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SCIENCE

INSIDE

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From testing to take-off

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THE BEST WAY TO BEAT JET LAG

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THE REAL JUNGLE BOOK EXPLAINED

JUNGLE BEASTS

+ LEARN ABOUT

- MOTION CAPTURE
- FIRING TORPEDOES
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- CAR AIR-CON
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- LIGHTNING BOLTS

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ISSUE 84

CUT-THROAT PIRATES

The savage tactics behind history's bloodthirsty buccaneers

WELCOME
The magazine that feeds minds!

"Blackbeard was worth an estimated $12.5 million"

Cut-throat Pirates, page 68

Meet the team...

Jo
Features Editor
While wearing the HTC Vive, I almost walked into a wall. Maybe I'm not ready for VR just yet, but it's having a huge impact on education and healthcare.

Jackie
Research Editor
The jungle feature left me singing *I Wanna Be Like You* all week. Everyday Science explains why, and – much to the team's relief – how to make it stop.

Katy
Production Editor
We tend to sip tea rather than swig rum here at **How It Works**, so Black Bart would fit in well! He also preferred a cuppa before setting off on a pirate raid.

Duncan
Senior Art Editor
I've often thought about building a plane in my shed in my spare time and jetting off around the world. Now I can, with our feature on page 58.

Briony
Assistant Designer
Put down the celery. On page 34, we expose the truth behind those superfood myths – it turns out beetroot is not the elixir of life!

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Hearing the familiar bouncy notes of *The Bare Necessities* transformed into a soaring orchestral score sent shivers down my spine.

The new *Jungle Book* movie looks and sounds as slick and majestic as the original must have seemed back in 1967. Now a whole new generation can experience the delight of Rudyard Kipling's tale, and you can explore the real-life secrets of the world's tropical forests in this issue, ahead of the release in April.

It's fascinating to uncover the truth behind our favourite films, and we don't stop there. Over on page 68, we present the real pirates of the Caribbean and I'm pleased to report that Johnny Depp's portrayal isn't far off the rum-swilling scoundrels that would rather trick sailors into handing over their treasure than spill blood for it.

On top of that, we find out how virtual reality will affect our future, go behind the scenes of building a plane and get to the bottom of life's little mysteries. At last, there's a scientific reason why coffee spills and it's not just that I'm clumsy!

Jodie

Jodie Tyley
Editor

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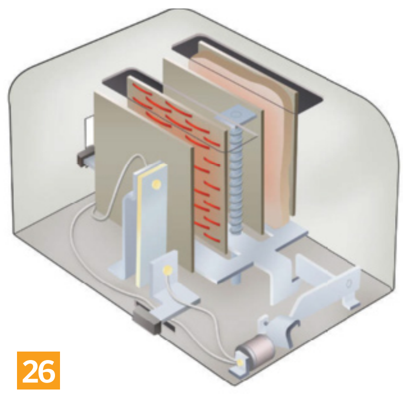

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The science of everyday explained

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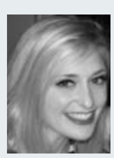
Meet the experts...

Laura Mears
Over the years, Laura's explained research that will save lives and help us colonise the Moon, but this month she tackles topics much closer to home. Find out why teapots drip, toast burns and more, on page 26.

Gemma Lavender
This month, our resident astrophysicist received a strange package in the mail – a self-sustaining miniature universe! Find out more on page 40.

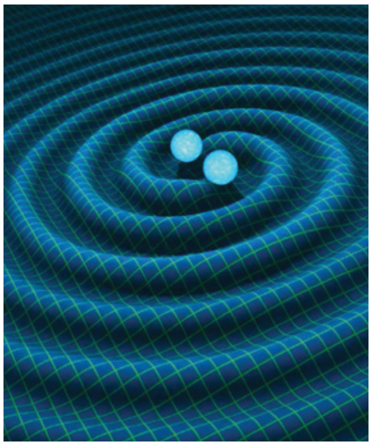
Steve Wright
SciFiNow's Steve has spent years reviewing the latest TV, films and books, and while there are no vampires or time-travellers in this magazine, he's the perfect critic for our new book reviews section.

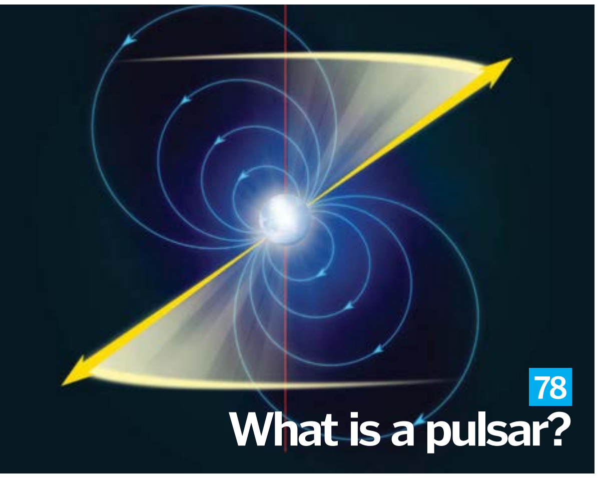


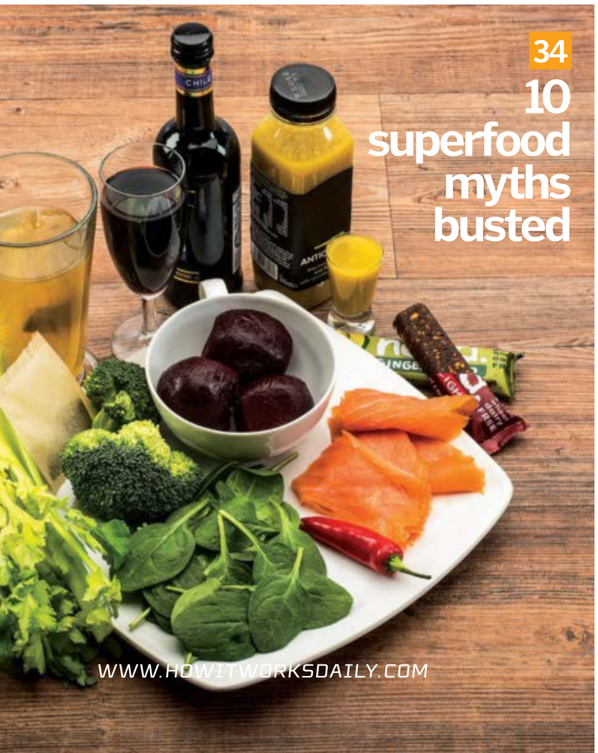
Ella Carter
After watching a Disney movie in the name of work, Ella took on our blockbuster cover feature. Did you know the real-life Baloo can be heard eating ants from 100m away?!

Alicea Francis
All About History's Alicea reveals the true buccaneer lifestyle in the 17th century. You might be surprised to learn what a democratic bunch they were!

REGULARS







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Ripples in space-time: what do they mean?

How the discovery of gravitational waves could shape our understanding of the universe

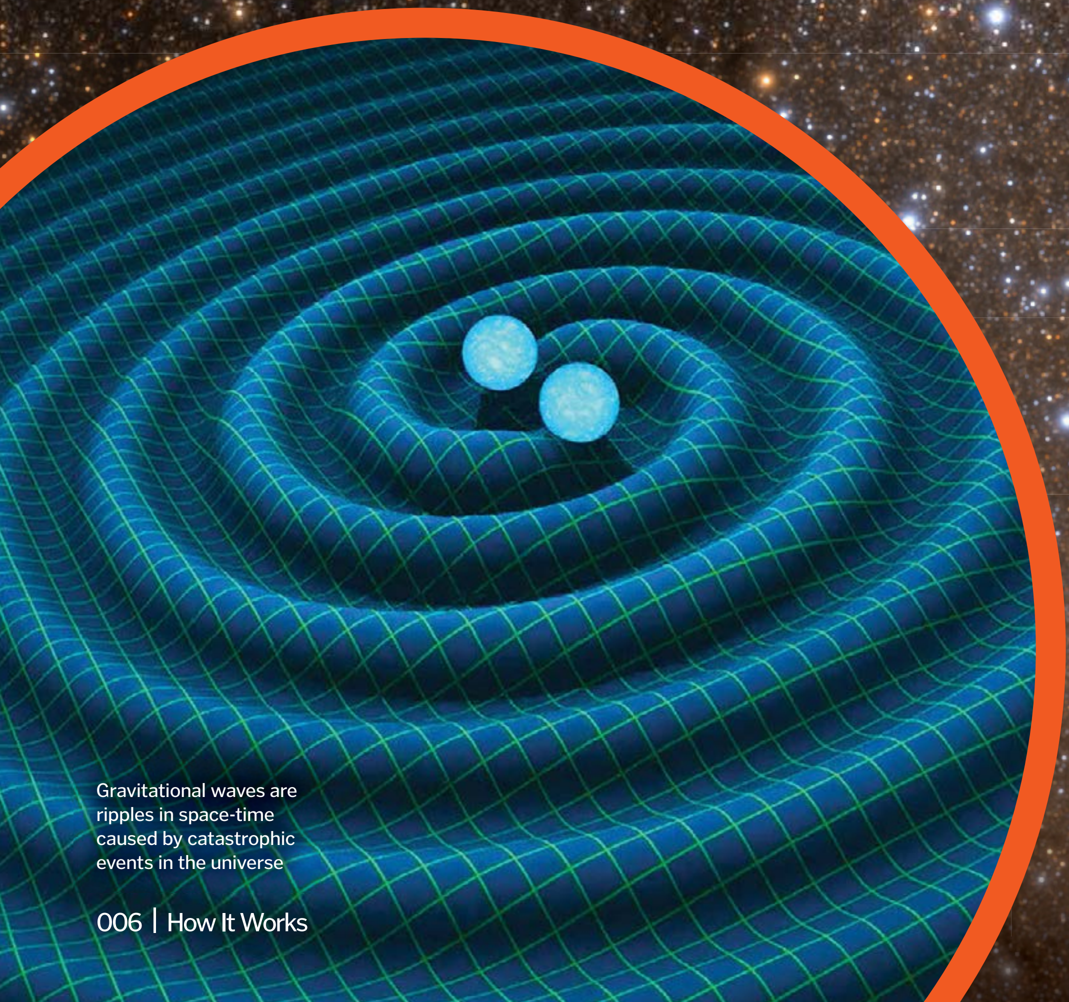
Back in 1915, Albert Einstein was the first to predict that massive accelerating objects, such as neutron stars or black holes orbiting each other, cause ripples in the fabric of space-time, a little bit like the ripples caused by a stone hitting the surface of a pond.

He proposed that these ripples – called gravitational waves – travel at the speed of light through the universe, and carry information about the catastrophic events that caused them and the nature of gravity itself.

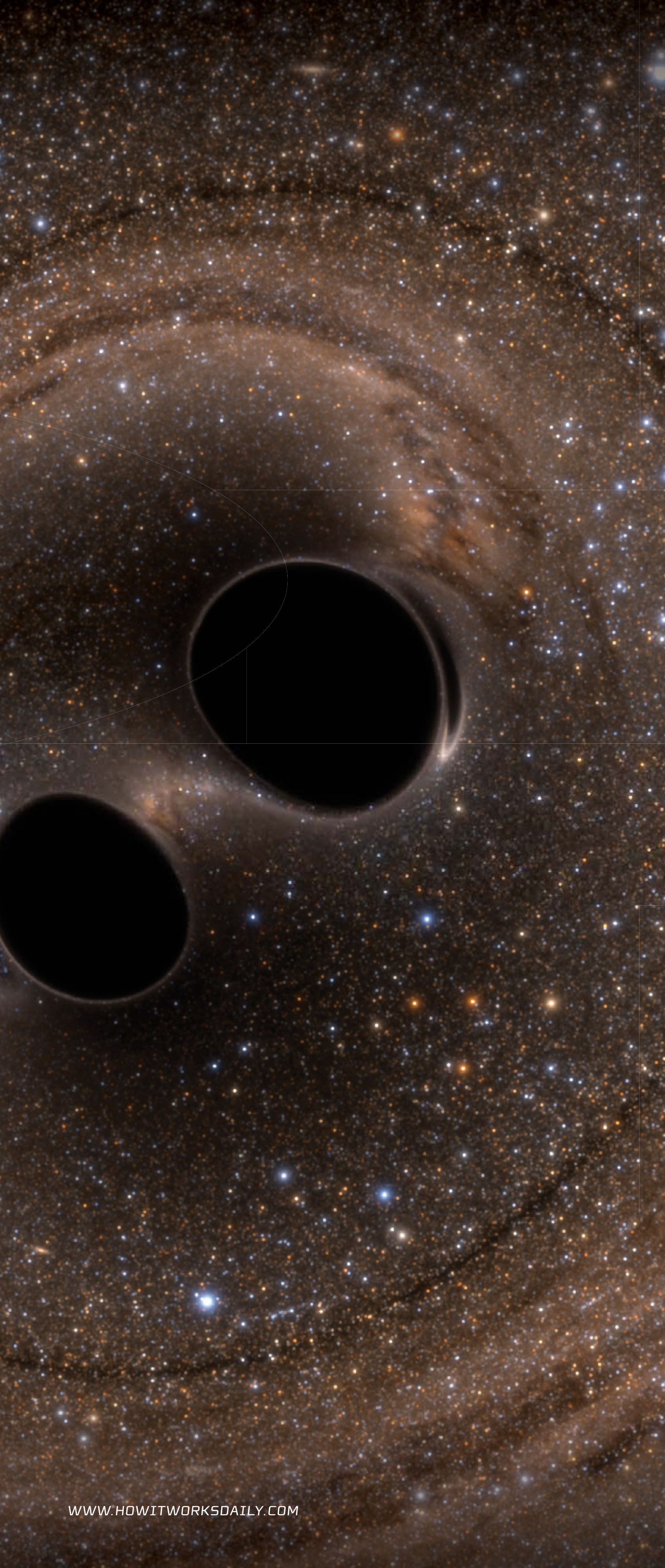
Though Einstein was convinced that gravitational waves existed, proof didn't come until 1974, 20 years after his death. By studying two extremely dense and heavy stars orbiting around each other, known as a binary pulsar, astronomers found that the orbit was slowly shrinking because of what must be the release of energy in the form of gravitational waves.

With their existence proven, the next step was to observe the gravitational waves themselves here on Earth, a feat that has finally been achieved by an international team of scientists using the two Laser Interferometer Gravitational-Wave Observatory (LIGO) sites in the US. This monumental achievement means that scientists now have an entirely new way to study the universe. Many parts of the cosmos, such as black holes, are invisible to the light-based telescopes used today, and space dust can distort the images they capture. Detecting gravitational waves will overcome these problems, and give us a better understanding of objects such as supernovas and neutron stars.

Eventually, it is hoped that gravitational waves will even make it possible to see the Big Bang itself, giving us a better idea of exactly how the universe began and solving some of the biggest puzzles in physics.



Gravitational waves are ripples in space-time caused by catastrophic events in the universe

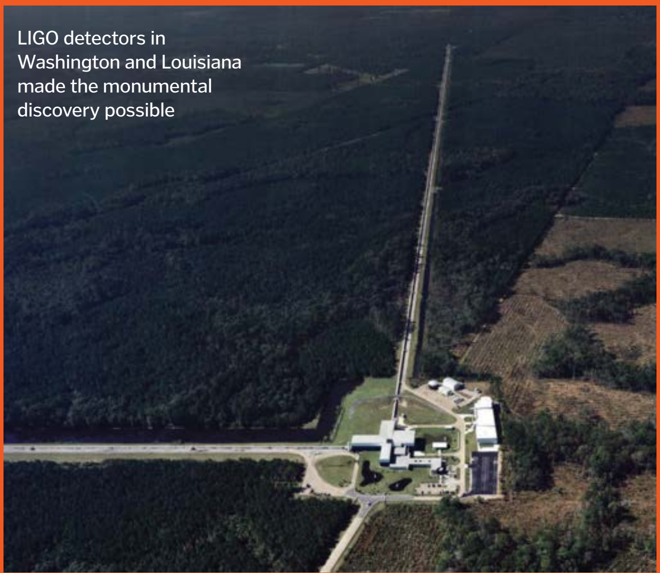


The collision of two black holes was the source of the first gravitational waves that scientists have been able to detect

How were gravitational waves observed?

At each of the two LIGO sites in the US there is a large L-shaped instrument called an interferometer; each of its arms is four kilometres long. A laser beam fired into the interferometer is split by a special mirror, sending a beam down long vacuum tunnels in each arm of the 'L'. When they reach the end of each arm, the beams are reflected back again by another mirror and then recombine into one laser beam that is picked up by a photodetector. If both beams have travelled the exact same distance, the recombined beam should be as bright as it was before it was split. However, if it is brighter or dimmer than it was before, this indicates that the distance travelled has changed.

When two black holes over 29 times the mass of the Sun collided 1.3 billion years ago, they emitted a strong burst of gravitational waves. These waves finally reached Earth on 14 September 2015, and caused the length of the interferometer's arms to stretch and squeeze by just 1/10,000th the width of a proton. This change of distance was enough to alter the brightness of the recombined beam, allowing scientists to observe the effects of gravitational waves for the first time.



LIGO detectors in Washington and Louisiana made the monumental discovery possible

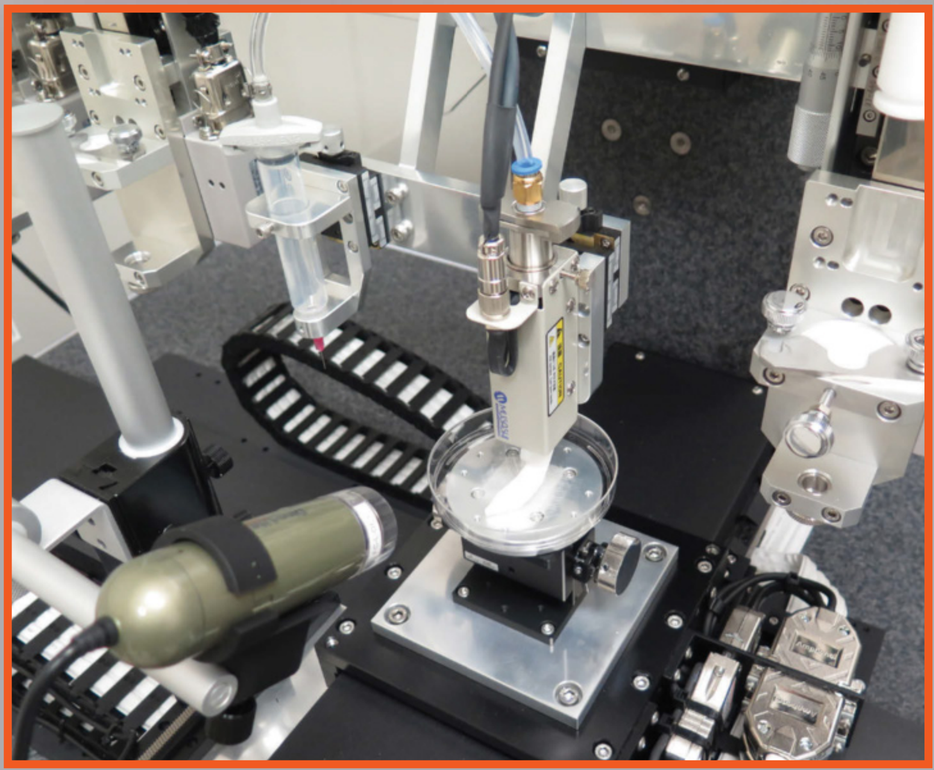
A 3D-printed ear could be implanted onto humans in the near future

3D printing of living body parts

Scientists prove it's possible to print human bones, muscles and cartilage

3D printers aren't just for producing car parts and plastic toys, they can also create bits of human. Scientists at Wake Forest Baptist Medical Center in North Carolina, US, have printed custom ear, bone and muscle structures, which have matured into functional tissue when implanted into animals.

The tissue was printed from a biodegradable plastic-like material to form the shape of the structure, and water-based gels containing cells. Micro-channels printed into the structure then allowed nutrients and oxygen from the host body through, keeping the cells alive while they developed a system of blood vessels and nerves. They now hope to be able to use these tissue structures to replace injured and diseased tissue in human patients.



The Integrated Tissue-Organ Printing System producing a jawbone structure

The flexible future of smartphones

Bend-control helps bring Angry Birds to life

When using the world's first wireless flexible smartphone, you can interact with apps simply by bending the handset. Bend sensors behind the LG Display Flexible OLED touch screen sense the force you apply, and this information can be used to flick through the pages of an e-book, or stretch the sling when playing *Angry Birds*. A voice coil inside the phone will then simulate the feedback from these actions through vibrations, helping you feel the rubber band stretch and snap back or the pages flip through your fingers.

The ReFlex is the world's first wireless flexible smartphone

Drones can help find you in the woods

Smart flying machines learn to recognise forest trails and come to the rescue

While drones are already good for search and rescue missions in open areas, they have trouble spotting those in distress beneath dense forest canopies. To combat this problem, researchers have developed artificial intelligence software that enables small quadcopters to detect and follow forest paths, allowing them to fly among trees to find lost hikers and alert human rescuers to their whereabouts. Small cameras on the drone capture its surroundings, a clever algorithm interprets the images to spot nearby paths, and the software directs the machine on the right route.

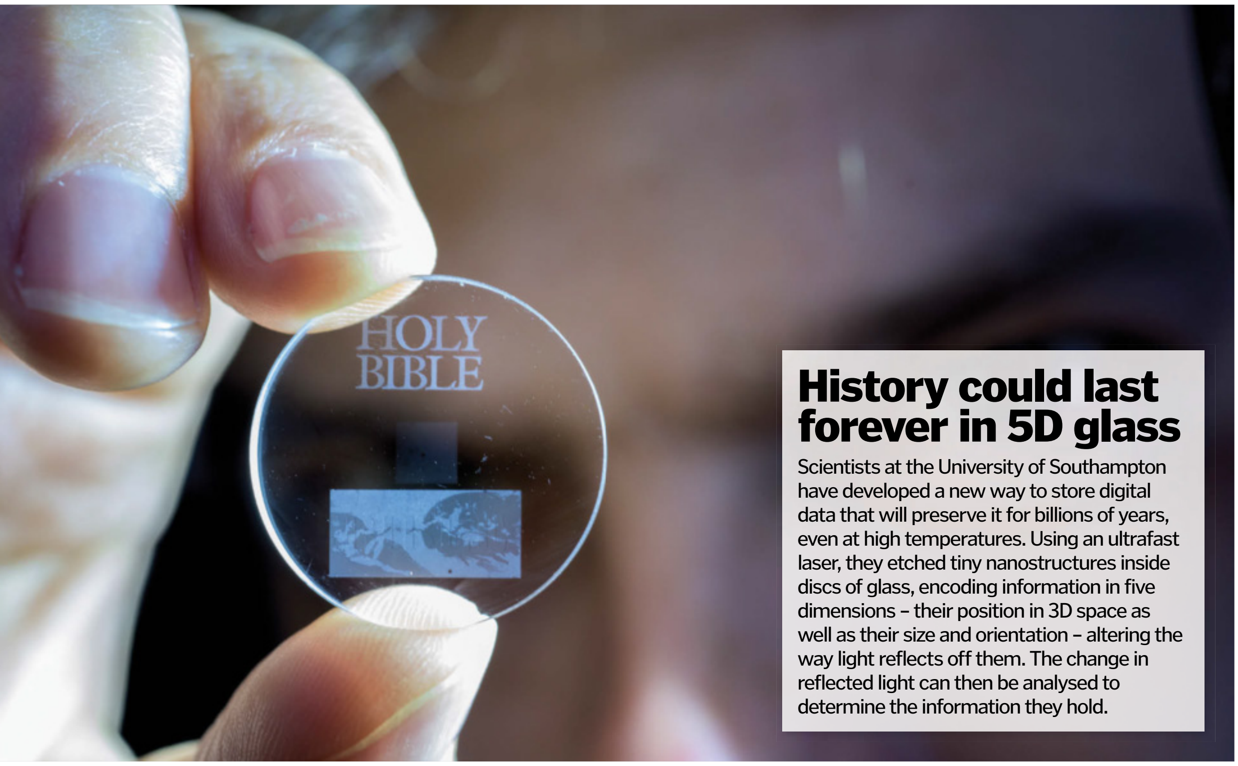
The software means the drones are better than humans at identifying previously unseen trails

Artificially intelligent drones can help rescue services to find lost hikers in the woods

GLOBAL EYE
10 COOL THINGS WE LEARNED THIS MONTH

Big-brained mammals are more likely to go extinct

For millions of years, mammals with large brains have had the upper hand when it comes to surviving extinction, but a new study has found the opposite is now true. By examining the relationship between brain size and endangerment status in 160 species, researchers found that mammals with larger brains relative to their body mass were more likely to be at risk.

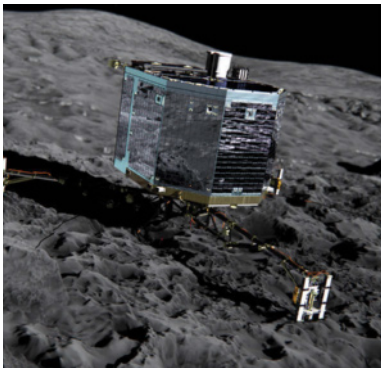


History could last forever in 5D glass

Scientists at the University of Southampton have developed a new way to store digital data that will preserve it for billions of years, even at high temperatures. Using an ultrafast laser, they etched tiny nanostructures inside discs of glass, encoding information in five dimensions – their position in 3D space as well as their size and orientation – altering the way light reflects off them. The change in reflected light can then be analysed to determine the information they hold.

A flower has grown in space

After successfully growing lettuce onboard the International Space Station last year, Commander Scott Kelly and his crew have shown off the first flower to be grown in space. The zinnia plant was grown using the station's Veggie system, specifically designed for growing crops in microgravity.



We have said farewell to Philae lander

The little spacecraft that successfully landed on Comet 67P in November 2014 has now gone into eternal hibernation. The lander has remained silent since July 2015, and is now facing conditions from which it is unlikely to recover, so ground control has given up sending commands.

Bananas are helping to diagnose skin cancer

The black spots that appear on bananas as they age are caused by the enzyme tyrosinase, which also causes the tell-tale spots of the skin cancer melanoma. This information has helped researchers in Switzerland develop a new imaging technique for measuring tyrosinase levels, which they were able to test on the fruit before trying it on humans.

Horses can read human emotions

By showing horses photographs of positive and negative human facial expressions, researchers at the University of Sussex have proved these animals can distinguish between happy and angry emotions. When shown an angry face, the horses looked more with their left eye – a behaviour associated with processing threatening stimuli – and experienced a rapid increase in heart rate, associated with stress.

Climate change will make transatlantic flights longer

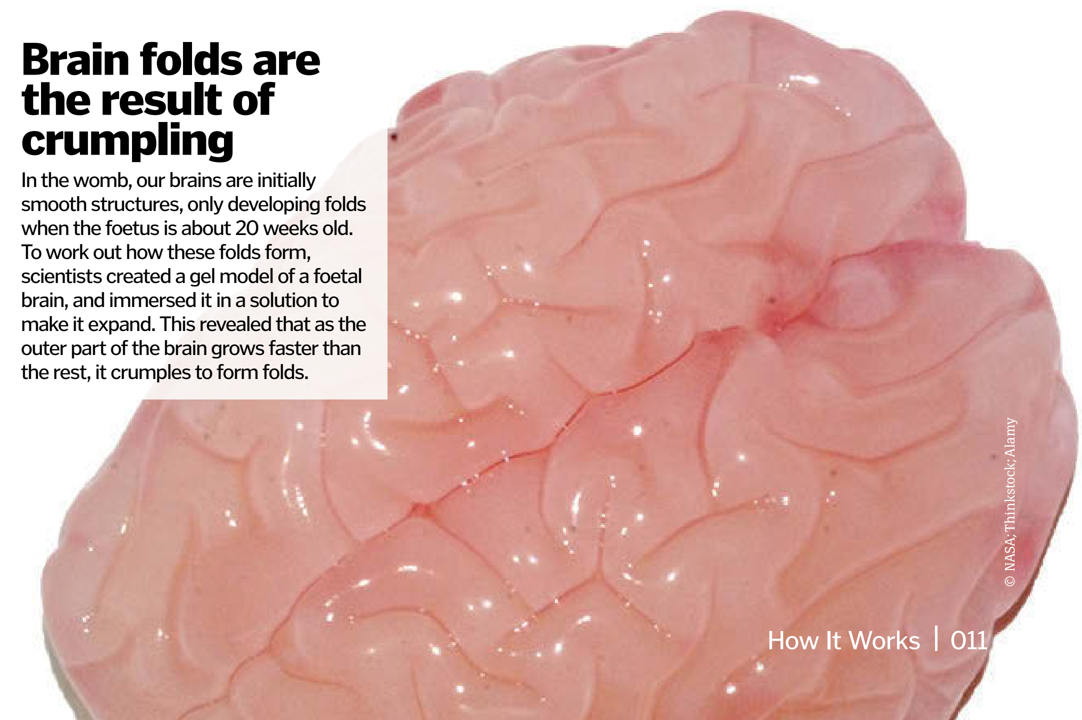
You'll get through more movies than usual on future flights from Europe to North America, as climate change slows down some journeys across the Atlantic. Scientists at the University of Reading have calculated that the jet stream – high-altitude winds blowing from west to east across the ocean – is speeding up, creating stronger headwinds for westbound flights. The good news though, is that eastbound flights will speed up, as stronger tailwinds help push aircraft towards Europe.

Spiderman's feet are not big enough

Ever wondered why you can't scale walls like your favourite superhero? Researchers at the University of Cambridge have revealed that in order to climb a smooth vertical surface, humans would need impossibly big feet as they would require adhesive pads covering 40 per cent of their body, or roughly 80 per cent of their front. They concluded that the maximum size an animal could be in order to climb walls is that of a gecko.

Hair follicles gradually turn into skin

As we age, our hair follicles slowly stop growing new hair, and now scientists in Tokyo know why. Age-related damage to our DNA triggers the destruction of the protein Collagen 17A1, causing stem cells inside the hair follicles to transform into skin, shrinking the follicles until they disappear.



Brain folds are the result of crumpling

In the womb, our brains are initially smooth structures, only developing folds when the foetus is about 20 weeks old. To work out how these folds form, scientists created a gel model of a foetal brain, and immersed it in a solution to make it expand. This revealed that as the outer part of the brain grows faster than the rest, it crumples to form folds.

DAY IN THE LIFE OF

A motion capture animator

What goes into creating the life-like animated characters in your favourite video games and blockbuster movies?

In the past, animators had to create their characters' movements from scratch, adjusting their position frame by frame in a painstakingly slow process. Nowadays, their job is made much easier by motion capture technology, as the movements of a person can be recorded and transferred onto the digital character automatically.

To do this, the actor must wear a suit covered with markers, which look a bit like ping-pong balls. The location of these markers is then tracked by a series of cameras positioned at different angles around them to create 3D trajectories of their movement.

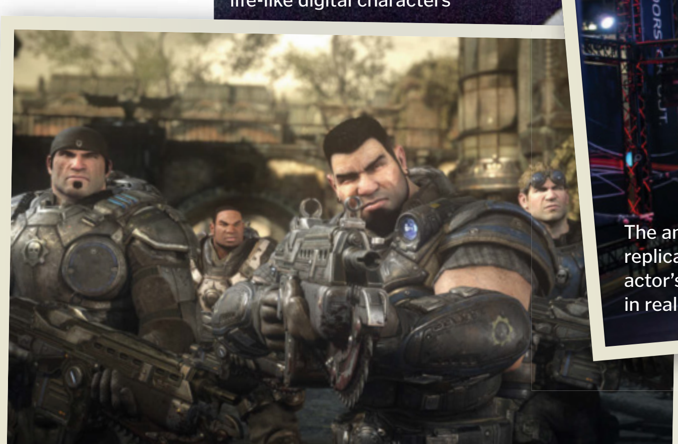
The most common method of motion capture is called 'optical-passive', and involves using reflective markers and infrared cameras. The cameras shine beams of infrared light at the actor, which are then reflected back when they hit the markers, allowing the camera's software to work out their exact position. Another method, known as 'optical-active', uses illuminated LED markers that flash with a certain frequency of light that can be picked up by the cameras.

Once the position of the markers has been mapped, their position and movements are used to create a digital skeleton, which forms the basis for the computer-generated character.

Motion capture suits feature a series of markers that are tracked by cameras

Full-body and facial motion capture can be used to create life-like digital characters

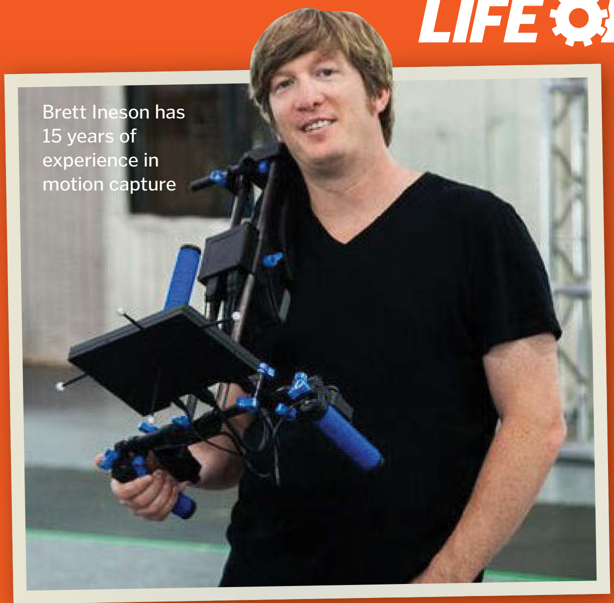
"The cameras shine beams of infrared light at the actor"



The animation can replicate the actor's movements in real-time

Making mo-cap magic

From wrestling suits off wolves to working with Hollywood stars, life in mo-cap is never dull


Brett Ineson has 15 years of experience in motion capture

With over a decade of experience in the visual effects industry, animator Brett Ineson decided to set up motion capture company Animatrik in Canada in 2004. He has since worked on films such as *District 9*, *Chappie* and *Warcraft*, and video games including *Gears of War* and *Just Cause 3*. We spoke to him to find out how the industry has changed and what it takes to make it in mo-cap.

What are the benefits of motion capture?
It's definitely about recreating the human performance. Animators are very talented at recreating many things in life, but a good actor is going to deliver a performance that is really going to sell the character to the audience. Motion capture is a very effective tool for making sure it stays true in the final product.

Does the motion capture process differ for games and movies?
They are largely the same process, but for video games we won't typically shoot on set with live action as well as digital characters. For that there is a whole slew of other technology that we use to be able to comp what you're seeing live with the digital characters at the same time.

How does that work?
It's called SimulCam and what we do is put markers on the film cameras to track where they move in 3D space. We then use that information to drive the computer-generated camera and merge the live action with the digital elements so that they appear in the same frame when viewed live on set.

When I first started out it was very difficult to see the work you were doing in real-time, so you would just have to capture, go away and then realise all the information you collected behind the scenes. Now, we're always seeing live characters when filming, which helps everybody answer a lot of questions about the performance we're getting.

What's it like to work with big-name directors and actors?
In the early days, directors didn't want to change the way they worked to accommodate all these new people and gear. But now, very early on in pre-production, motion capture is being chosen as the tool to use and might even be the driving force for the production. We're also finding that if actors haven't been in a motion capture suit, they're quite upset. They tend to really enjoy the process as they don't have to spend huge amounts of time in make-up, and everything they are doing is based on imagination. Everything relies on their performance.

What is the strangest subject you have motion captured?
Probably wolves. It's a big deal to get a motion capture suit on a wolf. The trainers worked with them for a couple of weeks to slowly get them used to the suit. The problem is that the wolves are very protective and territorial, so even though they reject the suit at first, once you get them used to it, it then becomes their suit and they don't want to give it back.

"It's a big deal to get a mo-cap suit on a wolf"

What qualifications and skills are required to work in the industry?
We expect all our candidates to have a degree in animation, since all the work we do is in 3D and can be quite technical. Also, in a typical animation role, animators tend to be hidden away in a back room, but in a motion capture studio we tend to have people moving around. They might need to be out on the stage interacting with producers and actors, so we need them to be quite social. We do that because we find that people who work in post-production do much better when they also understand the shooting side and vice versa, so we move staff back and forth through that process.


Brett's film credits include *Chappie*, as select scenes of the robot were animated using motion capture

Mo-cap in numbers

The stats behind this exciting industry

140 days
Longest time spent capturing for a single video game (*Heavy Rain*, 2010)

38-85
Number of markers on a typical mo-cap suit

$2.7 billion
Most lucrative movie ever made using motion capture technology (*Avatar*, 2009)

Longest continuous time spent capturing for a single live action movie (*Avatar*, 2009)
3 years

1.5 terabytes
Amount of motion capture data gathered per day for *Beowulf*, 2007

2000
First feature film created using 3D optical motion capture was released (*Sinbad: Beyond the Veil of Mists*)

Sensors on the mo-cap suit help relay the wearer's movements

Suits, cameras, action

How a digital masterpiece is created using motion capture

Filming a person prancing around in a skin-tight suit covered with ping-pong balls might seem strange, but it's all in a day's work for a motion capture animator. They can be tasked with animating characters for a wide range of different projects, from television commercials to entire video games and movies, and each one requires a great deal of creativity and skill. A project can take anything between a couple of days and a few years to complete and may involve shooting on location, directing action-packed stunts and even working with animals, not to mention collaborating with big-name directors and actors.

CALIBRATE THE CAMERAS
8:40am

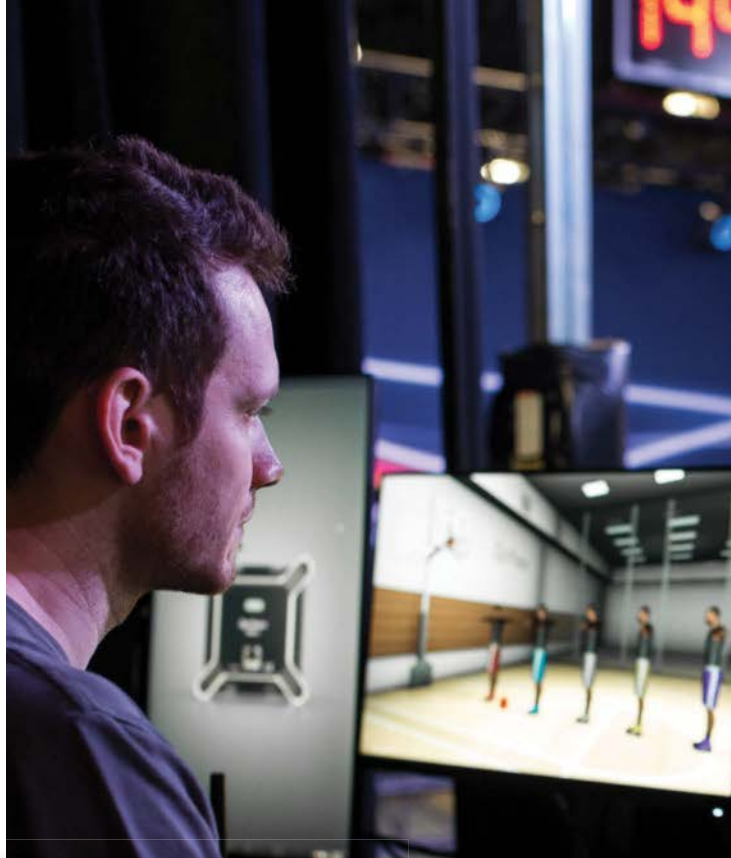
On a shoot day, some members of the team will arrive early to calibrate the system. To do this, they wave a calibration wand, essentially a stick featuring a series of markers, in front of the cameras so they can all 'see' it at the same time. This enables the software to work out the position of each camera in relation to the others for more accurate motion capture.

PREPARE THE LENSES
8:50am

As the camera lenses are curved, the software must also be calibrated to account for any distortion. This enables the 2D coordinates of the suit markers to be plotted accurately onto a 3D Cartesian grid, from which the 3D skeleton of the computer-generated character can be created. Without this step, the animated character would appear out of proportion.

MEET WITH THE CLIENT
9:00am

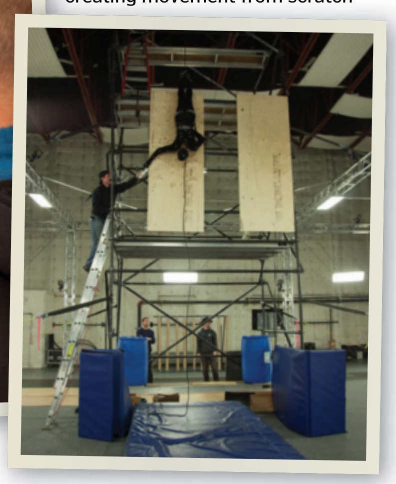
Over breakfast and coffee, the motion capture team meets with the director of the project to discuss the brief. If they



Mo-cap animators edit the digital footage to create the finished product

On a shoot, the digital characters mimic the actors' movements in real-time on a screen

With mo-cap data, animators avoid creating movement from scratch



are well practiced in motion capture, they will be able to help plan the shoot, but if they have not used the technology before then the animation team will organise the day and help guide them through it.

SUIT UP
10:00am

The actor or actors will get changed into motion capture suits, which are usually skin-tight so that the markers can be placed as close to their body as possible. Markers are positioned at key points all over the torso, and facial features if required, helping the mo-cap system to capture even their slightest movements.

PREPARE THE SET
10:00am

While the actor is suiting up, the team will prepare the set ready for the day's shoot. To ensure the movements they capture are as natural as possible, they will use real-life props for the actor to interact with, such as platforms they can jump off from, or fake weapons they can wield.

GET WARMED UP
10:30am

Once they arrive on set, the actor will start to move around in front of the cameras to give the software a chance to learn where the markers are on their suit. The data it captures can be used to create a 3D digital skeleton based on the actor's shape and size, which can then be animated based on their movements.

RECORD THE ACTION
11.00am

The mo-cap team and director are able to see the digital characters moving in real-time on a screen as they shoot, enabling them to give the actor direction and perform multiple takes until it looks just right. Throughout the shoot, the cameras are re-calibrated every couple of hours to ensure the data captured is accurate.

POST-PRODUCTION
4:00pm

When the mo-cap data has been captured, the animators will start editing out set pieces, props and crew members, and 'cleaning up' the computer-generated characters to deal with any calibration errors that have occurred. This can take anywhere from a couple of days to several months, depending on the nature of the project.

THE REAL JUNGLE BOOK EXPLAINED
JUNGLE BEASTS

The animals may not talk in this green tropical utopia, but their lives and habitat are every bit as dramatic as Disney's new blockbuster

Rudyard Kipling's literary masterpiece *The Jungle Book* was first published in 1894. Since then the story of the man-cub Mowgli, raised by wolves and on the run from the man-eating tiger Shere Khan, has become a classic tale, immortalised in animation by Walt Disney himself in 1967. Now the much-loved story has received a Hollywood revamp, with incredible CGI animals and a star-studded cast bringing characters such as Bagheera the black leopard and Baloo the sloth bear to life. But movie glamour aside, what is life really like in the jungle? How close are the similarities to the film and where do the real animals live?

Kipling based his iconic tale in the lush Indian jungle, thought to be around what is now the Madhya Pradesh region. Here, areas of protected land support vast tropical forests, bordered by open grasslands and swampy rivers and lakes. The monsoon rains and changing seasons make it a wild and unpredictable place, and the animals that live there are both rugged and beautiful. Bandhavgarh National Park in particular has the highest density of Bengal tigers known in all of India, as well as ruins of an ancient fort covered in thick moss and ferns. It's an environment where you can easily imagine King Louie swinging through the trees, or Kaa slithering out of the mist, through the vines that creep into every available space in the canopy.

The Bengal tiger

Shere Khan is a suave and ruthless man-eater, and although it is very rare for wild tigers to attack people, the predatory instinct remains

1 Camouflage
As patchy sunlight filters through the trees, the tiger's stripes break up its silhouette, allowing it to blend well with the background.

2 Keen eyes
Front-facing eyes and binocular vision give the tiger greater depth perception to aid hunting, and it can also see excellently in low light.

3 Rough tongue
A tiger's tongue is covered in tiny projections that give it a rough texture. This helps it rasp meat off a kill, and clean away the traces.

4 Muscular build
A strong, muscular body helps the beast leap, climb and swim. Loose skin on the belly protects against any kicking prey.

5 Sturdy paws
Giant paws act as paddles in the water and allow for quiet creeping on land. The tiger's huge claws can seize prey and provide grip for climbing.

SHERE KHAN
The fictional tiger Shere Khan is every bit as powerful as his real-life counterpart.

Solitary hunters

Prowling the jungle alone, a tiger will wait patiently for the perfect moment to pounce

1 Stealthy stalking
Tigers are cunning, silently tracking their prey until they're close enough to launch an attack. With excellent camouflage and large, padded paws, the big cat creeps slowly forward.

2 Surprise attack
When the prey is between six and nine metres away, the tiger will use its powerful back legs to lunge and pounce. It dispatches prey with a swift bite to the back of the neck.

3 Secretive eating
Tigers don't like to share their meals, so once the prey is secured, it will drag the kill to a safe, secluded place where it can eat. Some tigers will cover their leftovers to save for later.

