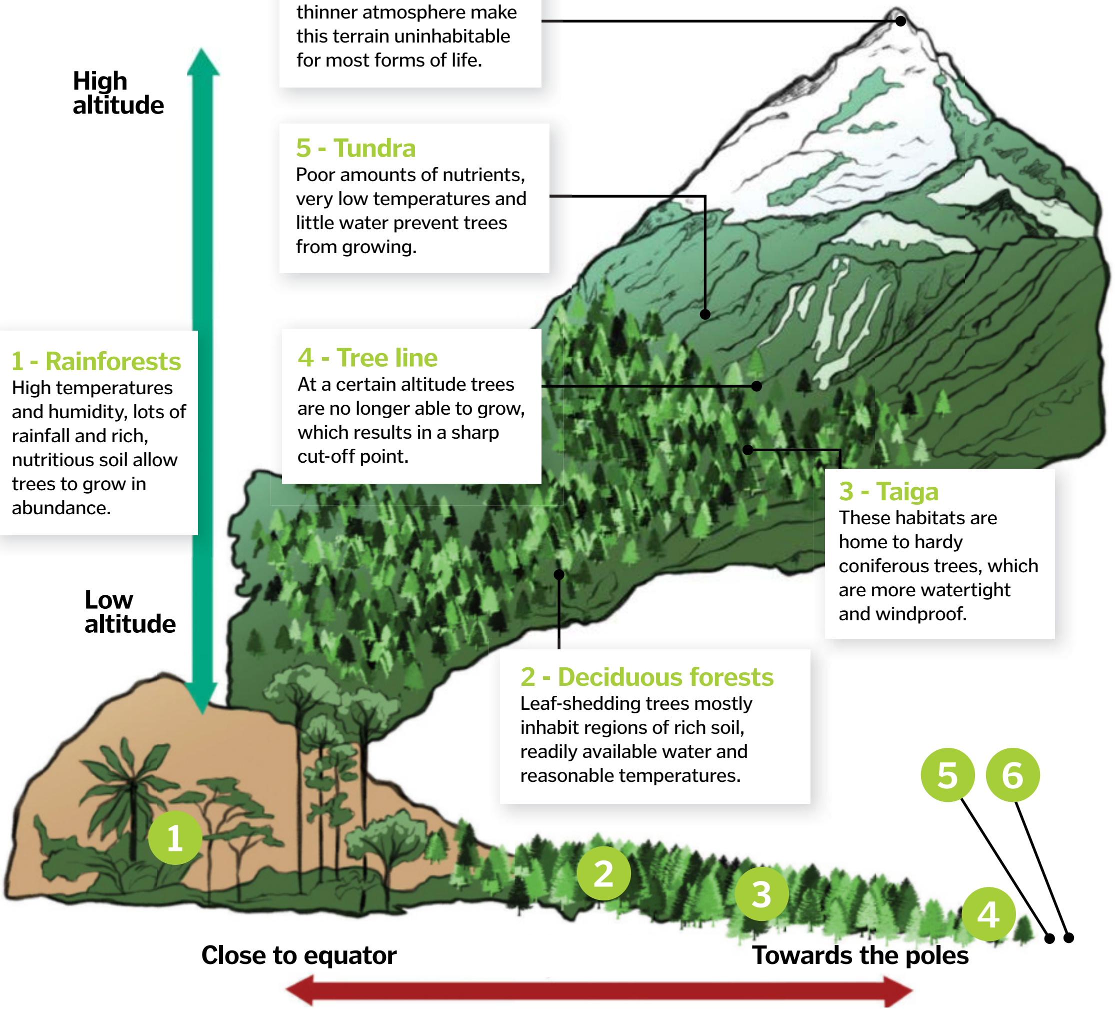
However, a popular theory describes temperature as the major factor, rather than altitude. The cold climate at these heights is thought to damage cells, impact carbon balance and inhibit the growth of young trees. And because of the proximity of the trees looming over their offspring from just below, the Sun's rays are blocked from reaching the soil and warming it.



Treeless mountaintops are a common sight

An abrupt stop

At high altitudes, even the most robust types of trees are unable to grow



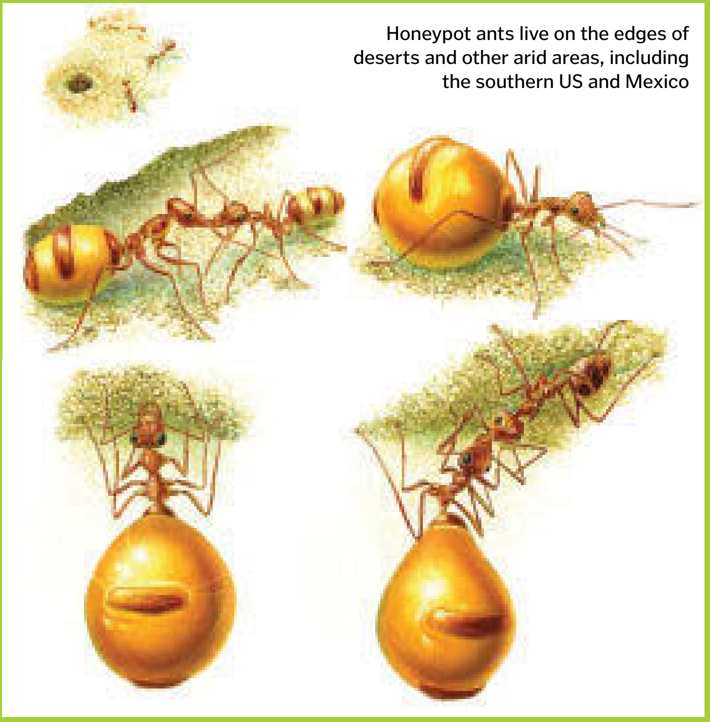
Honeypot ants

When supplies run low, some species of ant store huge amounts of food in their abdomens

During the dry season, honeypot ants are hard-pressed to find enough food to feed the colony. To combat potential starvation, species in the Myrmecocystus genus purposely overfeed a selection of workers with 'nectar' from flowers, fluids and fats from prey. This is done during the rainy season when food is plentiful. The bloated ants become so full of the vibrant honey-coloured fluid that they are unable to leave the nest. They are called repletes, and simply hang motionless from the top of tunnels, their abdomens swollen to the size of a grape.

When food reserves begin to dwindle, the nectar is drained from the ant by another worker, who strokes the replete's antennae to initiate regurgitation of the foodstuff.

To allow their abdomens to expand to such large sizes, honeypot ants have a different molecular structure in their cuticle to others of their kind. They are more soft and flexible, which weakens their exoskeletons slightly and decreases their chances against hungry predators. Other ants will even try and invade the colony to claim the nutrients and energy from the tasty nectar for themselves.



Honeypot ants live on the edges of deserts and other arid areas, including the southern US and Mexico

Can plants communicate?

Discover the secret signals plants send to each other on the wood wide web

Plants can warn each other about invasions of destructive insects, such as aphids

Just as we have many different methods for staying in touch with friends, plants have their own ways of communicating with each other. The main purpose for this is to help each other out, warning nearby plants of approaching dangers, such as insects, infections or drought, so that they can take appropriate action.

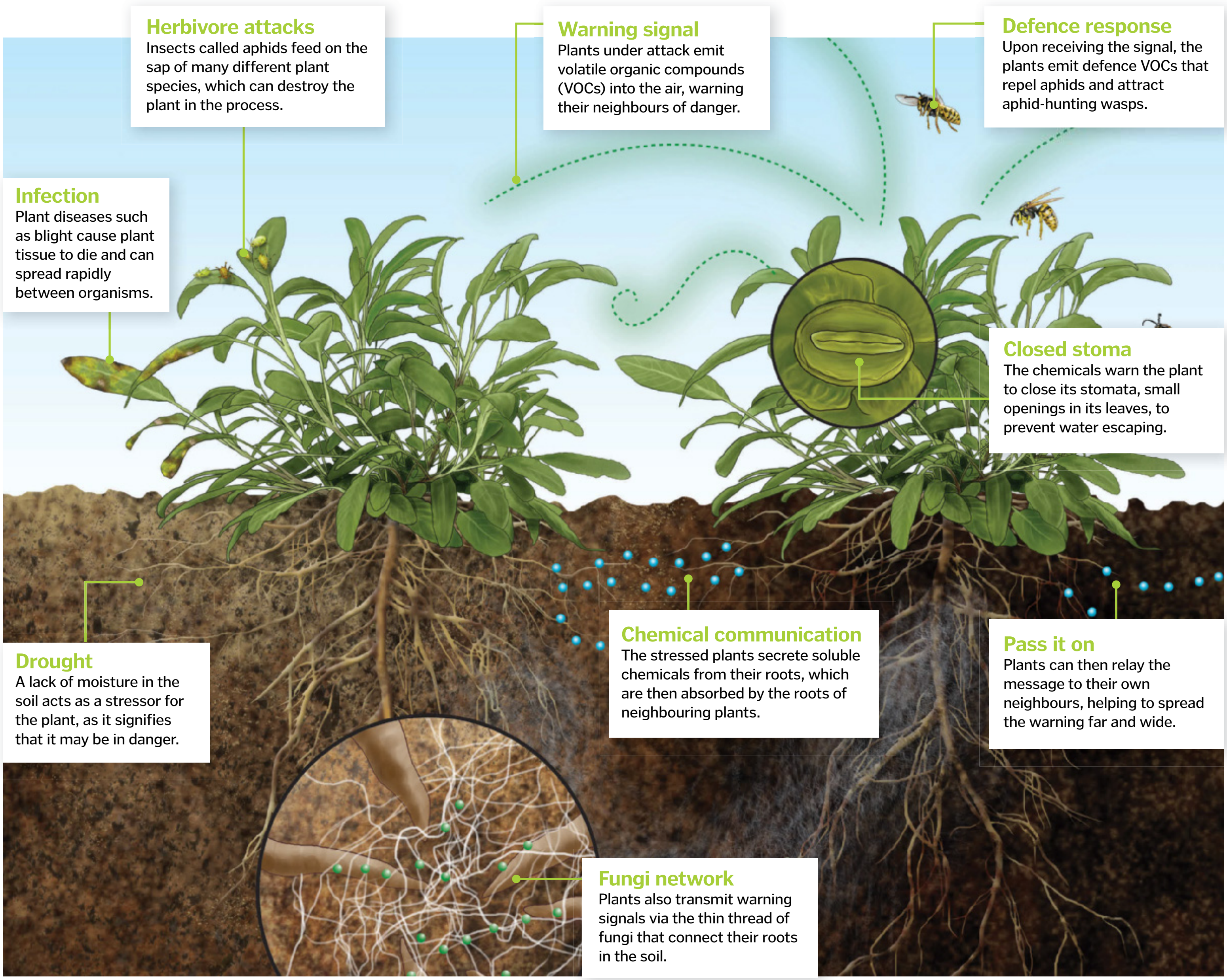
One method they use to do this is to emit invisible volatile organic compounds (VOCs) into the air. Other plants can then detect these compounds and know to defend themselves, or signal for help. Another method is below ground, and enlists the help of fungi. Beneath the mushrooms on the surface is a mass of thin threads called mycelium. These threads link the roots of different plants, allowing them to transfer compounds and communicate a specific message.

The final way plants talk to each other is by secreting chemicals through their roots, which diffuse through the soil and are picked up by other plants, alerting them to danger.

This complex plant communication network has been named the 'wood wide web' by biologists, but like our own version of the internet, it has a dark side. Some plants use mycelium to steal carbon from each other, while others use it as a method of attack, delivering toxic chemicals along the fungal threads to inhibit the growth of their competition.

The internet of plants

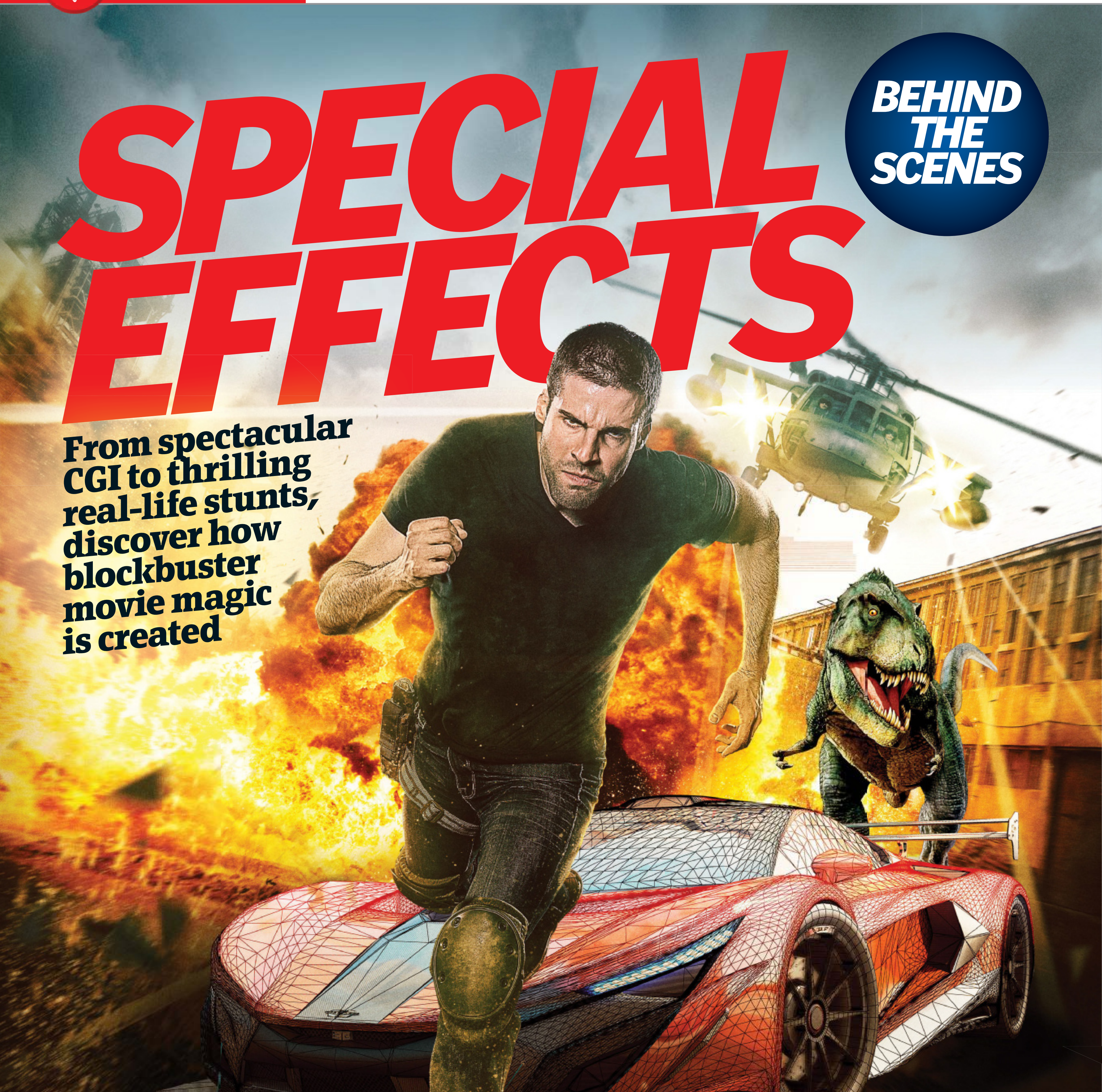
How do plants warn each other of impending dangers?



SPECIAL EFFECTS

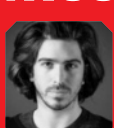
BEHIND THE SCENES

From spectacular CGI to thrilling real-life stunts, discover how blockbuster movie magic is created



Meet the experts

Some of the biggest names in special effects reveal their secrets



Alexis Wajsbrot
CG supervisor at Framestore
Alexis has delivered stunning CGI effects for movies such as *Edge Of Tomorrow*, *Iron Man 3* and *Gravity*, and recently worked his magic for Marvel's *Dr Strange*.

Chris Corbould OBE
Special effects supervisor
From Batman to Bond, Chris has created amazing stunts and explosions for several blockbusters. He won an Oscar for his work on *Inception*, and has an OBE for his services to film.

Mike Stringer
Prosthetic artist and director at Hybrid FX
Mike's company transforms actors using prosthetics and make-up. His credits include many TV shows and movies such as *Mad Max: Fury Road* and *Lord Of The Rings*.

TO READ THE INTERVIEWS IN FULL, HEAD TO WWW.HOWITWORKSDAILY.COM

CGI MAGIC

Creating digital effects that are out of this world

Computer-generated imagery (CGI) has made the impossible possible in movies, from creating fictional creatures and locations, to replicas of animals or outer space. Recent spell-binding examples of this digital wizardry can be found in superhero blockbuster *Dr Strange*, the latest instalment from the Marvel Cinematic Universe. In the movie, surgeon turned sorcerer Stephen Strange learns the mystic arts and travels to other shape-shifting dimensions, so a lot of CGI was needed. The person in charge of the digital effects was CG supervisor Alexis Wajsbrot, who led a team of over 120 people at creative studio Framestore to deliver 350 separate shots for the movie.

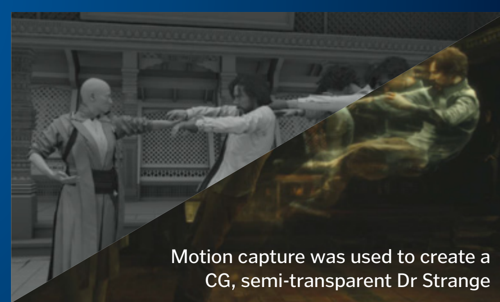
"We have modellers, animators, lighters, riggers, lots of different departments, and as CG supervisor I connect them all together so that we can deliver images to the VFX supervisor for artistic comment," explains Wajsbrot.

Wajsbrot and his team worked on the project for a year, creating 20 different effects. "It was a huge challenge for us because it was the first *Dr Strange* movie, so we had to work out how everything was supposed to look," says Wajsbrot. "It's also such a magical movie, so all of the effects are very subjective. We had to invent a visual language that's going to be reused in *Dr Strange 2* and in *Avengers*."

Astral projection was one of the most complex effects to create. This is when Dr Strange exists in the astral plane, becoming semi-transparent and able to fly through objects. "It required a lot of detail to make the effect subtle, so you can see the presence of the character, but also convey that it's not the normal Strange, he is now in his astral form," says Wajsbrot. Work to create the effect began on set, with motion capture and aerial stunts used to record Benedict Cumberbatch's facial expressions and movements and then apply them to a virtual puppet of Dr Strange. The next challenge was lighting the shot. "When they are in astral mode, the characters are supposed to be emitting light," explains Wajsbrot. "This meant we had to model the whole room, which was a hospital operating theatre for that scene, in an incredible amount of detail, and track each prop to light it from the character."

Thanks to advances in technology, Alexis and his team were able to create these incredible never-before-seen effects in stunning detail, but he believes there is still room for improvement. "On Dr Strange we animated cool and complicated effects that we were not able to do a few years back. Now the challenge is to do them faster and faster as well as better."


Dr Strange's magical shields were created using CGI in post-production


Motion capture was used to create a CG, semi-transparent Dr Strange


The spinning corridor scene required a CG model of the set

Creating a portal

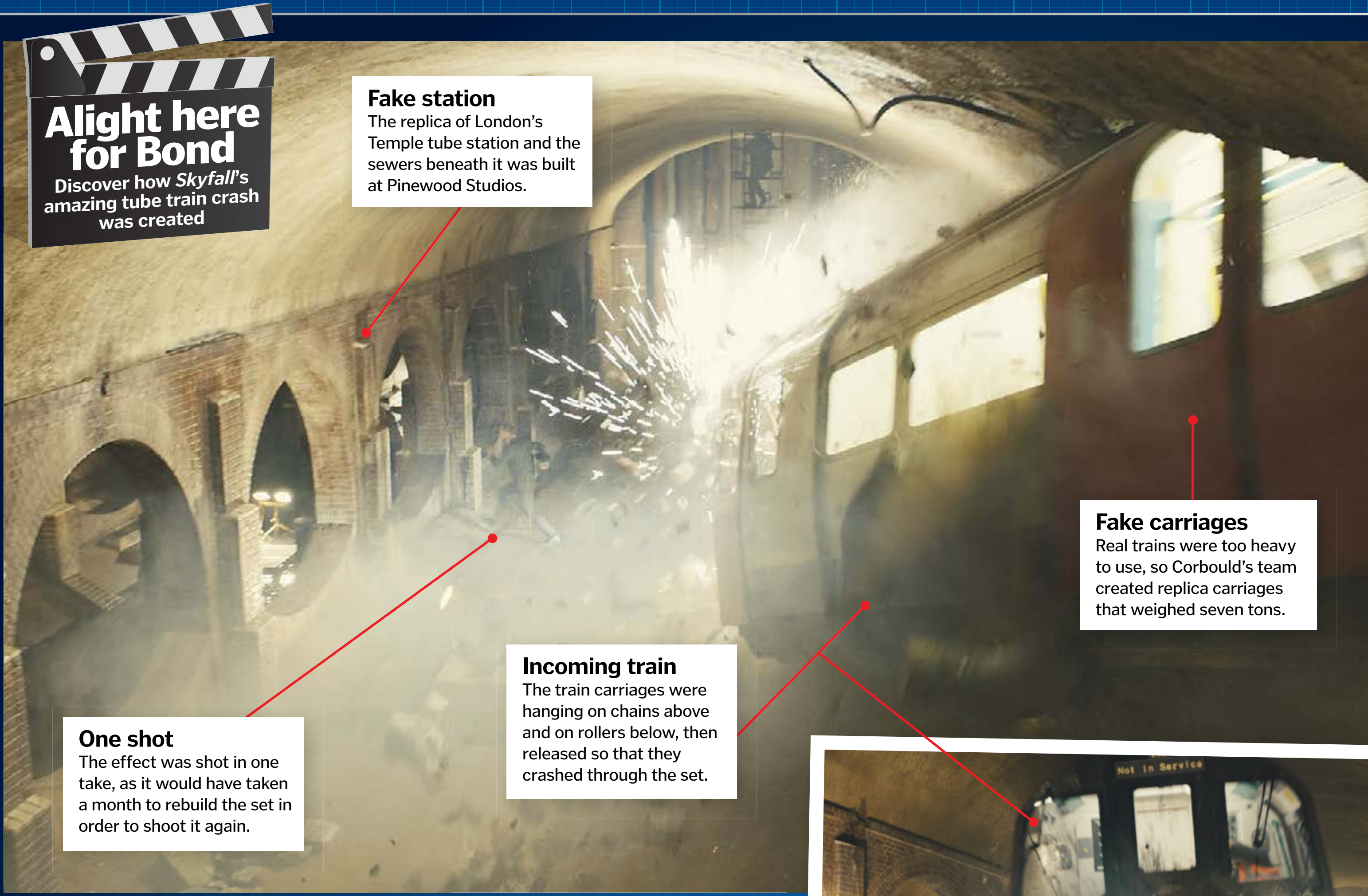
The real-life magic behind Dr Strange's gateway to other dimensions

LED lights
On set, the portal is created using a ring of LEDs which helps to light the scene.

Green screen
For this shot, Dr Strange's world is entirely CGI, so a green screen is used as his backdrop.

3D animation
Animators add in the sparks in post-production, controlling their length, curvature and intensity.

Finished effect
Finally the CGI and real-time footage is layered together to create the final shot.



PHYSICAL EFFECTS

When high-speed car chases and fiery explosions are all in a day's work

While CGI can make spectacular effects much easier, cheaper and safer to create, some directors, such as Sam Mendes and Christopher Nolan, prefer to use as many practical effects in their movies as possible. For this, they enlist the help and expertise of a special effects supervisor, such as Oscar and BAFTA winner Chris Corbould.

After getting his big break at the age of 16 when he was tasked with opening 500 gallons of tinned baked beans for a stunt on the movie *Tommy*, Carbould has gone on to create awe-inspiring and record-breaking effects for huge movies, including the James Bond, Batman and *Star Wars* franchises.

Where do you start when taking on a new movie project?

First the script is broken down into sequences and then discussed by all major heads of department. During these meetings the director will outline his vision for the film, after which all departments will contribute ideas to achieve this vision.

The next phase is where we design, build, test and video each component of the sequence. It might be a series of explosions as seen in *Spectre*, or it might be a complex mechanical rig such as the sinking hotel in *Casino Royale*. All aspects of the process are videoed and shown to the director for comment. I would say that testing makes up about 50 per cent of our entire workload. Sometimes we will test the same effect 20 times to establish safety parameters along with achieving the highest spectacle.

A major part of our job involves engineering, starting at the CAD (computer-aided design) phase through to the machining, welding and commissioning of each rig.

What's involved in filming these sequences?

Filming all the components that you have been testing over the previous months may involve shipping them all over the world to different locations. On *Spectre* we filmed in Austria, Mexico, Morocco and Italy, so the logistics of making sure that the right equipment and manpower is sent to the right location at the right time is immense. At one stage I had workshops and crew spread over all four locations, as well as preparing major sequences in the UK film studios. The filming period can vary between six weeks on small films to 28 weeks on large blockbusters.

How did you achieve the Rome car chase in the film *Spectre*?

We had eight Aston Martins and four Jaguars all specially constructed for the film. The vehicles were tested almost to complete destruction by the stunt department to discover any weak links. We also had to consider that we were filming the movie in a 2,000-year-old city that cherishes its ancient architecture and would not take very kindly to a car hitting any part of it at high speed.

The stunt cars were adapted with roll cages, safety fuel tanks, hydraulic handbrakes, racing harnesses and much more. In addition, we might have cars with a remote driving pod mounted on the roof, giving the illusion that the actor is driving at high speed while in fact being driven by a stunt performer from the roof. Also, there may be a requirement for a car to crash into static objects. This is usually achieved by taking the engine and all unnecessary weight out and then mounting a steel tube inside. This tube forms a piston, which can then be fired from a static nitrogen reservoir at speed.

The chase itself is a logistical nightmare, with large parts of the city locked off to ensure that nobody walks out their front door into the path of a speeding Jaguar.

How did you go about creating the movie's record-breaking explosion in the Moroccan desert?
We tested approximately 15 different explosion looks that would be multiplied and linked together to form one travelling explosion. The wiring of the ignition system is a crucial part of the operation and must be carried out slowly and methodically. On this occasion we used a system of computerised detonators whereby

"It could have been disastrous had Daniel Craig not got the line right"

each detonator is programmed to go off at a certain time. The only downside is that there is a three-second delay after pressing the button before the sequence starts initiating. This meant that we were pressing the button half way through a line of Daniel Craig's dialogue, which could have been disastrous had Daniel not got the line right. However, Daniel is a true professional and nailed the dialogue.

How has your role changed over the years?
The technology has changed immensely. We can now control hydraulics, pneumatics, winches and ignition systems using computers, while in my early years it was all controlled by people pulling levers and pressing buttons. Computers give us consistency, repeatability and a high degree of accuracy, which in turn means greater safety and financial economy.

What are the benefits of physical effects?
The benefits of practical effects are clear when you are actually watching reality. On *The Dark Knight* we somersaulted a huge articulated truck. The reaction on the day was incredible.

For interior driving shots, David Bautista's Jaguar C-X75 in *Spectre* was actually being driven by a stunt man on the roof

Spectre used 8,418 litres of fuel and 33 kilograms of explosives to make cinema's largest explosion ever

Corbould's team built a massive model of Venice's Hotel Danielli in a giant water tank for *Casino Royale*

For *The World Is Not Enough*, Corbould fitted a helicopter with sawblades that slices through Pierce Brosnan's BMW Z8

PERFECT PROSTHETICS

The painstaking moulding, sculpting and gluing behind some of the greatest movie transformations

> *"Transforming an actor into an entirely new character still takes a long time"*

When you see a fictional character from a fantasy world on screen, they've not necessarily been created on a computer. All those hard-working movie actors aren't out of a job just yet, as instead of being made redundant they're being made unrecognisable by prosthetics artists and a whole lot of silicone.

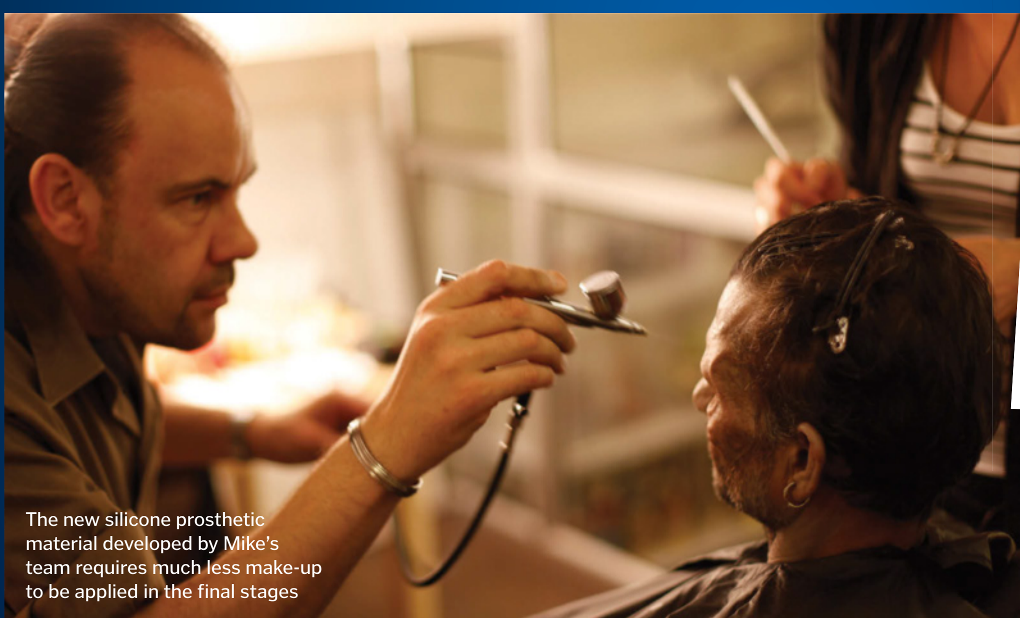
From their UK studio, Mike Stringer and his team at Hybrid FX have transformed the young into the old, the living into the undead, and the human into a dwarf warrior from Middle Earth. In fact, they've even transformed the entire prosthetics industry. Before the movie *The Lord Of The Rings: The Two Towers* was released, the typical material of choice for making prosthetics was soft, squishy foam latex.

However, after Hybrid FX used their newly developed and more flesh-like silicone to create the face of Gimli the dwarf, everyone began using a version of their revolutionary new material for other movies.

That's not the only new technology that has changed the industry though. "3D scanning is very helpful, particularly for full body casts," explains Stringer. "Instead of having to mould someone's whole body, which takes hours and is messy and uncomfortable for everyone involved, the client can simply wear a skin-tight suit and be scanned in five minutes." An accurate model of their body is then cut from rigid foam, ready to be used as a base for sculpting the prosthetics.

Although this has sped up part of the process, transforming an actor into an entirely new character still takes a long time. Prosthetics can take several weeks to create, and then there's the matter of applying them and removing them. "The application time for a full face character like Gimli the dwarf is around three hours or more," says Stringer. "Removal time is also painstaking and needs at least 30 minutes, as the materials cannot simply be ripped off the skin. If they came off that easily, they wouldn't stay on reliably for a whole shooting day of eight hours or more."

That's not the longest time the Hybrid FX team have spent applying a prosthetic though. When working on the 2003 horror movie *Creep*, it took them seven hours every day to transform actor Sean Harris into a hideously deformed killer. "We started at midnight and would be ready for when the crew turned up for the shoot at 7am," Stringer explains.



The new silicone prosthetic material developed by Mike's team requires much less make-up to be applied in the final stages

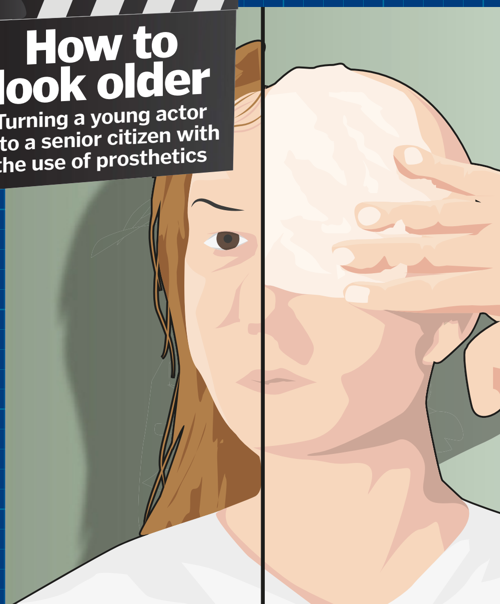
Mike says the secret to creating a gruesome zombie look is often having a good actor underneath

Hybrid FX created Gimli the dwarf's facial prosthetics for the second and third *Lord Of The Rings* movies

Mike transformed actress Ingrid Pitt into the leprous character The Sybil for the 2006 horror movie *Minotaur*

How to look older

Turning a young actor into a senior citizen with the use of prosthetics



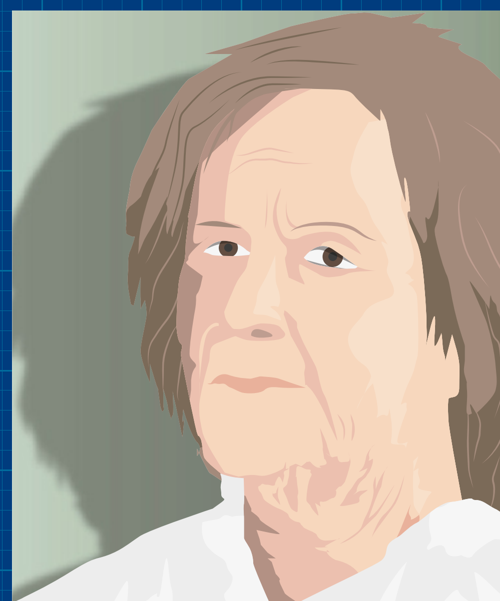
1 Make an impression
The actor's face is covered in alginate, a material usually used to make impressions of teeth, then wet plaster bandages.

2 Sculpt a mask
Once hardened, the material is removed and lined with plaster, which hardens into a mask. A layer of plasticine is added and sculpted with wrinkles.

3 Make moulds
The plasticine mask is cut into sections and a thin plaster impression is made of each piece. These are covered in plaster to create positive moulds.

4 Pour in gelatine
The plasticine sections are placed on the moulds and covered in more plaster, creating negative moulds. Hot gelatine is then poured inside.

5 Glue in place
The gelatine hardens to form flexible prosthetic pieces. Eyebrows are threaded in before the masks are applied to the actor's face using surgical glue.



6 Add finishing touches
Make up is applied to the prosthetic to create age spots and accentuate the wrinkles. Finally, a grey wig is added.

> *"The actor's face is covered in alginate, a material used to make impressions of teeth"*

Creating sound effects

Many of the noises you hear in movies weren't actually recorded on set. This may be because the sound wasn't made in the first place, such as the hum of a lightsabre, or because it was obscured by background noise and couldn't be used. Instead, the sounds are recorded later by foley artists in a recording studio. They act out entire scenes of the movie to capture the noise of footsteps and clothes swishing before synchronising the track with the picture. When it comes to creating fictional noises, their work often requires the use of some unusual props. For example, if a scene features someone's head hitting the ground, a frozen lettuce is thrown on the floor to create the desired sound effect.

Strange props
A frozen lettuce can be used to create bone or head injury sound effects.

Foley artists use props in order to produce realistic sound effects for movies

AMAZING ANIMATRONICS

The advanced robotics behind some of our best loved, and most feared, movie characters

When movies such as *Alien*, *Jaws* and *ET* hit the big screen, computer-generated effects weren't quite up to scratch when it came to bringing nonhuman characters to life. Instead, real-life robotic versions of the characters were built, with complex engineering and incredible artistry required.

However, even now, when it's possible to make virtual characters more realistic than ever before, some directors and special effects technicians still opt for animatronics. For example, many of the nonhuman characters in the recent *Star Wars* movie, *The Force Awakens*, were in fact real-life moving robots, including BB-8. The reason many give for using this technique is that they prefer having the character present on set, instead of adding them in later. Some also argue that actors are able to give a better performance if the character is there to interact with and react to.

One of the most groundbreaking examples of movie animatronics was the T-Rex in *Jurassic Park*. While many of the dinosaur's running shots were created using CGI, the close-ups were all of a full-size, life-like robot that stood at seven metres tall and weighed over 4,000 kilograms. An animatronic of that size had never been created for a movie before, and it had to be much stronger and more believable than any theme park robots.

