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HOW IT WORKS BOOK OF

Amazing ANSWERS to Curious QUESTIONS

Volume 05

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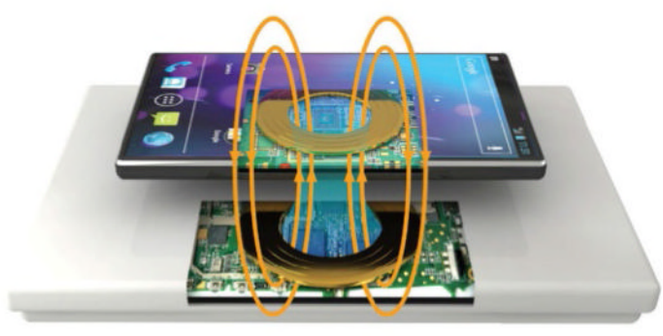
How It Works

Book of Amazing Answers to Curious Questions Volume 3

Welcome to

Amazing ANSWERS *to Curious* QUESTIONS

If you're curious about the world we live in, you've come to the right place! In this fifth volume of How It Works Book of Amazing Answers to Curious Questions, discover the elusive explanations behind life's most intriguing conundrums. Do you know what zombie ants are? Head to the Environment section to find out. Have you ever wondered why catnip is so irresistible to cats? Flick to the Science section. Are you interested in how New York's subway system was constructed? That's in the Technology section. With sections dedicated to six themes, including Space, Transport and History, you are sure to satisfy your hunger for knowledge within these pages! So if you've ever pondered on the inner workings of YouTube, considered what would happen if two planets collided or even questioned what airless tyres are, join the club and continue reading!



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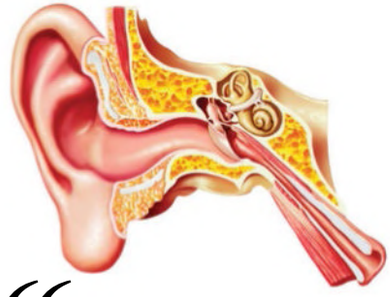

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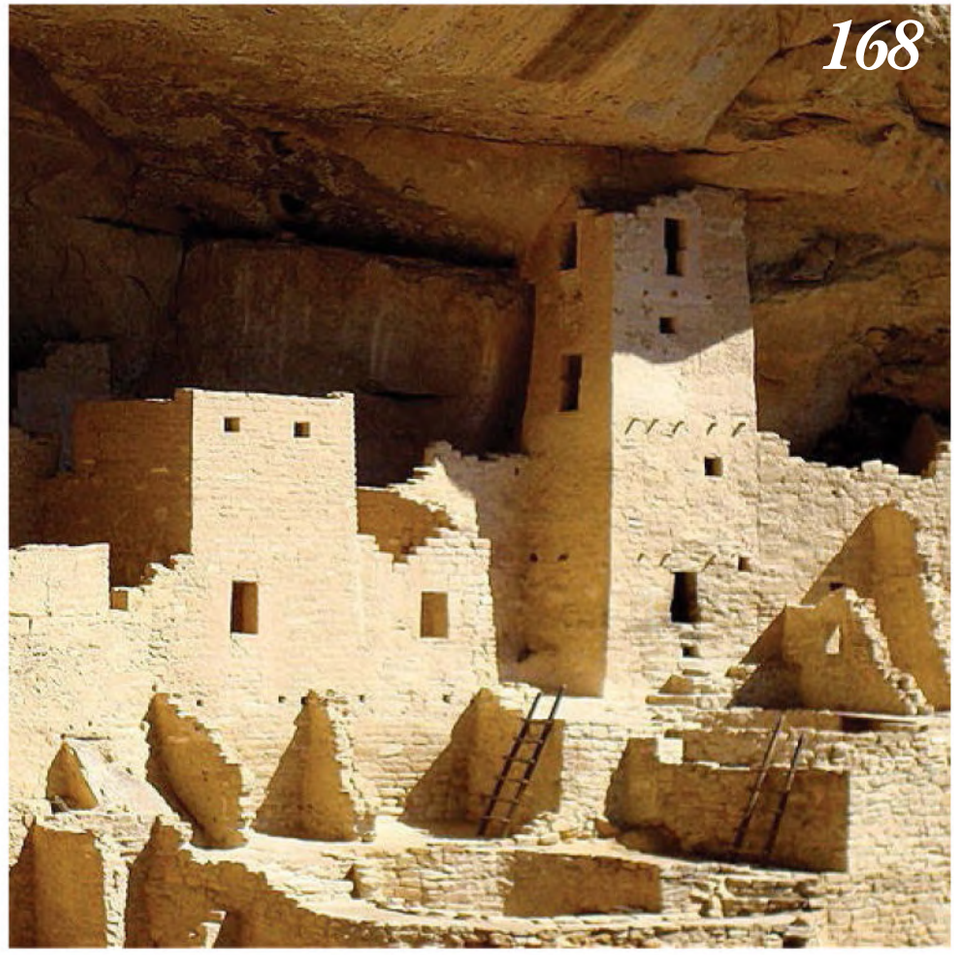


Environment

What species inhabit the African savannah?

These majestic plains hold the secret to a delicately balanced ecosystem that supports the largest beasts on land

The savannah environment is a huge expanse of wide-open grassland that is home to a web of incredible plants and animals. Formed exclusively around the tropics, savannahs are characterised by just enough rainfall in the wet season to enable plants to flourish, yet not enough for a rainforest, and almost arid conditions in the dry season, but not dry enough to form a desert. The plants and animals that live here have developed amazing means of coping with this extreme environment.

Around the world, savannahs are known by different names; in Asia they are 'steppes', they are 'prairies' in North America, and in Australia they are 'rangelands'. Usually only African grasslands are given the name 'savannah', and one of the most famous is the Serengeti Plains in Tanzania. This ecosystem is home to some of Earth's most incredible creatures: big cats, elephants, rhinos and giraffes to name just a

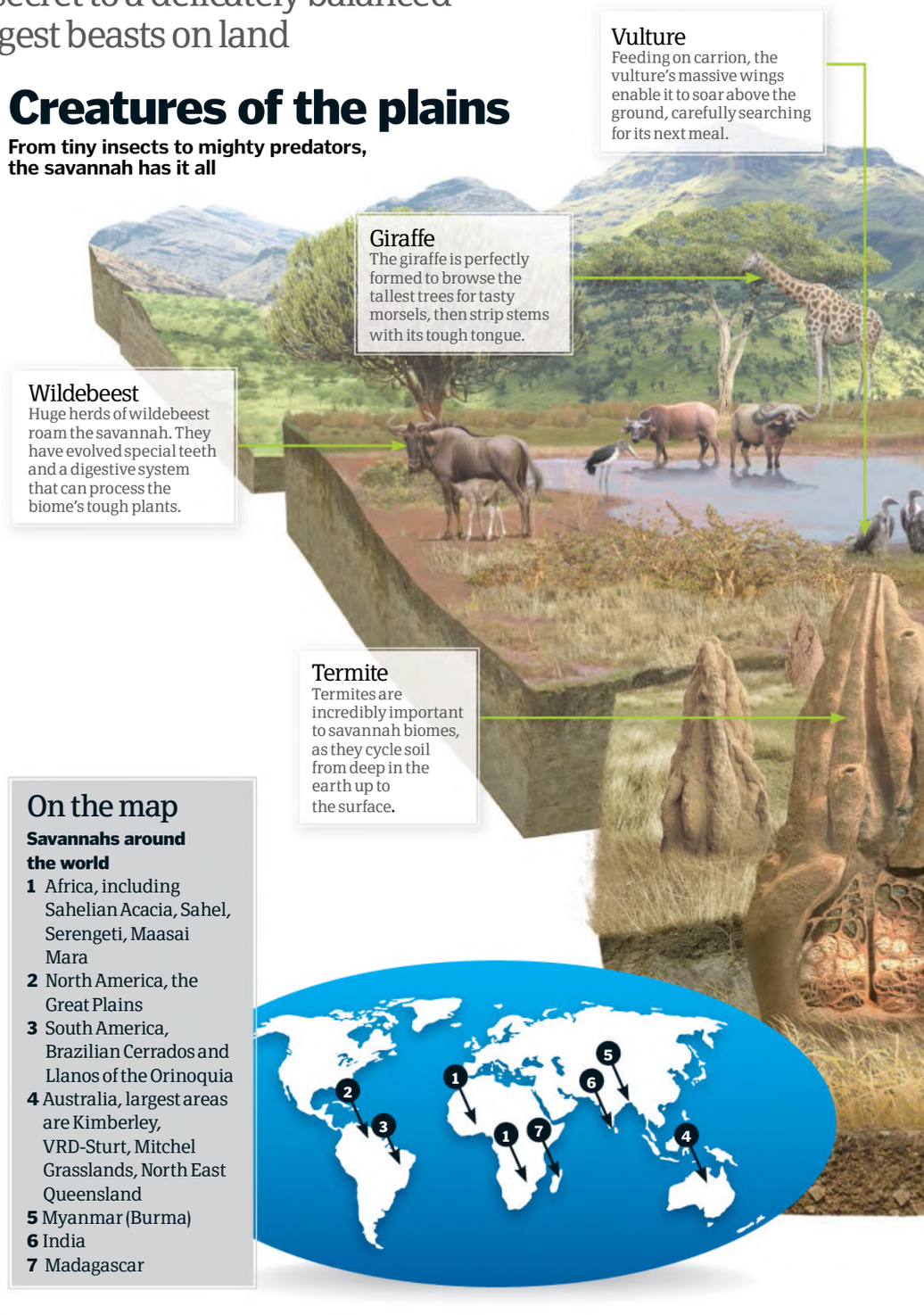
At the water hole

In the savannah, water holes are incredibly important features of the landscape, especially during the dry season. The seasonal or permanent pools of water, fed by rivers or aquifers, provide much-needed hydration for all animals of the savannah, sometimes drawing them in from many miles away.

Predator and prey alike gather to drink, and these connections keep the all-important savannah food web healthy. With all the animals gathering in one place, the predators have enough food but kill only what they need, which monitors the population naturally. Meanwhile the prey species are able to take a good long drink before moving on to their next destination.

Creatures of the plains

From tiny insects to mighty predators, the savannah has it all



Vulture
Feeding on carrion, the vulture's massive wings enable it to soar above the ground, carefully searching for its next meal.

Giraffe
The giraffe is perfectly formed to browse the tallest trees for tasty morsels, then strip stems with its tough tongue.

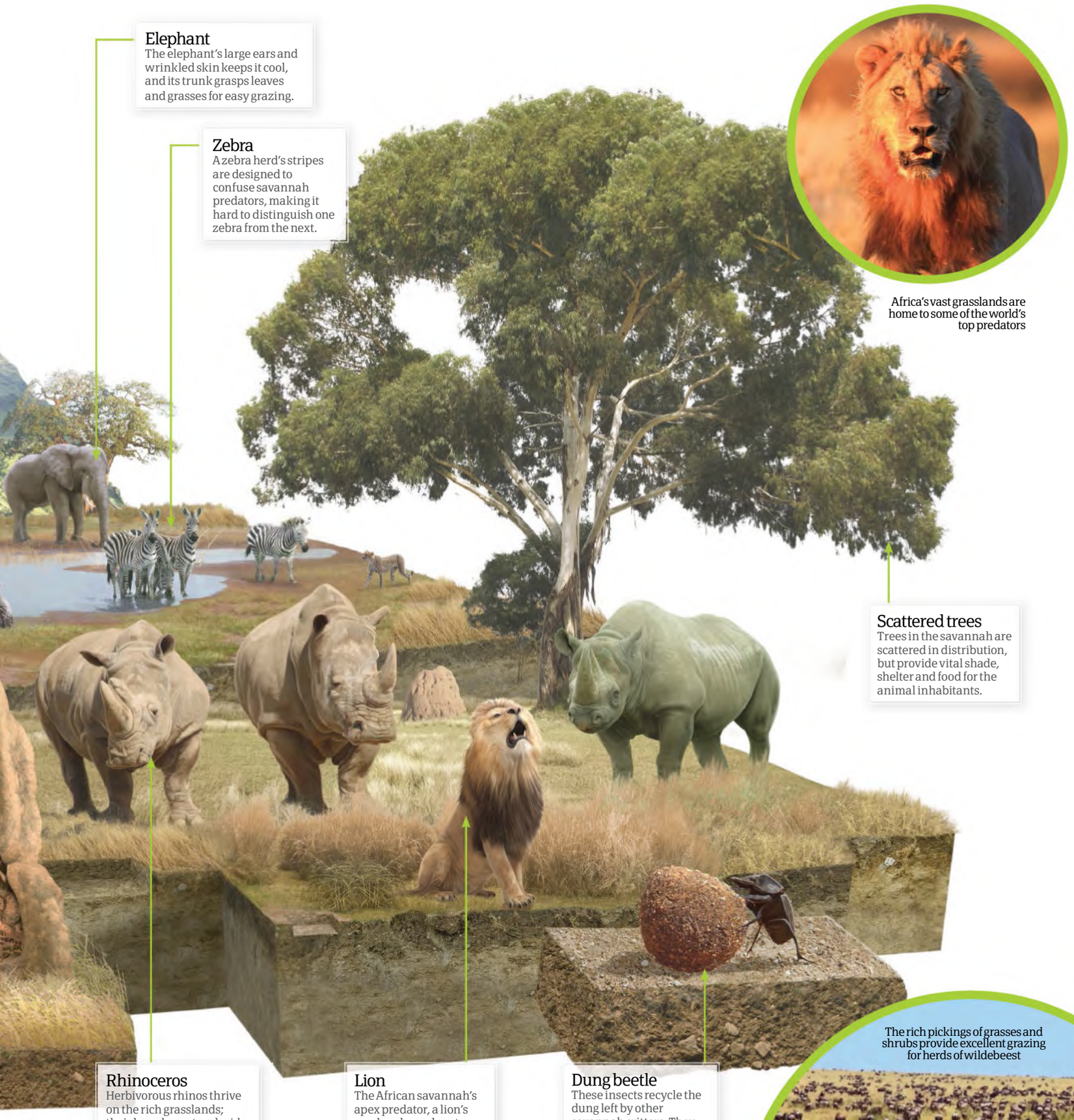
Wildebeest
Huge herds of wildebeest roam the savannah. They have evolved special teeth and a digestive system that can process the biome's tough plants.

Termite
Termites are incredibly important to savannah biomes, as they cycle soil from deep in the earth up to the surface.

On the map

Savannahs around the world

1. Africa, including Sahelian Acacia, Sahel, Serengeti, Maasai Mara
2. North America, the Great Plains
3. South America, Brazilian Cerrados and Llanos of the Orinoquia
4. Australia, largest areas are Kimberley, VRD-Sturt, Mitchel Grasslands, North East Queensland
5. Myanmar (Burma)
6. India
7. Madagascar



Elephant
The elephant's large ears and wrinkled skin keeps it cool, and its trunk grasps leaves and grasses for easy grazing.

Zebra
A zebra herd's stripes are designed to confuse savannah predators, making it hard to distinguish one zebra from the next.

Africa's vast grasslands are home to some of the world's top predators

Scattered trees
Trees in the savannah are scattered in distribution, but provide vital shade, shelter and food for the animal inhabitants.

Rhinoceros
Herbivorous rhinos thrive on the rich grasslands; their broad snout and wide upper lip are perfectly adapted for grazing.

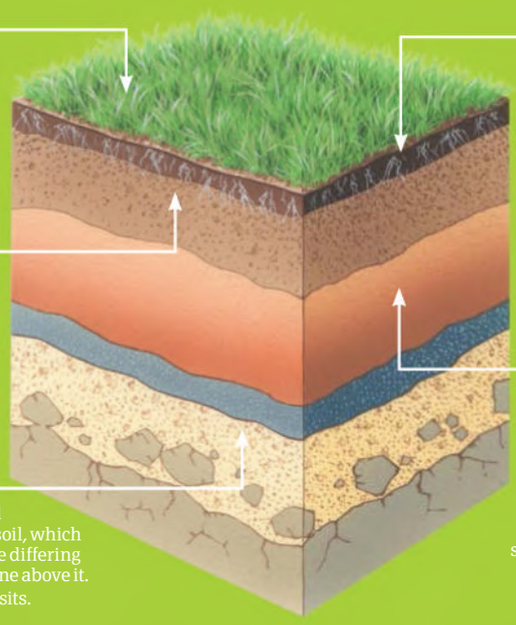
Lion
The African savannah's apex predator, a lion's sandy coloured coat helps it to camouflage in the grass to stalk prey.

Dung beetle
These insects recycle the dung left by other savannah critters. They break down droppings and use them to lay eggs.

The rich pickings of grasses and shrubs provide excellent grazing for herds of wildebeest

Life on the ground

With a variable and distinctive soil profile, plants of the savannah have to be hardy to take root. Species must also be well-adapted to withstand extreme temperatures



Prevalence of grass
The fact that the laterite soil layer prevents trees from taking root is what favours the prevalence of so many grasses, which have much shorter root systems.

Laterite
Season upon season of rain and drought have caused the layers below the humus to become incredibly hard. The soil is so cemented that long tree roots are unable to penetrate it.

Horizons
The flow of nutrients head downwards through the soil, which creates horizons, each one differing in composition from the one above it. Below these, the bedrock sits.

Humus
The thinnest, uppermost layer in the soil profile is known as humus. It's made of the organic matter from decaying plants and animals, and provides vegetation with nutrients.

Distinctive red soil
During the wet season, intense leaching occurs where water draws out nutrients and chemical compounds from the soil. Iron oxide remains, which gives the soil its rusty colour.

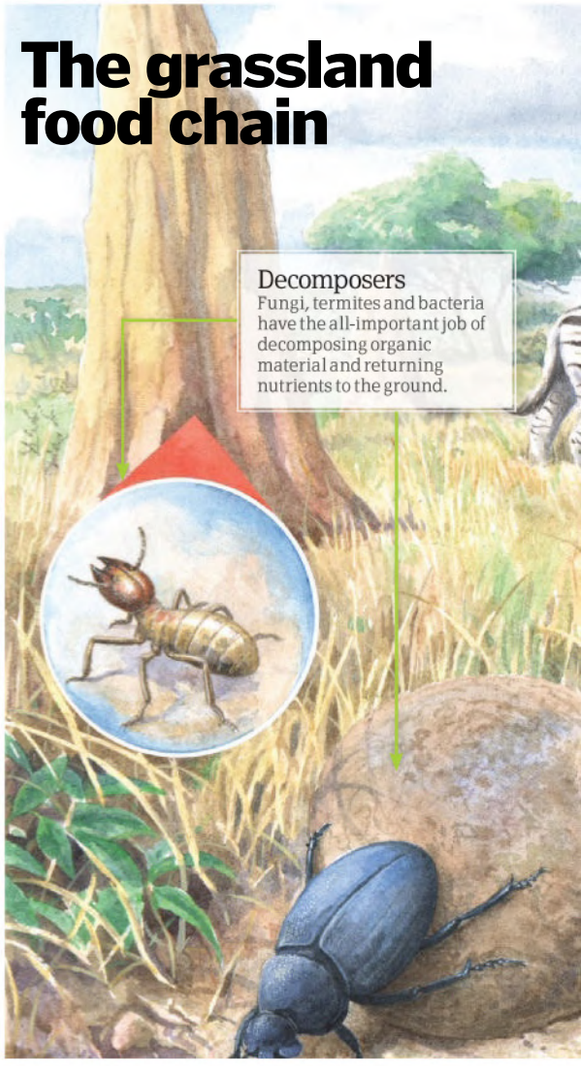
Savannah foliage

Acacia tree
The Umbrella acacia tree is a symbol of the African savannah. Providing a source of food for many creatures, the seedpods actually grow better after passing through an animal's gut!

Rhodes grass
This tufty grass has a long root system that extracts water from the soil from over four metres (13 feet) deep. This enables the grass to withstand short drought and grazing from animals.

Red grass
Incredibly, this grass is not only resistant to fire, but regular burning enhances the grass' prevalence, providing it's not overgrazed. The species is a good indicator of a healthy savannah.

The grassland food chain



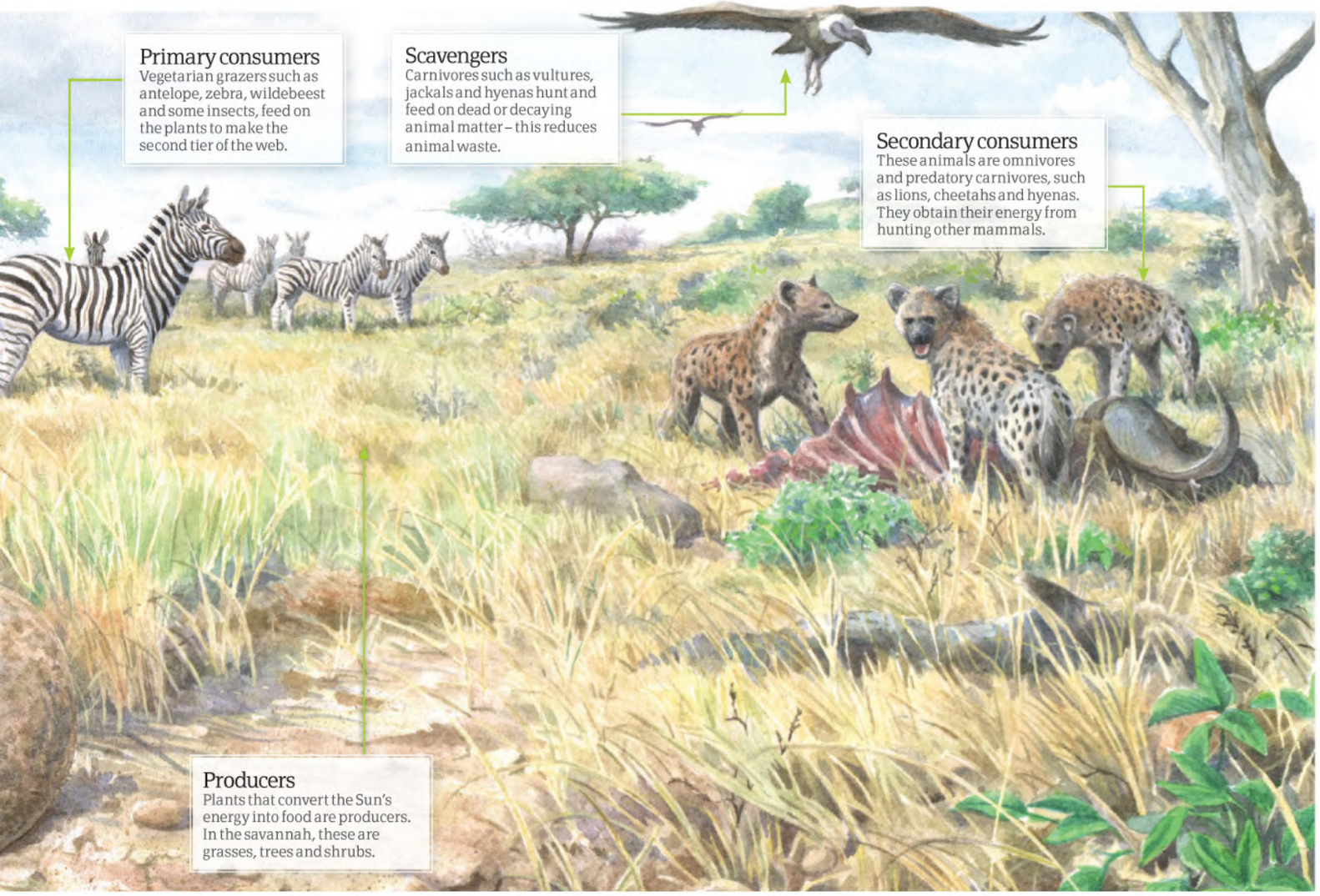
select few. When you think of the word 'savannah', rolling African grasslands come to mind, along with Mufasa's words to Simba: "Everything the light touches is our kingdom." Disney's classic cartoon actually portrays an ecosystem that is very real. Africa's most famous savannah regions encompass the Serengeti National Park, the Ngorongoro Conservation Area, Maswa Game Reserve, the Loliondo, Grumeti and Ikorongo Controlled Areas and the Maasai Mara National Reserve. So important is the 30,000 -square-kilometre (11,580-square-mile) region, that it contains two World Heritage Sites and two Biosphere Reserves.