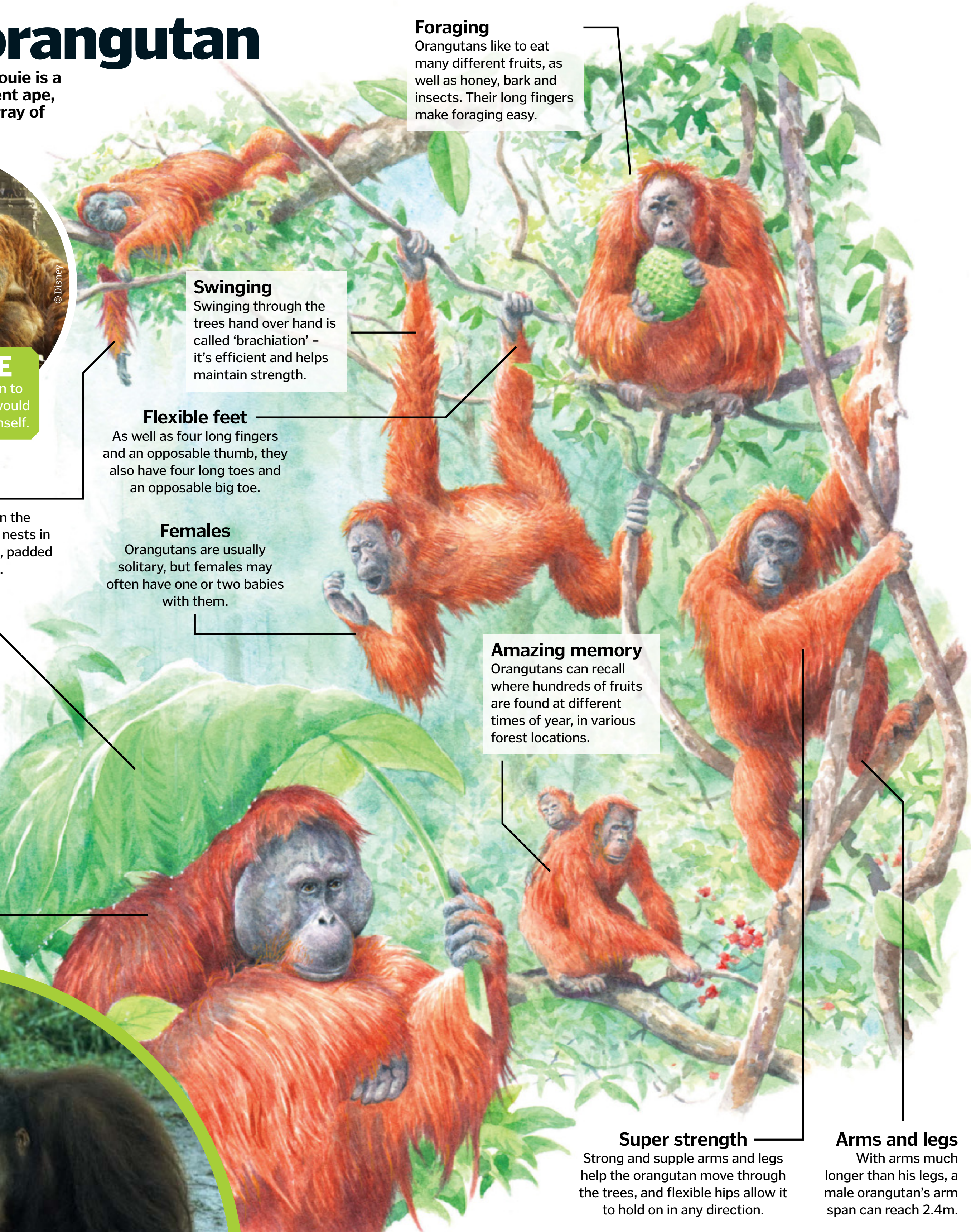
The orangutan

The real-life King Louie is a supremely intelligent ape, with an amazing array of skills for jungle life


© Disney

KING LOUIE

This fictional ape is keen to learn from Mowgli, but would have plenty of brains himself.



Foraging

Orangutans like to eat many different fruits, as well as honey, bark and insects. Their long fingers make foraging easy.

Swinging

Swinging through the trees hand over hand is called 'brachiation' – it's efficient and helps maintain strength.

Flexible feet

As well as four long fingers and an opposable thumb, they also have four long toes and an opposable big toe.

Nesting

Perfectly suited for life in the trees, orangutans make nests in the branches to sleep in, padded with leaves and grasses.

Females

Orangutans are usually solitary, but females may often have one or two babies with them.

Umbrellas

Some orangutans have been witnessed using large leaves to shelter themselves from the rain.

Amazing memory

Orangutans can recall where hundreds of fruits are found at different times of year, in various forest locations.

Males

Male orangutans are much larger and can grow hefty cheek pads and throat pouches.

Super strength

Strong and supple arms and legs help the orangutan move through the trees, and flexible hips allow it to hold on in any direction.

Arms and legs

With arms much longer than his legs, a male orangutan's arm span can reach 2.4m.


Orangutans are known to use tools to break open fruits with tough husks

Orangutans wanna be like you

Like humans, orangutans learn by observing those around them. They observe their parents using tools, and adopt these mechanisms for themselves. There are even incredible stories of orangutans watching humans fish, and then using a stick to remove a fish from a net.

Other ingenious orangutans have been witnessed using sticks to rake food, dip in honey, remove seeds from fruit with spines, spear fish in the water and test water depth. Some even use leaves as cups from which to drink water, or as instruments to amplify their vocal calls to warn off predators!

However, because Kipling never tied the story to a specific geographical location and used artistic license with the types of animals that lived there, the setting could be adopted by any one of the world's tropical forests. The terms rainforest and jungle are often used interchangeably, but they are actually two distinct ecological areas.

A tropical rainforest is a technical term for a biome characterised by a hot and humid climate and very tall trees, reaching up to 75 metres into the sky. Very little light reaches the ground, and the forest floor is often covered in decaying leaf matter dropped from above, which keeps the ground fertile. To walk through this type of rainforest is fairly straightforward, in contrast to walking though areas of jungle where you would have to cut a path through dense undergrowth. This is because 'jungle' describes an area with a lot of green, tangled vegetation. The plants grow thick and fast and the vines weave throughout, creating a dense and sometimes impenetrable web of sprawling greenery.

Patches of jungle appear in rainforests where sunlight can reach the ground. This often occurs in areas fringing the banks of rivers, where light from the open river course floods the forest and there is a ready supply of water, creating perfect growing conditions. Jungle can also appear in natural or man-made forest clearings, where the tall trees have been removed and light is let in to foster the flora below.

The plants that make up this dense tangle of undergrowth, as well as those that live in the rainforest environment are all perfectly suited to their hot and humid tropical home. The towering broad-leaved hardwood trees that form the backbone of the rainforest have huge buttress roots that anchor them into the thin but nutrient-rich soil, providing stability and strength. The leaves are waxy and tapered in shape, known as 'drip tips', which help to channel the rainfall off the leaves and onto the canopy below. This distributes the water throughout the layers of the trees. Shedding excess water also helps to prevent the growth of fungus and bacteria in the warm and humid conditions. Similarly, tree bark is thin and smooth to prevent any other plants taking hold and growing on its surface. These types of plants are called epiphytes, and include mosses, ferns and brightly coloured orchids that grow on other species of plants in order to gain height and get closer to the sunlight. Bromeliads are epiphytes that can bring miniature ecosystems to the forest canopy – attaching to tree branches, their large waxy leaves collect water and provide a home for aquatic critters. Frogs can hatch from tadpoles living 30 metres in the air.

Other masters of jungle life are the liana vines, woody climbing plants that use the tall trees as ladders to reach the sunlit forest canopy. Once the destination is reached, lianas then spread out up high, their roots in the ground supplying water and nutrients to the sprawling mass above.

Where sunlight is at such a premium, plants have adapted nifty strategies to maximise their chances of survival, such as having holes in their leaves and arranging fronds in specific ways so as to not throw shade on themselves. Leaves also tend to get larger the higher they get, making the most of the available light.

Tropical pitcher plants obtain their food from other sources. These strange jungle botanicals have a 'container', complete with lid, filled with an enticing liquid to attract insects. The aroma can be sweet or pungent, depending on the preference of the prey. When the unsuspecting creepy crawly falls into the pitcher, downward

The sloth bear

Looking like part anteater and part dog, this dishevelled bear is the inspiration behind Baloo

BALOO
Baloo's charming character is based upon the rugged and resilient sloth bear.

1 Shaggy fur
Thick fur protects the skin from insects, makes the bear appear larger to scare off predators, and also allows cubs to hold on tight.

2 Long claws
Elongated, curved claws are perfect for digging in loose soil, climbing trees, excavating ants and termites, and holding on to honeycomb.

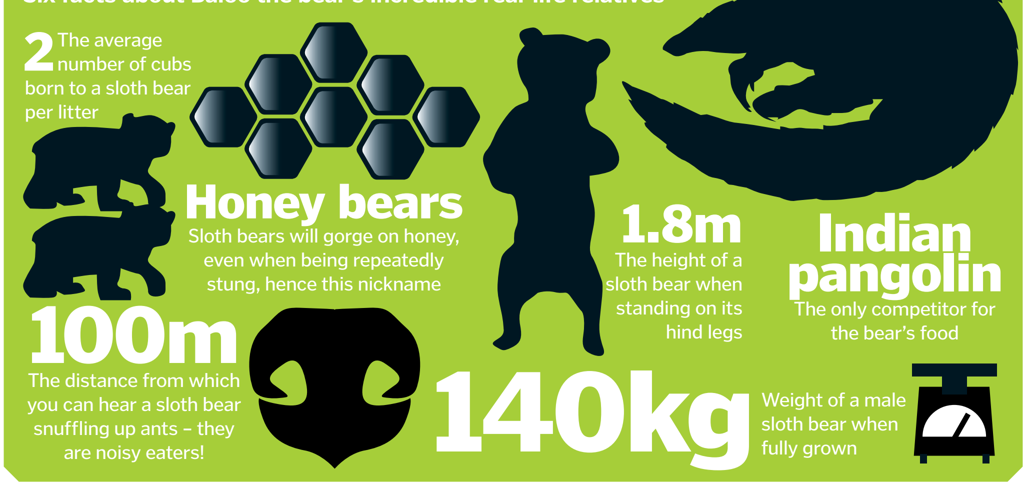
3 Flexible snout
The bear has a long tongue and flexible lips, allowing it to blow away dirt and obstacles, access termite holes and pick out tasty morsels.

4 Special teeth
A gap in the bear's sharp upper teeth allows it to suck up its favourite foods of termites, ants and honey with loud slurping noises.

5 Adapted nostrils
The sloth bear can open and close its nostrils at will, which allows it to keep dirt and insects out of its nose as it eats.

THE BEAR NECESSITIES

Six facts about Baloo the bear's incredible real-life relatives



The Indian black leopard

Meet the animal that Bagheera is based on, plus Kaa the cunning Indian rock python

BAGHEERA
Mowgli's friend Bagheera is a regular jungle inhabitant – the stealthy Indian black leopard.

KAA
Kaa is an Indian rock python, a large constrictor snake that cruises across the jungle floor.

"Indian black leopards are so at home in the trees that they will drag a kill into the branches to devour it"


The colossal buttress roots of some trees can extend 9m up before blending with the trunk

facing spines prevent its escape and the plant can start to digest its cleverly caught snack.

The amazing array of plants in the rainforest form the base of the food web, supporting every animal that lives within, from the birds and bats that nibble on the flowers, leaves, fruits and seeds, right the way through to the rulers of the realm, the elephants, big cats and primates. The plants also rely on the animals to eat and disperse their seeds and pollinate their flowers.

In an environment such as the Amazon rainforest, where there are thousands of species per square kilometre, all competing for space and food, the animals need savvy adaptations in order to survive. The entire web of plants, animals, birds and insects works in harmony, employing strategies such as camouflage, stealth and strength, as well as specific adaptations for snaring their favourite foods. For example, the Amazon rainforest's toucan has evolved its large bill as a feeding tool. It is lightweight and helps the bird to pluck fruit from branches that are too flimsy to support the bird's weight.

Kipling's charismatic animal characters are all perfectly adapted jungle dwellers. King Louie, the leader of the monkeys, is an impressive male orangutan. The Disney film portrays him as an all-singing, all-dancing great ape who is


An Asian elephant in the Bandhavgarh National Park – a real-life jungle that inspired Rudyard Kipling's story


Indian rock pythons are constrictors, choosing to squeeze their prey rather than poison it

desperate to advance into the realms of manhood, but in reality orangutans are incredibly intelligent but solitary animals. There are just two species, and they are found only in the rainforests of Sumatra and Borneo. Many of the rainforest primates share similar adaptations with the orangutan, such as long, strong limbs and flexible hands and feet for swinging through the trees. Many species also use a prehensile tail for balance, although orangutans don't have this.

The character of Baloo, the carefree bear who sings *that* catchy tune in Disney's animated version is based on a sloth bear, native to India and surrounding regions. While they're not known to sail down a river on their backs humming a famous ditty, they are indeed keen on eating ants and honey, so when Baloo sings "take a glance at the fancy ants, and maybe try a few," he's singing the truth. Sadly, due to habitat destruction and poaching it's thought that there are less than 10,000 sloth bears left in the wild.

Kipling borrowed the Hindi word for bear, 'bhalu', and the local name for tiger, 'sher' makes an appearance too. The Bengal tiger character Shere Khan is the undisputed king of the jungle. In real life Bengal tigers, although being incredible predators, aren't as bloodthirsty as Shere Khan, who wants to destroy the man-cub before he grows into a hunter. Blending in seamlessly to their surroundings with a striped coat, Bengal tigers also sport two dots on the backs of their ears – these can look like huge eyes, designed to fool any adversary into thinking that the tiger is even larger and fiercer than it is.

Mowgli's friend and mentor Bagheera is a similarly majestic big cat, and a jungle giant when it comes to the food chain. Indian black leopards are so at home in the trees that they have been known to drag a kill into the branches to devour it above the ground.

The largest animal to romp through the jungle is the majestic elephant. African forest elephants live in the fertile rainforest of the Congo Basin, and Indian elephants are known to roam forests and scrubland across Asia. They help to maintain the forest ecosystem by making clearings in the trees for jungle to grow, and also help to disperse the seeds of a huge number of plant species.

It's thought that Kipling was inspired by stories of children being raised by wolves when he was writing about Mowgli. There are certainly some tales of 'feral' children being found in the wild but whether these hold any truth is unclear. Wolves don't inhabit jungle, as the undergrowth is too dense for the pack to hunt. However, they do roam open grasslands in Madhya Pradesh, the region that provides the backdrop to the story.

The world's rainforests are home to over 30 million species of plants and animals. These huge areas of forest regulate our climate by cycling vast amounts of water and absorbing carbon dioxide from the atmosphere, replacing it with the oxygen we breathe. They're home to indigenous tribes, and contain incredible advances to science. Yet sadly, these complex ecosystems are disappearing at an alarming rate as land is cleared for logging, mining and agriculture.

Measures are being taken to protect many areas, as well as introduce more sustainable uses of the forest, in an attempt to preserve the ecosystem. However, most experts agree that we are still losing upwards of 300 square kilometres of tropical rainforest every day and destruction rates are 8.5 per cent higher now than in the 1990s. If their homes continue to be eradicated in this way, the real-life counterparts of Bagheera, Baloo and King Louie will only exist in works of fiction.

People of the forest

The Jungle Book tells of Mowgli the man-cub's journey to a nearby village. Although this community is a fictional place, in reality there are many villages throughout the world's rainforests where indigenous tribes live. The Amazon rainforest is the ancestral home of over one million Amazonian Indians, belonging to over 400 tribes.

Many villages are based around rivers, using everything the forest has to offer for survival. In these self-sufficient communities, spirituality and healing are intrinsically linked, and shamans use plants from the jungle surroundings for medicines and treatments.

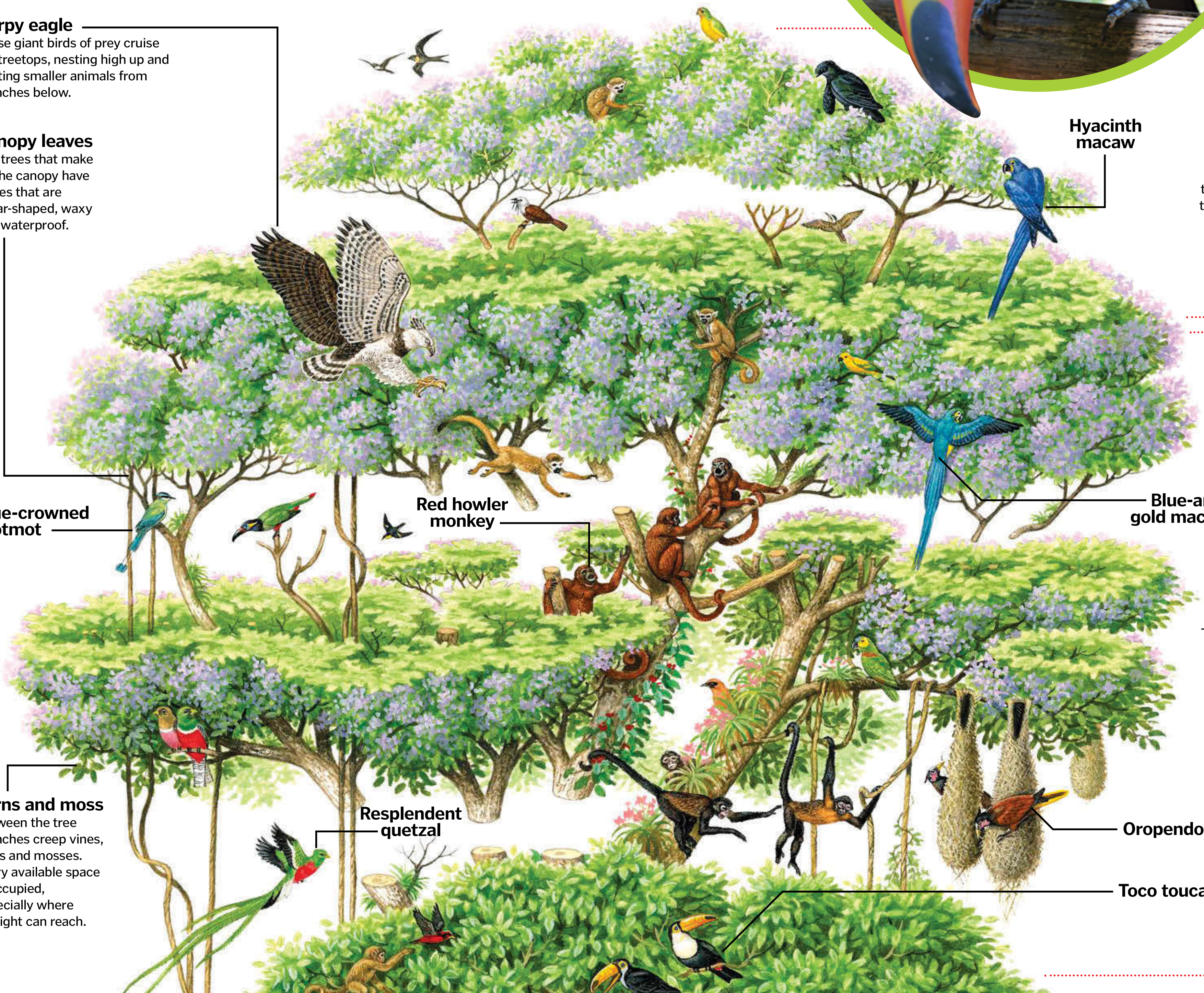
Timber from the forest is used to build homes, and some tribes still hunt for food using traditional methods such as bows and arrows, spears and poison-tipped darts and blowguns. They also cultivate and farm the land. However, dispute over land with other cultures and with developers and loggers is one of the greatest threats to rainforest communities.


Amazonian Huaorani Indians hunting with blowguns in the Yasuni National Park, Ecuador

Life in the trees

Many animals can be found weaving through the leaves at the rainforest's uppermost reaches

The bright colours of a toco toucan provide great camouflage in the rainforest canopy



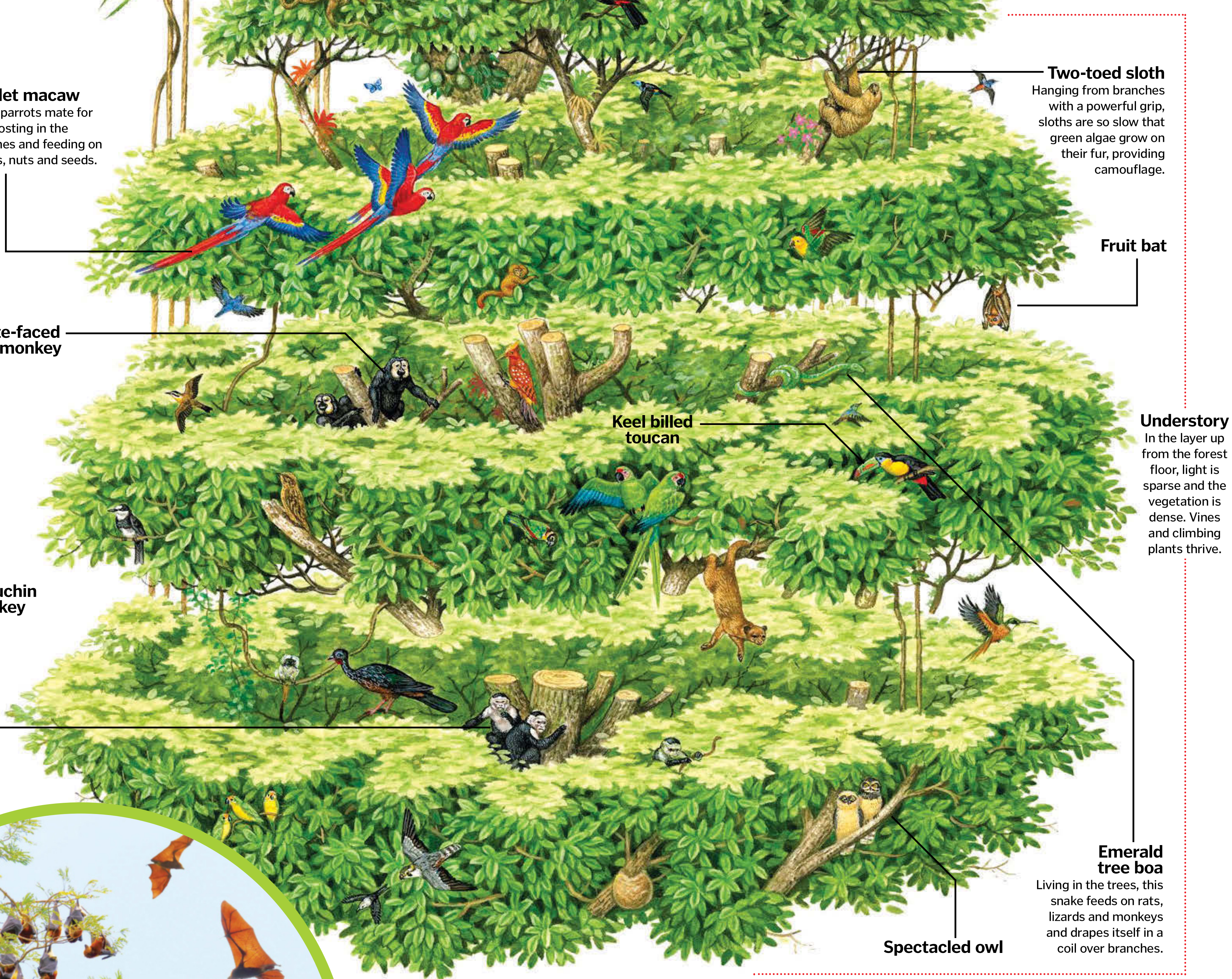
Harpy eagle
These giant birds of prey cruise the treetops, nesting high up and hunting smaller animals from branches below.

Canopy leaves
The trees that make up the canopy have leaves that are spear-shaped, waxy and waterproof.

Ferns and moss
Between the tree branches creep vines, ferns and mosses. Every available space is occupied, especially where sunlight can reach.

Emergent layer
At the top of the canopy, the tallest trees get all of the sunlight.

Canopy layer
The majority of trees are 20-40m tall, forming a 'ceiling' above the rest of the forest. Food is plentiful here.



"It's an environment where you can easily imagine King Louie swinging through the trees, or Kaa slithering out of the mist"

The fruit bat is said to have the best vision of all bat species

Predicting the weather

Discover the method that helps us prepare for the elements, come rain or shine

The weather affects us all, every day. From governing the difference between life and death, to providing a conversation topic to fill awkward silences at a party, it is an ever-present and ever-changing part of life. This means that predicting it accurately is a hugely important task.

In the UK, the Met Office is responsible for weather monitoring and prediction. Before a forecast can be put together, measurements from thousands of data recorders across the world are collected and analysed. Every day, around 500,000 observations are received, including atmospheric measurements from land and sea, satellites, weather balloons and aircraft. But, this is still not enough to represent the weather in every location.

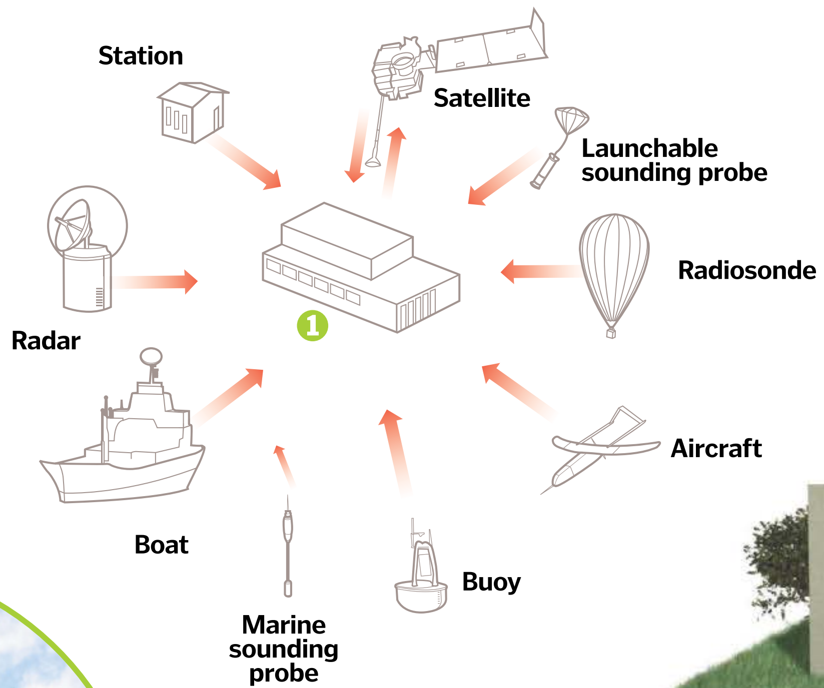
To fill in the gaps, the data is assimilated. This combines current data with what is expected, to provide the best estimate of the atmospheric conditions. To produce an accurate forecast, the data has to be fed into a supercomputer that creates a numerical model of the atmosphere. The process involves many complex equations, and the Met Office's IBM supercomputer can do more than 1,000 trillion calculations a second, running an atmospheric model with a million lines of code.

Forecasters can use this data and techniques such as nowcasting – using estimates of current weather speed and direction – to predict the weather in the hours ahead. For longer range forecasts, further computer models are relied upon.

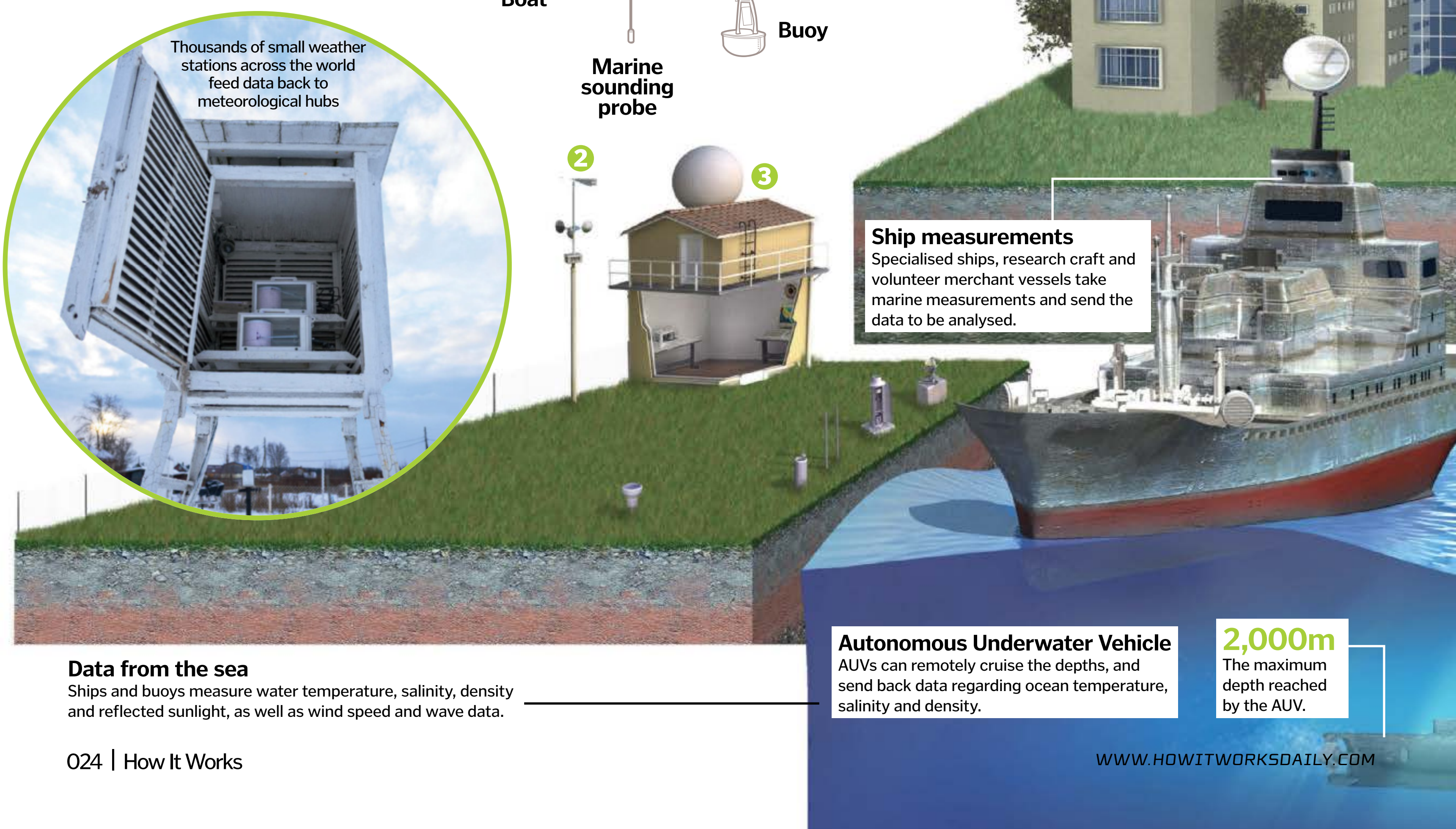
1 Data collection
Data from receivers all over the world is transmitted to a variety of hubs such as the World Meteorological Association in Switzerland.

2 Land-based data
Instruments on land measure temperature, atmospheric pressure, humidity, wind speed and direction, cloud cover, visibility and precipitation.

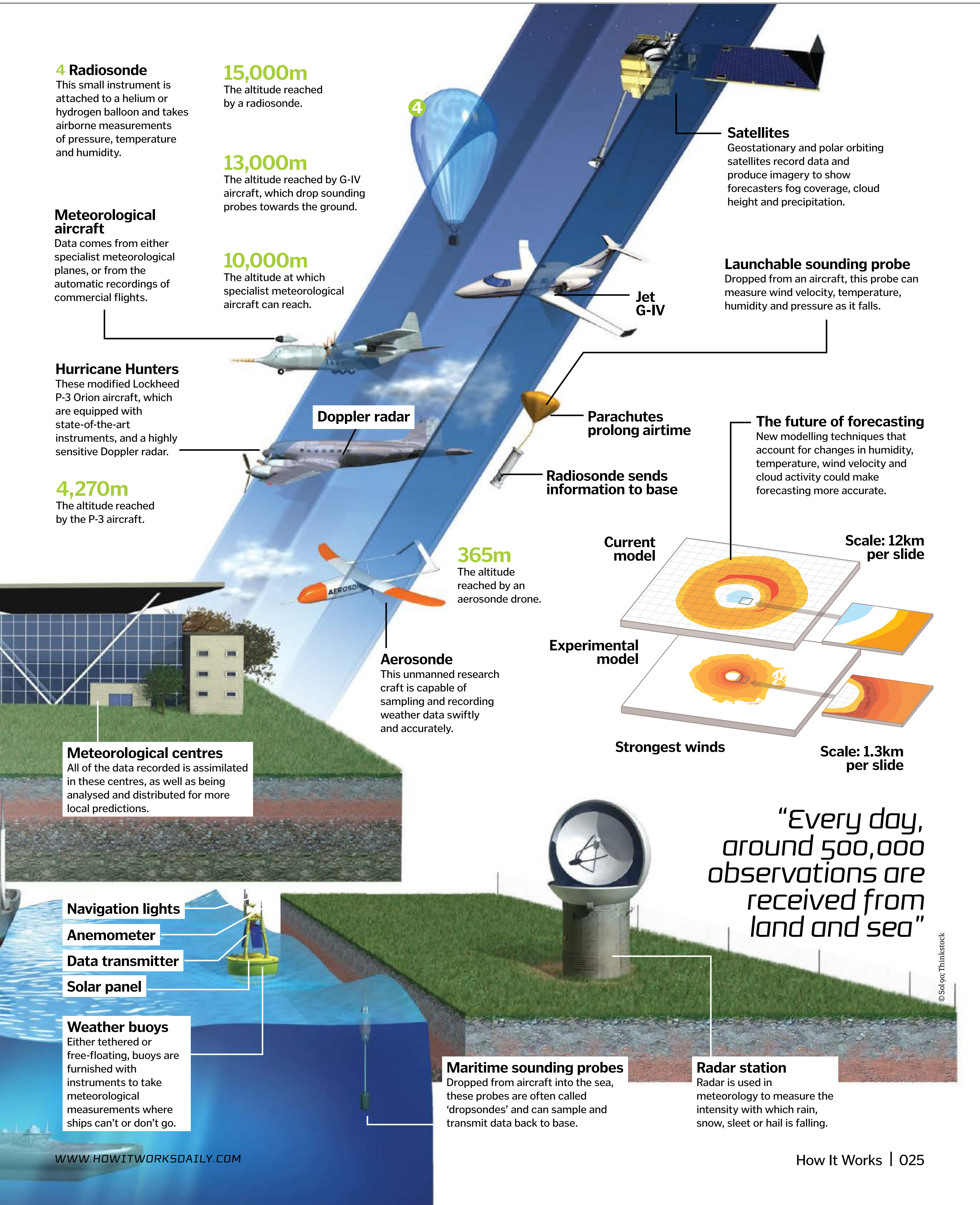
3 Meteorological station
Small weather stations take local readings, with thermometers for temperature, hygrometers for humidity and barometers to measure atmospheric pressure.



Data from the air
Satellites, weather balloons (carrying radiosondes) and aircraft all measure various parameters like temperature and composition of the atmosphere.



Data from the sea
Ships and buoys measure water temperature, salinity, density and reflected sunlight, as well as wind speed and wave data.



4 Radiosonde
This small instrument is attached to a helium or hydrogen balloon and takes airborne measurements of pressure, temperature and humidity.

15,000m
The altitude reached by a radiosonde.

13,000m
The altitude reached by G-IV aircraft, which drop sounding probes towards the ground.

10,000m
The altitude at which specialist meteorological aircraft can reach.

Meteorological aircraft
Data comes from either specialist meteorological planes, or from the automatic recordings of commercial flights.

Hurricane Hunters
These modified Lockheed P-3 Orion aircraft, which are equipped with state-of-the-art instruments, and a highly sensitive Doppler radar.

4,270m
The altitude reached by the P-3 aircraft.

Satellites
Geostationary and polar orbiting satellites record data and produce imagery to show forecasters fog coverage, cloud height and precipitation.

Launchable sounding probe
Dropped from an aircraft, this probe can measure wind velocity, temperature, humidity and pressure as it falls.

The future of forecasting
New modelling techniques that account for changes in humidity, temperature, wind velocity and cloud activity could make forecasting more accurate.

365m
The altitude reached by an aerosonde drone.

Aerosonde
This unmanned research craft is capable of sampling and recording weather data swiftly and accurately.

Meteorological centres
All of the data recorded is assimilated in these centres, as well as being analysed and distributed for more local predictions.

"Every day, around 500,000 observations are received from land and sea"

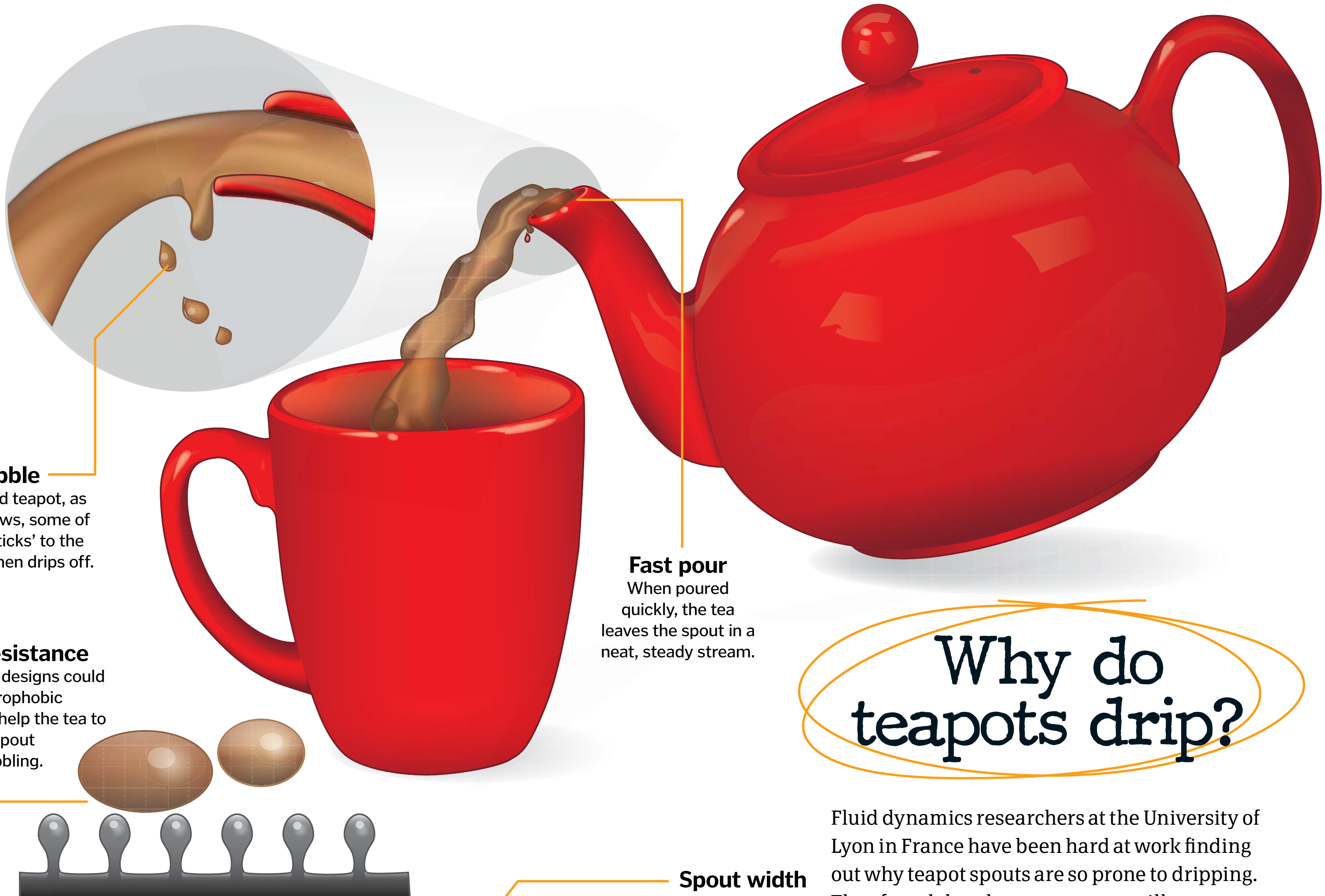
Weather buoys
Either tethered or free-floating, buoys are furnished with instruments to take meteorological measurements where ships can't or don't go.

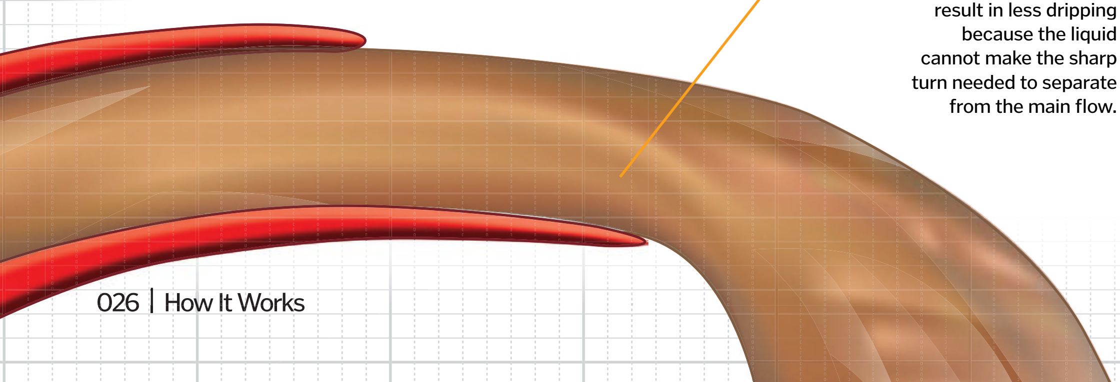
Maritime sounding probes
Dropped from aircraft into the sea, these probes are often called 'dropsondes' and can sample and transmit data back to base.

Radar station
Radar is used in meteorology to measure the intensity with which rain, snow, sleet or hail is falling.

EVERYDAY SCIENCE

FROM THE MIND-BLOWING TO THE MUNDANE, WE REVEAL THE SCIENCE BEHIND LIFE'S LITTLE MYSTERIES





Why do teapots drip?

Fluid dynamics researchers at the University of Lyon in France have been hard at work finding out why teapot spouts are so prone to dripping. They found that these post-pour spillages are down to the 'hydro-capillary' effect; as you pour the tea, some of the liquid tracks down the outside of the spout. This is influenced by the shape of the spout, how fast the tea is poured, and how water-repellent the teapot is. Metal teapots with straight-edged spouts are much less prone to dripping than their curvy porcelain counterparts.

Why does coffee spill?

Researchers at the University of California, Santa Barbara, recorded volunteers as they carried coffee cups to expose the secret behind the spill. What they found was that it's all down to a combination of cup size, coffee fluid dynamics, and the way we walk.

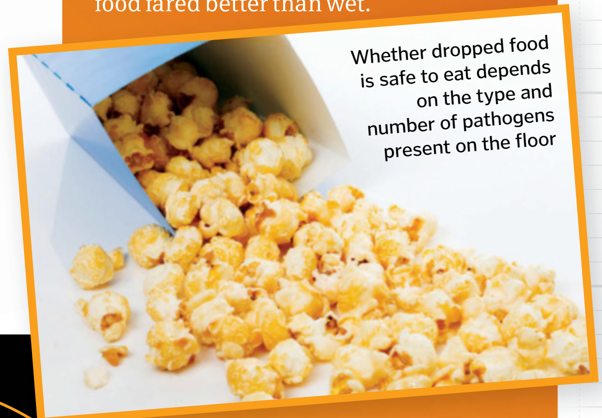
Fluid sloshing inside a container tends towards a natural frequency, a bit like a liquid pendulum. This varies with the size of the cup and the properties of the liquid, but for coffee in a regular mug, the natural frequency is close to walking rhythm. As you walk along, the liquid starts to sway and little irregularities in your step amplify the effect. The faster you accelerate, the more likely you are to spill.

Putting a lid on your cup can actually make things worse. As the coffee sloshes, some creeps along the underside of the lid, and climbs up the side of the cup. When these two streams collide, they shoot out of the drinking hole, creating a coffee volcano.

Researchers advise walking slowly and not filling the cup to the top

Is the five-second rule real?

Every schoolchild has heard that if you pick food up within five seconds of dropping it, it's safe to eat, but is this an urban myth? To test the idea, researchers at the Aston University in the UK dropped toast, pasta, biscuits and sweets onto a variety of different floor surfaces, and tested them for the presence of common bacteria at time points between three and 30 seconds. Bacteria do transfer before the magic five seconds is up, but generally the food is still edible. Dropping food onto carpet was better than flinging it at a hard, flat surface like laminate, and dry food fared better than wet.



Whether dropped food is safe to eat depends on the type and number of pathogens present on the floor

Why does the mind wander?

The 'default mode' for the brain tends towards introspection and daydreaming, but with a bit of effort we can switch to 'focus mode' and perform complex tasks. However, if these tasks are repetitive, the mind can start to wander and we can make mistakes. The technical term for these momentary lapses is 'maladaptive brain activity changes', but colloquially, they are known as 'brain farts'.

Researchers at the University of New Mexico discovered that you can spot these 'brain farts' coming a good 30 seconds before people make an error by using functional magnetic resonance imaging (fMRI), which monitors the blood flow to different parts of the brain.

Magnetic resonance imaging can be used to light up the active parts of the brain

Rewarding improbable research

You might wonder why scientists are spending their time researching spilled coffee, drippy teapots and the five second rule, but these strange research projects spark people's interest in science and should be celebrated. Each year in September, ten Ig Nobel Prizes are awarded for research that makes people "laugh, then think". Past winners have shown how to unboil an egg, measured the friction of a banana skin, and even demonstrated that asthma symptoms can be treated with rollercoaster rides.

In 2000, the Ig Nobel Prize for physics was awarded for levitating a frog in a magnetic field

Why does toast burn?

Toast can go from pasty white to charred and black in just a few seconds, but what is it about bread that makes it so prone to burning? The answer can be found in its chemistry.

Bread in its simplest form is made from wheat flour, yeast and water. The flour contains carbohydrates (long chains of sugars) and proteins (long chains of amino acids), and these are the key ingredients of a chemical reaction known as the Maillard reaction.

The sugars in bread (which include glucose, fructose, maltose and lactose) contain chemical groups called aldehydes (which have the formula -CHO). At temperatures above around 140 degrees Celsius, these groups start to react with the amino groups (-NH2) found on amino acids in the wheat proteins. This is the first step in the process of turning bread into toast.

The products of these reactions are unstable and quickly rearrange into chemicals called Amadori compounds. These then go on to react even further, making a variety of colourful compounds with distinctive smells and tastes.