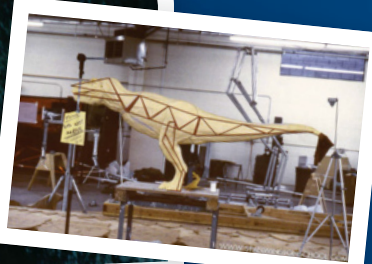
The T-Rex was originally intended to be a human-operated puppet, with large rods used to move the head, tail and limbs. However, it soon became apparent that it would be too big for any human to be able to create the movements fast enough to make them realistic. Electric motors wouldn't be quick enough either, so in the end hydraulics were used.

The finished robot was so big that the ceiling of the workshop where it was built had to be raised by almost four metres, and its base had to be anchored into the ground to stop it toppling over. It was dangerous too, as while gluing its skin in place from the inside, one of the crew got trapped in its belly when a power cut caused it to move. His colleagues had to prize open the jaws to pull him to safety.

> "An animatronic of that size had never been created for a movie before"

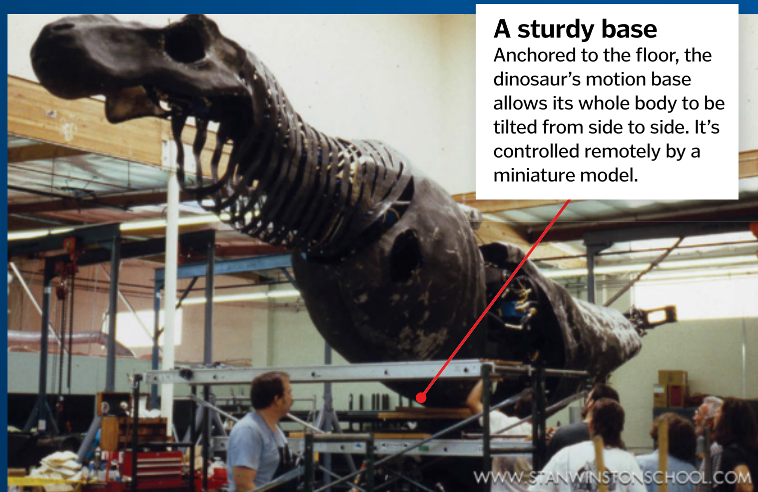
Building a T-Rex

Discover how *Jurassic Park*'s fearsome villain was brought to life

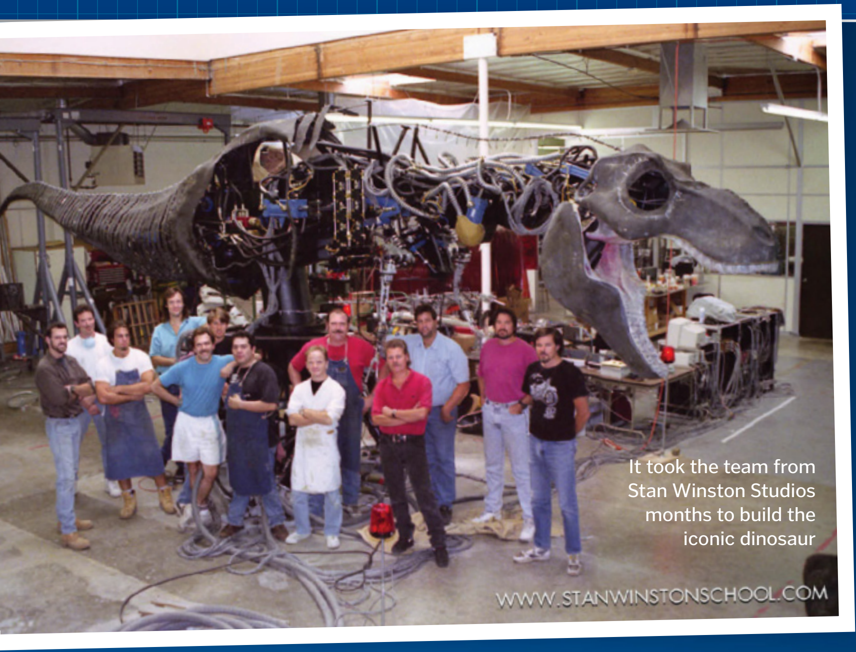


1 A metal skeleton
A fifth scale model of the T-Rex is sliced into pieces then each slice is scaled up and cut from wood. These wooden slices are then slotted onto a metal frame.

2 Sculpting the body
The main frame is covered in chicken wire and fibreglass, then a layer of clay. The clay is sculpted to look like T-Rex scales, and serves as a mould for the skin.



3 Mechanic movements
Alongside the sculpted T-Rex, a moving model is made. A steel frame fitted with hydraulics creates the T-Rex's movements at a speed of two metres per second.



It took the team from Stan Winston Studios months to build the iconic dinosaur

4 Secure the skin

Moulded from the original sculpture, the skin is pulled over a carbon fibre frame around the hydraulics. Made from foam and latex, it's stitched and glued in place.

5 Check mobility

Each possible movement is tested to ensure that the skin stretches but does not split or sag as the carbon fibre frame expands and contracts.

6 Finishing touches

The T-Rex's forearms, eyeballs, tongue and teeth, which are mostly made from foam, are all secured into place, and then it is ready to be transported onto set.

Eerily quiet

With only a gentle hiss from the hydraulics, the crew said the dinosaur was eerily quiet as it moved.

Amazing engineering

The T-Rex's hydraulic valves pushed 60 gallons of hydraulic fluid per minute.

Absorbing water

The T-Rex wasn't built for wet weather. Its foam skin absorbed lots of water on set, making it even heavier.

Thick-skinned

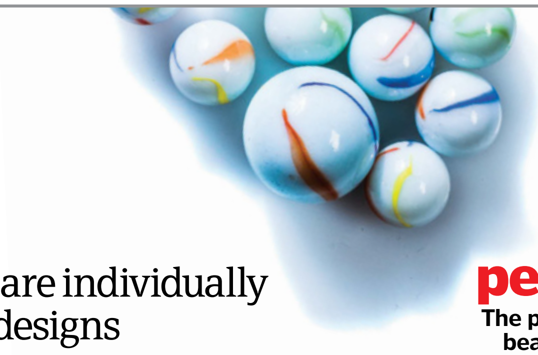
The skin was made five centimetres thick to conceal the metal skeleton and hydraulics underneath.

7 Ready for a close-up

Cinema history is made!

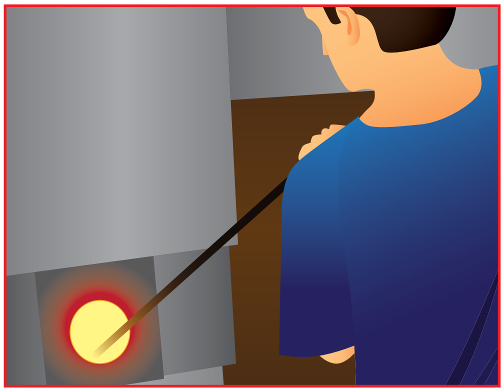
How marbles are made

When not mass-produced, glass marbles are individually handcrafted to include intricate internal designs



Creating the perfect marble

The process undertaken to fashion beautiful-coloured glass spheres

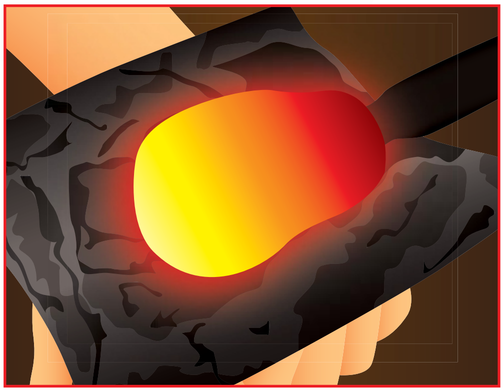


1 Melting the glass

To start, clear glass is preheated in a small oven before then being placed in a furnace and left overnight. The next day, the now melted glass can be retrieved using a steel rod.

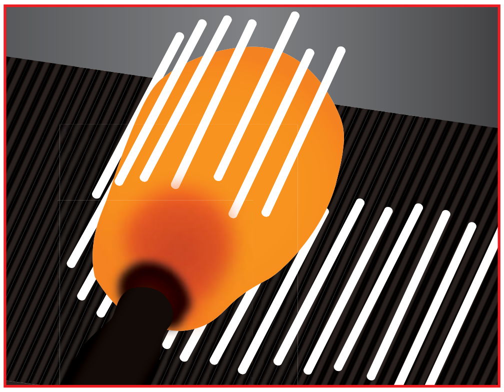
2 Coloured glass

Blocks of coloured glass are covered in molten clear glass from the furnace and moulded into five-metre-long strings, which will later be shortened into thin strips several centimetres long.



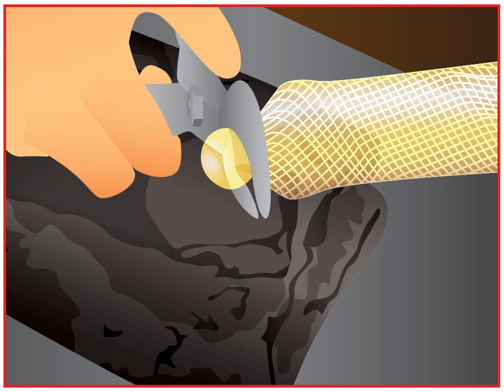
3 Forming the mass

Using the rod, a clump of clear glass is gathered and moulded into a spheroid shape. Wet newspaper (which doesn't stick to the molten glass) is used to help handle and shape it.



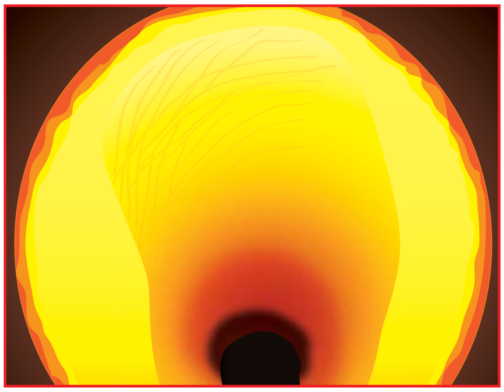
4 Into the furnace

The red-hot glass is rolled over preheated, coloured strings and then returned to the furnace. After heating, the metal clump is then run along a metal table to even out the shape.



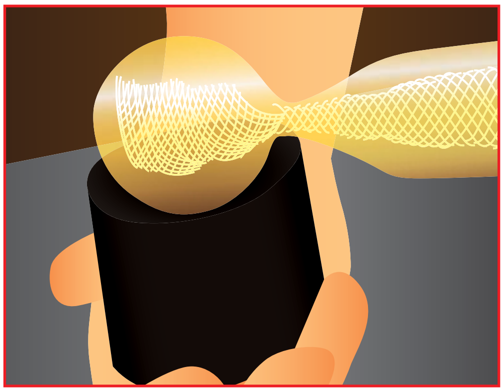
5 Roll and melt

After adding another layer of clear glass, the clump is stretched out to around half a metre in length and cut into multiple segments. These will form the central core of the marbles.



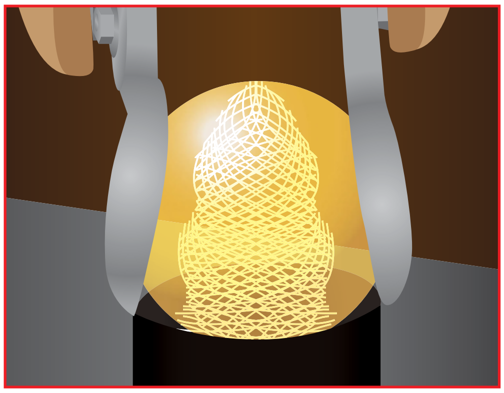
6 Flattening the ribbons

A segment of core is attached to ribbons – thicker coloured strips of glass – and covered with another layer of clear glass before moulding. Steps 4-6 are then repeated to create the desired pattern inside the marble.



7 Creating the sphere

Tools are then used to shape the molten glass into a sphere, and the formed marble is placed in a pipe to hold it still while it is broken off from the rest of the glass. The site of the break is melted to smooth the surface.



8 The finished marble

The marble is then put back into a furnace that cools overnight to strengthen the glass. The marble is now complete and is ready to be collected and played with!

Marbles took off after the 1846 invention of marbelschere (marble scissors) in Germany

Inside the iPhone 7

A closer look at Apple's most powerful smartphone ever

It's always a big event when Apple launches a new iPhone, and the iPhone 7 is no exception. The latest device has a powerful new processor that allows it to run incredible apps, speed through the user interface, and make everything feel snappy and quick. It's also waterproof, so users no longer need to worry about getting caught in the rain.

One of the biggest improvements in the latest model is that the iPhone 7 has a 12-megapixel camera that takes impressive photos, even in low light. The lens inside the phone offers optical image stabilisation – it is held by tiny springs that can compensate for shaky hands. This means videos and photos are always crystal clear, thanks to a clever combination between hardware and software that smooths out the shakes.

Viewing photos on the iPhone has also improved, thanks to a new, brighter display. It shows more colours thanks to a wider colour gamut (the range of colours that can be displayed on a device), and it features 3D Touch, which allows users to unlock more options within apps by varying the pressure of their touch.

Apple has managed to pack all of this into an iPhone that is the same size as the iPhone 6S, which is especially impressive considering the improved battery life that the iPhone 7 boasts. The trade-off in this case is the loss of the headphone jack – but with wireless headphones becoming more affordable, and the iPhone 7's new stereo speaker, there are still many ways to enjoy music on the go.

The new screen on the iPhone 7 shows more vivid colours, and is 25 per cent brighter than the iPhone 6S display

iPhone 7 teardown

How does it pack in all that tech?

Quad-tone flash
The flash that activates when you take a photo contains four LEDs that adjust light to make photos look natural.

Better battery
The new and improved battery gives up to two hours more life compared to previous models.

Waterproofing
An adhesive around the screen, and rubber gaskets on every button, help to make the iPhone 7 waterproof.

Taptic engine
This tiny engine sends minute vibrations through the phone when you press the home button, to make it feel like a button clicking.

12MP camera
The camera on the back of the iPhone boasts a wider aperture, a new lens design and a sensor that can compensate for flickering light.

The iPhone 7 Plus has two rear-facing cameras – one includes a telephoto lens for taking zoomed photos

Apple's A10 chip
Apple's latest chip packs four cores into an all-new design, and is more power efficient than the A9.

Stereo speakers
There are now speakers at the top and at the bottom of the iPhone 7, which is twice as loud as the 6S.

Front-facing camera
The seven-megapixel camera is great for selfies thanks to the wide colour capture mode it uses.

Logic board
This is where all the chips that control the phone can be found, including the wireless chips and many sensors.

Home button
The new home 'button' isn't actually a button at all – it's touch-sensitive and measures the force of your press.

"The iPhone 7 has a 12-megapixel lens that takes impressive photos"

iPhone 7 competitors

The Pixel
The Pixel is the very first phone completely made by Google. It features a fingerprint sensor on the back of the device, along with built-in Google Assistant.

The Xiaomi Mi Mix
The Xiaomi Mi Mix is among the first phones to almost totally lose the bezel around the edge of the display. This might well be the future of the smartphone.

HTC 10
The beautifully sleek HTC 10 ditches micro USB for the new USB-C standard, and packs in an incredible 564 pixels per inch on its large, 5.2-inch screen.

Smooth ride
The i360 can operate in winds of up to 70 kilometres per hour, using aluminium cladding to reduce vibrations.

Views
On a clear day, passengers can see as far as the Isle of Wight in the west to Beachy Head in the east.

Energy efficient
The pod's electricity demand is very low, at approximately less than one kilowatt-hour per passenger.

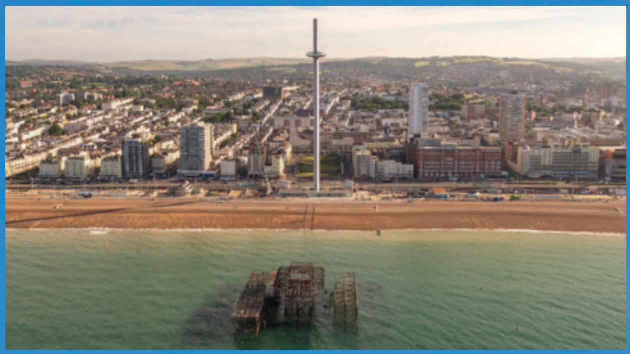
The i360

The tech behind the world's tallest moving observation tower

After a decade in the making, British Airways' i360 is now open for business. The 162-metre-high tower has been constructed in Brighton by the makers of the London Eye, and is listed as the world's most slender tower. For its construction, a 4,150-ton concrete foundation was laid over a bedrock of chalk and reinforced with almost 200 tons of steel. The tower has a unique design and is constructed out of 17 steel sections called cans. Made in Rotterdam, the cans are bolted together and then coated with zinc, aluminium and paint to protect against corrosion.

Members of the public can ascend the tower in a fully enclosed, glass observation pod. Taking as many as 200 passengers up to 138 metres in the air, the pod is ten times the size of a London Eye capsule. The system features energy-capture technology, so energy from the descent can be recycled to generate half that required to power the next ascent. The glass is double-curved and double-glazed, allowing for 360-degree views of the surrounding area. Innovative air conditioning technology allows the pod to dehumidify itself, and prevent condensation on rainy days if passengers are wearing wet clothing. At night, the top of the i360 lights up red, providing both a safety light for aircraft and an iconic beacon for the city.

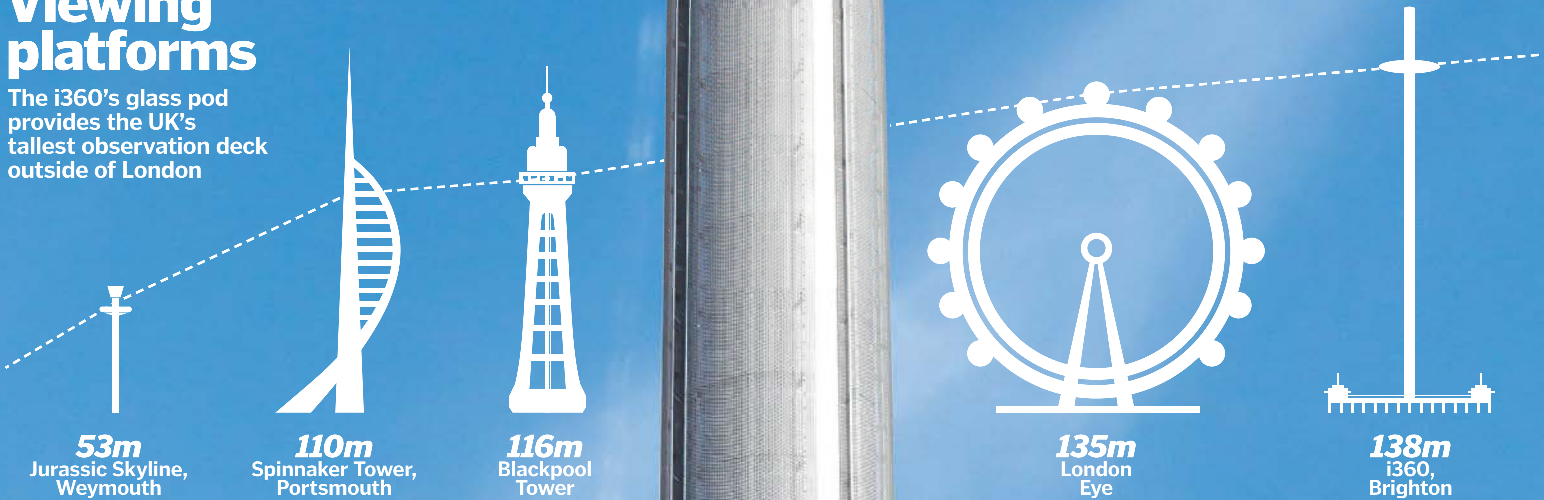
The views from the tower give an amazing panorama of both the city of Brighton and the English Channel



The pod is made from toughened glass, which was accurately cut to size and fitted in layers

Viewing platforms

The i360's glass pod provides the UK's tallest observation deck outside of London



HEROES OF… TECHNOLOGY

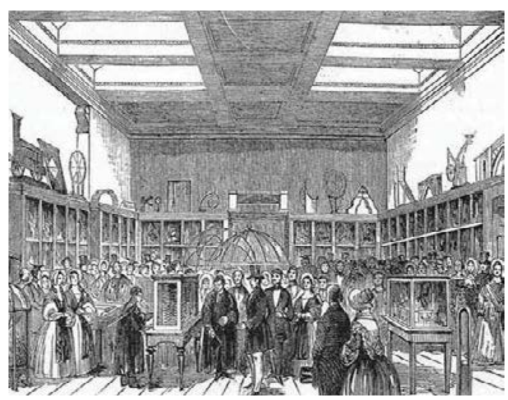
Ada Lovelace

A talented mathematician and a pioneering computer programmer

The daughter of a romantic poet and occasional freedom fighter, Ada Lovelace had a famous but absent father. She never knew Lord Byron, as just weeks after her birth in 1815, he divorced her mother Isabella Milbanke Byron and left to fight in the Greek War of Independence. In an effort to prevent Ada from developing her father's unpredictable temperament, Isabella decided that her daughter should devote her life to study, especially mathematics and engineering. Unknowingly, her mother had set Ada on the path to becoming one of the finest mathematic minds of the 19th century.

Ada studied hard, undeterred by a sickly youth and the fact that society did not encourage women pursuing interests in science. Her life changed when she met inventor Charles Babbage at a party. As he demonstrated a working section of his difference engine (a mechanical calculator), Ada was taken in by how it worked and wanted to know more. Impressed by the 17-year-old's obvious passion, the polymath became her mentor. She embraced his vision of creating a 'thinking machine' that could solve mathematical problems and then print the results.

A finished difference engine was never made due to an impatient British Government pulling the funding. Babbage moved on to work on an analytical engine that would be able to handle even more complex calculations, using punched instruction cards and stored numbers in a memory unit. Ada married in 1835 and became a



The analytical engine drew crowds when it was put on display in 1843 at the King George III Museum

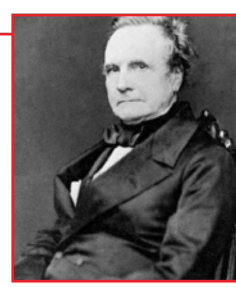
A LIFE'S WORK

A closer look at the extraordinary life of one of science's great theoretical thinkers

1815
Ada is born on 10 December 1815, the daughter of Lord Byron and Lady Anne Isabella Milbanke Byron.

1824
Raised by her mother following her parents' divorce after her birth, Ada is encouraged to learn maths and science.

1833
Aged 17, Ada meets inventor Charles Babbage at a party and soon becomes his protégé.



1835
Ada becomes a countess after marrying William King, the first Earl of Lovelace.

The big idea

How Ada paved the way for computing

Ada's ideas exceeded Babbage's work. He was convinced of the analytical engine's ability to solve mathematical problems, but she took it much further. Using how a loom weaves textiles as a metaphor, Ada's famous notes described how a system of letters, symbols and number sequences could be coded into repeated instructions. She estimated that forthcoming machines would be able to compose complex music and produce detailed graphics, an amazingly accurate prediction of the future. The system of algorithms she created is called looping, and is still used by computers today. She effectively bridged the gap between calculation and computation and this is why Ada Lovelace is often described as the first computer programmer.

A blue plaque is displayed at a house in St James' Square, London, where Ada once lived

mother, but she continued to take an active interest in study, socialising in intellectual circles with the likes of Charles Dickens and Michael Faraday.

Ada stayed in contact with Babbage, who in 1837 had proposed a new machine, the analytical engine. In 1843, Ada was asked to translate a French text written by engineer (and future Italian Prime Minister) Luigi Menabrea about Babbage's new design. After completing the translation, Ada was encouraged by Babbage to write her own notes on his work.

After nine months of hard work, Ada presented Babbage with a detailed list of notes that was three-times longer than the original article. In her calculations, Ada wrote what are considered the first ever computer algorithms to be used in a new type of machine. She essentially provided the first ideas for computer programming in what was a groundbreaking proposal on the potential of computers.

> "She embraced Babbage's vision of creating a 'thinking machine' that could solve mathematical problems and print the results"

Ada's contributions were a century ahead of their time. She died of cancer aged only 36 and her work was largely consigned to history until the 1950s when her notes were republished. Since then, the first Countess of Lovelace has received posthumous awards, and in 1979 the US Department of Defense named a programming language 'Ada' in her honour.

The difference engine was never fully constructed, until Babbage's son used parts he found in his father's lab to assemble what it could have looked like

Five things to know about… ADA LOVELACE

Ada studied hard from a young age and dedicated her life to mathematics and engineering

1 She was a countess
Ada was born into the aristocracy and her full name was Augusta Ada Byron. She became the Countess of Lovelace after she married William King-Noel, the first Earl of Lovelace, in 1835.

2 There's an Ada Lovelace Day
Celebrated annually on the second Tuesday of October since 2009, Ada Lovelace Day is held to acknowledge the achievements of women in science, technology, engineering and mathematics.

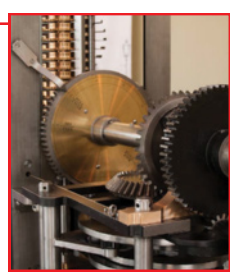
3 Her mother taught her self-control
Ada's mother did not want her daughter to turn out like her temperamental father. She forced Ada to lie still for long periods as she thought it would help with her self-control.

4 She was a gambler
In her later life, Ada took up gambling and lost much of her fortune this way. She tried to develop mathematical strategies to help her win.

5 She designed a flying machine
In 1828, when she was just 13, Ada created designs for wings so humans could fly. She even wrote and illustrated a book on her project, called *Flyology*.

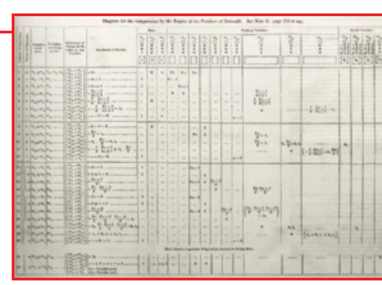
1837
Health problems begin with a bout of cholera, along with lingering asthma and digestive issues.

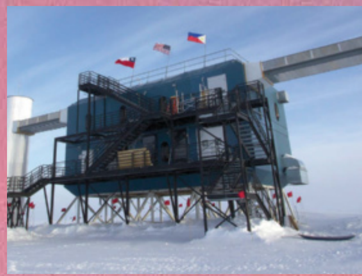
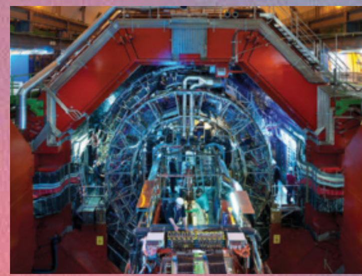
1843
After Babbage's engines become popular, Ada translates a French article into English, while including new and revolutionary ideas of her own.



1852
Ada passes away on 27 November, aged just 36. Sadly, her later life was marred by poor health.

1953
After much of her work is forgotten, Ada's memory is reignited after scientist B V Bowden republishes her findings in his work.




EXTREME SCIENCE

WELCOME TO THE MOST DANGEROUS AND REMOTE RESEARCH ON THE PLANET

"Volcanoes could explode at any moment, and volcanologists make it their business to explore them"

Volcanologists get close to active volcanoes to collect samples and gather data

WHY THEY DO IT

To predict eruptions
Volcanoes are a threat to people, property and aircraft.

To uncover ancient history
Mapping the history of eruptions can reveal the past.

To learn about Earth
Volcanoes can teach us what happens beneath the Earth.

Volcanology

These extreme scientists get up close and personal with active volcanoes

Volcanoes are some of the most wild and extreme places on the planet. They sink right into the molten heart of the Earth, connecting the ground with the magma that is normally hidden beneath. Some could explode at any moment, and volcanologists make it their business to explore them.

Many different sciences come together to understand how volcanoes work and when and why they might erupt. Researchers need to know about the structure of the Earth, the chemistry of the rocks and how they interact with other chemicals in the air or water. They also need to understand the physics of our planet, and what drives movement deep beneath the surface.

Volcanologists travel all over the world in pursuit of active volcanoes, and live for a few months of the year out in the field. There's no denying that this type of work is dangerous. The temperature of lava varies depending on the volcano, but it can reach upwards of 1,000 degrees Celsius. They also produce deadly gases, including suffocating carbon dioxide, which collects in low-lying areas, and hydrogen sulphide, which has a strong smell of rotten egg, and can cause respiratory damage or even death. In 1991, the Unzen volcano erupted in Japan, killing volcanologists Maurice and Katia Krafft, and Harry Glicken.

But accidents like this are rare. A lot of work is done with dead or dormant volcanoes, and for most of the year, volcanologists work safely back at base, crunching their data, analysing samples, teaching and remotely monitoring volcanoes for signs of activity.

Going under

Meet the research teams working at extreme depths

Most of the world's research labs sit at, or just above, ground level, but some enterprising teams have buried themselves deep below the Earth's surface.

Our planet is a noisy place; the Sun showers us with cosmic rays, communication towers spit out a constant stream of radio waves, and radioactive rocks and gases release a steady trickle of radiation. To get to grips with the particle physics that makes the universe go round, scientists need to block out this static so that they can examine the behaviour of particles in peace. To do this, they go underground.

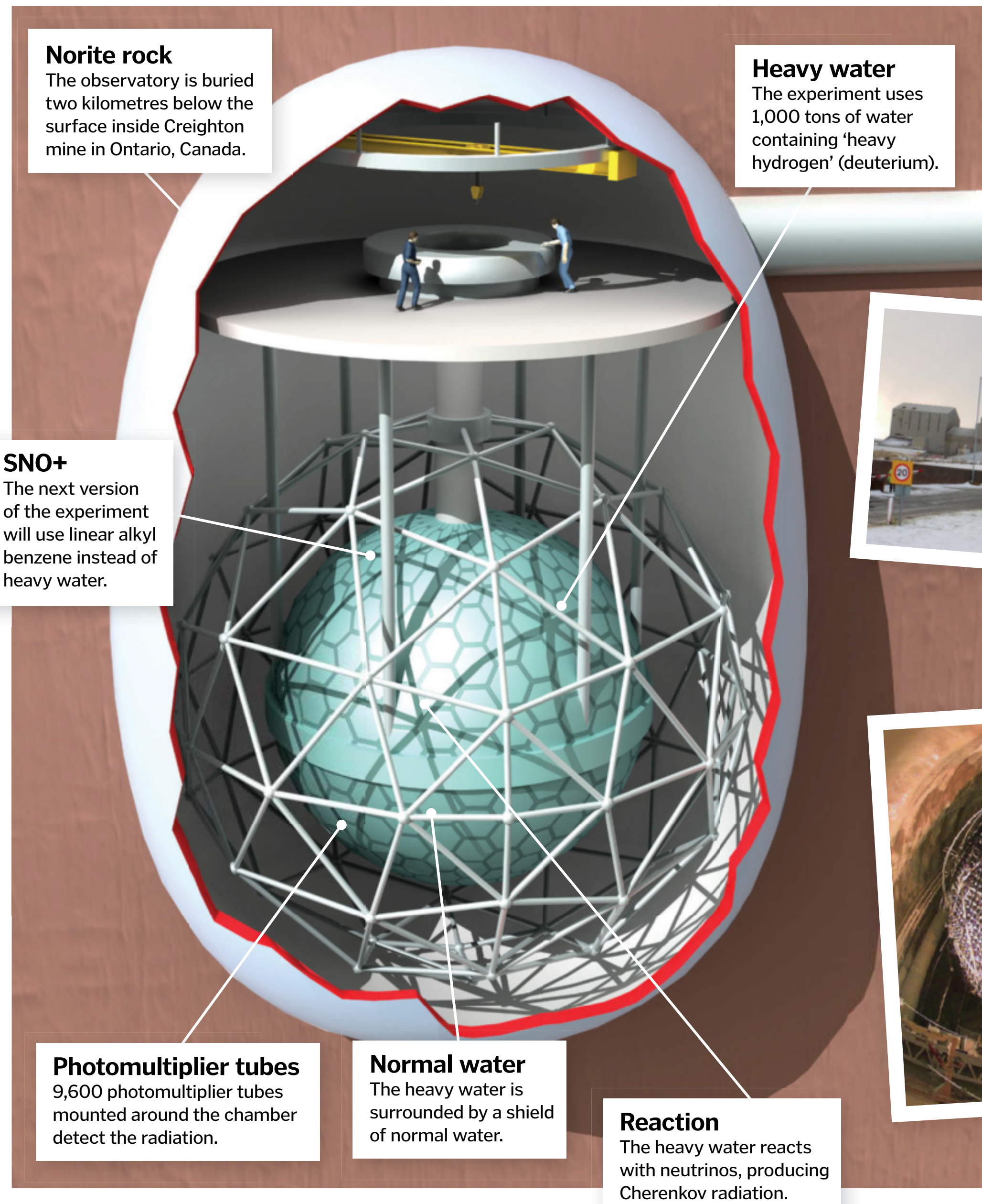
Muons are some of the most irritating particles, and constantly appear at Earth's surface as a result of cosmic rays. The further underground you go, the more are filtered out.

The deepest of these buried facilities is based in China, 2,400 metres below the mountain's surface. The China Jinping Underground Laboratory is hidden inside a mountain, and to add to its comic book credentials, the purpose of the lab is to search for dark matter.

This extreme research is at the cutting-edge of science, and it continues to produce exciting and groundbreaking physics again and again.

SNOLAB's SNO experiment explored

The Sudbury Neutrino Observatory detects neutrinos generated in the heart of the Sun



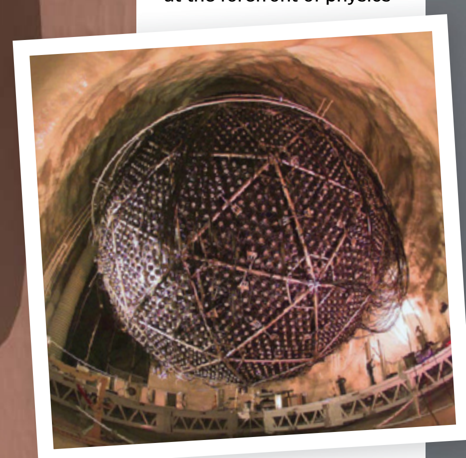
WHY THEY DO IT

To learn about subatomic particles
Tiny particles can be examined in detail.

Because the surface is noisy
The Earth shields sensitive equipment from cosmic rays.

It's groundbreaking
Excuse the pun. Research in this field has won Nobel Prizes.

From the outside, these labs look like any other, but underground they're at the forefront of physics



The SNOLAB SNO detector uses a sphere of heavy water to observe neutrinos

Underground labs

Experiments deep below the ground

SURFACE

KAMIOKA OBSERVATORY JAPAN *Operational*

1,000 M

STAWELL UNDERGROUND PHYSICS LABORATORY AUSTRALIA *Under construction*

1,100 M

BOULBY UNDERGROUND LABORATORY UK *Operational*

1,200 M

INDIA-BASED NEUTRINO OBSERVATORY INDIA *Proposed*

1,300 M

GRAN SASSO NATIONAL LABORATORY ITALY *Operational*

1,400 M

1,500 M

CENTRE FOR UNDERGROUND PHYSICS IN PYHÄSALMI FINLAND *Operational*

1,600 M

SANFORD UNDERGROUND RESEARCH FACILITY SOUTH DAKOTA, UNITED STATES *Operational*

1,700 M

MODANE UNDERGROUND LABORATORY FRANCE *Operational*

BAKSAN NEUTRINO OBSERVATORY RUSSIA *Operational*

1,800 M

AGUA NEGRA DEEP EXPERIMENT SITE CHILEAN-ARGENTINE BORDER *Proposed*

1,900 M

2,000 M

SNOLAB CANADA *Operational*

2,100 M

2,200 M

2,300 M

CHINA JINPING UNDERGROUND LABORATORY CHINA *Operational*

2,400 M

Research in the clouds

The Pyramid International Laboratory/Observatory is perched among the mountains of the Himalayas, at the base of Mount Everest. Far from civilisation, the facility utilises renewable energy in the form of solar panels for energy, and relies heavily on food deliveries to keep its inhabitants well fed.

At just over 5,000 metres above sea level, it provides a unique environment for scientific studies. At this altitude, not only is the climate and environment different, the human body also behaves strangely, and there is a clearer line of sight into outer space.