The savannah biome has two distinct seasons, wet and dry, but there is still too little rain for many trees to grow, and so grasses and shrubs dominate the ecosystem. These hardy plants are able to support the great migration of herds of herbivorous animals, such as zebra and wildebeest, which travel en masse, chasing the rains and spurred on by the growth of new grass. Hungry predators like lions and cheetahs anticipate the arrival of these herds.

The savannah temperature remains fairly constant, and water holes can be found at various points across the plains (depending on the season), where many different types of animals will gather to take a drink. The rainy season stretches from around November to May, and then the dry season sets in and temperatures remain around 27 degrees Celsius (81 degrees Fahrenheit).

The hoards of wildebeest, zebra and gazelle aren't the only animals willing to make a trek to find water. Elephants, living in their close-knit familial groups, can locate water holes up to 50 kilometres (31 miles) away in a relatively featureless environment. It's thought that they have excellent spatial

> "There is still too little rain for many trees to be able to grow, and so grasses and shrubs dominate the ecosystem"



Illustrations by Peter Scott / Ian Jackson / Art Agency

memories ,and can use this to recall where the water holes are in this radius. Safari goers to these regions have also noticed large ruts in the earth – this is caused by elephants using their long, strong tusks to dig down into the soil while searching for water or to eat the soil to take in valuable nutrients.

Grasses are the prime source of food for the elephants and with so many other grazers, such as antelope and even rhinos, it's difficult to see how the grass doesn't simply wear out. The secret to this lies in both the grasses' biology and in the niches filled by each animal. Constant cutting of common savannah grass species, such as red grass or elephant grass, actually promotes fresh growth. This is because the grass growth occurs from the bottom of the shoot, so while they're nibbling away, the creatures are also gradually cultivating a grazing lawn. Different types of animals also have their own feeding techniques and take greenery from various levels. For example, giraffes browse for shoots, leaves and buds from high up in the trees, while zebras graze on the savannah floor. This means that there is little competition when it comes to finding vegetarian food.

Another rather more curious way that savannah grasses stay in healthy balance is through fire. During the dry season wildfires are a common occurrence and can burn away huge patches of grassland. However, instead of being devastating, these fires can return much-needed nutrients to the soil and encourage new growth. Many different plant species are fireproof and can withstand the flames, and the fires also help to prevent encroaching forests from taking over the grassland.

The hunters of the savannah are the big cats that sit at the very top of the food chain. Lions are, of course, the kings of the plains, but leopards, cheetah and African wild dogs are also high up in the savannah court. When the migratory herds arrive it provides rich pickings for these stealthy predators, who ensure that only the fittest prey survive. And where there are predators, there are scavengers, lurking on the sidelines. Spotted hyenas are skilful hunters but they're not picky eaters and will happily feast on the leftovers of other kills, as well as clean up any natural deaths. A very tough digestive tract enables the hyena to devour just about anything, and items that can't be digested are swiftly regurgitated.

The large animals are just tiny cogs in the giant wheel that keeps the savannah biome in balance. Of equal importance are the smaller creatures and tiny insects that work the savannah soil and decompose the waste to recycle nutrients.

Humans also flourish on these grasslands. Tribes such as the Maasai have lived and farmed there for many years, as the soil facilitates the growth of cereal crops and the grazing of cattle. While we worry about garden invaders like foxes, the Maasai are concerned about elephants trampling and eating their produce! They are a culture steeped in tradition and have a strong bond with the land.

What are asperatus clouds?

Understand what's behind the world's newest cloud formation

The last time a new type of cloud was officially recognised by the UN's World Meteorological Organization was in 1951, but these choppy seas in the sky could be next.

After being unable to identify the clouds from photos sent in by sky watchers all over the world, the Cloud Appreciation Society has proposed that they should be officially classified as asperatus clouds, from the Latin word for 'roughened'. For this to happen, the cause of the cloud has to be identified first. Although their formation is not yet entirely understood, some experts believe they form under the same conditions as mammatus clouds, which look as though they have a series of pouches hanging below them. These occur when ice crystals in the clouds sink, but are too large to evaporate in the air below.

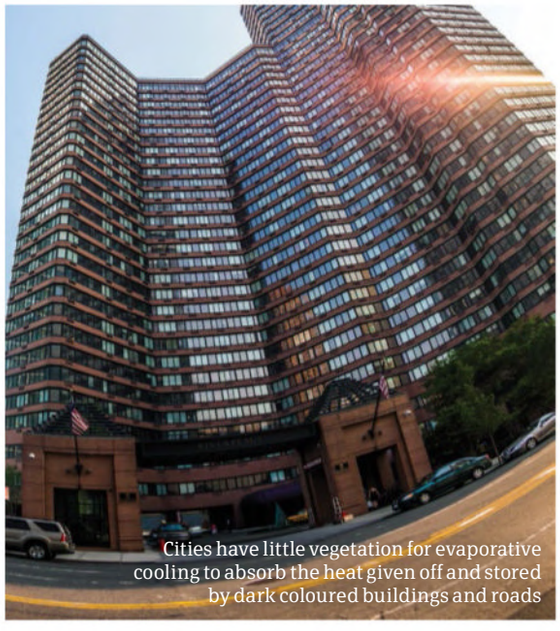
To form an asperatus cloud, strong winds then shear the underside of the mammatus cloud to form undulating waves instead of pouches. If they are classified, the clouds will be included in the International Cloud Atlas, which has not been published since 1975.

Why is it hotter in cities?

The effect that causes rising urban temperatures

It's not just busy public transport that makes city life feel sweatier than rural areas. On average, densely populated cities are one to three degrees Celsius (1.8 to 5.4 degrees Fahrenheit) warmer than their surroundings, resulting in a phenomenon known as the urban heat island effect. Dark surfaces of urban buildings and asphalt roads absorb lots of sunlight during the day. The stored energy is given off as heat, warming the area by as much as 12 degrees Celsius (22 degrees Fahrenheit). Cities also have less vegetation than the countryside, meaning plants can't help to cool the air by using the excess heat to evaporate the water they absorb. Use of cars and air conditioning also increases temperatures in urban areas.

> "Dark surfaces of urban buildings and asphalt roads absorb lots of sunlight during the day"



Cities have little vegetation for evaporative cooling to absorb the heat given off and stored by dark coloured buildings and roads

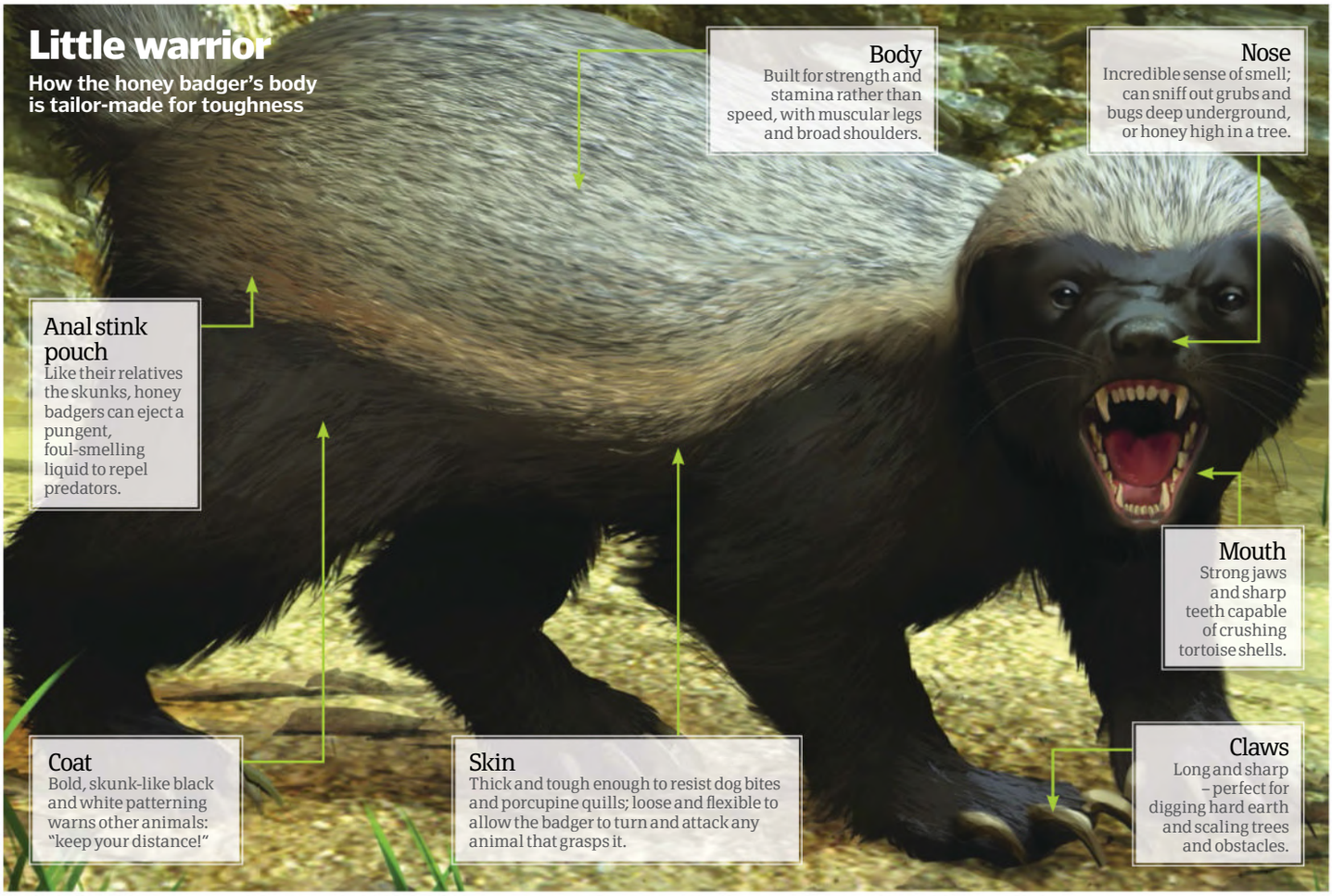
Why is the honey badger so fearless?

Even lions know better than to mess with the ruthless honey badger!

When you think of badgers, you probably imagine shy, snuffling woodland creatures with pretty, striped faces. But brace yourself, because the honey badger – despite its sweet name – is a whole different creature. In fact, it holds the official Guinness Book of World Records title for most fearless animal in the world!

Despite their name, honey badgers actually have more in common with weasels than they do with the other badger species. Around one metre (3.3 feet) in length and 30 centimetres (12 inches) tall, their bodies are squat, stocky and incredibly strong, and they move with a self-assured trot. They're nocturnal, generally solitary and a large brain-to-body size ratio makes them master problem solvers.

Honey badgers are also ferocious fighters, all rattling snarls and vicious lunges. They don't think twice about giving attitude to hyenas – animals five times their weight, with jaws more powerful than a lion's – and are reported to go for the scrotum. One account even tells of a trio of honey badgers teaming up to chase a group of seven lions from their kill. So, it may sound like the honey badger has a death wish, but this crazy little critter has every reason to be so bold. Virtually no predator can get the better of it, thanks to its secret weapon: its rubbery skin. At over half a centimetre (0.2 inches) thick, it is almost impenetrable to sharp objects, including spears, scorpion stings, and porcupine spines. Because the skin hangs loose around its muscular frame, a caught honey badger is able to twist right around and sink its vicious teeth and claws into its attacker's face. It can take a fully-grown leopard an hour to kill one of these tenacious little beasts!



Why is Lake Natron so inhospitable?

Understand the natural phenomenon behind Tanzania's this colourful – and super salty – soda lake

Situated in Africa's Great Rift Valley, Lake Natron's bright pink waters stand out in more ways than one. In addition to its eye-catching colour, the lake is also hypersaline, meaning that it is supersaturated with salt.

Ash from the once volcanic mountains nearby has enriched the soil on the lake bed with natron, the chemical compound from which the lake gets its name. Natron consists mainly of sodium carbonate, a salt that dissolves in the water to make it strongly alkaline. This type of lake is known as a soda lake, as its water has an extremely alkaline pH of between 9 and 10.5. Acidic rain sometimes reduces this value, but wet weather is erratic in the region.

Additional salts are also fed into the lake from nearby hot springs, and because the lake has no outlet, it is all left behind as the water evaporates. In fact, Lake Natron was originally a much larger freshwater lake, but as the hot, dry climate evaporated much of the water, it shrank and became very salty. The water is also a very warm temperature at 40 degrees Celsius (104 degrees Fahrenheit), but can sometimes reach a scolding 60 degrees Celsius (140 degrees Fahrenheit).

The lake's distinctive colour comes from the microorganisms that thrive on the salt within, but there aren't many other creatures that can survive these extreme conditions. Only one species of fish, the tilapia, is tough enough to live in the lake, but most other animals that venture into the water will die and become encrusted with salts when water levels drop. The natron, which was used in Egyptian mummification, helps to preserve their bodies, causing eerie stone-like figures to occasionally wash up onto the shore.

The lake's salt crust changes colour from red to pink or orange depending on the microorganisms present

Lake Natron is surrounded by freshwater wetlands and salt marshes

The wonderful wildlife of Lake Natron

One of the very few creatures that can thrive at Tanzania's hypersaline lake is the flamingo. The birds take advantage of the lake's extreme conditions, which keep their predators at bay. When the water level is just right, salt islands are exposed in the centre of the lake, providing the perfect nesting site. If the lake is too dry, predators are able to reach the young birds, and if there is too much rain, the nests can be flooded. The lake also provides an abundant source of food, as they feed on the blue-green algae, from which pigments called carotenoids give the birds their bright pink colour.

Most of the world's lesser flamingos use Lake Natron as their nesting site

"The water can sometimes reach a scolding 60 degrees Celsius (140 degrees Fahrenheit)"

How do aphids dictate ladybird behaviour?

These beautifully spotted insects begin their lives as grisly grubs

Animals' lives revolve around eating, and ladybirds are no different. Aphids, or greenflies, are a vital source of food for the 5,000 species of ladybird, but aphid colonies swell and shrink rapidly. Ladybirds time their reproduction with the growth of an aphid population to ensure their offspring will have enough to eat. There is more on the menu than aphids, however. Ladybirds also feast on plant matter and other insects, but females are more efficient feeders. They are significantly larger than males and are generally more active. They use a lot of energy searching for sites suitable for laying eggs, while males mainly just spend their time searching for females. To defend against bird predators, ladybird bodies are full of a chemical called precoccinelline. This is toxic, and their red colour acts as a warning to would-be scavengers. The quality of a young ladybird's diet dictates how poisonous it will be as an adult, which is why ladybirds eat up to 5,000 aphids in their lifetime.

Pupal stage
The larva sheds its outer layer of skin to form a cocoon and the transformation begins.

Mature larva
After spending three to six weeks feeding intensively and more than doubling in size, the larva is ready to pupate.

Freshly hatched
The larvae that emerge are only 2.5 millimetres (0.1 inches) in size. They instantly begin to search for food.

Laying eggs
Ladybirds lay up to 40 eggs at a time, delicately attaching them to the underside of a sheltered leaf for protection from predators.

Newly emerged
After seven days of pupating, the insect escapes its cocoon in adult form. It quickly changes from pale yellow to a glossy red.

Mating
After mating, a female ladybird can store male sperm for three months before fertilising the egg.

Though harmless to humans, ladybirds contain an alkaloid poison that is toxic to birds

Hibernation
When the temperature drops, ladybirds seek shelter in which to hibernate, such as tree holes or even inside houses.

This group of chimps in Gabon check themselves out in a zoo keeper's mirror

Can animals recognise their own reflections?

How vain are chimpanzees?

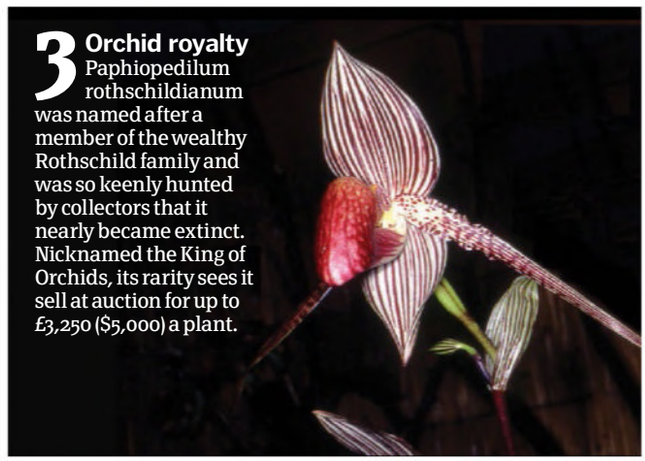
Most animals don't recognise their own reflection. Doing so requires a self-awareness that most animals possess. Developed in the 1970s by biopsychologist Dr Gordon Gallup Jr, the mirror test involves putting dots of an odourless and tasteless dye to the face of an animal, then placing it in front of a mirror. Touching the dye shows that it recognises itself. Apes such as chimps, bonobos and orangutans have been seen to pass the test, as have other species like dolphins, elephants and magpies.

What makes orchids special?

Blooming unbelievable traits of these beautiful, rare and exotic flowers

1 A rare beauty
The ghost orchid (Epipogium aphyllum, right) is among the rarest in the world. Strangely, this plant contains no chlorophyll and only grows tiny scale-like leaves, so it has to rely on an array of symbiotic fungi for nourishment.

2 Medicinal wonder
Orchids have been used in traditional Chinese medicine for centuries. Dendrobium nobile is used to combat kidney disease, while Cremastra appendiculata, known as the Chinese tulip, is supposed to tackle tonsillitis and even cancers.



3 Orchid royalty
Paphiopedilum rothschildianum was named after a member of the wealthy Rothschild family and was so keenly hunted by collectors that it nearly became extinct. Nicknamed the King of Orchids, its rarity sees it sell at auction for up to £3,250 ($5,000) a plant.

4 More various than birds
New species of orchid are being discovered each year, adding to some 25,000 already accounted for – twice as many as there are species of bird. Estimates show that about 5,000 orchid varieties remain undiscovered.

5 Human likeness
The bilateral symmetry of an orchid flower gives it a similar basic shape to a human face. It's been suggested this is what has led the plants to be so popular and sought after by collectors.

How do monarch butterflies live?

The butterfly king makes a spectacular migration, guided by instinct and an internal compass

The monarch is one of the most recognisable and beloved butterflies in the world. It is also one of the most remarkable. Each year, anywhere between 60 million and 1 billion of them undertake an incredible winter migration from the chilly regions of southern Canada and northern USA to southern California and the forests of western central Mexico – a distance of up to 4,828 kilometres (3,000 miles).

Monarchs have a wingspan of about 10.4 centimetres (four inches), and are identified by their striking black, white and orange colouring. Males and females are almost identical apart from a dark spot on the hind wing of the male – a scent gland that produces chemicals to attract females. As well as being undeniably beautiful, their bright colouring serves to warn predators that they are foul tasting and poisonous.

The butterflies actually develop their poisonous quality as caterpillars. Female monarchs lay their eggs on the toxic milkweed plant, and the caterpillars feed exclusively on this. Its glycoside toxins are harmless to the monarch, but poisonous to the monarch's predators. By munching milkweed, the caterpillars develop a reservoir of toxins in their bodies, which persist in their system beyond metamorphosis and make them an ill-advised meal.

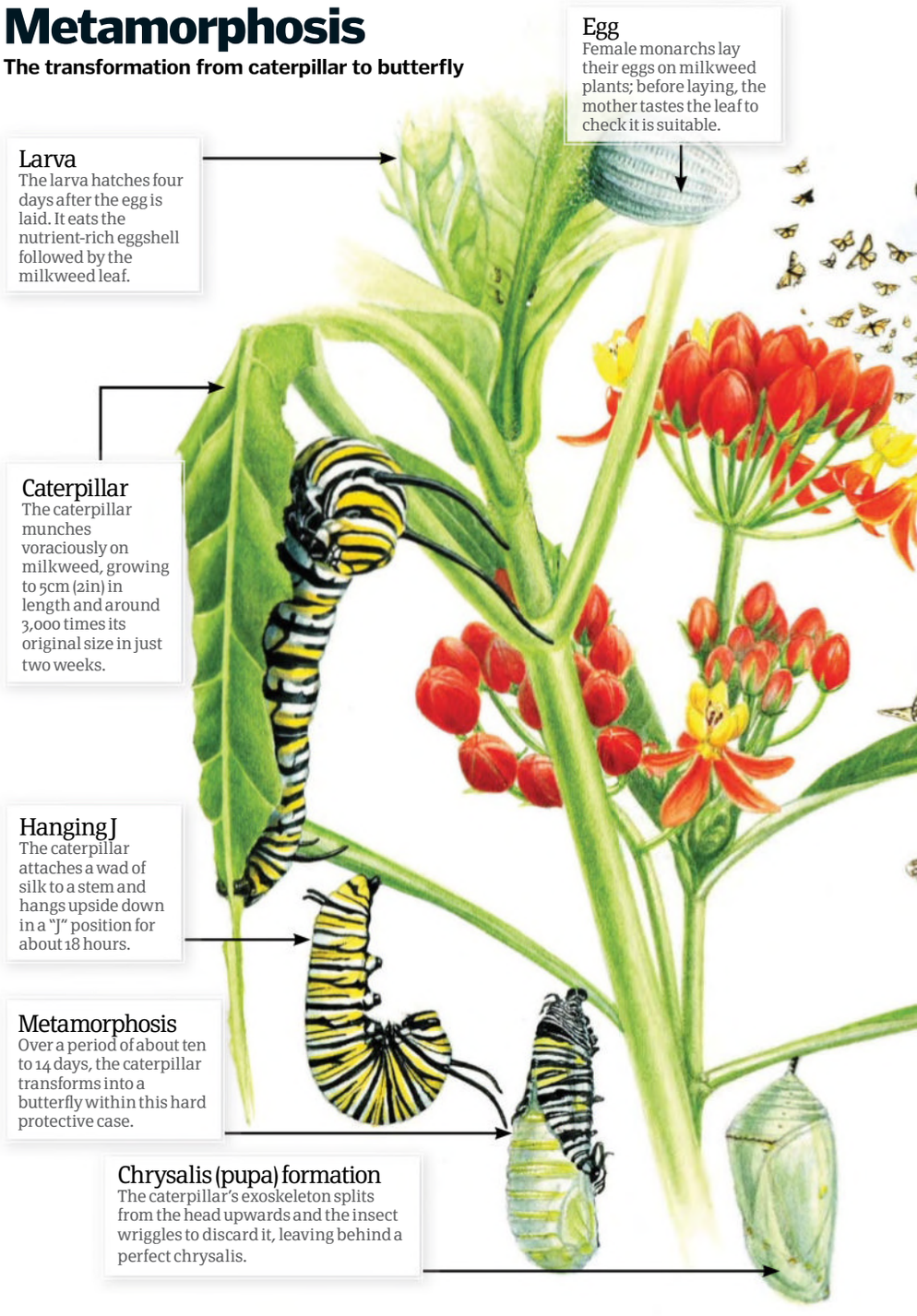
Most monarchs don't live longer than about five weeks. About three to five generations are born between early spring and the end of summer, but the generation that emerges from their chrysalises at the start of autumn is different. This is the "over-wintering" generation, and it's their job to fly south, away from the freezing North American winters, and ensure the survival of the species.