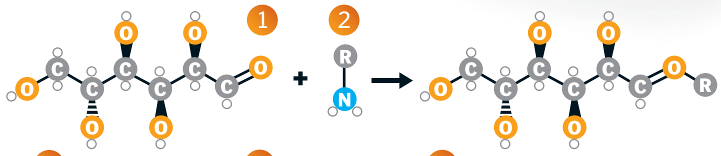
The rate at which your bread turns to toast, and then to charcoal, depends on its composition, and various sugars and amino acids produce different flavour and odour molecules when they undergo the Maillard reaction. In general, the drier the slice, the faster these reactions occur, and the quicker the toast will brown and then burn.

Alkaline breads (like those made with baking soda) should brown faster than acidic ones, and breads and buns glazed with milk or egg will colour more quickly thanks to the extra protein content on the surface.

Be extra careful when making fruit toast; the sugars will start to caramelise and will turn to crunchy carbon if left in the toaster too long.

Step 1

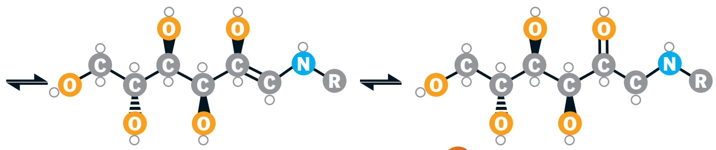
During the first stage of the Maillard reaction, a sugar and an amino acid combine.



3 Sugar (glucose) 4 Amino group 5 Glycosylamine (+ water)

Step 2

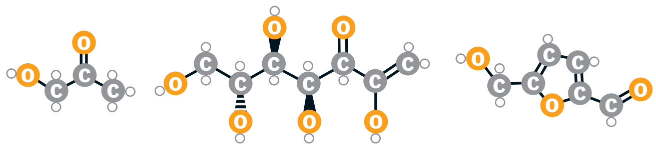
The structure made in step one undergoes rearrangement, forming an Amadori compound.



1, 2-Enaminol 6 Amadori compound

Step 3 7

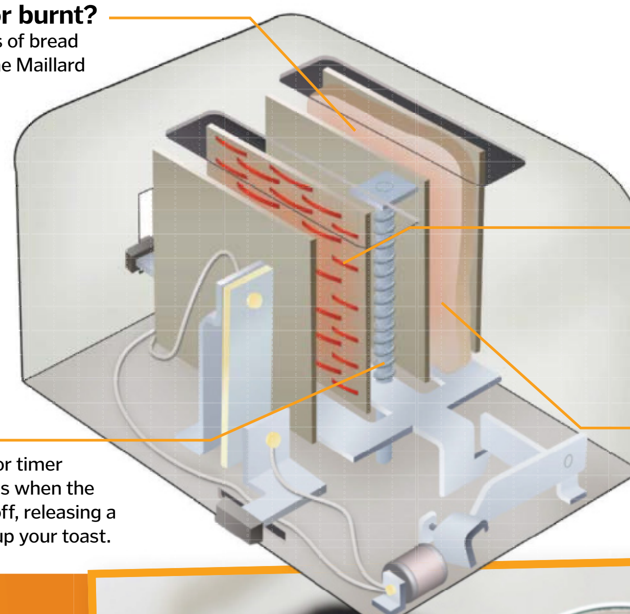
The compound made in step two can undergo further reactions, producing a range of different molecules.



Fission products Reductions Hydroroxymethylfurfural

Browned or burnt?

Different types of bread will undergo the Maillard reaction at different rates.



Filaments

When an electric current flows through these thin wires, they heat up and glow red hot.

Radiation

The filaments are spaced apart and radiate heat from both sides, cooking the bread quickly and evenly.

Pop-up

A thermostat or timer usually controls when the toaster turns off, releasing a spring to pop up your toast.

The taste of toast

Complex chemicals are responsible for the distinctive smell and taste of toast

1 Bread
Bread contains proteins (made of amino acids) and carbohydrates (sugars).

2 Heat
At temperatures above 140°C, amino acids and sugars start to combine.

3 Sugar
The sugars found in bread include glucose, fructose, maltose and lactose.

4 Amino acids
There are 20 amino acids, each with a slightly different structure.

5 Glycosylamine
Sugars and amino acids combine to form unstable compounds called glycosylamines.

6 Ketosamine
Glycosylamines are rearranged to form ketosamines, also known as Amadori compounds.

7 Products
Various chemicals can be formed as the ketosamines continue to react.

Is it worth hitting the snooze button?

The snooze button can feel like a welcome relief, but it might be better to set your alarm later and get up right away. Your sleep goes in cycles, beginning with a couple of minutes of dozing, followed by 10 to 20 minutes of light sleep, and then slipping into a longer period of deeper sleep. You cycle through around every 90 minutes, and as the night goes on, light sleep gives way to dreaming. It might feel good to put the alarm on snooze in the morning, but you'll already have broken the cycle, and the little bursts of light sleep won't make you feel any better when you finally kick back the duvet.

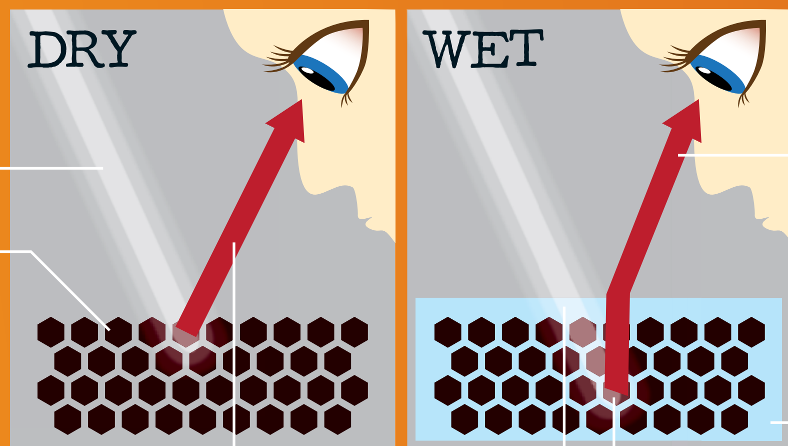
Forget the snooze button and enjoy your sleep uninterrupted

Why does wet fabric look darker?

It is easy to take this for granted, but the distinctive colour change of wet fabric is actually down to some interesting science. The amount of light reflected by a material depends on a property called the 'index of refraction', which determines how light moves through a material. When fabric gets wet, the light hitting the material has to travel through water instead of air, and this alters its path. Light moves much more slowly through water and, when it hits damp fabric, it bends. Rather than reflecting back out towards the eye, more light gets scattered within the fabric, making the colour appear darker.

Wet versus dry

Find out how waterlogged fabric changes the path of incoming light



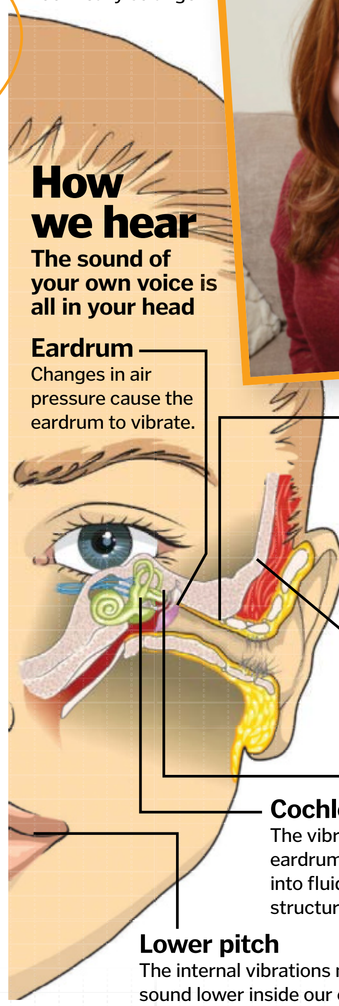
Do I really look and sound like that?

When you look in a mirror, the reflected image of yourself is a mirror image; you see yourself every single day back to front. If your face were symmetrical this would not matter, but because there are little asymmetries, it means that you mentally store a backwards picture of what you look like, and when you see your image the right way round, it can look strange.

The sound of your own voice can be even stranger. When you hear someone else speaking, the sounds travel through the air as vibrations, hitting your eardrum and causing it to vibrate. This moves fluid in the inner ear, which pushes against hairs and sends signals to the brain.

When you speak, the sound reaches your ear in a different way. Not only are you picking up the vibrations in the air, you are also detecting vibrations inside your own head. As you make the sounds with your vocal cords and tongue, the soft tissues in your head and neck vibrate, and so too do the bones in your face. These additional vibrations make your voice sound lower. When you hear your recorded voice, you don't get these undertones, and the higher-pitched version of you can seem very odd indeed.

We are so used to seeing our mirror image that a photograph can look really strange



Why do we see faces everywhere?

From religious figures on slices of toast to aliens on Mars, faces pop up in the strangest of places. The phenomenon is known as pareidolia, and happens thanks to a part of the brain called the fusiform face area, which is specially adapted to detect faces. If we see something that even vaguely resembles a human visage, it lights up. Researchers at the University of Toronto found that this rapid processing occurs in the prefrontal cortex (which handles what we expect to see) and the posterior visual cortex (which processes what we actually see). When people believe that they should see a face, their brain will do the rest.

Seeing faces
Your brain should automatically spot the faces in these pictures

How does staring at a screen strain your eyes?

The more we rely on electronic equipment for work, study and recreation, the more impact it is having on our vision. Similar to how repetitive motions can cause damage to the wrists, long periods looking at screens can temporarily strain the muscles of the eye. The lens is constantly making minute adjustments as it focuses on the screen, and glare, flicker, colour and brightness add extra layers of complexity, forcing the eye muscles to strain to keep everything looking sharp. The viewing distance and angle is often unnatural too, which can mean the eyes have to work even harder to maintain focus.

Screen glare
An anti-glare filter on your monitor can reduce the strain on your eyes.

Blink rate
You are likely to blink less often when using digital screens, so your eyes can get dry and tired.

Eye breaks
Focusing on a near object for long periods tires out your eye muscles, so give them regular breaks by looking at distant objects.

Repetitive motion can strain the muscles in and around your eyes

Why do songs get stuck in our heads?

This irritating phenomenon has many names in the scientific literature: imagined music, involuntary musical imagery, involuntary semantic memories, intrusive songs, or slightly disconcertingly, 'earworms'.

Hearing a song played on a loop inside your own brain is very common; the majority of people have experienced it, and for many it is at least a weekly occurrence. Playing music, listening to songs and singing can make it happen more often, and although people most often mention it when it becomes an irritation, it is not always unpleasant.

Earworms fall into the same category as spontaneous recollections of memories and mind wandering, and seem to be intrusive thoughts that are beyond our conscious control. Trying to get to the bottom of the science behind them is challenging, because researchers have to rely on the subjective reports of study participants, often through diaries and surveys that track the occurrence of earworms, and the effectiveness of different strategies to try and make them go away.

> *"Hearing a song played on a loop inside your own brain is common"*

One of the most popular ways to deal with an earworm seems to be just to leave it alone; enjoy the song, if you can, and allow the thought to pass. If that fails, distraction is another popular coping strategy, or some people even resort to engaging with the tune, listening to it in real life to get out of the loop inside their head.

However, there is a major problem to be overcome; the more you focus on whether your attempts to get rid of the song have been successful, the more your brain is likely to go back to looping the song again. This is an idea famously explored by psychologist Daniel Wegner in his paper, *Ironic Processes of Mental Control*. He points out that by monitoring whether or not you have managed to successfully get rid of a thought, you might just trigger it to start up again.

Getting rid of earworms

These popular strategies might help your brain to forget that annoying song

1 Doing an anagram

Studies performed at Western Washington University showed that anagrams could provide some relief from earworms. Puzzles that aren't too challenging proved more successful than trying very complicated tasks.

2 Chewing some gum

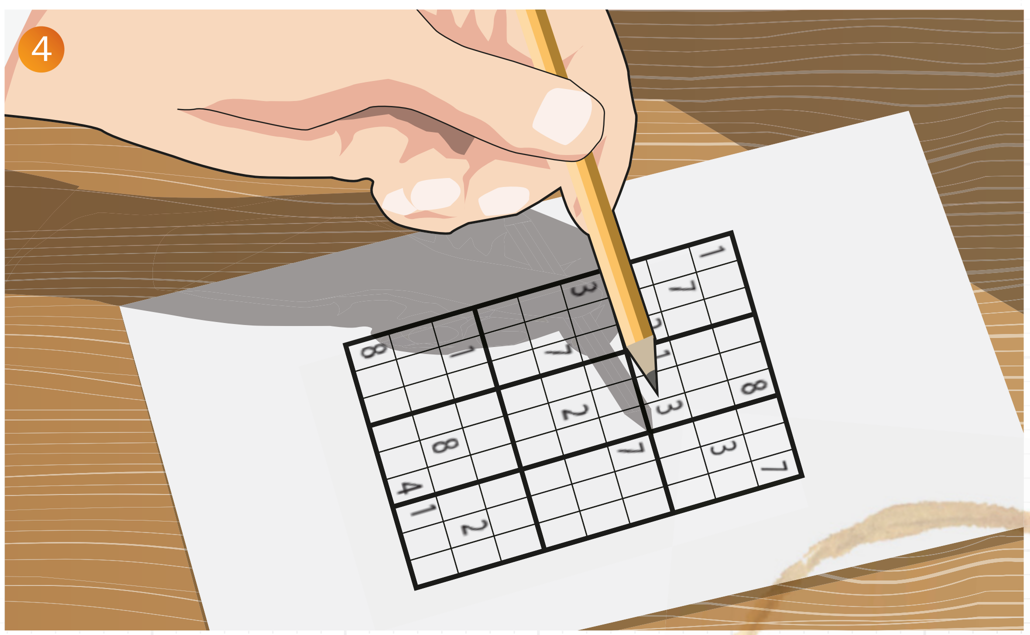
Researchers at the University of Reading tried giving chewing gum to volunteers after they had listened to catchy songs. Movement of the jaw is thought to interfere with short-term memory and the ability to imagine sounds in your head.

3 Replacing the song

In studies performed in Finland and England, a small percentage of participants reported using 'cure' songs to relieve the frustration of an earworm; by listening to well-liked classics, they distracted themselves from the unwanted song in their head.

4 Solving a sudoku

Western Washington University researchers reasoned that performing complex non-verbal tasks could also help to keep earworms away. Easy sudokus were most effective, while challenging puzzles prompted the mind to wander.



The pH scale

What do the terms acidic, neutral and alkaline really mean?

Indicator strips change colour depending on the pH of a solution

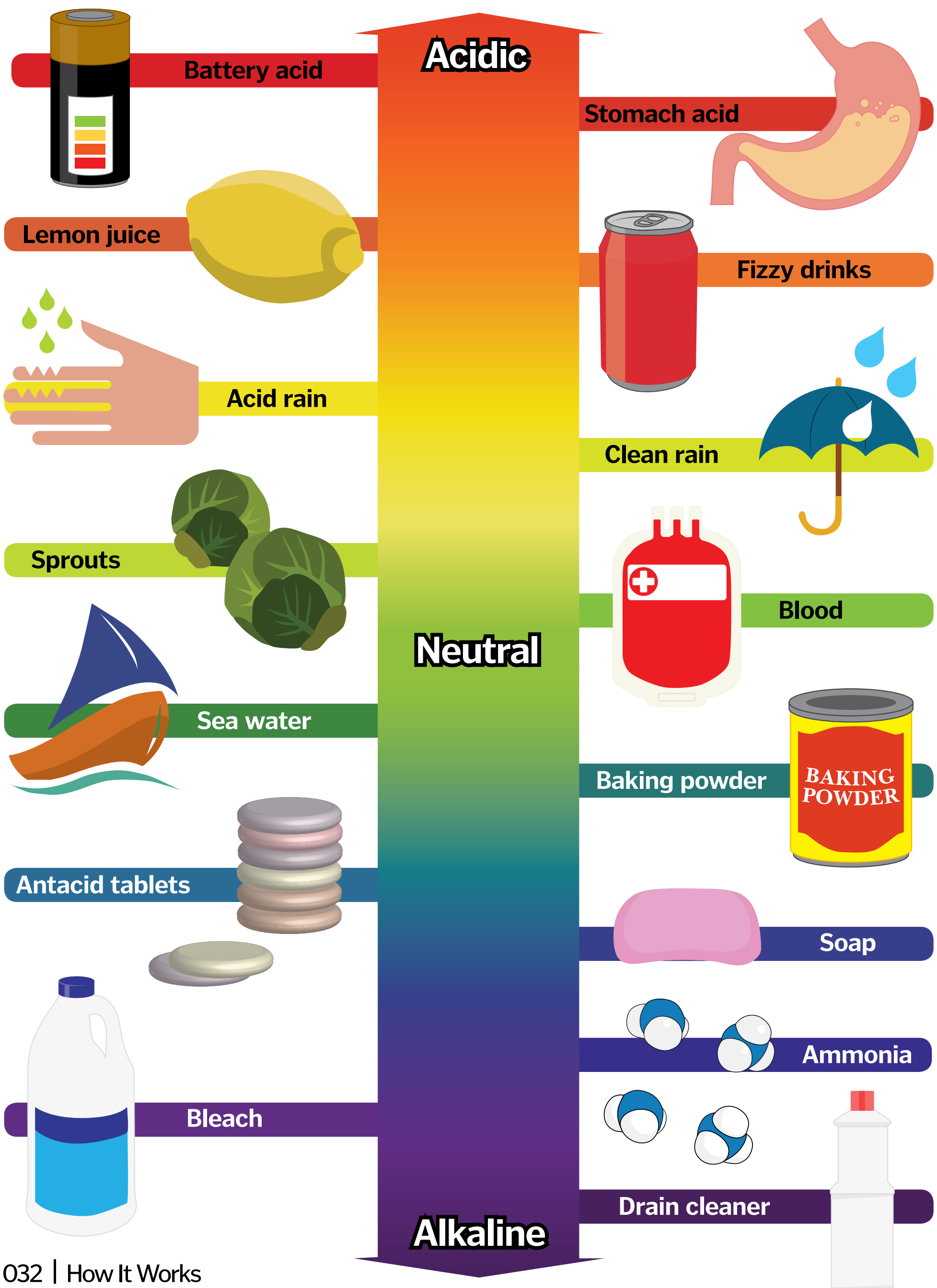
The pH of a solution is a measure of how acidic or alkaline it is on a scale in which 0 is the most acidic, 7 is neutral, and 14 is the most alkaline, but what are we measuring? Let's start in the middle. Pure water has the chemical formula H_2O, and is essentially made from two bonded ions: hydrogen and hydroxide . All of the ions are in pairs, one hydrogen bonded to one hydroxide, and the pH is neutral.

Acids have extra hydrogen ions that do not have hydroxide ions to pair up with, and for every step down in the pH scale, the concentration of these extra ions increases. Solutions of pH 6 have ten times the concentration of hydrogen ions as solutions of pH 7. Solutions of pH 5 have ten times as many again, and so on.

Alkaline solutions have extra hydroxide ions. The concentration increases tenfold with every step up on the pH scale. If you add an acid to an alkali, the extra ions can come together to form water, bringing the pH back towards neutral.

Everyday pH

Find out where everyday substances sit on the pH scale



Lightning rockets

We find out how scientists make lightning bolts by firing rockets into clouds

Lightning happens when water droplets and ice particles rub past each other in the clouds. Electrons are stripped away, and the bottom of the cloud becomes negatively charged. This charge gradually builds up until it is released, meeting with positively charged particles from the ground in a bolt of lightning.

It might be one of nature's greatest shows of strength, but by using a stretch of copper wire attached to a rocket, scientists can trigger lightning of their own. Kevlar-coated wire is attached to a rocket at one end, and to the ground at the other. The rocket is then shot into stormy clouds. As it flies upwards, the wire uncoils, forming a conductive path to the ground.

As the rocket heads towards the clouds, positive charges climb up the wire from the ground, and negative charges from the clouds start to reach down. The wire glows as it conducts electricity, and soon the heat generated becomes so great that it explodes. After the first flash, there is a delay, and then lightning, which travels through the path left by the vaporised wire.

This lightning strike was triggered by scientists at the University of Florida

10 superfood myths busted

The truth behind the headlines

Green tea prevents cancer

This commonly consumed beverage is well known for its potential anti-cancer properties, but the evidence is conflicting and far from confirmed. The chemicals thought to be responsible are called catechins, which are a type of compound known as polyphenols. These are also found in cocoa, prunes, vinegar and barley, among other foods. In 2009, the Cochrane Group gathered together 51 studies that have attempted to relate green tea to cancer prevention, including results from more than 1.6 million people, but they could not prove the link.

Eating celery results in negative calories

Celery is a popular diet food because of its low calorie content, but the idea that it takes more energy to digest than it provides to your body is a myth. Celery is tough, watery and full of fibres, and in a whole stick there are only around 10 kilocalories, but according to nutritionists, the energy you burn chewing, digesting and extracting this measly morsel is around five times less than that. In fact, according to a study of energy expenditure while chewing gum, it would take around an hour of chewing to burn the calories found in a stick of celery.

Broccoli reverses diabetes damage

Cruciferous vegetables (like broccoli, cabbage, kale and sprouts) are packed with fibre, vitamins and other nutrients, but the health claims about phytochemicals with miraculous abilities to fight cancer, diabetes and other health conditions are overblown. 'Phytochemical' just means 'plant chemical', and the one that people are particularly interested in here is called sulforaphane. In the lab, it seems to reduce free radicals made by damaged blood vessels, but this doesn't say all that much about the real-life effects of eating broccoli. The human body is much more complex than a test tube, and eating whole foods is very different to consuming purified chemical extracts.

Spinach is packed with iron

The commonly held idea that spinach is a good source of iron is attributed to the fictional character Popeye, but he actually preferred the leaves for their vitamin A. It is also often said that the amount of iron in spinach was miscalculated by a nutritionist, who put the decimal point in the wrong place and multiplied the value by ten, but this too seems to be an urban legend. The great strengths of spinach are its vitamins K, A and C. Gram for gram, it contains the same amount of iron as red meat, but it is in a form that is trickier for the body to absorb.

DID YOU KNOW? *Scientifically, there is no such thing as a 'superfood' – it is just a word used in marketing and the media*

A wheatgrass shot has more nutrients than 1kg of veg

Wheatgrass is supposed to pack a huge nutritional punch, and the standard 30-millilitre shot of juice comes with several health claims. The fresh shoots do contain vitamins and minerals, including zinc, iron and vitamins A, C and E, but the idea that these little green leaves squeeze in more nutrients than any other vegetable is untrue. Wheatgrass is about as nutritious as other green veggies, like broccoli, but in juiced, shot form, it doesn't even count as one of your five a day.

Red wine is good for your heart

Red wine contains a chemical called resveratrol, which has been found to have some beneficial effects on blood vessels and circulation in test tubes and in laboratory animals. However, whether drinking wine itself would protect humans is not known. In several studies, the amount of resveratrol used would be the equivalent of drinking several bottles of red wine a day, and the alcohol content of the drink, although possibly heart-protective at low levels, can raise blood pressure if consumed to excess. Many foods and drinks contain beneficial chemicals, but when taken as a whole package, the effects are much more complicated.

Gluten free foods are a healthier option

Rice, potatoes, tapioca, buckwheat, and other gluten-free grains are increasingly finding their way into products on our supermarket shelves, but are they really healthier than standard breads, biscuits and cakes? These products provide a safe alternative for the small percentage of the population who experience a damaging immune response when they eat wheat. However, if you do not have coeliac disease or a gluten allergy, avoiding wheat is unnecessary and potentially unhealthy. Whole-wheat products are rich in B vitamins and fibre, while gluten-free alternatives are often higher in fat and sugar to make up for their unusual taste and texture.

Beetroot is the elixir of life

In 2010, a study investigating the effects of beetroot juice on exercise performance in nine young, healthy men suggested some benefit in delaying exhaustion. This was an interesting observation, but a headline that it inspired was blown out of proportion; a national newspaper reported that beetroot juice might be the "elixir of youth", potentially helping the elderly to become more active. The study had not tested the juice on older people, and the sample size was much too small to be sure that the findings would apply to the general population. Catchy headlines can often misrepresent the underlying science.

Oily fish boosts brainpower

Eating the omega-3 and omega-6 fatty acids that are found in oily fish is good for us, but the claims that they boost brainpower are not backed up by scientific evidence. A two-year study of fish oil supplements in older adults found no difference in cognitive function, and a review of the evidence performed in 2006 found no reason to believe that omega-3 could help with dementia. One of the studies used to claim that omega-3 improved memory actually looked at whether it protected against oxygen starvation in the brain, and did not test memory at all.

Spicy food makes you live longer

In 2015, researchers from China published a study of over half a million people, showing that those who ate spicy food several times a week were less likely to die than those who did not. However, before you stock up on chillies, remember that correlation does not equal causation; just because two things share a pattern, they may not be directly linked. As the study authors explain, many other factors could be influencing the results, such as the speed of eating, the amount of rice eaten to calm the chilli burn, or something else entirely. More research is required to untangle these complexities.

The chemistry of matches

The secret of fire comes down to one key chemical element: phosphorus

The head of a safety match is all about fuel; the spark comes from the matchbox

The head of a safety match is coated in a cocktail of chemicals selected to produce an instant flame, but the secret to the perfect strike is in the matchbox itself.

The strip along the side of the box is made from a combination of ground glass and red phosphorus. As the match rubs against this rough surface, the friction heats the phosphorus, which transforms into white phosphorus in the air. White phosphorus spontaneously combusts, creating the spark to start the fire.

This is where the match head comes in. The end of the matchstick is coated with a combination of glue, ground glass, sulphur and a compound called potassium chlorate. As the spark hits, the potassium chlorate starts to break down, releasing oxygen and fuelling the fire. This enables the sulphur to catch light, and as it burns, the wood underneath ignites too.

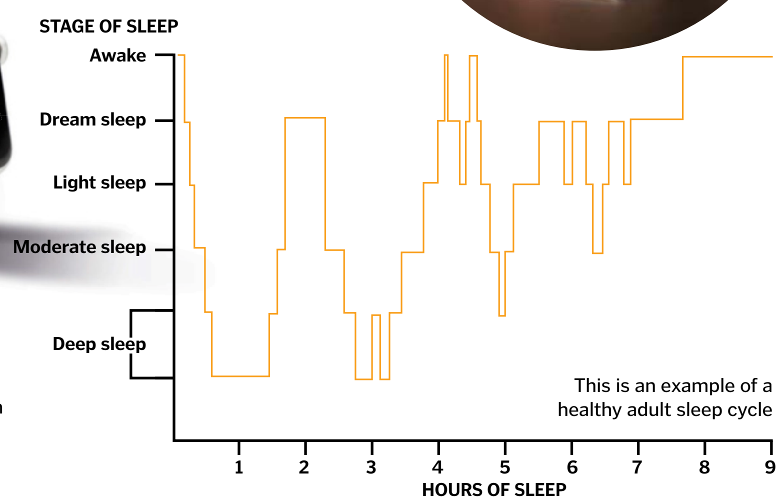
The perfect power nap

When to set the alarm to wake up feeling refreshed

10 minutes
A ten-minute nap is barely sleeping at all. Within this short time, the body slips into light sleep; a state just between asleep and awake. Dozing can be beneficial if you need a few minutes to relax, but you might not get the full effects of a proper nap.

20 minutes
Napping for 20 minutes will take you down into the second stage of sleep; body temperature drops and breathing evens out. You are relaxed, and asleep, but waking up should still be easy. Just 20 minutes provides the most refreshing nap.

30 minutes
A long nap could see you slipping into deep sleep. Blood pressure falls, muscles relax, and breathing slows. Waking up is much harder, and can leave you feeling groggy. Set an alarm for 90 minutes, when you'll have cycled out of deep sleep.



This is an example of a healthy adult sleep cycle

60 SECOND SCIENCE

Light

A GUIDE TO HOW LIGHT TRAVELS, AND WHY IT MOVES FASTER THAN ANYTHING ELSE

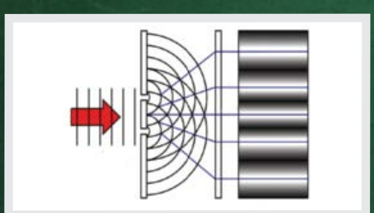
BACKGROUND

Light is electromagnetic radiation, and the word is mostly used to describe the parts of the spectrum we can see. It travels fast and in straight lines, but exactly how it does this is complicated. Isaac Newton favoured the particle theory, saying that light travelled in packages called 'corpuscles', while 17th century mathematician Christiaan Huygens proposed that light moved via waves, like sound. In fact, light is carried by particles called 'photons', which do travel and behave a bit like waves.

IN BRIEF

In 1801, physicist Thomas Young shone a beam of light through a pinhole, and allowed it to hit a piece of card with two slits. If light were carried by particles, it should have passed through the slits, lighting up two distinct spots. Instead, it formed bands, leading him to conclude that light is made up of waves. In 1860, James Clerk Maxwell extended this idea by explaining that light is electromagnetic waves, made up of electric and magnetic fields.

However, in the 1900s, Max Planck and Albert Einstein showed that electromagnetic radiation is divided into packets of energy called quanta, indicating that light is made up of particles, now known as photons.



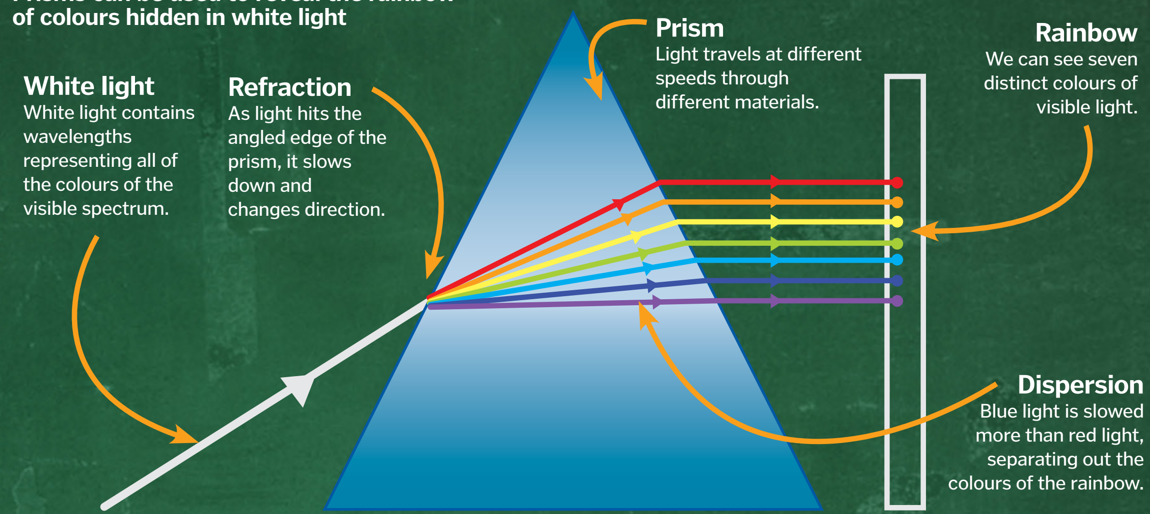
The two-slit experiment showed that light behaves like waves

SUMMARY

Physicists use both particle and wave metaphors to explain how light travels, and both ideas are valid. Photons behave like waves, and light can be described as both particles and as waves, or as neither.

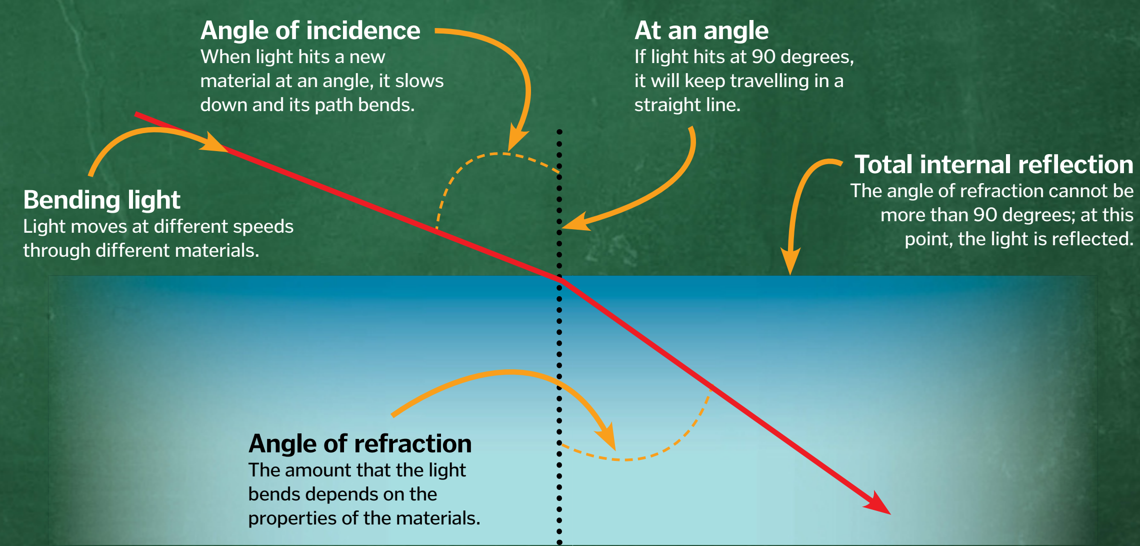
Separating the spectrum

Prisms can be used to reveal the rainbow of colours hidden in white light



Bending light

As light travels from one material to another, its path can bend



THE SPEED OF LIGHT

THE SPEED OF LIGHT IN A VACUUM IS 300 MILLION METRES PER SECOND. THIS IS THE SPEED LIMIT OF THE UNIVERSE; NOTHING CAN TRAVEL FASTER. BUT LIGHT DOESN'T ALWAYS MOVE THIS FAST. IN AIR, WATER AND OTHER MATERIALS, LIGHT INTERACTS WITH PARTICLES AND SCATTERS, SLOWING IT DOWN.

IN AIR, LIGHT IS ONLY SLOWED DOWN A LITTLE BIT, BUT IN WATER, ITS SPEED DROPS TO AROUND 226 MILLION METRES PER SECOND, AND IN GLASS, DOWN TO 200 MILLION METRES PER SECOND. MOVING THROUGH DIAMOND, IT IS SLOWER STILL, AT AROUND 150 MILLION METRES PER SECOND, AND RESEARCHERS AT HARVARD UNIVERSITY MANAGED TO SLOW IT DOWN TO A MEASLY 17 METRES PER SECOND BY SHINING IT THROUGH EXTREMELY COLD SODIUM ATOMS.

How knives cut

The cutting-edge science behind chopping up food

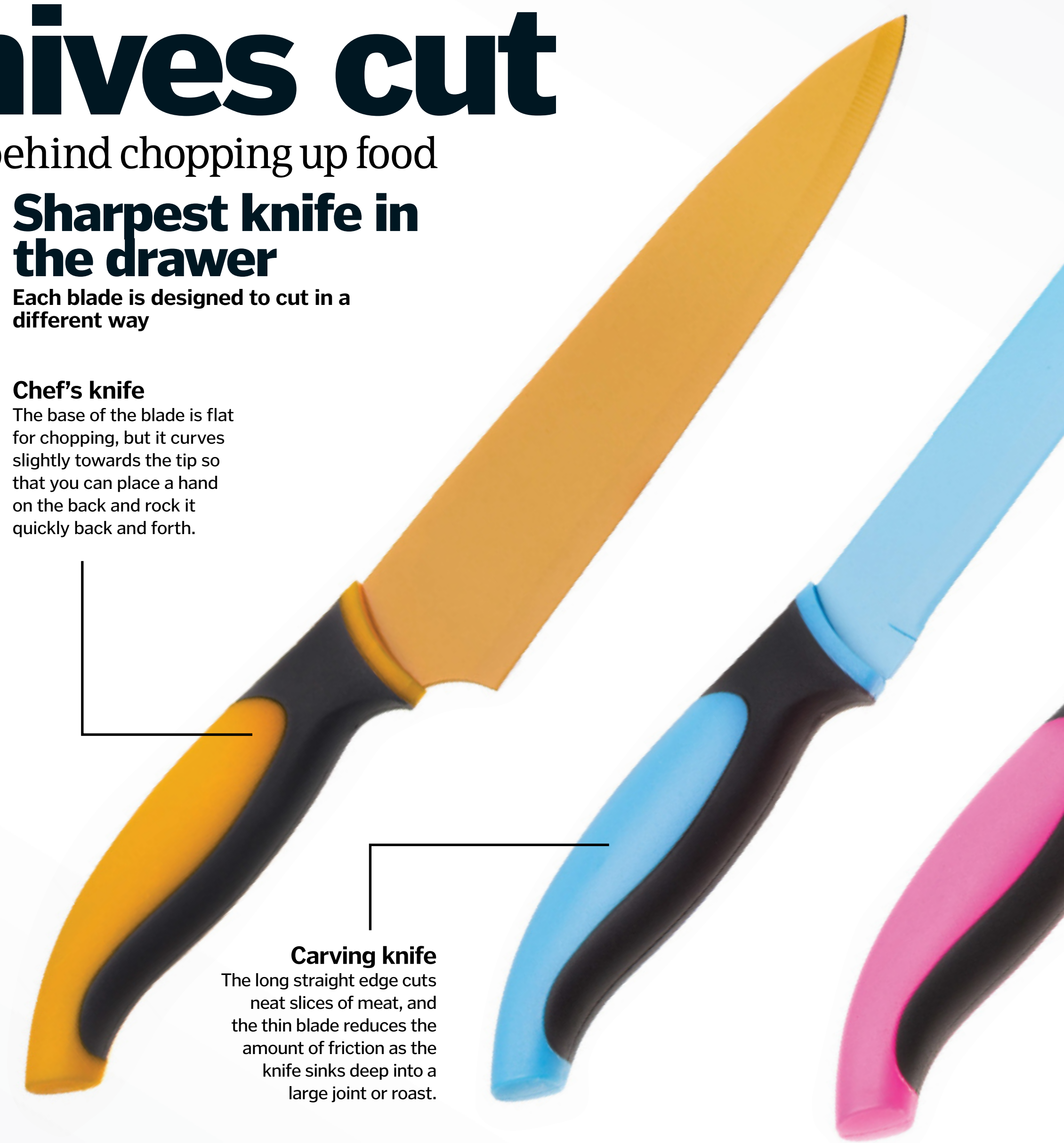
Imagine pushing your hand down flat on a block of butter; some of it will squish out on either side of your hand, but you have to work quite hard because you are mostly pushing the butter down, not sideways. Now try again with your hand vertical, as if you are performing a karate chop. This time it is easier to make a dent, because your contact area with the butter is smaller so you don't need to push so much of it downwards.

Like your vertical hand, a knife is a wedge. It converts the downward force you put on it into sideways force that separates an object into two halves. The sideways force stretches the bonds that hold the object together until the molecules are so far apart that the bonds are snapped. The thinner the knife edge, the easier it is to start off the process and this corresponds to the sharpness of the blade.

The angle of the wedge also makes a difference. An axe blade has a shallow angle that converts a lot of the downward motion of the axe into sideways force against the wood. This is essential as wood is very springy and the fibres must be forced a long way apart before they will split. However, for something delicate like raw fish, or a tomato, you need a very acute angle on the blade. Too much sideways force will crush the rest of the flesh. If you try to cut a tomato with an axe, you will make a mess, no matter how sharp the axe is.

Sharpest knife in the drawer

Each blade is designed to cut in a different way



Chef's knife

The base of the blade is flat for chopping, but it curves slightly towards the tip so that you can place a hand on the back and rock it quickly back and forth.

Carving knife

The long straight edge cuts neat slices of meat, and the thin blade reduces the amount of friction as the knife sinks deep into a large joint or roast.

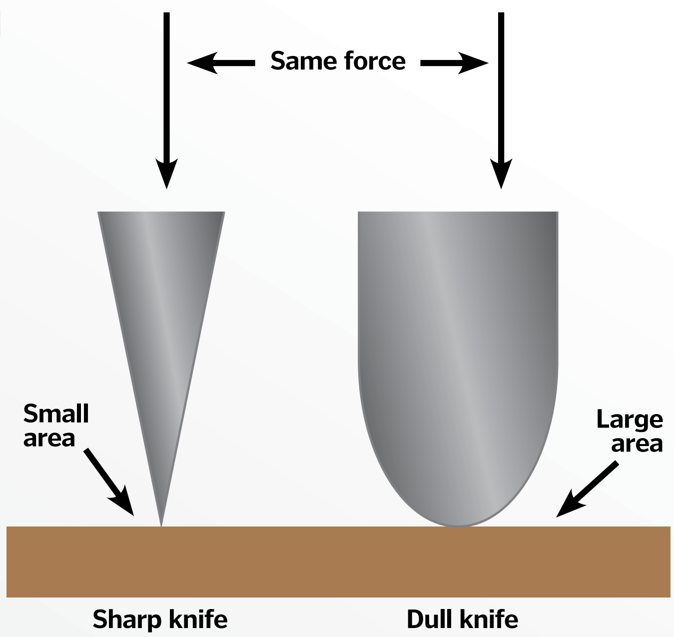
Self-sharpening blades

Some knife sets incorporate a grinding stone in the knife block so that each blade is sharpened as you push it back into its slot. But a truly self-sharpening blade is built from alternating layers of hard and soft steel, or steel that has a crystal 'grain', comprising hard and soft layers. As the blade saws back and forth, the hard layers grind down, but the softer layers in between wear faster, so the blade always presents a saw-tooth profile of hard points.

You can see the alternating hard and soft layers of steel in the vertical lines on these self-sharpening scissors

Magnifying force

Just as a magnifying glass concentrates the light from a wide lens into a narrow spot at the centre, a knife concentrates the force from your hand and arm into a thin line at the blade's edge. The sharper a knife, the narrower the contact area at the cutting surface. Since pressure is equal to the force divided by the area, a smaller contact area produces a higher cutting pressure from the same amount of force. This high pressure makes it easier to push the blade into the object you are cutting. However, sharp blades have delicate edges that wear away more quickly, so they need regular re-sharpening.



A sharp knife is safer than a blunt one, as you are less likely to slip while chopping

Utility knife
A smaller version of the chef's knife. Both of these are designed as general-purpose knives but the utility knife allows more precise slicing of smaller objects.

Cleaver
Cleavers are used for chopping like an axe. The blade is wider and heavier to give it extra momentum and the edge is tapered at a steeper angle so it doesn't blunt so quickly.

Bread knife
A serrated edge acts like a line of tiny knives that alternately cut and release. This allows springy food like bread to bounce back instead of getting squashed by a straight-edged blade.

Paring knife
The very short blade allows it to be easily controlled when you are cutting off the chopping board, and the sharp point is useful for making the initial incision.

High-carbon steel

This super-tough steel traps carbon atoms in the crystal structure, which makes it much harder than ordinary iron.

Stainless steel

This iron alloy has chromium added to it, which stops it from rusting but also makes it softer, so it blunts quicker.

Ceramic

Zirconium dioxide, or zirconia, is much harder than steel and doesn't need sharpening, but it can chip or snap.

Glass

Glass fractures with much sharper edges than any metal. Laboratory researchers use glass knives to prepare microscope samples.

Miniature worlds

Find out what these enclosed ecosystems can teach us

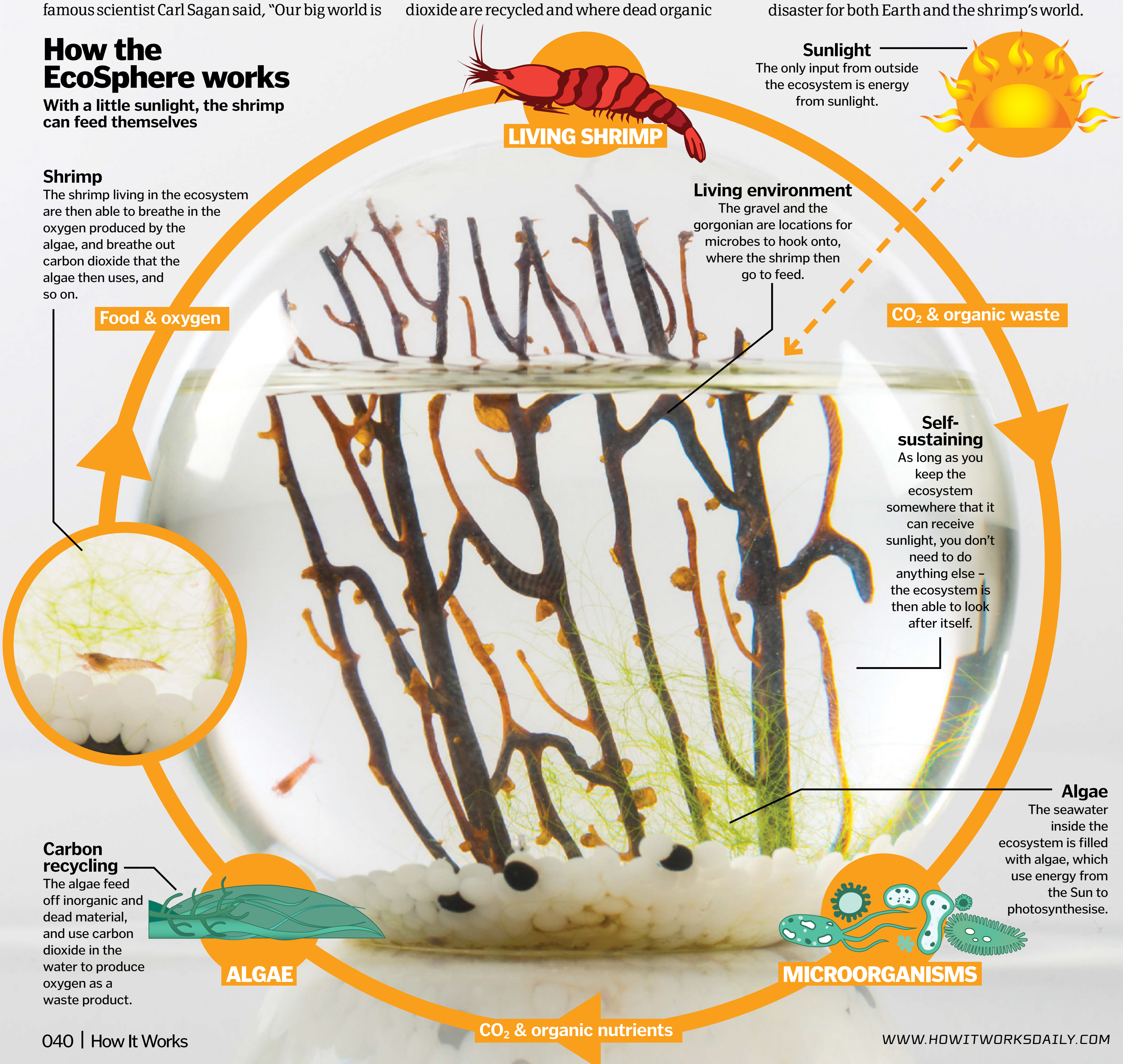
Imagine if you lived in an enclosed sphere with all the resources you need to survive and where the only outside input is sunlight. This is how the three shrimp that arrived in a package from EcoSphere Associates, Inc – a company that builds tiny enclosed ecosystems – not only survive, but thrive. The small glass globe is filled with seawater, algae, microbes, a tree-like gorgonian and gravel.