The Pyramid International Laboratory investigates space, climate and biology

Under the sea

Living and working underwater is more than just science fiction

The Florida Keys are home to the Aquarius Reef Base, a submerged laboratory run by Florida International University, which sits nearly 15 metres below the surface of the sea. At this depth, the pressure is around 2.5 times greater than it is on the surface. The lab sits next to one of the largest coral reefs in the world, providing a unique viewpoint to study these incredible ecosystems up close without the risk of disturbing them.

The base's inhabitants, known as 'aquanauts', train for five days before descending to the lab. They live at underwater pressure without returning to the surface for up to two weeks.

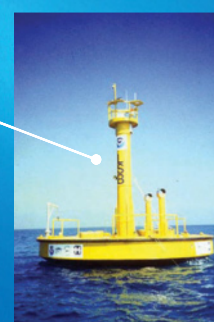
A floating life support system, complete with power generators, air compressors, and communications equipment, keeps them alive, and when it is time to come back again, the entire station decompresses slowly, allowing their bodies to adjust to normal air pressure before they swim back up.

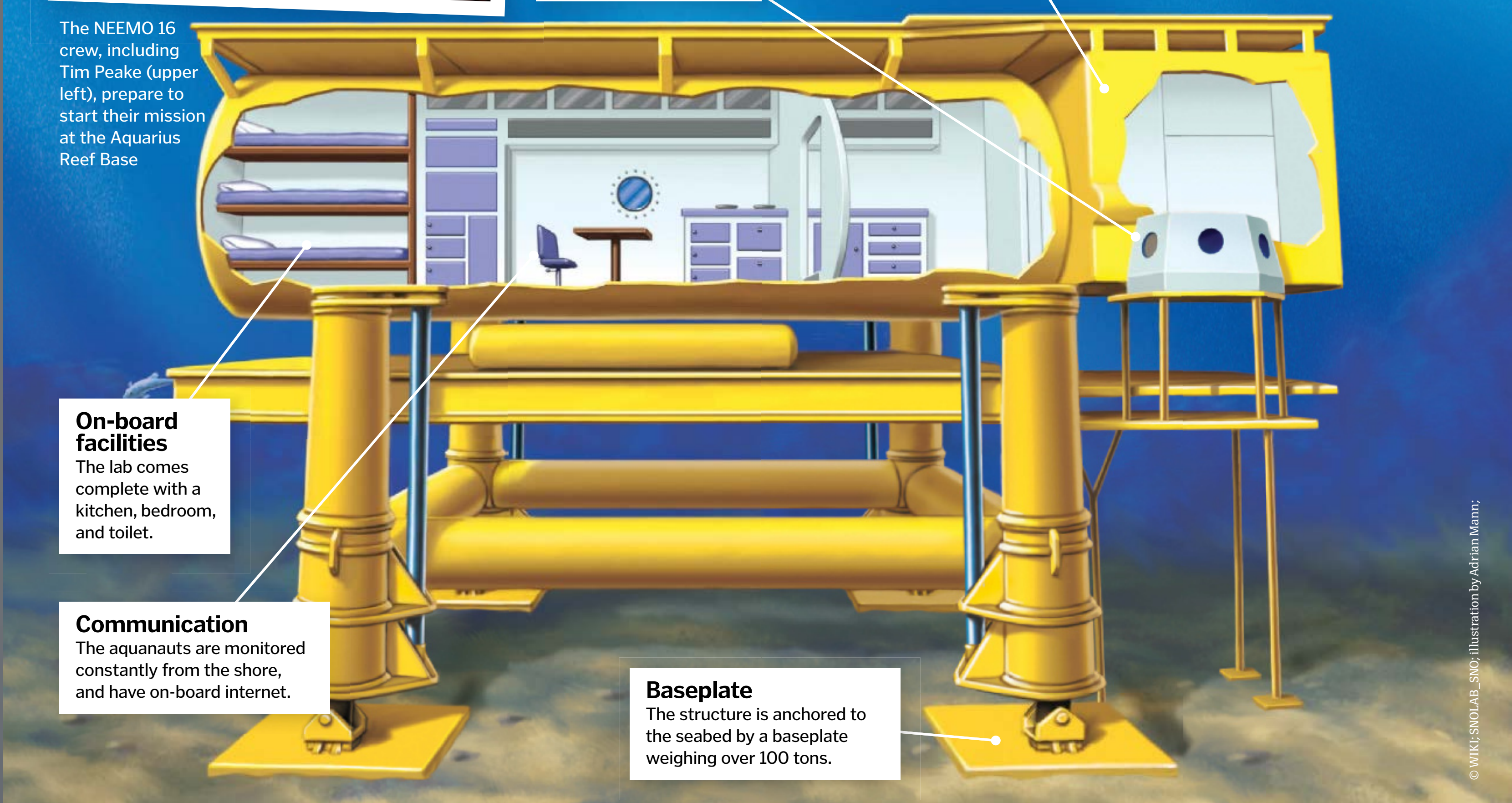
Not only do scientists use the base to study the environment, space agencies send astronauts there for training and mission simulations.

The NEEMO 16 crew, including Tim Peake (upper left), prepare to start their mission at the Aquarius Reef Base

That sinking feeling

Aquanauts spend around ten days at a time living on Aquarius station





Life on the ice

Hundreds of scientists brave Antarctic ice each year to experiment in this unforgiving environment

Antarctica is the only continent with no native human inhabitants and no permanent human residents, but visiting scientists make this isolated continent a temporary home. During the summer, a few thousand people arrive to begin their experiments, and in the depths of winter, a few hundred remain to keep the buildings and science ticking over until the place warms up again.

With average temperatures of -12 degrees Celsius at the coast and -60 degrees Celsius at high altitude, it's no wonder that the scientists don't remain all year round. Food and supplies can be delivered during the summer, but when winter hits the resupply stops. For some bases, this lack of fresh produce can last for ten months of the year, and the inhabitants must rely on frozen and canned stores.

Once these basic needs are taken care of, the stations are relatively safe places to stay; it's venturing out to perform experiments that poses the biggest danger. Research teams travel by sledge or air to key locations, and camp out in the wild until they have the data that they need.

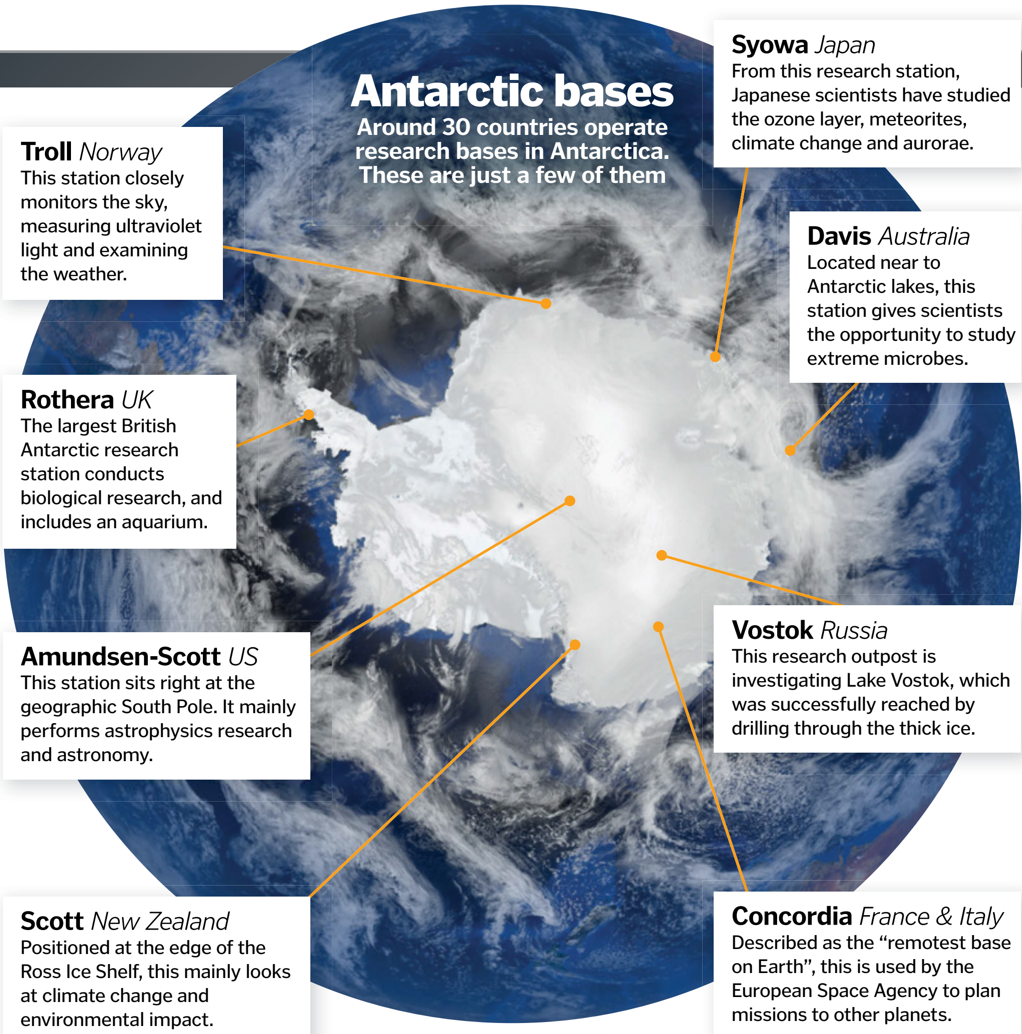
The weather in the Antarctic is unforgiving. Fog can descend over the ice, creating a whiteout and making it near impossible to make out the difference between snow and sky. Under these conditions, the crags, cliffs and sheer drops in the ice become invisible.

In the field, research teams shelter in tents and huts specially designed to resist the weather. Airbeds and sheepskins keep them as far from the frozen ground as possible, and insulated down-filled sleeping bags keep them warm. Layers of woollen clothes, topped off with wind and waterproof outerwear are also used.

Each scientist has a ration box that provides 3,500 calories per day, and human waste often has to be brought back to base when they're done to protect the environment – that's right, even the nasty stuff. Antarctic research is tough.

Antarctic bases

Around 30 countries operate research bases in Antarctica. These are just a few of them



Troll *Norway*
This station closely monitors the sky, measuring ultraviolet light and examining the weather.

Rothera *UK*
The largest British Antarctic research station conducts biological research, and includes an aquarium.

Amundsen-Scott *US*
This station sits right at the geographic South Pole. It mainly performs astrophysics research and astronomy.

Scott *New Zealand*
Positioned at the edge of the Ross Ice Shelf, this mainly looks at climate change and environmental impact.

Syowa *Japan*
From this research station, Japanese scientists have studied the ozone layer, meteorites, climate change and aurorae.

Davis *Australia*
Located near to Antarctic lakes, this station gives scientists the opportunity to study extreme microbes.

Vostok *Russia*
This research outpost is investigating Lake Vostok, which was successfully reached by drilling through the thick ice.

Concordia *France & Italy*
Described as the "remotest base on Earth", this is used by the European Space Agency to plan missions to other planets.

A diver dressed in thermal protective gear takes an icy plunge for underwater-based research

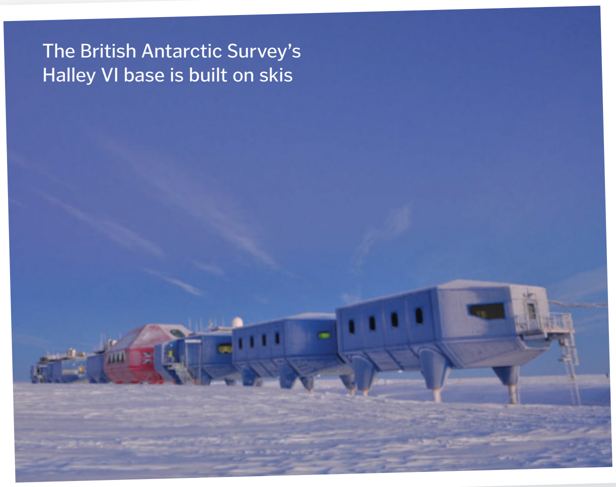
The IceCube Neutrino Observatory is buried deep beneath the ice

WHY THEY DO IT

To study a unique environment
Antarctica is wild and inhospitable to life.

To monitor climate change
The ice is vulnerable to changes in temperature.

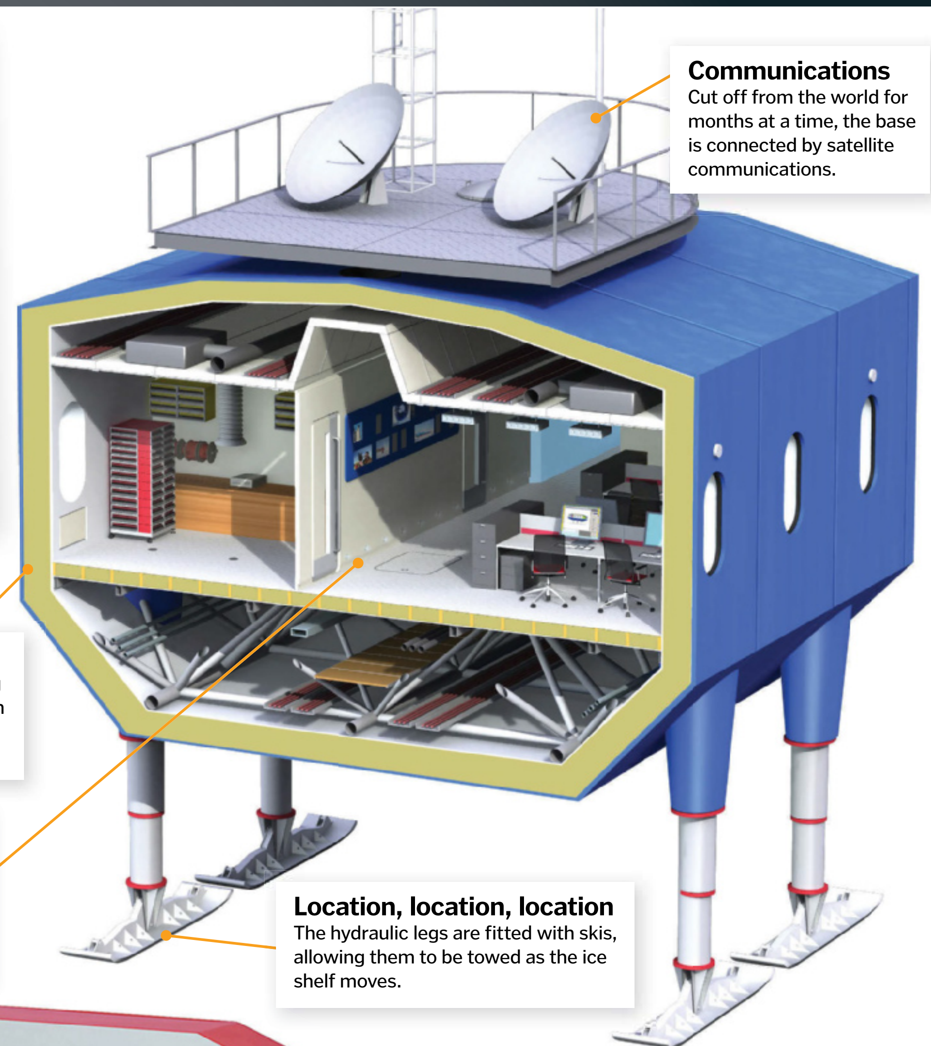
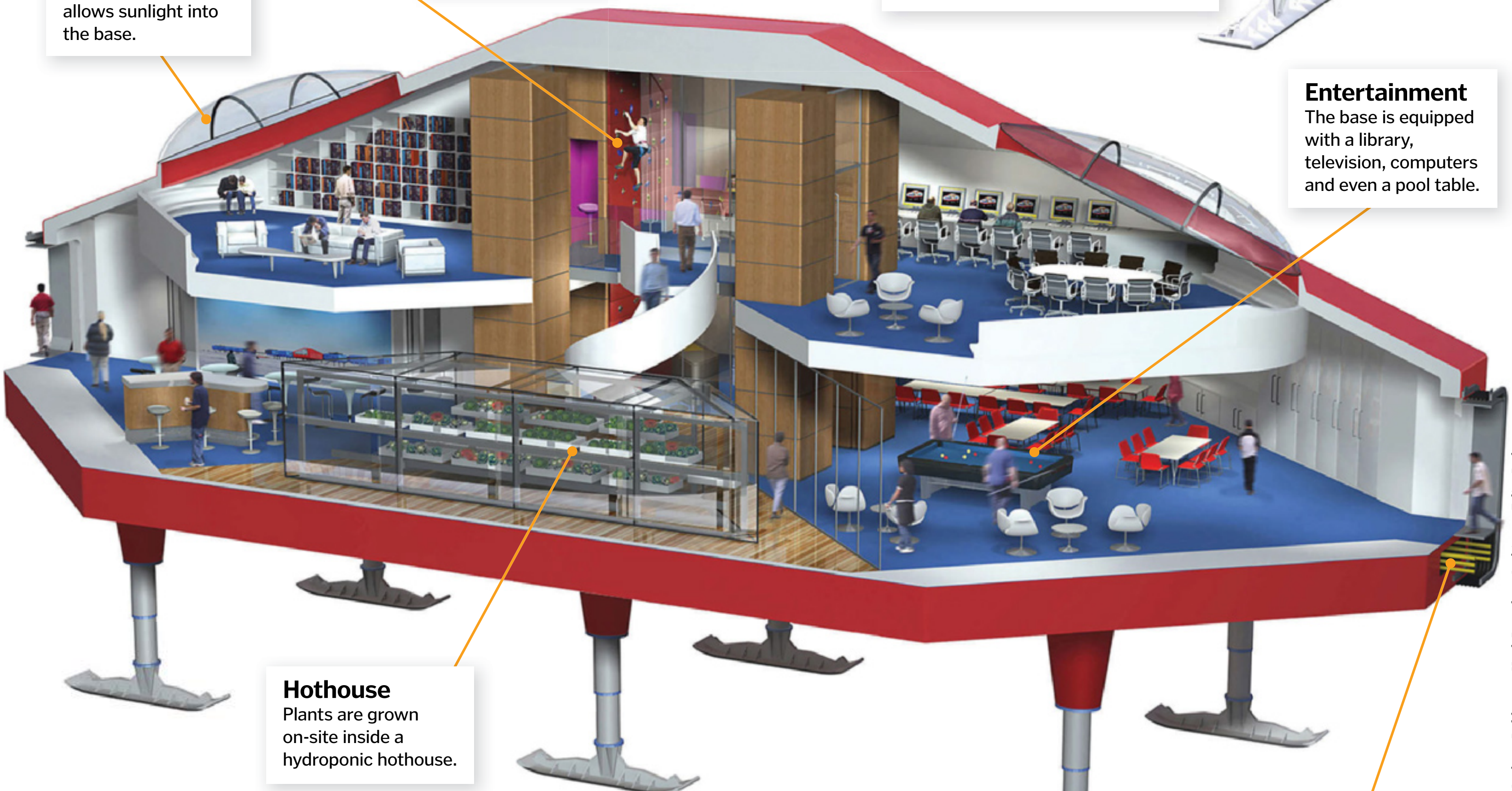
To open a time capsule
Locked away in the ice is information about Earth's history.



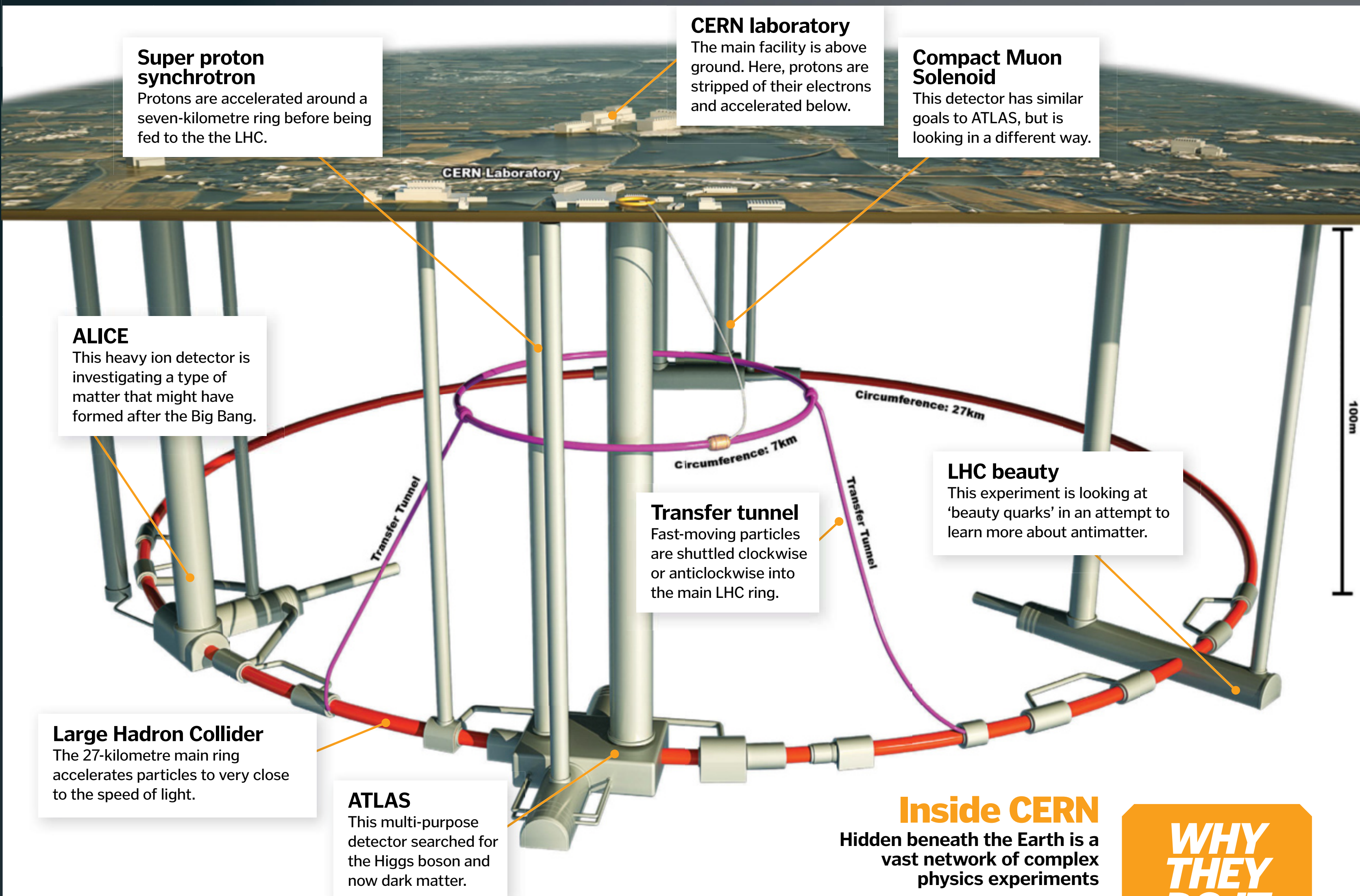
The British Antarctic Survey's Halley VI base is built on skis

Halley VI base

This British research station is perched on an ice shelf that moves half a metre into the sea every day

"Venturing out to perform experiments poses the biggest danger"



Inside CERN
Hidden beneath the Earth is a vast network of complex physics experiments

Extreme physics

CERN is the world's largest, and most famous, physics lab

This underground physics lab is one of the most cutting-edge facilities anywhere on the planet. It is located across the border of France and Switzerland, and is jointly operated by 22 member states, together known as the 'European Council for Nuclear Research' (CERN). The facility is home to the world's largest scientific instrument, the famous Large Hadron Collider (LHC), which is used to explore the fundamental structure of the universe.

The LHC is a ring-shaped particle accelerator, measuring a staggering 27 kilometres around its circumference. Particles are fed into this ring, and over 1,500 superconducting magnets guide them around this underground racecourse at almost the speed of light, until they violently slam together.

CERN assures us that there is no danger of creating a world-ending black hole; the main purpose of these experiments is to search for answers. The CERN team want to find out why there is more matter than antimatter in the universe – they should, theoretically, be equal. They are also still experimenting with the Higgs boson – a particle that is important for explaining why other particles have mass, following its discovery. And they want to learn more about dark matter and dark energy.

ATLAS is one of CERN's most famous detectors – its task is to search for dark matter

WHY THEY DO IT

To understand the universe
Particle physics underpins every other science.

To explore antimatter
To find out why our universe is mostly made of matter.

To work on the Higgs boson
This particle helps to explains why other particles have mass.

Science in space

The ISS is one of the most impressive laboratories ever built

The International Space Station is one of the greatest feats of human endeavour. This orbital laboratory circles the Earth at a height of 400 kilometres, with a permanent crew of at least three astronauts. Away from the fierce tug of Earth's gravity, the crew and equipment onboard are weightless, and in this strange environment all kinds of different experiments can be performed.

Microgravity affects the way that living organisms tell up from down, and it changes the way that chemicals behave. Experiments on cells, small animals, and the astronauts themselves, are helping scientists to understand the impact space has on life. It's the perfect place to test new ideas and technology for future space missions, and it is also a great spot to monitor what's happening back on the Earth below.

WHY THEY DO IT

To understand outer space
This unique environment allows constant access to microgravity.

To monitor the Earth
They can watch how the Earth changes over time.

For the future
The ISS is a test area for future long-term space missions.

Astronaut, Kate Rubins, was the first person ever to sequence DNA in space

Microgravity has strange effects on fire; this equipment allows astronauts to study it

Human cells can be grown on the space station for experiments, like these stem cells

Seriously scary science

From twisters to diseases, these scientists are on the front lines

Chasing storms

These extreme-weather scientists run towards dangerous storms in specially-adapted vehicles. Carrying cameras, communications equipment, Doppler radars and weather balloons, they get up close and personal with tornadoes.

Deadly predator studies

Physiologists and conservationists work with some of the most dangerous animals on the planet, bringing crocodiles, lions, bears and elephants down to be tagged, tracked and sampled.

Infectious disease scientists

Preventing, controlling and curing deadly infections takes years of research. Scientists working on diseases like Ebola need to get close to samples in their labs, but not without layers of strict protection.

Chemical bonds

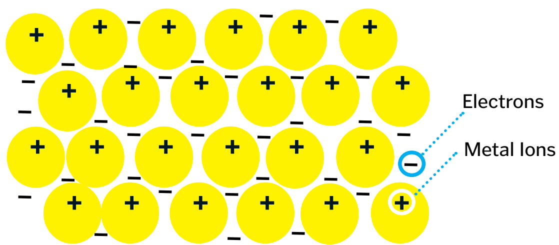
Bonding between chemicals is a simple matter of attraction

To understand the types of chemical bonding, we should first consider what the atoms of our universe are made of. To do this, we can use a simplified analogy of atomic structure by picturing an atom as a star being orbited by planets. The nucleus is the star, which is formed of positively charged protons and neutrons that have no charge. Negatively charged electrons are the orbiting planets.

In an atom's native form the number of electrons and protons are equal, which gives the atom a neutral charge overall. But other atoms are also attracted to these electrons, and when they're shared or stolen, a chemical bond is the result.

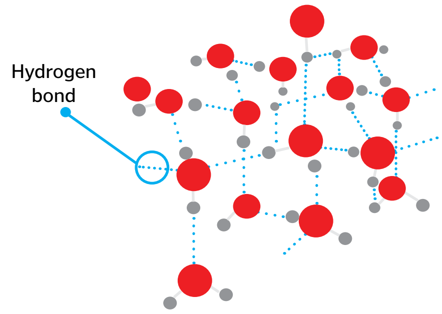
Types of bonding

How chemicals are bound together is largely dependent on how they share their electrons



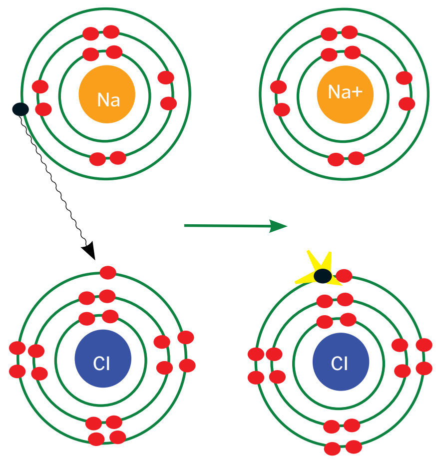
Metallic bonding

This type of bonding is strong and allows for the conduction of heat and electricity. Metals achieve this by universally sharing their electrons, becoming positive ions in a 'sea' of fluid electrons.



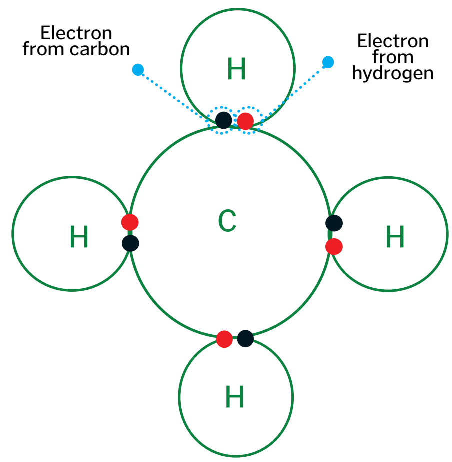
Hydrogen bonding

Hydrogen atoms carry a partial positive charge when part of a molecule, and form weak bonds with atoms of high electronegativity, which carry a partial negative charge. Many molecules can be bound via hydrogen bonding.



Ionic bonding

When an atom is less attracted to its outermost electrons, and another is greatly attracted to them, the electrons can be donated. This forms two ions – one positively charged and one negatively charged – that are attracted to each other.



Covalent bonding

These bonds occur in nonmetal atoms that share electrons. When both atoms are quite strongly attracted to their neighbour's electrons, they can both make use of them, and will become bound together as molecules in the process.

Thermography

How to visualise the heat that our eyes can't see

Every object emits or absorbs thermal radiation. And although we can sense it with our skin, we're unable to see it with our eyes. Infrared radiation falls just outside of our visible spectrum, but possessing the ability to see temperature would undoubtedly be of huge benefit to humans in certain situations. Fortunately though, we now have thermography, which can convert these invisible waves into visible light.

Devices that are capable of translating infrared waves into colours that we can see operate very similarly, but also distinctly, from video cameras. Rather than glass – which infrared radiation struggles to penetrate – infrared cameras use a material called germanium for their lenses. This allows infrared waves to pass through into detectors, which relay the radiation as information to sensor electronics. The information is then transformed into a scale of visible colours, which are directly proportional to the temperature that the object is emitting.

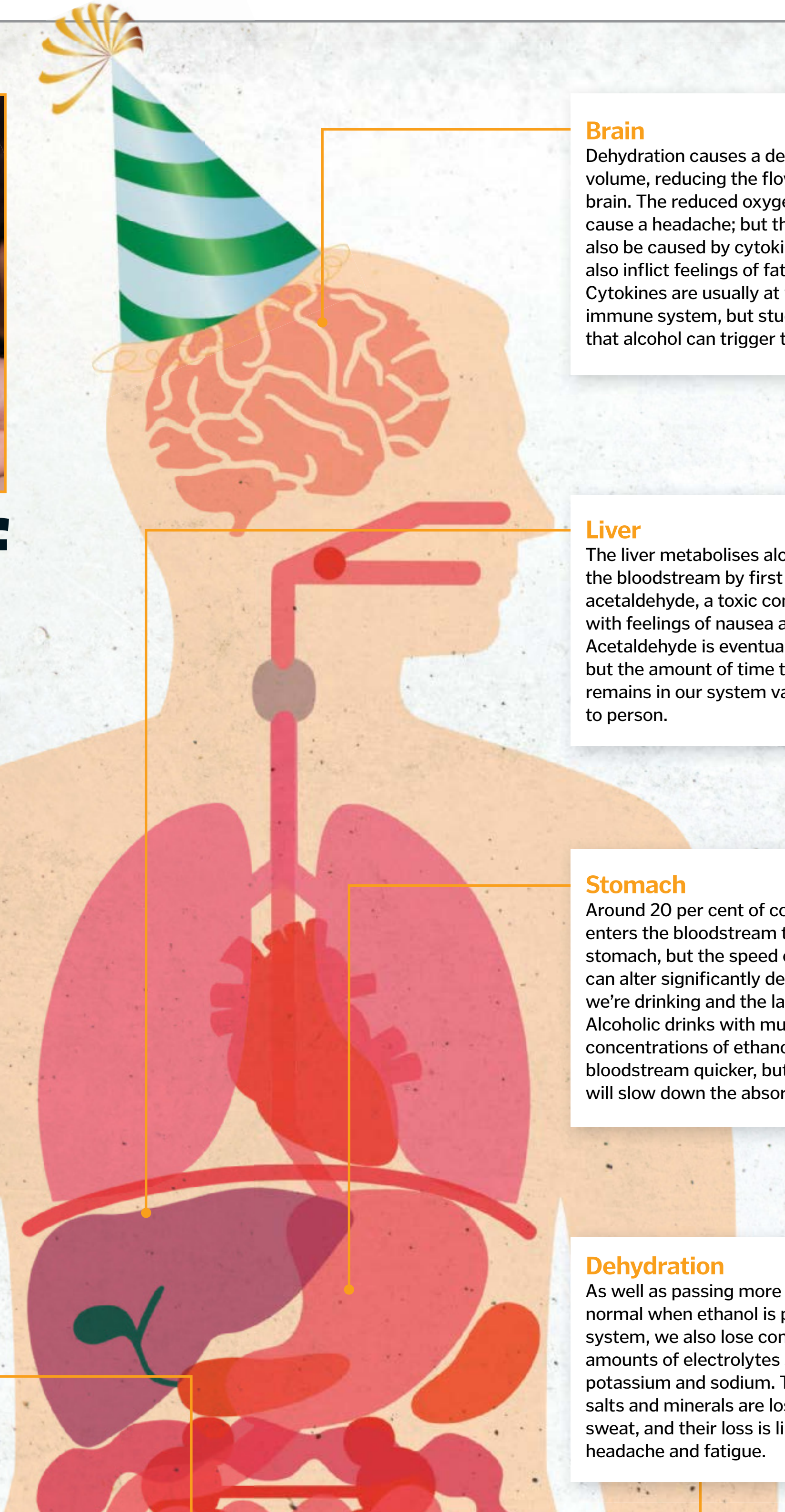
Thermographs can be used for many practical applications. These include a noninvasive way of monitoring electricity and power lines for overheating and other issues, analysing bodies in forensics and detecting the enemy during war. Firefighters even use it to see through smoke and find people.

A thermograph can clearly show a range of temperatures emitted by an object by just pointing at it

Anatomy of a hangover

What makes us feel a little worse for wear after New Year's Eve celebrations?

Party time
We're spoiled for choice when it comes to choosing which alcoholic drink we fancy. Different concentrations of ethanol are found in beers, wines and liquor, but packing more alcohol into a smaller volume isn't the only factor that contributes to inducing a hangover. Some drinks also have higher levels of congeners – chemicals produced during fermentation – that have been shown to contribute to negative symptoms.



Brain
Dehydration causes a decrease in blood volume, reducing the flow of blood to the brain. The reduced oxygen supply can cause a headache; but this symptom may also be caused by cytokines, which can also inflict feelings of fatigue and nausea. Cytokines are usually at work within the immune system, but studies have shown that alcohol can trigger their release.

Liver
The liver metabolises alcohol arriving in the bloodstream by first converting it into acetaldehyde, a toxic compound related with feelings of nausea and vomiting. Acetaldehyde is eventually broken down, but the amount of time the compound remains in our system varies from person to person.

Stomach
Around 20 per cent of consumed ethanol enters the bloodstream through the stomach, but the speed of this absorption can alter significantly depending on what we're drinking and the last time we ate. Alcoholic drinks with much higher concentrations of ethanol will enter the bloodstream quicker, but a full stomach will slow down the absorption process.

Small intestine
The remaining 80 per cent of consumed ethanol is absorbed via the small intestine. Here, it enters the blood stream and travels to other organs in the body. But our intestines are also home to bacteria, which may metabolise some of the alcohol and convert it into a toxic compound called acetaldehyde.

Dehydration
As well as passing more water than normal when ethanol is present in our system, we also lose considerable amounts of electrolytes such as potassium and sodium. These important salts and minerals are lost in urine and in sweat, and their loss is linked with nausea, headache and fatigue.

Bladder
Ethanol is a diuretic, which means it causes us to pass more urine. The consumed alcohol acts on the brain's pituitary gland, blocking the release of a chemical messenger called anti-diuretic hormone. As its name describes, this hormone usually prevents us from feeling the urge to urinate so often, but we can become dehydrated in its absence.