The migration is astounding, not only in terms of the distances the butterflies cover, but also for the fact that they instinctively know the route, despite never having made the journey before. Their arrival in Mexico usually coincides with Día de Muertos (Day of the Dead), one of Mexico's most important holidays. According to local legend, the arriving monarchs are believed to be the souls of the deceased returning to Earth.

Over-wintering monarchs live for up to eight months. They embark on the northward journey in early spring, mating on the wing and laying their eggs on milkweed plants in the southern United States. Their offspring will complete the journey northwards, before the whole cycle begins again.

Metamorphosis

The transformation from caterpillar to butterfly



Q&A

> Between 60 million and 1 billion monarchs undertake an incredible winter migration

Fluttering on the brink

Revered or not, the monarch is under threat. Populations have fallen drastically since the Nineties due to environmental degradation and human agricultural practices.

In Mexico, habitat loss from illegal logging, plus a string of natural disasters have reduced the availability of suitable overwintering grounds. In the US, herbicides used by farmers have decimated the monarchs' vital host milkweed plants.

Experts are also concerned about how global warming will affect rainfall patterns and alter the timing of the migration. Monarchs can't fly unless their body temperature is at least 30 degrees Celsius (86 degrees Fahrenheit), so cold snaps in Mexico – one of the predicted effects of climate change – could spell disaster for the species. According to the US Fish and Wildlife Service: "Unless we act now to help the monarch, this amazing animal could disappear in our lifetime."

Milkweed plants are essential to the monarch's survival

What are sinkholes?

The rare phenomenon behind that sinking feeling

Sinkholes form when water slowly erodes the bedrock underground, until the surface is no longer supported and collapses into the cavity beneath. This occurs most commonly in areas where the bedrock is made from salt or carbonate rocks (such as gypsum or limestone), which are particularly susceptible to dissolving.

In the absence of surface drainage, water accumulates in the sinkhole, draining through to the subsurface. Cover-subsidence sinkholes create a small depression at the surface, which sinks slowly. Cover-collapse sinkholes are far more dramatic, collapsing in a matter of just a few hours and potentially causing catastrophic damage. One of the most spectacular sinkholes ever seen opened up in Guatemala City in 2010, swallowing a three-storey building. It measured 20 metres (66 feet) across and had a depth of 30 metres (98 feet). Sinkholes are a natural phenomenon, but manmade changes to drainage flows (such as ground pumping) or land use changes can encourage them to occur.

Why do lizards like to bask in the sun?

What's behind the sun-seeking behaviour of these sneaky amphibians?

Lizards are covered with scales, which are very good at preventing moisture loss, but pretty bad at keeping in body heat. Because of this, lizards and other reptiles don't try to maintain such a fixed internal body temperature as birds and mammals do. At night their body temperature drops, so in the morning they bask on a rock until the Sun has warmed them up enough for their metabolism to operate efficiently. This strategy restricts most reptiles to warmer countries, but it also allows them to get by with much less food than mammals. For example, some crocodiles can go for a year without eating.

'Crab crossings' are set up to reduce the number of crabs crushed by vehicles during the migration period

Red crabs regularly invade local golf courses on their way to the coast

What's behind Christmas Island's red crab invasion?

Discover the amazing migration of 120 million crabs

Once a year on Christmas Island, Australia, tens of millions of red crabs descend from the rainforest, turning the island into a sea of red as they make their way to the coast to breed. The migration begins with the wet season, typically around October or November, and is linked with the phases of the Moon and therefore the tide.

The males leave their forest burrows first, and once they reach the shore they have a quick dip in the sea to replenish any body moisture lost during their journey. They then start to dig burrows in the sand and, once the females arrive, they enter the burrows to begin mating. After mating, the males make their return journey, leaving the females in the burrows to develop up to 100,000 eggs. About 12 to 13 days later, before dawn at high tide, the females emerge from the burrows and go to sea. Once they reach the water they deposit their eggs, which immediately hatch into larvae. In the water, the larvae grow into prawn-like creatures called megalopae, which breathe through gills. Those that manage to survive the harsh ocean currents and marine predators emerge from the sea four weeks later to shed their outer skin and become baby crabs. The infants, measuring just 5mm (0.2cm) across, begin their march inland to live on the forest floor, then after four years, they progress to join the migrating herds for breeding.

Which creatures thrive in the Orinoco plains?

Weaving through South America, the Orinoco River creates a unique habitat for giant anacondas, piranhas and more

The Orinoco River begins at its source in the Guiana Highlands, and then curves its way through Venezuela and Colombia until finally meeting the Atlantic Ocean. Along the river's route, there are rolling grasslands, marshes and forests, known as plains, or Los Llanos.

The tropical savannah climate of the marshes and swamps that fringe the wide-open grasslands are a perfect habitat for thousands of freshwater dwellers. Catfish, piranhas, giant otters and giant anacondas are just a few of the critters lurking beneath the surface. Wading birds also take full advantage of the rich pickings in the nutrient-laden mud, such as ibises that use their curved beaks to dig out a tasty crustacean dinner.

The gallery forests surrounding the plains provide plenty of shelter and cover for more elusive hunters. Jaguars are known to skulk around the trees, and thousands of bird species roost in the canopy. One of the tallest trees is the moriche palm, which can reach 35 metres (114 feet).

In spring, herds of deer graze the savannah, which is often flooded during the rainy season and extends the habitat of the water-dwelling Llanos residents. The grasses are also the perfect habitat for species such as giant anteaters that seek out termites, as well as birds like the northern screamer and the burrowing owl, which hunts small reptiles and mammals and excavates a burrow as a nest.

The Llanos biome is also an important habitat for migratory species, with an estimated 40 per cent of Colombia and Venezuela's Neotropical migratory bird species residing on the Orinoco plains throughout the year.

Peregrine falcon
As one of the fastest birds on Earth, an attacking falcon can reach speeds of over 300km/h (186mph).

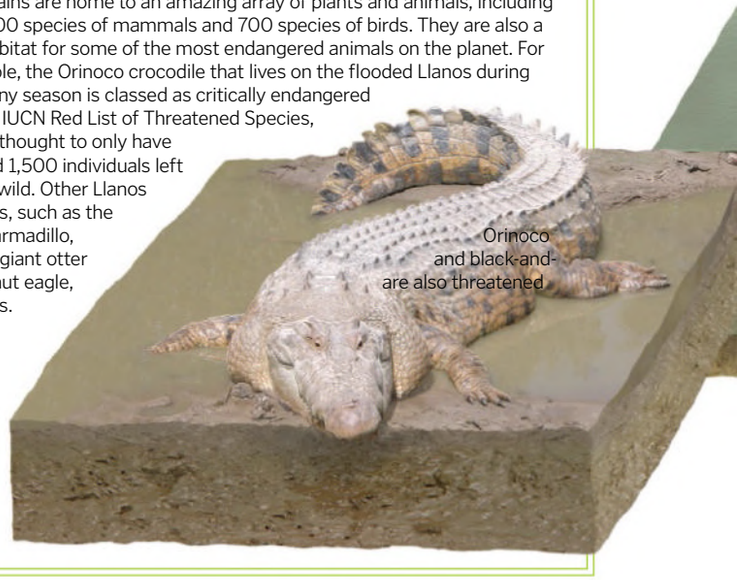
Wildfires help to regulate the landscape and promote new growth

Natural fires

During the dry season, from November through to March or April, the Llanos can become quite parched. Very little rainfall means the Orinoco River waters are at their lowest, while soaring temperatures dry out the vegetation. These combining factors can result in natural fires, which may sound severe but are actually an excellent way for the ecosystem to renew itself. These savannah fires burn away excess vegetation and expose new ground. This provides more room for new seeds to colonise, which provides the all-important base of the plains' food chain. Fires can also maintain the nutrient balance of the soil and regulate the growth and advance of trees on the grasslands. Burning away old vegetation also allows the fresh growth of existing plants. However, some Llanos species have adapted to this natural phenomenon, and so the plains are also populated with species of fire-tolerant trees that can withstand the natural flames.

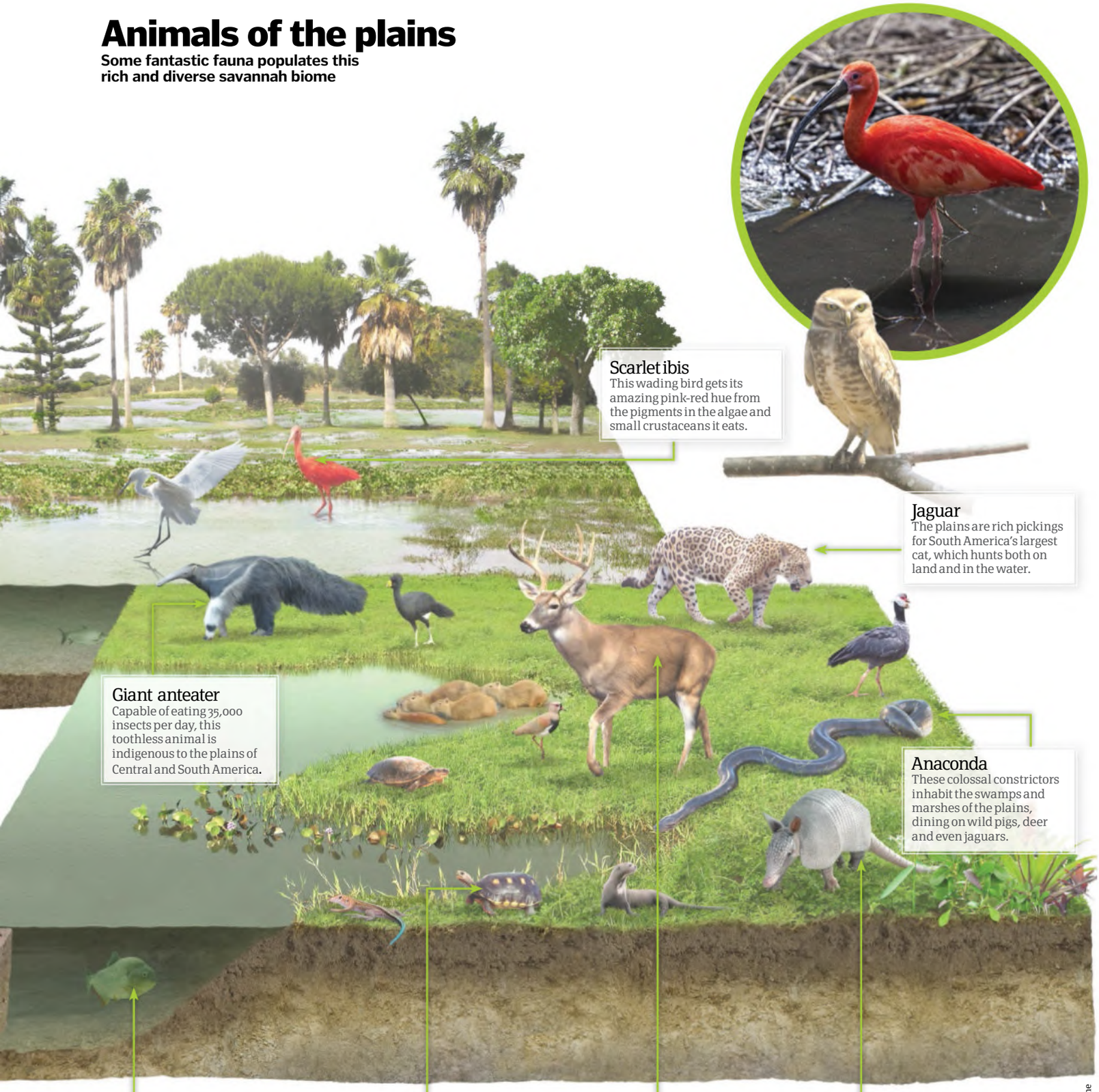
Endangered species

The plains are home to an amazing array of plants and animals, including over 100 species of mammals and 700 species of birds. They are also a key habitat for some of the most endangered animals on the planet. For example, the Orinoco crocodile that lives on the flooded Llanos during the rainy season is classed as critically endangered by the IUCN Red List of Threatened Species, and is thought to only have around 1,500 individuals left in the wild. Other Llanos species, such as the giant armadillo, turtle, giant otter and black-and-chestnut eagle, are also threatened species.



Animals of the plains

Some fantastic fauna populates this rich and diverse savannah biome



Scarlet ibis
This wading bird gets its amazing pink-red hue from the pigments in the algae and small crustaceans it eats.

Jaguar
The plains are rich pickings for South America's largest cat, which hunts both on land and in the water.

Giant anteater
Capable of eating 35,000 insects per day, this toothless animal is indigenous to the plains of Central and South America.

Anaconda
These colossal constrictors inhabit the swamps and marshes of the plains, dining on wild pigs, deer and even jaguars.

Black spot piranha
Living in large shoals, the piranha uses its needle-like teeth to munch on birds, crustaceans and vegetation.

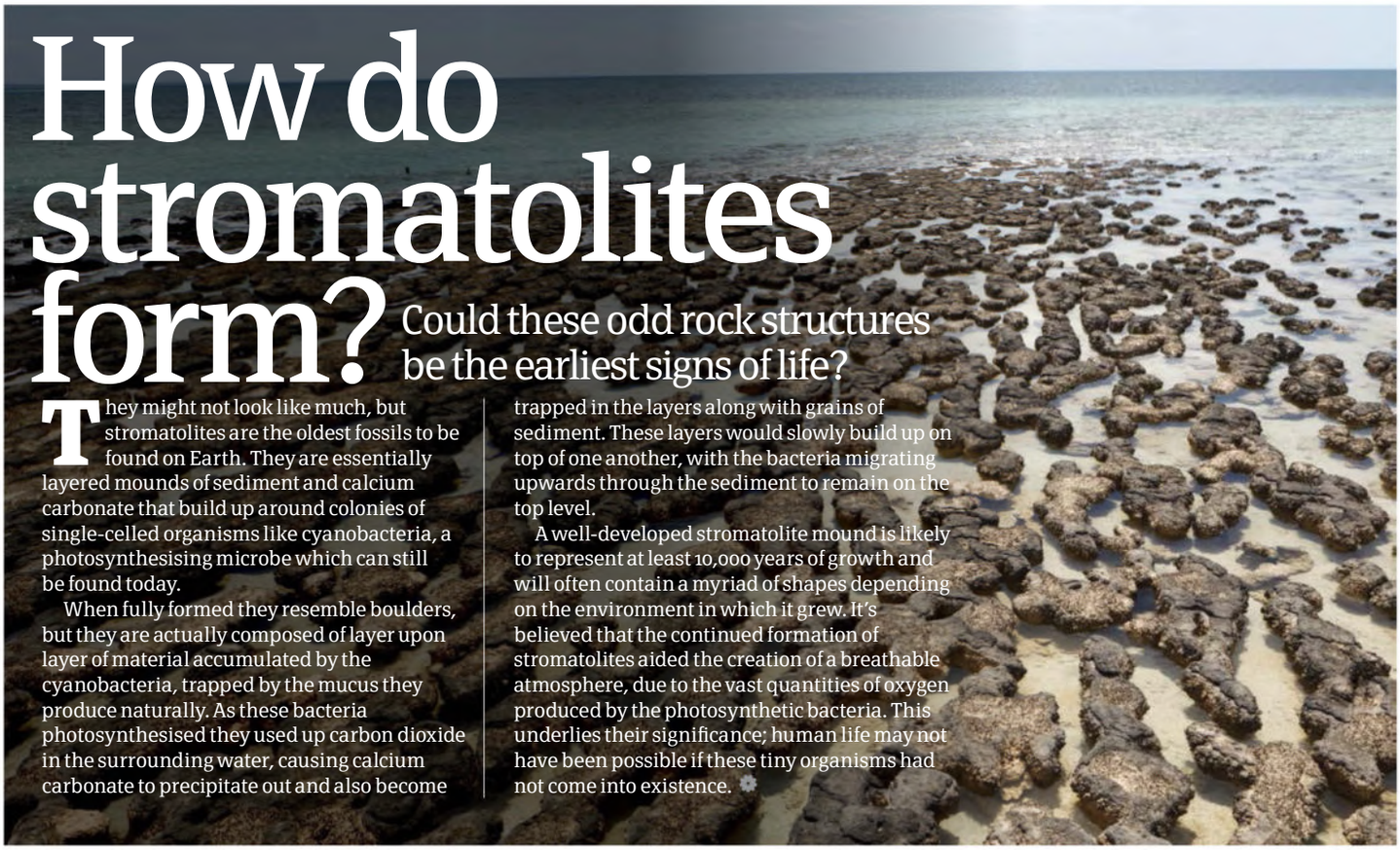
Red-footed tortoise
Living on the savannah grasslands and edges of the forests, these medium tortoises exist on an omnivorous diet.

White-tailed deer
Herds of these deer can be found grazing the rich grasslands of the Llanos.

Giant armadillo
These armoured critters can reach up to 150cm (59in) in length and are considered ecosystem engineers due to their digging excavations.

How do stromatolites form?

Could these odd rock structures be the earliest signs of life?



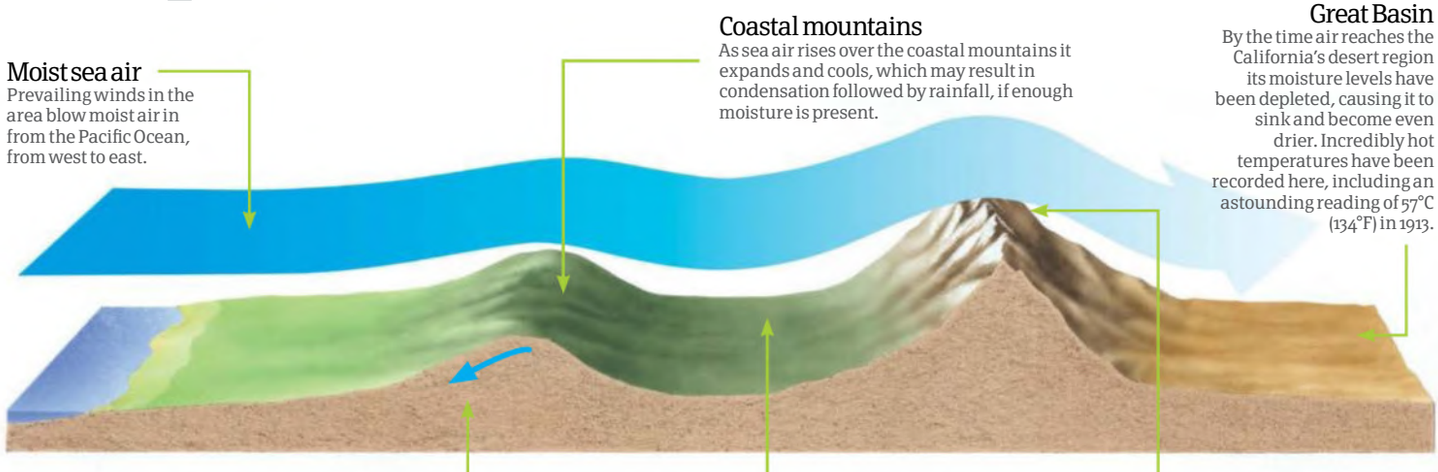
They might not look like much, but stromatolites are the oldest fossils to be found on Earth. They are essentially layered mounds of sediment and calcium carbonate that build up around colonies of single-celled organisms like cyanobacteria, a photosynthesising microbe which can still be found today.

When fully formed they resemble boulders, but they are actually composed of layer upon layer of material accumulated by the cyanobacteria, trapped by the mucus they produce naturally. As these bacteria photosynthesised they used up carbon dioxide in the surrounding water, causing calcium carbonate to precipitate out and also become trapped in the layers along with grains of sediment. These layers would slowly build up on top of one another, with the bacteria migrating upwards through the sediment to remain on the top level.

A well-developed stromatolite mound is likely to represent at least 10,000 years of growth and will often contain a myriad of shapes depending on the environment in which it grew. It's believed that the continued formation of stromatolites aided the creation of a breathable atmosphere, due to the vast quantities of oxygen produced by the photosynthetic bacteria. This underlies their significance; human life may not have been possible if these tiny organisms had not come into existence.

What's behind California's unique climate?

From moist sea air to dry desert, find out about North California's climate zones



How do weaver birds build their nests?

Learn how weaver birds knit and tie knots to build amazing structures

Not content with simply gathering a few twigs to fashion an open-top nest, weaver birds go to a lot more effort to create a home for their young. Their enclosed and intricately woven creations not only help to keep out predators, but are also used to attract prospective mate.

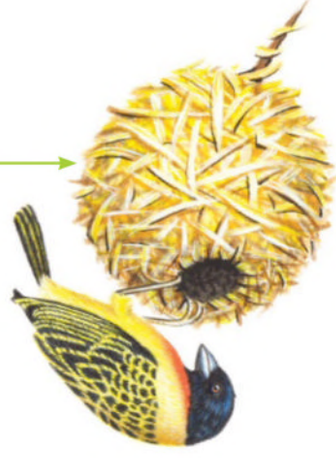
It's the male weaver birds that do the building, and the females judge who they want to mate with based on his construction skills. Therefore, it is vitally important that the structure is strong and secure. The male bird begins the process by finding a bare tree branch, and then gathers his building materials by ripping up strands of grass with his beak. Over 1,000 blades of grass are needed to make one nest, so a great deal of energy is required to harvest them one at a time. Only the freshest and most supple strands will do, as he needs to be able to fix them to the branch using complicated knots and stitches similar to the actions of a human weaver. Using his thin beak as the needle, he weaves a neat lattice-like pattern, alternately threading strands above and below the strands that run perpendicular to it, to create an incredibly strong structure. However, once the grass dries out and turns brown, the female will consider it too weak and unfit for her young, meaning he has to cut it down and start the process all over again.

How to weave a nest

The stages that every male weaver bird must complete to create a safe haven

1 Weave a ring
The bird starts by securing strands of grass or strips of leaves to a tree branch. He then loops them around to create a ring that is big enough for him to pass through. This ring forms the supporting structure for the rest of the nest.