After receiving a similar globe of shrimp, the famous scientist Carl Sagan said, "Our big world is very like this little one, and we are very like the shrimp...[but] unlike them, we are able to change our environment." If you think about it, the EcoSphere is very much like our own world – everything we need for life is contained on our planet, with only sunlight coming from beyond. The Earth and the shrimp's globe are both enclosed ecosystems where sunlight is turned into energy through photosynthesis, where oxygen and carbon dioxide are recycled and where dead organic matter decomposes and releases nutrients back into the system.

The shrimp breathe oxygen and exhale carbon dioxide, and the carbon dioxide is absorbed by algae to produce oxygen. For the EcoSphere to survive, the cycling of energy, oxygen, carbon dioxide and nutrients must be carefully balanced, and the shrimp must not eat algae faster than it can regrow. Too little sunlight, or using resources faster than they are replenished, could spell disaster for both Earth and the shrimp's world.

How the EcoSphere works

With a little sunlight, the shrimp can feed themselves



From training doctors to planning military ops, discover how VR is set to change the world

VIRTUAL REALITY

This is the year when virtual reality changes life as we know it. That's according to research from Deloitte, which predicts sales to reach $1 billion (£700 million) in 2016 when the Oculus Rift and headsets from Sony, HTC and PlayStation are finally released.

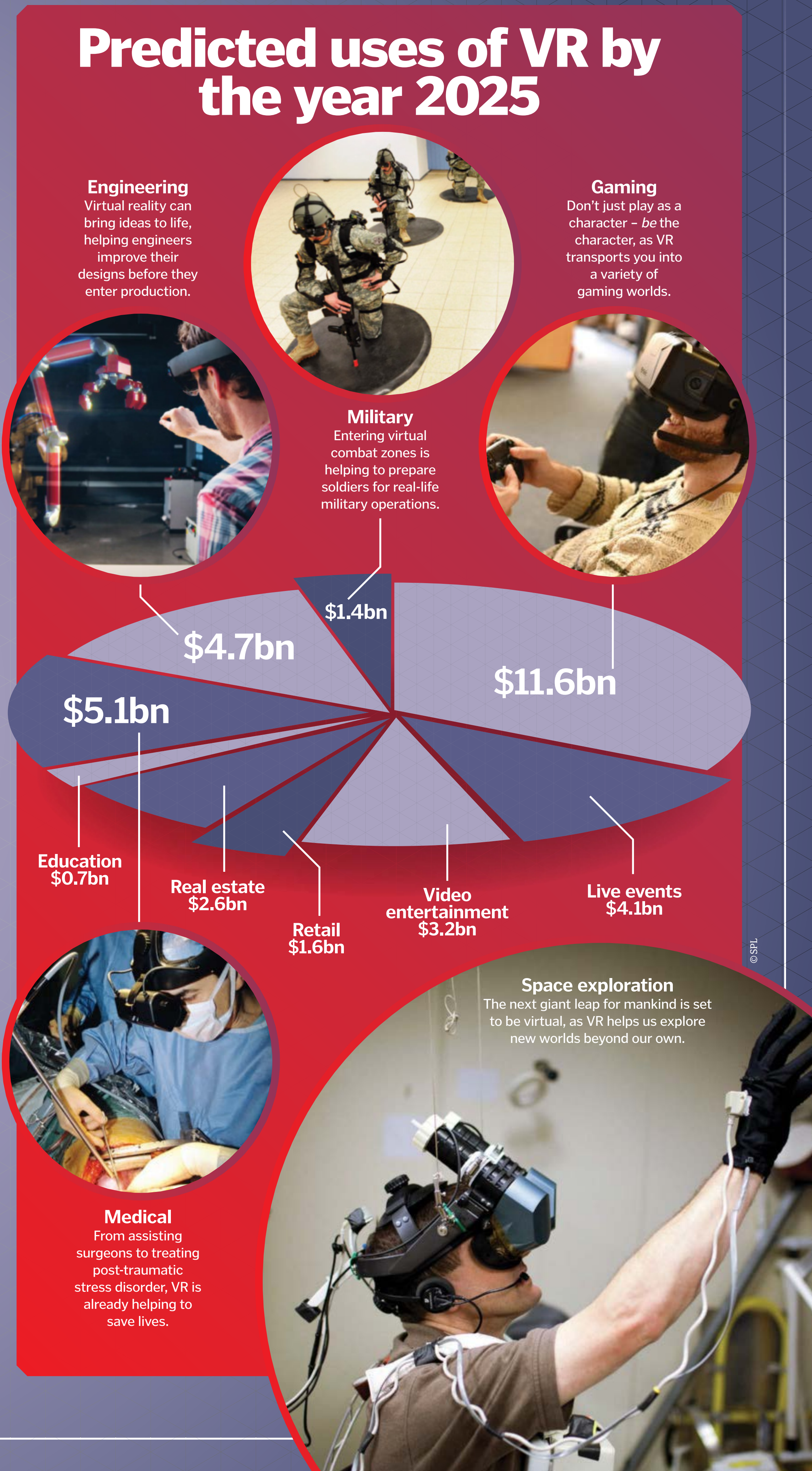
"Head-mounted displays are going to be like toasters," says Dr Albert 'Skip' Rizzo, Director of Medical Virtual Reality at the University of Southern California's Institute for Creative Technologies. "You might not use it every day but everybody's going to have one." Whether you want to step inside the video games you play, or explore far-flung places from the comfort of your sofa, VR is set to usher in an entirely new era of home entertainment.

For some people though, VR is already drastically changing day-to-day life, as the technology has a wide range of uses that extend far beyond gaming. From performing remote surgeries and treating medical conditions, to training soldiers and planning military operations, hundreds of groundbreaking applications are currently being explored.

But while this tech is getting most of us excited, there are some that are left feeling cybersick. The symptoms are similar to motion sickness and it's caused by a mismatch of sensory inputs. The brain expects things to be in sync, but in a simulated scenario, you observe movement – like the rickety track of a rollercoaster – but you don't feel it. It's the opposite of traditional motion sickness, which occurs when you feel movement in your inner ear, but you don't see it. The result is the same though, and it's a big obstacle to making virtual the new reality.

> *"Hundreds of groundbreaking applications for VR are currently being explored"*

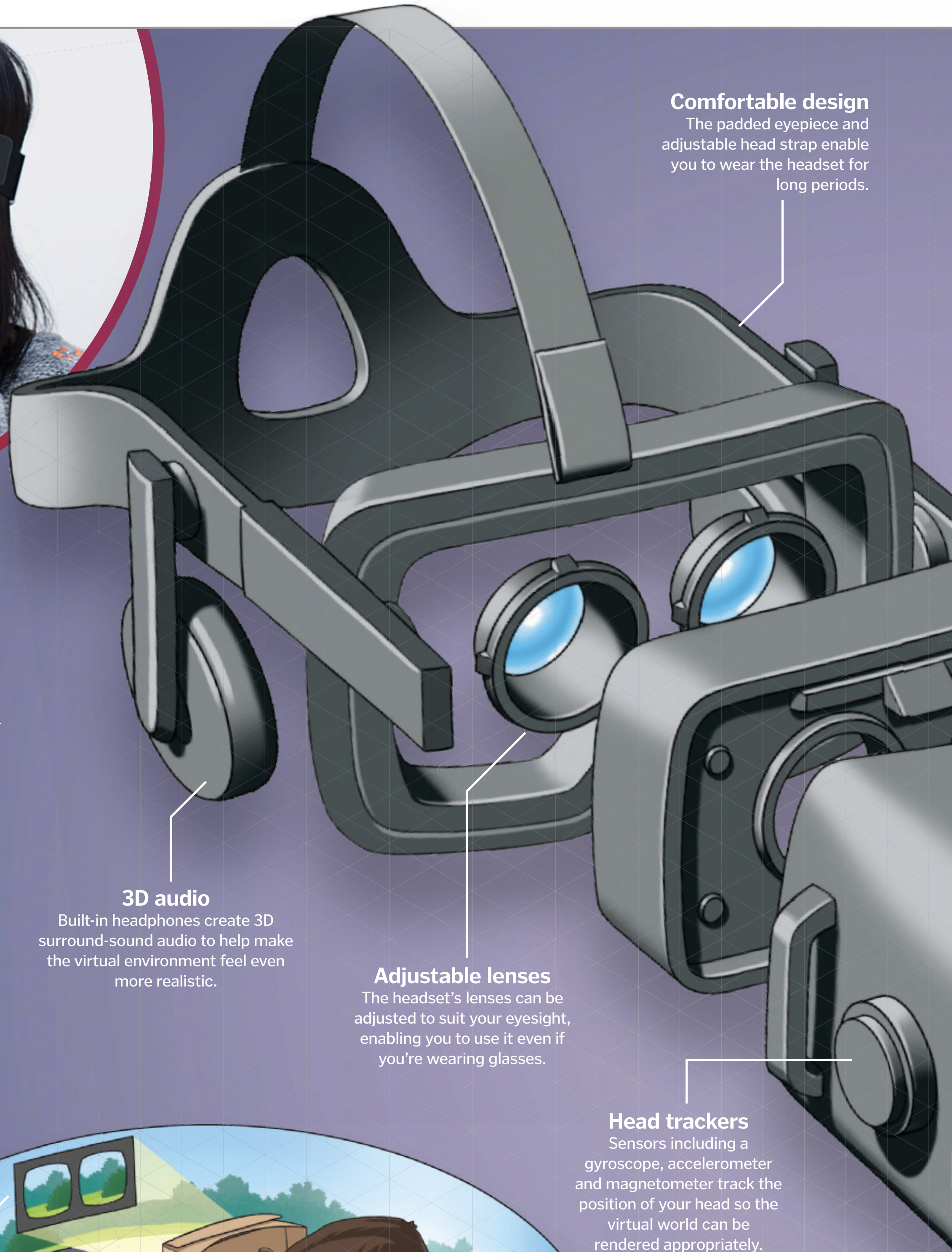
Receiving feedback other than visuals and sound is another issue, as it is difficult to recreate a sense of touch that enables you to fully interact with the world around you. On top of this, virtual reality is currently a solitary experience, as others cannot share what you're viewing through the headset. However, with developers already working on ingenious solutions, such as haptic feedback gloves, wireless tracking technology and programmes that can create avatars of your friends, the virtual future is set to be one of endless possibilities.



How does VR work?

The kit that transports you into virtual worlds

Several mobile headsets that require your smartphone to work are already available, but it is the high-end connected kits that will really show off what VR can do. The Oculus Rift and HTC Vive are the current front-runners, with the former already available to pre-order for around $600 (£425) and expected to start shipping in March. These headsets feature built-in displays, are powered via a cable and require external sensor systems to track your movements.



Comfortable design
The padded eyepiece and adjustable head strap enable you to wear the headset for long periods.

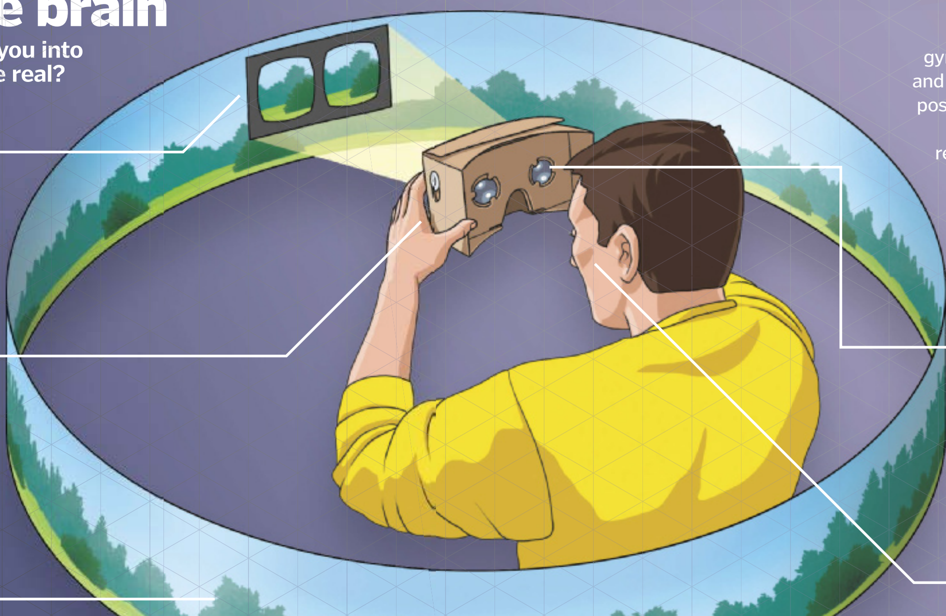
3D audio
Built-in headphones create 3D surround-sound audio to help make the virtual environment feel even more realistic.

Adjustable lenses
The headset's lenses can be adjusted to suit your eyesight, enabling you to use it even if you're wearing glasses.

Head trackers
Sensors including a gyroscope, accelerometer and magnetometer track the position of your head so the virtual world can be rendered appropriately.

Tricking the brain

How do VR headsets fool you into thinking virtual worlds are real?



Stereoscopic display
VR headsets use dual lenses or a split-screen display to put a slightly different image in front of each eye, recreating your normal stereoscopic vision.

Total immersion
The headset blocks out any other light, and headphones can be worn to block out sound, eliminating any distractions from the real world.

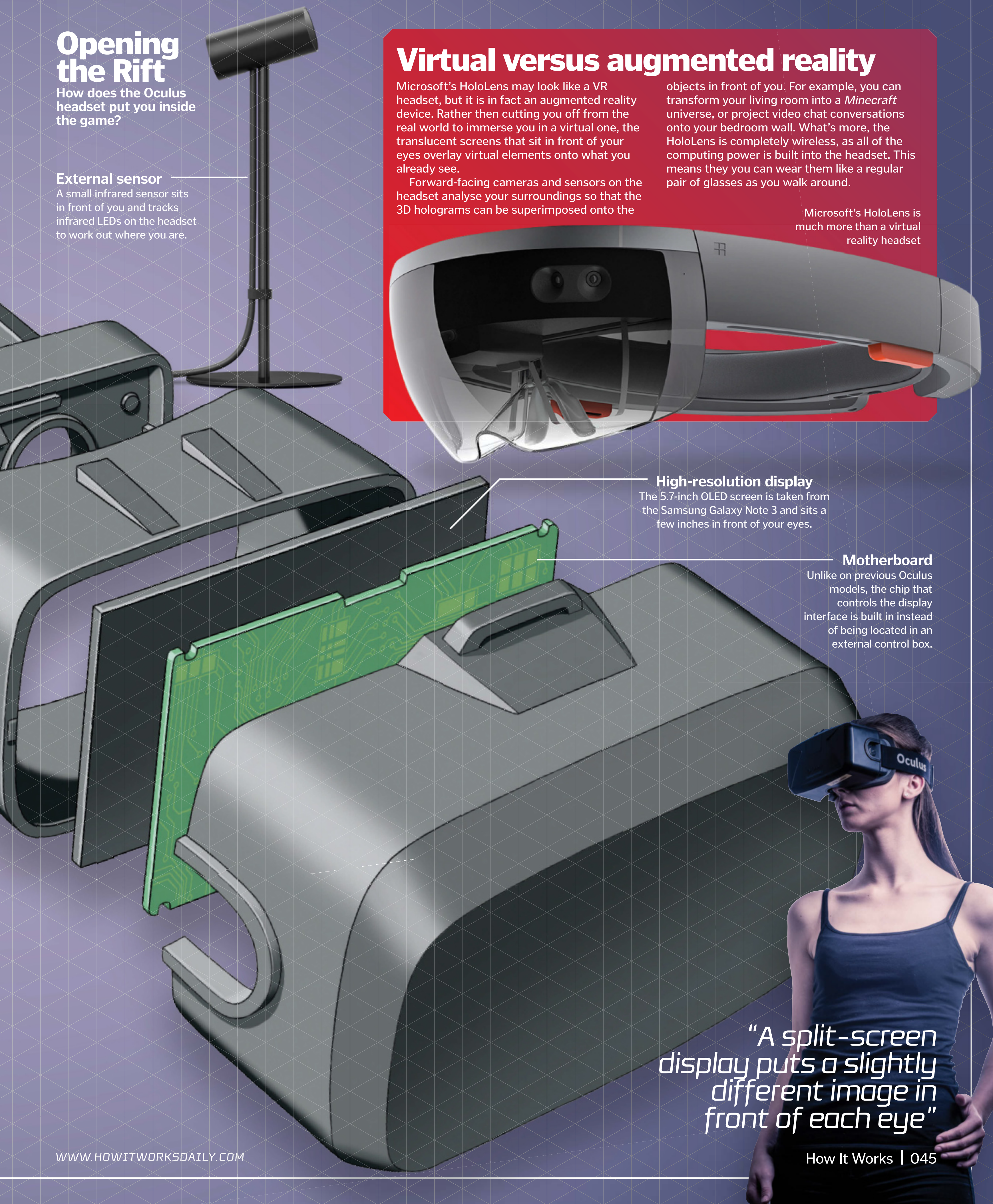
Smooth footage
The VR footage needs to refresh at a high frame rate to avoid any noticeable flickering that could leave you feeling nauseous.

Motion tracking
Built-in accelerometers and gyroscopes, or external sensors, work out the position of your head so the image can be adjusted accordingly as you look around.

Normal vision
When you see the world, each eye records the scene from a slightly different angle and your brain puts the two views together to create one 3D image.

Opening the Rift

How does the Oculus headset put you inside the game?



External sensor
A small infrared sensor sits in front of you and tracks infrared LEDs on the headset to work out where you are.

High-resolution display
The 5.7-inch OLED screen is taken from the Samsung Galaxy Note 3 and sits a few inches in front of your eyes.

Motherboard
Unlike on previous Oculus models, the chip that controls the display interface is built in instead of being located in an external control box.

Virtual versus augmented reality

Microsoft's HoloLens may look like a VR headset, but it is in fact an augmented reality device. Rather then cutting you off from the real world to immerse you in a virtual one, the translucent screens that sit in front of your eyes overlay virtual elements onto what you already see.

Forward-facing cameras and sensors on the headset analyse your surroundings so that the 3D holograms can be superimposed onto the objects in front of you. For example, you can transform your living room into a *Minecraft* universe, or project video chat conversations onto your bedroom wall. What's more, the HoloLens is completely wireless, as all of the computing power is built into the headset. This means they you can wear them like a regular pair of glasses as you walk around.

Microsoft's HoloLens is much more than a virtual reality headset

"A split-screen display puts a slightly different image in front of each eye"

Let VR entertain you

Get ready to redefine the meaning of fun

Gaming and other forms of entertainment have been the main driving force fuelling the development of this technology. It's predicted to be the main function for VR in the coming years, and already a wide range of accessories have been designed to enhance the experience. The Virtuix Omni is a motion platform that enables you to walk or run to control your avatar in a virtual world, as opposed to just staying seated and turning your head while you tap at an Xbox controller. Then there's Oculus Touch, a pair of wireless controllers that let you feel as though your virtual hands are your own, meaning you can reach out and interact with objects in the game.

Virtual hands

The tech that gives you the power to reach into the game

Haptic feedback
The controllers are able to deliver feedback when you interact with objects in the virtual world, helping them feel real.

Cable-free
The wireless controllers are tracked by the Rift system using infrared LEDs and sensors, so it knows where your hands are.

Pull the trigger
A 'hand trigger' input mechanism replicates the feeling of firing a gun for a fully immersive first-person shooter experience.

Step into the game

How the Virtuix Omni treadmill lets you take a virtual stroll

Safety first
A support ring and safety harness keep you tethered to the treadmill to stop you from falling out.

Wireless set up
The Virtuix Omni connects to your PC or mobile VR headset via Bluetooth and is compatible with much of the latest VR content.

Natural motion
Special low-friction shoes allow your feet to glide across the concave treadmill surface for smooth, 360-degree motion.

Smart tracking
Tracking pods in the shoes help the game calculate the speed and direction of your movements.

"Gaming is predicted to be the main function for VR"

VR coasters and virtual cinemas

You can already ride virtual rollercoasters using a VR headset – so long as you can stomach the slightly nauseous feelings – but one of the UK's biggest theme parks is now taking things a loop further. The new Galactica rollercoaster at Alton Towers requires each rider to pop on a VR headset, making them feel as though they are flying through space while they are in fact hurtling along a track at 75 kilometres per hour.

For the adrenaline averse, there's virtual cinema – apps that recreate the traditional movie theatre experience. Already available for the Oculus and Google Cardboard, they allow you to choose a seat and then enjoy the film without any annoying distractions from popcorn munchers. That's not all though, as film directors such as Ridley Scott are already producing VR content that will enable you to step into the films themselves.

Galactica is the world's first rollercoaster entirely customised for the full virtual reality experience

On the battlefield

Forget *Call Of Duty* – how can virtual reality revolutionise real-life military operations?

Military organisations are often among the first to adopt the latest technological innovations and virtual reality is no exception. There are many potential applications for VR in combat, but British engineers from BAE Systems are working on some truly groundbreaking concepts. They are planning to create a 'mixed reality', using headsets to overlay virtual images, video feeds, objects and avatars onto footage of the operator's actual surroundings, which are recorded by a front-facing camera.

One use for this is in developing a portable command centre that can be transported in a briefcase and set up anywhere. The user would simply put on a headset and interactive gloves, and be able to monitor situations anywhere in the world. This would enable them to direct troops and even bring in artificially intelligent avatars to provide updates and advice. Another use for mixed reality is the 'wearable cockpit', a headset that overlays virtual displays onto the pilot's real-time view, enabling them to customise controls based on their own preferences and mission objectives.

As well as assisting soldiers when they are in battle, VR can also be used to train them before they get there. Headsets can be used to simulate a real-life combat zone, which can be experienced from a safe, controlled environment, keeping the soldier out of harm's way.

Of course, staying stationary during training isn't ideal, so a variety of devices have been designed to give soldiers complete freedom of movement in virtual environments. The Virtusphere is a hollow ball on wheels, which rotates in any direction as the person moves inside. Sensors communicate the user's movements to their VR headset, so their view can be updated accordingly. Alternatively, the Cybersphere is another human-sized hamster-ball, which doesn't even need a headset to create a virtual battlefield.

A portable command centre would let military personnel manage emergencies from anywhere in the world

The Virtusphere lets soldiers move freely in a virtual battlefield environment

BAE Systems' wearable cockpit overlays the pilot's view with useful graphics

Step into the Cybersphere

The hamster ball for humans trains soldiers for battle

1 Freedom of movement
A hollow, translucent sphere measuring 3.5 metres in diameter sits on a cushion of air, which allows it to rotate freely.

2 Rolling around
As the user walks, runs or crawls, they cause the sphere to rotate, although the structure itself remains stationary.

3 A second sphere
The movement of the large sphere is transferred to a smaller sphere; spring-loaded supports connect the two parts.

4 Motion tracking
Rotation sensors record the movements of the smaller sphere to update the images that are then seen by the user.

5 Wrap-around view
Images of a virtual world are projected onto the interior walls of the sphere, so the user inside does not need to wear a headset.

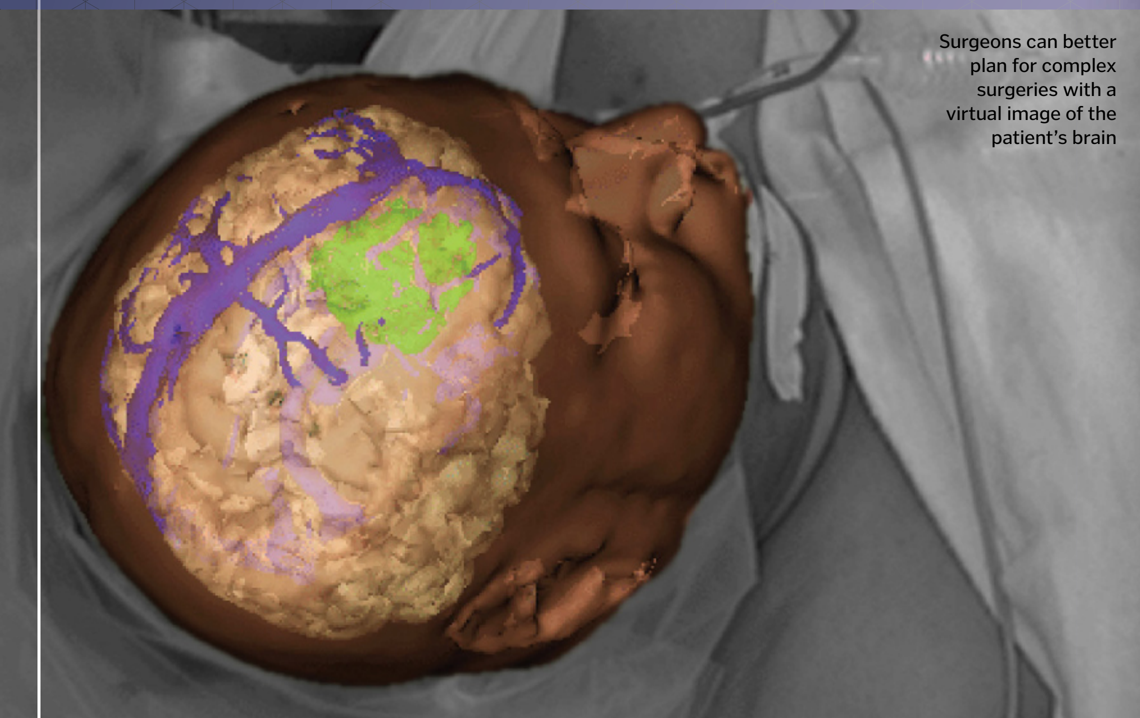
Is VR good for your health?

The groundbreaking applications in healthcare

In a recent report about the growth of virtual and augmented reality, investment banking firm Goldman Sachs estimates that the industry will be worth $80 billion by the year 2025. It also predicts that, aside from video games, healthcare will be one of the biggest applications for the technology.

Already, VR is being used to train surgeons, allowing them to practise complex procedures on a virtual patient before they get to the real thing, and it can even be used to conduct robotic surgeries too. Wearing a head-mounted display, the surgeon can control a robotic arm that is capable of making smaller, more delicate movements than human hands could ever manage, plus it enables them to operate on a patient remotely from an entirely separate location.

There is also a wide range of applications for which virtual reality can be used to treat patients directly. For example, VR can enable people with phobias and post-traumatic stress disorder to face their fears in a virtual world, in order to help combat them in the real one.



Surgeons can better plan for complex surgeries with a virtual image of the patient's brain

Education

Discover how VR can really bring lessons to life

Imagine being able to visit outer space or walk with dinosaurs instead of just reading about them in a textbook. Virtual reality could transform the way subjects are taught in the classroom, and one company is already developing a library of experiences that can educate students of all ages.

"Virtual reality offers a new way to view the world," says David Whelan, CEO of Immersive VR Education. "For the first time in humanity we can walk a mile in other people's shoes." The Apollo 11 experience, for example, lets you step onto the Moon as Neil Armstrong. "This is much more powerful than reading about the moon landing in a book," he adds. "Virtual reality has the potential to revolutionise education in the same way that reading and writing did thousands of years ago."

Virtual reality can enable students to experience events from history and impossible-to-visit places

Virtual treatments

At the University of Southern California's Institute for Creative Technologies, Dr Albert 'Skip' Rizzo and his team are using virtual reality for a number of game-changing clinical purposes. We spoke to him about their amazing work…

How are you using VR to treat post-traumatic stress disorder (PTSD)?
One of the typical treatments for PTSD is prolonged exposure therapy. You ask the person to close their eyes and imagine the trauma that they went through as if it's happening right then and get them to describe it to you. By doing that repetitively in a safe and supportive environment, eventually the anxiety that it provokes in them diminishes. It sounds kind of counterintuitive at first but there's actually quite a lot of research to support this. What we do with VR is simply to deliver this previous imagination-only approach in an immersive virtual reality simulation.

We have developed 14 different virtual worlds that represent a diverse range of experiences, and the clinician is able to adjust them in real-time, for example to change the time of day or introduce sound effects. The patient does exactly what they would do in traditional exposure therapy, but the clinician then tries to mimic their experience in the simulation to enhance the effects.

What other clinical VR projects are you working on?
One project is building a job interview training system for people with high-functioning autism – people that are very bright but have a difficult time with social interaction. We've built a simulation that has six different job interviewers, that can be set at three different levels, from a soft touch, nice interviewer to a more hostile interviewer that puts you ill-at-ease, giving them the opportunity to practise. We've also made virtual patients that give clinicians an opportunity to essentially mess up with a digital character before they get to a live one.

Are there limitations of the tech in this field?
The limitations right now have really diminished. I started in this game back in the early 90s, when it required a $200,000 computer, and you had bulky head-mounted displays with low resolution, limited field of view, poor tracking and primitive graphics. There was a network of people that wanted to do this work, but it was challenging because the technology really sucked.

But now the technology has finally caught up with the vision. Computing power has consistently gotten better and faster, which is needed for good rendering, and of course the games industry has driven advances in graphic development that are phenomenal. So the limits right now are the limits of our imagination and the funding to evolve these applications and test them in a consistent way.

Dr Rizzo uses virtual reality simulations to treat post-traumatic stress disorder

Virtual reality helps astronauts train for life and work in space

Space exploration

A new way to work in space and tour the Solar System

Virtual reality has already become a crucial part of astronaut training, enabling them to practise spacewalks in a virtual environment before doing them for real, and is even being used once they get into space. A Microsoft HoloLens onboard the International Space Station enables ground operators to see through the eyes of the astronauts and provide real-time guidance, as well as project helpful holographic illustrations onto their view. For tasks that astronauts are not able to do themselves, a head-mounted display enables operators on the ground to see through the eyes of NASA's Robonaut instead, which can then mimic its operator's movements to perform tasks just like a human. Virtual reality also makes it possible to explore other planets from the safety of Earth, as NASA scientists can step into images taken by the Curiosity Rover to walk on Mars for the first time.

"Ground operators can see through the eyes of astronauts and give real-time guidance"

Engineering

Visualising designs in 3D using virtual reality

When designing a new product, it's difficult to get a sense of what the finished item will be like from 2D illustrations. With virtual reality, designers and engineers can use 3D modelling to create virtual prototypes of ideas, and use a head-mounted display to examine them from all angles. For example, car manufacturers can sit inside the design of a new vehicle to make sure it looks and feels right before they build the real thing. Any tweaks can easily be made in the 3D design, rather than creating a new prototype from scratch.

Microsoft HoloLens will enable engineers to view and interact with their designs in 3D

Virtual world

Stereoscopic tech will touch almost every industry

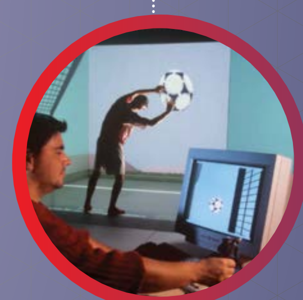
Archaeology

VR headsets enable archaeologists to walk around places as they would have appeared in the past, giving them a better understanding of what life was really like there. They also make it possible to see ancient sites that are otherwise too remote, dangerous or fragile to visit in person.

Crime solving

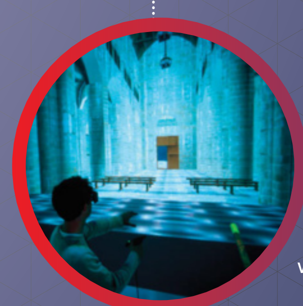
Based on factual data and photographs, 3D reconstructions of crime scenes can be created and explored using head-mounted displays. This enables investigators and even juries to examine the scene in great detail without contaminating any evidence, helping them to deduce what may have happened.

Sport



As well as creating a more immersive way to watch sporting events at home, virtual reality can also be used to improve the athletes' performance. While training in a virtual simulation, their body movements can be monitored in real-time, providing useful feedback to improve their game and help them avoid injury.

Tourism



Before you book your next holiday, your travel agent may be able to give you a taster of your destination using virtual reality. Popping on a headset will transport you to far away places, and even let you visit locations it's not possible, or too expensive, to travel to in real life.

Pinball machines

How the ball gets rolling on this arcade classic

Today's pinball machines are much flashier and more sophisticated than their ancestors, but they all retain the same basics of gameplay. The object of the game is to keep the ball from going down the drain, while scoring as many points as possible.

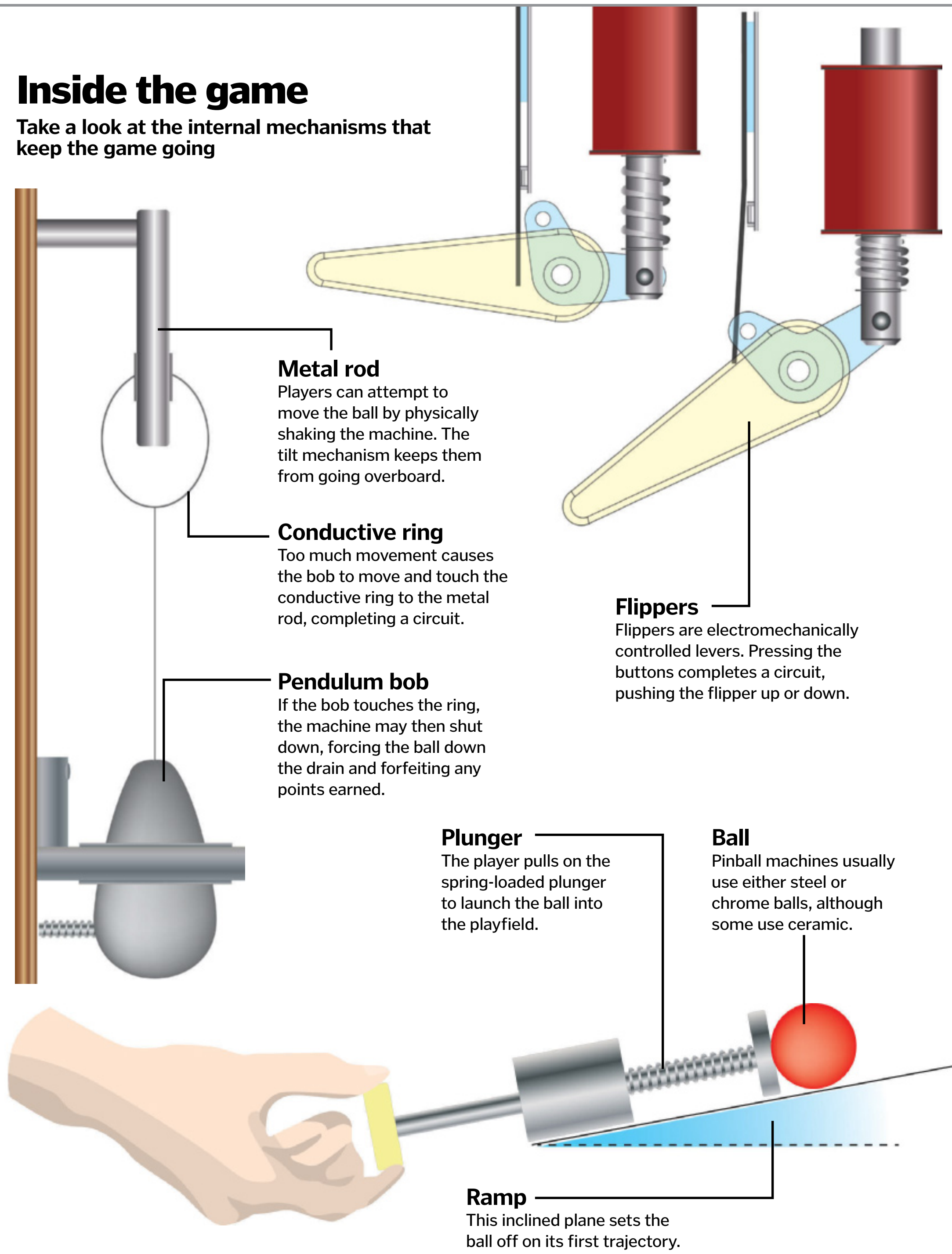
To launch the ball into the playfield, the player pulls back a spring-loaded plunger and releases. The tension of the spring can be manipulated based on how much the plunger is pulled, which is useful for aiming at specific targets. The playfield comprises one or more sets of flippers on each side, the only part of the game that the player can control once the ball is launched.

Numerous other features that can affect the ball include kickers, slingshots, switches, spinners, bumpers, ramps, and targets. The backbox, or back glass, contains all of the machine's electronics and is covered with decorative art. The player must carefully time when they move the flippers, sending the ball in the desired direction and stopping it from falling out of the playfield.


The player racks up points when their ball collides with targets

Inside the game

Take a look at the internal mechanisms that keep the game going

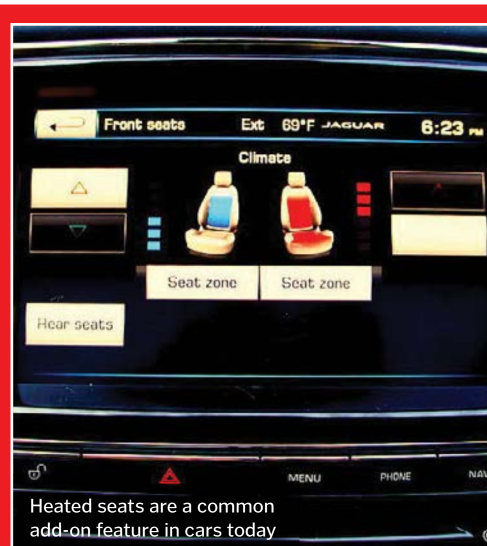


How heated car seats work

The tech that keeps you warm on a freezing winter morning

Swedish manufacturer Saab was the first company to offer electronically heated car seats in the early 1970s. They're now available on hundreds of car models and lend an extra bit of comfort on chilly days. Depending on the manufacturer, the seat can work in two different ways. Some are essentially like a heated blanket, meaning that a heating coil running under the seat is connected to a switch. A thermostat, usually located on the side of the seat or the steering wheel, allows the occupant to regulate the level of heat as the coil receives power directly from the car's battery. If the car has both heated and cooling seats, a thermoelectric device is used instead. The seats are made with a more porous material or even have perforations. Fans within the seat circulate either warm or cold air, depending on the direction of the electrical current.

Heated seats do come with a caveat: don't keep them on full blast for too long. Some users have experienced 'toasted skin syndrome' with discoloured skin on the rear, thighs, and backs of the legs, and some have even suffered burns.



Heated seats are a common add-on feature in cars today

How barcode scanners work

Wait for the beep – find out how these all too familiar scanners function

Head to a supermarket, take your groceries to the checkout and watch as the assistant passes your weekly shop through that little red scanner to tot up the total. As the tin of beans whizzes past, a laser hits the barcode, interpreting the information. This super-quick action is enough to calculate your receipt and also add the sale of the tin of beans to the store's database of stock.

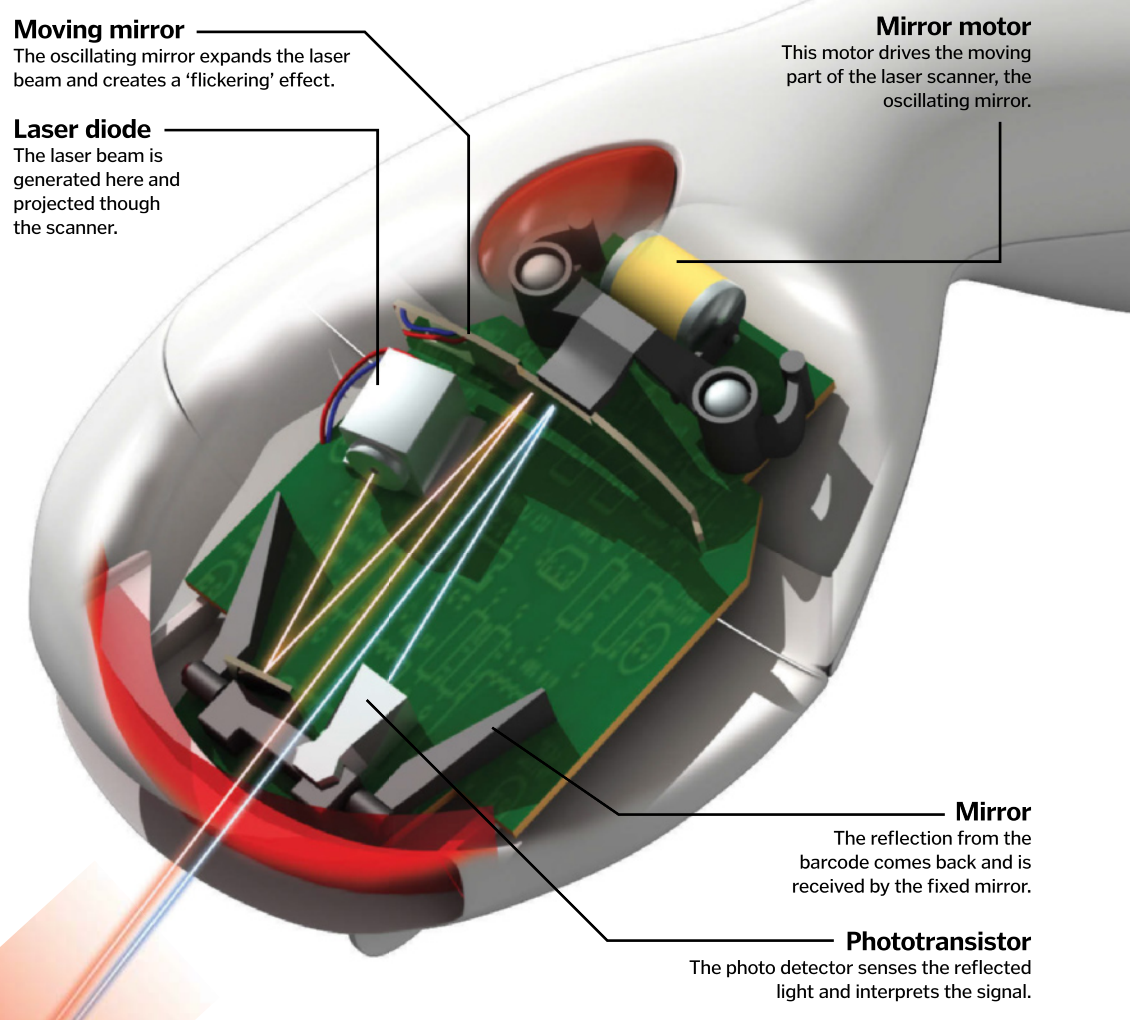
The scanners that large supermarkets use are complex omni-directional readers that can decode barcodes even when they are crumpled, torn or plastered on odd shaped items. There are many other types of barcode readers such as CCD readers, but the principal of these is the same.

There are three key parts to a barcode scanner: the illumination system, the sensor/converter and the decoder. A light source illuminates the barcode, which creates a reflection that can be read by the scanner and then interpreted.

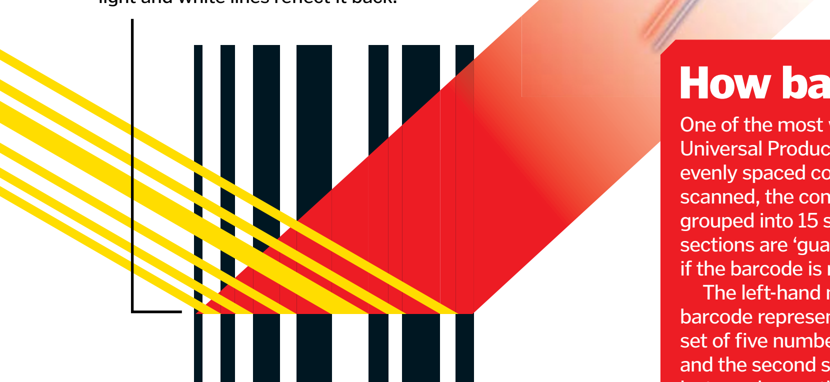
A laser scanner uses a laser beam, which is expanded into a line using a mirror that oscillates back and forth, causing a blinking effect. The reflected light from the white spaces of the barcode is picked up by a fixed mirror, which is then processed to create the digital and analogue signals that relay the information back to a central database.

Inside a barcode scanner

How this device gets to work on your groceries



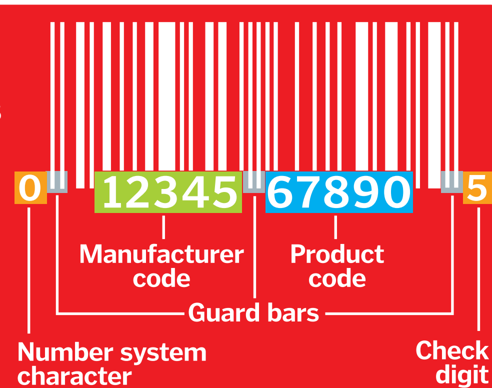
Barcode reading
Light from the scanner hits the barcode. Black lines absorb the red light and white lines reflect it back.



How barcodes work

One of the most widely used barcodes is the Universal Product Code (UPC). This is a series of 95 evenly spaced columns of black and white. When scanned, the computer creates a 95-digit code, grouped into 15 sections. The first, last and middle sections are 'guards' so that the computer can tell if the barcode is read left to right, or upside down.