Food preservation

We are in a constant food war with microbes determined to eat our meals

Our lives revolve around food, but so too do the lives of microscopic bacteria and fungi. They are in the air, in the water, on the kitchen counter, and if left unchecked they will bloom and spread throughout our meals, turning edible food into furry mush. And if the microbes aren't at it, molecules called enzymes, present naturally in plants and animals, will also have a good go at breaking some foods down, and oxygen will gradually turn fats rancid. Therefore, food preservation has one fundamental goal: to stop, or at least slow down, this process.

Pickling
Vinegar is acidic, and this causes serious problems for microbes. The acid affects their molecular machinery, twisting their enzymes out of shape and stopping them from functioning properly. Without enzymes, life quickly comes to a halt.

Desiccation
Removing moisture from foods makes them unpleasant places to live. The aim is to get the water content down to below 25 per cent, at which point lots of microorganisms will struggle to survive. All life on Earth needs water.

Canning
Putting food inside a sealed container and heating it to kill any microbes is a really effective method of preservation. Once the contents of the can have been sterilised, nothing can get in to start breaking the food down.

Freeze-drying
This is a step up from normal drying. Rather than heat the food to evaporate the water, it's frozen first and the ice is converted to gas in a process called sublimation. This helps to keep the structure of the food intact.

Freezing
Taking the temperature of food below zero doesn't kill microbes, but it does slow them down. They enter a state of suspended animation, and don't reproduce until they're warmed up again. But freezing food too slowly can create ice crystals.

"If left unchecked, bacteria and fungi will bloom and spread throughout our meals"

Smoking
This preservation method has a combination effect. Heat kills microbes, and the chemicals in the smoke itself slow or stop their growth. And, as the food smokes, it dries out, removing some of the water that organisms need to survive.

Fermentation
It might sound counterintuitive, but this preservation method works by actually allowing microbes to break foods down. Some yeasts and bacteria are safe to eat, and they produce acid or alcohol that help to stop the growth of nasty bacteria.

Vacuum-packing
This method works by removing air from around the food – like us, some microbes need oxygen. However, some can survive with very little, so vacuum-packing needs to be combined with other preservation methods to make sure the contents stay safe.

Sugaring
Soft summer fruits can become fuzzy with mould in a matter of hours, but sugar helps keep them edible for months. It works in a very similar way to salting, but with sugar, the end result is a sweet treat-like jam.

Salting
This ancient preservation method works by dehydrating microbes. The salt draws water out of their cells, stopping them in their tracks. It also interferes with the molecular machinery that microorganisms need to survive. However, some microbes can tolerate more salt than others.

Chemical preservation

Many preservatives change the taste and texture of foods, but there is another option that's widely used in prepackaged products. These are chemical preservatives, and they don't just keep food fresh, they also help to preserve its colour and taste.

There are three main types: antimicrobials stop the growth of microorganisms, antioxidants stop fats going rancid, and the others help to destroy enzymes.

Common preservatives include sulphur dioxide, which is responsible for keeping dried apricots orange. Nitrates and nitrites are used to preserve meats like bacon. And ascorbic acid (vitamin C) can help to stop fruits turning brown after they've been cut.

Processed foods often have preservatives added to help them last longer

Sensitive teeth

Why can eating cold foods be painful, and what can toothpaste do to help?

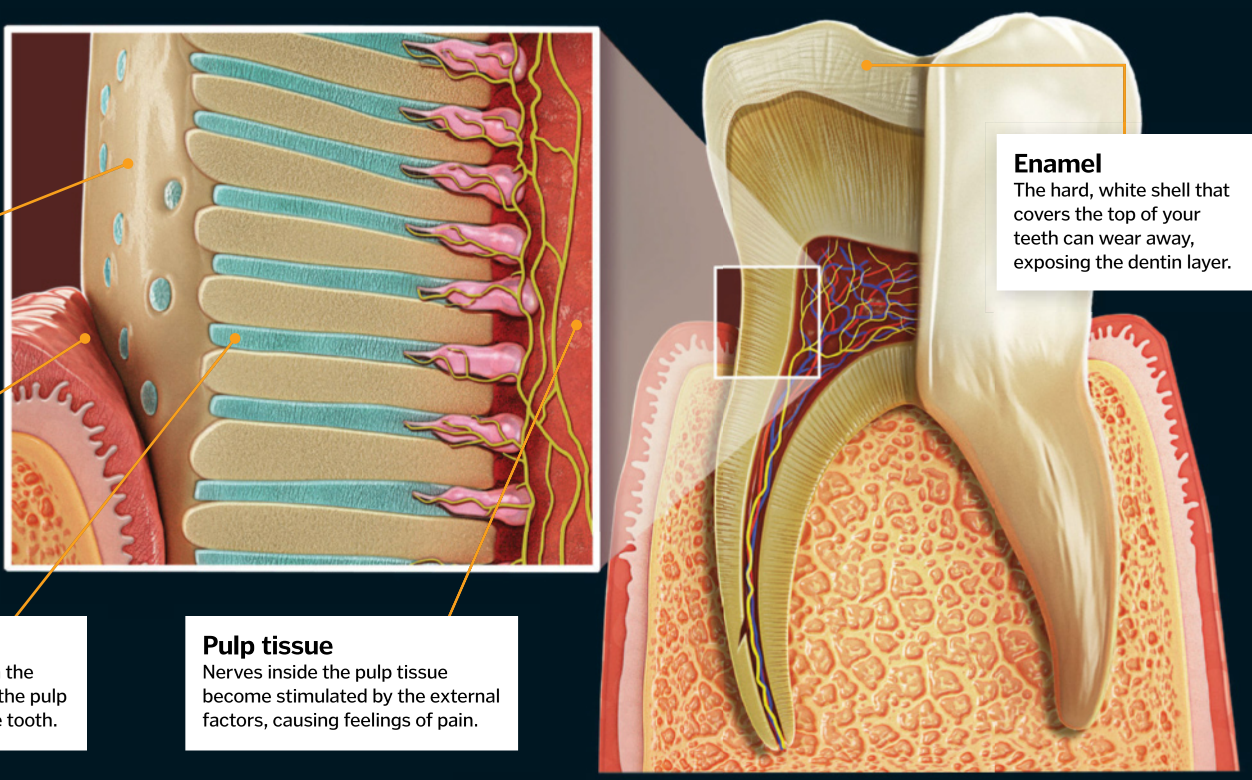
Hot or cold food and drink can cause sharp pains for those with sensitive teeth

If you've ever sipped on an ice-cold drink and felt a sharp pain in your teeth, then you've probably suffered from tooth sensitivity. It's a common condition caused when the soft interior layer of your teeth, known as dentin, becomes exposed, allowing hot or cold substances to reach the nerves inside.

Luckily, the problem can often be treated by simply changing your toothpaste. Special desensitising toothpastes contain ingredients that block the channels within the dentin layer, stopping anything from getting inside. However, if the problem persists, then it's best to see your dentist for alternative treatment.

Getting to the nerves

How do teeth become sensitive?



Dentin
This soft substance inside your teeth contains thousands of microscopic fluid-filled channels.

Gum tissue
The connective tissue in which your teeth grow can pull away from them, uncovering the dentin layer beneath.

Tubules
Heat or cold travels down the dentin channels towards the pulp tissue at the centre of the tooth.

Pulp tissue
Nerves inside the pulp tissue become stimulated by the external factors, causing feelings of pain.

Enamel
The hard, white shell that covers the top of your teeth can wear away, exposing the dentin layer.

Jaundice

What causes human skin to turn yellow?

Jaundice, also known as icterus, is a term used to describe the yellowing of the skin and the whites of the eyes. It is caused by a build-up of a substance called bilirubin in the blood, which is the yellow-coloured waste product produced when old red blood cells break down. Normally, bilirubin is filtered out of your bloodstream by your liver and then excreted, but people with conditions affecting their liver can be left with an excess of the substance, which can leak out into surrounding body tissue.

While adults and older children can get jaundice, it is most common in newborn babies. As an infant's liver is still developing, it can be slower to remove bilirubin from the blood than normal, but the symptoms usually disappear after a few weeks with no need for treatment.

However, if the jaundice becomes more severe, it can be treated using phototherapy, which involves using blue coloured light to break down the bilirubin in the blood. Alternatively, the infant could receive a blood transfusion, giving them more red blood cells to counteract the bilirubin.

Phototherapy can help break down the excess bilirubin in a newborn baby's blood

Treatment for jaundice in adults and older children typically involves treating the underlying condition that's causing it

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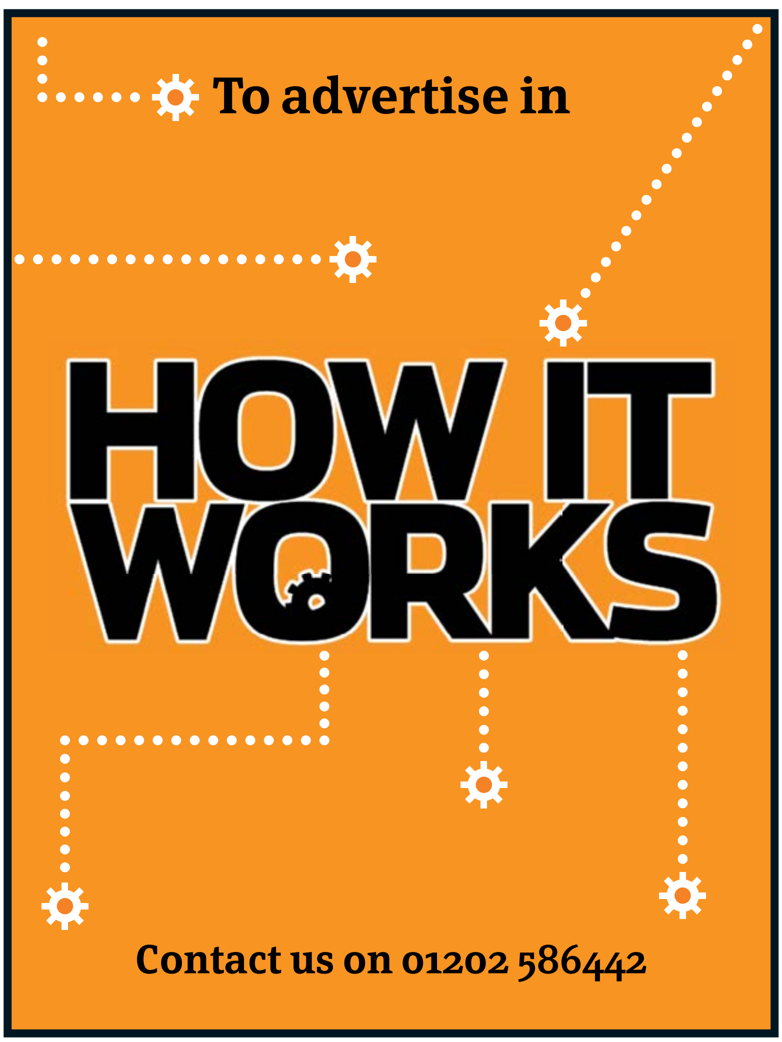

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THE NEW AGE OF SAIL

Meet the fleet of new wave ships that are giving sail power a 21st century makeover

Once upon a time, sail ships dominated the seas. Yacht-like clippers raced to be the first to bring back tea, spices and even gold from Asia to 19th century Europe. Perhaps the most famous was the Cutty Sark, which broke records when it sailed from London to Sydney in little over 70 days, reaching speeds of over 17 knots (31.5 kilometres per hour) in the process.

Trailing behind the clippers were the mighty windjammers, which carried up to 5,000 tons of heavy cargo, such as lumber, between continents. Even with five large masts and broad square sails they averaged approximately 7.5 knots (13.9 kilometres per hour).

Both clippers and windjammers were reliant on following the prevailing winds to circumnavigate the world. The opening of the Suez Canal in 1869 signalled the end of the age of sail. It offered a shorter route from the North Atlantic to the Indian Ocean, but travelled inland where winds were weakest. Steam ships became the preferred option, then the more efficient diesel engine.

Shipping continues to be the main way we transport goods today. In fact, shipping has grown by 400 per cent since the 1970s, and there are now an estimated 100,000 ships at sea carrying the products we consume. In our globalised world, 90 per cent of our international trade is now transported via the sea. But the 16 largest cargo ships can produce as much sulphur pollution as 800 million cars.

This is in part due to container ships burning low-grade 'bunker fuel', which is even more harmful than the refined petrol we use in cars. Regulations exist to control shipping emissions, but the harmful particles are believed to be responsible for thousands of human deaths each year. Organisations like the Sustainable Shipping Initiative are working to reform the industry by 2040, but climate change is moving faster.

However, a new generation of sailors and ship builders may have an environmentally friendly solution, which will draw on the past in order to save the future. The last decade has seen traditional sailing ships refitted to transport small quantities from the tropics like the clippers of old.

Meanwhile, the rising cost of fuel is also forcing big businesses that transport vast quantities to innovate, such as experimenting with modern twists on the classic windjammer. And the eco-friendly innovations of wind power aren't limited to cargo transport, with even luxury yachts like the Maltese Falcon utilising sails.

> "The 16 largest cargo ships can produce as much pollution as 800 million cars"

Self-standing masts
The three masts each contain five sails, which total 2,400 square metres of sail area.

Hydraulic system
Rather than using ropes to adjust the sails, a hydraulic system is used to rotate the masts so the sails can catch the wind.

The iconic Cutty Sark clipper transported cargo around the world between 1870 and 1922

Reinventing the sail rig

When the Maltese Falcon hoisted its sails on the yachting scene in 2006 it was hailed as revolutionary. Its sails were aerodynamically curved and the masts turned by hydraulics towards the best angle for the wind. Though it looked cutting-edge, the technology was actually developed by a German engineer in the 1970s.

Wilhelm Prölss, who worked for Shell Oil for 30 years, proposed an entire cargo ship built with freestanding, rotating sails, which he called the Dynaship (also known as DynaRig), as a way to get around surging fuel prices during the 1973 oil crisis. However, his ideas were not properly tested until American billionaire Tom Perkins commissioned the Maltese Falcon. This was in part because the technology wasn't there in the 1970s; hydraulics were not reliable enough and the masts were too heavy. But recent advances, especially in carbon fibre, have changed that.

Since its maiden voyage in 2006, the Maltese Falcon has proven the DynaRig concept works. Dykstra Naval Architects, which helped design the Maltese Falcon, have developed plans for the Ecoliner cargo ship in line with Prölss' original vision.

The Maltese Falcon super-yacht is proof that the concept for other eco-friendly ships, like the Ecoliner cargo vessel, can work

RADICAL REDESIGN

This container ship acts as a giant airfoil so it can sail directly into the wind

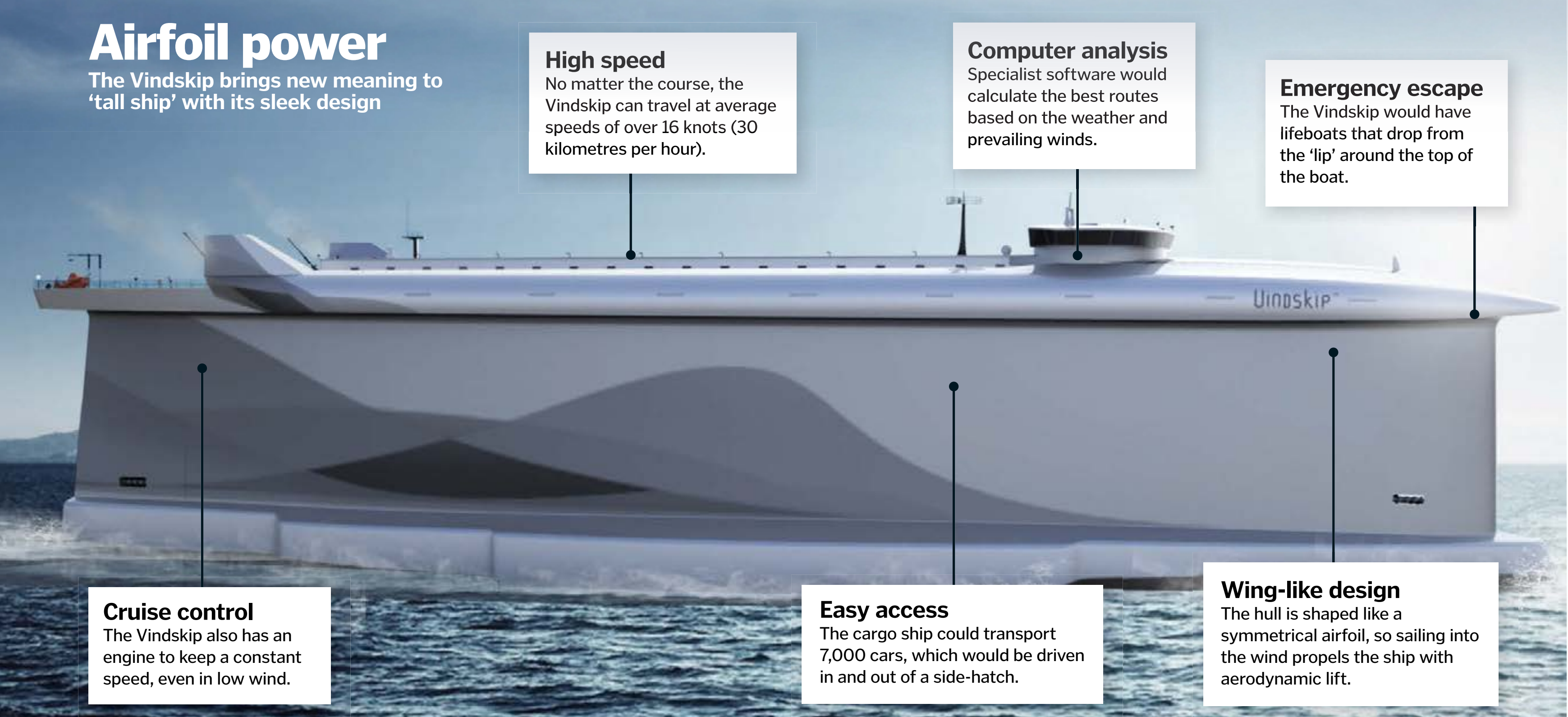
While the Ecoliner offers a modern twist on the classic sail ship, the Vindskip takes its lead from airplane designs. The ship has a uniquely shaped hull, with high sides that curve outwards like the shape of a plane's wing. This means that rather than sailing with the wind, the Vindskip would sail into the oncoming wind. Its airfoil shape would harness a force akin to aerodynamic lift, pulling the ship forwards.

Like the Ecoliner, the Vindskip is also a hybrid, equipped with a liquefied natural gas engine to get it going from a standstill. But because wind power will help to drive the Vindskip out at sea, the engines can be small, meaning that more space is free to store cargo, all the while achieving fuel savings of 60 per cent and reducing emissions by an impressive 80 per cent.

This innovative vessel was designed by Norwegian firm Lade AS, and there are plans for the first Vindskip merchant ships to appear by 2019 provided ship builders license the design.

Airfoil power

The Vindskip brings new meaning to 'tall ship' with its sleek design



TRADITIONAL TRANSPORT

Romantic rum-runners leading the eco-revolution

The Tres Hombres schooner looks like a relic from the first age of sail. But it has actually only been sailing since December 2009, and is at the forefront of the return to wind power. It's owned and operated by Fairtransport, a Dutch organisation dedicated to making eco-friendly cargo shipments a reality.

Rather than being fitted out with any cutting-edge technology, the Tres Hombres relies on a traditional complement of 12 sails. Despite this, it's kick-starting the wind power revolution by transporting rum, coffee and cocoa across the Atlantic with 90 per cent less carbon emissions. With only 35 cubic metres of space available for cargo, the Tres Hombres is not going to provide for all of the world's shipping needs. But it is not alone.

Fairtransport's Sail Cargo Alliance is currently developing a number of other ships, and another company, Sail Cargo Inc, just successfully crowdfunded their own carbon-neutral clipper, powered by a mix of wind and solar power. The drive towards greener shipping has truly begun.

The Tres Hombres transports modern cargo on a rebuilt 1940s minesweeper

A HIGH-FLYING FIX

Automated sails can reduce the amount of fuel existing ships use

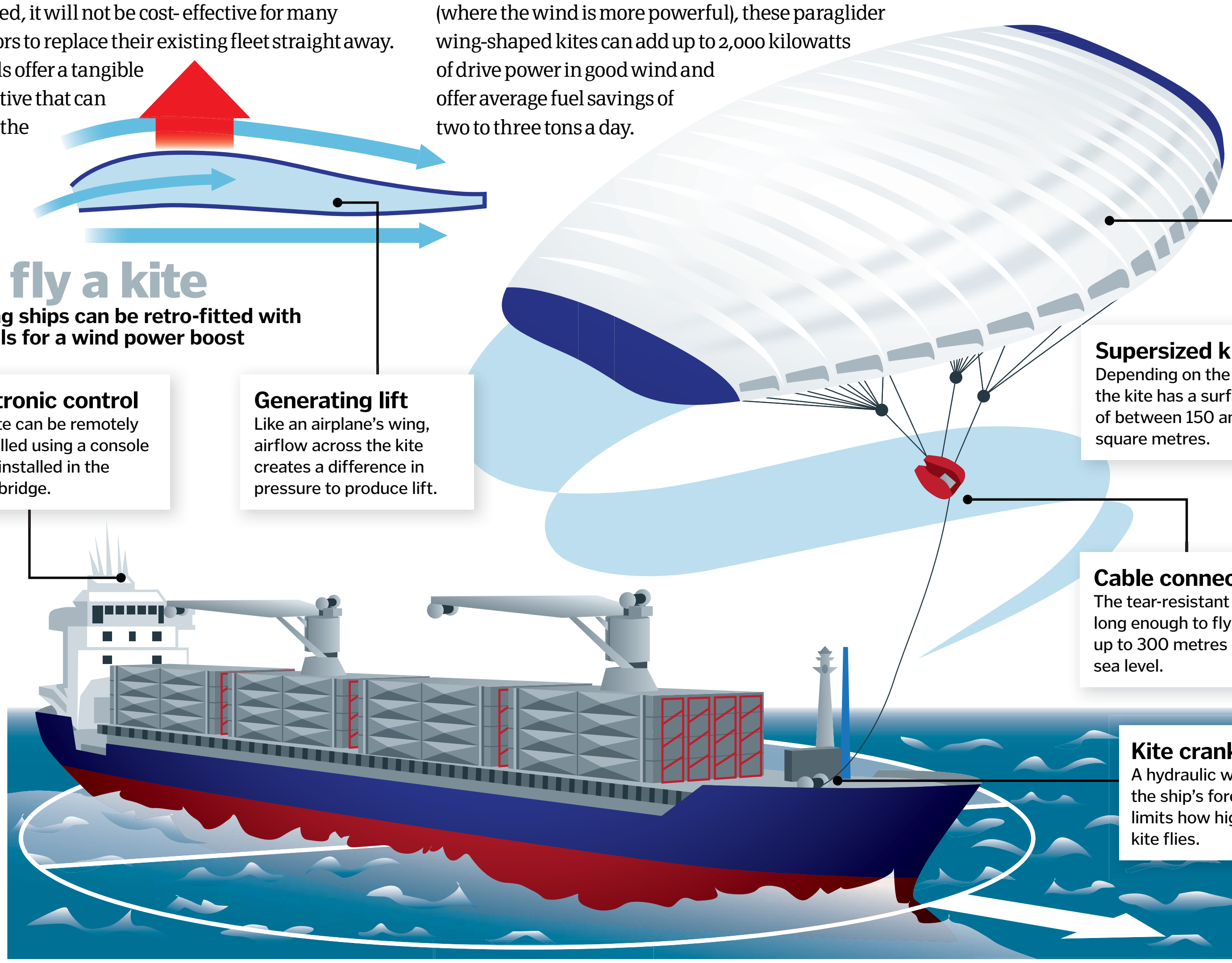
While there are lots of ideas for new wind-assisted ships, most are only at the prototype stage and are several years from setting sail. Meanwhile, 50,000 cargo ships will continue to pollute and contribute to climate change.

Even once the Ecoliners and Vindskip concepts are perfected, it will not be cost- effective for many operators to replace their existing fleet straight away. SkySails offer a tangible alternative that can reduce the amount of fuel today's merchant ships use immediately by retro-fitting them with tech to harness wind power.

Based in Germany, so far the company has equipped five ships with the kites. While they are not as powerful as sails, when flown at high altitude (where the wind is more powerful), these paraglider wing-shaped kites can add up to 2,000 kilowatts of drive power in good wind and offer average fuel savings of two to three tons a day.

Go fly a kite

Existing ships can be retro-fitted with SkySails for a wind power boost



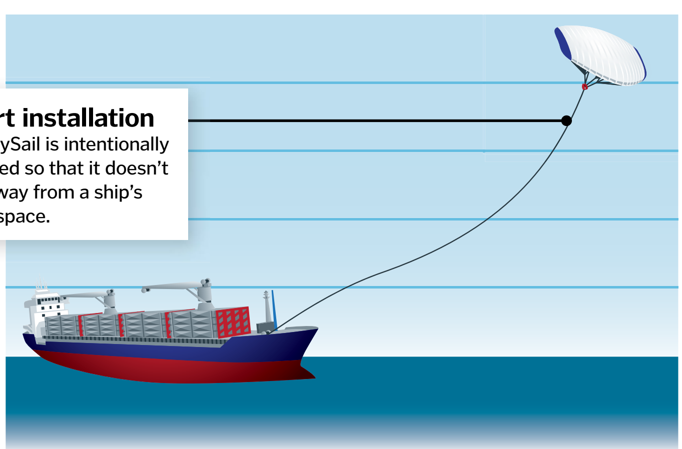
Electronic control
The kite can be remotely controlled using a console that's installed in the ship's bridge.

Generating lift
Like an airplane's wing, airflow across the kite creates a difference in pressure to produce lift.

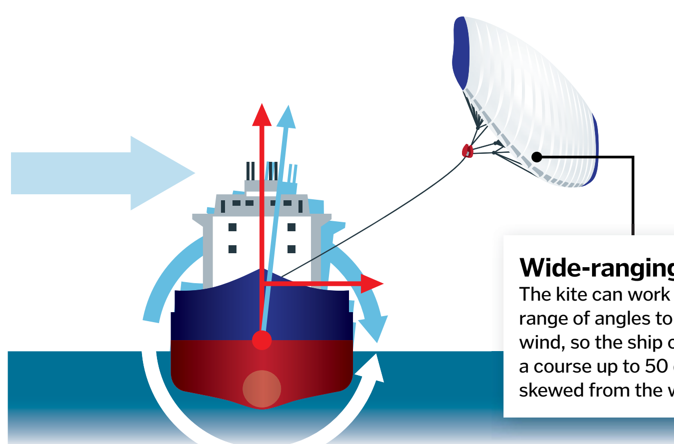
Supersized kite
Depending on the vessel, the kite has a surface area of between 150 and 600 square metres.

Cable connection
The tear-resistant rope is long enough to fly the kite up to 300 metres above sea level.

Kite crank
A hydraulic winch on the ship's foredeck limits how high the kite flies.



Smart installation
The SkySail is intentionally designed so that it doesn't take away from a ship's cargo space.



Wide-ranging
The kite can work over a range of angles to the ship, so the ship can take a course up to 50 degrees skewed from the wind.

Airplane flaps

How moveable panels help a plane take off and land safely

As a plane is taking off, it needs to generate lift to be able to get into the air. Flaps are hinged surfaces attached to the rear of both wings. During take-off they move downwards in unison, increasing the area of the wing and producing more lift. This is achieved as the curved shape of the flaps pushes more airflow downwards under the wings, and the aircraft is pushed higher into the air as a result. The flaps are retracted when cruising at high altitudes, but are used again during the descent to increase lift and drag for a safe, controlled landing.

Thrust, drag, weight and lift all play a key part in how an airplane moves

Secondary flight controls

How flaps and other devices help a pilot control an airplane

Rudder
Controlling yaw, the rudder makes the plane change its horizontal direction.

Winglet
Positioned on the tips of both wings, winglets help to reduce drag.

Horizontal stabilisers
These keep the aircraft flying in a straight line and prevent the aircraft from straying off course.

Elevator
These panels help the aircraft to climb and dive by altering the lift on the tail of the plane.

Leading edge slat
On the front of the wings are slats that assist flaps in changing the shape of a wing to increase lift and drag.

Ailerons
These metal panels that are placed near the wing tips help to turn the aircraft by raising one panel and lowering the other, changing the lift forces on each side.

KEY:
Orange = Slats and flaps
Blue = Primary flight controls

The EcoHelmet

How a recyclable paper helmet concept could make cycling safer

Bike-share systems are popular in many of the world's cities and provide a cheap and efficient way of travel. An invention that hopes to make this green method of transportation safer is the EcoHelmet. Since most people won't be carrying a helmet around with them just in case they fancy a spontaneous cycle, the foldable, portable and compact EcoHelmet could come complete with your ride at a bike rental spot, so you can set off fully protected.

A radial honeycomb pattern protects against impacts from any direction, and it's as strong as a standard polystyrene helmet. Its design works by spreading the force of an impact across the whole helmet, dissipating it, which will help protect your skull in a crash. The helmet is also rainproof for up to three hours and is made of a stretchy material that will fit most head sizes.

The concept is a small and inexpensive solution to help make cyclists safer, and is also 100 per cent biodegradable. The paper helmet can simply be recycled after use, unlike a standard styrofoam helmet, which takes 500 years to decompose.

Jaguar I-Type teardown

The British luxury car brand's first foray into Formula E, the pinnacle of all-electric racing

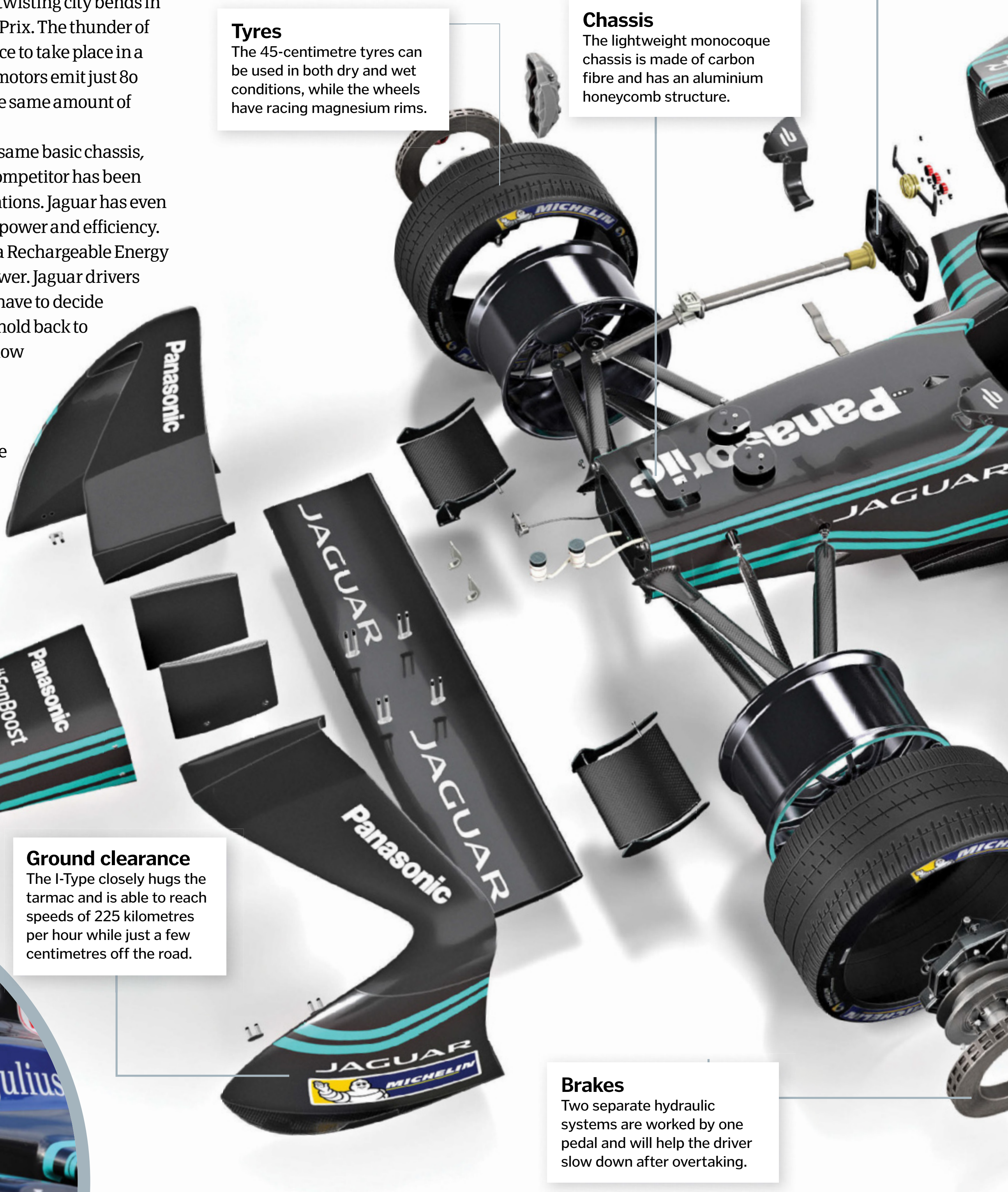
The third season of Formula E has welcomed a new competitor onto the starting grid. Jaguar has entered its own car into the international electric street racing series and is currently competing in 14 races across 12 world cities, from Montreal to Berlin. The I-Type can accelerate from 0-100 kilometres per hour in 2.9 seconds while navigating tight and twisting city bends in the approximately 50-minute long ePrix. The thunder of Formula 1 engines is too loud for a race to take place in a city centre, but Formula E's electric motors emit just 80 decibels of sound, which is about the same amount of noise as busy city traffic.

All Formula E's ten teams use the same basic chassis, but since the second season, each competitor has been allowed to make extensive modifications. Jaguar has even built its own powertrain to balance power and efficiency. And a lithium-ion battery that uses a Rechargeable Energy Storage System (RESS) is used for power. Jaguar drivers Adam Carroll and Mitch Evans will have to decide when to push forward and when to hold back to ensure that the battery doesn't run low during the race. The drivers have to manage coasting, braking and accelerating carefully.

The innovations used in the I-Type won't just be limited to a racing chassis, as there are plans to introduce these technologies to road cars in late 2018. Clearly, Jaguar is intent on pushing the boundaries of electric vehicles both on and off the racetrack.

The I-Type

The technology used to power Jaguar's hi-tech racer on tracks around the world



Steering
Rack and pinion steering enables the I-Type to handle very tight corners. The entire dashboard is integrated into the steering wheel.

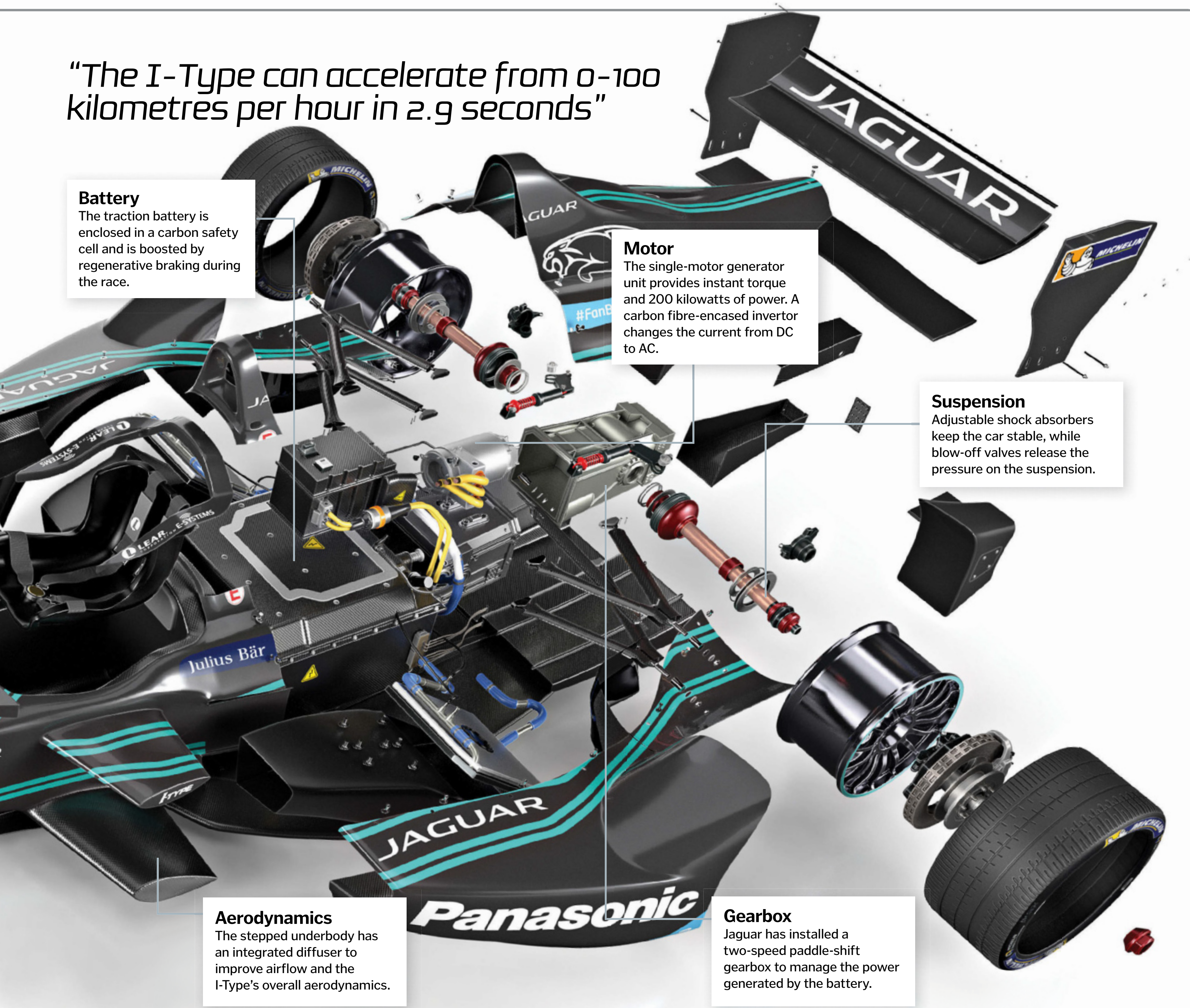
Tyres
The 45-centimetre tyres can be used in both dry and wet conditions, while the wheels have racing magnesium rims.