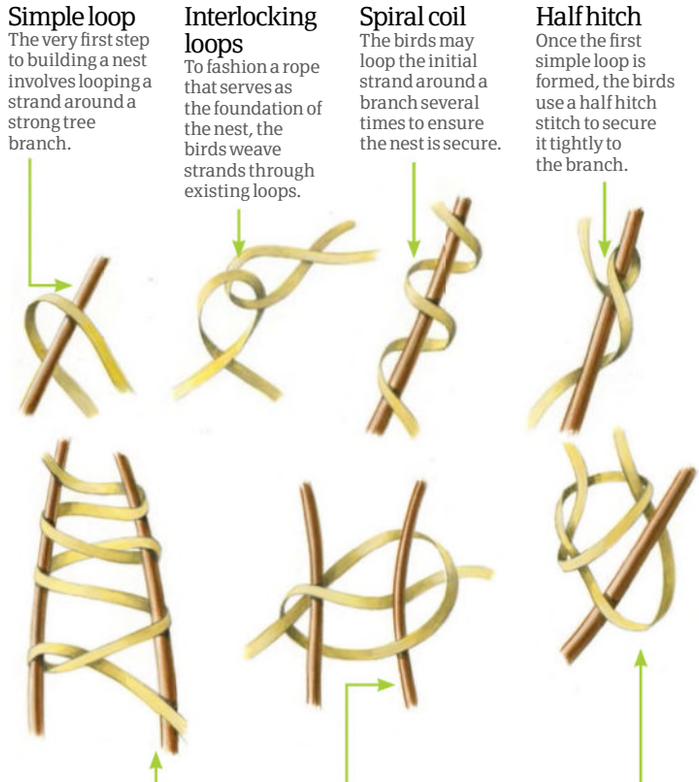
2 Add a roof
More strands are weaved onto the ring to build up the roof and walls of the nest. He does this by poking a strand through the ring structure, pulling it out the other side and then feeding it back through again, just like stitching.



3 Create a doorway
A hole is left at the bottom of the nest to serve as a doorway, and he constructs a long downward pointing entrance tube that leads to it. This helps to deter predators that would otherwise be able to swoop down and snatch the eggs or chicks from above.

Types of stitches

Some of the intricate techniques weaver birds use to build a nest



Simple loop
The very first step to building a nest involves looping a strand around a strong tree branch.

Interlocking loops
To fashion a rope that serves as the foundation of the nest, the birds weave strands through existing loops.

Spiral coil
The birds may loop the initial strand around a branch several times to ensure the nest is secure.

Half hitch
Once the first simple loop is formed, the birds use a half hitch stitch to secure it tightly to the branch.

Alternately reversed winding
To strengthen the foundation of the nest, the birds may weave the initial strand between two branches.

Overhand knot
The birds can loop a strand and feed the end back through to secure it to branches or other strands.

Slip knot
Weaver birds can use complicated slip knots to weave strands and branches together to form their nests.

Why is Lake Abraham flammable?

What forms the explosive bubbles trapped beneath these frozen waters?

It may look spectacular, but this frozen lake should be approached with caution, particularly if you're holding a lit match. The incredible white patterns visible within the ice are actually bubbles of methane, which is a highly flammable gas.

As the lake melts in spring, these bubbles are able to reach the surface, where they pop, allowing the methane to escape. Some brave scientists have even tested the presence of this gas by poking holes in the ice and holding a lighter over the surface, sending huge flames into the air.

The methane is produced by bacteria that feeds on organic matter like leaves and dead animals that have fallen into the lake. Because the man-made lake bed was covered in trees, grass and plants before it was flooded in 1972, it also contains much more organic matter than any natural lake would. This means there is more for the bacteria to feast on, which causes them to produce a larger amount of methane.

Although the lake is great for putting on amazing fire shows, it is not so good for climate change. Methane is a greenhouse gas 25 times more potent than carbon dioxide, trapping heat in the Earth's atmosphere to cause global warming. This is also creating a vicious cycle. As warmer temperatures cause more of the frozen ground around the lake to thaw and collapse, more trees fall into the water. This increase in organic matter leads to more methane production. This methane released by Lake Abraham alone won't have much of an effect, but there are thousands of other bodies of water around the Arctic producing it too. Scientists estimate that more than ten times the amount of methane currently in the Earth's atmosphere will come out of these lakes in the near future.

How do frost flowers form?

How do these stunning ice blooms grow?


Frost flowers are typically found in the Arctic and Antarctic

They may look like strange plants or even sea creatures, but these beautiful formations are actually intricate ice sculptures that grow naturally on thin ice. They have been spotted on frozen lakes, ponds and sea ice, but require very specific conditions to form. The air above the surface of the ice must be still, dry and about 20 degrees Celsius (68 degrees Fahrenheit) colder than the temperature of the ice itself. This makes it possible for the surface ice to sublimate, meaning that it changes directly from a solid to a gas, skipping the liquid stage in-between. As this water vapour hits the cold air above the ice, it condenses to form ice crystals that attach to imperfections or cracks on the surface. With very little wind around, the crystals do not blow away, and are left to grow naturally into stunning frost flowers. As they grow, the flowers also draw up more water from the ice below, and this often contains microorganisms. In fact, the density of bacteria found in many frost flowers means that each one is its own temporary ecosystem.

> "Each one is its own temporary ecosystem"

What's the difference between frogs and toads?

As difficult as they may be to tell apart, frogs and toads do show some differences

Frogs and toads both belong to the Anura order of the class Amphibia, but they usually have features that help to separate them. Frogs have long legs to enable them to jump and mucus-covered skins. Toads are fatter and have dry skin and shorter legs. Frogs tend to stay close to water, while toads are more often found inland. While this category is huge, we tend to think of 'true frogs' as members of the Ranidae family, and 'true toads' as members of the Bufonidae family, each of which contains hundreds of different species.

Do zombie animals exist?

The human version may be fictional, but in the animal kingdom, zombies have no mercy…

They're not quite the classic brain-eating, gormless slow-shufflers of horror movies, but for some species, the zombie threat is very real. The culprit? Parasites: small organisms with complex life cycles that set up camp inside their animal hosts. These gruesome body-snatchers are able to control the animals' minds, using them as living-dead puppets and steering them to positions of optimal benefit.

One classic case is the zombie ant. The parasite is a mind-controlling fungus (Ophiocordyceps camponoti-rufipedis) that manipulates carpenter worker ants into straying far enough from the colony that their social immunity is impaired. The fungus makes the ant bite down underneath a leaf, where it is anchored until it dies, then the ant's corpse is used by the fungus to grow. The fungus also releases spores that rain down and infect more ants, and so the nightmare continues.

One insect group responsible for zombifying its victims and turning them into mindless drones are wasps. The jewel wasp (Ampulex compressa) injects venom directly into the brains of cockroaches, targeting two specific locations that render the roach's free will useless. The wasp leads the cockroach to a burrow and lays an egg on the roach's abdomen. The zombie roach only dies once the egg has hatched and the larva devours it piece by piece.

Another wasp species, the green-eyed wasp (Dinocampus coccinellae), makes light work of harnessing the power of the ladybird. The wasp lays her eggs inside the bug, and new evidence suggests that a virus also attacks the ladybird's brain, paralysing and enslaving it as a zombie babysitter. The larva emerges and weaves a cocoon between the ladybird's legs so the paralysed bug acts as a bodyguard until the larva is ready to leave. Amazingly, a quarter of ladybirds recover from their zombification!

Rodents of the undead

Animals are biologically hard-wired to fear and flee from their predators. However, one parasite is capable of reversing a rodent's natural fear of felines, even encouraging them to actively seek cats out.

Related to the parasite that causes malaria, Toxoplasma gondii is a single-celled pathogen that infects many types of mammal and bird, causing a disease known as toxoplasmosis. Like every life cycle, Toxoplasma has to reproduce, and the only place that this specific microbe can do so is in the gut of a cat.

When it infects rodents, Toxoplasma reverses the fear of cats in a rodent's brain and encourages it to seek out felines by making the rat attracted to the scent of cat urine. Inevitably, this results in the infected rat getting eaten, allowing Toxoplasma to continue its life cycle within the feline hunter.

The zombie ant

How a mind-controlling fungus enslaves carpenter ants, one worker at a time

Death

The fungus then kills its host and uses the nutrients from the ant's body to grow a large stroma (a spore-releasing stalk). This extends down from the back of the ant's head.

Mind-control

The fungal cells release chemicals that control the ant's central nervous system, forcing it to find a site where conditions are perfect for fungal growth. The ant bites down to anchor beneath a leaf.

Infection

As they forage in their woodland home, slightly too far from the colony for social immunity to protect them, worker ants unwittingly get exposed to fungal spores.

Spores scatter

Once the fungus matures, the spores are given off. The fungus is perfectly placed to shower the forest floor with zombie-making spores to enslave new ants.

Death-wish fish

Killifish in California have been discovered to play host to a mind-sucking parasite that alters behaviour in order to further its own species. These zombie fish are infected with a fluke – a small, parastitic worm that reproduces in the guts of sea birds. The flukes are able to limit the production of serotonin in the fish's brain, which makes it very restless. Ordinarily shy of the surface and its dangers, infected fish will actively swim near and even flick the water's surface, greatly enhancing the changes of getting plucked out and eaten by a bird.

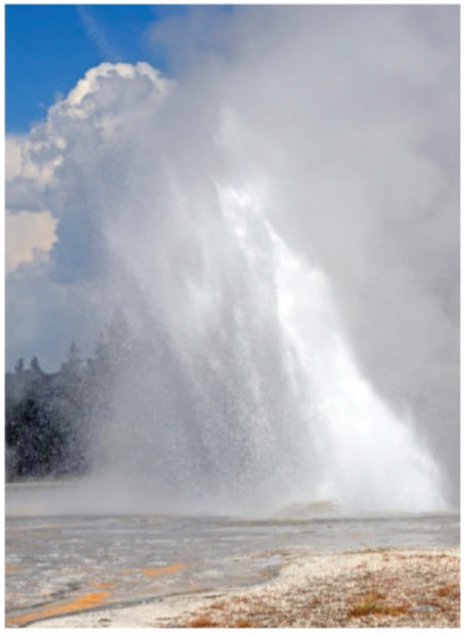
How does dry cleaning work?

How do chameleons camouflage themselves?

Certain species of chameleon have layers of cells called chromatophores, which contain different-coloured pigment granules; by moving these granules around, they are able to control their colour. However, this technique is more commonly used as a method to signal emotions than for camouflage, and the species with the best colour-changing abilities tend to use their talents to attract a mate rather than to hide from predators. For most species of chameleon, camouflage works in a similar way to camouflage in other animals, and they have evolved over time to blend in with their surroundings. For example, the mottled colour and spiky shape of the brown leaf chameleon make it almost invisible among dead leaves.

Why do geysers spurt out hot water?

A geyser is a natural vent in the Earth's surface, which intermittently spurts out tall columns of hot water and steam. They form in areas that have volcanic activity. What makes a geyser such a unique and incredible phenomenon is that it requires at least three very specific conditions to form: a water supply that refills the geyser after an eruption; a heat source, which is normally hot rocks that heat the water; and a pressure-tight plumbing system to store the water as it is heated. As more hot water flows through the narrow pipes of the plumbing system, intense pressure causes it to erupt.



Why is it dangerous to look directly at the Sun?

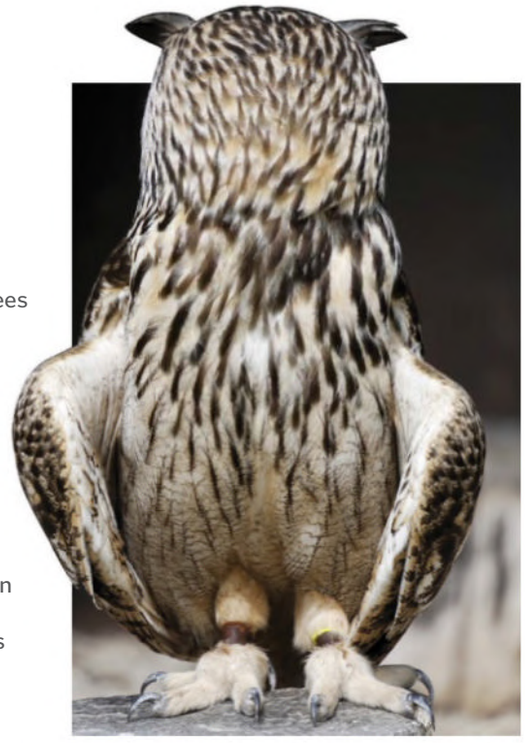
The Sun's light contains far more energy than our eyes can safely absorb, and it can damage the eye's delicate structures within seconds. Staring directly at the Sun for a few seconds typically causes photokeratitis, a condition similar to sunburn, which leads the cornea to become cracked and inflamed. Though it is very painful, patients usually recover fully. Longer exposure can damage the retina, causing vision to become blurry or discoloured for several months. Eyesight may never return to normal. Damage to the macula, a portion of the retina used for detailed vision, can result in permanent loss of visual acuity.

Why don't spiders stick to their own webs?

Not all the threads on a spiderweb are sticky. The spokes of the web pattern are made from a dry, structural silk and spiders mostly walk on these threads as they move around the web. But they also need to be able to handle the sticky spiral threads when building and repairing the web, without getting stuck themselves. They can do this because their legs are covered with stiff bristles that minimise the surface area in contact with the sticky droplets. They also have an oily substance that repels the adhesive and acts as a non-stick coating.

How far can an owl's head rotate around?

An owl can swivel its head 270 degrees in either direction. Some scientists have claimed this is due to bone and vascular structures that run along its neck to the skull. It is these structures, rather than the fact an owl has double the number of bones in its neck compared to a human, that enable it to turn its head that far. Its head is also only connected by one socket pivot, making it more flexible than ours, which is connected by two. The reason an owl does this is because it has fixed eye sockets and therefore poor peripheral vision.

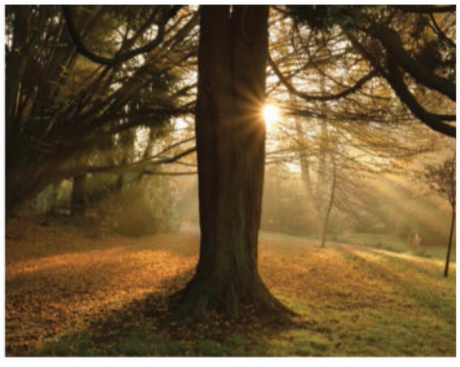


What is mohair?

Mohair is a silky, luxurious textile produced from Angora goats. After shearing, the hair is spun into yarn, then knitted, crocheted, or woven onto a cotton backing. The name 'mohair' likely comes from the Arabic 'mukhayyar,' referring to a cloth made of goat hair. Mohair is a popular fabric because it can be easily dyed and is wrinkle resistant, flame resistant, and moisture resistant. It's also very durable and warm while being light. Mohair was so highly prized in Turkey that export of both the fabric and goats was restricted until the 1820s.

Why do trees only grow to a certain height?

A number of factors can limit tree growth, but water transport is what puts the ultimate cap on their height. The taller a tree, the further it needs to carry water and the harder it needs to work against gravity in doing so. Although trees gain an advantage in growing taller than their neighbours and capturing more sunlight, beyond a certain point it costs them more energy-wise to keep their uppermost leaves hydrated than they gain from the additional light, causing them to stop growing. Other environmental factors such as nutrient or water limitation and climate, also affect how tall a tree can grow.

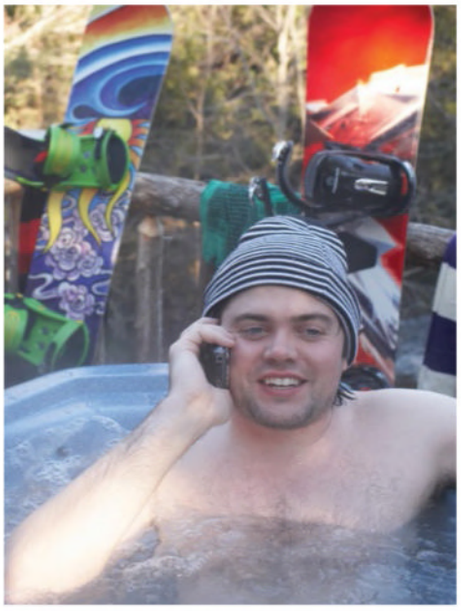


Why are eggs egg-shaped?

Eggs have evolved to be egg-shaped – known as an asymmetrical tapered oval – for a few reasons. The shape makes it easier for the hens to lay the eggs, as their cloacae (the vent through which hens pass eggs, as well as waste) muscles find more surface area on the tapered end. An egg's shape also makes it less likely to roll out of the nest, because it will make a circular path when it rolls. Finally, the shape also means more eggs can fit into the nest and that they can fit snugly together to stay warm.

What's the difference between a bumble bee and a wasp?

Let's start with the similarities. Bumblebees and wasps are both flying insects belonging to the order Hymenoptera. And they are both yellow and black. That's basically it. Bumblebees are a group of about 250 species which are all members of a single genus, Bombus, they live in small social groups of 50 to 400 and they eat nectar and pollen. Wasps are a much larger group of 30,000 loosely related species. Nearly all of them are solitary predators that lay their eggs in the body of another insect. Only about a thousand wasp species are social and live in colonies, but these are the ones we tend to see most often.



Does putting a wet mobile phone in rice really dry it out?

All water, except distilled water, contains impurities that make it electrically conductive. This will short-circuit the battery destroying it within seconds and no amount of rice will save you. So the most important thing is to remove the battery immediately – don't even wait to power down first. Packing it in dry rice for 24 hours after that will help to absorb the water that might corrode the electrical contacts or get trapped under the screen. But dismantling it as much as possible and leaving the parts in a warm airing cupboard is just as effective.

How fast can a woodpecker peck?

According to a study conducted at Beihang University in China, woodpeckers move their heads at speeds of up to seven metres (23 feet) per second, that's over 25 kilometres (15 miles) per hour.

Can you eat the rind on cheese?

Cheese rinds are safe to eat, bar a few exceptions where the cheese is coated in a layer of wax. Rinds form when bacteria and fungi colonise the outside of cheese, changing its appearance, taste and texture. There are three main types of rind. Bloomy rinds, found on brie for example, form after cheeses are sprayed with penicillin spores. Washed rinds result from regular baths in brine or alcohol. Finally, natural rinds (parmesan, for example) develop when a cheese is allowed to age naturally, forming a hard crust as it dries out. All are edible, although many find the hard texture of natural rinds unappealing to eat.

What makes food organic?

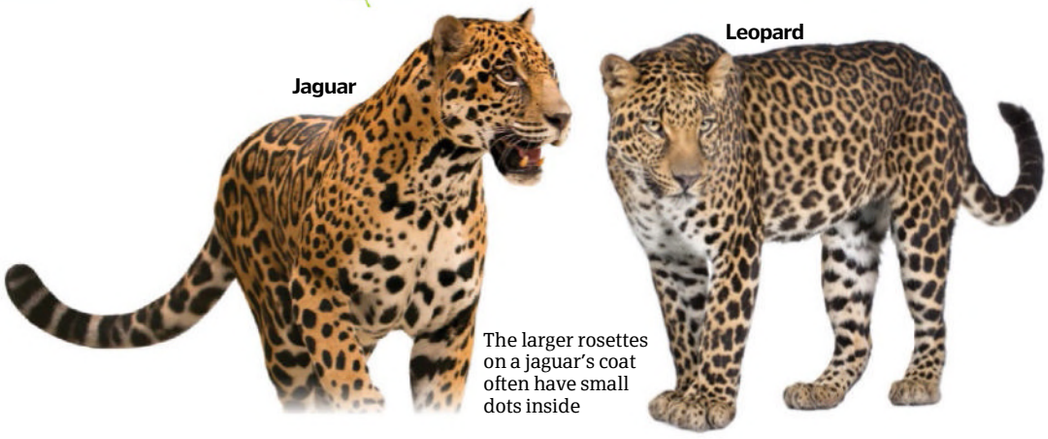
The requirements needed for a food to be labelled as organic vary from country to country but they generally include avoiding unnecessary chemicals (such as fertilisers), genetically modified crops and certain types of processing. Limited use of pesticides is allowed, however. Livestock raised organically meanwhile, enjoy higher welfare standards. However, there are a number of controversies surrounding organic food and its health benefits. While many in favour of organic food suggest that it is more nutritious, most studies indicate that this is not necessarily the case. Although organic food contains fewer pesticides, conventional food still has pesticide levels well below what is considered unsafe to consume.

Why do kangaroos jump?

At high speeds, a kangaroo's hopping is considerably more energy efficient than running, enabling these creatures to travel comfortably at average speeds of around 30 kilometres (20 miles) per hour for long periods of time. This ability is key in the barren Australian outback, where animals frequently have to cover large distances in search of food or water. The kangaroo's morphology has evolved to maximise efficiency, with strong, elastic tendons designed to store and release energy. As it hops, the back and forward movement pumps air in and out of its lungs, saving even more energy.

If a plug socket is switched on but there is nothing plugged in, is it wasting power?

No. The switch on a wall socket just connects the live wire to the pin in the plug. It's there to provide a convenient way to switch off devices that don't have a on/off switch. But there's no difference between a wall socket that is switched on and a socket that doesn't have a switch at all. Those sockets are live all the time but they don't use any power until something is plugged in to complete the circuit between the live and neutral pins. There is no 'standby power' for a wall socket because they don't have any electronics inside them.



The larger rosettes on a jaguar's coat often have small dots inside

What's the difference between a jaguar and a leopard?

It can be difficult to tell these two big cat species apart, but usually you can look closely at the patterns on their fur. Both jaguars and leopards have rosette patterns, but the rosettes on a jaguar's coat are usually larger, and tend to have spots inside of them (unless they're melanistic, or black).

Another way to tell the difference is by their body shape and size. Leopards have longer tails and longer, leaner bodies, while jaguars are usually more compact and have broader heads. Jaguars live in South America, while leopards can be found across Africa and Asia.

Why are moths attracted to light?

We know moths as a species are positively phototactic, which means they are naturally drawn toward light. However, exactly why they're attracted has yet to be scientifically proven, but there are a few likely theories. In fact, a behaviour called transverse orientation could explain the phenomenon. This is where an insect will use a distant natural source of light, such as the Sun or Moon, as a reference point to help them navigate. So it's possible that a moth can be disorientated by artificial light and fly toward it in confusion.

Why is hot water better for washing up than cold?

Hot water works better than cold water when doing the dishes for the same reason that sugar dissolves faster in a cup of hot tea. According to the second law of thermodynamics, as the temperature rises, the water molecules gain more energy. They move around more quickly and bash into your dishes at higher speed, making it easier for them to pull particles into the dishwater. When washing your clothes though, hot water isn't always better. Old-style detergents use chemical machines called enzymes to break down the dirt on your clothes, and these work best at around 30-40°C (86-104°F). However, new detergents are designed to work just as well at lower temperatures. Turning your washing machine's temperature down saves both energy and money, while keeping your clothes looking their best for longer.