The left-hand number at the bottom of the barcode represents the type of barcode, the first set of five numbers is the manufacturer's code, and the second set refers to the produce code. The last number on the right is the check digit, so the computer can verify that it has been read correctly.



How wristwatches tick

Keep time with the springs and gears of a mechanical watch

Before you could check your smartphone, and even before quartz batteries, a personal timepiece was an incredibly valuable commodity. There are two types of mechanical watch: a hand-wound watch and an automatic or self-winding watch. Although the starting mechanisms are different, the movement inside is essentially the same. It all comes from the back and forth motion of the mainspring – this is a tightly coiled and precisely measured spring, wound into a perfectly weighted cog known as the balance wheel.

This wheel is able to move back and forth because it's helped by another series of cogs that transfer energy from the winding pin all the way to the balance wheel. This usually involves three cogs, and these correspond to the hour, minute and second hands on the face. When the second hand makes a complete revolution, the minute hand has moved one graduation, and so on.

When each of the cogs turns the next, the last one in the chain moves what is known as the escape wheel. This wheel has large teeth on it, shaped so that it jogs a piece called the pallet fork into motion, which then in turn moves the balance wheel. As the balance wheel swings back, the other side of the pallet fork knocks the balance wheel again, and so a back-and-forth swing motion continues, helping the watch to keep perfect time.

Watch jewels

When you see a watch that has a phrase like '17 jewel' inscribed on the back, this is nothing to do with the watch face. It may be adorned with numerous precious stones on the front, but this inscription refers to the gemstones (usually man-made sapphires or rubies) that are contained within the watch's mechanisms.

These jewels are not precious gemstones and have no monetary value, but they are incredibly important for keeping the watch ticking smoothly, providing highly polished surfaces to decrease friction and improve accuracy.

The jewels also increase the life of the watch. They are usually tiny – just millimetres in diameter – and come in different shapes for their specific jobs. There are two pallet jewels on the pallet fork that keep the balance wheel moving back and forth. There are also cap jewels, hole jewels and impulse jewels, among many others.

Here the cap and hole jewels are visible, providing smooth movement for the gears

Chronograph watches have an extra hand that can be used as a stopwatch

Telling the time

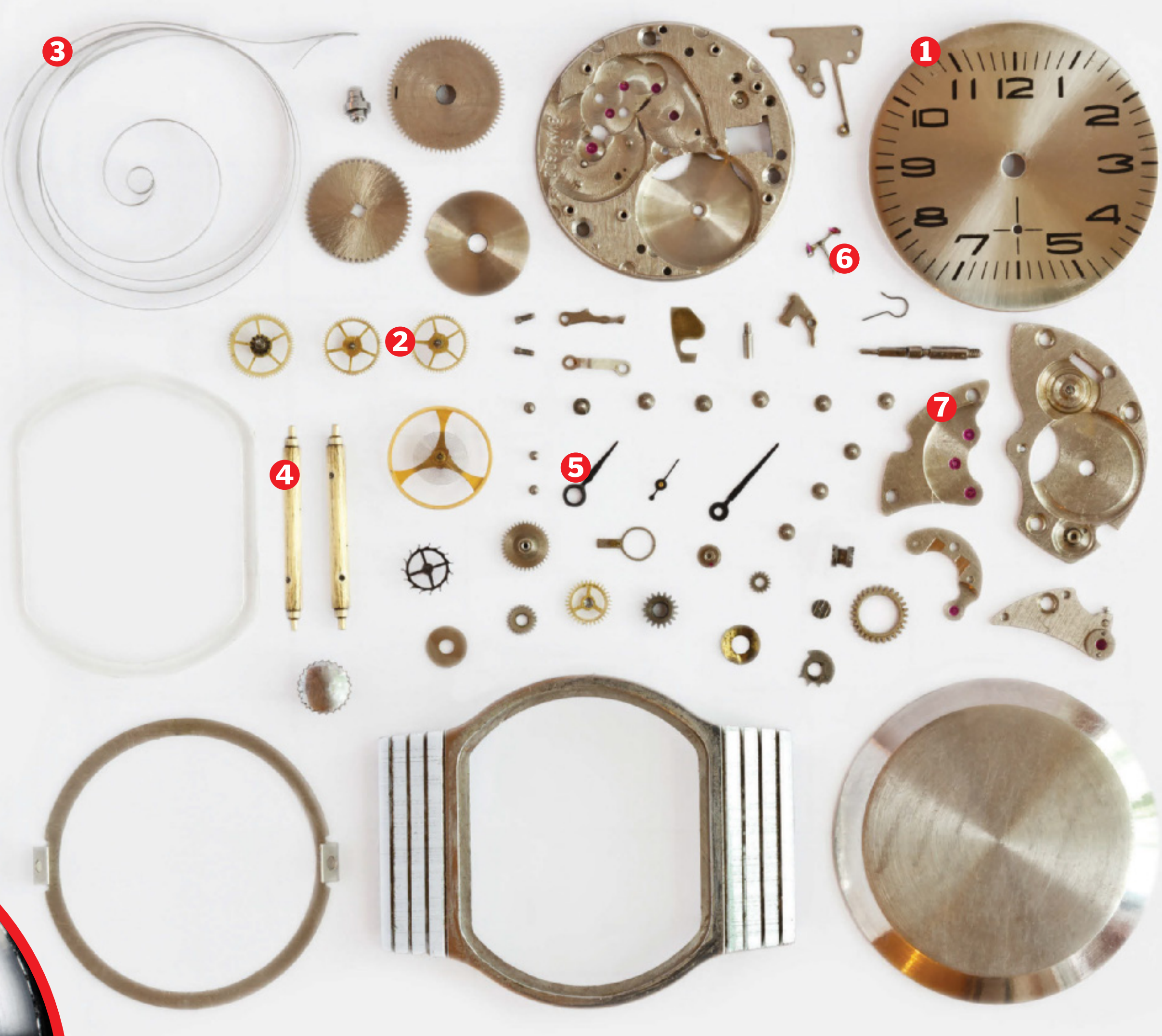
How individual parts fit together so everything goes like clockwork

1 Watch face This is the part that tells you the time, yet there's plenty going on behind the scenes.

2 Gears These facilitate the transfer of energy from the winding pin to the balance wheel, and move the watch's hands.

3 Main spring It needs a wind up every two weeks or so to keep going and provide the constant and accurate ticking movement.

4 Watch pins Not involved in the movement but important nonetheless, the pins attach the watch to the strap.



5 Hands Attached to gears behind the watch face, the hands turn in perfect unison to show the wearer the time.

6 Pallet fork This is the little T-shaped fork (with pallet jewels) that connects the escape wheel to the balance wheel.

7 Jewels The precision cut synthetic rubies help keep the gears moving smoothly and accurately.

Washing machines

97 per cent of UK households own one, but how do they work?

A washing machine is essentially a colander inside a food blender, on top of a kettle. The clothes are placed in the inner, perforated drum, which is surrounded by an outer, watertight drum. The outer drum fills about a third of the way up with water from the cold tap, which is then heated by an electric element. A motor turns the inner drum just fast enough that the clothes tumble against each other and dislodge the dirt particles. Most washing machines have an inlet for hot water as well, but this is just to allow you to take advantage of your domestic hot water supply, which may be heated by a more economical gas boiler.

After the wash and rinse cycles, the inner drum is spun much faster to press the clothes against the walls of the drum by centrifugal force. This squeezes most of the water out through the perforations in the drum and a pump sends the waste water to the drain.

Originally, washing machines were all top-loading, but this meant that they couldn't be installed under kitchen counters. The risk with a front-loading machine though, is that it will flood your kitchen floor if you open the door midway through the cycle. To prevent this, the door locks shut automatically and won't release until the drain sequence has fully completed.

Another safety feature detects excessive vibration and automatically shuts off the spin cycle if the drum is unbalanced. This can happen if you wash a coat or heavy jumper on its own, but throwing in some towels at the same time will help to balance the load.

Different soaps for different folks

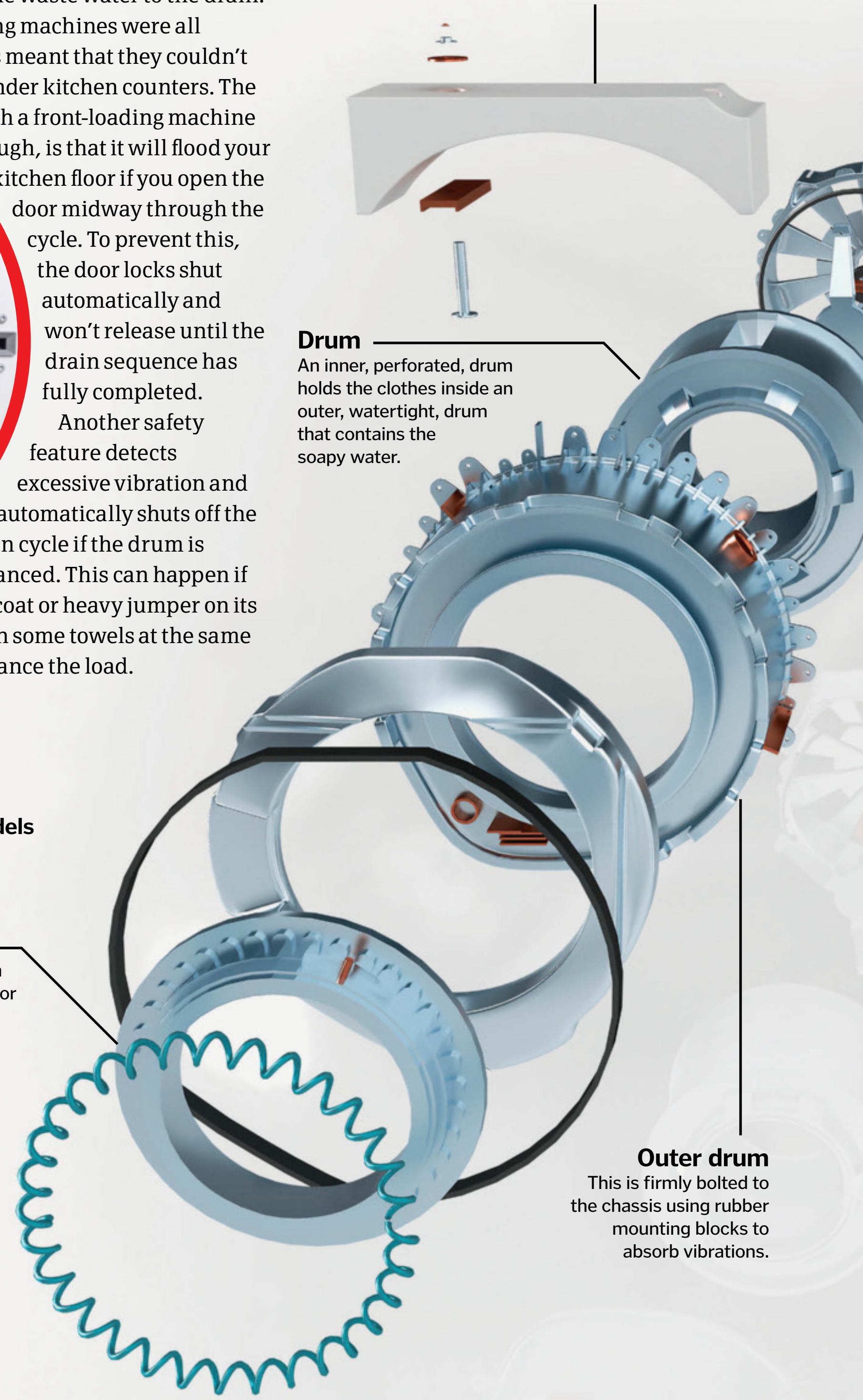
Washing machines don't rub clothes very much, so most of the cleaning work must be done by the detergent. Laundry detergent is designed to produce very little foam because otherwise the bubbles can work their way into the door seal and leave sludge deposits. To prevent limescale deposits in hard water areas, washing powder contains phosphonates and zeolites that bind to calcium ions to stop them precipitating out of solution. Most washing powder also includes an oxygen-based bleaching agent to keep your whites bright.

Biological detergents add enzymes to this mix, to digest specific tough stains, like blood and grass. But newer washing powders, which are designed to be kind to your colours, are actually the simplest formulations, since they just omit both the bleaching agent and enzymes, and rely entirely on the detergent.

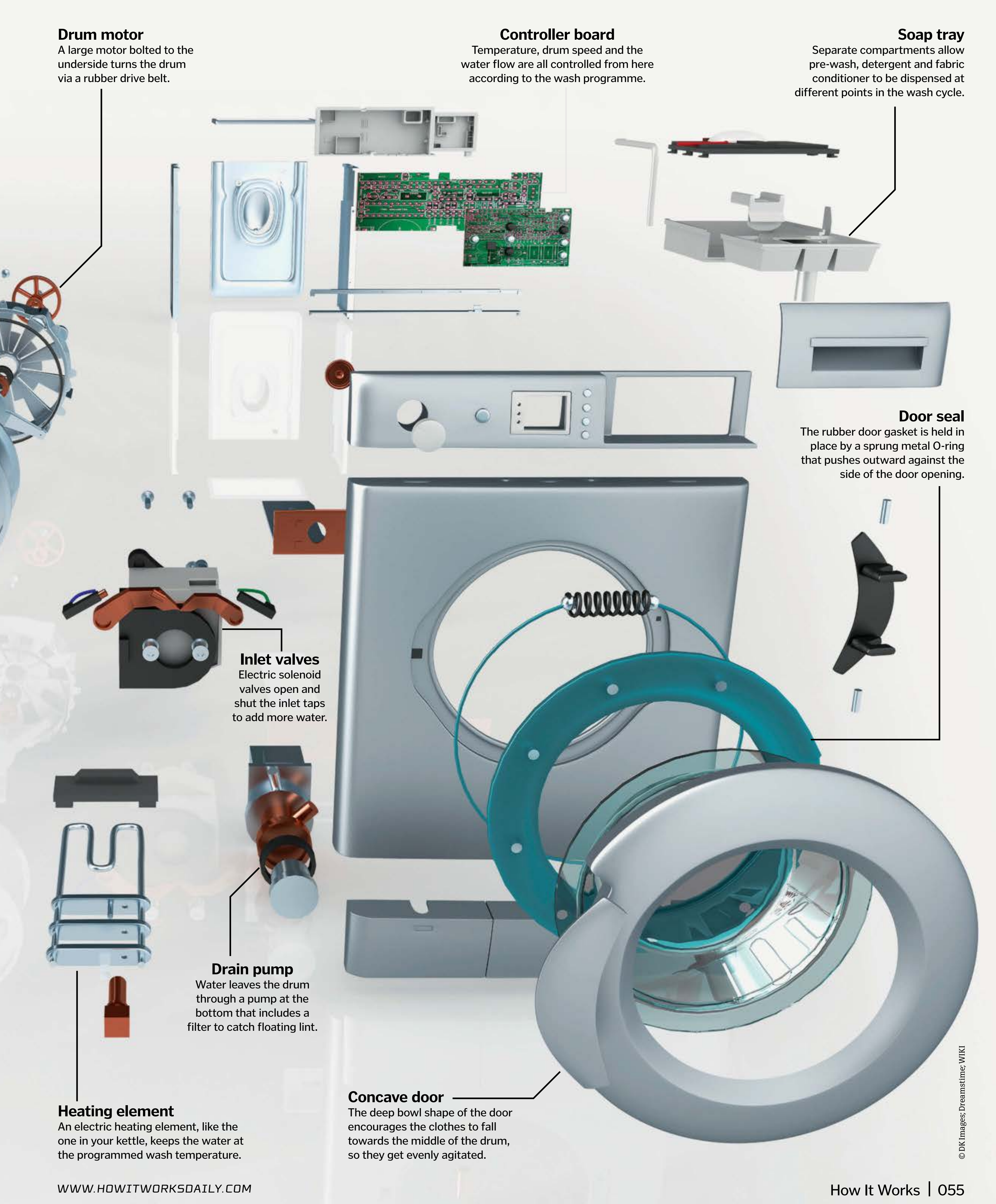
In 1907, Persil was the first commercially available detergent that included bleaching agents

Getting in a spin

Even the latest models still use the same simple design



"A motor turns the inner drum just fast enough that the clothes tumble against each other and dislodge the dirt particles"


Drum motor
A large motor bolted to the underside turns the drum via a rubber drive belt.
Controller board
Temperature, drum speed and the water flow are all controlled from here according to the wash programme.
Soap tray
Separate compartments allow pre-wash, detergent and fabric conditioner to be dispensed at different points in the wash cycle.
Door seal
The rubber door gasket is held in place by a sprung metal O-ring that pushes outward against the side of the door opening.
Inlet valves
Electric solenoid valves open and shut the inlet taps to add more water.
Drain pump
Water leaves the drum through a pump at the bottom that includes a filter to catch floating lint.
Heating element
An electric heating element, like the one in your kettle, keeps the water at the programmed wash temperature.
Concave door
The deep bowl shape of the door encourages the clothes to fall towards the middle of the drum, so they get evenly agitated.

Inside a loud speaker

Hear that? It's the sound of you learning about how speakers make noise

All speakers great and small use electromagnet mechanisms to pump out the sound waves

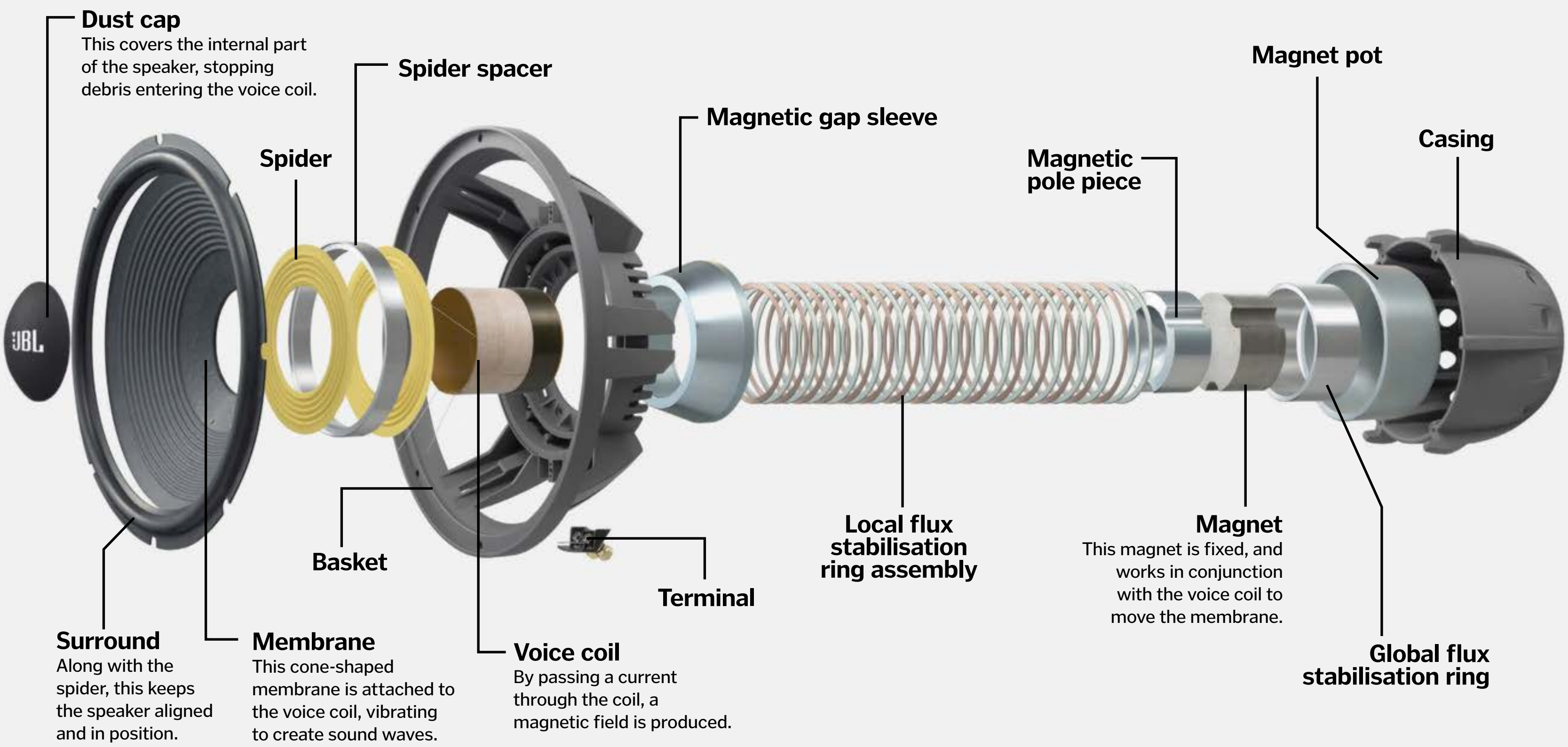
Whether you're listening to an audiobook through headphones on a train or drowning in sound in the front row at a festival, the key to how electric speakers work is magnetism.

In their simplest form, speakers use an electromagnet to move a cone-shaped membrane that vibrates to make noise. Inside the speaker, the mobile electromagnet is placed in front of a fixed, normal magnet. As electricity passes through the coil of the electromagnet, the direction of the magnetic field rapidly changes. This causes the electromagnet to continually be repelled by and attracted to the normal magnet, moving the cone-shaped membrane back and forth. The membrane pushes and pulls the surrounding air molecules, creating waves of sound that reach your ears.

The pitch of the sound is governed by the frequency of the vibrations, while the volume is controlled by the amplitude, or height, of the sound waves. Some types of speakers use multiple cones of various sizes to replicate the different frequencies in a piece of music.

Inside a Harman speaker

The key components that allow you to listen to music loud and clear



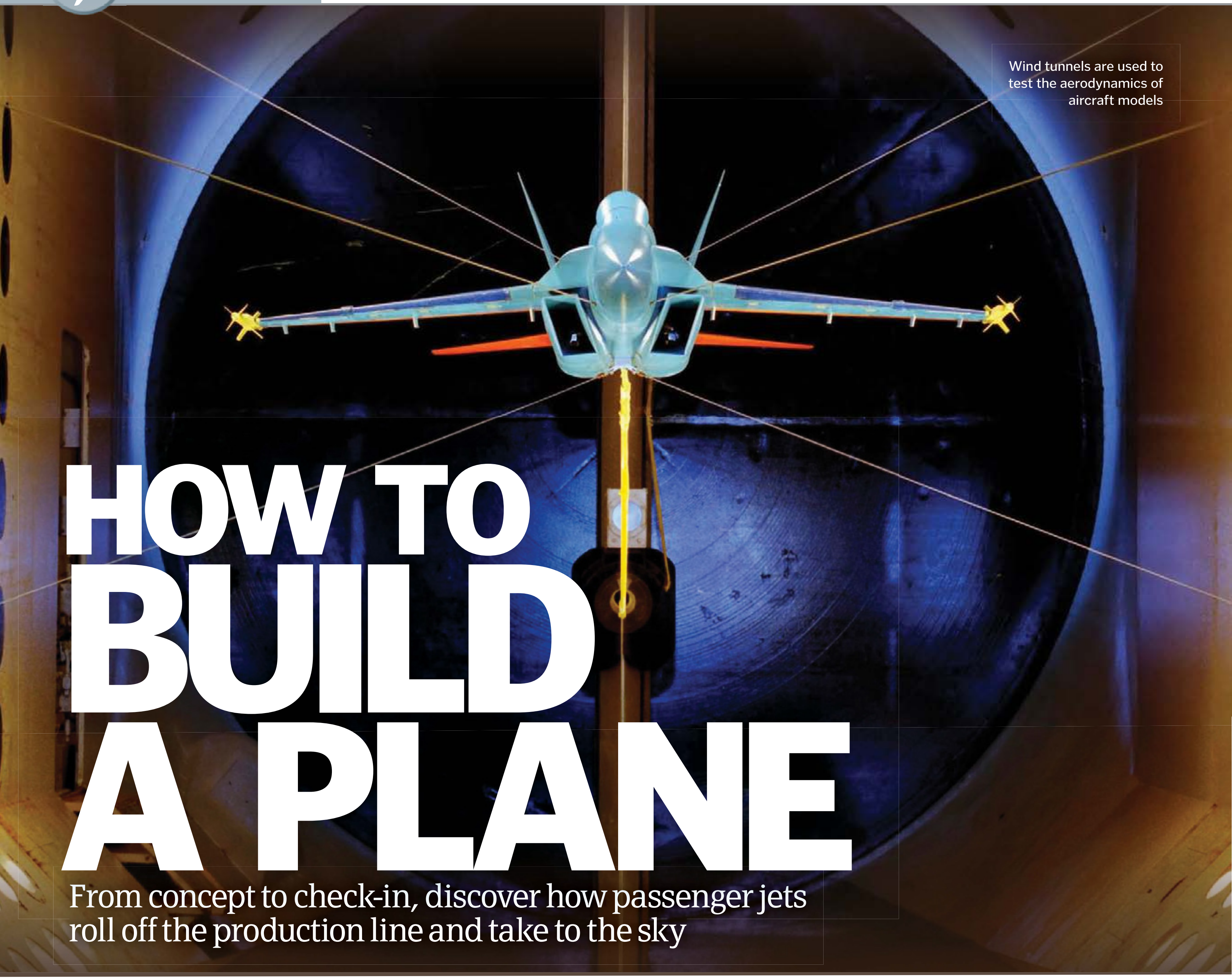
Egg timers eggsplained

It's a simple piece of kitchen kit, but do you know what makes it tick?

This trusty gadget can be the difference between satisfied bellies or a 'hangry' mob. Some mechanical egg timers count three minutes exactly (soft-boiled perfection guaranteed), but others are general-use timers that can extend to an hour or more. Turn the knob to the time desired, and leave the mechanism to tick steadily back before ringing out to let you know it's done.

As you twist the knob to the right, it winds up a spring inside the timer. This powers the countdown. A pendulum then swings back and forth to ensure that the seconds are ticking away accurately, like the mechanism inside a pocket watch. The pendulum is attached to a series of gears by an anchor, which ensures the gears cannot turn any faster or slower than the pendulum allows. As the seconds tick away, the spring uncoils towards its original position. When this is reached, the bell is triggered, letting you know your eggs are done.

Roasts, cakes, soufflés or just boiled eggs – the egg timer keeps tabs on time



Wind tunnels are used to test the aerodynamics of aircraft models

HOW TO BUILD A PLANE

From concept to check-in, discover how passenger jets roll off the production line and take to the sky

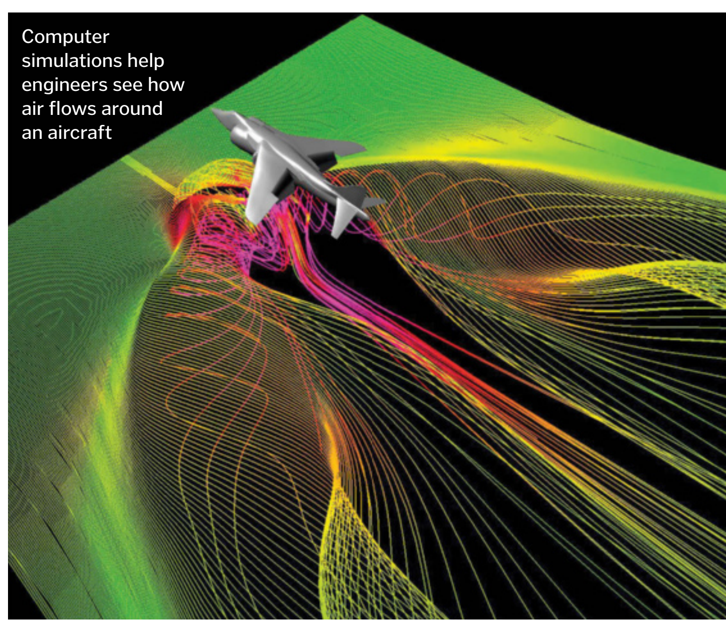
STEP 1: Design and testing

Before building can begin, the aircraft must first be designed in great detail. Thousands of engineers across the world often work together to design one plane, and it can take several years to get it right.

When designing an aircraft, there are four main areas to consider. First it must be aerodynamic, so that air flows around it with as little resistance as possible. To test this, engineers create computer simulations of the plane and examine how airflow and pressure will affect the body and wings when it is in flight. They then build a scale model of the aircraft and place it in a wind tunnel, where air is blown towards it at varying speeds in order to test its flight performance.

Next they must design the engines, making sure they are powerful enough to keep the aircraft in the air, fuel efficient to minimise running costs and pollution, and not too noisy. The way the plane handles in the air must also be considered, and so flight simulators are used to ensure it is easy and safe for the pilot to fly.

Finally, engineers determine what material to build the aircraft from, considering strength, weight, durability and cost, and how exactly it will be built.



Computer simulations help engineers see how air flows around an aircraft

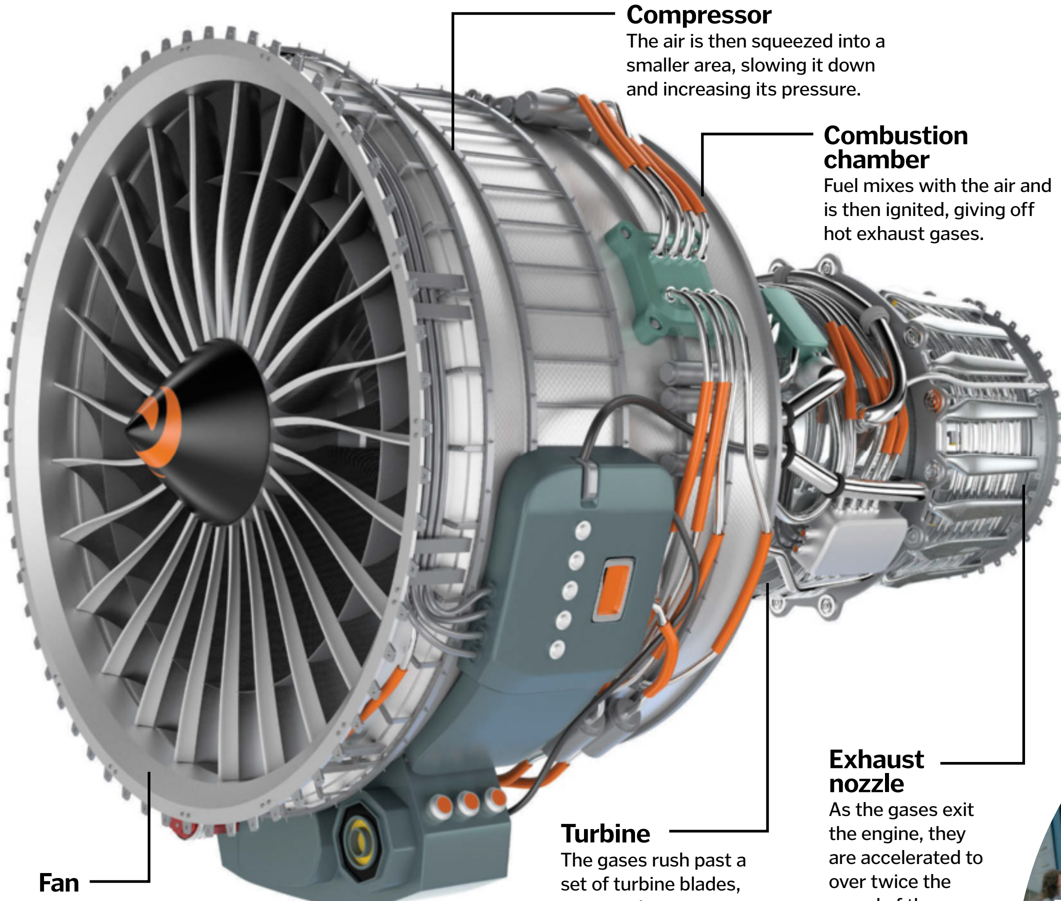
STEP 2:
Making the parts

A plane is made up of millions of different parts, from the enormous fuselage shell to the tiny rivets that hold it together. Many are made by the aircraft manufacturer itself, while others, including the engines and landing gear, are produced by external contractors. A huge number of different skills are required to build an aircraft, from mechanics and electronics, to plumbing and painting, so it takes teams from all over the world to make the finished product. Coordinating the production of a plane is a task in itself, as everything has to be made to a tight schedule and then transported to where it is needed for assembly. Plus, each part has to undergo rigorous testing to ensure it functions properly and is safe to use in the final aircraft.

Engineers building the aircraft spars, supporting beams that run the length of the wings

2.65 million
The number of parts in an Airbus A350 jet

How do jet engines work?
The machines that turn fuel into thrust



Compressor
The air is then squeezed into a smaller area, slowing it down and increasing its pressure.

Combustion chamber
Fuel mixes with the air and is then ignited, giving off hot exhaust gases.

Fan
The big spinning fan at the front of the engine sucks in large volumes of air.

Turbine
The gases rush past a set of turbine blades, causing them to spin and drive the compressor and fan.

Exhaust nozzle
As the gases exit the engine, they are accelerated to over twice the speed of the incoming air to create thrust.

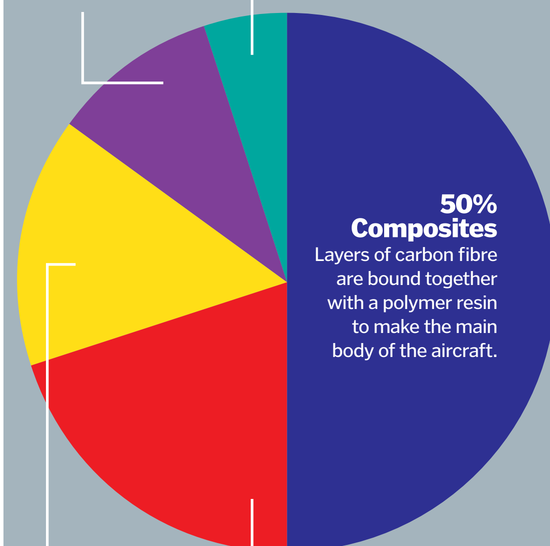
What is a plane made of?

The very first planes were built from wood and fabric, but thankfully modern aircraft are made of much stronger – and less flammable – stuff. Metal was once the material of choice, with strong, light aluminium used to build the main airframe and outer skin, but it was soon discovered to be corrosive and susceptible to stress.

Nowadays, manufacturers favour composite materials, which are stronger and more durable, yet still incredibly lightweight. To build the wings and fuselage of an aircraft, layers of carbon fibre and resin are built up, like layering several strips of sticky tape on top of each other.

The entire aircraft part is then placed in an enormous oven, called an autoclave, to harden the composite material until it becomes incredibly strong. Once it is complete, the windows and doors are cut out, and the whole thing is covered in a green protective coating, ready to be assembled.

What's in a plane?
The materials used to build a typical jumbo jet



10% Steel
Steel is stronger than aluminium so is used to build the landing gear.

5% Other
Plexiglass windows, fabric upholstery, and many other materials complete the aircraft.

50% Composites
Layers of carbon fibre are bound together with a polymer resin to make the main body of the aircraft.

15% Titanium
Its ability to withstand high temperatures makes titanium a good choice for constructing the engines.

20% Aluminium
Lightweight and strong, aluminium is still the main metal of choice for many parts of an aircraft.

Enormous ovens are used to harden the composite material on an aircraft

STEP 3: The final assembly

Putting together an enormous passenger jet requires an even more enormous building to do it in. Aircraft hangars are some of the largest buildings in the world, and are able to house several aircraft at once as they are passed from team to team along the assembly line.

First though, all the parts need to get there, and this is done by road, river and even air. Cargo aircraft such as the Airbus Beluga and Boeing Dreamlifter, are designed specifically to transport large pieces of aircraft to the final assembly point.

The individual pieces of the fuselage are fastened together using thousands of rivets, then the electrical and hydraulic systems, plumbing and insulation are installed. Next the wings are connected, using laser alignment to ensure they are perfectly level, and the landing gear is fitted underneath. This is followed by the tail, vertical stabilisers and an auxiliary power unit, which provides power to the aircraft when the engines are turned off. The cabin and cockpit interiors are then added, complete with seats and toilets.

Last of all, the engines are installed, as these are the most expensive component of the aircraft, representing over a third of its total value. Once assembly is complete, the plane is painted – this can take up to a week, depending on its size.


Planes are assembled in huge aircraft hangars by thousands of engineers


Aircraft slowly move along the assembly line as new parts are added


Giant cranes lift the parts of the fuselage in place, ready to be connected

72,000 square metres
The size of the Airbus aircraft hangar in Toulouse, France


The engines are fitted last, as they are the most expensive part of the aircraft

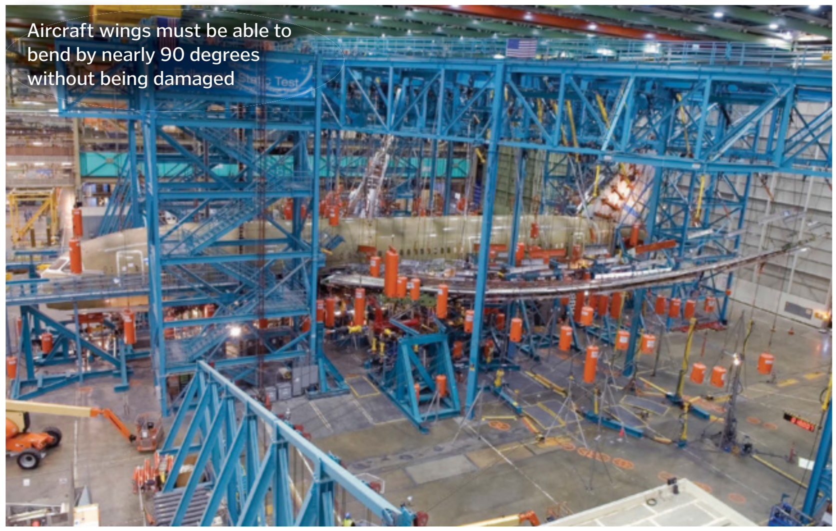
The Airbus Beluga cargo plane is so-called because it resembles a beluga whale

STEP 4: In-flight testing

If the aircraft is a new design, then the first few planes to roll off the assembly line undergo extensive prototype testing. This involves fitting them with a variety of sensors, and flying in extreme conditions, such as very hot and cold climates and really high altitudes. The individual elements of the aircraft are also tested, as the wings are forcibly bent to evaluate their strength, and dead birds are fired into the engines to see how they would cope with a bird strike.

To ensure the plane can withstand the stress of multiple take-offs and landings, computer-operated hydraulic jacks place heavy loads on the airframe for extended periods of time, and the plane may even be subjected to artificial lightning strikes to see how it performs in a storm. Once the first few planes have been rigorously tested, all successive aircraft are taken on their own test flights before they are deemed airworthy and delivered to airlines around the world.

Aircraft are tested on their ability to land on a waterlogged runway



Aircraft wings must be able to bend by nearly 90 degrees without being damaged

Ready for take-off!

The first Triple E was delivered in July 2013, and named the Maersk Mc-Kinney Moller

The world's largest ship

How this record-breaking vessel rules the waves

The largest, most monstrous, hands-down winner in the big ships size class is Maersk's Triple E design. Only a few metres wider and longer than the previous world record holder (also made by Maersk), the Triple E offers 16 per cent more container space due to its wider, bulbous bow.

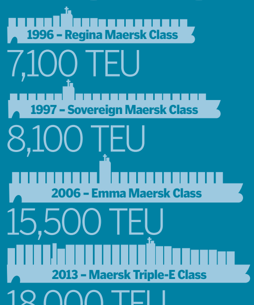
The engine is also positioned further back to aid stability and allows for yet more containers to be squeezed in above and below deck. The propellers are larger, and move slower to conserve fuel and reduce emissions, and the eco-friendly upgrades don't stop there. The hull is designed to be completely recyclable, while the ship's waste heat recovery system captures the heat and pressure from the exhaust and uses it to move turbines.

Colossal ships like this often look rather top-heavy, but they manage to stay afloat due to buoyancy. The weight of water the ship displaces is equal to the weight of the ship, so the forces balance and it floats.

The length of the vessel is so enormous that it has to be built in a way that can withstand the force of waves. To do this, cargo ships are made from flexible materials that can actually bend with the movement of the ocean. Inside the long corridors, it's possible to see the walls flexing and distorting as the craft moves in heavy swell.

18,000

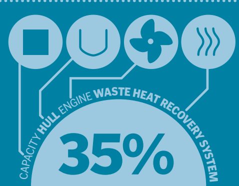
The Triple E can carry 18,000 20-foot equivalent unit (TEU) containers – that's 2,500 more than Maersk's second-largest vessel, the E-Class. One TEU can carry around six thousand pairs of trainers, so the Triple E can carry 108 million pairs – almost enough to provide everyone in Mexico with a set of sneakers!



$190 million USD

The estimated build cost of each Triple E vessel is roughly equivalent to the production cost of *Star Wars: The Force Awakens*.

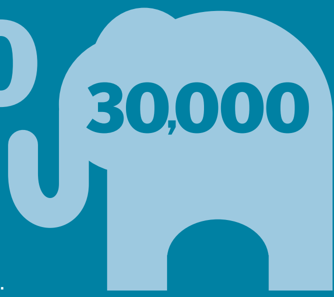
2 giant propellers



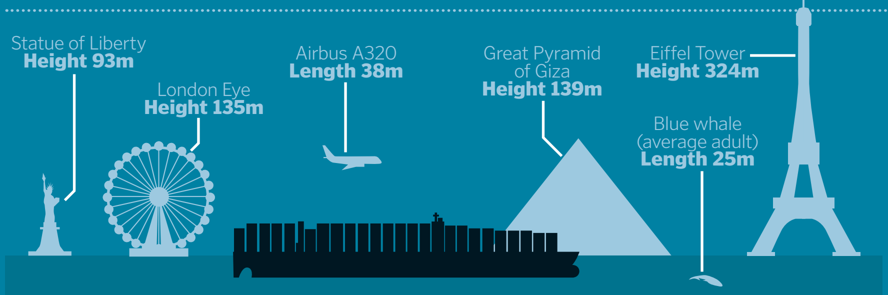
less CO_2

The Triple E design is more environmentally friendly.

165,000 metric tons



With a steel hull constructed from 425 individual pieces, the overall weight of the Triple E is 165 thousand metric tons – approximately the same weight as all the gold ever mined, or 30,000 African bush elephants.



400m long x 59m wide

The length of the Triple E cargo ship is slightly more than ten Airbus A320 passenger jets laid end to end.

13,500 nautical miles in 23 days

Reaching a top speed of 23 knots (43km/h), the Triple E will travel the Europe-Asia shipping route, delivering Chinese imports such as appliances, textiles and car parts.

WIN A SCALEXTRIC ARC AIR SET

Bring slot car racing to life with a revolutionary new system

Last year, Scalextric gave their slot car system an innovative update, launching ARC App Race Control to merge the on-track racing experience with on-screen gameplay functionality. By attaching the ARC ONE powerbase to the track you can wirelessly create and manage your races with your smart device, allowing you to set the number of laps, organise tournaments with your friends and even share your results online.

Now the update has been taken to the next level with the ARC AIR powerbase kit, which is compatible with any analogue Scalextric set. New features include wireless controllers, which allow you to move freely around the track and vibrate to alert you when you need a pit stop, as well as app updates on weather conditions and race incidents.

To get your hands on this revolutionary new racing game experience, all you need to do is answer one simple question. Two lucky winners will each win a Scalextric ARC ONE System Set and ARC AIR Powerbase Upgrade Kit worth over £200.

How to enter:

For a chance to win a Scalextric ARC AIR kit worth over £200, visit **howitworksdaily.com** and answer the following question by 21 April 2016.

In which decade did the first Scalextric set go on sale?