Chassis
The lightweight monocoque chassis is made of carbon fibre and has an aluminium honeycomb structure.

Ground clearance
The I-Type closely hugs the tarmac and is able to reach speeds of 225 kilometres per hour while just a few centimetres off the road.

Brakes
Two separate hydraulic systems are worked by one pedal and will help the driver slow down after overtaking.

"The I-Type can accelerate from 0-100 kilometres per hour in 2.9 seconds"



The I-Type's rivals on the track

Renault
Season two's champions have refined their winning design. The two-speed gearbox is gone, replaced by a direct drive system that lessens weight and friction. They are currently setting the pace this season.

Mahindra
The M3Electro enters the third season of Formula E with the new curved front wing. 150 kilowatts rather than 100 kilowatts will be regenerated by the RESS, transferring more power to the wheels.

NextEV
This time around the first season victors have new transverse twin motors that run on direct drive. NextEV finished top of qualifying in Hong Kong, this season's first circuit.

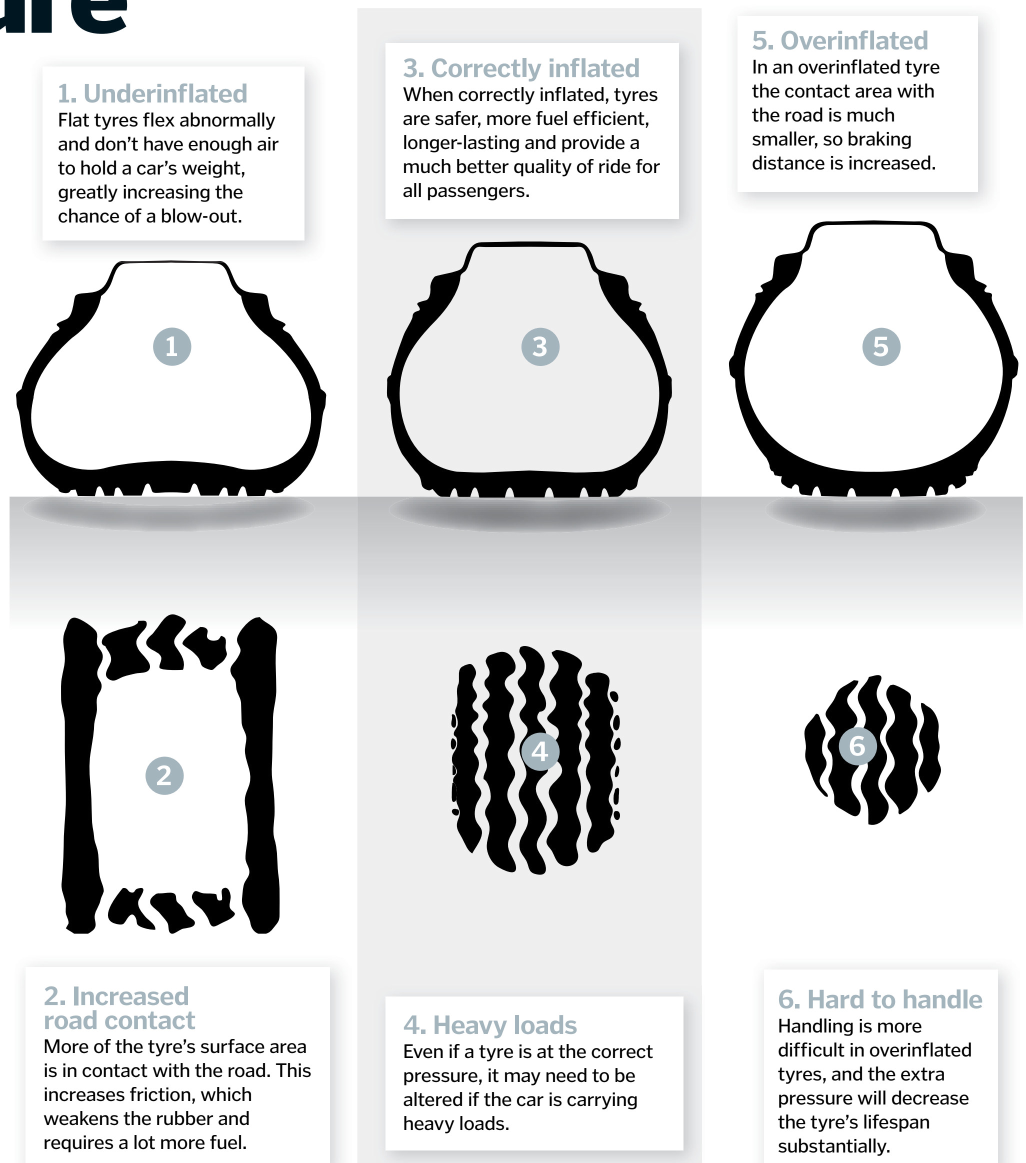
Tyre pressure

Why tyre inflation is vital to the performance, safety and efficiency of your car

Tyre pressure affects a car's handling, and if they are pumped up too little, or even too much, driving can become unsafe. An underinflated tyre is more likely to overheat, while overinflated tyres can lead to reduced traction. Tyre pressure is typically measured in pounds per square inch (PSI), and should be checked with a gauge while cold at least once a month. On average, front tyres last for at least 32,000 kilometres, while rear tyres can keep going for at least 64,000 kilometres. Airplane and racing car tyres are often filled with nitrogen rather than air, as this gas is more suited to extreme conditions encountered at altitude and high speeds.

Are your tyres inflated correctly?

Tyre pressure levels can make the difference between a safe and a dangerous journey



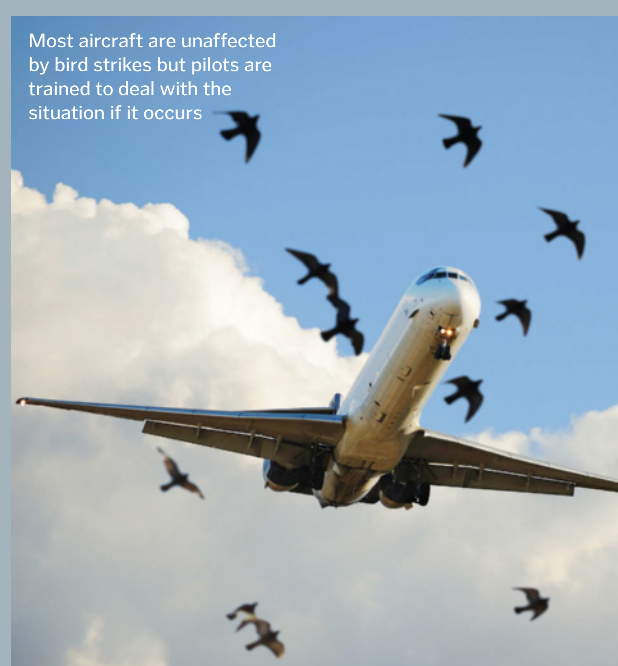
Bird strikes

The collisions between aircraft and wildlife that can be disastrous

When an aircraft is taking off or landing, it is at its highest risk of a bird strike. If a bird is swallowed by a jet engine, the blades can become bent or damaged, while on smaller aircraft in particular, the damage can also create dents in the fuselage. It is rare for a collision to result in a precautionary landing or an abandoned take-off. However, when a particularly large fowl is sucked into the engine, the pilot can experience a loss of thrust and control.

For instance, a near six-kilogram Canada goose colliding with an aircraft going at 240 kilometres per hour would hit the plane with the force of a 450-kilogram weight being dropped from three metres. If an engine is disabled by the impact, pilots can adjust the rudder to fly with only one engine.

Nevertheless, over 250 air travel injuries have been attributed to bird strikes worldwide since 1988. One such incident brought down US Airways Flight 1549 in 2009, which was forced to make an emergency landing on the Hudson River. Bird strikes are most common at coastal airports or when a flight path clashes with a migration route. Airports often undertake habitat management to decrease nearby food and shelter for birds, or install bird-scaring technologies such as pyrotehnic cartridges .



Most aircraft are unaffected by bird strikes but pilots are trained to deal with the situation if it occurs

Inside a Series 1

Land Rover have released 25 fully restored Series 1s built to the original 1948 specifications

Passenger safety
A dashboard handrail gave passengers something to hold when travelling on uneven ground.

Bodywork
The Series 1's aluminium body made it lightweight, and with a low centre of gravity, it was stable on rough terrain.

Engine
The Land Rover Series 1 relied on a 1.6-litre engine, which provided about 50 brake horsepower.

Suspension
The strong axles and leaf-spring suspension made the ride very bumpy. Coil springs were used for later Land Rover series.

4x4
The Land Rover utilised a four-wheel-drive system for improved off-road performance.

Fuel tank
The fuel tank held up to 45 litres of petrol or diesel, and was located under the front seat on the right-hand side.

Chassis
The simple and cheap chassis was made up of four flat strips of metal welded together.

Land Rover Series 1

The vehicle that began the famous 4x4 dynasty was inspired by WWII jeeps

Now a British motoring icon, the legendary Land Rover was first launched back in 1948. Unlike its prototypes, the retrospectively named Series 1 did not contain any components from war jeeps. The Land Rover had a 1.6-litre engine to power the vehicle during off-road tasks, just one aspect that made the Series 1 a durable vehicle. It had attachments that came as standard, including a towing plate and a pintle pin that were fixed to the rear and could be used to haul trailers and other heavy loads. The designers hoped it would prove popular with farmers and industrial workers.

The Land Rover was based on performance and did not come with all the creature comforts you may expect. But they were incredibly versatile, with features like removable doors and an optional combine harvester towing plate that could simply be added to the vehicle.

The Land Rover proved incredibly popular, and soon enough the Series 1 was being sold as fast as it was being made. During its ten years of production, newer vehicles came to be installed with a larger two-litre engine and increased chassis sizes, which paved the way for the Series 2 and a whole line of Land Rovers.

The post-war Rover revelation

The Series 1 Land Rover brought variety to a company that had previously specialised in selling luxury saloons. It was initially designed as a temporary model when steel was in short supply after World War II. Aluminium was mostly used to construct the body panels rather than steel, and the Series 1's panels were riveted together at right angles so expensive press tools could be avoided. Even engines and gearboxes were taken from other models and re-used. The Series 1 really was a triumph of frugality.

Some of the Series 1 vehicles are still in a workable condition today

YOUR FUTURE IN SPACE

JUST BECAUSE WE WERE BORN ON EARTH, IT DOESN'T MEAN WE'RE DESTINED TO STAY HERE

It goes without saying that the Earth is the perfect home for us. From the last universal common ancestor to the human beings that have spread across the planet today, we've been slowly fine-tuning ourselves through evolution to perfectly suit our environment.

But it may not be that way forever. We continue to burn fossil fuels in abundance and our population continues to boom, which is damaging our environment and placing a strain on resources. How long our planet can continue to support the ever-growing population of humans is a major cause for concern.

Aside from our self-inflicted destruction, we may still be forced to move elsewhere. We already know of at least one mass-extinction event that's been caused by an asteroid colliding with our home, and what happened to the dinosaurs could also happen to us. An asteroid crashed into Siberia in 1908, causing devastation to the local environment. Fortunately, it was only about 50 metres wide and our species survived, but much larger comets and asteroids fly through our galactic neighbourhood fairly regularly. How long until the next one hits?

So an extraterrestrial future, at some point at least, seems inevitable. But rather than fleeing into the expanses of space, there are also many positive reasons for the human race to broaden its horizons.

Travelling far away could improve life at home in many ways. By journeying to, and mining from, asteroids, we could harvest many desirable materials and save our planet's deposits. By spreading our species across the cosmos we'd also be safer from a universal extinction event, preserving our – as far as we know – unique intelligence and consciousness. And having fewer humans on Earth can only be a good thing, as the biodiversity of other species could expand and thrive in our absence.

Perhaps just as importantly, what an inspirational step it would be for humankind. We're born explorers; we love encountering and discovering the unknown. What better way to scratch this itch than by embarking towards the final frontier?

In this feature, we'll explore the possible future of humanity as an interplanetary species. It's a goal that many around the world are already working towards.

WHERE COULD WE GO?

The Solar System and beyond is full of planets and moons, but which is best?

When surveying potential options for our new home that are within reach, we may feel our choices are limited at first. But with the correct technology, we'd actually have quite a few to pick from, even in our own Solar System. We could colonise another planet, a moon, or even space itself.

Currently the most romantic choice seems to be Mars. As a close neighbour that could potentially house an enclosed habitat, it's certainly appealing. But we needn't limit our imaginations to just Mars. Every night another potential home rises to greet us.

We already know we can get to the Moon, and its closeness to Earth makes it a candidate. Materials, supplies and even new colonists could be transported there with ease. Due to the relatively short distance (astronomically speaking) contact with Earth would also be much quicker.

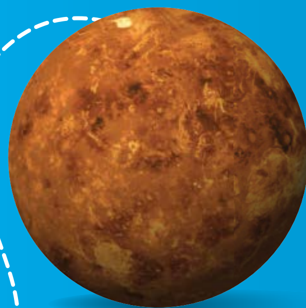
But, unlike Mars, the Moon is almost completely devoid of water. However, the same can't be said for some of Saturn's moons. Some of these satellites even have liquid water, which spurts out from oceans below their surface. They could offer a potential way for us to harvest water, an integral ingredient for survival.

Once settled on a planet or moon, our eventual goal would be terraforming. This would involve generating gases to form an atmosphere like Earth's, allowing life to flourish. But this would be no small task, so perhaps getting to these planets would just be the easy part.

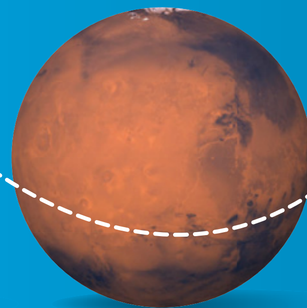
Billions and billions of worlds exist beyond our Solar System, but reaching them will be challenging

Possible destinations

Astronomers have identified a whole host of worlds that could potentially become our new home

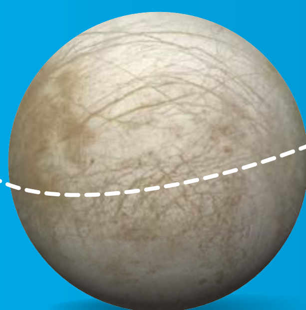


Venus
261mn km
Although sometimes described as 'Earth's sister' due to its similar mass and close proximity to us, Venus' closeness to the Sun has raised surface temperatures to 462°C – so we'd have to live in floating cities in the clouds.

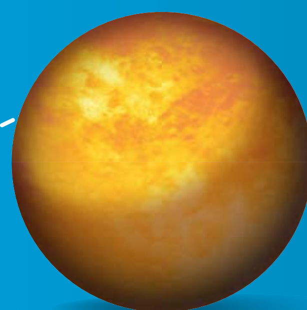


Mars
225mn km
The extensive research that's currently being conducted on the surface means we'd be better prepared if we eventually settle there. We've already identified buried ice and also understand the dangers that await us.

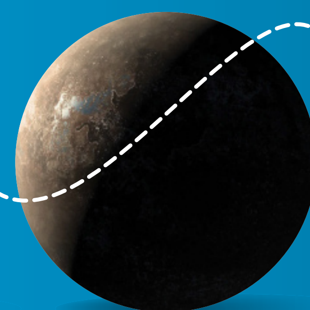
The Moon
384,400km away
Being the closest large space object to us makes the Moon a strong candidate for the first extraterrestrial colony. Materials and people could be transported to and from Earth much more easily than elsewhere.



Europa
628.3mn km
With plenty of oxygen and oceans of liquid water, Europa could be one of the best places for life in our Solar System. But it's low gravity and freezing temperatures may mean it's better for us to reside in an orbiting space habitat.

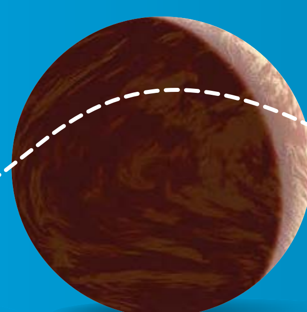


Titan
Approx. 1.4bn km
Saturn's largest moon has lakes, clouds and rain – but they're not made of water. On Titan, methane exists in liquid form and cyanide gas floats over the surface. Underground habitats would provide the most protection.

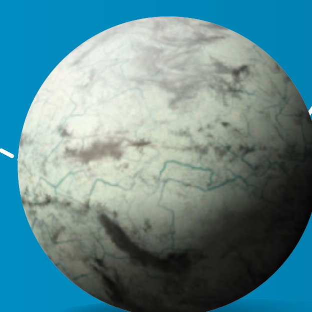


Proxima Centauri b
4.2 light years
This planet is exciting as it orbits our closest stellar neighbour. It's probably also a victim of constant bombardment from solar flares as it's so close to its star, but it's a rocky planet with the right temperatures for liquid water.

GJ 667 Cc
23.6 light years
This planet is also within a desirable range of its local star for it to possess liquid water. Unfortunately, the dwarf star is likely to produce solar flares. To settle there, we'd have to shield ourselves from this radiation.



Wolf 1061 c
13.8 light years
This planet orbits its star in the 'Goldilocks zone', meaning that it is neither too hot nor too cold for liquid water. And it doesn't appear to get hit with too much solar radiation either, making it a potential safe haven for humans.



Kapteyn b
12.8 light years
This planet could be one of the most habitable of all known space objects. It's heavy, has favourable temperatures for liquid water, and it is thought to be twice as old as the Earth – so it may already in fact host life.

ON THE MOVE

Overcoming the distances between systems is one of our biggest challenges

Even if we decided to 'only' venture as far the nearest star cluster from our Solar System, we'd still be talking huge distances. More than four light years, in fact. That means that even if we were travelling at near the speed of light it would still take us years, and today's rocket engines can't even reach one per cent of light speed.

But despite the mammoth stretch involved it may be worth our while to venture there. But how would we do it? The answer may lie with designing a new propulsion system that's capable of much higher speeds than the rocket-fuelled ones of today. The majority of such designs remain in the theoretical phase, but some have the potential to increase velocities much closer to the speed of light. This means we could traverse the gap between systems in perhaps decades, rather than millennia.

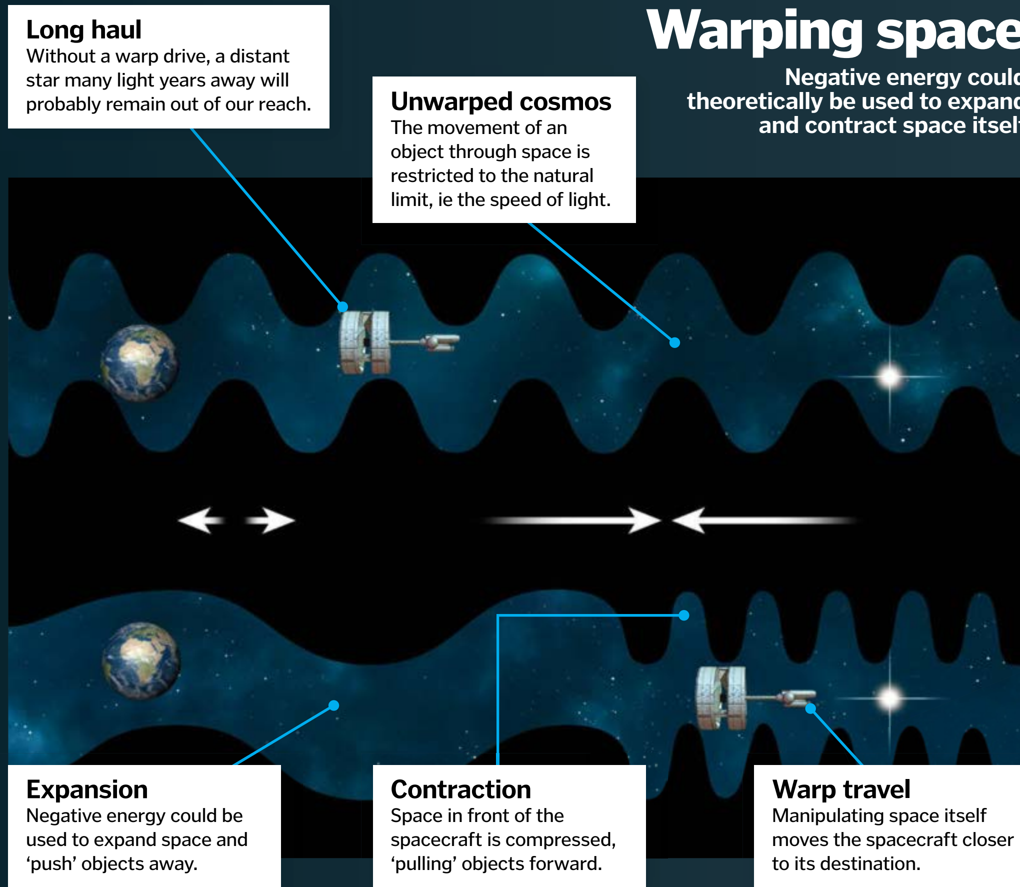
What makes these innovative engine concepts so interesting is their choice of fuel, and how we can best make use of them. Ionised gases, interstellar hydrogen and even antimatter have all been proposed as potential options, and could, in principle, be employed to shoot us quickly towards distant stars. Or, rather than high-speed travel, how about bending space-time around us instead?

Of course, it sounds impossible, but according to Einstein's theory of relativity, it isn't. And this knowledge has given birth to the idea of a warp drive. By using an elusive form of energy known as negative energy, we could expand and contract space around spacecraft in order to move them closer to a goal in a time span that would otherwise be completely impossible.

For the foreseeable future, warp drives are just an abstract idea. But some of the other designs are in development right now, and could be ready for blast-off sooner than we think.

Warping space

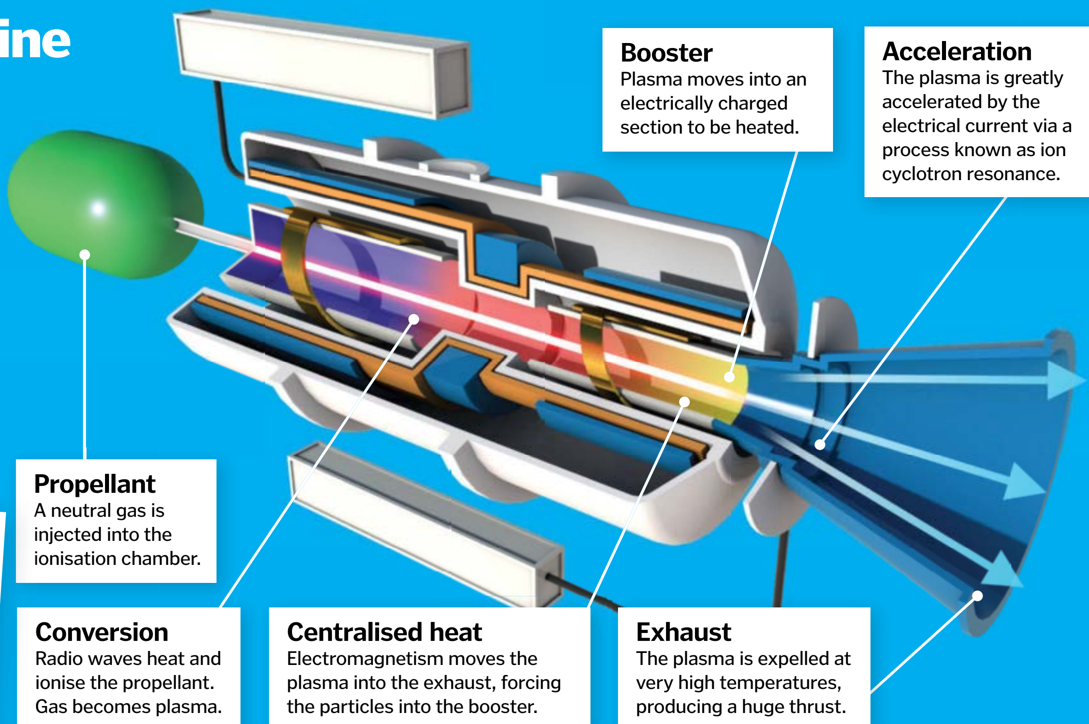
Negative energy could theoretically be used to expand and contract space itself



The VASIMR engine

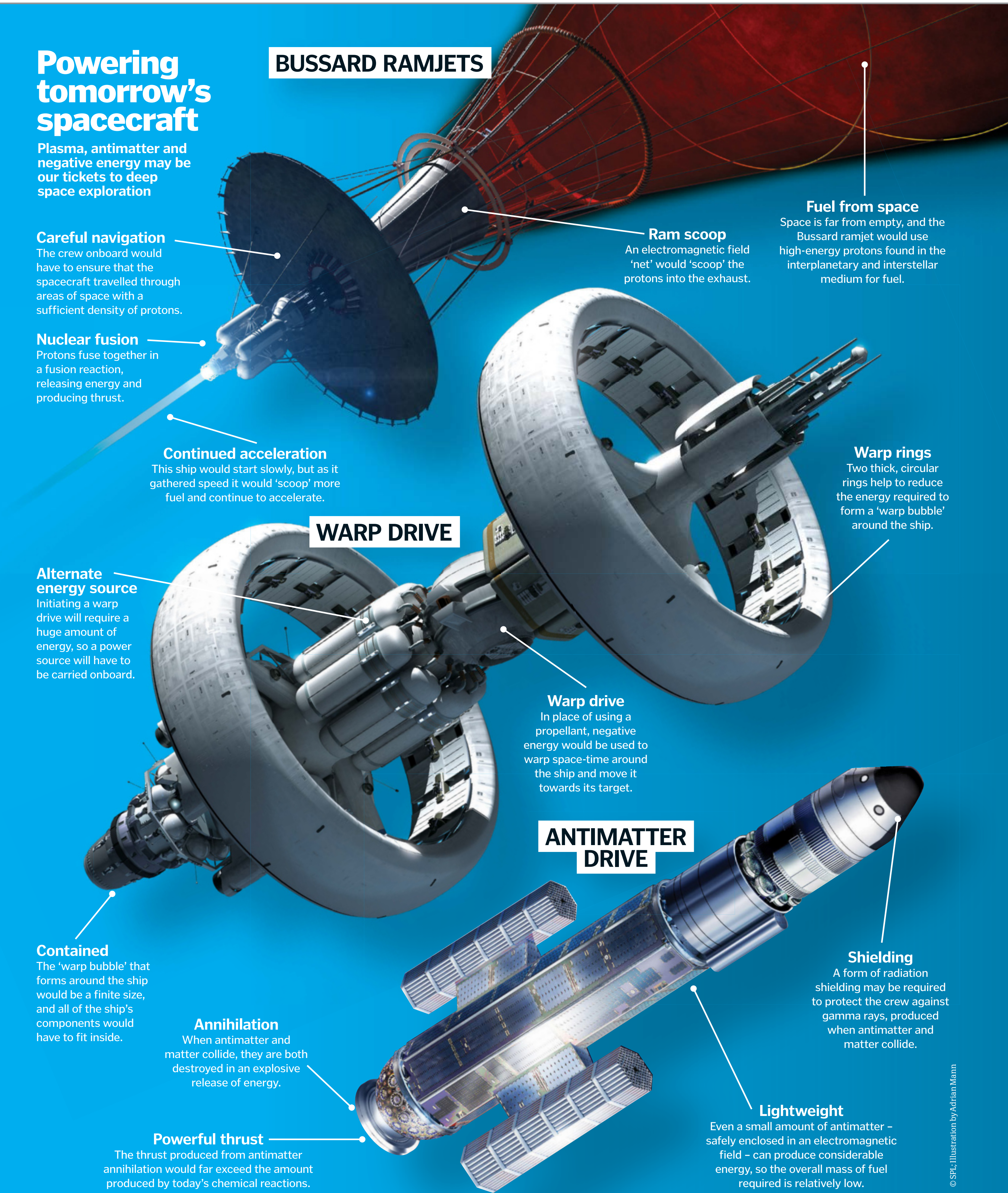
Today's rockets are launched by a chemical reaction, which involves quickly combusting a lot of fuel to get spacecraft off the ground. But although this approach has worked for us so far, chemical reactions are inefficient, and will be largely ineffective for taking us into the far reaches of space.

The Ad Astra Rocket Company's VASIMR (Variable Specific Impulse Magnetoplasma Rocket) offers a much more efficient, and faster, engine design. By supercharging simple gas into a viable propellant, spacecraft will require less fuel and will be able to travel consistently at higher speeds. This would allow us to travel further and faster than ever before.



Powering tomorrow's spacecraft

Plasma, antimatter and negative energy may be our tickets to deep space exploration



BUSSARD RAMJETS

Careful navigation
The crew onboard would have to ensure that the spacecraft travelled through areas of space with a sufficient density of protons.

Nuclear fusion
Protons fuse together in a fusion reaction, releasing energy and producing thrust.

Continued acceleration
This ship would start slowly, but as it gathered speed it would 'scoop' more fuel and continue to accelerate.

Ram scoop
An electromagnetic field 'net' would 'scoop' the protons into the exhaust.

Fuel from space
Space is far from empty, and the Bussard ramjet would use high-energy protons found in the interplanetary and interstellar medium for fuel.

WARP DRIVE

Alternate energy source
Initiating a warp drive will require a huge amount of energy, so a power source will have to be carried onboard.

Warp rings
Two thick, circular rings help to reduce the energy required to form a 'warp bubble' around the ship.

Warp drive
In place of using a propellant, negative energy would be used to warp space-time around the ship and move it towards its target.

Contained
The 'warp bubble' that forms around the ship would be a finite size, and all of the ship's components would have to fit inside.

ANTIMATTER DRIVE

Shielding
A form of radiation shielding may be required to protect the crew against gamma rays, produced when antimatter and matter collide.

Annihilation
When antimatter and matter collide, they are both destroyed in an explosive release of energy.

Powerful thrust
The thrust produced from antimatter annihilation would far exceed the amount produced by today's chemical reactions.

Lightweight
Even a small amount of antimatter – safely enclosed in an electromagnetic field – can produce considerable energy, so the overall mass of fuel required is relatively low.

SETTLEMENTS IN SPACE

Giant space habitats could allow us to bring a slice of Earth with us into the cosmos

An extraterrestrial civilisation of humans, wherever they may be, would need to rely on a home that could provide a similar amount of nourishment and protection as we receive on Earth. As we would need to consider air, heat, radiation, water, gravity, food, and ample habitable space, it would be a monumental task.

We know that nowhere nearby can provide all of these necessities, and terraforming will be a long, difficult, and perhaps impossible process. So maybe the easiest way to control these variables would be to assemble our own space habitat. This gigantic structure could either be a new permanent home, or a means to set off on a multi-generation migration.

The second option would be a quest unlike anything humanity has ever faced, and would involve many generations spending their entire lives in space, safely enclosed in a living habitat. But our universe is a very big place, and this may be our best way to explore it.

By realising our ambitions of mining asteroids we could gather the required materials, and by taking advantage of the centripetal force produced by spinning objects, we could simulate gravity. This project would be undeniably huge, but humans are capable of achieving great things, and we have an idea of how we could do it. In stark contrast to the sterile, squashed spacecraft we're used to, these settlements would be a true home away from home, containing many of the pleasures we enjoy on our planet's surface.

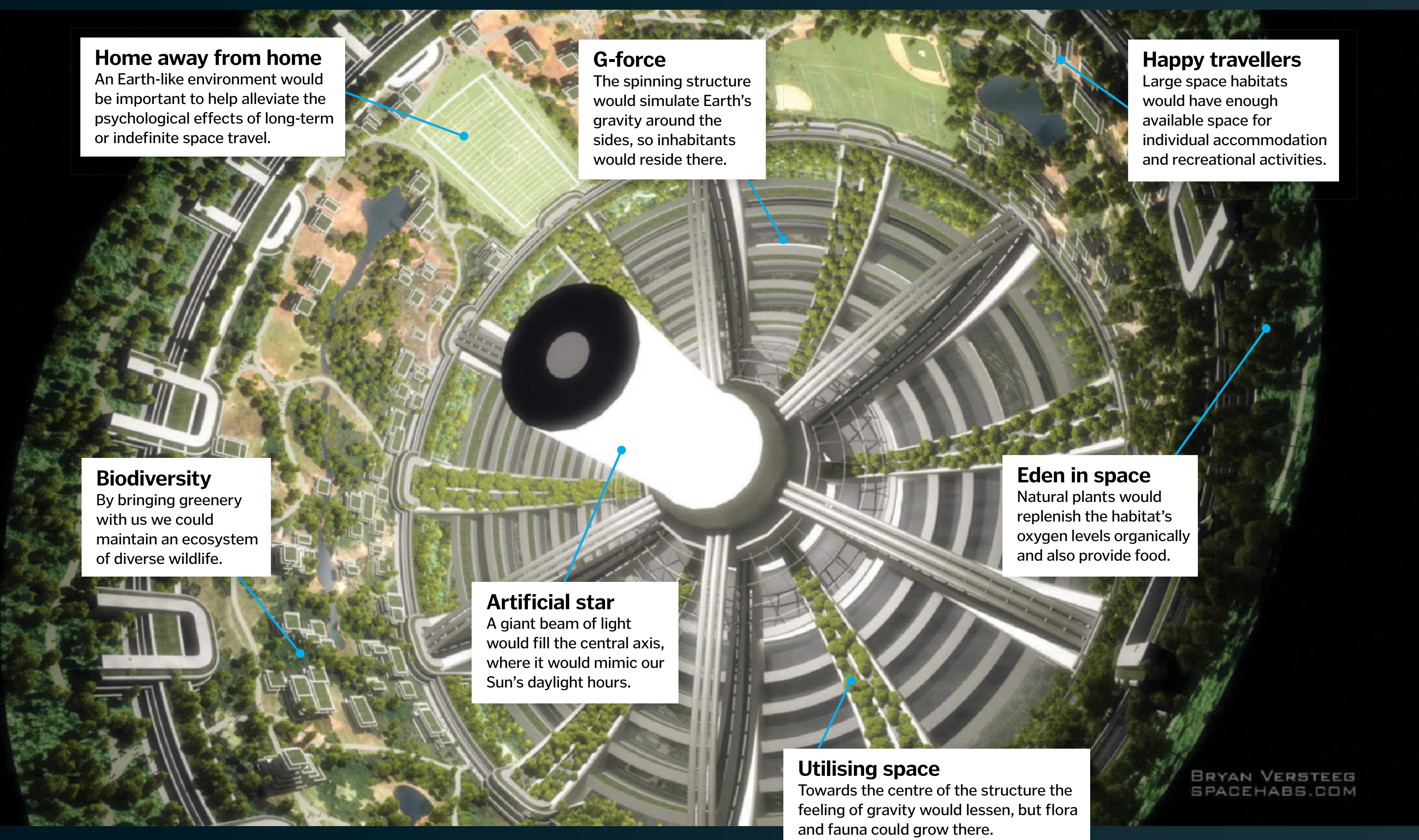
There's also one more aspect to consider about this possible future. If some colonists remain on Earth, others in space, and others on distant planets and moons, then our species may eventually begin to diversify. Remaining apart for many generations, throughout consistent subjection to different forces of gravity and atmospheres, could eventually mean some of us may not be simply humans any longer. Our future in space may create a new alien species: our descendants.