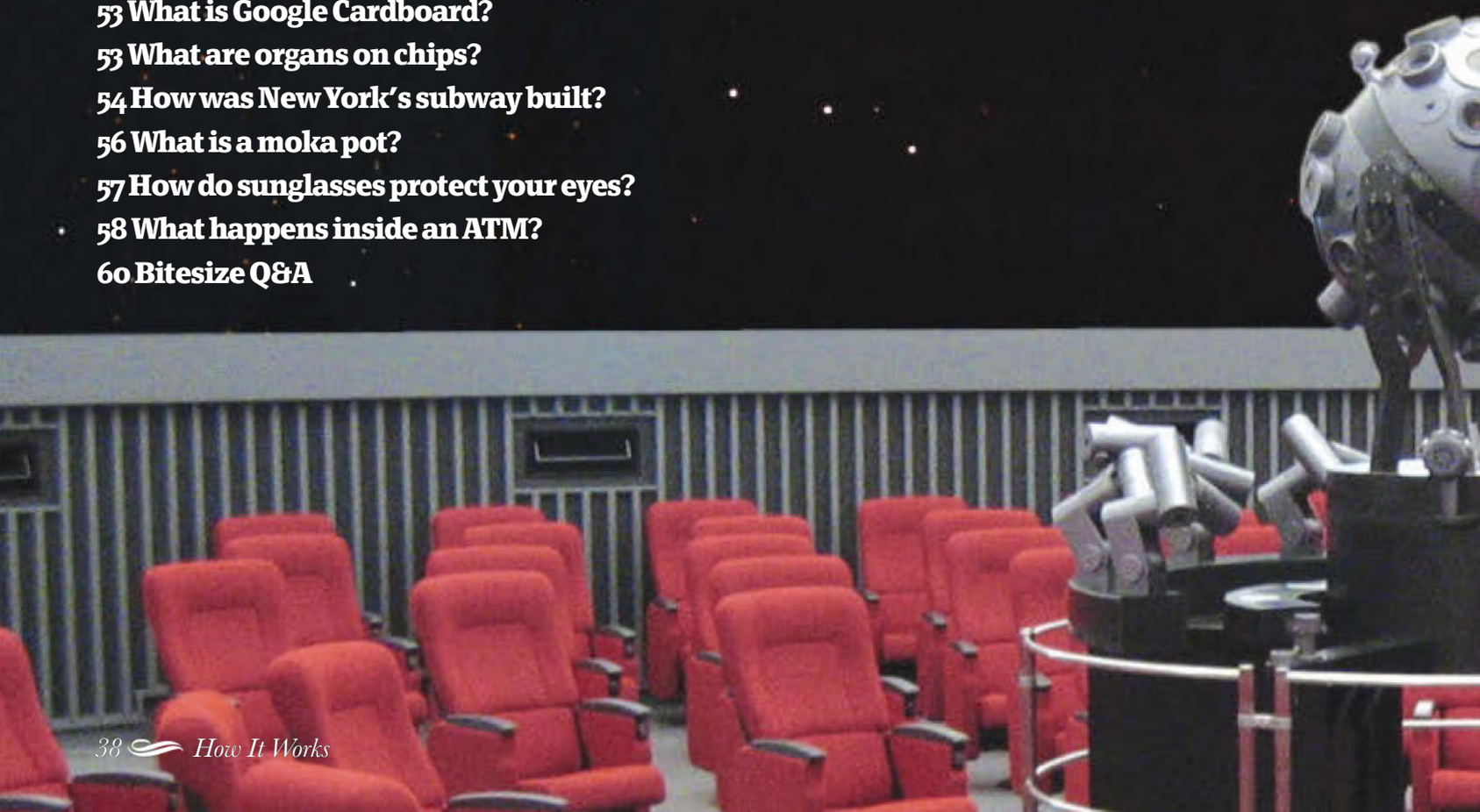
Is there sound in space?

Sound exists as waves that travel through air, but in space there's no air through which these waves can travel. However, in 2013 a NASA physicist announced that he had recorded sounds in interstellar space. Don Gurnett used an instrument that detects the electromagnetic vibrations that electrons make as they travel through plasma. They aren't sound waves, but they do pulse at similar frequencies. Once the data was recorded and processed, it could be heard as sound. Gurnett was seeking proof that Voyager 1 had left the heliosphere. It picked up audible tones that were very low at around 300 hertz as it travelled inside, thanks to bursts of plasma called solar storms. Once the ship left the heliosphere and began travelling through interstellar medium, the frequency changed to between two and three kilohertz because the gas there is denser. So there is not true 'sound' in space, but you can hear something if you have the right knowledge and instrumentation.

What causes the wet dog smell?

The smell of wet dog is pretty unpleasant. This distinct aroma actually comes from the excrement of small microorganisms, such as yeast and bacteria, which live within the animal's fur. When these organisms come into direct contact with water, it breaks their chemical bonds, which in turn releases musky molecules into the air. Leaving a wet dog to air dry can make the odour considerably more pungent. This is because when water evaporates off a surface it creates a relative humidity around it. As humid air can hold more molecules, this means you will get a much stronger whiff of wet dog.

Technology



How does YouTube work?

The incredible technology behind the world's most popular video sharing site

Q&A

Since it first launched in 2005, YouTube has quickly become the number one destination for video content online, attracting over one billion regular users. The Google-owned site gained popularity by enabling people to share their videos with others all over the world, whether it's an amusing clip of their pet,or footage of them dancing in their living room.

It's not all about cute cat videos and funny home movies though, as YouTube has also helped people launch careers. For example, pop star Justin Bieber was first discovered when a talent scout saw videos of him singing on the site, and Zoe Sugg, aka Zoella, has got her own book deal and range of beauty products as a result of her popular video blog, or 'vlog'. You can even earn money directly from YouTube too, as the site shares some of the revenue it makes from companies who pay to run adverts before or over your video.

The popularity of YouTube is mainly down to how easy the website is to use. Videos in a range of file formats can be uploaded as YouTube converts it into its Adobe Flash video format, with the file extension .FLV, for you. This enables the video to be played using YouTube's Flash player, which can be installed on your computer or smart device for free.

Another benefit of YouTube is the ability to embed videos on other websites. By simply copying and pasting a bit of HTML code, you can enable people to watch a video on your own website using the YouTube player. This saves you having to host the video on your site which requires a lot of bandwidth. Bandwidth

> "The popularity of YouTube is mainly down to how easy the website is to use. Videos in a range of file formats can be uploaded and viewed"

YouTube sensation Zoe Sugg, aka Zoella, films her beauty videos in her bedroom

Going viral

How to become a YouTube celebrity

1 Find your niche
Choose a topic or theme for your YouTube channel that's interesting and or entertaining, and hasn't been done before. For example, YouTube celebrity Zoella gives fashion and beauty tips and reviews her favourite products.

2 Create a studio
You could film your video using your smartphone, but for a more professional look, set up a camera on a tripod. Either make use of the natural light by shooting outdoors or in a well-lit room, or you can set up your own lighting.

3 Upload your video
Finish off your video using editing software, cutting out unnecessary footage and making sure the audio can be heard. Now create a YouTube account and upload your video. The site will automatically convert it into the correct Adobe Flash video format for you.

4 Give it a title
When naming your video, make sure you include any keywords relating to the topic featured and think about what sort of terms people might search for to find it. Also give it an appropriate thumbnail image and a comprehensive description.

is the range of signal frequencies needed to transmit data over the internet and you have to pay for the amount you use. YouTube streams vast amounts of data each day, carrying the bandwidth burden for other sites that want to display video.

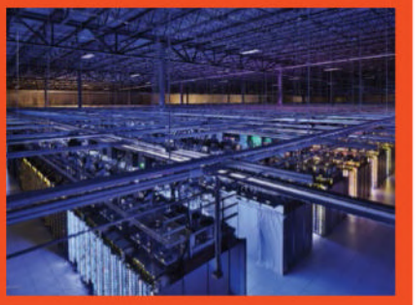
Although embedding is great for spreading your videos further across the internet, most people will actually find them simply by searching. To help connect users to the videos they are looking for, YouTube uses a complex algorithm made up of over one million lines of code. When you search for a video, the algorithm decides which search results it will show you and in what order. One of the main factors used to rank the results is video metadata. This is the title, description, thumbnail and tags that you give your video when you upload it, so you should make sure they are relevant to the content of the video and what people might search for to find it. However, the other ranking methods YouTube uses are out of your control. The site used to rank its videos by how many times they had been viewed, but this presented a few problems. It often meant that new videos were pushed to the bottom of the list as their view counts had not yet had a chance to grow, and it also enabled people to manipulate their ranking by clicking on their video repeatedly, as clicking the play icon counts as a view. To combat these problems, YouTube has switched to a new system of measuring a video's quality by the length of time it has been watched for. If several users have stopped watching after a few seconds, this suggests that the video had a misleading title or thumbnail and didn't give viewers what they were looking for, whereas if they stayed to watch until the end it was most likely appropriate for the search terms used and therefore worthy of a high ranking. The rest of YouTube's ranking tricks are a mystery though, as the company is very secretive about its algorithm and changes it all the time to stop people manipulating it. What we do know, however, is that YouTube does take some steps to ensure a video's view count indicates it's quality and this is highlighted by the mysterious number 301. You may have noticed, that as a video's view count climbs, it quite often pauses at this number for a few hours or even days. This is because when a video reaches just over 300 views, a team of YouTube employees has to verify that the number accurately represents the popularity of the video. They do this by analysing the viewing statistics to make sure people are watching the video all the way through and not just clicking play to raise the count. While they do this, the view count is frozen at 301 until it has been confirmed as genuine.

Over **500** years of YouTube videos are watched on Facebook every day

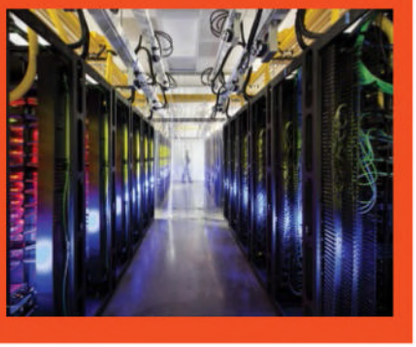
> "The site used to rank its videos by how many times they had been viewed, but this presented a few problems"

Video storage

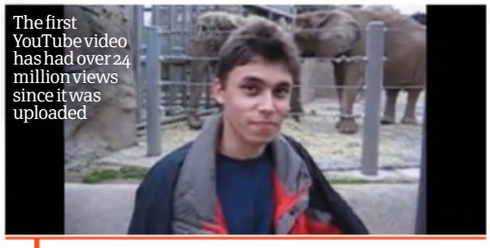
Every video uploaded to YouTube is stored in at least one of Google's 14 data centres spread across the world. These enormous buildings contain thousands of servers – the powerful computers that handle the billions of Google searches made every day and also store your videos. Giant cooling towers keep the temperature inside at a steady 27 degrees Celsius (80 degrees Fahrenheit) to ensure the equipment runs smoothly, and each piece of data is stored on at least two servers for extra security. The data centres can also communicate with each other to send information between them. When you upload your video it will be stored at the data centre nearest you, but when someone wants to play it, the video will be sent to their nearest data centre for quick access. This also means that in the event of a fire or other disaster, the data is sent to another data centre so that it's always accessible.



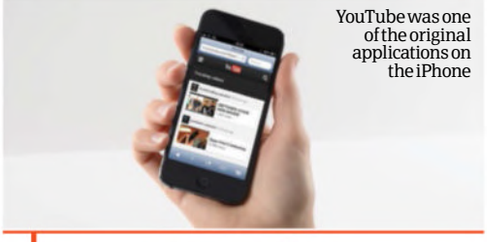
Google data centres can be found in Europe, Asia and North and South America



A brief history of YouTube



The first YouTube video has had over 24 million views since it was uploaded



YouTube was one of the original applications on the iPhone

2005
The first YouTube video was uploaded by the site's co-founder Jawed Karim. It's an 18 second clip of him at the zoo.

2006
Google buys YouTube for £883 million ($1.65 billion) in shares. The site now has around 72 million visitors each month.

2007
YouTube Mobile is launched enabling people to watch videos on their smartphones, and the site begins showing adverts.

2008
720p HD support is added, enabling high definition videos to be uploaded and viewed widely for the very first time.

The journey of a YouTube video

What happens to your video once it has been uploaded?

1 billion people regularly use YouTube to watch and upload videos

Uploading

1 Uploading
Once you hit Upload, YouTube copies your video into several different file formats with differing levels of video quality.

2 Video packets
Each version of the video is then chopped up into several different pieces called packets.

3 Wireless transmission
The packets are then encoded as radio waves which are sent over Wi-Fi or a mobile network.

4 Delivered to YouTube
When the signal reaches a cell tower or router, it is transmitted via a wired connection to YouTube's servers.

5 Reassembly and storage
YouTube's servers receive the packets, reassemble them into a video and store it at Google's data centres.

300 hours of video are uploaded to YouTube every minute

Downloading

1 Click play
When someone clicks to play your video, a request is sent over the internet to YouTube's servers.

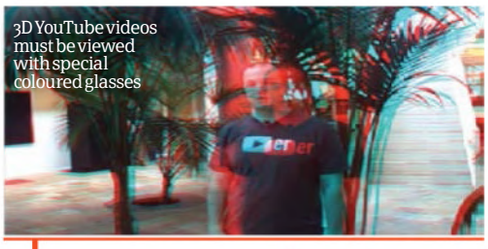
2 Video chopped up
YouTube selects the best video format for the browser being used to view it and chops it back into packets.

3 Delivered to the viewer
The packets are sent via wired and wireless connections to the viewer's computer.

4 Instant playback
The packets are delivered in order to form the original video at the optimum quality.

5 Buffering
If the internet connection is slow, the video may buffer when waiting for the next packet to be delivered.

Over **700** YouTube videos are shared on Twitter each minute


3D YouTube videos must be viewed with special coloured glasses


The live streaming service enables people all over the world to watch events as they happen


Spherical videos can be used with VR headsets, offering users 360-degree panoramas

2009
Users can now upload and view up to 1080p HD footage. Support for 3D videos is also added for a better viewing experience.

2010
YouTube keeps up with technology and includes support for ultra-high definition 4K videos to be uploaded to the site.

2011
YouTube's Sliced Bread project enables videos to be sent to your device a little bit at a time to help prevent buffering.

2012
The live streaming service is improved, enabling over 1,200 events during the London 2012 Olympics to be watched live.

2014
Support for videos that play at 60 frames per second (fps) is added, which provides much smoother playback.

2015
Spherical videos can now be uploaded, enabling the viewer to see a scene from absolutely any angle of their choice.

Which drill bit should you use?

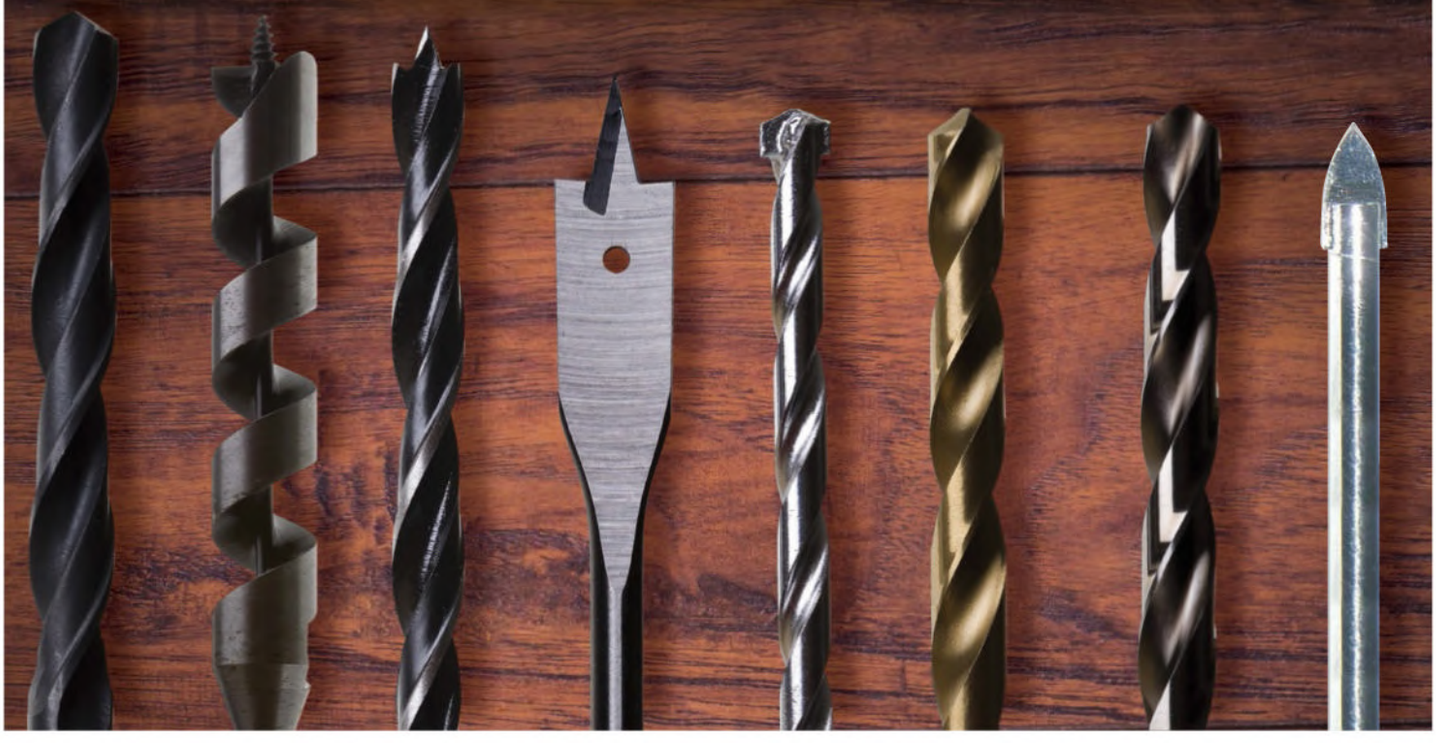
Learn why selecting the correct drill bit lets you make the right hole in the right place

Rudimentary drills were invented by early humans so they could bore holes in materials. These days, the ability to drill provides society with a range of benefits, from accessing petroleum to curing toothache. The technology behind household drills is very simple in design. Squeezing the trigger initiates an electric motor, causing the chuck to spin the drill bit, which cuts into the target material.

Despite the simple design, inefficient drilling can still create problems, potentially damaging the material or the user in the process.

This highlights the importance of using the correct drill bit, which is where the real technological advancements lie. Today there is a plethora of drill bits on the market in a variety of shapes and sizes. Most have either a tapered or sharpened end that cuts away material and an auger (a spiral screw thread), that removes the drilled material from the hole. Numerous speciality drill bits also exist. These have a unique design and specialised function, such as the cone drill bit, which can drill different-diameter holes in thin materials.

Certain geometric characteristics play a role in how drill bits cut through a material. The spiral, or rate of twist, is responsible for moving the drilled material from the hole and is varied depending on the required cutting speed. The material to be drilled determines the point angle, which is the angle formed at the bit's tip. Harder materials need a larger angle in order to drill them, while softer materials need a sharper angle. It's vital the correct one is used; this will reduce the risk of the drilled hole being uneven or in the wrong location.



© Dreamstime

HSS-Rolled
The most common kind of drill bit, ideal for use on plastic, wood and metal.

Spur auger
Similar in function to spade drill bits, they leave neater holes and require less torque to spin, hence they are a popular choice for hand-powered drills.

Brad-Point
This drill bit offers precise drilling in all types of wood, due to its centring tip.

Flat/Spade
With this drill bit it's possible to drill cleanly and accurately through wood. They are also easy to sharpen and inexpensive to buy.

Masonry
As its name suggests, this bit is used on concrete and bricks. They have a tungsten carbide coating for maximum durability.

HSS-Titanium
This bit will quickly drill a variety of metals, including silver, bronze, iron and copper.

Multipurpose
This drill bit works well for most tasks encountered domestically. It has a centring tip for added precision, along with tough, diamond-ground edges.

Glass and tile
Designed to work with soft tiles, ceramic porcelain and standard glass, this drill bit has a tungsten carbide head for superb durability.

Q&A

How do electric razors work?

How these spinning blades cut hair, not skin

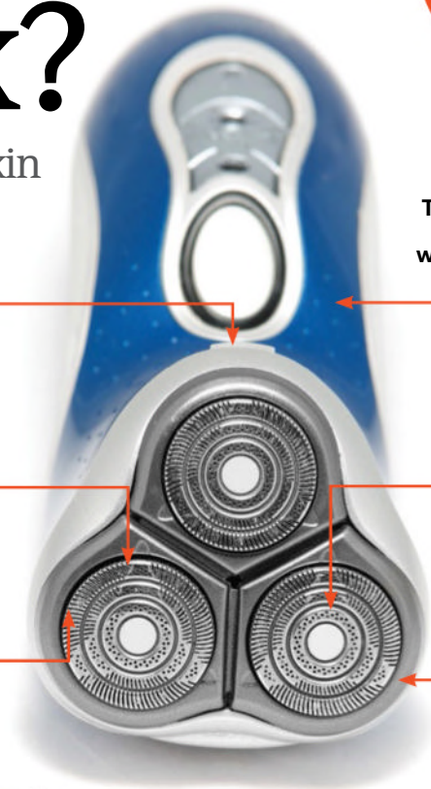
Body hair is tough; both men and women's hair is as hard as copper wire of equal thickness, so any razor we use needs an effective cutting mechanism. Electric razors use either a foil or rotary system. Foil shavers contain oscillating blades beneath a thin, steel, perforated foil. The foil functions to lift hair toward the blades, helping the user obtain a very close shave.

Rotary razors have circular blades that cut by spinning. The blades can typically flex within the shaver, allowing easier access to curved areas than other razors. The rotary razor works best with a circular motion, which encourages hair to slip into the razor head gaps.

Which to go for depends as much on personal preference as it does on functionality, but you are far less likely to incur a life-threatening injury from either one compared to the cut-throat razors of old.

The rotary electric razor

Take a closer look at how a rotary electric razor deals with our varied hair growth



Easy access
This button releases the razor's head, allowing the user to clean the razor and remove the collected trimmings.

Long hair slits
These slits target the longer hairs, forcing them toward the razor's blades.

Three blades
Typically a rotary shaver has three blades in a triangular structure, providing a large surface area.

The body
The razor's body is lightweight and easily manoeuvrable, housing the rechargeable battery and motor system.

Short hair gaps
These small circular holes target short hairs, and vary slightly in size to compensate for varied hair length.

Ergonomic flexing
The three blades are able to flex up and down within the razor, allowing effective shaving of curved areas.

How are musical notes amplified?

Discover how they can convert the sound of strings into a thundering stadium anthem

It is widely accepted that the introduction of the guitar amplifier changed music forever. Whether you're into Jimi Hendrix or Eric Clapton, it's hard to imagine either without their legendary riffs blasting out through guitar amps.

A three-way process is used to amplify the strings' sound. The strings vibrate at a particular frequency; once plucked their signal passes through the guitar's pickups to the preamplifier. The preamplifier boosts the voltage of the signal generated by the guitar. The preamp also reduces the noise and interference within the guitar's sound, which could distort the resulting overall sound when amplified.

The power amp now amplifies the whole signal and sends it to the speaker, which emits the guitar's sound at an adjustable volume. Amps for both the electric and acoustic guitars as well as bass guitars are commonplace today, shaping the sound of all genres of modern music.

The 'combo' amplifier

Inside a combination guitar amp that contains both the amplifier and speaker

Speaker
This part of the amp produces the amplified sound. The wattage, and therefore power, can vary depending on preference.

Mounting bracket connectors
These two red wires connect the mounting bracket to the speaker via two small nodes.

Reverb box
Many amps now come with the reverberation effect built in. This serves to impart an echo on the guitar's sound.

What is 5G?