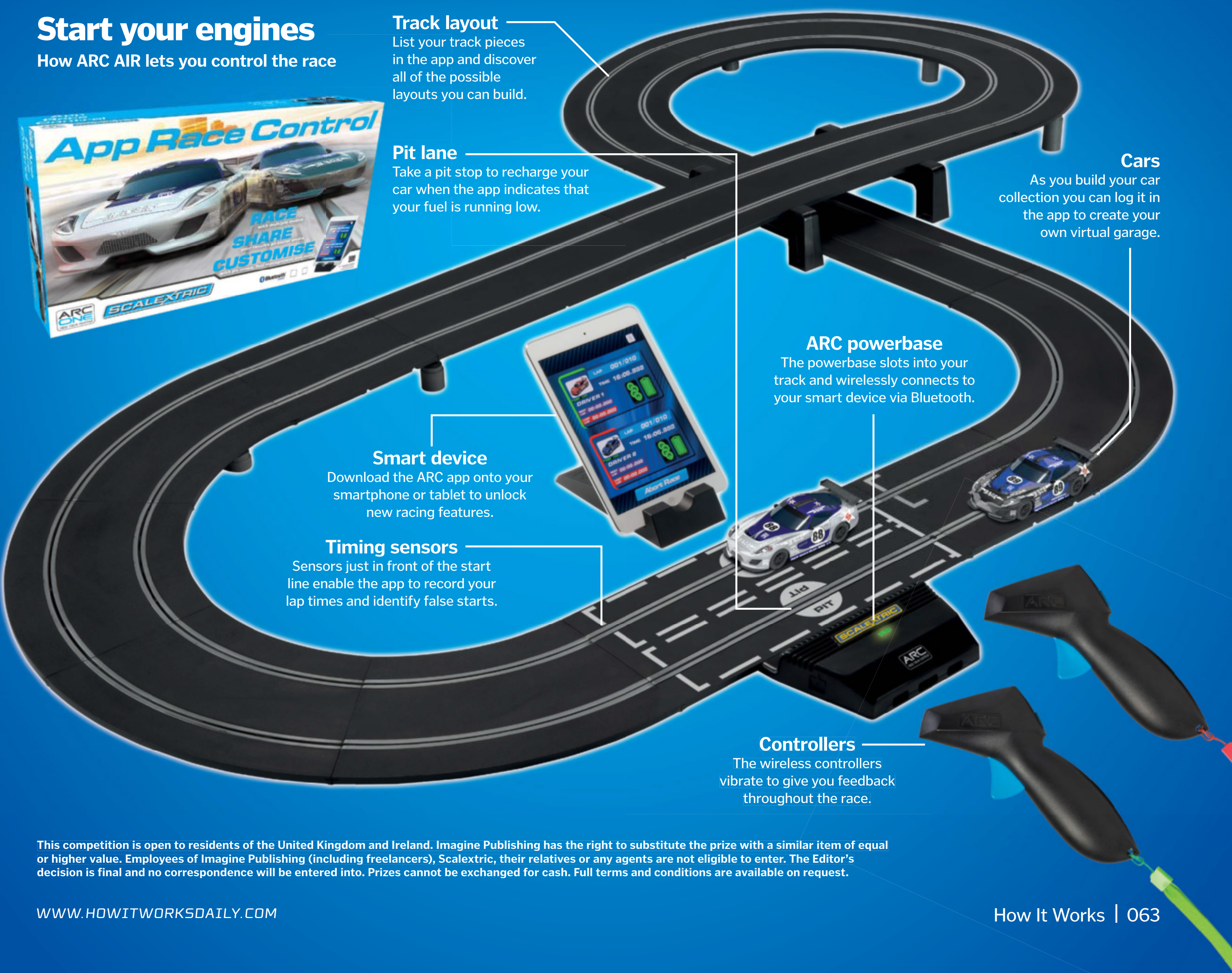
A) 1940s

B) 1950s

C) 1960s

Start your engines

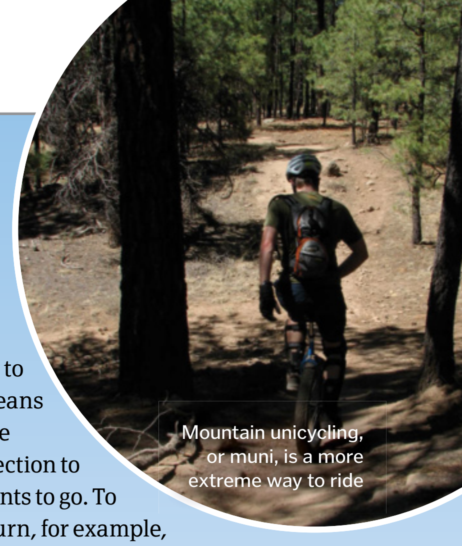
How ARC AIR lets you control the race



This competition is open to residents of the United Kingdom and Ireland. Imagine Publishing has the right to substitute the prize with a similar item of equal or higher value. Employees of Imagine Publishing (including freelancers), Scalextric, their relatives or any agents are not eligible to enter. The Editor's decision is final and no correspondence will be entered into. Prizes cannot be exchanged for cash. Full terms and conditions are available on request.

Balancing on a unicycle

Get a handle on the forces that keep you upright on one wheel



Mountain unicycling, or muni, is a more extreme way to ride

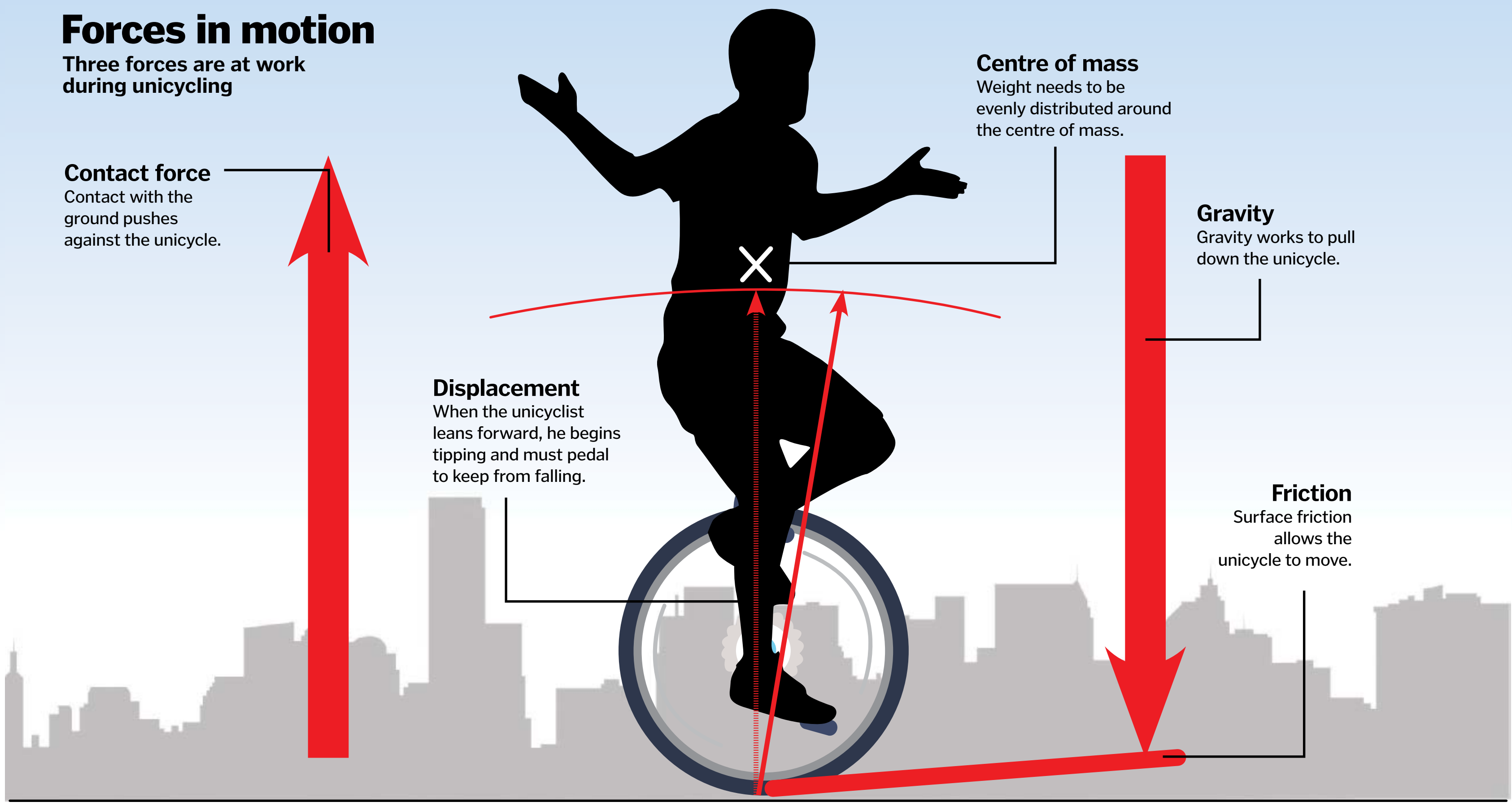
To balance on a unicycle, you have to keep pedalling. It's Newton's first law: an object in motion tends to stay in motion. Maintaining balance, however, is the hard part.

Three forces are at work here: gravity, contact and friction. Gravity pulls the unicycle down and contact force with the ground pushes back. The surface that the unicycle is moving along exerts friction, which is what allows the unicycle to balance, speed up and slow down. The rider has to keep perfect posture, in alignment with the frame of the unicycle. As soon as he starts to tip, he will fall as he is in unstable equilibrium. However, he must tilt his body to move.

In order to go forward, the unicyclist leans forward. This means changing the point of contact to maintain the centre of gravity, which means continuous pedalling. He also has to countersteer to turn. This means moving in the opposite direction to where he wants to go. To make a left turn, for example, he first steers slightly to the right so that he can lean to the left. It's a juggle of forces worthy of a circus.

Forces in motion

Three forces are at work during unicycling



What happens in a burnout?

This showy car manoeuvre has its origins in drag racing

Drivers execute a burnout by spinning their car's wheels while keeping the vehicle stationary. In a rear-wheel drive car with an automatic transmission, this means holding down the brake while pressing on the gas, then allowing the wheels to reach 5,000 RPM before releasing the brake. Burnouts in a manual transmission car are trickier, as the driver must release the clutch and quickly move that foot to the brake, while pressing the other foot on the gas. While the wheels spin, friction heats the tyres to as high as 200 degrees Celsius. This causes chemicals in the tread to vaporise, while any moisture around the tyres converts to steam.

Burnouts are illegal on the street, but they are so popular that there are even contests that measure the length of the streaks of rubber left on the pavement. They also serve an important function in drag racing, as they heat the tyres to the optimum temperature for racing, remove any foreign matter from the wheels, and create better traction at the starting line.

Burnouts are an impressive sight, as well as a great way to quickly ruin your tyre tread

Your car's air con explained


This cool tech relies on a chemical refrigerant to work

The subtle engineering that is sure to keep you cool behind the wheel

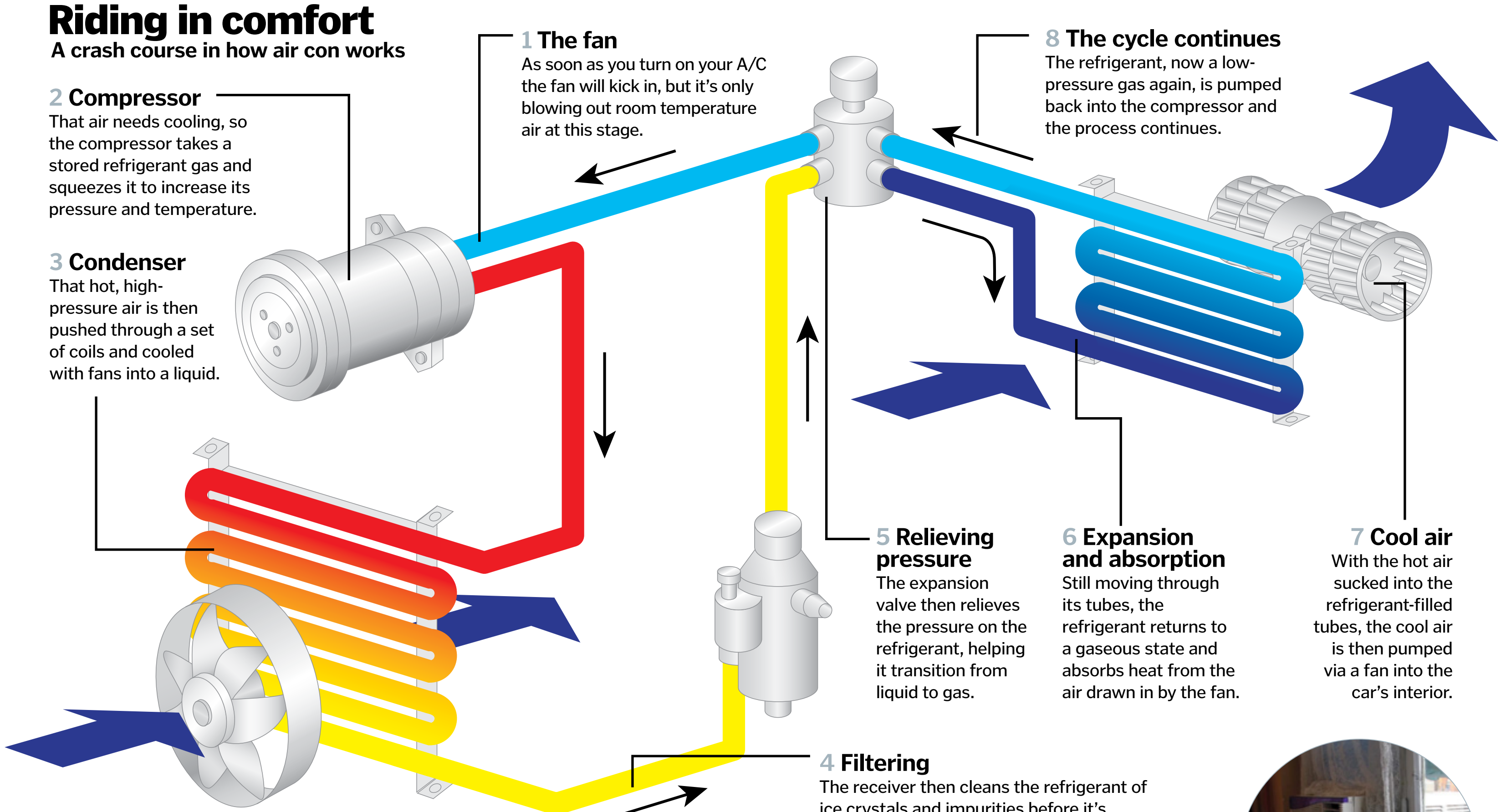
Like its stationary counterparts, the air conditioning unit in a car works on much the same principle. The process is broken down into four main stages – evaporation, condensation, compression and expansion – with each playing a vital role. It all starts when you press the A/C button on your dashboard. First off, a refrigerant gas (usually Puron or Freon) is pumped through a series of tubes by a compressor. Acting as the heart of the process, the compressor forces the vapour into a high-pressure state, causing its temperature to rise.

This hot air passes through a condenser, which uses fans to cool the refrigerant gas into a liquid. The cool liquid is then pumped into a receiver, which removes any moisture or ice crystals that could damage the circuit. Finally, it is pumped into an expansion valve that reduces its overall pressure, allowing it to pass into the evaporator.

The refrigerant has a very low boiling point and so becomes a gas again, even at the temperature of the car cabin. Heat from the air drawn in by the fans on the dashboard is then absorbed by the refrigerant, and the cool air that remains is pumped into the car's interior.

Riding in comfort

A crash course in how air con works



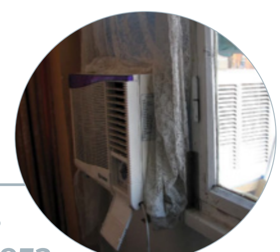
A brief history of A/C

1758
Humble beginnings
An early A/C is constructed by Benjamin Franklin and British chemist John Hadley as they discover alcohol can be used to freeze water.

1902
First commercial unit
US engineer Willis Carrier invents a unit that blows air over sets of cold coils to cool the warehouse of a publishing company.

1931
In the home
HH Schultz and JQ Sherman invent the first home-based air con unit, built outside of the house. This design is still used.

1939
Going mobile
The first air con unit is installed in a car by luxury company Packard, but they were already used in limousines from 1933.



1953
Air con takes off
After the US housing boom, air con units become a mainstay in suburbs across the nation. In 1953 alone, one million units are sold.

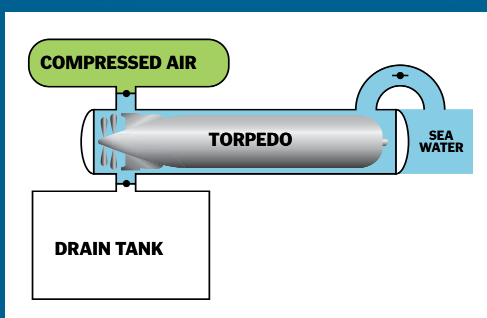
Firing torpedoes

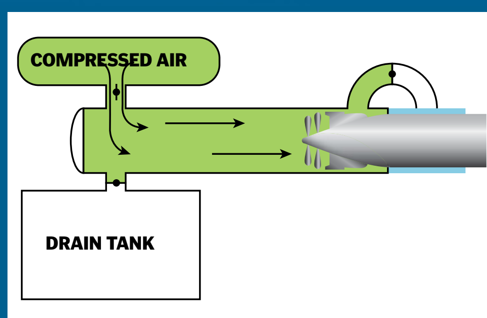
Learn how to unleash the ultimate underwater weapon

Torpedoes can be launched from both ships and submarines, using torpedo tubes lined up along the hull. World War II-era torpedoes were guided towards the target using an internal gyroscope, and their path could be fine-tuned using the rudders. A pendulum inside the torpedo kept it level. Many modern torpedoes are wire guided, so they can be controlled remotely after launch, before the wire is cut off and the internal guidance system takes over. Once the torpedo detects an enemy ship, or makes contact with it, the onboard explosive is detonated to rip a hole in its side and send it sinking without a trace.

Torpedoes are fired from ships and submarines through torpedo tubes

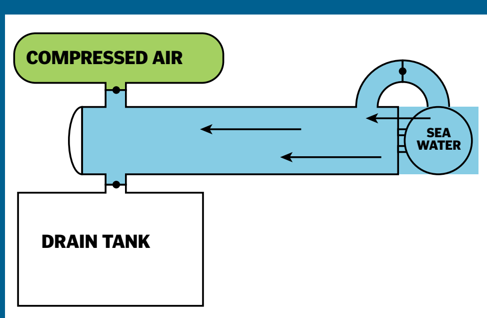
Load, aim and fire! How to fire a torpedo during battle

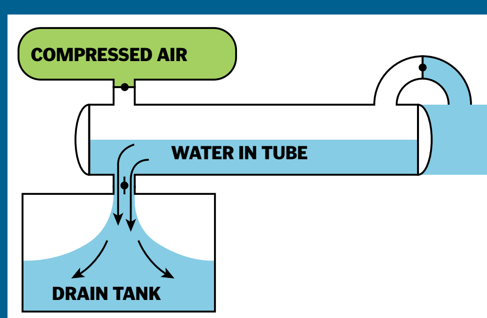




1 Load your weapon
Load the torpedo through the breech door at the back of the torpedo tube and then close it. Open the valve to flood the tube with seawater from outside the ship, equalising the pressure inside and outside the tube.

2 Fire!
Open the muzzle door at the front of the torpedo tube, then open the compressed air valve to eject the torpedo. The air is vented into the ship, so that a bubble cannot escape to the surface and give away the ship's position.





3 Maintain balance
Shut off the compressed air valve and the torpedo tube will then fill with seawater through the open muzzle door. This will help to offset the lost weight of the torpedo to keep the ship balanced.

4 Reset and repeat
Shut the muzzle door and open the valve to the drain tank to empty the water from the torpedo tube. Once it is empty, you can then open the breech door and load another torpedo to start the process again.

How do trams work?

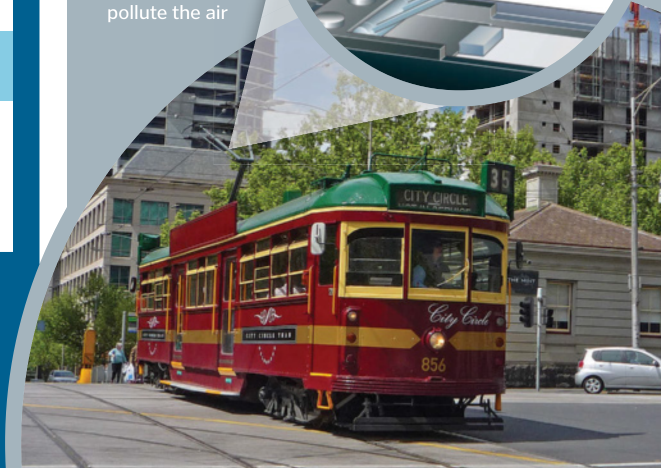
Hop aboard and discover how these green vehicles stay on track

The first trams were powered by horse and then steam, but the systems we have today are driven by electricity. Each tramcar has a long pole on its roof called a pantograph, which uses a spring-loaded mechanism to maintain contact with an overhead wire, called a catenary, running above the track. An electric current flowing through the wire is passed down the pantograph and to the tram's motors, which drive the wheels to keep it moving. To control the speed of the vehicle, the driver simply adjusts the amount of electricity that reaches the motors, increasing it to go faster, and decreasing it to go slower.

After flowing through the motors, the electricity is passed through the wheels to the rails of the track, where it flows back to the main power supply to complete the electric circuit. If any part of the circuit breaks, such as if the pantograph loses contact with the catenary wire, or the wheels come off of the track, the flow of electricity will stop and so will the tram.

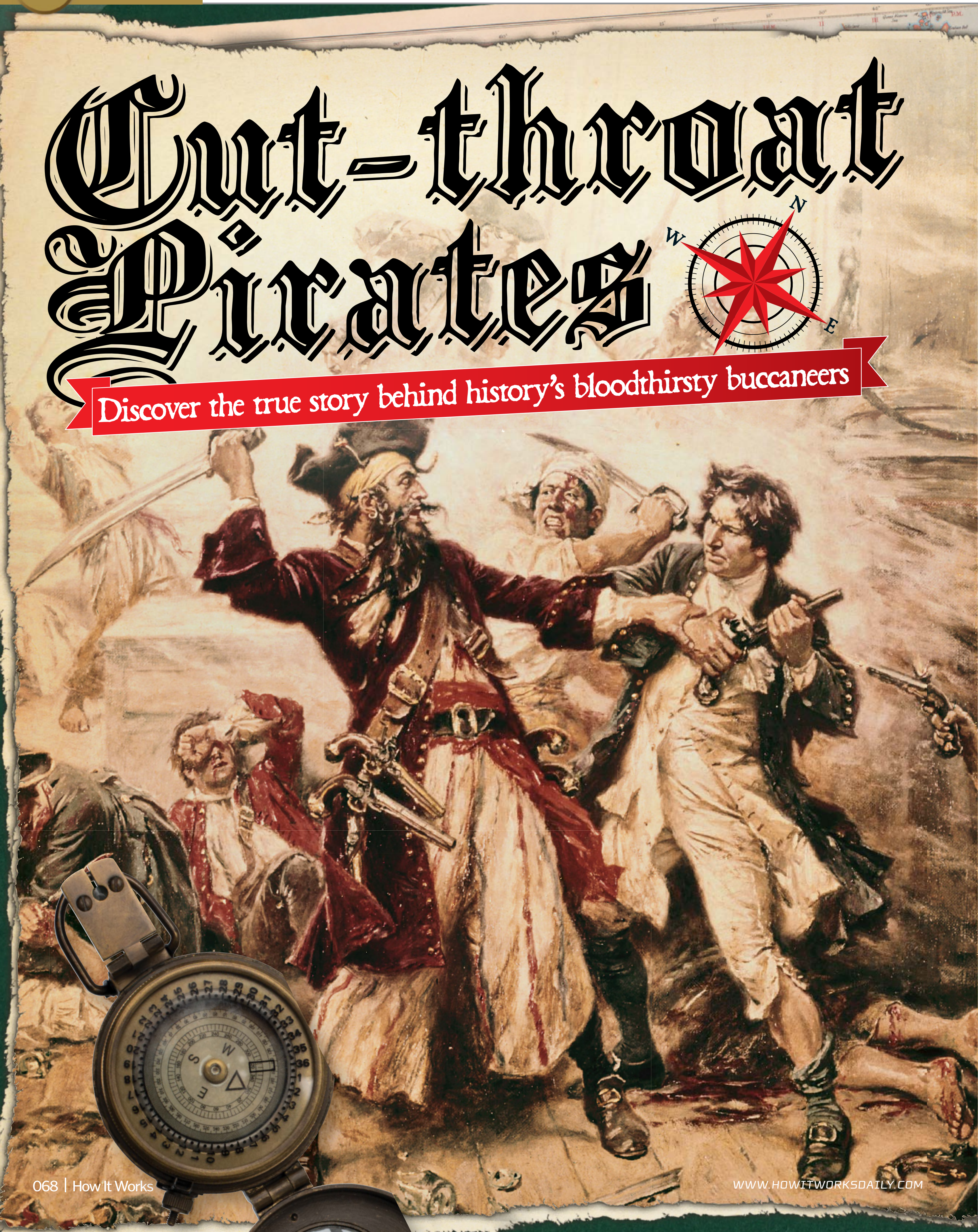
Electricity flowing through the overhead wire is passed to the tram via a pantograph

Electric-powered trams are quieter than buses or trains and do not pollute the air



Cut-throat Pirates

Discover the true story behind history's bloodthirsty buccaneers



In the 1600s, the ghoulish sight of the Jolly Roger could strike fear into the hearts of even the bravest seamen. Pirates had existed for as long as man had sailed the seas, but it was at this time that they truly began to rule the waves.

The colonisation of the New World and the birth of the slave trade meant that the oceans were swarming with richly laden merchant ships, and many men and women turned to a life of crime on the high seas. And what a life it was! A bottle of rum at breakfast and a buxom wench at supper, and in between a day spent stalking ships and trading spoils in pirate havens.

These hives of villainy, hidden away on islands in the Caribbean and Indian Oceans, served as launch sites for raids on enemy outposts and merchant ships. Here, pirates could repair their vessels away from the watchful eye of the Navy, while taverns, gambling halls and brothels provided welcome respite for pirates who had spent months at sea.

Over the years, pirates' lives became easier and even more lucrative. Sailors knew these bandits were skilled, well-armed, and willing to risk it all – the chance of winning a battle with them was slim. Ships that did put up a fight were shown no mercy, so their best option was to raise the white flag and surrender.

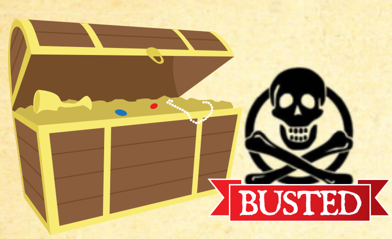
However, as the problem of piracy grew, merchant communities began to take matters into their own hands, arming and equipping ships at their own expense to protect commerce. These ships, captained by 'privateers', were licensed by the crown and could attack any enemy vessel. Over time, the line between privateer and pirate became blurred.

In a world where native populations were being wiped out or bound in chains, pirate life represented freedom and democracy. It's easy to see why many found it hard to resist the spoils of the Golden Age of Piracy.

From 1650 to 1720, thousands of pirates prowled the seas

PIRATE MYTHS BUSTED

Think you know these fearsome seafaring fiends? Think again, as we expose the truth behind the tales

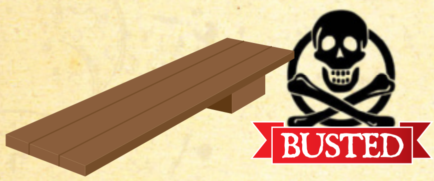


They buried their treasure

Loot was spent or sold immediately – a pirate's life was far too short for forward thinking.

They were brutal and bloodthirsty

It was much easier to capture a ship without conflict, so pirates encouraged them to surrender peacefully.



People had to walk the plank

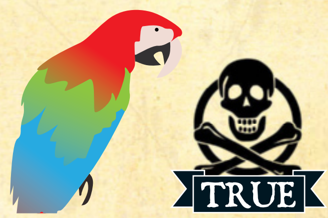
Anyone who did not surrender was simply thrown overboard – there was no time for elaborate ceremonies.

They flew the Jolly Roger

Initially flying a national flag to lure in victims, they quickly replaced this with the chilling skull and crossbones.

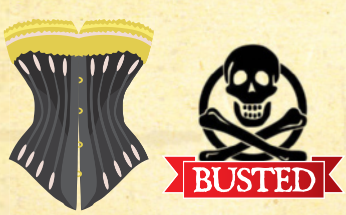
Captains were cruel tyrants

Pirate captains were elected democratically. If they stepped out of line, the crew could depose them.



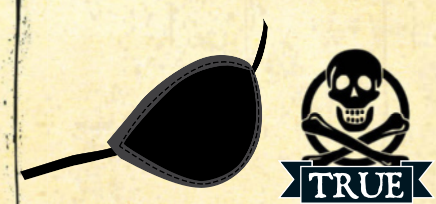
They had parrots on board

Plundered parrots could fetch a high price, so it wasn't uncommon for a pirate to have one on his shoulder.



Pirates were always men

Anne Bonny and Mary Read are just two of many female pirates that set sail, although both dressed as men.



They had peg legs and eye patches

Given the dangerous nature of their jobs, many pirates did lose a limb or an eye along the way.

SPOILS OF THE NEW WORLD

The discovery of the Americas not only fuelled economies, but also a reign of terror

When Spanish explorer Christopher Columbus set sail on what he believed to be a westward route to Asia, no one could have predicted that instead he would stumble across one of the most resource-rich continents in the world.

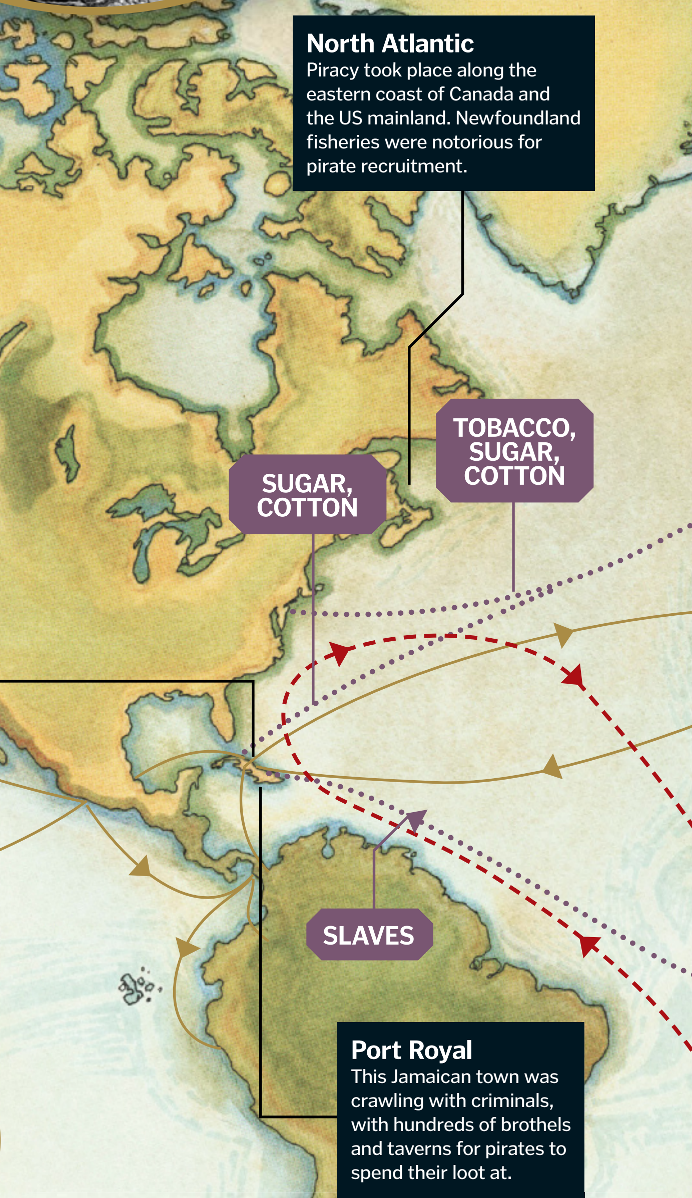
He returned from the Americas laden with gold, pearls and a strange plant called 'tobacco', kick-starting an era of frantic colonisation by Spain and other European powers, including the English, Portuguese and Dutch. They quickly began stripping the new land and sending back ships laden with its bounties.

As wars between the colonisers waged, many settlers and sailors cottoned on to the riches that these galleons had to offer. By the 1630s, buccaneers were in operation in the Caribbean, mostly made up of Frenchmen who had been driven off the island of Hispaniola by the Spanish. They relocated to the island of Tortuga, which provided limited resources on which to live. It was partly in retaliation and partly out of necessity that these buccaneers began attacking Spanish ships, plundering them for every penny.

The English, French and Dutch embraced these newly established pirates as they dealt a much-needed blow to the ever-strengthening Spanish. The English capture of Jamaica only served to bolster piracy, as its early governors semi-legitimised piracy and offered a safe haven in Port Royal – in return for a slice of the booty.

As Spain's power waned, the appeal of piracy faded with it, and letters stating legitimacy became harder to obtain. The buccaneers needed a new hunting ground. Rumours of ships laden with precious silks and spices sailing unprotected through Indian waters soon reached the rotten bunch, and in 1693, pirate captain Thomas Tew decided to seek one out. Setting sail from Bermuda, Tew cornered the Cape of Good Hope and cruised along the East African coast to the Red Sea, where he ran down a ship sailing from India to the Ottoman Empire. Despite its enormous crew, the ship surrendered and Tew's pirates helped themselves to £100,000 worth of gold and silver, as well as ivory, spices, gemstones and silk. The route, which was dubbed the Pirate Round, became one of the most profitable on the planet.

Pirate Henry Every captured a Mughal trading ship carrying £600,000 worth of goods

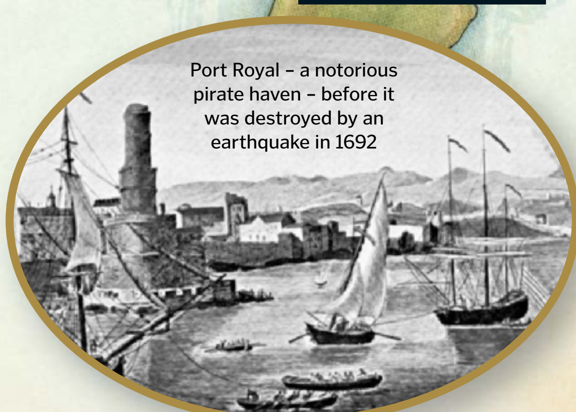


Precious cargo

Tobacco
Plunder like tobacco fetched a high price – if the pirate could bear to part with it.

Gold
Really lucky pirates might have stumbled across a vessel shipping Aztec treasures from Mexico to Spain.

Slaves
Not only could captured slaves be sold on, they could also be ransomed or made part of the crew.

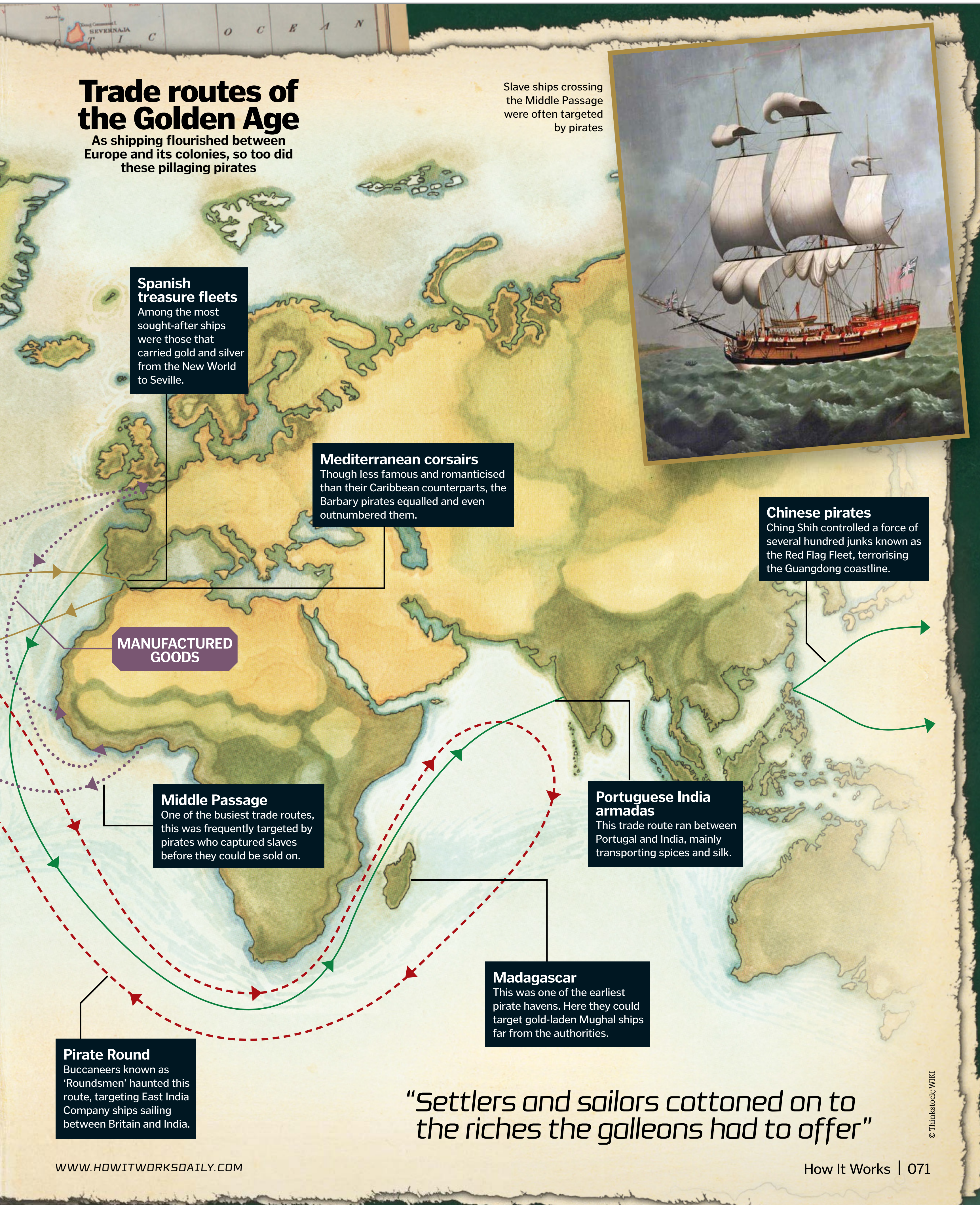


Port Royal – a notorious pirate haven – before it was destroyed by an earthquake in 1692

DID YOU KNOW? *Africans and African-Americans, often escaped slaves, made up a substantial part of the pirating force*

Trade routes of the Golden Age

As shipping flourished between Europe and its colonies, so too did these pillaging pirates



Slave ships crossing the Middle Passage were often targeted by pirates

Spanish treasure fleets

Among the most sought-after ships were those that carried gold and silver from the New World to Seville.

Mediterranean corsairs

Though less famous and romanticised than their Caribbean counterparts, the Barbary pirates equalled and even outnumbered them.

Chinese pirates

Ching Shih controlled a force of several hundred junks known as the Red Flag Fleet, terrorising the Guangdong coastline.

Middle Passage

One of the busiest trade routes, this was frequently targeted by pirates who captured slaves before they could be sold on.

Portuguese India armadas

This trade route ran between Portugal and India, mainly transporting spices and silk.

Madagascar

This was one of the earliest pirate havens. Here they could target gold-laden Mughal ships far from the authorities.

Pirate Round

Buccaneers known as 'Roundsmen' haunted this route, targeting East India Company ships sailing between Britain and India.

"Settlers and sailors cottoned on to the riches the galleons had to offer"

PIRATES VS PRIVATEERS

Tasked with keeping waters safe, privateers became as brutal as pirates themselves

Merchant vessels were a tempting target not only for opportunists, but also for rival countries. It was the English who first commissioned privateers to protect their cargo while in transit, issuing them with licenses to attack any ship that posed a threat. However, as time went on, the promise of plunder became just as legitimate a reason for battle as self-defence. Rather than a wage, privateers were paid with an agreed share of the takings, and the line between piracy and privateering became very blurred indeed.

On the face of it, the difference between these two vocations was simple. Pirates were criminals who acted alone, while privateers worked under the order of the crown. But the methods and end goals were the same. When Elizabeth I came to power, she encouraged merchants to keep port towns safe by preventing pirate ships from entering sea lanes. Anglo-Spanish relations were deteriorating, and war seemed inevitable. By allowing privateers to attack Spanish ships, Elizabeth could deny any direct involvement, while still getting a share of the profits. Her 'sea dogs', as they became known, included explorers Francis Drake and Walter Raleigh, but the Spanish saw them as simply state-sponsored pirates. Throughout this turbulent era, the status of many captains and crews swung between privateer and pirate depending on the state of international affairs and the paperwork they carried.

Many privateers were knighted, but others were not so lucky. In 1701, Scottish sailor William Kidd was hanged for piracy. He had set sail several years earlier with a government commission to suppress pirates in the Indian Ocean. Here, like many privateers of the time, he began to plunder foreign vessels indiscriminately, but conflict was growing among his crew. When they threatened mutiny, he struck the ship's gunner on the head with an ironclad bucket, delivering him a slow and painful death. When Kidd returned to the West Indies, he discovered he had been declared a pirate, and was arrested and sent back to England. After his hanging, Kidd's body was gibbeted over the River Thames as a warning to any would-be pirates.

HALL OF INFAMY

Historical records indicate that some pirates amassed incredible fortunes

Samuel 'Black Sam' Bellamy

The richest pirate in history, Black Sam treated his captives with mercy and likened himself to Robin Hood.

ESTIMATED EARNINGS

$120 million

Thomas Tew

With his flagship the Amity, Tew mapped one of the most infamous routes of the Golden Age – the Pirate Round.

ESTIMATED EARNINGS

$103 million

Bartholomew 'Black Bart' Roberts

Considered the most successful pirate of the era, Black Bart captured a staggering 470 ships.

ESTIMATED EARNINGS

$32 million

Henry Morgan

Perhaps now best known for the rum named after him, 400 years ago Morgan was renowned for his brutal raids.

ESTIMATED EARNINGS

$13 million

Edward 'Blackbeard' Teach

The terrifying sight of Teach and his notorious beard would make any sensible captain surrender immediately.

ESTIMATED EARNINGS

$12.5 million

Edward England

England started out as a privateer, but pledged his allegiance to piracy after being captured.

ESTIMATED EARNINGS

$8 million

Stede Bonnet

Nicknamed the Gentleman Pirate, Bonnet turned to a life of crime after growing tired of his upper class background.

ESTIMATED EARNINGS

$4.5 million

Charles Vane

This pirate was infamous for his barbaric leadership style, and loved nothing more than to torture his crew members.

ESTIMATED EARNINGS

$2.3 million

Edward Low

Low became a pirate after his wife died in childbirth. He was known for his horrifically creative torture methods.

ESTIMATED EARNINGS

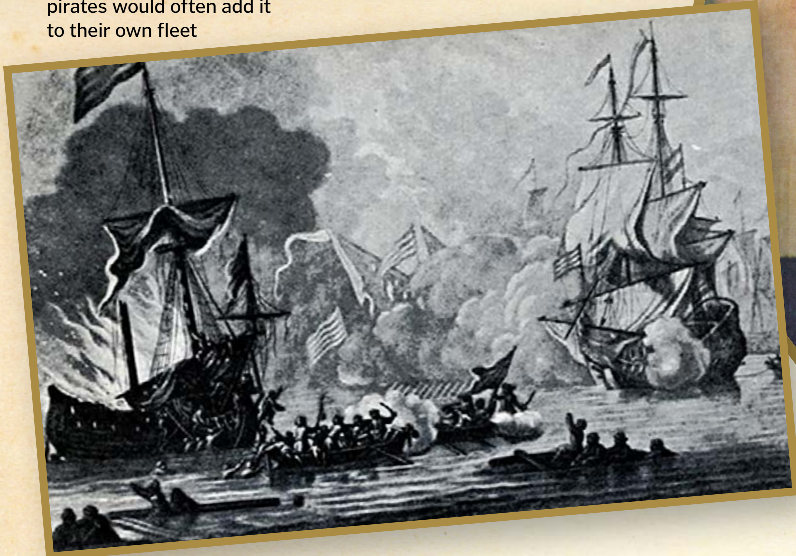
$1.8 million

John 'Calico Jack' Rackham

Calico Jack designed the Jolly Roger, and had two infamous female pirates in his crew – Mary Read and Anne Bonny.

ESTIMATED EARNINGS

$1.5 million


After capturing a ship, pirates would often add it to their own fleet


Blackbeard was one of the most dreaded pirates of the era

SEIZING MERCHANT VESSELS

Far from being spontaneous attacks, pirate raids were meticulously planned

1 The perfect location

Not only was the Caribbean the epicentre of trade between Europe and the colonies, it was also teeming with uninhabited islands and secluded coves in which pirates could covertly lie in wait for their prey.

2 Gathering intelligence

Pirates didn't attack any old ship. On land, they would eavesdrop in taverns to find out what cargo was to be transported and when, and at sea they would stalk targets to find out how many men and weapons were on board.

3 Raising the Jolly Roger

The sight of the dreaded skull and crossbones often scared sailors into surrendering peacefully, but before it was raised, pirates flew the flag of the victim ship to lull them into a false sense of security.

4 Attack!

A warning shot was fired to signal an imminent attack. Grappling hooks were used to pull the ship close enough for the pirates to board and wooden wedges were jammed into the rudder to prevent it from being steered.

5 Dealing with the enemy

What do you do with a captured sailor? Well, there were a few options. Pirates could hold them for ransom, integrate them into their crew, or keep them as slaves. Anyone who tried to fight back would be thrown overboard.

6 The booty

The sailors were stripped of any valuables and the cargo holds ransacked. The loot would then be divided up between the crew, with the captain receiving the biggest portion. The ship would be added to the pirate fleet or sunk.

QUEEN ANNE'S REVENGE

Like her captain, this infamous pirate ship started life in the Royal Navy

Despite his legendary reputation, little is known about why a young sailor named Edward Teach decided to grow out his beard and turn to a life of piracy. Blackbeard, as he became known, is believed to have lived in Bristol before setting sail for the Caribbean, where he worked on privateer ships during Queen Anne's War. In around 1716, he joined the crew of renowned pirate Benjamin Hornigold, and later that year he was placed in command of his own sloop.

It was in autumn 1717 that Blackbeard and his fellow pirates captured the French slave ship La Concorde – originally a Royal Navy ship – off the coast of Martinique. With the French crew already weak with dysentery and scurvy, they hastily surrendered, and the ship fell into Blackbeard's hands. He made her his flagship and renamed her Queen Anne's Revenge, and for several months he cruised the Caribbean, plundering ships along the way.

By May 1718 he had reached Charleston, South Carolina, and it was here where he made one of the most audacious moves of his career: he blockaded the Charleston harbour. Demanding a ransom of a chest of medicine, his demands were eventually met, but it was not enough to save his beloved flagship. On leaving the port, Queen Anne's Revenge ran aground, and Blackbeard was forced to abandon ship.