In the distant future we could be spoiled for choice, so let's get to know our options and take a tour of a space settlement.

Constructing a giant space habitat would be a monumental task for humanity

Making space home

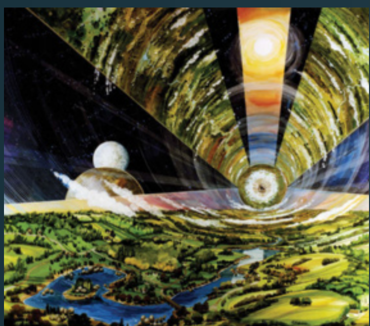
A habitat like the Kalpana One design would allow us to travel through space in style



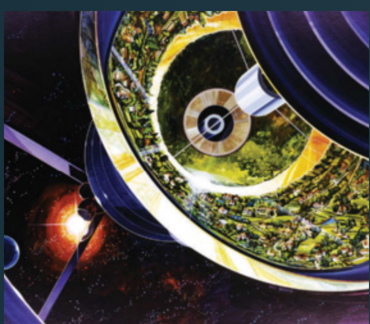
DID YOU KNOW? Over £10.5 [$13.4] billion has been invested in private space companies that plan to mine asteroids in the future

Retro concept designs

In the 1970s, a NASA-funded team inspired a generation of space enthusiasts with three spinning structures



O'Neill Cylinder
Three strips of land and three gigantic sections of glass would be assembled in a structure approximately eight kilometres wide and 32 kilometres long. Two of these structures could be positioned in a counter-rotating pair to stabilise the cylinders, which would otherwise rotate across their long axis as they spin.

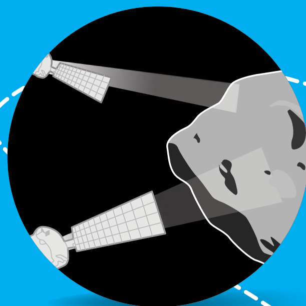


Bernal Sphere
Originally proposed by scientist John Bernal in 1929 before it was adapted in the 1970s, this design is similar to a globe in shape, only this time we would live on the inside of a hollow shell, rather than on the outside. Earth-like gravity would be felt along the equator and lessen as you neared the poles.

Stanford Torus
This concept would involve residents living inside a ring structure, which could either have a transparent ceiling or even an open top. The spinning motion would keep most of the atmosphere pressed within the rings, so spacecraft could easily come and go.

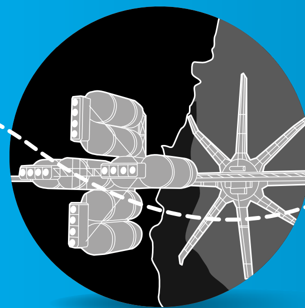
SPACE JOBS

A host of new careers will be up for grabs on our future space settlements



Extraterrestrial surveyor

Gathering sufficient resources will be one of the most important jobs for a space habitat, and asteroids will be the place to get them. A surveyor will assess these space rocks and decide on the best mining locations.

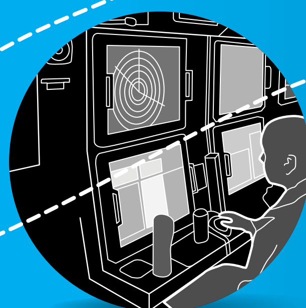


Asteroid miner

It is unlikely that a miner will go out on spacewalks and manually operate the equipment, as this would be extremely dangerous. Instead, they will be in charge of remotely operating and overseeing the machinery from the safety of their space habitat.

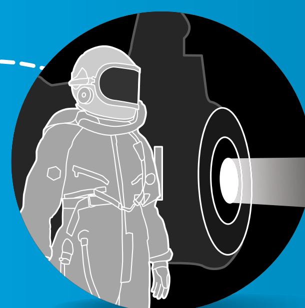
Atmosphere overseer

In this role, you'd have the lives of all of the other space inhabitants in your hands. Maintaining an Earth-like atmosphere in a space habitat will involve regulating oxygen and carbon dioxide levels, temperature and the amount of ultraviolet light.



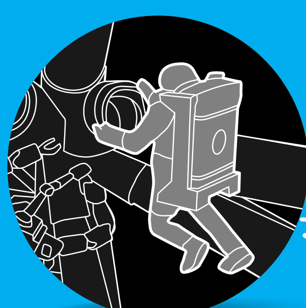
Communications and navigations specialist

One space habitat won't be enough to carry everyone, so the multiple ships will need a way to communicate. As well as sending and receiving signals, these specialists will ensure their ship stays on the right path.



Propulsion engineer

Whatever choice of futuristic engine is used to power the movement of our habitats, it will require monitoring and most likely refuelling. Propulsion engineers will oversee these processes and ensure the engine doesn't overheat or leak radiation.

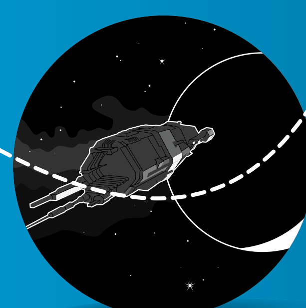


Habitat construction and maintenance

As it will be much easier to assemble huge structures in zero gravity, a construction team may well decide to build in space. They'll also repair any damage caused by space debris.

Exercise physiologist

A physiologist will make sure that the centripetal force caused by the spinning space station sufficiently mimics Earth's gravity, and will recommend weighted exercises for those who need to build more muscular strength.



Space voyager

When exploring the unknown it may be necessary to send human scouts to an object. Smaller spacecraft usually attached to the main habitat will be used for this task, with a dedicated team of space adventurers inside.

Inside the Sun

Our parent star is a structure of immense, turbulent energy

The Sun is the biggest reactor for trillions of kilometres. At its core, an incredible 600 million tons of hydrogen is used up every second, as it is transformed into helium via nuclear fusion. This continuous process generates an enormous amount of radiation and extreme temperatures of around 15 million degrees Celsius. But the energy forged in the core does not remain there – instead it begins a journey outwards through the distinct zones of this gigantic burning star until it finally reaches the solar atmosphere.

The Sun's anatomy

Discover the structure of our local star

Distance from Earth
Our planet orbits at an average distance of 150 million kilometres from the Sun; the right distance for liquid water to exist and for life to flourish.

Flare
Magnetic energy accumulates in the solar atmosphere and eventually explodes from the surface as a solar flare.

Chromosphere
The area directly above the photosphere is actually hotter than the region below it, with temperatures ranging from 3,700 to 7,700 degrees Celsius.

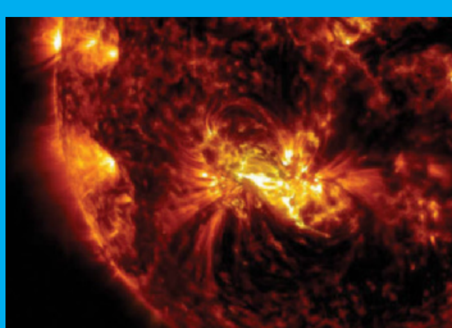
Corona
At the outermost layer of the Sun, temperatures rise significantly to around half a million degrees Celsius.

Convective zone
Energy migrates towards the surface via convection currents formed of heated and cooled gas.

Solar flares

Large solar flares emit truly monumental amounts of energy in the form of radiation. This radiation comes in the form of waves from all across the electromagnetic spectrum, from completely harmless radio waves to very harmful gamma rays.

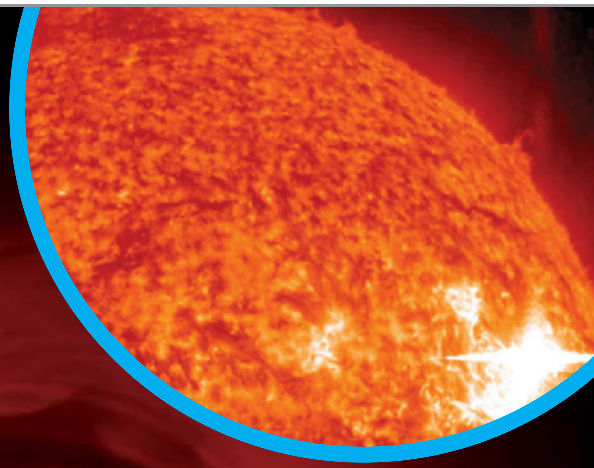
The amount of energy released in some solar flares is truly breathtaking – it can be roughly equivalent to detonating millions of nuclear bombs at the same time! This incredible burst of energy is the result of heated and accelerated particles in the solar atmosphere, which then move through the outermost layers of the Sun. Here, they cause temperatures to rise up to half a million degrees Celsius and the particles are emitted into space in the form of a flare.



Solar flares release incredible amounts of energy in the form of radiation into the cosmos

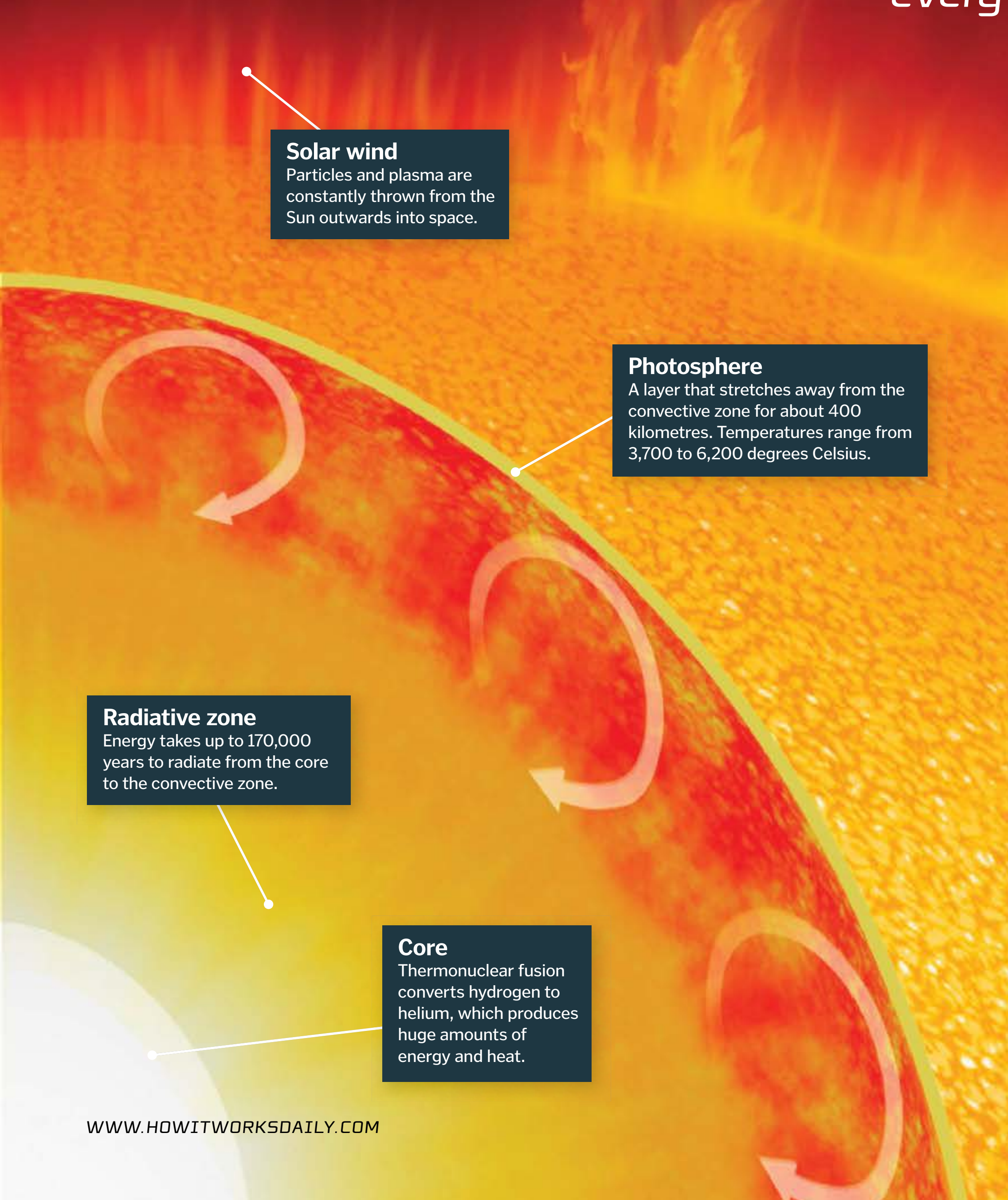
Unlike on Earth, this atmosphere is not just dominated by gas; on the solar surface, highly energised particles of plasma are also in abundance. This state of matter is excitable, and is involved in many of the Sun's turbulent behaviours. Solar flares, prominences (curved beams of plasma) and solar winds all involve plasma blasting outwards into space, and scientists are still unsure as to why these occurrences appear to happen irregularly.

As we're mostly protected from the Sun's violent outbursts of energy – thanks to our atmosphere and the planet's magnetic field – it's easy to think of it as a dormant beacon of light. But our local star is in fact very active, and as we learn more about its individual layers we begin to understand more about its activity. There are multiple missions planned to investigate the Sun in more detail. We can only collect data from so far within, but these missions will provide more insight into our volatile solar neighbour.



The Sun is a much more turbulent entity than most people realise

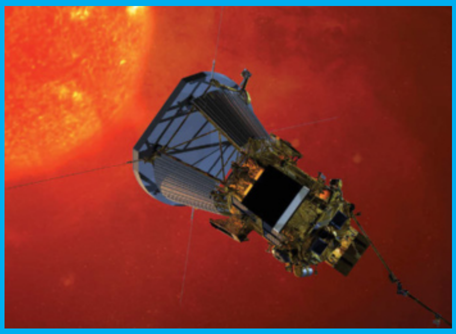
"At its core, an incredible 600 million tons of hydrogen is used every second"



Studying the Sun

Although researchers now know more about the Sun than ever before, it still holds many mysteries. NASA's Solar Probe Plus, currently scheduled for launch in 2018, aims to fly seven-times closer to the Sun's surface than any previous mission in order to collect new data on solar activity.

The probe will have to withstand extreme heat and radiation as it travels within Mercury's orbit, swooping within 6.2 million kilometres of the Sun's surface. To cope with such conditions, the probe will be fitted with an 11.4-centimetre-thick heat shield, enabling it to operate when external temperatures are over 1,300 degrees Celsius. But at least power won't be a concern; at such close proximity, the craft's solar arrays will receive more than enough energy.



The heat shield will keep the Solar Probe Plus' instruments cool enough to function

Planet Nine

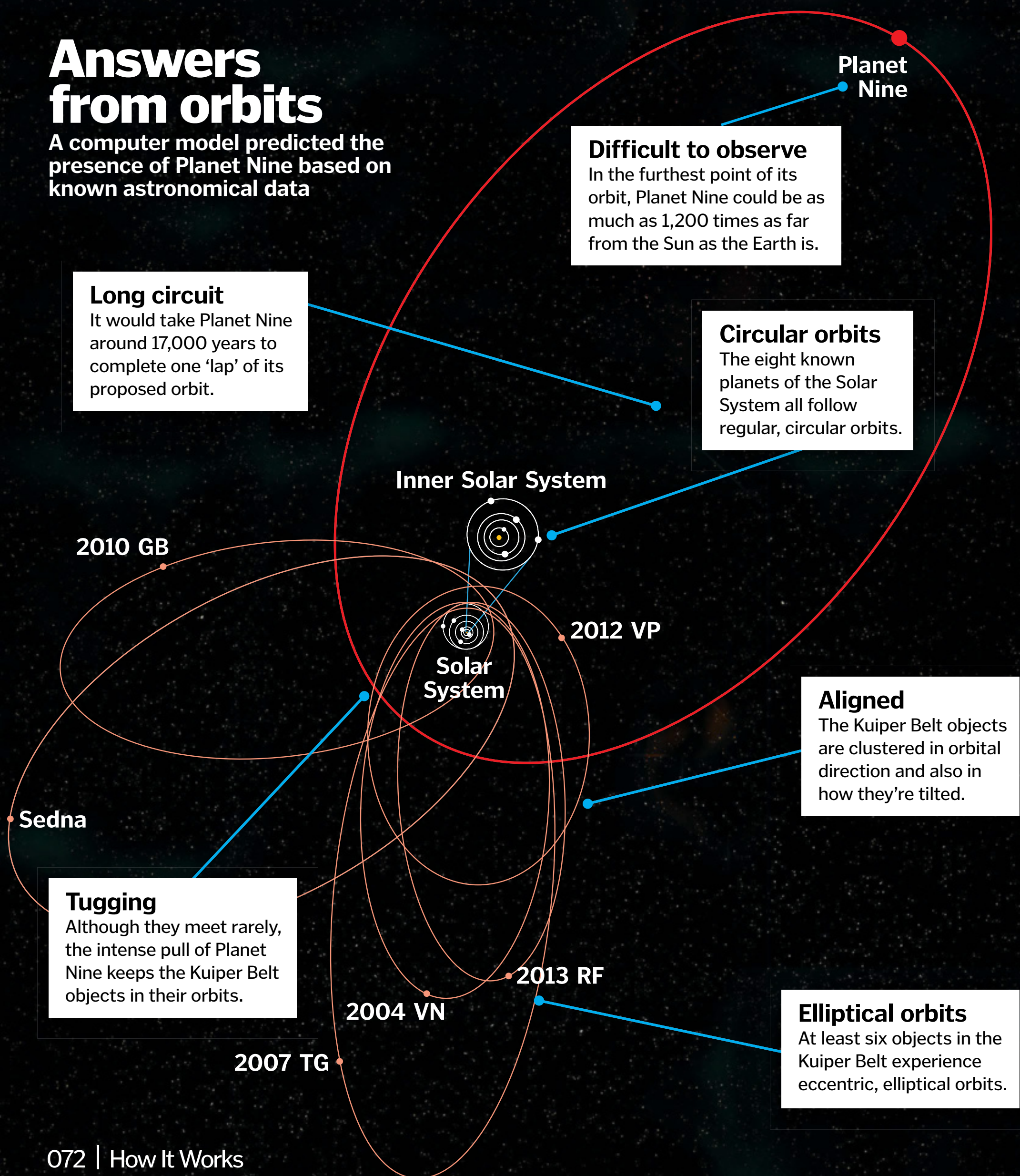
Could an elusive ninth planet be responsible for bizarre anomalies in our Solar System?

It wasn't too long ago that Pluto was stripped of its title as the ninth planet of our Solar System. But in an interesting turn of events, the same researcher who was instrumental in its demotion has now suggested a replacement. This comes in the form of Planet Nine, a theoretical world some 30 billion kilometres from the Sun, which offers an explanation for some of the most intriguing mysteries in our Solar System.

Until recently, it was widely believed that the Sun's gravitational influence ended at the Kuiper Belt – a ring of comets and other objects that follow a distant circuit around our local star. But Mike Brown, Pluto's great foe, discovered several anomalies within the belt. He saw that six objects were aligned in their movement, as if influenced by a foreign object. This eventually led him towards the theory of Planet Nine, a distant body influencing orbits from very far away indeed.

Answers from orbits

A computer model predicted the presence of Planet Nine based on known astronomical data



Ancient stars

Astronomers have discovered cosmic relics that have been burning bright for billions of years

An ancient star analysed by Australian scientists may have formed 13.7 billion years ago, making it one of the oldest in our galaxy. When the universe was very young – only a few hundred thousand years into its 13.8-billion-year life – hydrogen atoms began to accumulate and heat up. These clouds of hot gas then came together to form the very first stars, and within the confines of these massive orbs new elements were forged: first helium, and then heavier elements, including iron.

But unlike the elements that precede it, iron doesn't produce energy in a fusion reaction; it consumes it. And almost 14 billion years ago, within a primordial star around 60 times the size of our own Sun, the metallic iron core grew and grew until it collapsed in a dramatic implosion. However, unlike the huge supernova explosions we are familiar with in recent history, which eject all the elements into the cosmos, this early event only had enough energy to throw out the lighter elements. Iron and other heavy elements were swallowed into a black hole that formed in the star's wake.

The lighter elements eventually came together once more to form new stars. At least one of these second-generation stars exists today, still shining 13.7 billion years later.

The oldest known stars in our galaxy, like the Methuselah star pictured, are thought to be almost as old as the universe itself

LOST CITIES

History's forgotten settlements that vanished for hundreds of years

When an empire falls, its legacy is sometimes taken with it, lost in the sands of time. Many ancient cities have perished throughout history, whether from devastating earthquakes, ransacking invading forces or a decline in natural resources. Some ancient cities, like Rome and Athens, have remained continuously inhabited since they were founded, and some of their iconic structures, like the Colosseum and the Parthenon, still stand today. However, some cities have not been so well preserved.

A number of ancient civilisations were absent from the history books for many years after being lost in fire or buried by sand. From the Age of Exploration onwards, adventurers have uncovered nearly all the hidden corners of Earth and have located cities that were once only the stuff of legend. These settlements are an insight into the ancient world, and modern dating technology has helped us identify the era in which these cities were at their peak.

The remnants of ancient cities are dotted across the globe. Their ruins let us peer into the past and help us understand how different civilisations lived and worked. Many of these sites are now protected to prevent them from being lost forever. You never know, there could even be more lost cities out there just waiting to be discovered.

Ayutthaya, Thailand

This island metropolis was one of Asia's most magnificent cities

The city of Ayutthaya was the second capital of the Siamese Kingdom and grew in prominence following the fall of Angkor, the capital of the Khmer Empire.

The city reached its peak between the 14th and 18th centuries and was known for its splendid architecture, which included tall towers, known as Prang, and grandiose Buddhist temples. With a population of around 1 million, the city amassed its wealth through warfare, trade and taxes. Designed in a grid and built upon three rivers, inhabitants could travel along canals. A hydraulic system was also constructed to manage water flow.

Coveted by rival powers, the city was protected by gates, forts and towers. It was also resistant to a naval assault thanks to the intense tides of the Gulf of Siam. Even so, Ayutthaya finally fell to the Burmese in 1767 after a year-long siege. Its temples and palaces were burned to the ground and the city was plundered.

Ayutthaya's location in Southeast Asia meant it avoided conflicts between Asian, Arabic and European powers

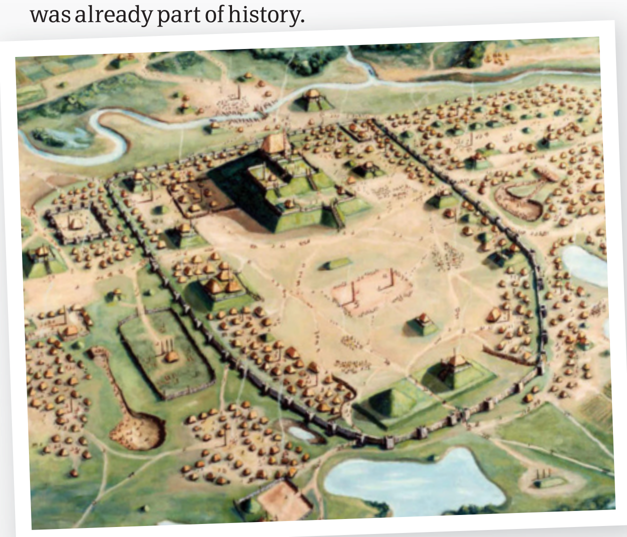
Cahokia Mounds

The capital of a forgotten native North American civilisation

Arising from an amalgamation of smaller settlements established in the area in 700 CE, by 1050 CE Cahokia Mounds was one of the greatest cities in North America. The city stood in what is now Illinois, and was the centre of an ancient Mississippian culture. An abundance of maize provided the population with a reliable food source that was kept in storehouses dotted across the city.

Cahokia Mounds owes its name in part to Monks Mound, the city's centrepiece and the largest man-made earthen mound in North America. As the city prospered, so did the need for its defence. Over 100 years, four wooden palisade walls, supported by deep trenches, were sequentially constructed to repel attacks. Despite these strong defences, concrete evidence of any invading forces is yet to be discovered, and a mass burial site of ritual sacrifices suggests that the city was home to a violent society in its early history.

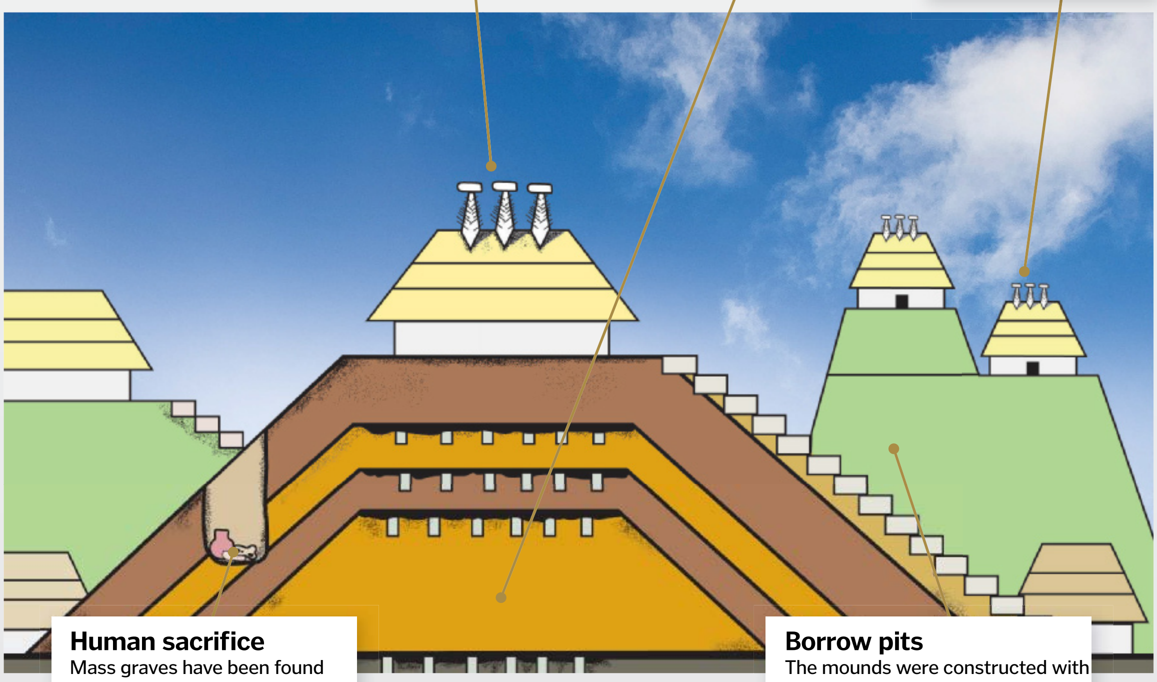
The city's population began to decline in the 13th century. The reasons why aren't entirely clear, but it is believed that disease, political or climate changes, or a decline in resources is to blame. The inhabitants of Cahokia Mounds largely disappeared in the 14th century and the area was later occupied by the Oneota culture and Illiniwek Native Americans. By the time Columbus had set foot in the New World, the city was already part of history.



The city once contained around 120 mounds covering an area of over 1,600 hectares

Ancient earthworks

Cahokia Mounds had some of the largest man-made mounds north of Mexico



Elite dwelling
The chieftain governed from atop Monks Mound, which rose to a height of 30 metres.

Earthworks project
Around 15 million cubic metres of earth was shifted to create the mounds.

Pole and thatch buildings
At the top of many of the mounds had ceremonial buildings built atop them to house members of the elite.

Human sacrifice
Mass graves have been found within one of the mounds, indicating that human sacrifice may have taken place in the city.

Borrow pits
The mounds were constructed with earth dug out of pits using wooden and stone tools. It was carried in baskets to the mound site.

Other lost cities

Persepolis
Locked away deep in a mountain range, Persepolis, in modern-day Iran, was to become the capital of the Achaemenid Empire.

Vulci
One of the centres of the Etruscan civilisation, this ancient Italian culture thrived before the dominance of ancient Rome.

Machu Picchu
It's likely that this famous Peruvian settlement was a sacred location and abandoned after the Inca Empire collapsed.

Hattusa
Located in modern-day Turkey, Hattusa was an influential city during the second millennium BCE. Built on a hill, it was the capital of the Hittite Empire.

Mohenjo-daro
This ancient city, located in modern-day Pakistan, had elaborate draining systems and a watertight pool, suggesting an emphasis on cleanliness.

Tenochtitlán

The lavish capital of the Aztec Empire built upon a lake island

Tenochtitlán was the centre of Aztec culture and one of the most impressive cities in history. Founded in the 14th century CE, the city utilised an elaborate system of canals and causeways. A stone aqueduct that harnessed the lake's water supply helped to maintain the population. At the heart of the city was the twin-pyramid Templo Mayor, where human hearts were believed to be ripped out during bloody human sacrifices conducted to honour and appease Aztec gods.

Spanish conquistadors first spotted the city in 1519. Led by Hernán Cortés, the Europeans were hungry for gold and using a large force, they captured the city and massacred the population.

Rediscovered in 1881, Timgad is sometimes referred to as the Pompeii of North Africa

Timgad

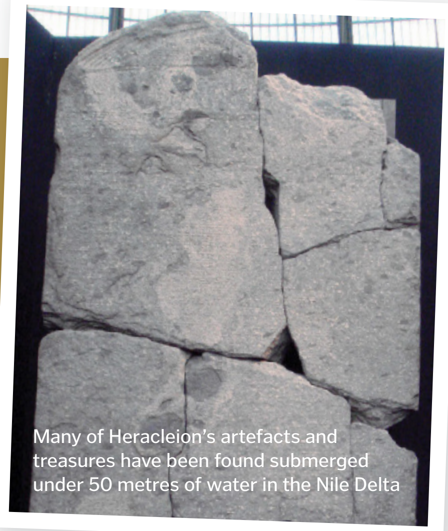
The Roman city hidden under the Saharan sands

In the 1st century CE, the Roman Empire was extending its considerable reach and had expanded southwards into Africa. Timgad was one of many Roman cities in Africa and stood in modern-day Algeria. Its construction was ordered by Emperor Trajan, and the walled military colony was built on a plateau near the Aurès Mountains. It helped defend from attacks against the local Berber people and housed army veterans from the Third Legion.

Impressive stone buildings stood throughout the city, including temples, a forum, markets, 14 public baths and a 3,500-capacity theatre. Timgad soon outgrew its walls and had quadrupled in size by the time of its fall. Along with the rest of the Western Roman Empire, the city declined in the 5th century and was sacked by the Vandals in 430 CE. Its demise was completed after an Arab invasion in the 8th century.

Heracleion

This coastal city was once an affluent trading centre in the ancient Mediterranean. Previously believed to be only a legend, a recent discovery has shed light on the city's history. Heracleion appears to have once been a main route for the trade of gold and bronze between Egypt and Greece, but it likely perished around 1,400 years ago due to rising sea levels. The now submerged site revealed many sunken ruins, including multiple colossal statues.



Many of Heracleion's artefacts and treasures have been found submerged under 50 metres of water in the Nile Delta

Knossos

The glorious capital of Minoan Crete that was lost in mysterious circumstances

Dating as far back as the 3rd millennia BCE, Knossos is one of Europe's oldest cities. The Minoans had a huge influence on trade across the Aegean Sea, and were a skilled people who produced pottery as well using a hieroglyphic script of writing. At the centre of Knossos stood a grand palace, with thick walls and eventually a drainage system, which was built for both splendour and defence. In Greek mythology the palace was the home of King Minos, who kept the Minotaur locked in the Labyrinth: a maze within the palace.

The Minoan civilisation was severely damaged by natural disaster in 1450 BCE and then by the invasion of the Mycenaeans. With the exception of the palace, the city of Knossos was lost, but influences of Minoan culture could still be seen in early ancient Greek society.

In 1900, a team of 32 diggers led by archaeologist, Sir Arthur Evans began excavations in Knossos

The remains of the palace at Knossos can still be seen today

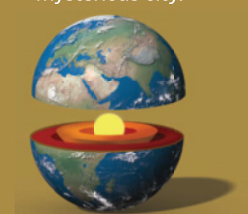
Legendary lost cities

Atlantis
The legendary island city was a mythical utopian society before it was submerged underneath the Atlantic Ocean.

Shambhala
The theory of a lost Himalayan kingdom was first popularised in the 16th century, and was thought to be a place of wisdom.

El Dorado
Tales of a city made of gold drove European adventurers deep into South America in the search of incredible wealth.

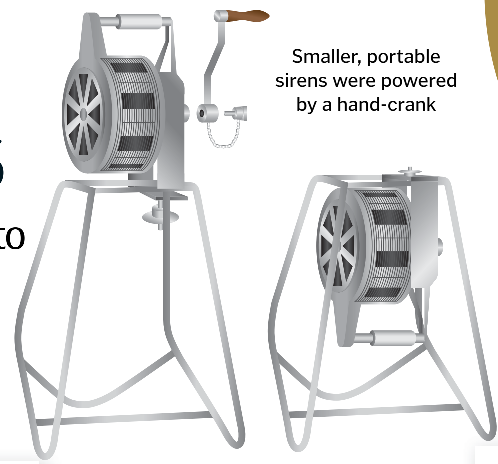
Lost city of Z
Believed to be located deep in the Amazon, British explorer Percy Harrison Fawcett went missing trying to find the mysterious city.



Agartha
This mythical subterranean city is believed to be situated deep within the Earth's core, and only accessible via hidden entrances on the Earth's surface.

World War II air-raid sirens

How distinctive wails alerted the Allies to bombardments from above



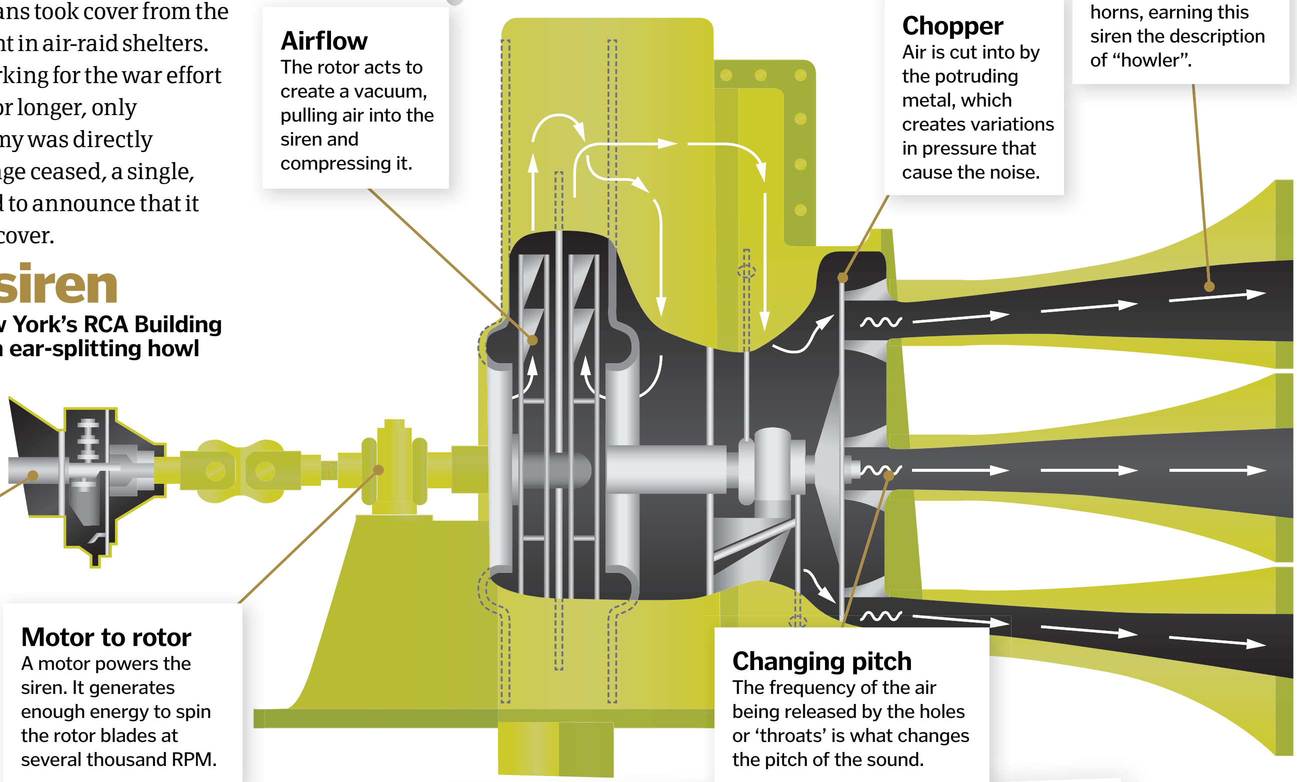
Smaller, portable sirens were powered by a hand-crank

Some countries still use sirens today to warn citizens of dangers, such as natural disasters

Two distinct tones were sounded by air-raid sirens when the German Luftwaffe was inbound, and would begin blaring as soon as danger was sighted. Upon hearing the signal, civilians took cover from the impending bombardment in air-raid shelters. But some brave souls working for the war effort would remain exposed for longer, only sheltering when the enemy was directly overhead. Once the barrage ceased, a single, continuous note sounded to announce that it was safe to emerge from cover.