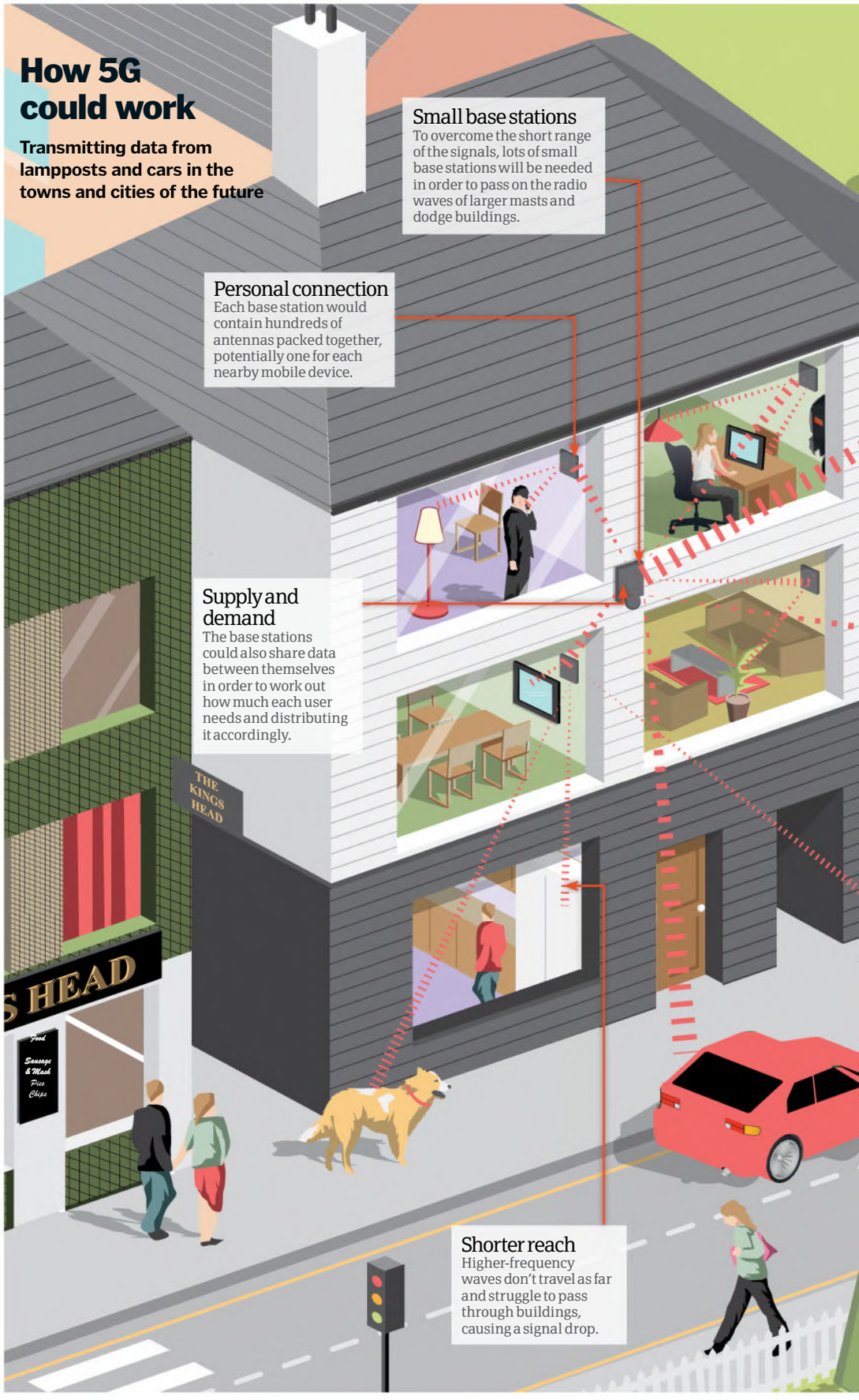
How the next generation of mobile communication could help to connect us, our homes and our cars

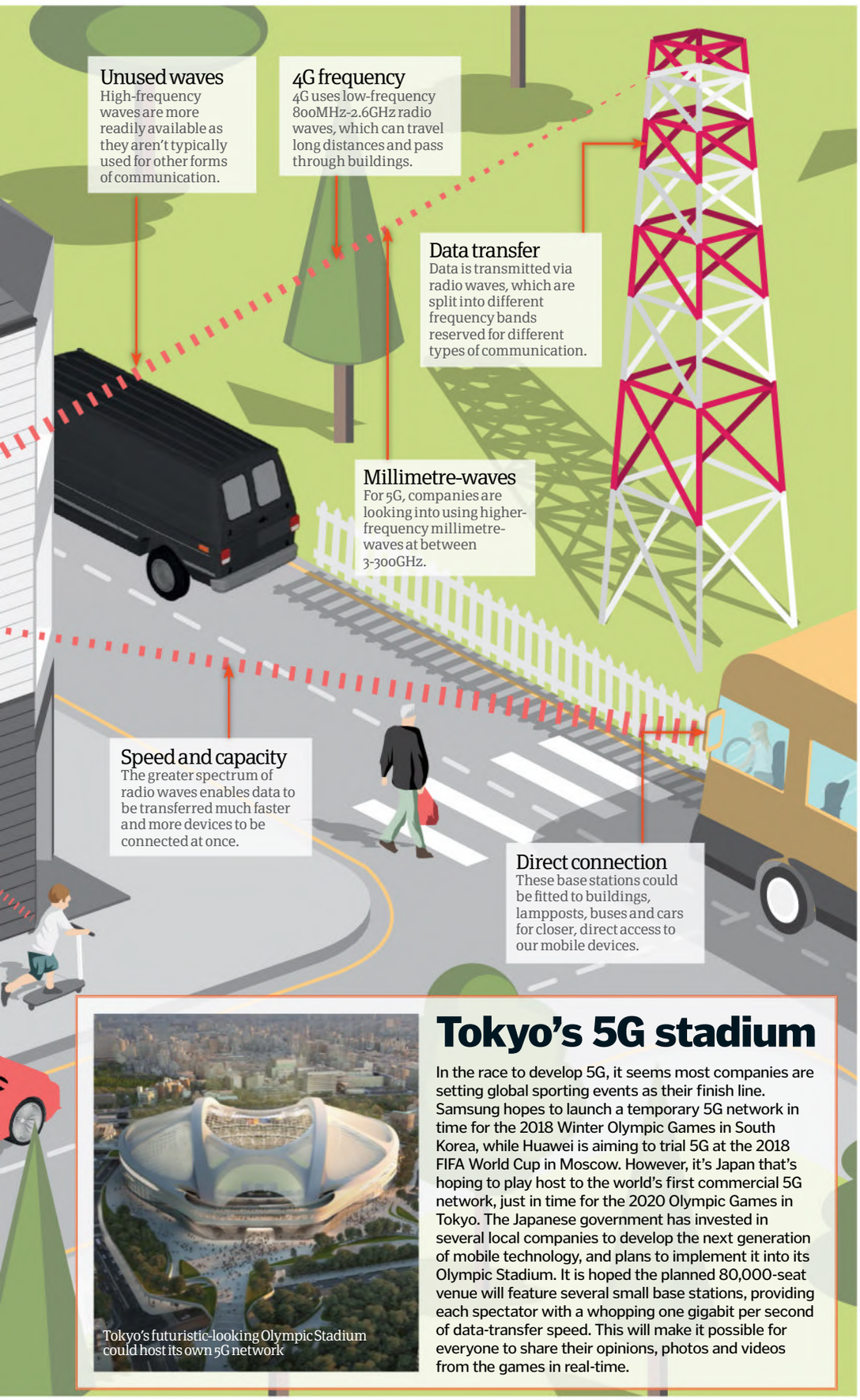
Many of us don't even have access to the 4G mobile network yet, but already the race is on to develop 5G. With demand for mobile data doubling each year, this fifth-generation technology will soon be required to satisfy our ever-increasing need to browse the web and stream online content on our mobile devices. It will also be needed to connect the technology of the future, such as driverless cars, smart cities and the 'Internet of Things' – a network of everyday objects that communicate with each other to make our lives easier.

Although some parts of the world are expected to have 5G as early as 2018, the technology behind it hasn't actually been fully figured out yet. Some companies are looking to build on existing technologies, simply making 4G radio frequencies faster. Others believe the entire radio network will need to be restructured. For example, one promising concept for 5G involves using high-frequency millimetre-waves and a series of base stations connected to buildings and lampposts.

What we do know is that 5G will be incredibly fast. It's expected to be about 100 times faster than 4G, allowing you to download an entire film in under a second. Latency – the time it takes for data to start transferring – will be greatly reduced, meaning the video you want to stream will start instantly when you press play. 5G will also have a much larger capacity, enabling more users to access the network at once and potentially bringing an end to those restrictive data limits imposed my mobile operators.

Of course, your current mobile phone is unlikely to work with any future 5G network, as it will probably need new hardware and software to support it. However, by the time 5G does become available, you will probably have upgraded your handset anyway, and manufacturers are guaranteed to have kit out their newest models with the most up-to-date technology available.





Tokyo's 5G stadium

Tokyo's futuristic-looking Olympic Stadium could host its own 5G network

In the race to develop 5G, it seems most companies are setting global sporting events as their finish line. Samsung hopes to launch a temporary 5G network in time for the 2018 Winter Olympic Games in South Korea, while Huawei is aiming to trial 5G at the 2018 FIFA World Cup in Moscow. However, it's Japan that's hoping to play host to the world's first commercial 5G network, just in time for the 2020 Olympic Games in Tokyo. The Japanese government has invested in several local companies to develop the next generation of mobile technology, and plans to implement it into its Olympic Stadium. It is hoped the planned 80,000-seat venue will feature several small base stations, providing each spectator with a whopping one gigabit per second of data-transfer speed. This will make it possible for everyone to share their opinions, photos and videos from the games in real-time.

Q&A

5G plans

Professor Rahim Tafazolli from the 5G Innovation Centre (5GIC) explains the current outlook for the next generation of mobile networks.

Why is there a need for 5G?
5G will be fully focused on users and their needs, unlike previous mobile communication networks. The aim will be to give the user the impression of infinite capacity and availability while juggling available resources. Two ways of achieving this will be to predict user demand better so that applications perform bandwidth-heavy tasks when the network is least loaded – optimising network response times where needed using a measure known as 'latency' – and to make better use of all available wireless networks.

What problems need to be overcome in developing 5G?
In developing the 5G network there will be a pressing need to reduce end-user costs: given that data requirements may grow up to a hundred-fold, monthly bills cannot increase by the same amount if emerging technologies are to be accessible for mainstream use. Reducing energy consumption will be another key focus, both in order to lessen emissions and to improve end-user benefits such as enabling longer battery life and providing innovative energy solutions for wearable devices. One result will be that in the future, there will be a wide range of business models – for example, as well as paying operators to provide us with coverage, we may be able to charge others for the coverage we provide with our Wi-Fi routers or femtocell home-base stations.

What will be the main benefits of 5G?
5G won't be simply a new network like 2G, 3G and 4G were. It will be a heterogeneous network (HetNeT) that will provide wireless coverage in an environment with a wide variety of wireless zones, ranging from an open outdoor environment to office buildings, homes and underground areas. In particular, the network and devices will decide how to use the access networks available in that location (2G, 3G, variations of 4G, Wi-Fi, small cells, wide-area mobile etc) and different frequency bands in order to deliver sufficient capacity to all active users so that they have the impression that the capacity is always sufficient.


5GIC at the University of Surrey is the UK's centre for 5G research and development

How do cordless phones work?

How digital cordless communication became a household essential

Cordless phones are one of those inventions that are hard to live without. Packed with technology, they originated in the 1980s and were the first devices to enable landline conversations to be taken all around the home. Made up of a handset and a base, the former relies on the latter to work. The base is plugged into the telephone jack and receives the incoming call as an electrical signal, which it then converts into a radio signal that it transmits to the handset. The radio signal gets reconverted into an electrical signal by the handset, where it is sent to the speaker and made audible. As you talk into the handset, your voice is broadcast as a radio signal to the base, where it is converted to an electrical signal and sent through the phone line.

Range, sound quality and sound security are all essentials, and have got better with time as analogue frequencies have been replaced with digital. Some long-range cordless phones enable you to make and receive calls even when you are 50 metres (164 feet) away from the base station.

© Corbis;Alamy

How do iceboxes keep food cool?

These portable chillers save us all from wilting sandwiches at a picnic, but how do they work?

Iceboxes are usually rather ugly looking things made out of bulky plastic with a thick lid. But attractive aesthetics are sacrificed for good reason – the name of the game here is insulation. The walls of an icebox consist of multiple layers, filled with an insulating material such as polystyrene that is full of air pockets. Air is a poor conductor of heat, so the gaps in the foam help to slow down the energy transfer of heat from the outside to the inside of the box.

Heat is transferred in three different ways: convection (heat moving through fluids – liquids or gases), conduction (heat moves through a substance by particles colliding), and radiation (heat is given off and absorbed by an object via electromagnetic waves). When cold food is placed into the icebox and the lid is shut, very little heat can reach the food via convection because warm air from the outside cannot pass through the box. Conduction is also poor because the air bubbles in the polystyrene layer are good insulators. Some iceboxes or cool bags also have a reflective outer coating to deflect radiation, such as sunlight, away from the precious picnic cargo.

What is inductive wireless charging?

How to rid our homes of messy plugs and cables

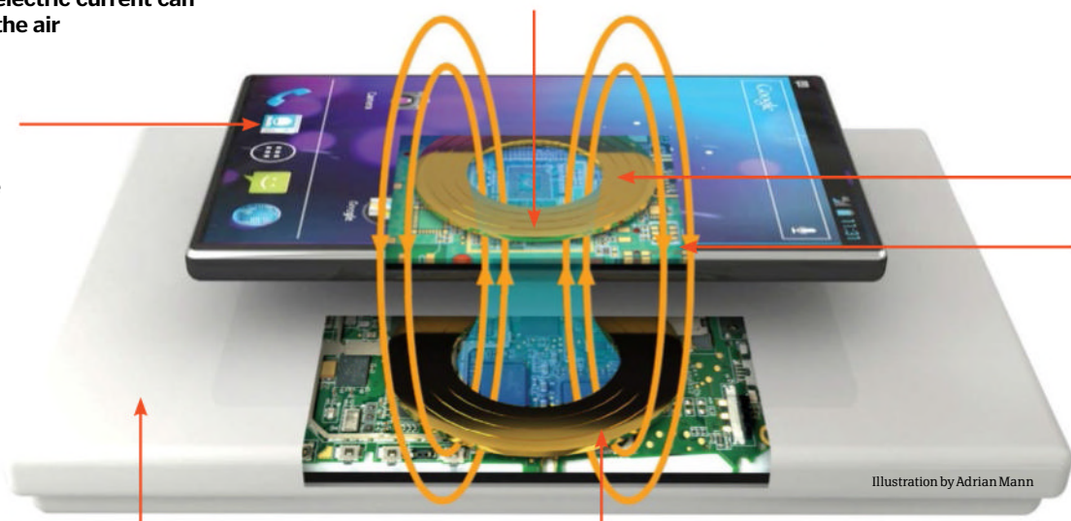
If you have ever had to wrestle with a messy tangle of cables, then the introduction of wireless phone charging will come as a welcome relief – but this useful technology isn't actually all that new. Physicist Nikola Tesla first concluded that you could transfer power between two objects via an electromagnetic field in the late 1800s, and by the 1990s wires and electronics could be made small enough to make wireless charging feasible for devices such as artificial hearts and electric toothbrushes.

These days, the inductive charging method can be used for smartphones, tablets and even electric cars, but if it's so convenient, why aren't we using it all the time? One reason is that it isn't very efficient, as a lot of energy is lost as heat – so your device takes longer to charge. It also requires your device to be very close to the charger to work, so it effectively still tethers it to a power source just like a cable charger.

However, this could change with a new method called inductive wireless charging that is in development and will enable power to be transferred over greater distances.

How inductive wireless charging works

Find out how an electric current can be sent through the air



1 Power source
The power coming from the plug sockets in your walls is alternating current, which changes direction several times a second.

2 Transmitter
The current is sent to the transmitter circuit in the wireless charger, which then sends it to a transmitter coil of wire.

3 Magnetic field
As the alternating current flows through the transmitter coil it creates a changing magnetic field.

4 Receiver
The magnetic field generates an electric current within the receiver coil of a device when it comes within a close distance.

5 Direct current
The alternating current flowing through the receiver coil is then converted into direct current by the receiver circuit.

6 Battery power
The direct current, which goes in one direction, can then be used to charge the battery of the device.

Illustration by Adrian Mann

How do erasers work?

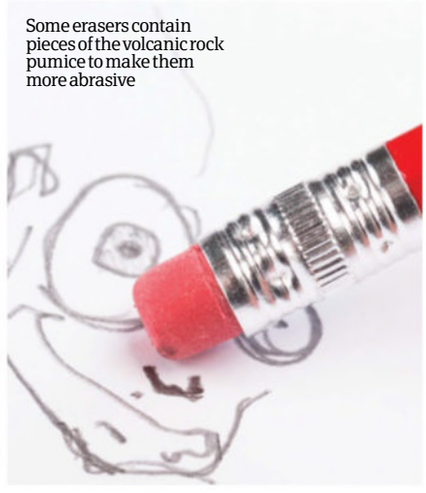
Why we no longer use bread to rub out our mistakes

To understand how erasers remove pencil marks, we first need to know a bit about the pencil itself. Contrary to popular belief, pencils are no longer made from lead; instead they consist of a mixture of graphite (a soft mineral made up of a crystalline form of carbon) and clay.

When you write on a piece of paper, flakes of this mixture cling to the paper fibres, leaving visible marks. Erasers are able to remove these marks simply by being stickier than the paper fibres, so the graphite and clay particles cling to the eraser instead.

In fact, anything stickier than paper can be used as an eraser, and until the 1770s, moist bread was most people's material of choice. Reportedly, when scientist Joseph Priestly accidentally picked up a piece of latex instead of bread, he discovered this new substance could also rub out pencil marks, which is where the name 'rubber' originated from.

Nowadays, because natural latex rubber is expensive and some people are allergic to it, erasers are typically made from synthetic petroleum-based rubbers, for example polyvinyl chloride.



Some erasers contain pieces of the volcanic rock pumice to make them more abrasive

What's inside a planetarium?

The incredible theatres where you can explore the night sky and beyond

You no longer need to train for several years as an astronaut to explore space, as planetariums can give you an amazing virtual tour of the universe while you keep your feet firmly on the ground. Instead of a big cinema screen at the front of the room, images are projected onto a domed ceiling to create a more immersive experience.

"There's no edge to the screen so it's like you're actually there," says Jenny Shipway, Head of the Winchester Planetarium in the UK. "During a show you shouldn't be aware of the dome at all, the dome should be invisible so your brain can imagine you are actually in this three-dimensional virtual universe."

Early planetariums simply had paintings of the night sky on the inside of the dome to give people a clear view of all the constellations. However, when projectors were developed they could depict moving celestial objects as well as fixed stars, and represent views from different points on the Earth's surface too. Traditional planetariums use mechanical star ball projectors, but they are limited to showing the stars and planets that can be seen from Earth.

The most modern planetariums now use digital projectors hooked up to computers instead, and can project any image onto the dome to show incredible views from anywhere in the universe. Combining data from space agencies, spacecraft and telescopes all over the world, realistic graphical representations of entire galaxies can be projected onto the dome.

"We use software called Uniview and it has a virtual model of the known universe in it", says Shipway. "We use it as a flight simulator. It's literally like playing a computer game; just using a computer mouse you can fly anywhere. You can do a seamless zoom all the way out from Earth right to the edge of the visible universe."

A star ball projector can only show the view from one hemisphere

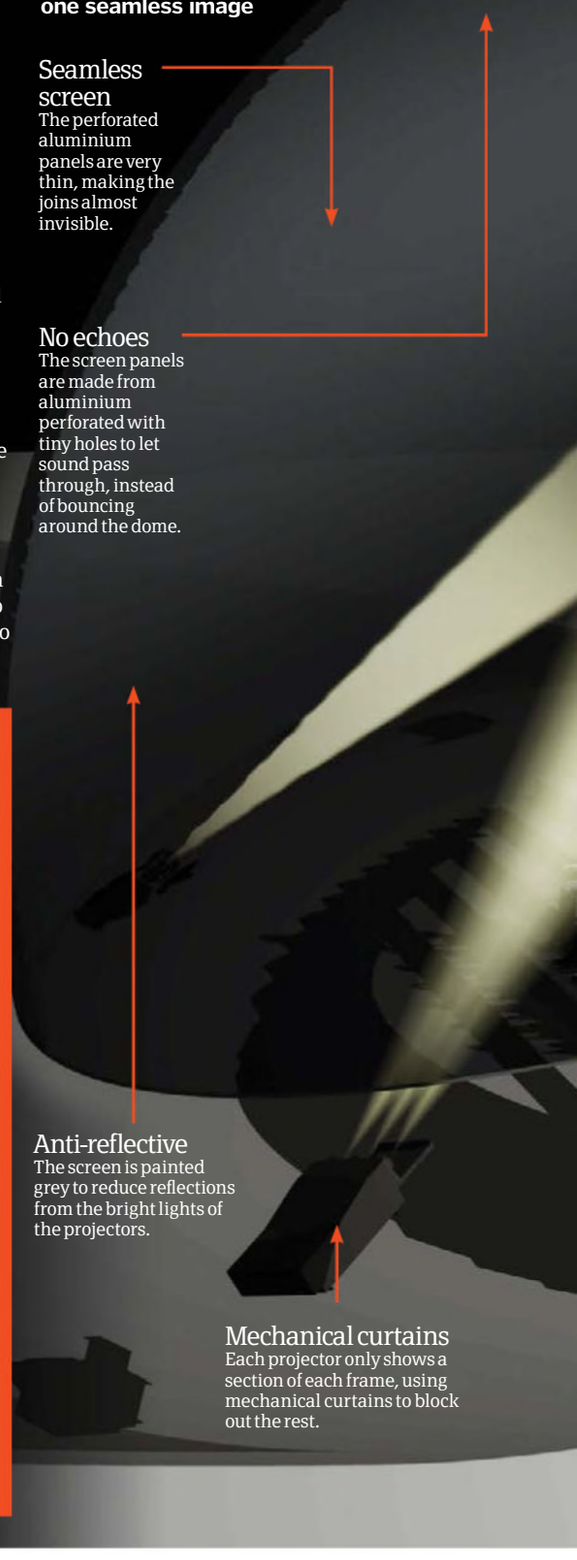
Star-ball projectors

Some planetariums still use traditional analogue projectors known as star balls. These metal spheres sit in the middle of the audience and have a bright electric lamp inside that shines light through several small lenses surrounding it. The lenses are used to represent stars, focusing light onto the planetarium dome to recreate the night sky as it can be seen from Earth. Single star balls are often fixed at one end so can only show the view from one hemisphere.

However, many projectors feature two star balls attached together in a dumbbell-shaped structure so that they can represent the view from anywhere on Earth. Additional moving projectors can also be attached to show moons, planets and other moving celestial objects. The main limitation of star-ball projectors is that they can only show the view from Earth, while digital planetariums let you explore the far reaches of the universe too.

Inside a modern planetarium

How several projectors work together to create one seamless image



Hanging screen
The screen is attached to a metal frame that hangs from the roof and is tilted for a more comfortable viewing experience.

Calibration
The projectors need to be lined up perfectly with the same brightness and contrast settings to create one seamless image.

One image
The image sections from each projector blend in with the images from neighbouring projectors to create one big image.

Projectors
A series of digital projectors are positioned around the edge of the inside of the dome.

Pilot's desk
The planetarium shows are controlled from the pilot's desk at the back of the room using a tablet and computer.

Fish-eye lens
Each projector has a fish-eye lens, which distorts the image to stretch it across the curved dome surface.

Reclining seats make it much more comfortable to view the action overhead

A main server controls the footage displayed by the projectors

How are man-made waves made?

Deep in north Wales' Conwy Valley, a giant underwater snowplough is rolling out some serious swell

Wave hunters – rejoice! In an old aluminium quarry in north Wales, an inland surf facility is edging ever closer to completion and when it opens, surfers from across the globe can visit to ride the world's longest man-made waves.