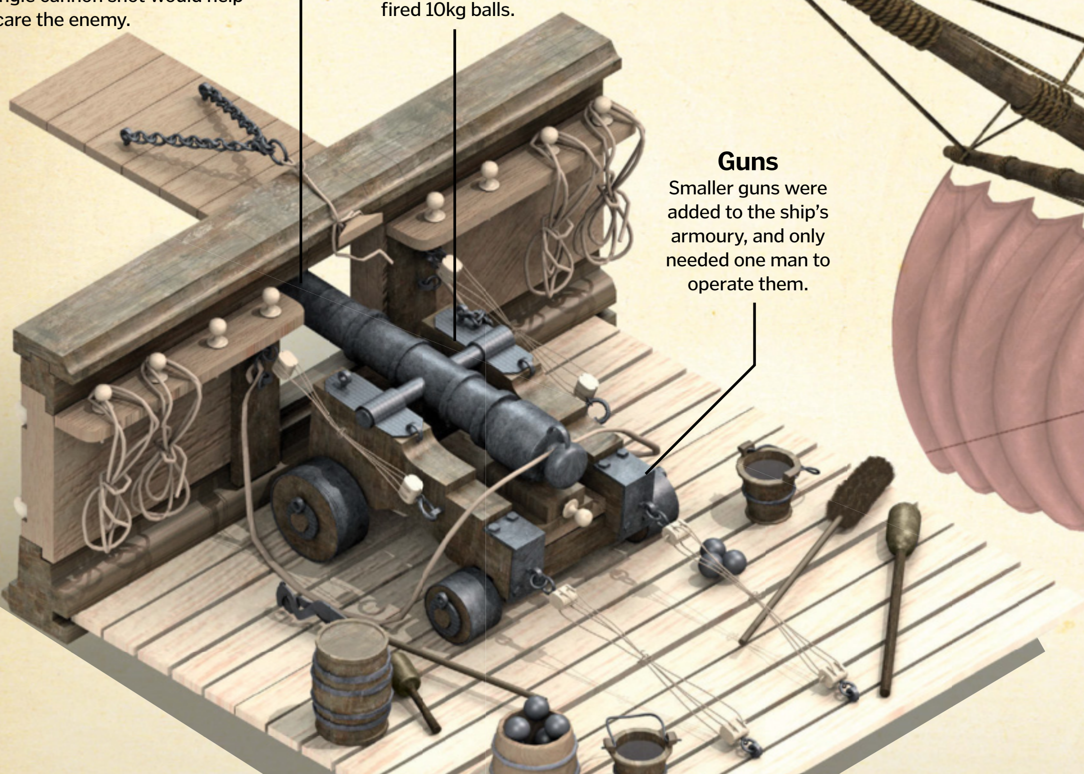
The decline of piracy

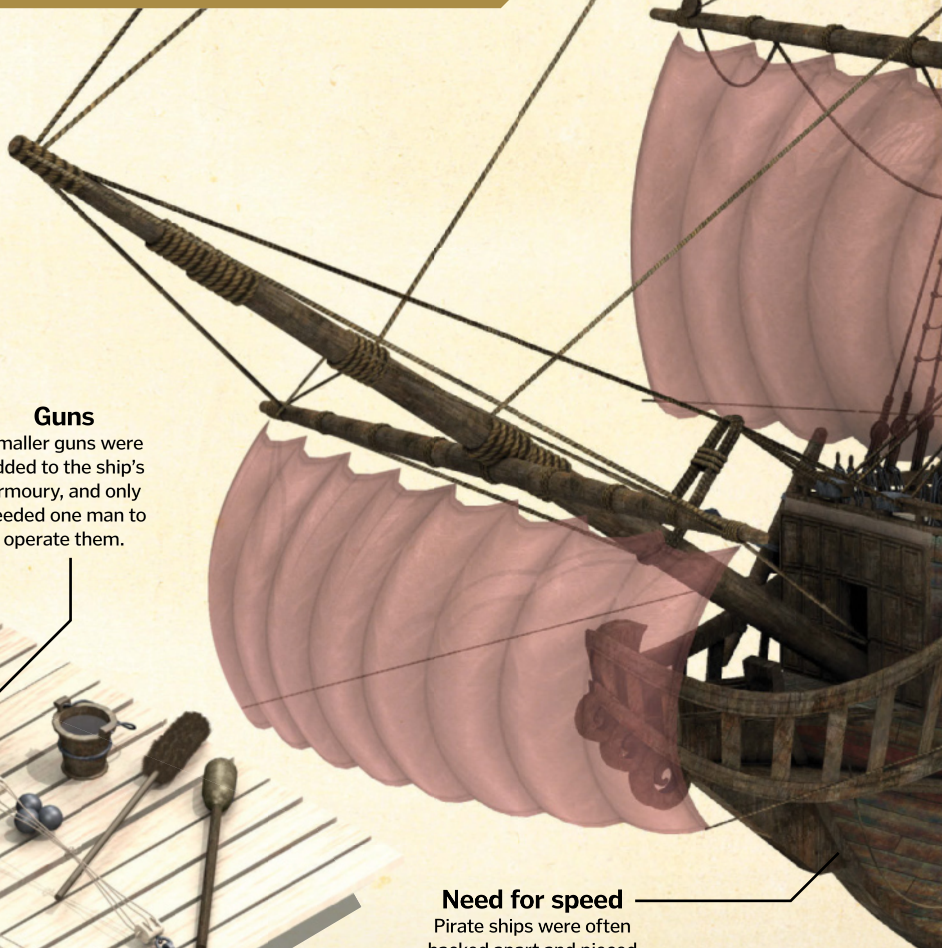
By the 18th century, nations had grown weary of the sea battles that waged between the belligerents of the Spanish Succession. In 1713, a peace treaty recognised Philip, Duke of Anjou, as King of Spain, ending the chance of French rule. Many of Spain's colonies were divided up between European states, and the war ended the following year.

With this newfound peace came a surplus of sailors, previously employed as privateers or by their nation's navy. Initially this led to an increase in piracy, but in response European countries bolstered their naval forces. With the lure of Spanish treasure gone, and with navies now patrolling every port, pirates had very little left to live for, and by 1719, most were on the run. The Golden Age of Piracy was dead.

Not for the faint hearties

Take a look at the tech and weaponry that made this ship so successful

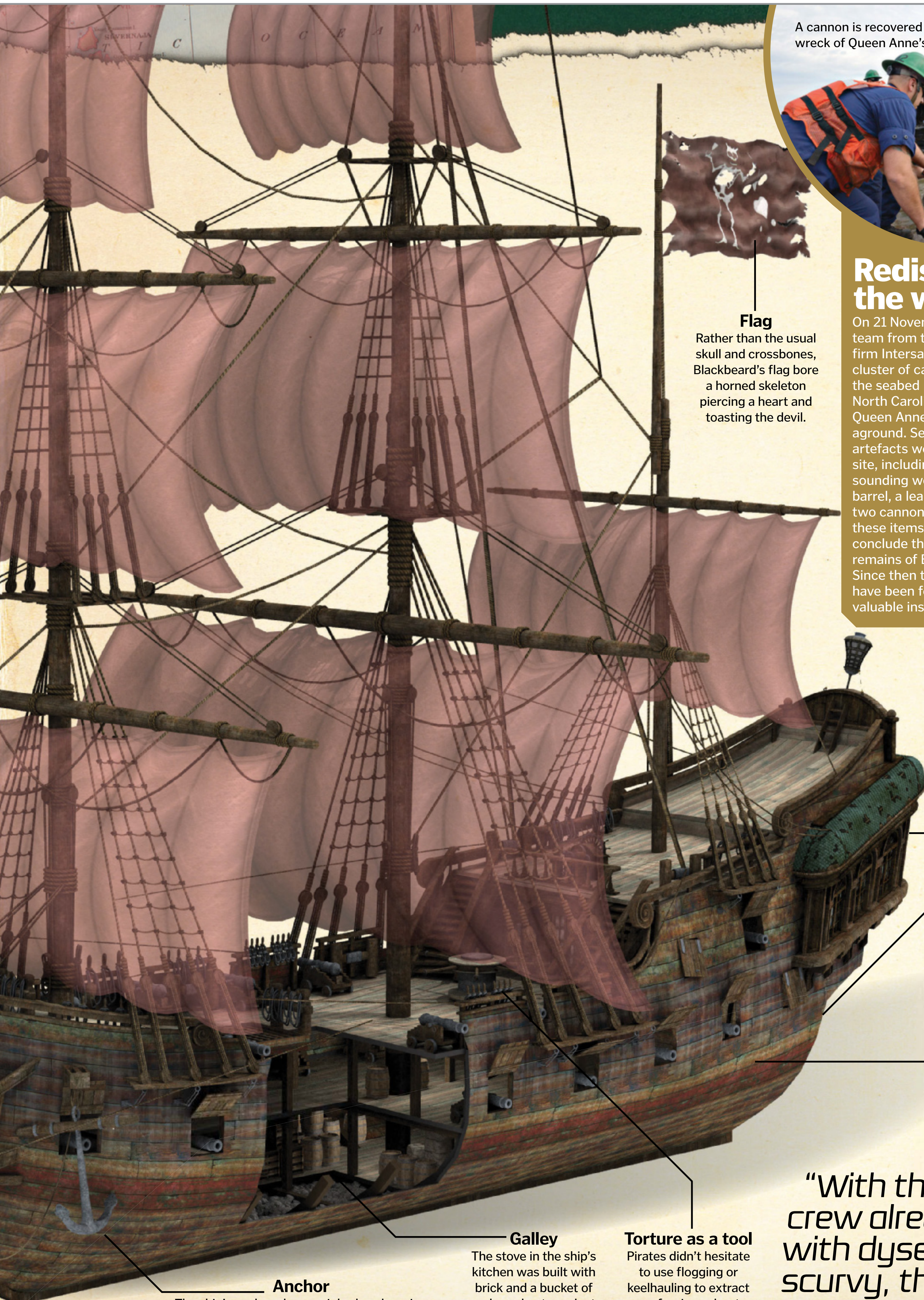




A cannon is recovered from the wreck of Queen Anne's Revenge

Rediscovering the wreck

On 21 November 1996, a search team from the private research firm Intersal, Inc. discovered a cluster of cannons and anchors on the seabed near Beaufort Inlet, North Carolina – the spot where Queen Anne's Revenge had run aground. Several early 18th century artefacts were recovered from the site, including a bronze bell, a sounding weight, a blunderbuss barrel, a lead cannon apron and two cannon balls. The discovery of these items led the researchers to conclude that this was indeed the remains of Blackbeard's flagship. Since then thousands more objects have been found, offering a valuable insight into life on board.



Flag
Rather than the usual skull and crossbones, Blackbeard's flag bore a horned skeleton piercing a heart and toasting the devil.

Blackbeard's quarters
Located at the rear, the captain's cabin was sheltered from the elements and easy to defend in case of a mutiny.

Supplies
Previously a slave ship, the vessel had a huge hold that could store rigging, food and drinking water.

Lucky dip
Merchant ships could be carrying anything from sugar and rum, to gold and jewels.

Torture as a tool
Pirates didn't hesitate to use flogging or keelhauling to extract confessions about hidden treasure.

Galley
The stove in the ship's kitchen was built with brick and a bucket of sand was kept nearby to put out flames.

Anchor
The ship's anchor alone weighed a whopping 1,400kg, and took almost an hour to raise.

"With the French crew already weak with dysentery and scurvy, they hastily surrendered"

Flying close to the Sun

Solar physicist Lucie Green explains the daring mission to answer big questions about our star

Lucie studies the activity of our nearest star and how it affects us on Earth

Ever since she first looked at the Sun through a solar telescope, Lucie Green has been fascinated with finding out how it works. Although our closest star has given up many of its secrets over the years, there is still a great deal left to discover about the huge ball of plasma that provides our heat and light. Working at University College London's Mullard Space Science Laboratory, and alongside space agencies such as NASA and the European Space Agency, Green is involved in some exciting projects to learn more about our host star. From studying giant eruptions on its surface to measuring strong solar winds, she hopes to be able to answer some of the biggest questions about not just the Sun, but the entire universe too. We caught up with her to discuss how she plans to get closer to the heart of our Solar System than ever before.

Why is it important to study the Sun?

The Sun is the star that we can study in the most detail because it's the closest star to us. When we look at the Sun, we see the whole object. We can see the surface, the atmosphere, and we can make out certain features, whereas when you look at the majority of other stars, they're just points of light. So the Sun ends up being a bit like a Rosetta Stone for other stars. We can develop techniques to understand what's happening on the Sun and then apply them across the universe. Another reason is that solar activity has an impact on our planet. It drives space weather, which can have a negative impact on our technology.

How much do we already know about how the Sun works?

We've been observing the Sun with telescopes for over 400 years, and from space since the 1940s, so we have a good observational description of what the Sun does. We are now trying to see the physical processes happening at smaller and smaller size scales that we can't make out with our telescopes.

Another thing we want to know is how the solar cycle works. The Sun's activity follows an 11-year cycle where it rises and falls and we know that this is driven by an evolution of the Sun's magnetic field. However, because it

"The Sun's activity follows an 11-year cycle, and we know that this is driven by an evolution of its magnetic field"

occurs inside the Sun where it is very hard to probe, we don't have a fully developed physical understanding of how it operates as a star.

What technology is being used to try and answer these questions?

On the ground we have detectors that look at the Sun in the wavelengths of light that make it through the atmosphere, such as visible light and some parts of the radio spectrum. Then we can also do detections of particles on the Earth as well. For example, a by-product of the fusion process that powers the Sun is particles called neutrinos, and you can measure those neutrinos on the ground.

There's also a lot that we want to do from space, in particular focusing on parts of the Sun's emissions that we can't detect on the Earth. For example, wavelengths of light like ultraviolet, X-rays and gamma rays that don't make it through the Earth's atmosphere.

Another benefit of being above the atmosphere is that we get a much clearer view. For example, we have telescopes that create artificial solar eclipses, called coronagraphs, and they are typically flown in space. Using these coronagraphs you can see the ejections that the Sun sends out into the Solar System, so you get a crisper view of one of the forms of solar activity.

What projects are you currently working on?

One project I'm working on is Solar Orbiter. It's a really ambitious project, a sort of Icarus-like mission to fly close to the Sun and take close-up pictures. However, as well as taking images, the spacecraft will sit in the flow of material that constantly comes out of the Sun, so we can sense it directly as it washes over it.

That's going to allow us to answer some of the big questions about the Sun. For example, the Sun produces a strong wind but we don't know exactly how it is produced. Solar Orbiter is going to measure the wind as it blows over the spacecraft, so we will be able to work out what it's made of, the temperature of it, what magnetic field is in it, the characteristics of it and then try and understand more information about how that wind is formed.

How will you overcome the challenges of getting a spacecraft near to the Sun?

The side facing the Sun will heat up to 600 degrees Celsius, and as you can imagine, you can't have that heat falling on your instruments. A heat shield has been developed that stops that intense radiation falling on the main part of the spacecraft. Also, because the orbit of this spacecraft goes close to the Sun then takes it further out again, its temperature is changing from hot to cold and back again, so we need to create a stable environment behind that heat shield. Solar Orbiter has solar panels that will tilt so that you can regulate how much light is falling on them as you get closer to or further away from the Sun.

Joining an astronomical society is a great way to get stargazing advice

"Telescopes in space can create artificial solar eclipses, so you get a crisper view of solar activity"

What other big space stories have you been most excited about recently?

Mars is the focus for me at the moment. I am working on a European Space Agency mission to go to Mars so I'm always keeping an eye on what the rovers are looking at. Then there's Pluto and the New Horizons mission. The images taken by that spacecraft are absolutely incredible. I can't believe there are floating mountains on Pluto, and vast nitrogen plains. They are still downloading data from that spacecraft, so I can't wait to see more results.

Learn more

Lucie Green's *15 Million Degrees: A Journey To The Centre Of The Sun* is released on 31 March 2016.

Lucie Green's astronomy top tips

Learn the constellations

"Start off by familiarising yourself with the night sky. Orion is my favourite constellation because it's got everything, including star-forming regions and stars that have been kicked out of the constellation in the past."

Get kitted out

"Buy a pair of binoculars and then work up to having a telescope. You can also get lots of support and share in the excitement of learning about astronomy by joining a local astronomical society."

Look at the moon

"You can look at the Moon during the different phases, and spot different craters. You can really get a feel of the 3D nature of the surface by looking at the shadows that are cast. I never tire of getting my binoculars out and looking at the Moon."

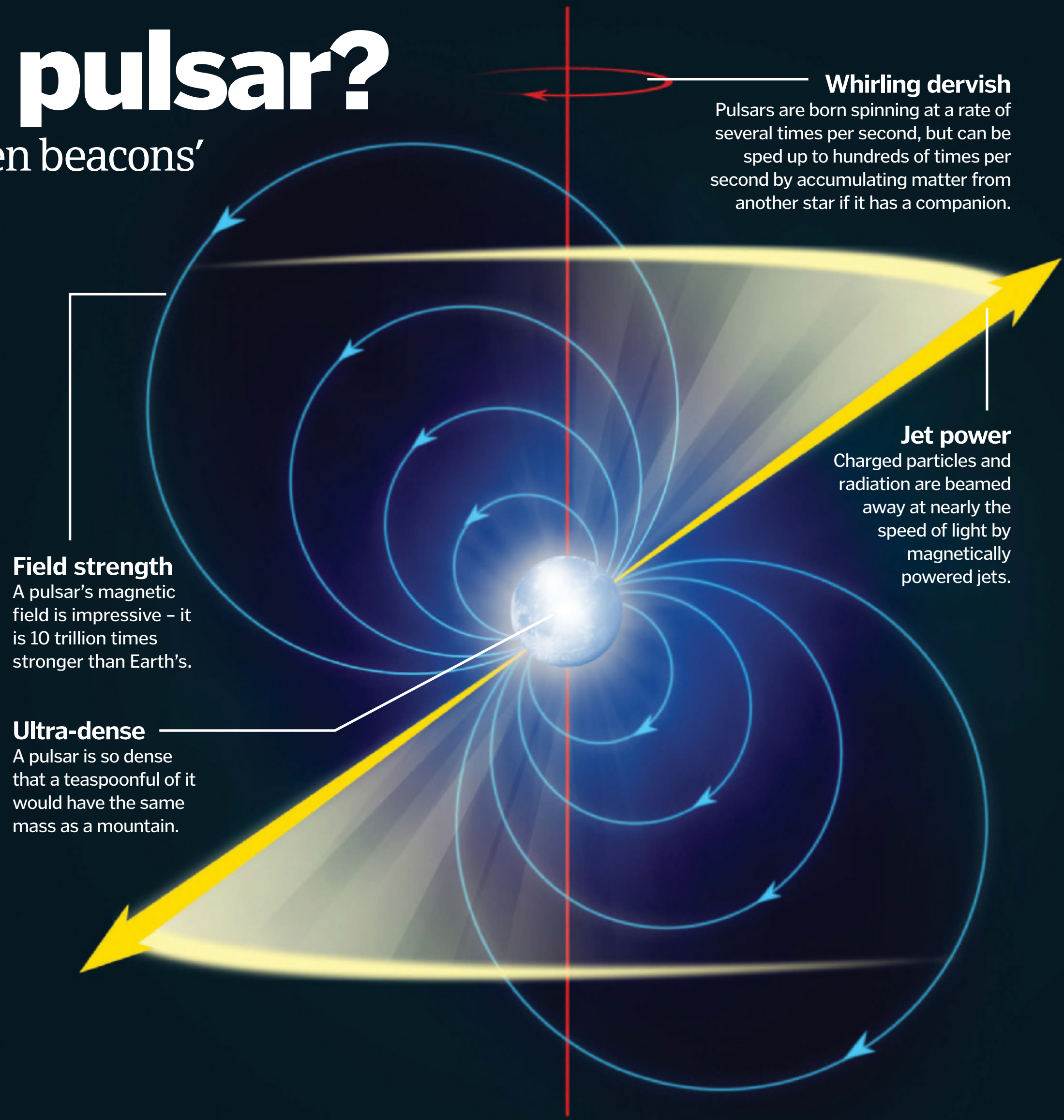
What is a pulsar?

The truth behind the 'alien beacons'

When pulsars were discovered in 1967 by Jocelyn Bell, nobody knew what they were. They were so mysterious that the first pulsar was half-jokingly nicknamed 'LGM-1', for Little Green Men. Today, however, we know that pulsars have nothing to do with aliens, but come from something just as dramatic. They are the rapidly spinning condensed cores of massive stars that have exploded as supernovae.

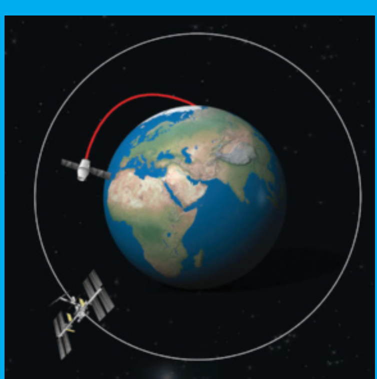
When a star greater than eight times the mass of our Sun reaches the end of its life, it stops generating energy from fusion power within its core. This causes the core to collapse into an object so dense that electrons and protons merge to form neutrons. The outer layers of the star quickly fall onto this collapsed core before a shock wave blows them back out, causing the star to explode. The core survives, however, as a 'star' of neutrons about 20 kilometres across.

This neutron star is highly magnetic and is born spinning. Its magnetic field funnels away charged particles along two jets bursting out from its magnetic poles. As the neutron star spins, these jets spin with it, flashing in our direction. We see them as a rapid sequence of light pulses – a pulsar.



Docking a spacecraft

How astronauts in the Soyuz capsule board the International Space Station



Reaching space
It only takes a matter of minutes to blast into space, but it can take hours or even days to reach the International Space Station (ISS). Following blast-off, the Soyuz capsule enters orbit by firing its rockets parallel to the spacecraft's direction of travel.

Transfer into higher orbit
The ISS orbits the Earth at a higher altitude, so the Soyuz has to reach it via an elliptical path called a Hohmann transfer orbit. This features two engine burns – one to take the Soyuz into the higher orbit and another engine burn to keep it there.

Small corrections
The Hohmann transfer orbit isn't always precise, and the Soyuz has to perform small thruster burns to manoeuvre itself into an orbit around Earth with a period of 86 minutes – four minutes faster than the slightly higher ISS, which is moving at around 28,000 kilometres per hour.

Overtaking the ISS
As the Soyuz is moving faster, it overtakes the ISS above it, then fires its engines again to enter another Hohmann transfer orbit that brings the spacecraft just in front of the ISS, 400 kilometres above Earth. Then the Soyuz turns around, fires its engines to slow down, and docks.

How Earth got its core

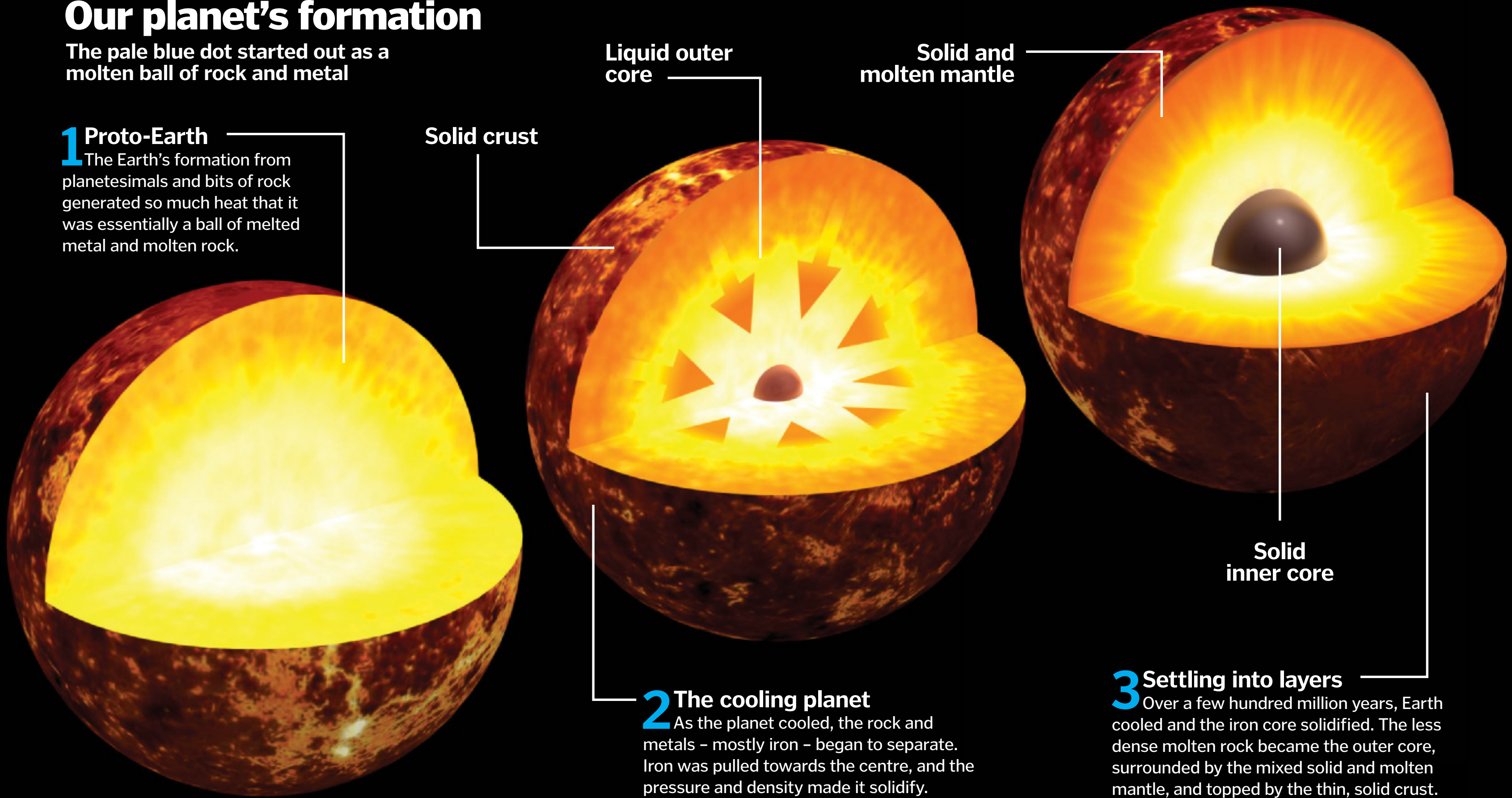
Intense heat and immense pressure formed Earth's iron centre

We know that the formation of the Earth's layers was a long and complex process, but scientists have been puzzled as to how the inner core became a solid ball of iron. Initially, experts thought that the core began to form early in the process, when the upper mantle was still molten rock. Droplets of iron fell into the hot magma ocean and once it reached the solid lower mantle, the iron sank slowly as gravity pulled it towards the centre.

However, a more recent model suggests that the core formed later, when the entire mantle was solid rock. Intense pressure at about 1,000 kilometres below the crust was strong enough to force the molten iron out of silicate rock. Small blobs of the metal joined together to form channels, and then percolated through the solid mantle towards the centre. The temperature of the core is about 5,200 degrees Celsius – much higher than the melting point of iron. Yet the iron is so dense and under such extreme pressure that it is crystallised into a solid. The core continues to grow by about a millimetre a year, as the Earth cools and parts of the liquid outer core crystallise.

Our planet's formation

The pale blue dot started out as a molten ball of rock and metal



1 Proto-Earth
The Earth's formation from planetesimals and bits of rock generated so much heat that it was essentially a ball of melted metal and molten rock.

2 The cooling planet
As the planet cooled, the rock and metals – mostly iron – began to separate. Iron was pulled towards the centre, and the pressure and density made it solidify.

3 Settling into layers
Over a few hundred million years, Earth cooled and the iron core solidified. The less dense molten rock became the outer core, surrounded by the mixed solid and molten mantle, and topped by the thin, solid crust.

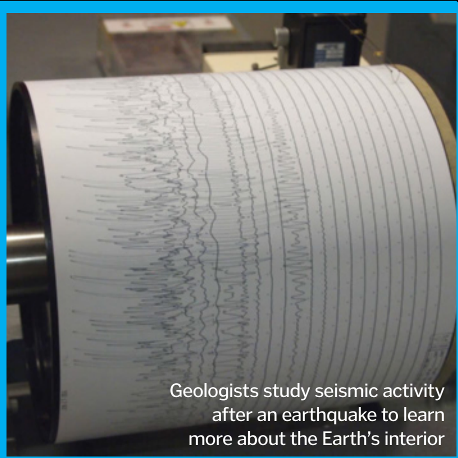

Geologists believe that molten iron was drawn through channels to the Earth's centre

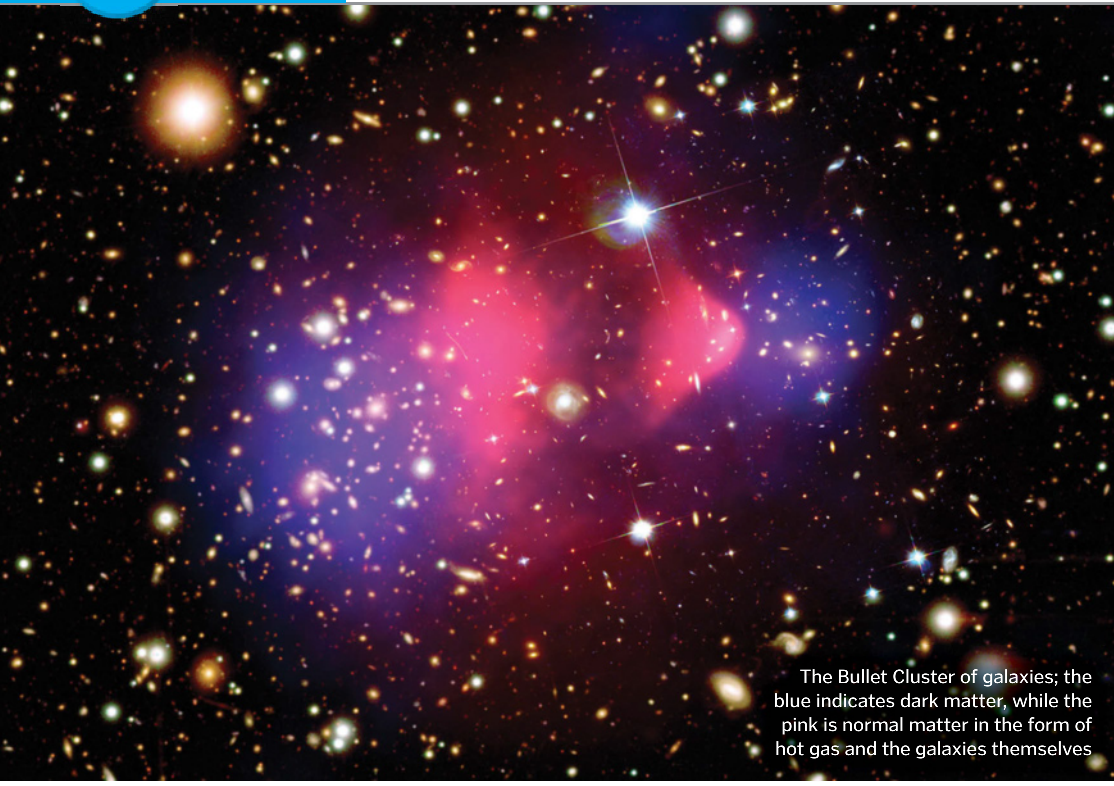
The inner-inner core

Since the core is 5,000 kilometres below the surface, we have to rely on earthquake activity to study it. That entails analysing the waves that travel from an earthquake's epicentre and pass through the planet. S-waves travel through solids but not liquids, while P-waves travel through both, but change speed and direction.

By looking at where and when the waves arrive on the surface, we refine our understanding of the planet's make-up, similar to how doctors use ultrasound. That's how geologists have determined that the centre of the Earth actually has two parts: an outer-inner core and an inner-inner core.

The iron crystals at the innermost part are aligned east to west, while the crystals in the outer-inner core are aligned north to south. Something big must have happened to cause the inner-inner core's crystals to be oriented differently, but we're yet to unravel the mystery.


Geologists study seismic activity after an earthquake to learn more about the Earth's interior



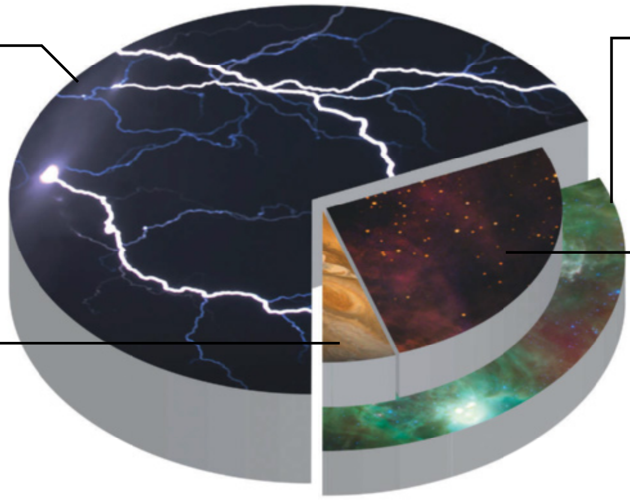
The Bullet Cluster of galaxies; the blue indicates dark matter, while the pink is normal matter in the form of hot gas and the galaxies themselves

What is the universe made of?

The cosmos is filled with material and energy that we cannot see

If you look up at the night sky, you can see the light of hundreds of stars, as well as nebulae of gas and giant galaxies tens of thousands of light years across. Believe it or not, everything that we can see in the universe emitting light in the electromagnetic spectrum makes up only 4.9 per cent of its total matter and energy. This accounts for all the planets, moons, comets, stars and nebulae, and all the atoms in the periodic table. So what is the other 95.1 per cent?

It was Albert Einstein, with his famous equation $E=mc^2$, who said that matter and energy were equivalent. This allows for most of the universe (68.3 per cent to be exact) to be made from energy and it is causing the expansion of the universe to accelerate. No one knows what it is, so scientists call it 'dark energy'. The remaining 26.8 per cent is made from another dark substance, called dark matter. Astronomers know it exists because its gravity affects the motions of stars and galaxies, and it can bend the light of more distant galaxies. But it emits no light of its own and no one knows what it's made of.



Clean and tidy galaxies

A tidy galaxy allows its stars to sparkle and astronomers to measure its precise distance

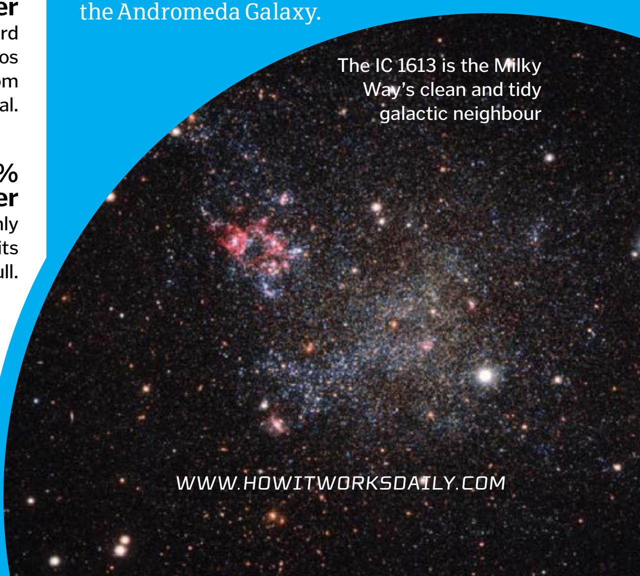
Unlike our dusty, dirty Milky Way galaxy, the nearby dwarf galaxy IC 1613 is comparatively clean, sporting very little in the way of cosmic dust.

Galaxies become dusty because their member stars are like cosmic soot machines. When they die, either by expanding into red giants and planetary nebulae, or as explosive supernovae, stars throw out huge amounts of dust into space.

For example, the supernova that exploded in the Large Magellanic Cloud in 1987 produced enough dust to make 200,000 Earth-sized planets! This dust is not like the dust bunnies that collect by your skirting board, but smoke particle-sized grains of heavy elements that go into producing the next generation of stars and planets.

The last main burst of star formation in IC 1613 took place 7 billion years ago. Without many stars forming, dust has not been produced in great quantities. This is an advantage though, because dust tends to scatter blue light, leaving stars and galaxies looking redder than they really are. When this happens, it's hard to judge their distance based on their luminosity.

In the case of IC 1613, however, we can see its stars clearly and measure its distance as 2.3 million light years, which is closer than the Andromeda Galaxy.



The IC 1613 is the Milky Way's clean and tidy galactic neighbour

Anatomy of a spacesuit

How this incredible device allows astronauts to survive the extremes

Spacesuits are an astronaut's life support system, providing them with oxygen, keeping them warm and protecting them from the vacuum of space. They provide communications with fellow astronauts and mission control, monitor their health and are sealed against the harsh environment outside. One of the most important parts of any space suit is the backpack: the Primary Life Support System, or PLSS. It's more than just an oxygen pack – it keeps the suit pressurised to prevent hypoxia (caused by the decrease in oxygen within the blood stream), removes harmful carbon dioxide and cools the suit by pumping water around it. It also houses medical monitors and the communication equipment.

The PLSS life support system is a closed loop, so everything is recycled. Inside the suit the astronaut wears a skin-tight Liquid Cooling and Ventilation Garment, which removes body heat through perspiration. Oxygen, carbon dioxide and water vapour are also sent back to the PLSS; the carbon dioxide is then removed by reacting with lithium hydroxide, producing lithium carbonate and water. The water vapour condenses and is also removed and stored in the pack, while oxygen is recycled back around the suit for the astronaut to breathe. Sometimes, spacesuits are referred to as an astronaut's own personal spacecraft. If an astronaut on a spacewalk (also known as extravehicular activity, or an EVA) finds themselves drifting off into space, then the modern NASA spacesuits have a device called the Simplified Aid for EVA Rescue, or SAFER for short, which is composed of little manoeuvering jets that can fly them back to the space station.

ESA astronaut Alexander Gerst tests his spacesuit at NASA's Johnson Space Center in Houston, Texas

Design details

An essential piece of clothing for space travel, each part of a spacesuit has an important job

Helmet with visor
The helmet features a visor coated with a thin layer of gold to filter out harmful solar rays.

Build a spacesuit
Spacesuits do not come in a single piece, but are built from several pieces that are fastened together: the upper torso, the arms and the lower torso assemble.

Toilet break
While in the middle of a spacewalk you can't just pop to the loo, so a spacesuit contains a 'maximum absorption garment' – a fancy name for a nappy!

Gloves
Space is so cold that the fingertips in an astronaut's gloves contain miniature heaters. The gloves are made to be dexterous while providing a strong grip.

Dexterity
Spacesuits have to provide astronauts with a range of motion for when they are working outside of the space station.

Footwear
The boots on current spacesuits are soft and not really made for walking, just floating. New boots will have to be designed for going back to the Moon or Mars.

Life support system
The life support system contains oxygen tanks as well as a battery for power, water-cooling equipment and a fan for essential air circulation.

Ventilation garment
The Liquid Cooling and Ventilation Garment is made from skin-tight Spandex and worn beneath the space suit. It contains over 90 metres' worth of tubing to remove and recycle body heat, carbon dioxide and perspiration.

SPACESUIT NUMBERS...

-160 to +120 degrees Celsius
Spacesuits protect astronauts from the extreme temperatures outside the ISS.

1961
The very first spacesuit – the SK-1 – was worn by cosmonaut and first man in space, Yuri Gagarin.

$12 million
The most recent spacesuits each cost in the region of $12 million to manufacture.

145kg
With the life support system attached, a spacesuit weighs in at around 145 kilograms. The suit alone weighs about 55 kilograms.

19,000m
Spacesuits are required beyond an altitude of around 19,000 metres to supply the oxygen needed to breathe and maintain a pressure around the body.

On board the Dream Chaser

With the Space Shuttle in retirement, NASA is looking to the next generation of space planes

Sierra Nevada's Dream Chaser is a smaller, more adaptable version of the Space Shuttle and will spend much of its time going on trips to resupply the International Space Station (ISS). Unlike the Space Shuttle, Dream Chaser can fly autonomously, without a human pilot. Crewed versions will also be developed, capable of carrying seven astronauts plus cargo.

Once in space, it will be powered by twin hybrid rocket engines, which use two propellants – one solid, the other gaseous or liquid. These are mixed together and tend to be less explosive than purely solid rocket fuel when they fail. In the case of Dream Chaser, the solid propellant is a rubbery material called 'hydroxyl-terminated polybutadiene', while the gas propellant is nitrous oxide. Its engines are so powerful that, when docked with the ISS, Dream Chaser can raise the Space Station's altitude, useful for avoiding pieces of space debris.


The Dream Chaser will be able to return from space and land like an airplane

Dream Chaser is a fairly modest spacecraft in terms of size; its wingspan is seven metres, compared to the 23.8-metre wingspan of the Space Shuttle. It will be capable of carrying over five tons of cargo into space before returning to Earth hours later, landing like an airplane on a runway.

Expected to first launch sometime in 2018-2019, there will be two versions; the Dream Chaser Cargo System sports folding wings to allow it to fit into the cargo fairing rockets such as the Ariane 5, while the crewed Dream Chaser Space System will launch on an Atlas V rocket to carry astronauts to the ISS.


Compared to the giant Space Shuttles, Dream Chaser is modest in size

Spacecraft design

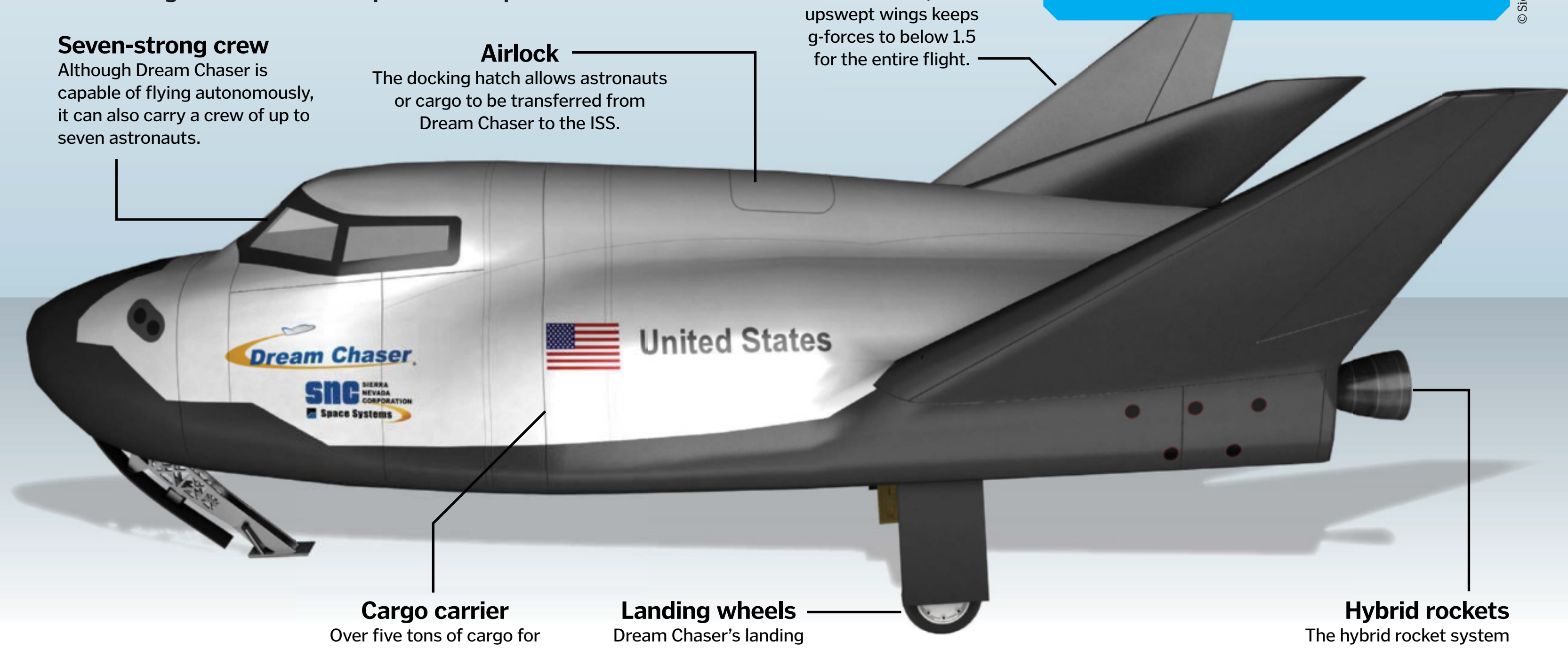
Mark Sirangelo, head of Sierra Nevada Corporation Space Systems, tells us more

"Dream Chaser is a pilot-automated space plane that has many similarities to the Space Shuttle. It is smaller in terms of overall size – it doesn't have the huge cargo compartment that the Shuttle did – but it has a similar sized pressurised crew compartment. This means that it can still take up the same number of astronauts (seven) and the same amount of protected cargo in the pressure hold as the Shuttle.

It's a highly reusable vehicle and, presuming that there's a mission and rocket, we can launch each Dream Chaser vehicle potentially five times a year. We're planning on having a fleet so that we can fly one while we're getting the next one ready to fly again. We are expecting our first orbital flight to be in 2018 but we're probably not going to have any crew on board to begin with."

What dreams are made of

Introducing one of the most sophisticated space vehicles ever built



Seven-strong crew
Although Dream Chaser is capable of flying autonomously, it can also carry a crew of up to seven astronauts.

Airlock
The docking hatch allows astronauts or cargo to be transferred from Dream Chaser to the ISS.

Wing profile
Dream Chaser's streamlined shape with upswept wings keeps g-forces to below 1.5 for the entire flight.

Cargo carrier
Over five tons of cargo for resupplying the ISS can be crammed into Dream Chaser's hold.

Landing wheels
Dream Chaser's landing gear allows it to touch down on a runway just like an airplane.

Hybrid rockets
The hybrid rocket system uses non-toxic propellants for the first time in the history of space flight.

BRAIN DUMP

Because enquiring minds need to know...

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How It Works magazine

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Almost all the water in our oceans was carried here by comets and asteroids

Has all the water on Earth been here since the planet first formed?

Lara Rankin

■ Most of the water that we see on Earth today was not around when our planet formed; it was transported onto Earth by comets and asteroids. When the Solar System formed 4.6 billion years ago, water molecules would undoubtedly have been present in the swirling dust and rocks that accreted to form planets. But without an atmosphere, any water on Earth's surface would have vaporised under the high temperature conditions and escaped into space. However, over the next 700 million years, our planet was pummelled with comets and asteroids. These contained ice, which melted into liquid water once they reached Earth's surface. **AC**

The bald eagle is native to the US and is its official emblem

How did the bald eagle become America's national bird?

Monique Bryans

■ Soon after the Declaration of Independence was signed on 4 July 1776, Benjamin Franklin, Thomas Jefferson and John Adams were tasked with designing an official seal for the new nation. Years later, after disapproval of the designs by the Continental Congress, Secretary of Congress Charles Thomson combined the best elements of the designs he'd seen. The eagle had initially been introduced by lawyer William Barton. Thomson decided to make it a prominent feature and turned it into an American bald eagle, a symbol of strength and native to the US. The design was adopted by Congress on 20 June 1782. **SB**

MEET THE EXPERTS

Who's answering your questions this month?