Inside an siren

How the siren atop New York's RCA Building in the 1940s created an ear-splitting howl



Dancing plagues

Why did some medieval communities break into dance for weeks on end?

People are believed to have danced for days despite their severe hunger and exhaustion

In the summer of 1518 in Strasbourg, France, a woman named Frau Troffea began to dance in the street. She eventually encouraged hundreds of people to jig along with her, but the people of Strasbourg weren't simply moving their feet to the sound of the medieval beat.

In fact, it is thought that the dancing was induced by stress. The plague was preceded by terrible famine and disease, so the dancing wasn't at all enjoyable; some of the dancers were even reported to have screamed, convulsed and writhed in agony as they moved. The authorities decided to construct stages and halls to allow the dance epidemic to continue, confident that the mass hysteria would eventually peter out. And some even paid for musicians and professional dancers to help maintain the surreal dance.

Ultimately, their actions had the opposite effect, and the dancing continued until many died from sheer exhaustion.

It's thought that the people were able to dance for such lengthy amounts of time because they had entered a trance-like state. Similar crazes had broken out sporadically in medieval Europe before, but the 1518 epidemic was the last serious outbreak, and remains something of a mystery.

Animation before film

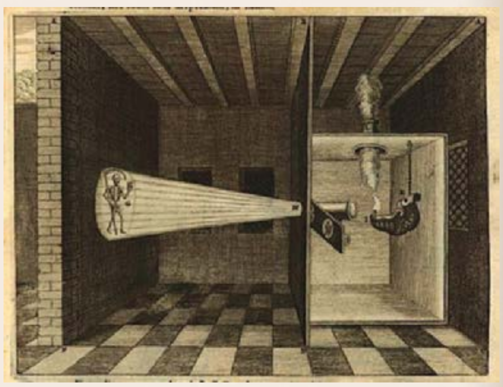
Some of the very first inventions that simulated movement by tricking our eyes

Although this may come as a surprise to some, animation was once a field dominated by mathematicians and physicists. Rather than attracting purely creative minds, logical brains developed these innovative contraptions – with many basing their research on the work of Michael Faraday and Sir Isaac Newton.

The goal of these scientists and inventors was to create the illusion of motion, and they accomplished this goal in intelligent ways. All of their apparatus took advantage of the limits of the human eye, which takes about one-hundredth of a second to process a single image. If we see more than one image in that time, then to us, they seem to blend together with no interruptions. And it was this knowledge, and how to make use of it, which gave rise to the field of animation.

By producing a collection of images that slightly differed from each other, and showing them to the human eye in quick succession, the image would appear to come alive and move. And to accomplish this, the inventors took advantage of spinning objects to whirl the images in front of our eyes. Some of these were more complex than others, but they were all based on the same principle.

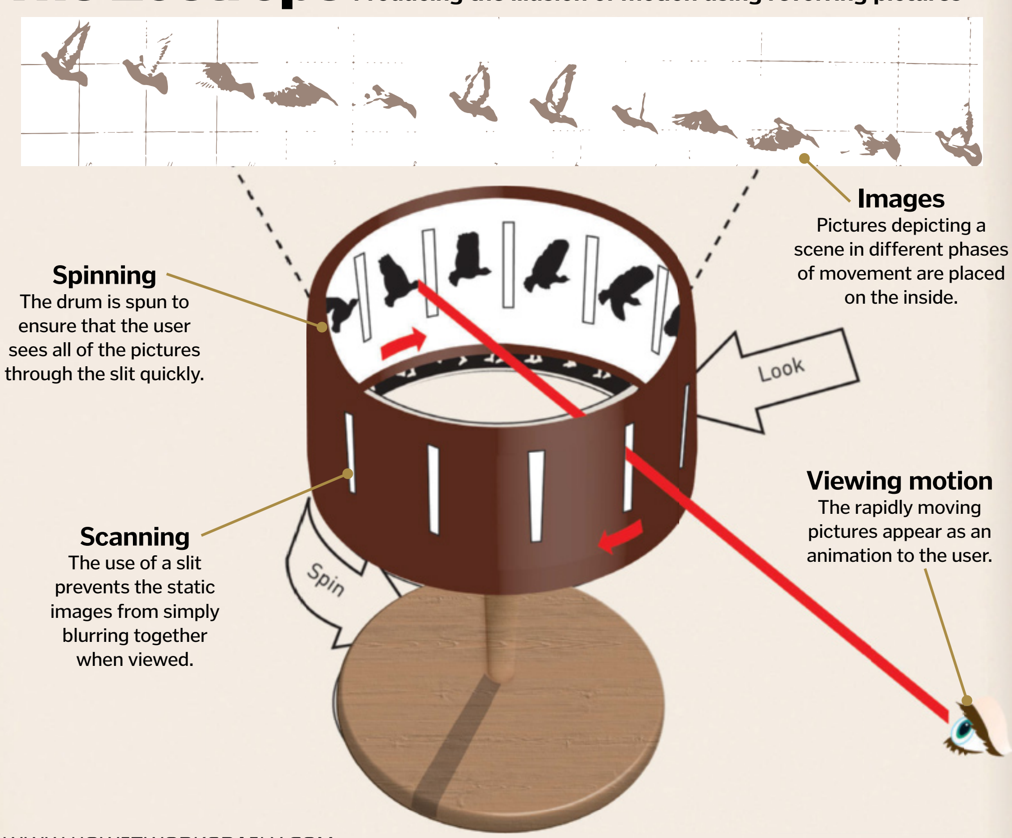
Today, children still make use of a similar toy – the flipbook. We've probably all flicked through the pages of one before, and seen a cheetah or a car dash across the pages, and it's interesting to think that very similar toys were being played with almost 200 years ago.

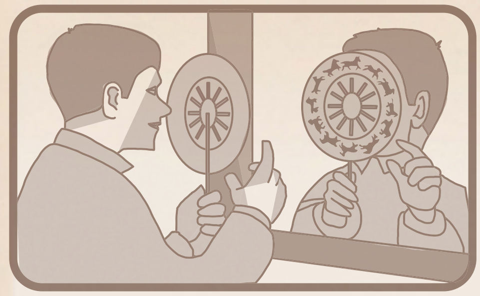


Early image projectors such as the magic lantern could be combined with animation tools

The Zoetrope

Producing the illusion of motion using revolving pictures



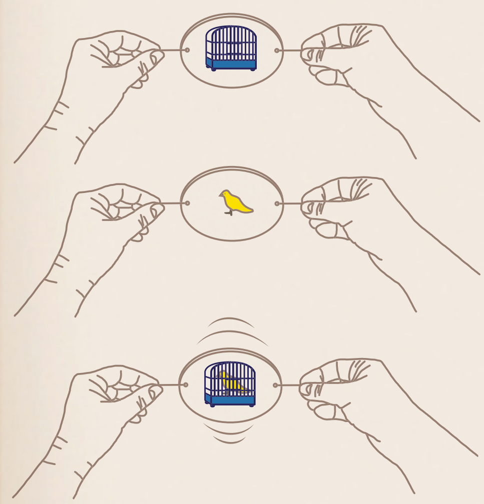


Phenakistoscopes

This early invention worked by coating a spinning disc with a series of drawings depicting different phases of movement. Another disc with equally spaced slits around its axis, and a handle, would then be added. The user could spin the disc while facing a mirror, and by looking through the slits they would see the pictures blend into a seemingly moving image.

Praxinoscopes

The praxinoscope was invented in 1876. A series of stationary mirrors were attached to a central cylinder, and these were used to reflect images that had been painted on the inside of a larger cylinder revolving around them. This meant that multiple onlookers could enjoy the 'moving picture' in the centre.



Thaumatropes

A simple disc or piece of card was attached to two pieces of string, and on the front and reverse of the disc two different images were drawn. Twirling the card quickly by rolling the string in your fingers would make the images appear to merge together.

Polar dinosaurs

Evidence shows that some dino's survived cold, dark winters

For a long time both experts and the public believed dinosaurs only thrived in tropical regions. But imagine everyone's surprise if the latest *Jurassic Park* movie had our heroes running around in thick winter coats for a change. It may seem unlikely, but our perception of dinosaurs is changing, as recent fossils have shown that dinosaurs also called much colder places home.

One such chilly habitat was the landmass now known as Australia. Nowadays this region is far from cold, but 65-100 million years ago it was considerably further south, resting right next to the continent of Antarctica.

So how did dinosaurs survive in these conditions? A previous theory suggested that they migrated to warmer climates as the coldest season descended. But this has now largely been debunked; the 'over-wintering' theory, which involves dinosaurs either enduring the cold or tucking in for winter, is now in favour.

Some of the smaller dinosaurs, in particular, are believed to have possibly burrowed into a den for winter hibernation – much like polar bears do today. But we know that this wasn't the case for all prehistoric beasts. Analysis of polar dinosaur bones has shown that they grew all year round, which suggests that these animals did not spend months sleeping.

Fortunately for these animals, the poles weren't quite as cold as they are today, but they did experience prolonged, dark winters. This made it difficult for plants to thrive, but some hardy vegetation could provide nourishment for herbivores, which in turn was good news for the carnivores, because they had more prey to hunt.

The duck-billed giant

The fossil of a nine-metre-long herbivore unearthed in a remote part of Alaska in 2015 is the furthest north a polar dinosaur has ever been found. Paleontologists confirmed this newly discovered species after studying a set of fossilised remains, and it displays distinct differences to its relatives found further south.

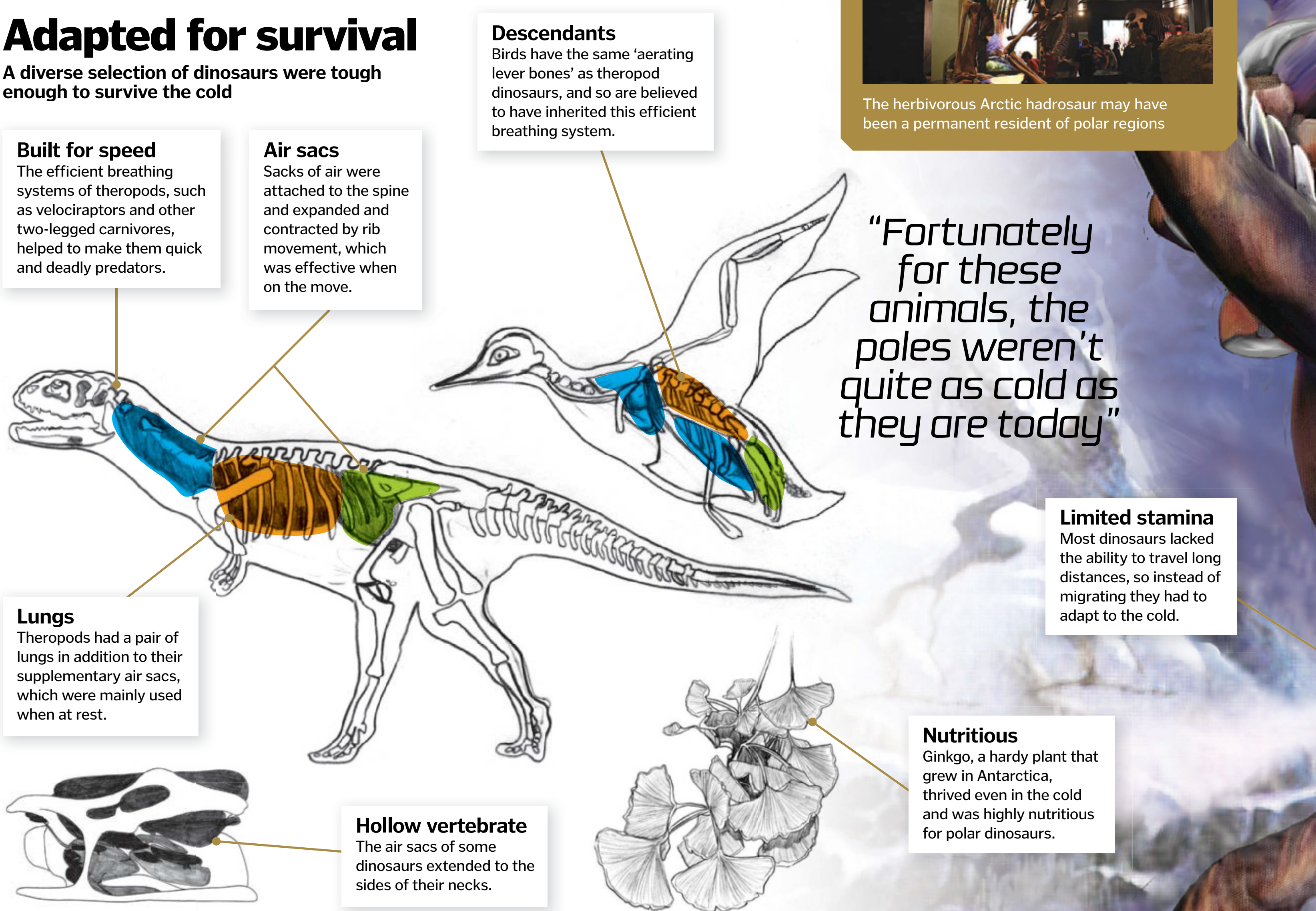
It's believed the Arctic hadrosaur stood on two of its four legs to reach food from up high. An interesting duck-billed facial structure and hundreds of teeth helped this gigantic beast to tackle the coarse forage.

As well as its ability to devour the bountiful vegetation, the hadrosaur was able to endure months of darkness and a drop in temperature over winter – and perhaps even snow. These exciting findings help to paint the picture of polar dinosaurs, solidifying their reputation as tough and adaptable animals.

The herbivorous Arctic hadrosaur may have been a permanent resident of polar regions

Adapted for survival

A diverse selection of dinosaurs were tough enough to survive the cold



> "Fortunately for these animals, the poles weren't quite as cold as they are today"

Limited sunlight
Some polar dinosaurs had enlarged optic lobes, which adapted their vision for long periods of winter darkness.

Insulated
A thick body of plumage would have kept the dinosaurs warm.

Warm-blooded?
If some dinosaurs could control their body temperature internally, rather than relying on the environment for heat, they would have endured the cold better.

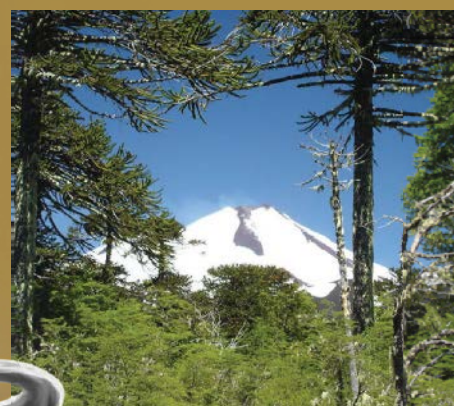
Fodder
The poles were warmer during the Mesozoic era than today, so vegetation flourished during the summer.

Burrowers
Smaller dinosaurs may have hibernated or denned themselves in throughout the coldest periods.

A warmer Earth

Although polar dinosaurs were equipped for the cold, it's unknown whether they would have been able to cope in the incredibly harsh Arctic or Antarctic conditions of today. Modern day polar regions experience temperatures so low that only the most resilient life can survive, which is quite a contrast to the land of lush vegetation that was able to grow during the Mesozoic era.

Dinosaurs were able to enjoy higher temperatures thanks to the much greater levels of carbon dioxide in the atmosphere. This warmed the planet, melted the poles, and allowed life to prosper. However, between the end of the dinosaur era and the early years of humankind, natural processes lowered the carbon dioxide levels, temperatures fell, and the poles froze once more.



Increased temperatures from high carbon dioxide levels made it easier for flora and fauna to flourish near the poles

Learn more

To learn more about the fascinating lives of these prehistoric beasts, pick up a copy of the Dinosaurs bookazine today. Available now from **www.imagineshop.co.uk** and **www.greatdigitalmags.com**

The pianola

Pianos that played themselves were all the rage in the early 1900s

Many pianolas had their automatic playing equipment neatly housed inside a typical piano casing

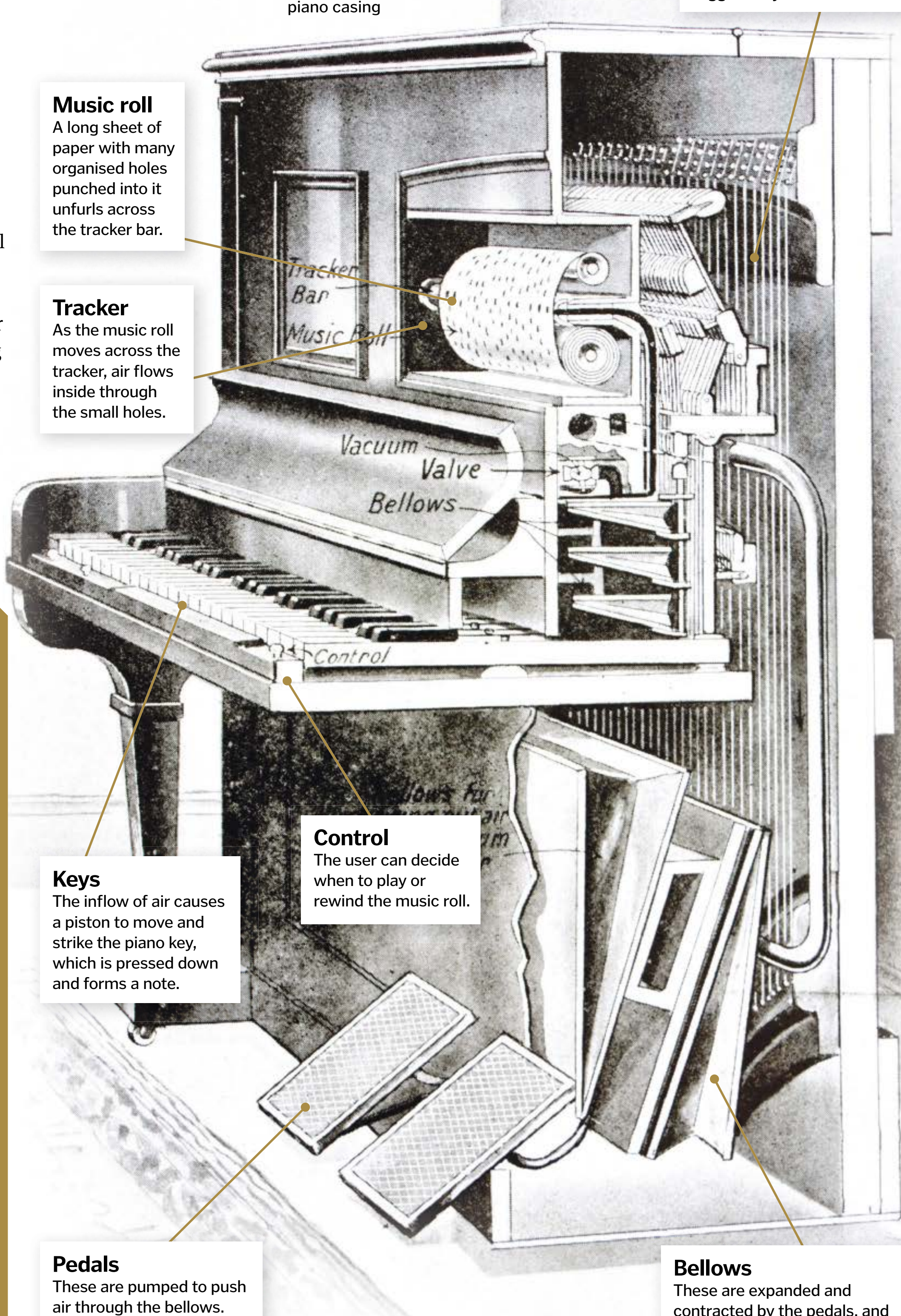
At a dinner party around 100 years ago, it wouldn't have been a peculiar sight to see a piano gently performing a solo all on its own. This wasn't the work of a harmonious poltergeist; player pianos had recently been established as fashionable pieces of musical equipment.

The most popular of all of these was the pianola, which became so successful that the name was used to describe any player piano. The very first pianola could be attached to the front of any ordinary piano, and could be used to play any piece of music its owner desired. All they needed was the correct piano roll and a willing pair of legs to pump the pedals.

Later pianola models looked just like regular pianos, with all of the clever automatic playing equipment stored on the inside. Now, anyone could take a seat at the piano and pump the pedals to activate the pneumatic system housed within. The keys would be pushed down and the notes would play, which meant even the most unskilled pianist could fill a room with Mozart.

Inside a player piano

Automatic playing took advantage of pneumatic, or gas-operated, machinery to recreate music



Pneumatic action
Each key is connected to a specific finger, which is triggered by the flow of air.

Music roll
A long sheet of paper with many organised holes punched into it unfurls across the tracker bar.

Tracker
As the music roll moves across the tracker, air flows inside through the small holes.

Keys
The inflow of air causes a piston to move and strike the piano key, which is pressed down and forms a note.

Control
The user can decide when to play or rewind the music roll.

Pedals
These are pumped to push air through the bellows. Harder pumping increases the tempo of the music.

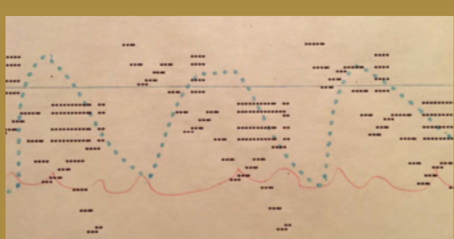
Bellows
These are expanded and contracted by the pedals, and suck air from the hundreds of individual bellow fingers.

Piano rolls

While they look very different from sheet music, piano rolls operate in a similar way. Just by looking at them you can see when, and for how long, notes and chords will be played – thanks to a series of organised perforations in the paper.

But these holes aren't designed as instructions for a musician; they are there to dictate to the instrument itself. The perforations each align with a particular key, and as air enters through these gaps, the key is struck. This can happen quickly and at the same time as other notes, so piano rolls can be used to perform even the most complex melodies.

Musicians would also write music for player pianos using a recording piano. This involved performing the piece normally, but as a key was pressed a pneumatic valve would also be triggered. This would cause a corresponding rod to make an impression onto a piano roll in time with the other notes, forming a primitive type of musical recording.



Piano rolls capture a permanent version of a pianist's performance

BRAIN DUMP

Because enquiring minds need to know...

Want answers?

Send your questions to...

How It Works magazine @HowItWorksmag

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MEET THE EXPERTS

Who's answering your questions this month?

Laura Mears

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

Alexandra Cheung

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

Tom Lean

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

Shanna Freeman

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

Joanna Stass

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

Jet engines can stall if their fuel or air supply is interrupted

Can aircraft jet engines stall like car engines?

Rhian Moors

■ The pistons in a car engine are attached to an axle, called the crankshaft, which turns around as the fuel ignites inside the cylinders. If the crankshaft stops turning, the engine stalls. It can happen for a number of reasons, including a lack of air or fuel, or problems with the electric spark or the mechanical parts. A jet engine operates slightly differently, but it can stall just the same.

Rather than burning fuel to drive pistons, a jet constantly takes in air, compresses it with fuel, and ignites it to create a steady stream of exhaust. This then passes through turbines, making them spin. As with a car engine, if the air or fuel supply run short, or if the engine components fail, the engine can stop turning. For example, if debris or a bird were to find their way into the engine, the airflow can be disrupted, causing a compressor stall and a momentary drop in power. **LM**

What is the Bermuda Triangle?

Ellie Hannigan

■ There is no evidence to suggest that ship disappearances are more common in the Bermuda Triangle than anywhere else. The Triangle encompasses the water between Florida, Puerto Rico and Bermuda. Speculation that it played host to unexplained and possibly paranormal phenomena grew in the 1960s and early 1970s. Despite claims at the time that thousands of people had mysteriously vanished inside the Triangle, one investigation found that few of these reports were accurate, and that accidents in the area were no more frequent than other areas with similar amounts of shipping. **AC**

Accident rates in Bermuda are comparable to other parts of the world

The hovercraft World Speed Record is 137.4 kilometres per hour

How fast can hovercraft travel?

Peter McKinnon

The average speed of a hovercraft is 56 kilometres per hour, although some can travel faster than 130 kilometres per hour. Their maximum speed is affected by two main factors: terrain and weather. The smoother the surface the craft is travelling over, the faster it will be able to go, as there is less friction to slow it down. Therefore, it can travel faster on ice and smooth water than it can on rough water or grass. If the hovercraft is facing a headwind, this can also slow it down as the wind increases drag, reducing its forward momentum. **JS**

Memory foam is also used on X-ray table pads and for military body armour

How does memory foam work?

Mick Robinson

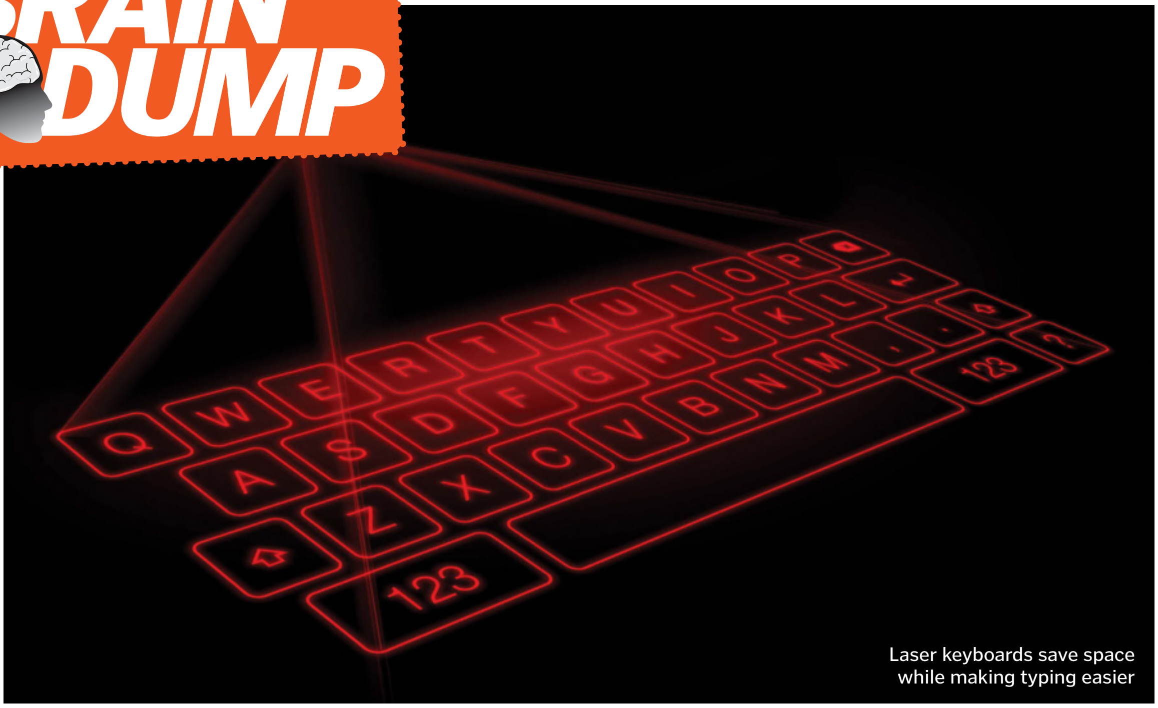
Memory foam is a viscoelastic substance, which means that it deforms easily, but then returns very slowly to its original shape. It is made by injecting gas into a flexible polymer matrix, creating many tiny bubbles that can shift around and reorganise themselves when pressure is applied. Heat also makes the foam more malleable, meaning that it can mould around the contours of a human body, supporting a person's weight evenly across its surface. Originally developed by NASA to cushion the seats in spacecraft, memory foam is now found in a wide variety of products, from mattresses and pillows to shoe insoles and helmets. **AC**

What is a marsupial?

Kendra Leicester

Marsupials are mammals that have a marsupium, or pouch, for their young. They need this pouch because female marsupials do not have a placenta, the spongy organ that transfers nutrients to the baby. This means that their gestational period is very short and their babies are born undeveloped, often still resembling an embryo. As soon as it is born, the baby will crawl to the mother's pouch to feed on milk from her nipples, getting the nutrients it needs to grow. Because the nipples swell in its mouth, the baby will only be able to detach and leave the pouch once it is fully developed. **JS**

Kangaroos, wallabies and koala bears are all marsupials, or pouched mammals



Laser keyboards save space while making typing easier

How do laser keyboards work?

Jenna Rowland

■ If you're not a fan of touchscreen keypads, and don't want to carry a portable keyboard for your smartphone or tablet, then a laser keyboard might be what you need. Inside these chewing gum packet-sized devices, a red diode laser shines through a diffractive optical element featuring an image of a QWERTY keyboard. A set of optical lenses then enlarges the keyboard image and projects it onto any flat, non-reflective surface. Just millimetres above the keyboard is an invisible thin plane of infrared light that runs parallel to the flat surface. As you type, your fingers pass through this infrared light, and a complimentary metal-oxide semiconductor (CMOS) inside the device records their position. A sensor chip called a virtual interface processing core then analyses this information to work out which keys you were trying to press, then notifies your device via a USB cable or Bluetooth connection. **JS**

Siberian tigers stick out against white, but are hidden in dappled shade

Can Siberian tigers camouflage in the snow?

George Smith

■ Siberian, or Amur, tigers live in the mountains of eastern Russia and northern China. In this chilly part of the world, the ground can be blanketed with snow, and you might think that the rust and black stripes of these big cats would stick out like a sore thumb, but they don't. Siberian tigers don't live out on the tundra – their prey cannot survive in empty, snow-covered wastes – instead, they inhabit forests and mountains. In the dappled light of the trees, and between brown rocks and stripes of snow, their coloured pelts help to break up their outline, keeping them hidden from view. **LM**

FASCINATING FACTS

How do 'colour-matching' make up products work?

So-called 'smart' make up that changes colour when it touches the skin does so because the pigment is contained within drops of oil. When they are rubbed, they release the colour inside. **LM**

Some makeup brands 'colour match' by making dozens of shades to suit all skin tones

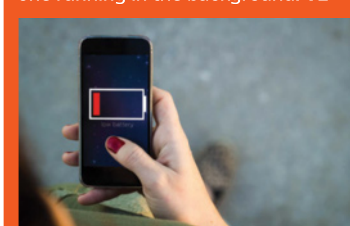
Does planet Earth have a flag?

There is no internationally agreed-upon flag to represent Earth, but many concepts have been designed, including one by design student, Oskar Pernefeldt. Although his design is a graduation project, it appears all over the internet. **SB**

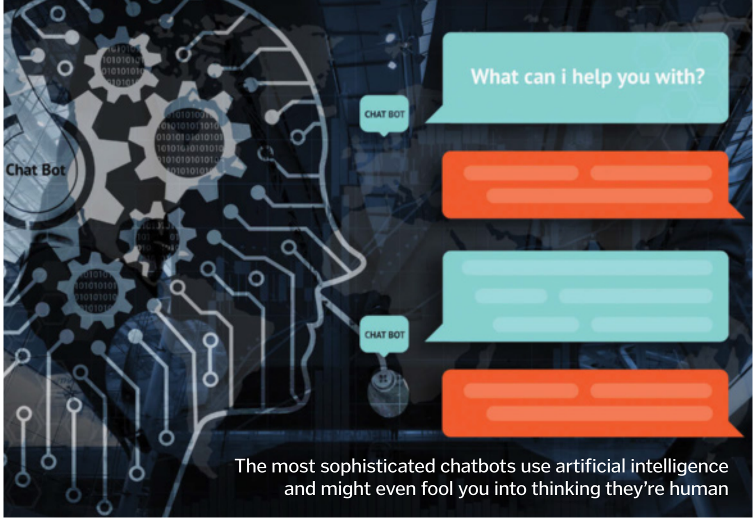
The United Nations flag is perhaps the closest thing to a planet Earth flag – for now

Does closing apps preserve your phone's battery life?

Smartphones manage apps to preserve battery life. Disrupting this by closing apps yourself can actually shorten battery life as more power is needed to reload an app than to use one running in the background. **TL**



Closing down apps may actually shorten your phone's battery life



The most sophisticated chatbots use artificial intelligence and might even fool you into thinking they're human

What is a chatbot?

Kevin James

■ Chatbots are computer programmes that you can have a conversation with, either through text or speech. A basic chatbot might just answer questions, like the ones used by websites for customer queries. Often based on pre-programmed rules, they recognise keywords in your question and find a match with the best answer they have stored in their database. Advanced chatbots, like Apple's Siri, are far smarter, using artificial intelligence techniques to understand your questions and generate unique responses as required. They can even make small talk, and as their technology develops, they could become common in online shopping and household smart appliances. **TL**

What would happen if everyone turned vegetarian?

Alek Barzan

■ Meat production has a huge impact on the climate. About 70 per cent of all agricultural land is used for livestock, which produce greenhouse gases. A vegetarian world would mean more space for forests and crop-growing, stemming climate change and encouraging biodiversity. The health benefits would reduce mortality rates and result in cheaper medical bills. However, many livelihoods depend on livestock, and undernourished populations would struggle to consume a healthy amount of calories. **SB**


There would be advantages and disadvantages to a world of vegetarians

Why do only some countries drive on the left-hand side?

Melody Smith

■ When roads were first used, it didn't really matter which side of the road you chose, but customs gradually appeared. Horsemen might have preferred the left, facing their right-handed sword arm into the centre of the road, while wagon riders are thought to have preferred to keep right, because they whipped their horses with their right hands and didn't want to accidentally whip oncoming traffic. Different preferences became entrenched in different parts of the world, and when Henry Ford produced his first mass-market vehicles, he put the driver on the left. Right-sided road-use is now the norm, but in Britain and many of its former colonies, they still drive on the left. **LM**


Most countries drive on the right-hand side of the road


Freeze-dried strawberries can taste fresh for years

How does freeze-dried food work?

Ian Gallagher

■ Freeze drying is often used to preserve food. It begins by freezing food so quickly that large ice crystals (which would damage the food and give it a soggy texture) don't have time to form. The freezing also preserves the nutrients of the fresh food. Next the frozen food is dried by warming it slightly at low pressure, so that ice in the food sublimes straight into gaseous water vapour instead of melting into liquid. This vapour is then sucked away, gradually drying the food before it's sealed in packaging. The micro-organisms that spoil food need water, but because there's so little water left, freeze dried food can stay fresh for over 20 years. **TL**

Can counting sheep really help you get off to sleep?

Lauren Malcolm

■ The boredom of imagining an infinite number of sheep jumping over a fence is said to aid insomnia and speed up the process of falling asleep. However, its mundanity has led researchers at Oxford University to suggest it is not effective. They claim it takes longer to fall asleep if we count sheep than if we don't, and that imagining a relaxing scene takes up more brain power and is therefore more effective. **SB**


If you're struggling to sleep, imagine a tranquil waterfall or relaxing holiday rather than counting sheep

BRAIN DUMP

Just a few drops of water can transform smooth, molten chocolate into a lumpy mess

Why does melted chocolate sometimes 'seize up'?

Nikki Clarins

■ If molten chocolate comes into contact with water, tiny droplets of sugar syrup form, separating from the chocolate's fats and creating a stiff, grainy texture. Chocolate is a suspension of solid cocoa particles dispersed in fat (cocoa butter), to which sugar, and (for milk chocolate) milk protein are added. When cocoa beans are refined to make cocoa butter and solids, the water they contain is expelled, leaving a dry substance. The cocoa butter is water repellant (hydrophobic), while the sugar behaves in completely the opposite way (hydrophilic). When water is introduced, it first forms droplets as it doesn't mix with the fat. The sugar meanwhile, does mix with the water, wetting the sugar crystals, which causes them to cling together. The end result is a clumpy, inhomogeneous mixture. To avoid this when melting chocolate, make sure your cooking equipment is fully dry. **AC**

Can wearing glasses if you do not need them actually 'weaken' your eyes?