Surf Snowdonia is a £12 million ($18.7 million) project built by surfers, for surfers. The engineers of Wavegarden are keen wave riders, and wanted to create something remarkable that can help existing surfers to train and budding wave riders to learn, without having to wait for unpredictable waves at the coast.

The technology that can create these waves looks a lot like a giant snowplough. It is pulled smoothly along underwater (with a protective covering to keep surfers safe) through the centre of the 300 metre (984 foot) long lagoon, pushing the water ahead of it into large, tubing waves that the designers claim are just like, if not better than, shredding the real thing. At their highest point the waves can reach two metres (6.6 feet) high and peel for 150 metres (492 feet), which is the equivalent of a 20-second ride for the surfer.

At a rate of one wave generated every minute, the waves that are created by the expertly engineered snowplough-like wave foil also interact with the contours on the bed of the lagoon. This provides different and predictable wave profiles at various points of the pool, meaning that there's a place at the lagoon for surfers of every age and ability.

Surfer Miguel Pupo rides the man-made waves at a Wavegarden test facility in Spain

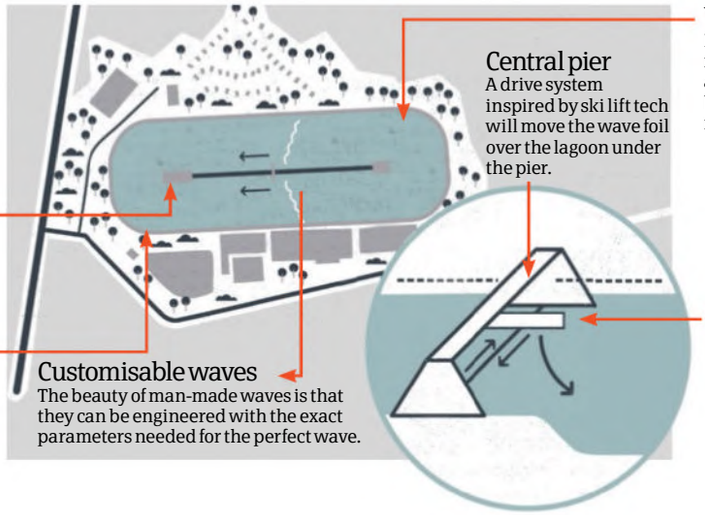
Wave machine vs ocean waves

Most ocean waves begin out at sea and are a product of the wind blowing over the water's surface. This causes friction and as the wind continues to blow, the wave builds and builds. A 'singular' wave extends vertically down the water column and so as it approaches the shore, the shallow water causes drag on the 'base' of the wave. This causes the wavelength to shorten, which forces the crest of the wave higher until it eventually spills over itself and breaks, like the waves we see crashing on the shore.

The difference between these waves and those at Wavegarden's Surf Snowdonia is that the man-made waves don't have the wind to whip them up, nor miles of ocean to grow in size and power. Instead, the wave foil smoothly 'shovels' the water in front of it, pushing it upward and ahead, mimicking the very last stages of a breaking ocean wave on the shore.

Totally tubular tech!

A tour of the artificial surfing lagoon that creates consistent and perfectly-formed waves



Computer tech
At each the end of central pier, towers house the computer-based technology that controls the wave foil.

Lagoon lining
The unique grid-like shore lining of the lagoon is designed to dissipate the energy created by the waves.

Central pier
A drive system inspired by ski lift tech will move the wave foil over the lagoon under the pier.

Customisable waves
The beauty of man-made waves is that they can be engineered with the exact parameters needed for the perfect wave.

Water supply
Rainwater from mountain reservoirs will pass through a nearby hydroelectric plant before powering the waves in the lagoon.

Reversible rides
The plough is pulled forward and back across the lagoon, so surfers can ride in both directions.

Surfers galore
Up to 52 surfers at a time will be able to ride the waves in the lagoon.

A CGI impression of the Surf Snowdonia lagoon, expected to open in Summer 2015

What is Google Cardboard?

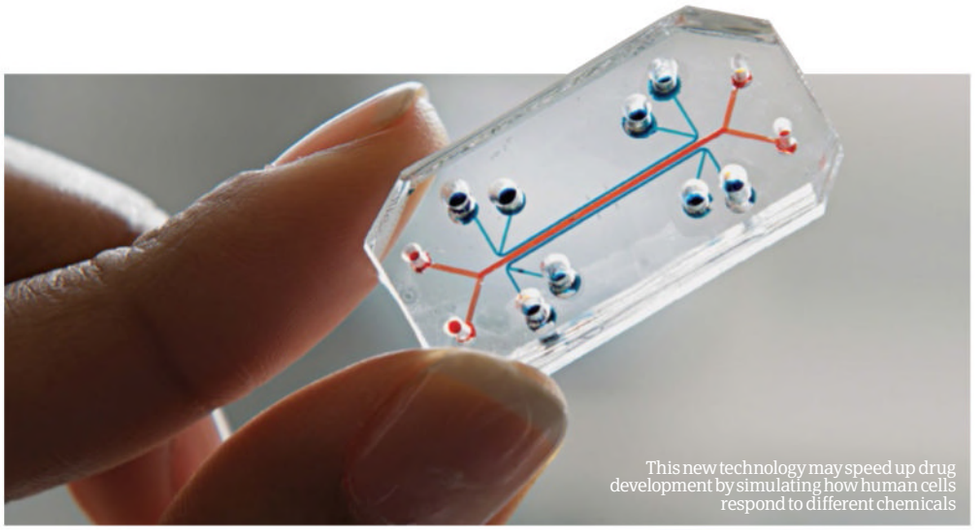
Turn your smartphone into a VR headset with a cardboard box, a magnet and a handful of Velcro!

Google's Cardboard venture has opened up the world of virtual reality to everyone. To whisk us away into a fantasy world, Google invites us to make our own VR headset using just a few items that can be found in your garage.

Various cardboard headsets can also be purchased ready-made, so it's not all about DIY. Once you've sourced the headgear, all you need to do is download the Google Cardboard app to get started.

Your smartphone sits in the headset and the app shows you a specially designed split-screen view. When you look at the screen through the headset's lenses that are placed at an optimum distance from the screen, this concentrates your field of view and creates a 3D effect. Your smartphone's motion sensor detects your movement and so all of these factors come together to enable you to walk, run and jump through your own virtual world.

Google has made this technology incredibly accessible for developers, so there is also a huge array of compatible VR apps available to take your Cardboard experience to the next level.



This new technology may speed up drug development by simulating how human cells respond to different chemicals

What are organs on chips?

Is this the end of animal testing?

Designed to imitate the functions of complex organs such as the heart, lungs and intestines, these silicon microchips are only the size of a small USB stick, but could have the power to transform medicine. The chips are embedded with microfluidic channels, which are lined with human cells from particular organs. Chemicals can then be pumped through these tubes, enabling researchers to see how these 'organs' will react through a microscope.

The lung chip, for example, features human lung cells on one side of the chip and blood capillary cells on the other. These are divided by a porous membrane – a thin walled structure that enables air or liquid to pass through. Air runs through one side and a blood-like solution flows through the other, while a stretching motion generated by a vacuum replicates the mechanics of breathing.

Several different organs have been replicated so far by scientists at the Wyss Institute at Harvard University, who continue to test and evaluate the limits of their chips. It is hoped that these devices could be used to develop drugs without the need for animal testing.

Inside the chips

Find out how these tiny devices can mimic a human lung

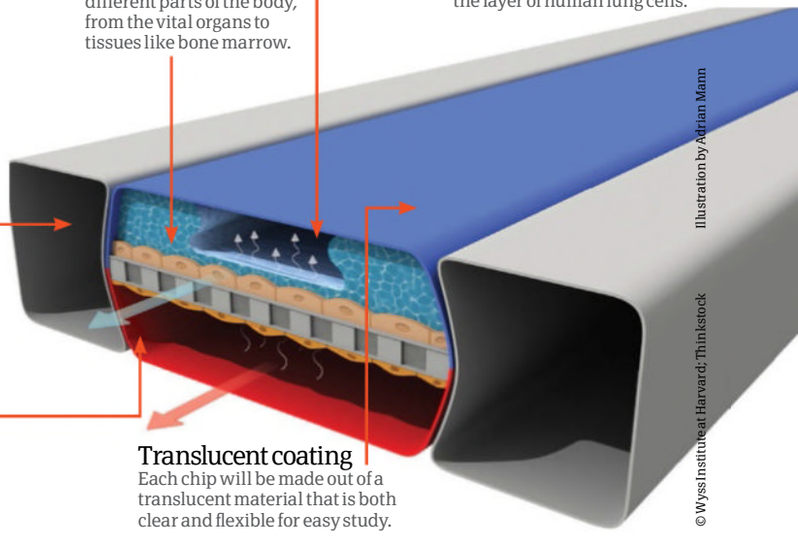
From head to toe
These silicon devices can be used to mimic many different parts of the body, from the vital organs to tissues like bone marrow.

Air channel
Air is pumped through one of the channels so that it flows past the layer of human lung cells.

Analysis
The new instrument will allow for real-time observation and analysis of the human body's biochemical functions.

Vacuum
The vacuum channels on either side cause the 'lung' to regularly stretch and relax, to mimic breathing in and out.

Human response
The chips are lined with human cells to give the best possible indication of how the body reacts to certain substances.



Translucent coating
Each chip will be made out of a translucent material that is both clear and flexible for easy study.

Illustration by Adrian Mann

How was New York's subway built?

Find out how about the feat of engineering that took place over 100 years ago

Underneath the city's pop-up-book skyline lies a sprawling subway system. Transporting nearly two billion passengers annually, it operates 365 days a year, 24/7, on over 1,287 kilometres (800 miles) of track, connecting the boroughs of New York, except Staten Island.

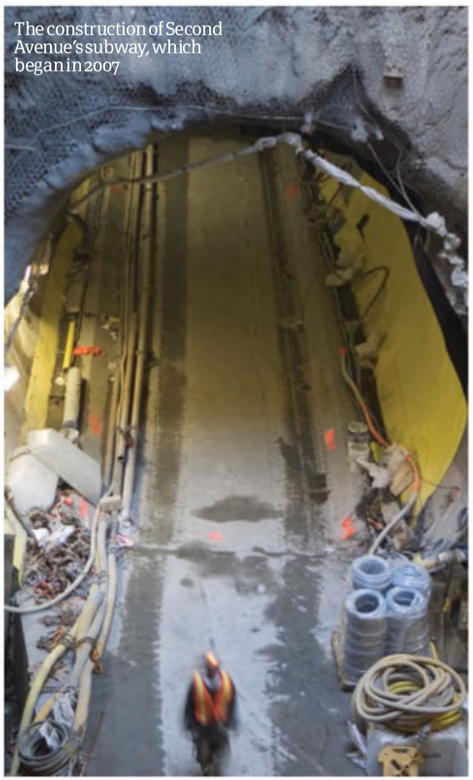
During the late 19th century, New York experienced a population boom due to the huge numbers of immigrants that arrived from Europe, meaning that almost 3.5 million people were living there by 1900. This placed an enormous strain on the existing transport systems; roads were more congested and travel became increasingly difficult and dangerous. The authorities realised they needed a subway that could quickly and efficiently move people in, out and around Manhattan.

The construction of the first subway line began in 1900. Engineers of the time had to take into account various challenges such as uneven topography, hard bedrock and the sheer number of water, sewage and gas pipes that already lay underground. The project was no mean feat – around 8,000 labourers were employed to excavate the subways, thousands of which sustained injuries and more than 40 lost their lives.

For shallower tunnels, the engineers often preferred to dig down from the road surface, as this made it easier to avoid the utilities that were already buried below. They could then replace the pipes above the subway, modifying their design if necessary, and reconstruct the road surface.

For deeper tunnels, engineers used powerful explosives that were more efficient than digging by hand, but did result in a number of casualties. A variety of techniques were used to overcome some of the installation problems, such as passing the tunnel through a river.

To build some of the underwater subway areas, engineers cleverly constructed the tunnel sections above ground and then sunk them into a dredged part of the river, before pumping the water out.



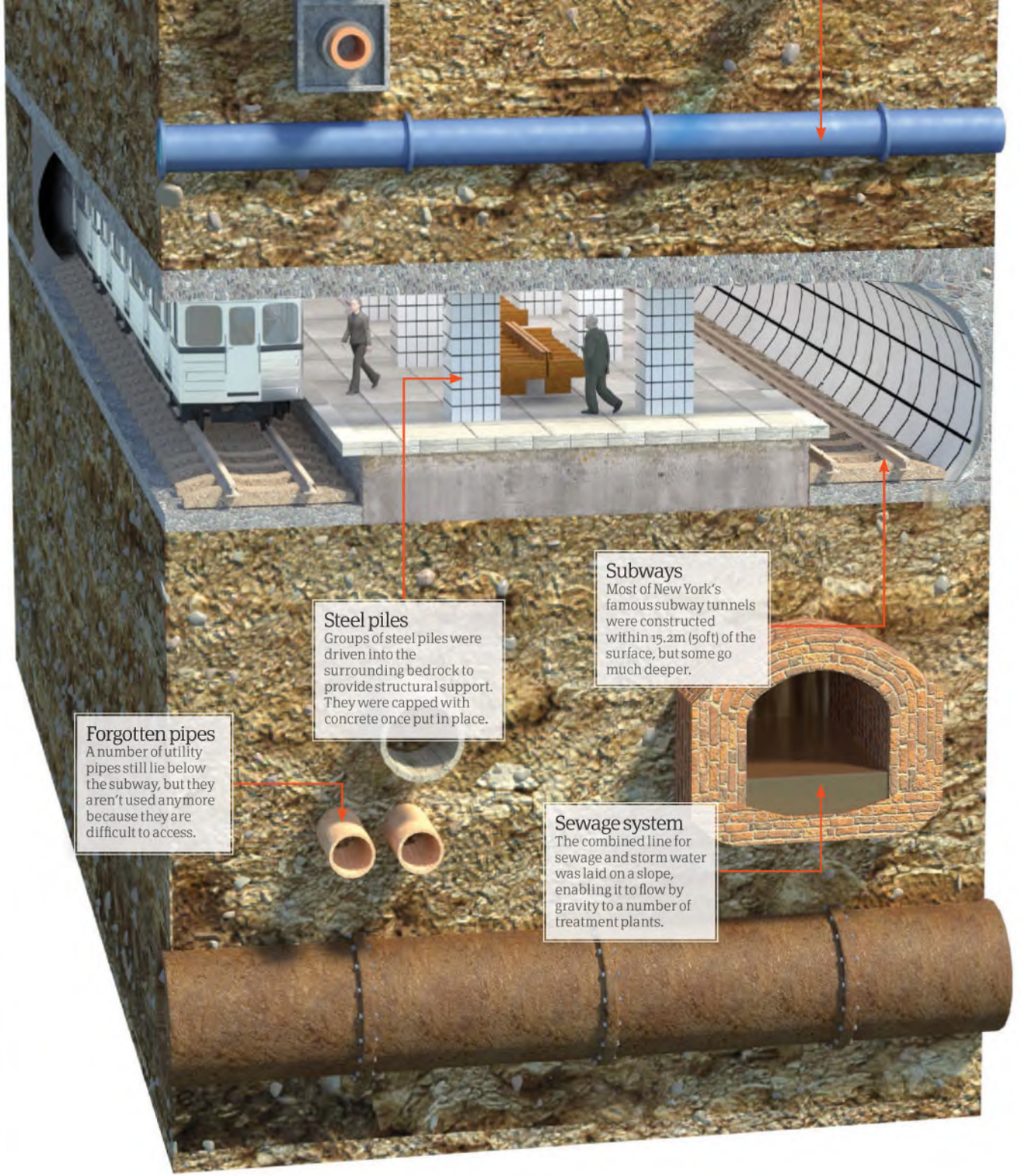
The construction of Second Avenue's subway, which began in 2007

See the distinct layers that make up NYC's vast subterranean network

Expanding the subway system

The New York City underground system is now over 100 years old. It wasn't designed to accommodate the enormous numbers of people that use it daily, so the decision was made to expand it. The plan is to add around 34 kilometres (21 miles) of new tunnel throughout the city, via the East Side Access, Second Avenue Subway, and the 7 Line Extension projects, which are estimated to cost over £9.6 billion ($15 billion).

Engineers would normally use a single tunnel boring machine (TBM) to create the new tunnels. However, in the case of the East Side Access project, such a large tunnel would collapse under the weight of the city above it. This problem has led the designers to employ a slightly unusual technique. Using four smaller TBMs, they will produce four more stable tunnels, which will then be fused to form one larger tunnel. This is accomplished using dynamite to blow out the rock between the small tunnels. Firstly, the top two small tunnels are fused, at which point the roof of the tunnel is reinforced to stop the underground network above collapsing downwards. Once the roof has been strengthened, the remaining two tunnels are joined to create a single tunnel. Work is scheduled for completion in 2022.



What is a moka pot?

A simple but ingenious design that brought barista-style coffee home

The moka pot, also known as a stovetop espresso maker, uses basic physics to achieve a perfectly brewed cup of coffee. It consists of three chambers; one for water, one for the coffee grounds and one for the finished blend.

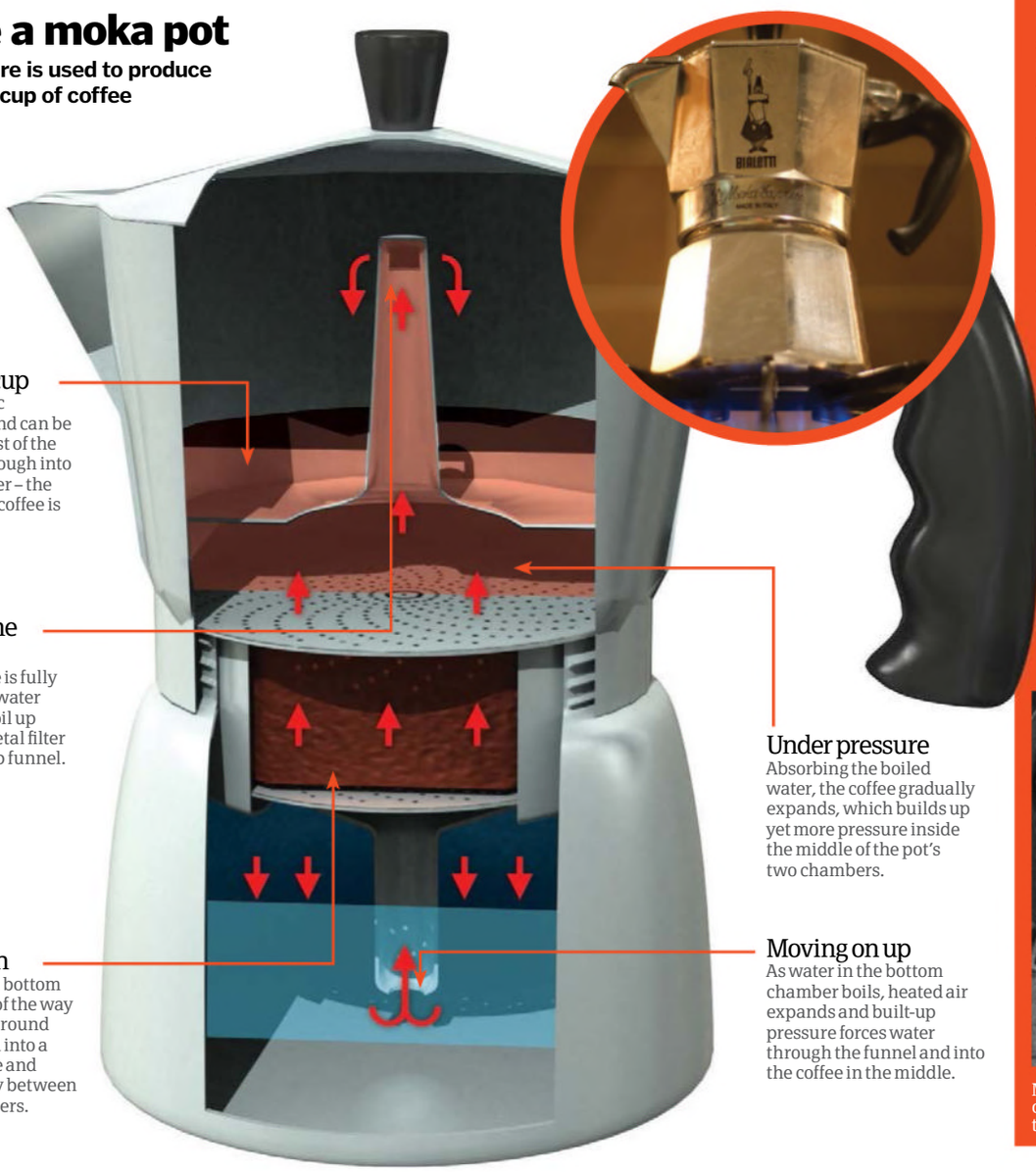
When the moka pot is placed on the stove, the water heats up and generates steam. This increases the pressure in the bottom chamber and pushes the water up through the coffee granules and into the top chamber where it is ready to be poured.

The pressure built up in the pot's chambers reach only 1.5 bars, nowhere near the nine bars achieved in traditional espresso makers. Nevertheless, the simplicity of its design and ability to produce quality cups of coffee made it a hit in households.

It was invented in the 1930s by Alfonso Bialetti, who was said to be inspired by observing his wife doing laundry. Their primitive washing machine consisted of a bucket of soapy water that was brought to the boil over the fire. The water was pushed out of the tube and onto the dirty clothes. Bialetti developed a similar technique for the coffee pot and his design remains much the same to this day. Since its first release in 1933, over 300 million pots have been sold around the world and it remains a staple among coffee enthusiasts everywhere.

Inside a moka pot

How pressure is used to produce the perfect cup of coffee



Time for a cup

A characteristic sputtering sound can be heard as the last of the water boils through into the top chamber – the signal that the coffee is ready to serve.

Escaping the chamber

Once the coffee is fully saturated, the water continues to boil up through the metal filter and into the top funnel.

Preparation

After filling the bottom chamber part of the way to the top, the ground coffee is placed into a separate cradle and screwed tightly between the two chambers.

Under pressure

Absorbing the boiled water, the coffee gradually expands, which builds up yet more pressure inside the middle of the pot's two chambers.

Moving on up

As water in the bottom chamber boils, heated air expands and built-up pressure forces water through the funnel and into the coffee in the middle.

Born out of fascism

Bialetti's pot emerged during Benito Mussolini's regime, when Italy was in a stage of militarisation and its imports and exports were tightly controlled. The bauxite ore necessary for aluminium were native to Italy, and so were favoured by the fascist regime over other imported metals. Accordingly, moka pots were made from this 'national' metal, and so were cheap and quick to produce. Additionally, the Italian invasion of Abyssinia (modern Ethiopia) in 1935 brought with it the African country's rich coffee plantations. This fuelled an already coffee-obsessed country with even more of the precious beans and the patriotic pot was the perfect vessel to cook them in. In the post-war period the pot found international success in Central Europe and the wider Latin world.

Mussolini's regime saw the trade of coffee and metal ores become tightly controlled

How do sunglasses protect your eyes?

The sight-saving secrets of a summer style staple

Reaching for our sunglasses on a bright, sunny day is second nature; we all know that spending time in the Sun puts us at risk of eye damage and no one enjoys a squinting-induced headache. Perhaps you take them for granted, but there's more to your sunnies than shaded lenses.