Tom Lean

A historian of science at the British Library, Tom works on oral projects on British science and the electricity industry. His first book, *Electronic Dreams: How 1980s Britain Learned To Love The Home Computer*, is out now.

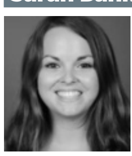
Laura Mears

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.

Sarah Bankes



Sarah has a degree in English and has been a writer and editor for more than a decade. Fascinated by the world in which we live, she enjoys writing about anything from science and technology to history and nature.

Shanna Freeman

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

Stringed cheese is a popular snack for kids and adults alike

What makes stringed cheese so stringy?

Neil Merson

Stringed cheese is cheese that has been heated until the milk proteins align, which is at about 60°C, then stretched until it has a stringy texture. Originally, mozzarella cheese was used and the cheese was braided into strips. Today, stringed cheese can be made from cheddar or several other types of cheese, and it can be found either braided or pressed into a log shape. **SF**

What happens in your brain when you feel bored?

Declan Gray

The science of boredom hasn't been fully explored, but it is an active area of research. It is linked to attention, and according to researchers at York University in Toronto, Canada, boredom comes down to not being able to engage. When you feel bored, you want something to catch your attention, but it either doesn't or can't. In response, you either start to switch off, or you can begin to get agitated. Boredom is reportedly common in people with chronic attention problems, and in thrill seekers. **LM**

A bored brain just wants to be engaged

Moons orbiting other planets were not discovered until the 17th century

Why doesn't our Moon have a name?

Abby Constant

Our moon does have a name: it is called 'Moon' as it was the first moon discovered – all others are named after it. The word derives from the Old English term 'mona' and was initially used just for our Moon. The term came to describe other planets' natural satellites in the 17th century, after Galileo first observed Jupiter's moons in 1610. The Moon has other names in other languages: 'Selene' in Greek (giving the word selenology – the study of the Moon's geology) or 'Luna' in Latin (giving rise to words such as lunar). **AC**

Why does coloured shampoo become white when you rub it into your hair?

Nina Singh

Coloured shampoos and conditioners contain dye molecules, which absorb photons of certain wavelengths but not others. Some colours are therefore hidden whereas others show up when light passes through the shampoo. When we rub shampoo into our hair, the sodium lauryl sulfate produces foam, which appears white because light is reflecting off the surfaces of the bubbles. Light that reflects off a surface is known as specular reflection and is not coloured. So although the walls of the bubbles contain dye molecules, there are not enough to show through – the light bounces off and is scattered in many directions, so the foam looks like a white mass. **SB**

The colour of a shampoo disappears when it's rubbed in due to specular reflection

FASCINATING FACTS

Is there a height limit for building skyscrapers?

There's no definitive answer for the maximum height of a skyscraper. A mile or two is probably within the limits of current engineering. However, difficulties with installing lifts and the massive building costs make such towering skyscrapers unlikely at present. **TL**

Several things limit the height at which skyscrapers can be built

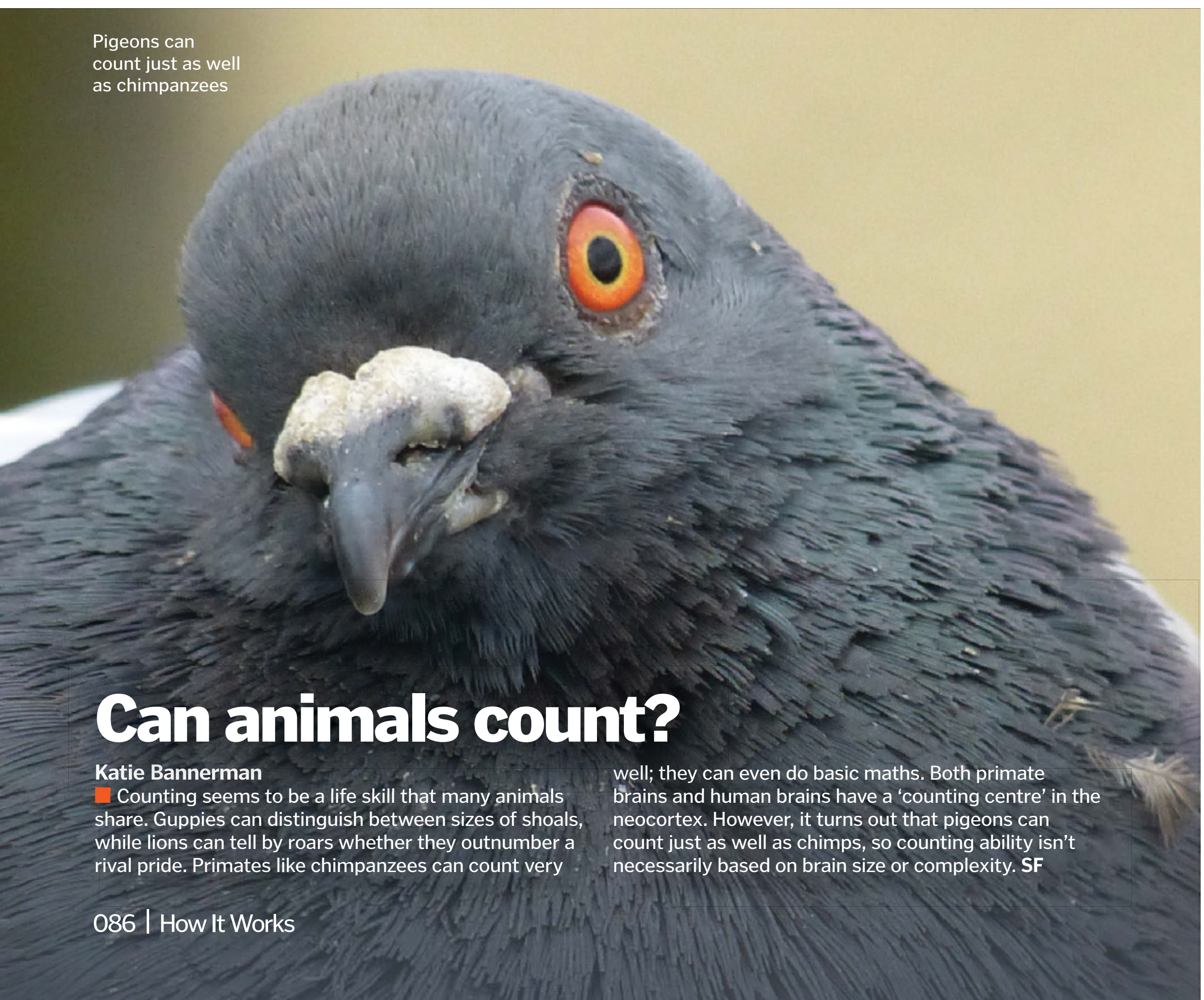
BRAIN DUMP

Your Snapchat selfies may not have been lost forever

What happens to Snapchat photos after they have been viewed?

Ruth Chorley

Snapchat claims that photos are automatically deleted from the servers once viewed. The photo on your phone will be deleted too. However, several people on the internet have claimed to have found ways to view snaps deleted from their phones, although new versions of Snapchat have tried to prevent this. In general, electronic files aren't actually erased when you hit delete. The file will be marked as deleted and disappear from view, but it's still there. The file's data will remain stored until overwritten, so it can sometimes be recovered. **TL**



Pigeons can count just as well as chimpanzees

Can animals count?

Katie Bannerman

Counting seems to be a life skill that many animals share. Guppies can distinguish between sizes of shoals, while lions can tell by roars whether they outnumber a rival pride. Primates like chimpanzees can count very well; they can even do basic maths. Both primate brains and human brains have a 'counting centre' in the neocortex. However, it turns out that pigeons can count just as well as chimps, so counting ability isn't necessarily based on brain size or complexity. **SF**

FASCINATING FACTS

What are 'blanks' in a gun?

Blanks are cartridges that have wads of paper or cotton as their projectiles instead of bullets. They don't travel very far due to their low mass, but they still explode from the muzzle with great force and are dangerous if fired at close range. **SF**

A blank cartridge from an automatic machine gun

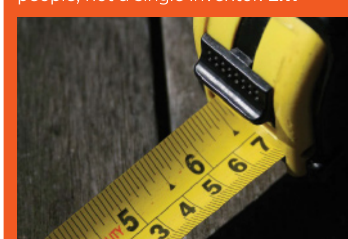
Why is it called a ten-gallon hat?

One theory claims it to be a corruption of the Spanish modifier 'tan galan', meaning 'really handsome'. Others believe it to come from the Spanish 'galon' – a narrow-braided trimming around the crown. **SB**

There are many theories that attempt to explain where the phrase 'ten-gallon hat' originated

Who invented the metric system?

The modern metric system was designed during the French Revolution in 1790, but it was the work of several people, not a single inventor. **LM**



The metric system bases its units of quantity on powers of ten

The more you enjoy a song, the more likely you are to remember its lyrics

Why are song lyrics so easy to remember?

Alyson Dunn

Our brains seem to be wired to remember song lyrics better than facts, or even what we had for dinner. When you remember the lyrics to a song, you're also remembering the music and the voices, so there are several associations for your brain to access. If you hear the song over and over, repetition also helps you to retain it. It's a form of practice. The patterns in songs, such as the beat or rhyming lyrics, also help our brains retain them. Finally, if you like the song, your brain will work harder to remember it because of the emotional connection. **SF**

Why do some people sleepwalk?

Hannah Claridge

Sleepwalking most often happens during deep sleep, and is more common in children than in adults, but the exact cause is not yet known. It often affects more than one family member, suggesting that there might be a genetic component.

By looking at families with a history of sleepwalking, a team of researchers in Washington pinpointed chromosome 20 as a possible location for a faulty gene. However, some sleepwalkers have no family history at all.

Many different sleepwalking 'triggers' have been identified, including sleep deprivation, stress and a high temperature. Sedatives, such as alcohol, can also trigger sleepwalking in some people, and for others, simply waking up suddenly during deep sleep can cause it to happen. It is a myth that you should not disturb a sleepwalker; they are just more likely to get hurt if you let them continue walking. If possible, it is best to carefully guide them back to bed. **LM**

Sleepwalking can run in families, but doesn't always

How do rechargeable batteries work?

Verity Deane

All batteries rely on chemical reactions to produce an electric current. Inside a battery are two electrodes made of different sorts of metal, named an anode and a cathode, and an electrolyte, often an acid. Chemical reactions between the electrodes and electrolyte create a flow of electrons from anode to cathode when the battery is connected – an electric current. In the process the electrodes and electrolyte gradually become depleted as they react with each other. In a non-rechargeable battery this reaction is irreversible, and the battery will eventually stop working. When a rechargeable battery is charging, an electric current is passed the opposite way through the battery. This reverses the chemical reaction and rejuvenates the electrodes and electrolyte to a state where they can once again produce electricity. However, even a rechargeable battery can only be recharged a certain number of times before it can no longer hold a charge. **TL**

Charging a rechargeable battery reverses the chemical reaction that depletes its power

Cats aren't necessarily afraid of water, but don't like how long it takes to get dry

Why are cats afraid of water?

Bernadette Ewens

The top layer of cat fur is relatively water resistant, so a light rain shower won't bother it too much. But when a cat gets soaked, its fur tends to become waterlogged. This not only makes the cat sluggish, but it also makes it difficult for the cat to return to a dry, warm state quickly. Another theory suggests the so-called fear comes from when owners used to shield their cats from the rain in the earliest periods of domestication. **SB**

Why is it called Bluetooth technology?

Amit Mantsebo

Despite the technology being relatively new, the name Bluetooth actually has medieval origins. It was chosen by the largely Scandinavian team of engineers that created the wireless communications technology back in the 1990s, and is the English translation of the name of a Viking king.

When looking for a name that signified their new invention's ability to connect PCs and cellular phones, the team thought of King Harald Blåtand of Denmark, who was famous for uniting parts of Denmark and Norway with non-violent negotiations. The name's origins are also evident in the Bluetooth symbol, as it is king Blåtand's initials written in Norse runes. **TL**

King Blåtand, meaning Bluetooth in English, inspired the wireless tech's name

BRAIN DUMP

What are the criteria for determining a new species?

Steph Leigh

Generally scientists consider a species to be new if it has its own gene pool and evolutionary lineage. If you think that you've discovered a new species, there's a long process to go through. The first step is to get some specimens to compare against other species that are closely related. You collect all of the data about the species, then comb through the literature about related species to be sure that what you have doesn't match with any other description. Once you're reasonably sure that it's new, you publish the data in a peer-reviewed scientific journal so that others can learn about the species and help verify that it's new. Naming the species comes last, and there are rules here. Depending on what type of species you've discovered, you'll follow criteria set by an international organisation, such as the International Commission on Zoological Nomenclature. **SF**

The Ranitomeya amazonica frog is one of more than 1,000 new species recently discovered in the Amazon

FASCINATING FACTS

Who determined the speed of light?

Studying eclipses of Jupiter's moon Io, Danish astronomer Ole Roemer noticed that these often occurred behind or ahead of schedule, and used this information to make the first estimate of the speed of light. **AC**

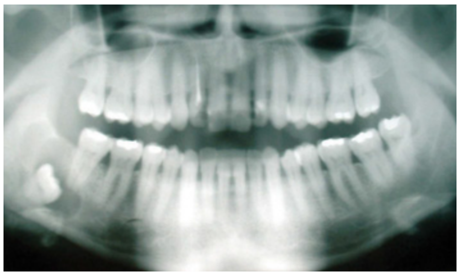
Roemer used patterns in planetary eclipses to deduce the speed of light in 1676

Why does milk curdle?

Nick Fallon

Milk contains many compounds, primarily lactose (a natural sugar), proteins and fat. The proteins exist in a colloidal solution, so the molecules float around – usually repelling each other. However, when the pH of their solution drops and becomes more acidic, the protein molecules attract each other and clump together in a process known as curdling. This chemical reaction happens faster in warmer temperatures – for instance, when you leave the milk out the fridge – because bacteria in the milk start to eat and digest the lactose. This produces several by-products, including lactic acid, which results in a lower pH level and a sour taste. The structure of some proteins, such as casein, change as a result of this reaction, and they stick together. The liquid that's left is called whey, which appears yellow because the casein protein is what gives milk its white colour. **SB**

Leaving milk out in room temperature results in a chemical reaction that makes it curdle



With smaller jaws than our ancestors, many people do not have space for wisdom teeth

Why don't we need to keep our wisdom teeth?

Amar Zadeh

Wisdom teeth, like other molars, are best suited to grinding and crushing, and having an extra set would once have been very useful. In the days before cooking, our ancestors ate raw, fibrous vegetation. This would have gradually taken its toll on their molars, wearing them away. However, as our species evolved, our brains became larger, our jaws became smaller and our diets changed. Today, many people don't have space for their wisdom teeth any more, and when the third molars try to erupt, they get stuck. Taking them out helps to relieve the discomfort, and with our modern diets, our remaining molars cope just fine. **LM**

The uvula is packed with glands that produce watery saliva

What does the dangly bit at the back of your throat do?

Florence Boon

■ The dangly bit at the back of your throat is called the uvula, and it's actually a really interesting little organ. It is involved in speech, vibrating against the tongue to create 'uvular sounds', like the rolled 'r' in French and Spanish. It can trigger the gag reflex, helping to prevent choking. It produces lots of thin saliva, helping to keep the back of the throat lubricated, and it also seems to prevent the voice from sounding too nasal by changing the way that air resonates in the head and neck. People who have had their uvula removed can experience a dry throat and changes to the sound of their voice. **LM**

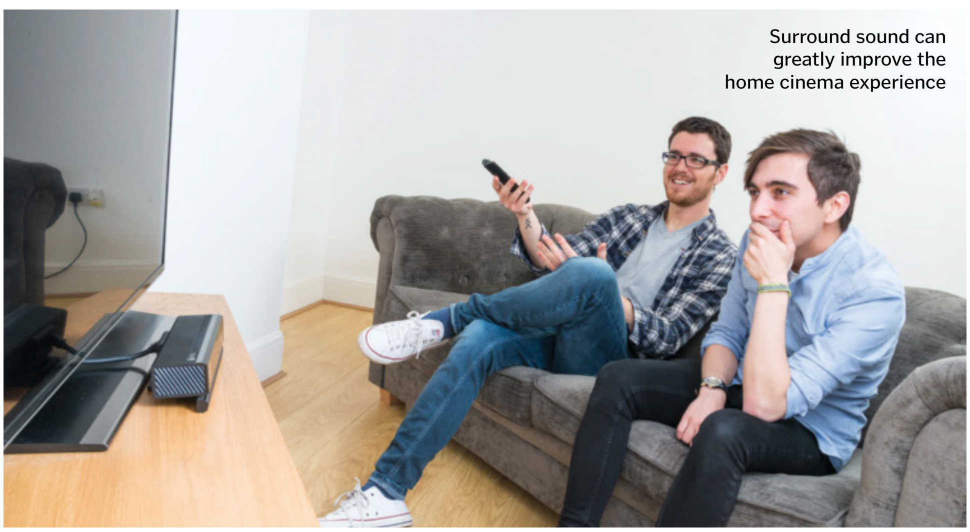
To minimise jet lag, start adjusting well before you board the plane

What is the best way to beat jet lag?

Dominic Rolfe

■ Controlling your light exposure and melatonin levels, ideally before you travel, is the most effective way of overcoming jet lag. These cues influence your circadian rhythm, an internal clock that governs sleep, hunger and other cycles – and causes you to feel jet-lagged when you switch time zones. A few days before travelling, use a bright light to mimic the time of day at your destination. When it's early evening there, take melatonin, a hormone released naturally by your body to induce drowsiness and prompt you to go to sleep. This should give you a head start on beating jet lag. **AC**

How does surround sound work?



Surround sound can greatly improve the home cinema experience

Joe Parker

■ There are various different surround sound systems, but they all rely on having a number of speakers surrounding the listener. For example, in a 5.1 surround sound system commonly found in home cinema, there is a centre speaker, including a subwoofer for bass, two stereo speakers in front and another pair of surround sound speakers behind the listener. A film soundtrack has components for each speaker encoded, so when it is played, the various sounds come from different parts of the room. The trick to make it seem like someone is walking up behind you is simply to play the sound from the speaker in that direction. **TL**

Hydrogen bombs can be thousands of times more powerful than the atomic bomb dropped on Nagasaki

What is the difference between a hydrogen and atomic bomb?

Howell Bradley

■ Both types of bomb harness the energy released by nuclear reactions, but a hydrogen bomb is powered by nuclear fusion, whereas an atomic bomb relies on nuclear fission. Hydrogen bombs are far more powerful, causing explosions equivalent to millions of tons of TNT. By contrast, the atomic bombs dropped on Hiroshima and Nagasaki had a yield of 15 to 20 thousand tons. This is because fusion fuel is made of smaller atoms, so more fuel can be packed into a hydrogen bomb. **AC**

New Brain Dump is here!

■ Don't miss issue 35 of **Brain Dump**, the digital sister magazine to **How It Works**, when it lands on the virtual newsstand on 7 April. You'll find out why male lions have manes, what your fingernails are made of and how glow worms produce their own light in the darkness. Also inside this issue: why drinks taste strange after brushing your teeth and the reason why spiders don't stick to their webs. Every edition is packed with stunning images and fun facts to entertain your friends with. Download the new issue of **Brain Dump** at the beginning of every month from iTunes or Google Play. If you have a burning question, you can ask at **www.facebook.com/BraindumpMag** or Twitter – the handle is **@BrainDumpMag**.

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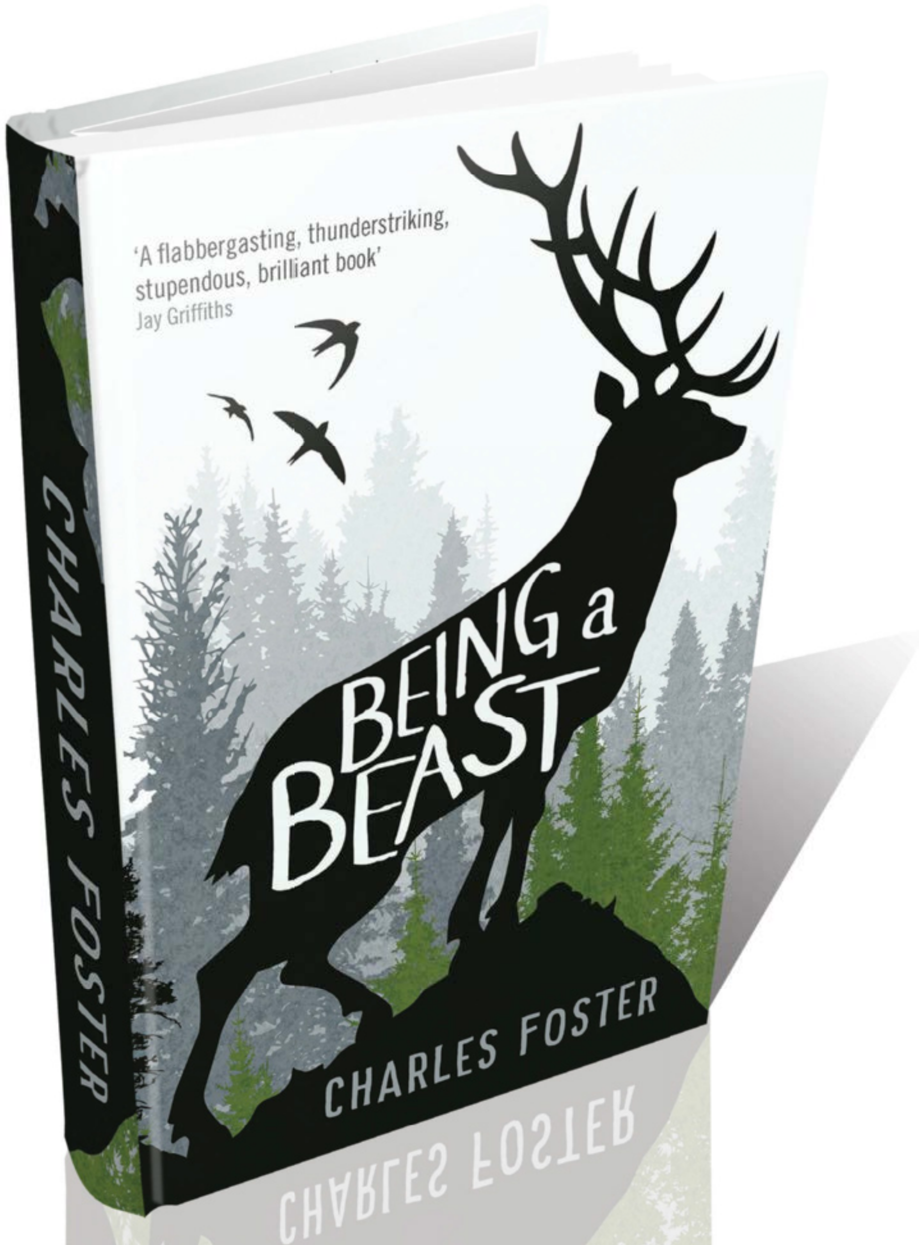
BOOK REVIEWS
The latest releases for curious minds

Being A Beast
Embrace your inner animal

- Author: **Charles Foster**
- Publisher: **Profile Books Ltd**
- Price:**£14.99 (approx $28)**
- Release date: **Out now**



Much as *Freakonomics* is aimed at the rogue economist, and Ben Goldacre's *Bad Science* is perfect for the discerning science enthusiast, *Being A Beast* is a book for nature lovers unlike any other. It sees author Charles Foster going above and beyond in order to gain an insight into what makes various animals tick – by living like them.

To this end, he swims in a stream like an otter, huddles in a badger's sett, and forages in the streets of London like a city fox. At least we think he does. Unless this is one huge *Animal Farm*-esque allegory that we've missed the point of entirely (hopefully we're safe; this is housed in the non-fiction section of the book shop), then this is one of the most committed auditions to be Bear Grylls' assistant that we've ever read.

Not that living like a 21st century shaman is the point, of course. In his own way, Foster comes across as a Bill Bryson for the animal kingdom, furnishing his experiences with anecdotes and informative tidbits relating to the subject matter, intermingled with his own thoughts on his subjects. Inevitably his own biases come into play – most notably a dislike of otters and cats – but this personal touch only serves to enhance the reading experience.

Even so, this book never forgets its target audience – the hardened nature lover – and his first person accounts are steeped in science and data. It's undeniably informative, but doesn't exactly help make it accessible. Perhaps this complaint is churlish however; after all, Foster does spend a good while comparing how different worms taste.

In truth, nothing we say will adequately prepare you for this book – even the most ardent Attenborough fans will likely have experienced nothing like this. You will be baffled, enlightened and amused in almost equal measure – and how many books can honestly claim to do that?

★★★★☆

> "Foster is a Bill Bryson for the animal kingdom, furnishing his experiences with informative tidbits"

YOU MAY ALSO LIKE...

A Short History Of Nearly Everything
Author: **Bill Bryson**
Publisher: **Black Swan**
Price: **£9.99 / $16.99**
Release date: **Out now**

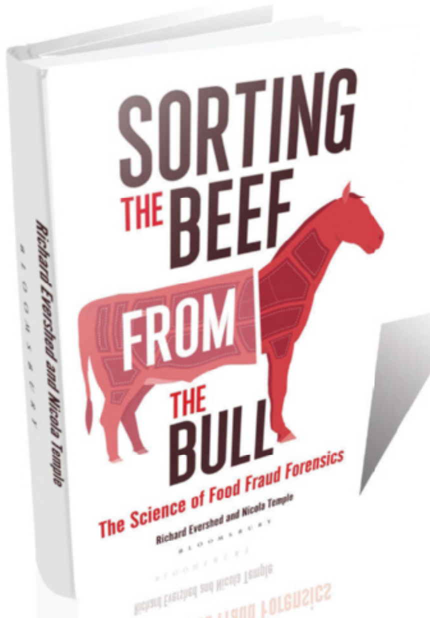
Bryson explores what science has revealed about the world around us, through captivating prose and interviews with experts from a range of fields. You owe it to yourself to read this book.

The Horse: A Biography Of Our Noble Companions
Author: **Wendy Williams**
Publisher: **Oneworld Publications**
Price: **£20 (approx $28)**
Release date: **Out now**

Like Foster, Williams blends scientific insight with amusing anecdotes to describe the history of our relationship with horses.

Cabin Porn: Inspiration For Your Quiet Place Somewhere
Author: **Zach Klein, Steven Leckart**
Publisher: **Particular Books**
Price: **£20 / $30**
Release date: **Out now**

Lose yourself by discovering how others have lost themselves. A coffee-table book with a difference.



Sorting The Beef From The Bull: The Science Of Food Fraud Forensics

Eating isn't believing

- Author: **Richard Evershed, Nicola Temple**
- Publisher: **Bloomsbury**
- Price: **£16.99 / $27**
- Release date: **Out now**

Worried that the horse-meat scandal was just the tip of the iceberg? This collection of food-fraud tales from around the world isn't likely to make you rest easier.

From Chinese fruit being rebranded as Australian to make it more expensive, to microscopes discovering fragments of beetles in ground pepper, this book will shock, educate and surprise in equal measure, and ultimately make you less trusting about what's really in your food.

The potential for panic is alleviated slightly by the knowledge that science is fighting back, but it's still a stark reminder to question where your food is from.

★★★★★

The Anglo-Saxon Age: The Birth Of England

Britain's beginnings

- Author: **Martin Wall**
- Publisher: **Amberley**
- Price: **£20 / $34.95**
- Release date: **Out now**

Public interest in the Anglo-Saxons has been galvanised since the discovery of the Staffordshire Hoard in 2009, which author Martin Hall uses as a starting point for his examination of a fascinating time in British history.

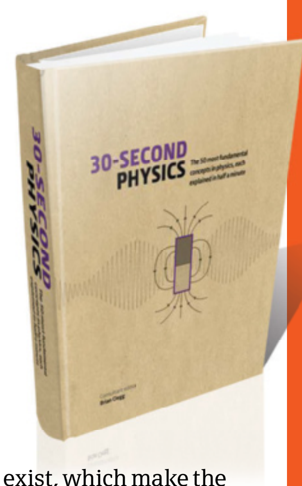
From their entry into the British Isles when they were Roman-held, all the way through to the Norman conquest, Hall takes an entertaining approach to chronicling this time period, frequently providing light-hearted interludes by referencing myths and culturally significant occurrences, as well as injecting his writing with a pervasive sense of humour. It's the perfect read if you're looking for an easily accessible route into Anglo-Saxon history.

★★★★★

30-Second Physics

Science soundbites

- Author: **Brian Clegg (editor)**
- Publisher: **Ivy Press**
- Price: **£14.99 (approx $21)**
- Release date: **Out now**



Physics isn't exactly the easiest of topics to break into – so it's a good job that books like this exist, which make the subject easily accessible for those of us who don't have PhDs.

From biographies of pivotal figures like Galileo and Einstein, to concise explanations for concepts like Schrödinger's equation and glossaries of key terms, this book has basic physics covered. Its titular boast may be slightly facetious (sure, it takes 30 seconds to explain, but a lot longer to understand), but this is a minor quibble with what is otherwise a well-written and informative book. If only we'd had this to get us through GCSE Science...

★★★★☆

100 Things To Know About Space

A generous helping of facts

- Author: **Alex Frith, Jerome Martin**
- Publisher: **Usborne**
- Price: **£9.99 (approx $14)**
- Release date: **1 April 2016**

Infographics are all the rage right now, and when you apply their usage to a subject matter as number-heavy as space, you have the perfect recipe for an informative – and aesthetically pleasing – book.

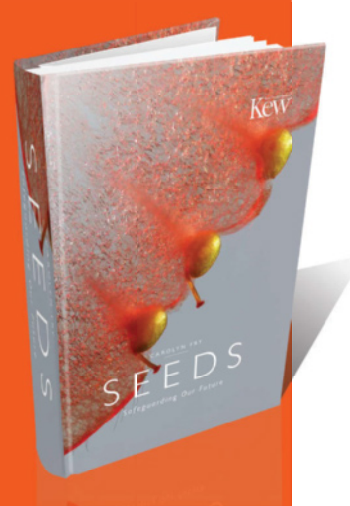
Ostensibly aimed at children by way of its bright and colourful style, in truth there's a lot here for adults who haven't retained everything they learned at school. In addition to the more basic facts that you would be expected to know, there is room for a surprisingly large amount of trivia, all presented in a style that gives the information room to breathe. Any aspiring astronauts could definitely benefit from having this in their collection.

★★★★☆

Seeds: Safeguarding Our Future

How species can be saved in spite of climate change

- Author: **Carolyn Fry**
- Publisher: **Ivy Press**
- Price: **£19.99 (approx $28)**
- Release date: **April 2016**



With the population growing and climate change ensuring that Earth will become more and more of an inhospitable place by the day, the importance of biodiversity has never been more paramount. Indeed, this book makes this case very strongly, detailing the evolution of various seed varieties and explaining the attempts being made to prolong their existence.

It's dense subject matter, and won't necessarily appeal to anyone with only a passing interest in the topic, but it's an alluring read nonetheless. If your curiosity gets the better of you, then that's no bad thing; the combination of research-led articles and diagram-heavy design will keep you going.

★★★☆☆

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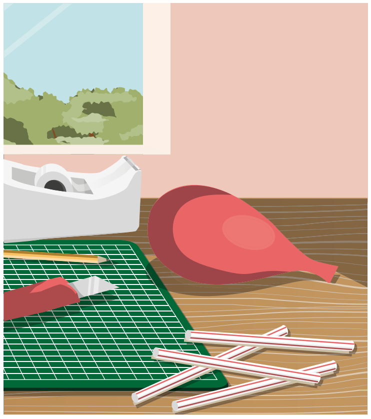
Make a balloon-powered rocket car

Use the power of thrust to create a speedy vehicle in minutes



1 Understand the science

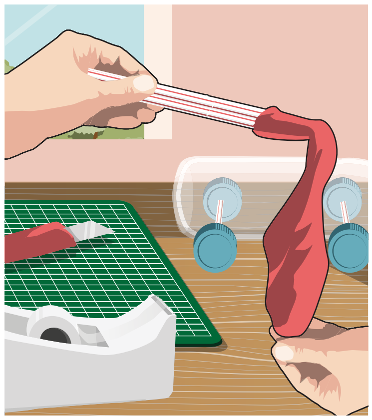
At their most basic, rockets are chambers filled with pressurised gas. Balloons create the same effect when they're inflated, and will be used to power our car. Blow up a balloon a few times to loosen the rubber, and find four drinking straws – these will form the small opening that will cause the forward thrust when air is expelled. First, though, we need to create the body of the rocket car.

2 Make the body

To make your rocket car's body you will need a plastic bottle – this will form the chassis. Remove the lid, and find three more lids of the same size. Together, these four lids will become the wheels of your rocket car. To attach the wheels to your bottle chassis, first cut another drinking straw into two smaller strips. Tape this to the bottom of your bottle to create the holders for the axles.

3 Wheels down

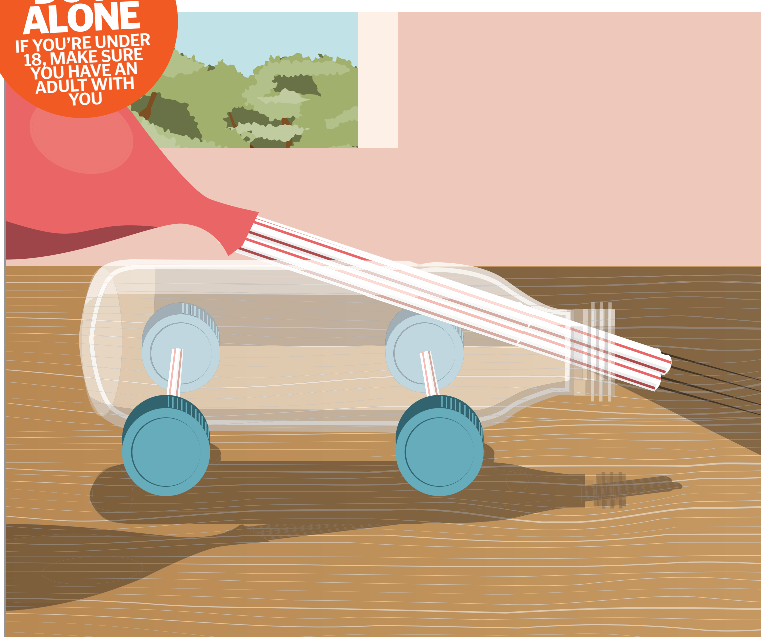
Now it's time to add your wheels. Get a wooden skewer and cut it so it's around 5cm longer than the straw pieces on your bottle. Use something sharp to poke a hole in each of the four lids you gathered, then attach one at each end of the two wooden skewers. Secure them in place with tape – take your time to ensure they all align properly, so your rocket car drives straight!



4 Create the nozzle

Now for the important part: the nozzle. Grab those four drinking straws, hold them all together, and secure them with tape. Now take the balloon that you inflated a few times earlier on and place it over the ends of the straws. Secure the balloon with duct tape to ensure there is a tight seal. Use a knife to cut an 'X' shape in the top of your car, around 20cm from the neck.

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



5 Ready for launch!

Carefully bend down the sides of this X to create a square hole. Slide the four straws into this hole and out the neck of the bottle. Blow into the straws to inflate the balloon, and then pinch the end of the balloon to keep the built-up pressure in, as you take position. Place the car on your chosen track and let go – the pressure will force air out of the nozzle and the car will be thrust forward!

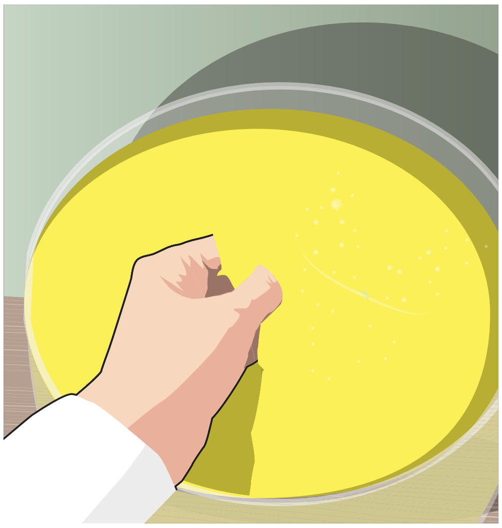
In summary...

The nozzle is the key to this creation – if it is too small, the air won't be pushed out with enough force to propel the car forward. If it is too big, the air will escape too fast and the car will be slow. If four straws don't work for your car, try more or fewer!

NEXT ISSUE
- IMPROVE YOUR WIFI SIGNAL
- MAKE A FIZZY BATH BOMB

Create quicksand

This gloopy mix behaves a lot like the real thing



Illustrations by Edward Crooks

1 Mix it up
Quicksand occurs when the right kind of sand becomes saturated with water. In nature, this often happens when sand is sitting on a substance that doesn't absorb water, such as clay. However, the grains of sand all need to be the same size – and perfectly round – to form quicksand. You won't find this sort of sand easily, so instead we'll mix 2.5 cups of cornflour and two cups of water together in a plastic bowl to create a similar kind of material.

2 Just like quicksand
When you're finished, the mixture should have the consistency of honey. If you came across quicksand in real life it would look solid on top, but when you gently agitate it (by standing on it) it behaves like a liquid. The mixture you have created is just the same – slowly lower your hand into the mixture and you'll find that it should sink in. Move your hand around slowly, then speed up your movement; do you notice that the faster you move, the greater the resistance?

3 The real test
Now for the real test! Try punching the cornflour mixture. Be careful – make sure you don't hit the bowl! You need to punch quite hard, and immediately pull your hand away once you've made contact. If the mixture splattered everywhere, you need to add more cornflour. But, if the mix was right, it should've felt solid against your fist. This substance, like quicksand, is known as a non-Newtonian liquid, as it doesn't follow Sir Isaac Newton's law of viscosity.

In summary...
The state of non-Newtonian liquids depends on the force and pressure applied to them. So, when you gently lower your hand into the bowl (or an unaware traveller steps softly on quicksand) it sinks into the liquid. This is also why trying to quickly pull your foot out of quicksand won't work – the force will cause it to act like a solid!

Wireless wonder
Connect the speaker to your smartphone or tablet via Bluetooth for a wireless setup.

Connect and enjoy
Use the 3.5mm input to physically connect the speakers to your device's headphone socket.

WIN!

A stereo speaker system worth £149

The NS1 from Steljes Audio is the perfect partner for your desktop computer or mobile devices. With a beautifully compact design, the 155mm-tall stereo speaker system features built-in amplification, and comes in a choice of eight fabulously finished colours.

Oculus VR, the company behind the Oculus Rift headset, was acquired by which corporation in 2014?

a) **Google** b) **Microsoft** c) **Facebook**

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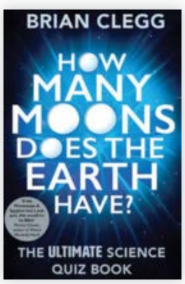
AMAZING PRIZE FOR NEXT ISSUE'S LETTER OF THE MONTH!



THE ULTIMATE SCIENCE QUIZ BOOK

Quiz your friends and family with some of the most puzzling science questions, including why is the sky blue? And what is spaghettification?

Letter of the Month

4D vision

Dear **HIW,**

I love your magazine and the new stuff in it each month. My question is, in what dimension do humans see? I think we can see in 4D but my family all think that we see in 3D, so which one is right?

Jacob Maginn (aged 11)

Strictly speaking, neither! Your retina is essentially a flat sheet of light sensitive cells, so your view of the world is projected onto a screen that is just two-dimensional. But, of course, we have two eyes and they are a few centimetres apart so they receive slightly different images. Your brain uses this difference to calculate the distance to an object. This lets you locate an object according to its position left or right of you, above or below you, and near or far from you. That's the X, Y and Z dimensions but even this still isn't true 3D vision because we can't see around the back of an object. On the other hand, we can see moving scenes as well as static ones, and movement depends on the fourth dimension, which is time. So maybe we could describe this as a 4D view of 3D objects.

We can trick our brains into seeing in 3D by manipulating what the left and right eyes see

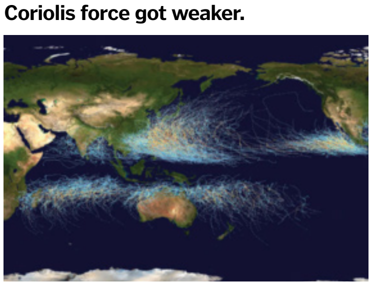
Reversing a hurricane

Dear **HIW,**

I have really enjoyed reading about 'Extreme Oceans' in Issue 81, especially about the extreme storms. It got me thinking, if hurricanes go anti-clockwise in the Northern Hemisphere and clockwise in the Southern Hemisphere, what happens when they travel over the equator?

William Tucker

Good question, William! In fact, hurricanes and cyclones can't cross the equator. They are driven by the Coriolis force, which is strongest at the poles and falls to zero at the equator. This means that hurricanes always form at least ten degrees north of the equator and cyclones always form at least ten degrees south of it. Once they form, the prevailing wind directions tend to blow them further from the equator. Even if one happened to drift towards the equator, it would dwindle out to nothing the closer it got, as the Coriolis force got weaker.



This image shows the path of every hurricane or tropical cyclone from 1985 to 2005

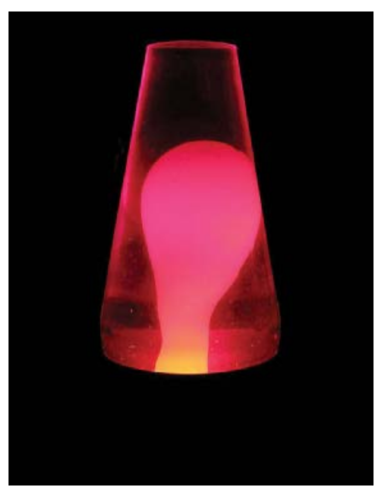
Mystery lava

Dear **HIW,**

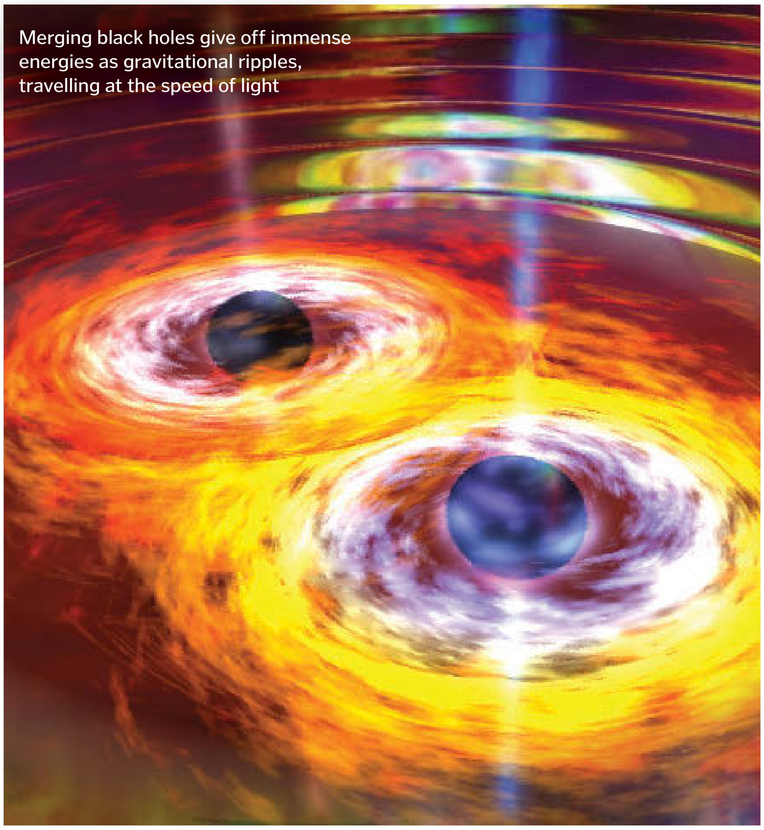
I got my first **How It Works** magazine today and I just couldn't stop reading it! The stuff you put in it is just so interesting! Anyway, I got a lava lamp not long ago and I just couldn't work out how it worked. Can you explain?

Stewart Oxley (aged 11)

We're glad you're enjoying it, Stewart! The 'bubbles' in a lava lamp are made of a wax mixture. Its density at room temperature is just high enough to sink in the coloured water. When the lamp is on, the heated base makes the wax melt and expand so that it is now less dense than water and a blob floats to the top. As it cools, its density rises so it sinks again and so on.



A lava lamp is just water and wax taking it in turns to float and sink!



Merging black holes give off immense energies as gravitational ripples, travelling at the speed of light

Delayed gravity

Dear **HIW,**
I really like to read your magazines and I always can't wait for the newest edition to come in the post. I came up with a question recently, does gravity have speed and if so, how fast does it travel?
Cathal Dafydd Brace

Yes, the effects of gravity travel at the speed of light. Einstein's theory of special relativity places an upper limit on the speed of any interaction between two objects in the universe and that includes gravitational interactions. Gravity is an incredibly weak force, so gravitational waves are extremely difficult to detect. But a 2003 measurement of Jupiter passing in front of a distant quasar provided tentative figures for the speed of gravity and this was finally confirmed this year at the LIGO observatory in the US, which detected gravitational waves for the first time.

"The effects of gravity travel at the speed of light"

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@HHulson
@HowItWorksmag My teenage son would love this magazine, so fascinated by science and how everything works, may help his studies as well

@Octopus_Books
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Help YouTube inventor Colin Furze come up with his next crazy vehicle via **@HowItWorksMag buff.ly/24565Mw**

@harpistkat
How much junk is in your genetic trunk? I'm on the case in **@HowItWorksmag**

@neiltyson
In science, when human behaviour enters the equation, things go non-linear. That's why Physics is easy and Sociology is hard.

@Dr_Lucie
I will never tire of looking at the images taken by **@NASANewHorizons**

@StationCDRKelly
Hosted **#SuperBowl** party on **@space_station**, but no one showed up. I would have served nachos! **#YearInSpace**

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