Chloe Baekelandt

■ It depends. For adults, wearing glasses you don't need or wearing the wrong glasses is not thought to damage your eyes, but it is still not advisable as it means that your eyes have to work harder and you might suffer eyestrain, headaches and other problems as a result. However, wearing the wrong glasses or unnecessary glasses can cause lasting damage to the eyes of children, as their vision is still developing as they grow up. For example, presenting children's eyes with specialised eyewear for conditions such as amblyopia (lazy eye) can exert more changes over the eye. **TL**

Wearing the wrong glasses can put a strain on your eyes and lead to headaches

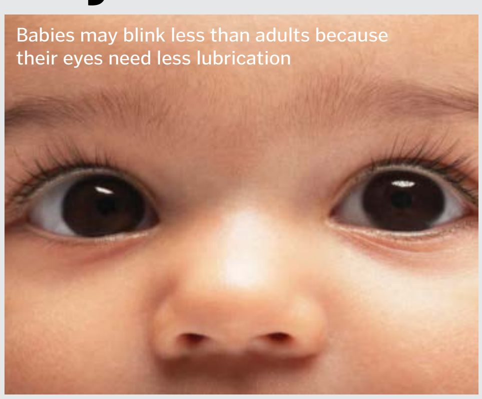
Kennedy's on-screen charisma is thought to have contributed to his eventual victory

When was the first US presidential debate?

Kelly Patterson

■ The first US general election presidential debate took place on 26 September 1960, and saw John F Kennedy, the Democratic nominee, facing Republican nominee Richard Nixon. **AC**

Why do babies blink less than adults?



Babies may blink less than adults because their eyes need less lubrication

Jenny Vaughan

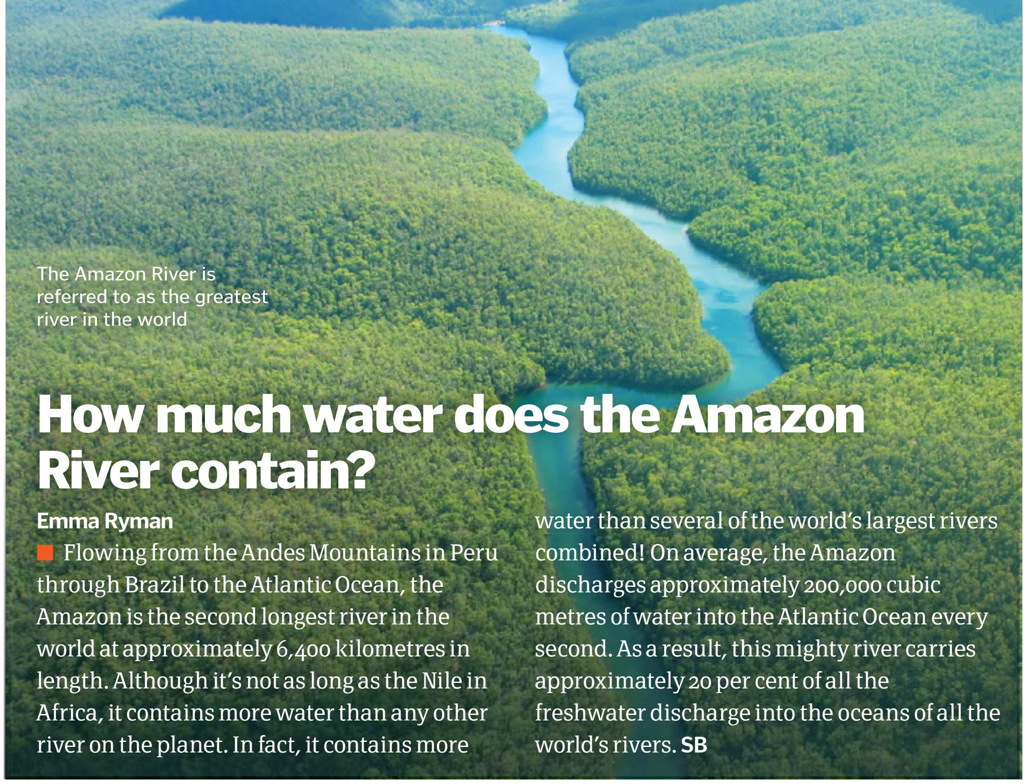
■ While adults typically blink ten to 15 times per minute, an infant's average blink rate is less than two times per minute. However, no one really knows why. Blinking is your body's method of lubricating your eyes, as each time you blink your eyelids spread oil and mucus over them. It's believed that babies may need to do this less often than adults for two reasons. One is that their eyelid openings are smaller, exposing less of the eye to the dry air. Another is that they sleep more, giving the eyes less time to dry out. **JS**

FASCINATING FACTS

Can you see the Great Wall of China from space?

Dennis Bale

■ You can just about see the Great Wall of China from low-Earth orbit, but only with a very good zoom lens, not with the naked eye. **JS**



The Amazon River is referred to as the greatest river in the world

How much water does the Amazon River contain?

Emma Ryman

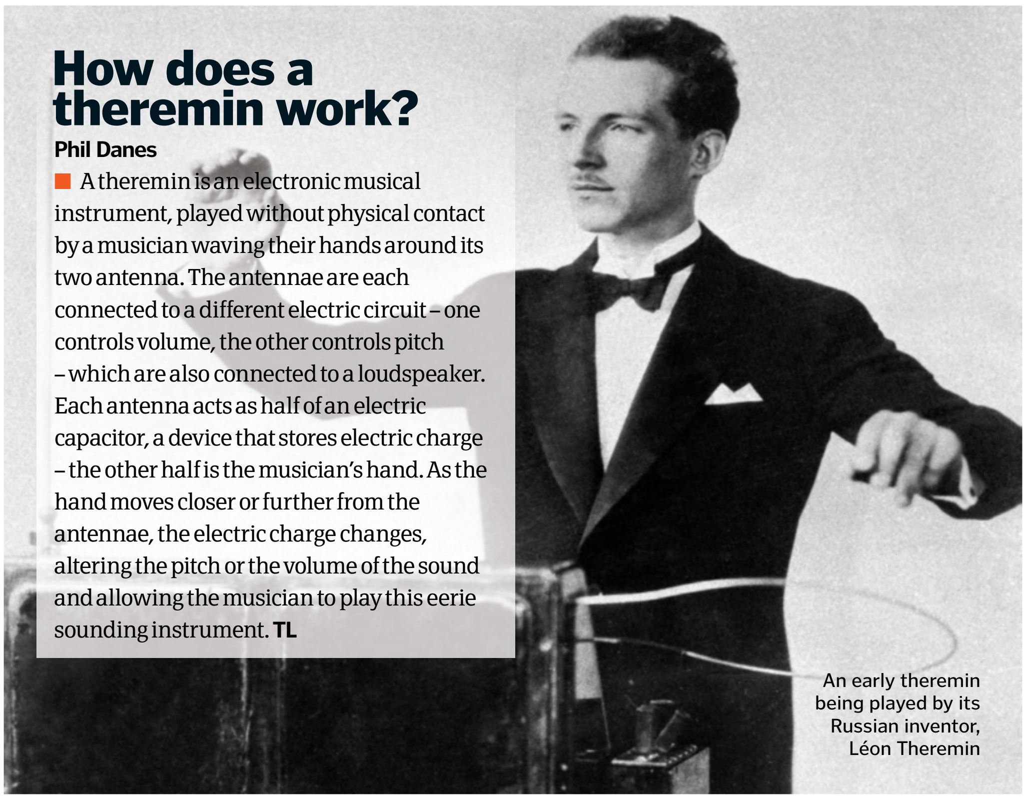
■ Flowing from the Andes Mountains in Peru through Brazil to the Atlantic Ocean, the Amazon is the second longest river in the world at approximately 6,400 kilometres in length. Although it's not as long as the Nile in Africa, it contains more water than any other river on the planet. In fact, it contains more water than several of the world's largest rivers combined! On average, the Amazon discharges approximately 200,000 cubic metres of water into the Atlantic Ocean every second. As a result, this mighty river carries approximately 20 per cent of all the freshwater discharge into the oceans of all the world's rivers. **SB**

How did the days of the week get their names?

Naomi Gale

■ The Greeks named the days of the week after the Sun, the Moon and the five known planets at the time, which were named after the gods Ares, Hermes, Zeus, Aphrodite and Cronus. The Romans then substituted the Greek deities with their equivalent gods: Mars, Mercury, Jove (Jupiter), Venus and Saturn. Later, the Germanic people substituted all of these gods except Saturn with Tiu (Twia), Woden, Thor and Freya (Fria). So, the Sun's day became Sunday, the Moon's day became Monday, Tiu's day became Tuesday, Woden's day became Wednesday, Thor's day became Thursday, Freya's day became Friday and Saturn's day became Saturday. **SB**

The names of the days of the week evolved throughout ancient history



How does a theremin work?

Phil Danes

■ A theremin is an electronic musical instrument, played without physical contact by a musician waving their hands around its two antenna. The antennae are each connected to a different electric circuit – one controls volume, the other controls pitch – which are also connected to a loudspeaker. Each antenna acts as half of an electric capacitor, a device that stores electric charge – the other half is the musician's hand. As the hand moves closer or further from the antennae, the electric charge changes, altering the pitch or the volume of the sound and allowing the musician to play this eerie sounding instrument. **TL**

An early theremin being played by its Russian inventor, Léon Theremin

Do sweeteners raise your blood sugar levels?

Sarah Corbin

■ Sweeteners try to replicate the taste of sugar without the energy spike. Some sweeteners, like xylitol and sorbitol, do raise your blood sugar a little – these are known as 'nutritive' sweeteners. But artificial sweeteners, like aspartame, are different – they can't be used as fuel and don't affect blood sugar directly. However, there is some research to suggest that artificial sweeteners could have an indirect effect. They are thought to change the types of bacteria living in the gut, which may have an impact on your ability to control blood sugar. More research needs to be done before a link is made. **LM**

Nutritive sweeteners still contain some calories. Artificial sweeteners do not

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365 Things To Do With LEGO Bricks

Build a new LEGO creation every day for a year!

- Author: **Simon Hugo**
- Publisher: **DK**
- Price: **£16.99 / $24.99**
- Release date: **Out now**

LEGO lets your imagination run wild, and it's no surprise that it was voted the greatest toy of all time. Whether you're following instructions in a specific set to create an amazing construction, or just making it up as you go along, getting creative with LEGO is great fun. This book aims to inspire readers to create some more unique things, by challenging you to complete a task in a set time using the timer on the front cover.

It's really simple to use – you can set the device to randomly pick a number between one and 365. You can then flick through the book to find what it has told you to make, and from there you can start a stopwatch to see how long a build takes, or challenge yourself to complete it in a certain number of minutes. It works well, and it's perfect if you can't decide what to make.

The builds themselves are extremely varied – you can make everything from a drinks coaster puzzle to a full-on LEGO magic show. The builds are split into categories, like 'one-player games' and 'tricks and pranks', which mean you can find the perfect builds quickly from the contents page. The numbering system is a little confusing at first, but you'll soon be flicking back and forth like a pro.

The builds are mostly quite simple, meaning anyone will be able to have a go. They're rated based on time, so you know roughly how long each one will take, and a section at the front of the book gives you advice depending on what you want to construct and the number of bricks you have available.

However, this book is not without its problems, the key one being the lack of detail used to explain the more complex builds. Even the biggest builds only take up two pages of the book, so the fine details are left out. As a result, some of the builds involve a lot of guesswork, and while it's fun to experiment, a few more instructions would be helpful. Still, this is only a small obstacle, and one that certainly won't bother true master builders.

★★★★☆

YOU MAY ALSO LIKE...

LEGO Star Wars: Build Your Own Adventure
Author: **Daniel Lipkowitz**
Publisher: **DK**
Price: **£17.99 / $24.99**
Release date: **Out now**

Star Wars fans will love this book. It's similar in style to *365 Things*, but every page covers a different *Star Wars* item, from podracers to the treehouses of Endor.

LEGO DC Super Heroes Character Encyclopedia
Author: **N/A**
Publisher: **DK**
Price: **£14.99 / $18.99**
Release date: **Out now**

This book is full of stats and facts on all of the characters from the LEGO DC Universe, and includes a pirate Batman minifigure.

LEGO City: Build Your Own Adventure
Author: **Simon Hugo**
Publisher: **DK**
Price: **£17.99 / $24.99**
Release date: **Out now**

Build your own city out of LEGO with this helpful book. You can create everything from cars to picnic benches, or the exclusive fire truck design you'll find inside.

13 Journeys Through Space And Time

Christmas Lectures from the Royal Institution

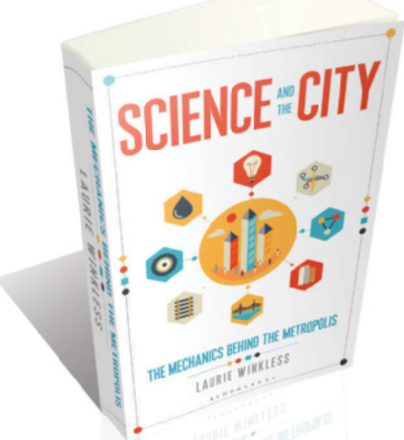
- Author: **Colin Stuart**
- Publisher: **Michael O'Mara Books Limited**
- Price: **£12.99 (approx $16.50)**
- Release date: **Out now**

Astronaut Tim Peake explains in the foreword of this book that the world-famous Christmas Lectures all began with scientist Michael Faraday seeking to educate young minds about the wonders of science.

He certainly succeeded, as world-renowned scientists have been captivating audiences at this annual event for almost 200 years. Colin Stuart has now compiled 13 of the most engaging lectures ever presented through transcripts, photographs and handwritten notes.

While no substitute for the real thing, the use of imagery, quotes and further explanations from the author recreate these tales of space and time admirably.

★★★☆☆



Science And The City

The mechanics behind the metropolis

- Author: **Laurie Winkless**
- Publisher: **Bloomsbury**
- Price: **£12.99 / $27**
- Release date: **Out now**

It's easy to take modern city living for granted. In Earth's biggest cities, millions of us scurry around on underground rail networks, emerging into a land of skyscrapers filled with people working and communicating with others across the globe.

In *Science And The City*, Winkless deconstructs these fantastic feats of science and engineering into individual blocks, providing a guide to building a modern metropolis. Those with a curious mind will relish this book and enjoy its chatty and inclusive style.

★★★★★

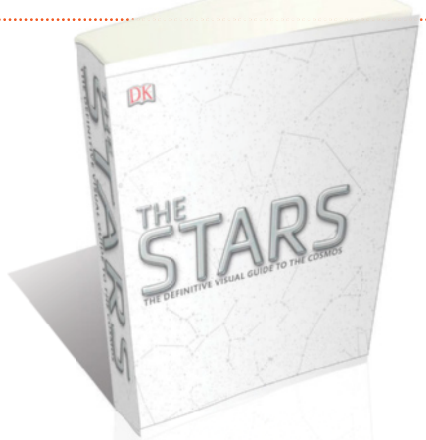
The Stars

A definitive visual guide to the cosmos

- Author: **Maggie Aderin-Pocock MBE**
- Publisher: **DK**
- Price: **£20.00 / $30**
- Release date: **Out now**

There's much to admire about this book. Authored by a collection of experts and brilliantly illustrated with enticing diagrams and images, the two aspects come together to educate us on all things stars while remaining easy to follow. The first and last sections, which focus on our Solar System and the cosmos that surrounds it, are particularly engaging.

The majority of the book, however, is dedicated to the constellations in our night sky. This section in particular may be more applicable as a reference tool, yet you may find yourself a much bigger fan of astronomy after you've finished reading nonetheless – which surely, can only be a good thing.

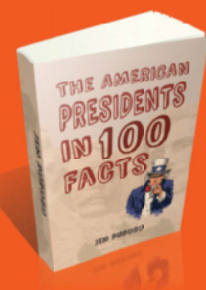


★★★★☆

The American Presidents In 100 Facts

Fun facts on every US head of state

- Author: **Jem Duducu**
- Publisher: **Amberley**
- Price: **£7.99 / $15**
- Release date: **Out now (UK) / 14 March (US)**



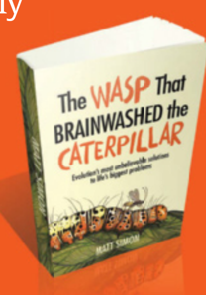
This latest release is a great addition to Jem Duducu's 100 facts series. The book dedicates two or three bite-size pages to each president, and Duducu does a great job of maintaining interest even when it comes to the lesser-known leaders. Who knew John Quincy Adams kept a pet alligator and a pool table in the White House, and even organised a trip to the North Pole to search for mole people? These fascinating details are interspersed throughout, adding to the light-hearted tone of the book and its all-round accessibility. Highly recommended.

★★★★½

The Wasp That Brainwashed The Caterpillar

A look into the fantastically freaky world of evolution

- Author: **Matt Simon**
- Publisher: **Headline**
- Price: **£12.99 / $20**
- Release date: **Out now**



Have you heard of zombie ants or regenerating salamanders? Evolution has led to some bizarre solutions to the problems faced by animals. In this book, Matt Simon showcases some of the weirdest creatures on the planet. Given how truly absurd some of the animals are, Simon's engaging and witty tone suits this journey through the weird and wonderful world of evolution. Many amazing critters are covered, with ingenious and baffling adaptations that you'll want to share with friends and family.

★★★★★

The Science Of Stress

The causes and solutions to today's stress-filled world

- Author: **Gregory Fricchione, Albert Yeung & Ana Ivkovic**
- Publisher: **Ivy Press**
- Price: **£20 / $35**
- Release date: **Out now**

Workaholism, money worries and 24-hour news: it's easy to see how our modern lifestyles have created a stress epidemic. What is less obvious, however, is the significant effect this prolonged stress has on our minds and bodies. This book covers a variety of factors that contribute to our constantly frazzled minds, including sleep deprivation and poor diets, and also includes illustrations to help explain the effects. As this title is a collection of essays rather than one cohesive book, the information might be a little too specialised for some, but it's a fascinating and informative read nonetheless.

★★★★½

HOW TO...
Practical projects to try at home

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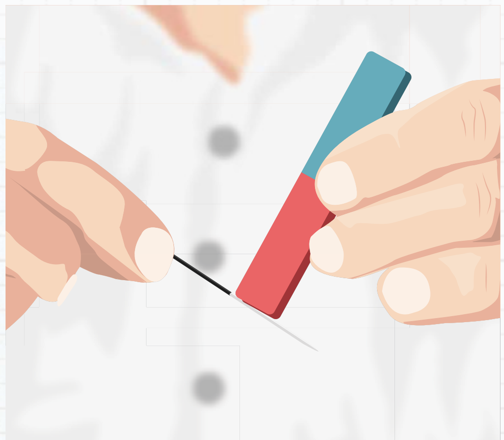
Make a compass

Learn how to find your way north using simple household objects and the power of magnetism

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

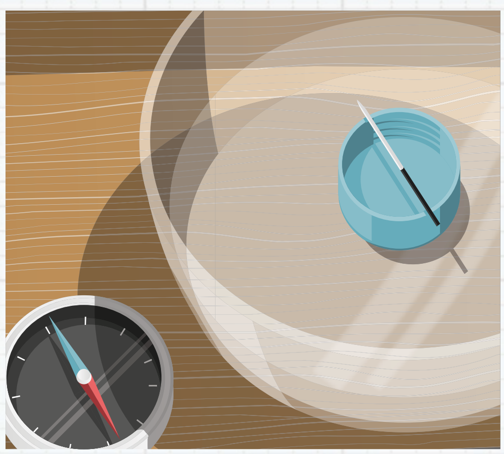
1 Assemble your tools
For this navigational experiment we'll firstly need a sewing needle, which is going to become the point of our compass. We'll also need a dish, water, some sticky tack or glue, a permanent marker pen and a magnet. A bar magnet will work best, but you can use a fridge magnet instead if you can't find one. A piece of stainless steel cutlery may work as well.



2 Magnetise the needle
Colour one end of your needle using the marker pen; this will help distinguish between north and south later. Next, magnetise the uncoloured end of the needle by stroking your magnet in one direction across the surface. Make sure to lift the magnet away with each new stroke. If you're using a bar magnet, you can choose which way the uncoloured end will point.

3 Attach a float
Now you've got yourself a magnetic needle, but it won't be able to rotate towards north or south until you place it on a surface where there's little friction; so the next task is to build one. Take the plastic bottle cap and place it upside-down on your work surface, then use the sticky tack or glue to securely attach the needle to the rim of the bottle cap.

4 Add to water
Take your dish and add water to a depth of approximately two or three centimetres. Next, carefully place your compass on the water. As a liquid, water is an excellent choice for a low-friction surface. If the Earth's magnetic field was stronger the needle could move on a solid surface, but when sat on water the needle will face little resistance when turning towards the poles.



5 Find your orientation
As the water settles the needle will begin to turn and face the poles. Try gently spinning the compass; you should notice that the needle soon realigns itself to face the same direction as it did before you span it, just like any other compass. If you have a real compass or a smartphone with a compass app handy, you can now check to see which side of your needle is pointing north.

"As the water settles the needle will begin to turn and face the poles"

In summary...
Metals that needles are made from – such as iron, nickel and cobalt – all have magnetic areas called domains. These usually point in different directions, but when exposed to a strong magnetic field they can briefly align and become magnetic. The needle then tries to line up with the Earth's magnetosphere, which is created by our planet's molten iron core.

Build a rocket

Send your creation blasting into the skies with a simple chemical reaction

NEXT ISSUE
MAKE A JUNGLE IN A BOTTLE
GROW A STALACTITE

1 Construct your frame

For a successful launch we'll need an empty plastic bottle that holds about 500 millilitres, its bottle cap or a piece of cork, three pencils, tape, a paper towel, a funnel, a tablespoon, baking soda and vinegar. First, tape the pencils to the bottle, ensuring the ends are bound a few centimetres higher than the bottle top. This will support the rocket when it's turned upside-down.

2 Prepare your fuel

Fill your rocket with vinegar to around three-quarters full, then carefully move it to one side. Next, lay a paper towel flat on a work surface and add a heaped tablespoon of baking soda to the centre. Spread the powder out a little then, starting from one side, fold the paper towel into a narrow roll. Carefully twist the ends of the roll to seal the baking soda tightly inside.

3 Blast off!

You're almost ready for lift-off! Make sure your launch pad is outside – in an area where a bit of mess is okay – and that you're working under adult supervision. Now add your roll of baking soda to the bottle filled with vinegar and quickly seal the hole with a cork or the bottle cap. Shake the rocket, flip it upside-down and place it on your launch pad, then take cover and wait for blast off!

"Flip it upside-down and place it on the launch pad, then take cover"

In summary...
For a rocket to be pushed off the ground, enough thrust must be generated to overcome gravity. This comes in the form of the carbon dioxide gas that's made as a product of the baking soda and vinegar reaction. The gas accumulates inside the bottle until the pressure is high enough to force off the cork or cap.

WIN!

A K'nex 3-in-1 Classic Amusement Park building set worth £49.99

Construct your own theme park attractions with this classic K'nex kit. Build a Ferris wheel complete with an electric motor so it moves like the real thing, plus a swing ride and a boom ride. The set comes complete with easy to follow step-by-step instructions for each amusement, and is suitable for ages nine and up.

What is the name for the art of recreating sound effects for film and TV?

a) **Foley** b) **Holey moley** c) **Roly poly**

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AMAZING PRIZE FOR LETTER OF THE MONTH!
HOW SUPER COOL STUFF WORKS
Packed with teardowns and illustrations, discover the inner workings of the latest gadgets and tech in this brilliant book from DK.

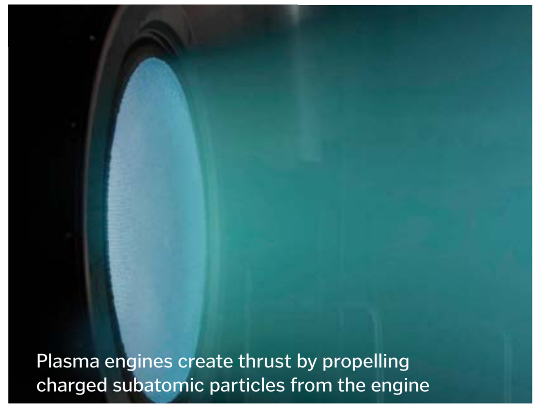
Letter of the Month
Plasma rockets

Dear **HIW**,

My brothers and I love your magazines – we get them delivered (a magazine each) all the way to New Zealand! I love astronomy and the science around it, so because of this, I was watching a documentary on the future of space exploration, and it mentioned new rocket types and something called plasma. That led me to ask, what is plasma and how does a plasma rocket system work? My brothers and I would love to hear from the team, clearing the air on these new rockets.
Yours faithfully,
Mitchell (12), Callum (14) and Ethan Bowmar (16)

Hello from the UK! And thanks for the question. Plasma is actually the most common fundamental state of matter in the universe – there's more of it around than solids, liquids and gases! We refer to matter as plasma when gases become ionised, which happens when the atoms split into separate charged subatomic particles: positively charged protons and negatively charged electrons.

Plasma is different from gas because it conducts electricity and interacts with magnetic forces. These features are what we're interested in when we want to build a powerful engine. Plasma engines – or ion thrusters – create ions by separating electrons from atoms. Inside the engine, strong magnets regulate the ionising process, and the created ions travel through a series of charged grids. The final grid is highly negatively charged and pulls the positive ions towards it at speed. The positive ions are then ejected out of the thruster as an ion beam.


Plasma engines create thrust by propelling charged subatomic particles from the engine

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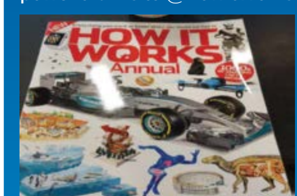
@BrynLucas
Go on, ask me anything! I now have the power thanks to @HowItWorksmag



@chazz1959
Why cheetahs don't roar. Great article about Big Cats in issue 92 of @HowItWorksmag

@funkbun
@HowItWorksmag Happy birthday!

@RobertoJones84
@HowItWorksmag Brought issue 90 on holiday, surprised to read about the Bamburgh sword, so had to visit! #coincidence

@gillyt202
@HowItWorksmag Hi guys, just to say thank you for my prize I won with you recently! This book is great!!

@angep1969
@HowItWorksmag :) we love your work!

Making gold

Dear **HIW**,

I read lots of different articles that mention the ways of changing lead into gold, and one of them mentioned that the Russians successfully changed lead into gold by using lead as a protection cover in a nuclear power plant. Is this possible?
Panzer Doge

It's possible to turn lead into gold, but it's not common practice as the cost of the engineering process would outweigh the gold's value.

All elements are distinguished by the amount of protons they have in their nuclei. Gold has 79 and lead has 82, so to change lead into gold you'd need to remove three protons. This is a difficult task because lead is a stable element, but during a nuclear reaction there are lots of energised particles available. These are capable of knocking protons from lead, and are the reason gold was found at a Soviet nuclear research facility in the 1970s.


Lead can be changed into gold by removing three protons from its nucleus


Nobody knows for certain what conditions are like at the centre of a black hole

The singularity

Dear **HIW**,

Ever since my first **How It Works** I have loved the magazine. I have been reading about the history of the universe lately. A lot of what I was reading had information about black holes, which made me wonder. All the matter that goes into them is crushed by gravity, which I know, but it cannot be crushed into nothing, can it? So my question is: what is at the bottom of a black hole?
Thanks,
Olly Perry

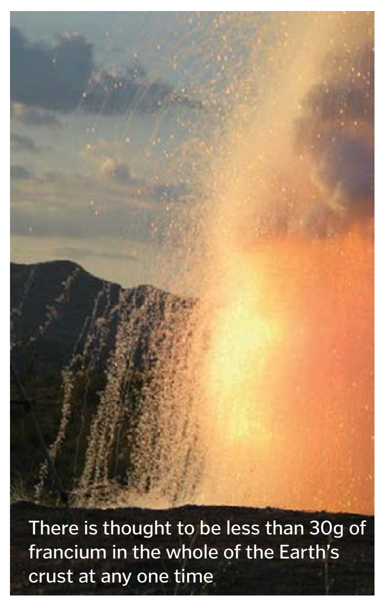
You're right to say it can't be crushed into nothing – it's more the opposite. Everything with mass bends space-time – the heavier the mass, the more space-time bends. At a black hole's centre – the 'singularity' – the mass is so heavy space-time bends infinitely. This means there may be no sense of time, with everything crushed into a black hole that stretches on forever.

Big explosions

Dear **HIW**,

Your magazine is by far the best I have ever read because it covers all areas of science. I have a question for you: how much force would be created if all of the francium in the world was dropped into the sea? What would happen to the world?
Ollie Carroll (aged 12)

You'd think francium would have a devastating effect if dropped into the sea. It's the most volatile element of the alkali metals, a group that causes explosions in water because they're eager to give away an electron. However, francium is unstable and decays in minutes, so there's hardly any of it on Earth at any one time. So, to answer your question, there'd be a big splash, but no large-scale damage.


There is thought to be less than 30g of francium in the whole of the Earth's crust at any one time

HOW IT WORKS

Future Publishing Plc
Richmond House, 33 Richmond Hill
Bournemouth, Dorset, BH2 6EZ
☎ +44 (0) 1202 586200
Web: **www.howitworksdaily.com**
www.greatdigitalmags.com
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Editorial
Deputy Editor **Jackie Snowden**
jacqueline.snowden@futurenet.com
☎ 01202 586264
Senior Art Editor **Duncan Crook**
Research Editor **James Horton**
Production Editor **Charlie Ginger**
Senior Staff Writer **Jack Griffiths**
Assistant Designer **Laurie Newman**
Editor in Chief **Dave Harfield**
Photographer **James Sheppard**
Picture Editor **Tim Hunt**

Contributors
Stephen Ashby, Sarah Bankes, Ella Carter, Alexandra Cheung, Ed Crooks, Nicholas Forder, Rebekka Hearl, Amelia Jones, Tom Lean, Adrian Mann, Adam Markiewicz, Laura Mears, Jack Parsons, Jo Smolaga, Joanna Stass, The Art Agency

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Head of Sales **Hang Deretz**
☎ 01202 586442
hang.deretz@futurenet.com
Account Manager **Lee Mussell**
lee.mussell@futurenet.com

International
How It Works is available for licensing. Contact the International department to discuss partnership opportunities.
Head of International Licensing **Cathy Blackman**
☎ +44 (0) 1202 586401
cathy.blackman@futurenet.com

Subscriptions
For all subscription enquiries:
howitworks@servicehelpline.co.uk
☎ 0844 815 5944
☎ Overseas +44 (0)1795 418680
www.imaginesubs.co.uk
Head of subscriptions **Sharon Todd**

Circulation
Circulation Director **Darren Pearce**
☎ 01202 586200

Production
Production Director **Jane Hawkins**
☎ 01202 586200

Management
Finance & Operations Director **Marco Peroni**
Creative Director **Aaron Asadi**
Editorial Director **Ross Andrews**

Printing & Distribution
Wyndeham Peterborough, Storey's Bar Road, Peterborough, Cambridgeshire, PE1 5YS

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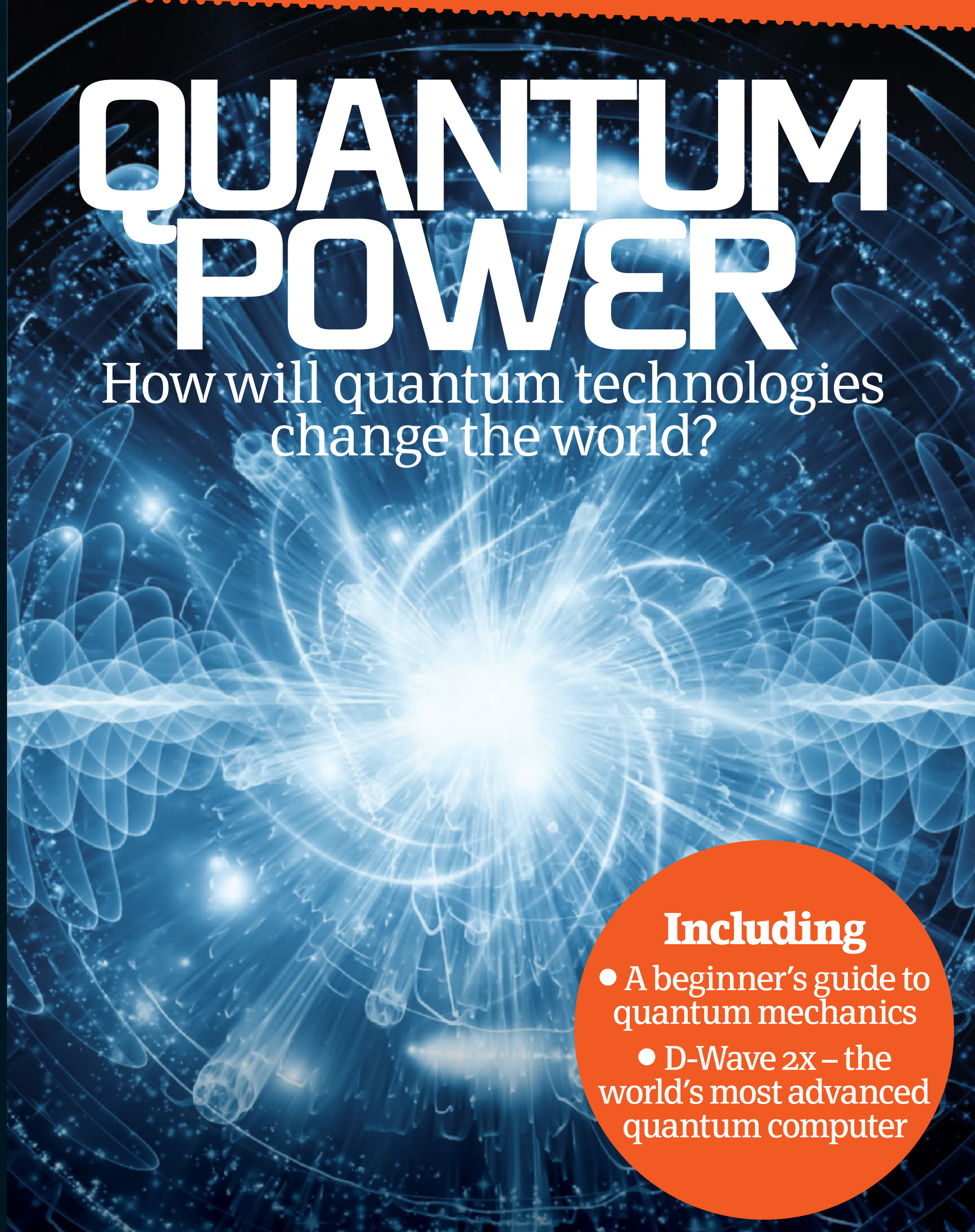

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FAST FACTS

Amazing trivia to blow your mind

Anglo-Saxons called January the 'wolf month', as this was when the canine was seen most in England

93% OF AMERICANS EAT PIZZA AT LEAST ONCE A MONTH

1.4 MILLION
THE ESTIMATED NUMBER OF ANTS FOR EVERY HUMAN BEING ON EARTH

2.4 MILLION BILLION
NUMBER OF COLLISIONS SEEN BY THE LHC'S CMS AND ATLAS EXPERIMENTS SINCE APRIL 2016

20,000
THE ESTIMATED NUMBER OF PEOPLE WHO WERE SACRIFICED WITHIN THE AZTEC EMPIRE EVERY YEAR

80 DECIBELS
THE SOUND OF A FORMULA E CAR – ABOUT THE SAME AS A WASHING MACHINE

99.8%
AMOUNT OF THE SOLAR SYSTEM'S MASS HELD BY THE SUN

YOU'RE MORE LIKELY TO BE STRUCK BY LIGHTNING THAN ATTACKED BY A SHARK

395
AVERAGE NUMBER OF iPHONES SOLD EVERY MINUTE

2 HOURS
HOW LONG ASTRONAUTS ON THE ISS HAVE TO EXERCISE EACH DAY

The Hawaiian volcano Kilauea has been erupting continuously since 1983

12
PEOPLE WHO HAVE WALKED ON THE MOON

59%
THE PROPORTION OF THE UK POPULATION WHO ADMITTED TO BREAKING THEIR NEW YEAR'S RESOLUTIONS IN 2015

200,000
THE ESTIMATED POPULATION OF TENOCHTITLÁN AT THE START OF THE 16TH CENTURY