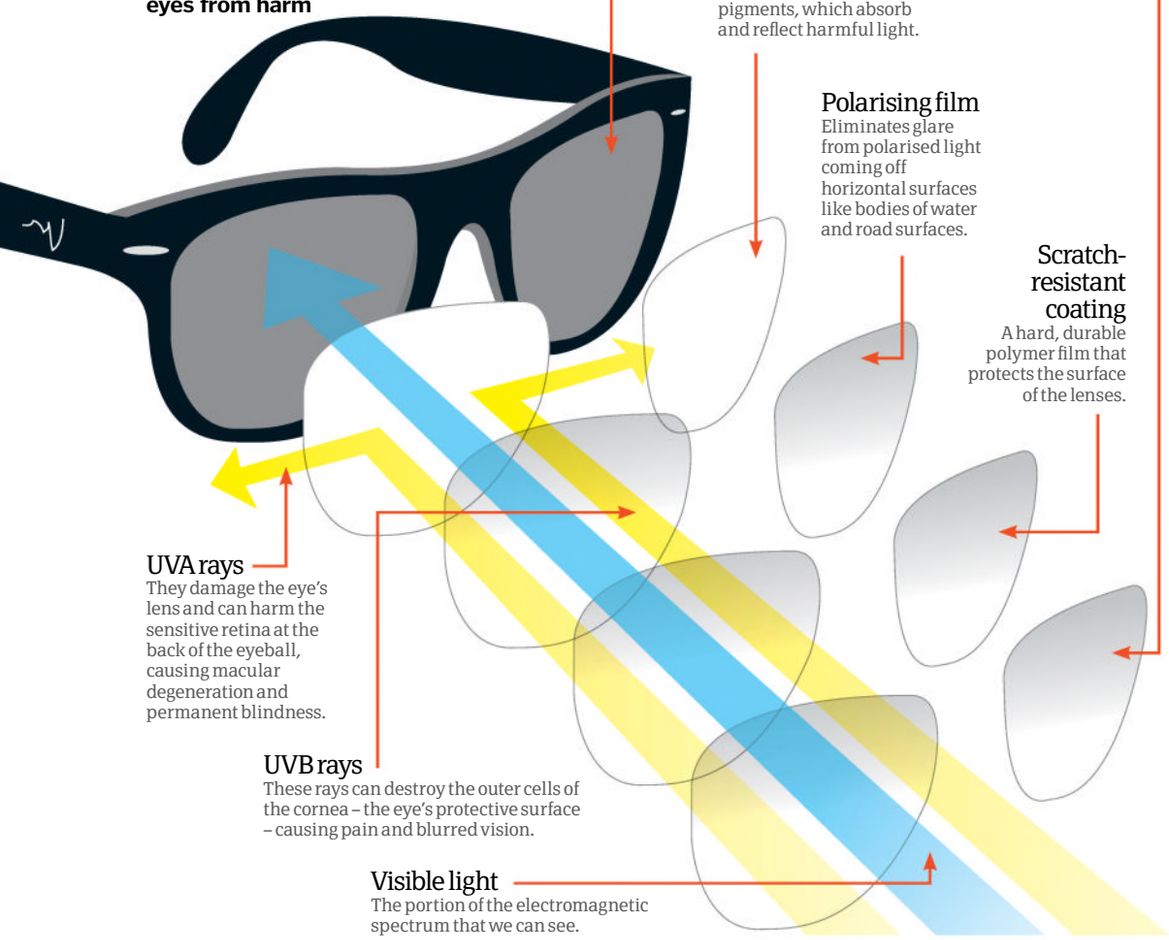
Aside from lending mere mortals an air of film star mystique, sunglasses' premier function is to block the Sun's harmful ultraviolet (UV) rays. There are two types of UV rays: UVA (which cause skin cancer and premature ageing) and UVB (responsible for sunburn). Both types have higher frequencies than the visible light our eyes can perceive. They damage our eyes the same way they damage our skin, except that even in the shade reflected rays pose a threat to our eyes.

Sunglass lenses are made from glass, plastic or polycarbonate, with a special UV-absorbing coating. A good pair blocks more than 99 per cent of UV radiation from reaching your eyes. Tints and mirror coatings relieve you from squinting by absorbing or reflecting intense, dazzling light in the visible part of the spectrum (the light we can actually see). The highest-grade sunglasses also incorporate a polarising film to combat glare from reflective horizontal surfaces like water, sand and snow.

Light waves vibrate just like sound waves do. There's a mish-mash of horizontal and vertical components to these vibrations, but when light waves strike a uniform horizontal surface they are reflected with a strong, horizontal polarisation. The glare we experience is the jam of light waves all vibrating in the exact same plane. Sunglasses fitted with a polarisation film eliminate this kind of glare by only enabling vertically polarised light to pass through.

Safeguarding your vision

The ins and outs of how your sunglasses keep your eyes from harm



Selecting the perfect pair

UV damage is cumulative, meaning it's never too early – or too late – to start protecting your eyes from the Sun. The most important thing is to choose sunglasses that offer 100 per cent UVA and UVB protection, just as you would with sunscreen. The larger the frames you pick out, and the more they hug your face, the less stray light will reach your eyes from around the edges.

Most people mistakenly believe that the darkness of the lenses is what protects their eyes. In fact, some clear transparent lenses can offer full UV protection, but those with a tint will cut out some portion of the light in the visible part of the spectrum too. Different tints offer various advantages – for example, ambers give sharp definition while greens reduce glare and increase contrast. Finally, if you intend to spend time on the water, beach or ski slopes – invest a bit more and up your protection level with polarising lenses.

Sunglasses with 100 per cent UVA and UVB protection are a must

What happens inside an ATM?

Understand how ATMs access your money, while keeping your details safe

Screen
The screen, commonly an LCD on modern machines, will prompt the cardholder through the transaction in a step-by-step format. It will either be touch screen or have buttons on either side.

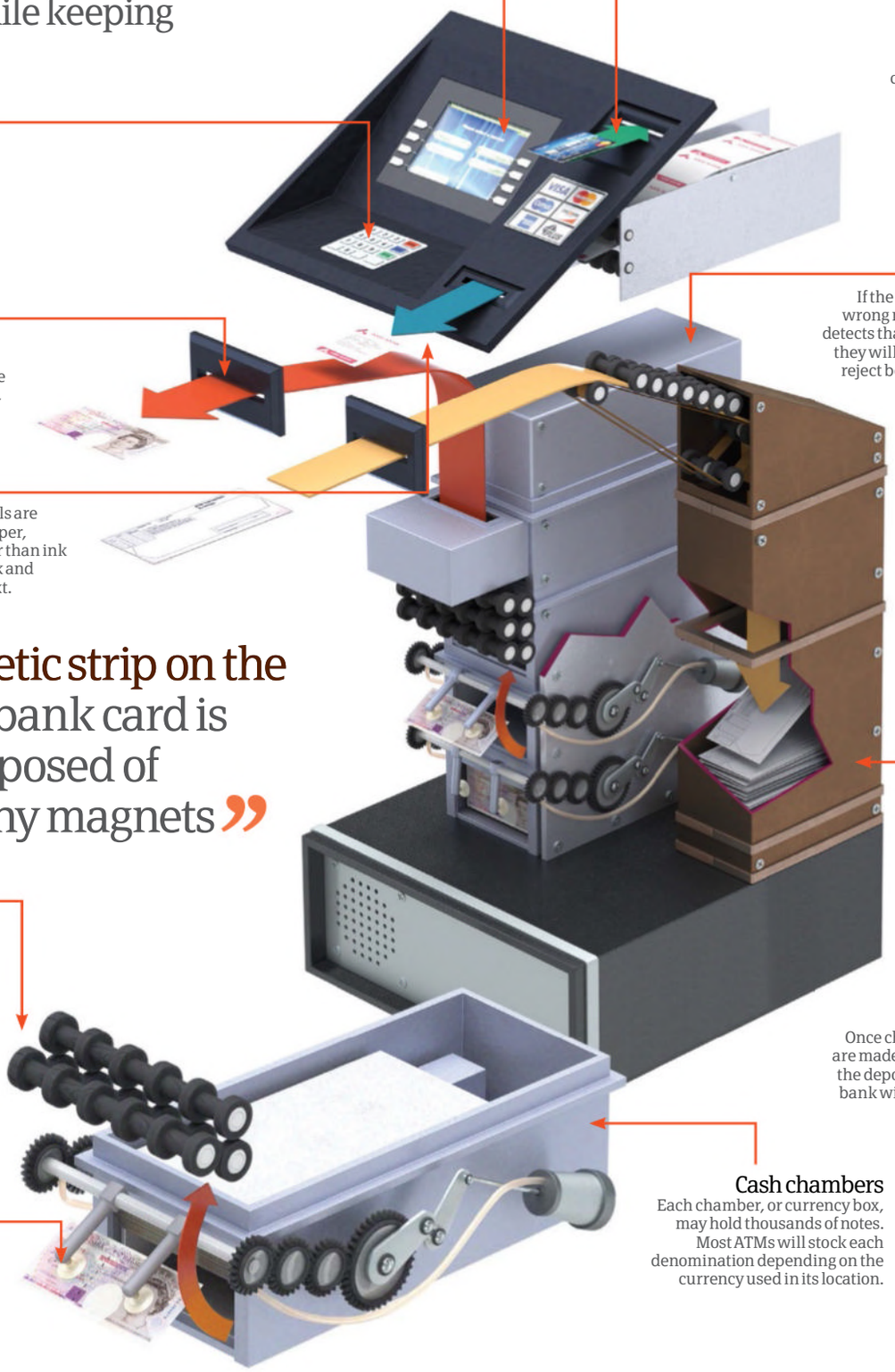
Card slot
Once a card has been entered, its black magnetic stripe is read to authenticate the card and its owner.

Keypad
The keypad is where users enter their four-digit PIN. This is then sent to the cardholder's bank in an encrypted form in case someone intercepts it.

Reject box
If the machine pulls the wrong number of notes or detects that one is damaged, they will be dropped into a reject box and the process will be repeated.

Cash dispenser
Once the transaction is complete, the requested amount of cash will travel up from the vault through the roller mechanism to the dispenser, where it can be collected.

Receipt slot
Your transaction details are printed on thermal paper, which uses heat rather than ink to turn the paper black and form the necessary text.



> "The magnetic strip on the back of your bank card is actually composed of millions of tiny magnets"

Rollers
The rollers check the thickness of each note to make sure that two notes aren't stuck together, so the cardholder receives the correct amount of money.

Deposit box
Once cheques or deposits are made they are stored in the deposit box, where the bank will collect them at a later stage.

Cash chambers
Each chamber, or currency box, may hold thousands of notes. Most ATMs will stock each denomination depending on the currency used in its location.

Suction cups
The suction cups pick up notes individually, before the rollers process them.

Illustration by Nicholas Forder

It's somewhat hard to imagine our modern world without cash machines, yet they only became the norm during the 1970s. The first machine that dispensed cash was invented by John Shepperd-Barron and was installed outside a branch of Barclays Bank in Enfield, Greater London.

Today, they work to give us access to our money 24 hours a day in a multitude of locations – and they are far more convenient than queuing in a bank. However, there are many challenges for them to overcome in order to provide the required level of service. They have to check that you and your card are legitimate, find your account information and carry out the transaction required, all while protecting the thousands of pounds stored inside its vault.

The magnetic strip on the back of your card may look like a solid black line, but it's actually composed of millions of tiny magnets, each one magnetised either north or south, which two magnetic readers understand like a binary code. The first reader confirms the card is real, while the second reads your account number and PIN, checking this against the code that you entered on the keypad.

Once your PIN is confirmed, the machine automatically connects to your bank's network which relays a signal back to the built-in vault, giving it a specific set of instructions. The ATM will then complete the transaction that has been requested. If you forget to take your cash for whatever reason, modern cash machines will swallow the money after a short period of time so you won't be out of pocket.

PIN code shields like the one pictured are one way of reducing fraud

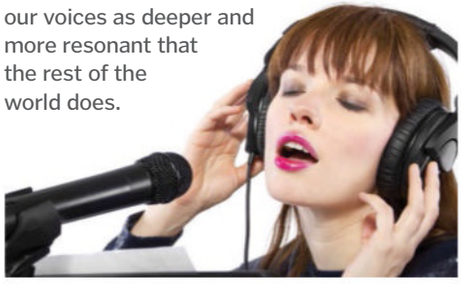
There are numerous ways that cash machines can be tampered with, from hidden cameras to card traps, so it is best to take precautions

The rise of ATM fraudsters

Today our cash machines are constantly under threat from organised crime, with a number of techniques available to criminals that can quickly and cheaply access your card details. The skimmer attachment is one of the most commonly used scams, and involves a small device being fitted to the cash machine which will then read and record your card details. Coupled with this is often a hidden camera, cleverly concealed in panels above the machine or somewhere nearby to find out what your PIN code is. Card traps are also becoming increasingly popular – they work by trapping your card in the machine for the fraudster to collect at a later date. To combat these problems, the police recommend that you always remain vigilant when using a cash machine. By checking for anything unusual or out of the ordinary, you can spot most attempts to rip you off, especially if you use the cash point in question frequently. Make sure you cover your PIN at all times and be wary of any suspicious bystanders hanging around the ATM.

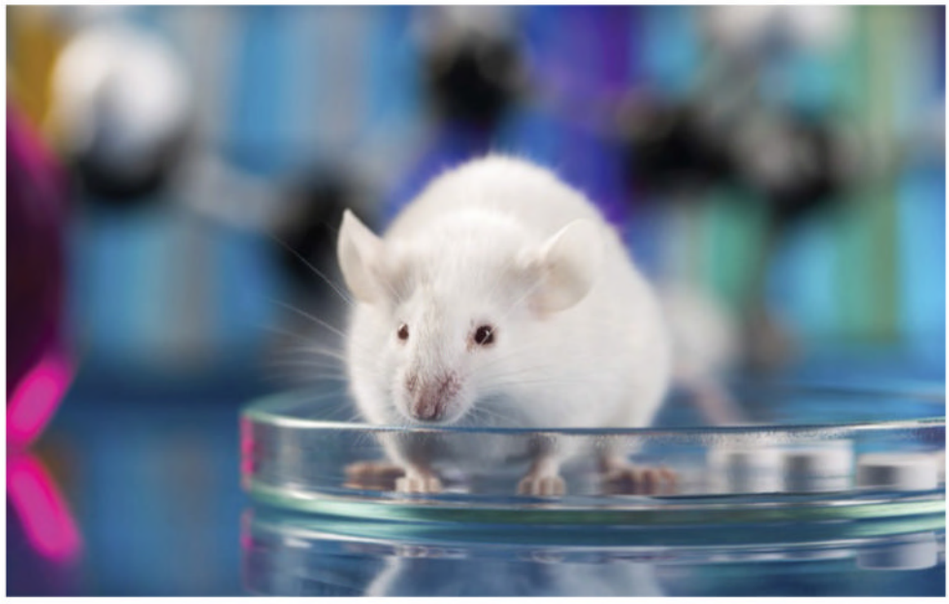
Why does my voice sound different on a recording?

A recording only captures part of the sound of your voice – the part that travels through the air to the microphone. This is the same as the sound that reaches the ears of everyone else, so the recording sounds just like your real voice to them. But when we normally hear our own voices, the sound is a combination of this airborne sound, and the sound that travels through the bones of our jaw and skull. This favours the lower sound frequencies, so we all hear our voices as deeper and more resonant that the rest of the world does.



How do insecticides kill creepy crawlies?

There are many types of insecticides and each works in a different way. Old-fashioned insecticides, like organophosphates and DDT, attack the nervous system. They are effective but they don't just work on insects and can cause serious harm to humans. Newer insecticides are made to specifically target unwanted species. The insecticides used to kill fleas on your dog stop the insects from producing a new exoskeleton, preventing them from shedding their skin. Other insecticides used to kill beetle and moth infestations, contain chemicals that mimic insect growth hormones, keeping the insects in a juvenile state to stop them reproducing.



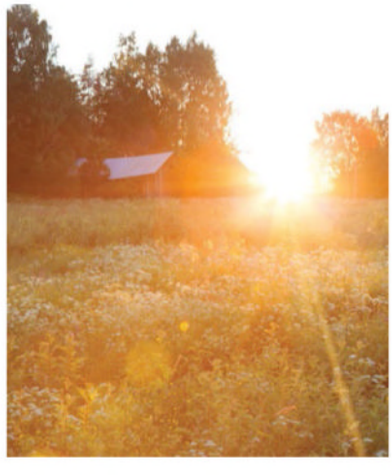
Why are mice typically used for animal testing in labs?

Mice are convenient because they are small, easy to keep and quick to breed. They are mammals like us and have 99 per cent of the same genes as us. Mice have been used for long enough now that there are lots of mutant varieties commercially available to researchers that allow them to simulate various human diseases or quickly stimulate the growth of cancer tumours. Testing medical treatments on mice is generally considered more ethical than using highly experimental drugs on humans, but it is only a first step. Many drugs that cure cancer in mice have turned out to be less effective in humans.

> "Testing medical treatments on mice is generally considered more ethical than using highly experimental drugs on humans"

What causes lens flare in photos?

Lens flare can be problematic as it's capable of drastically reducing contrast in an image as well as introducing halos and scattered polygonal shapes across the frame. That being said, many photographers opt to include lens flare in their photos for artistic effect. It occurs when a bright light, such as from the Sun, hits the surface of the lens at an unusual angle, as opposed to straight on. This strong stream of light will then reflect and bounce off multiple elements within the lens before finally reaching the sensor where it will be recorded as part of the picture.



Why do kettles sometimes whistle?

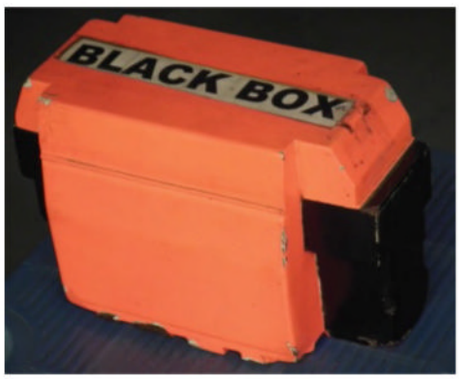
The high-pitched whistling sound produced by a classic stove kettle is designed to alert you when the water inside reaches the boiling point. The actual whistling sound is created when built-up steam is forced to escape through the steam whistle, which is attached to the end of the spout. The steam whistle features two narrow holes that restrict the flow of air. The first opening contracts the steam as it enters and creates a concentrated jet of steam. The jet, however, loses stability as it passes through the whistle towards the exit hole, much like a jet water from a hose will begin to break into droplets after a certain distance. This means that the steam can't flow steadily out of the whistle and will instead bounce off the whistle wall, creating vortices. It is these vortices that produce the well-known whistling sound of a kettle.

Does charging your phone overnight kill the battery?

No. Overnight charging is actually the scenario phones are designed for. The charging circuit in your phone will cut out when the battery reaches maximum capacity. So you can't overcharge your phone, no matter how long you leave it plugged in. If you never unplug your phone from the wall, you will eventually lose battery capacity, though. That's because lithium batteries slowly degrade if they are held at maximum charge for long periods. After an entire year at full charge, a battery will lose 20 per cent of its maximum capacity, compared with just four per cent after a year at half charge.

What are black box flight recorders made from?

Cockpit flight recorders are enclosed in a steel or titanium box (which is painted orange to make it easier to find). Inside that there are some racks of very rugged electronics, but most of these don't actually need to withstand a plane crash, as long as the tapes or memory chips containing the actual data do. They are stored in an inner armoured steel case coated in a flame retardant paint and lined with several layers of insulating materials. Blocks of paraffin wax are used at various points as thermal barriers. In a fire, the paraffin melts and absorbs some of the heat.



Can gas be a conductor of electricity?

Gases are generally poor conductors of electricity. Good electric conductors, such as metals, have loosely bound electrons that can move freely when exposed to an electric potential, producing a current. Gases have no free electrons and therefore do not conduct electricity easily. Under a strong enough electric potential or in extreme heat, gases can, however, become ionised, breaking apart into charged ions and electrons to create a different state of matter known as plasma. This occurs, for instance, during a lightning strike or inside a neon light. Unlike gases, plasmas are good conductors of electricity.

Why do we change the clocks during the year?

It was originally suggested in Britain by William Willett in 1907, to avoid wasting the daylight during the summer when the Sun normally rises long before anyone gets out of bed. The idea wasn't tried until 1916, a year after Willett's death. By that time Britain was at war and lighter evenings allowed the government to save fuel and money on lighting. At various times in the 20th century, Britain has experimented with double summer time, and staying one hour ahead of GMT all year. Lighter evenings in summer result in fewer road accidents overall, but winter mornings would be very dark if we didn't move the clocks back again.

How do noise-cancelling headphones work?

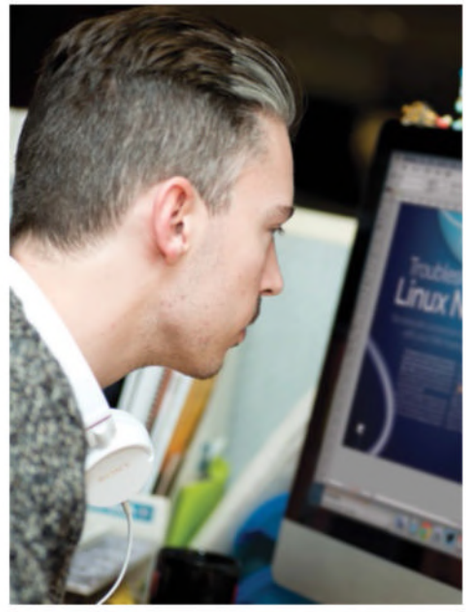
All sound, whether music or general background noise that interferes with our music, is compression and rarefaction of the air around us. Noise-cancelling headphones work thanks to the materials they are made of, which block out unwanted noise. Passive noise-cancelling headphones, such as circumaural headphones, maximise noise-filtering properties by being packed full of sound-absorbing material, such as high-density foam. This makes them heavy, but blocks out interfering noise, such as that of an engine. Active noise-cancelling headphones go a step further and actually erase lower-frequency sound waves. They contain a tiny microphone that listens to the ambient noise. Their internal electronics measure this and create a noise-cancelling wave that is 180 degrees out of phase with the intruding waves, or ambient noise. This wave cancels out the annoying 'surrounding' sounds without erasing the audio that you want to hear through the headphones. These headphones can reduce noise by a further 20 decibels.

How exactly do vacuum flasks work?

Heat can be transferred in three ways: conduction, convection or radiation. Conduction involves atoms physically colliding with each other to transfer their kinetic energy. Convection does this too, but also takes advantage of the fact that hot fluids have lower density and so will rise, taking their heat with them. Vacuum flasks have a double glass wall and the gap in the middle is a vacuum. This means it contains no atoms that could transfer heat across the gap by conduction or convection. That leaves radiation, but the sides of the glass are also silvered, which helps to reflect radiated heat from either side.

How do fitness trackers count your steps?

Electronic fitness trackers have accelerometers that use micro-electro-mechanical systems (MEMS) technology. They consist of a pair of three metal plates sandwiched together. The middle one has a counterweight that can move in response to sudden accelerations. This moves the middle plate slightly closer to the outer plate on one side or the other, which can be detected as a change in the capacitance between the plates and converted into a measure of the acceleration. Three of these tiny accelerometers are packed at right angles to each other on the same chip, so the fitness tracker can measure the movement of your wrist in three dimensions. Since you swing your arms as you walk or run, software algorithms can translate this into the number of steps you have taken. Most trackers are only around 90 per cent accurate, though.

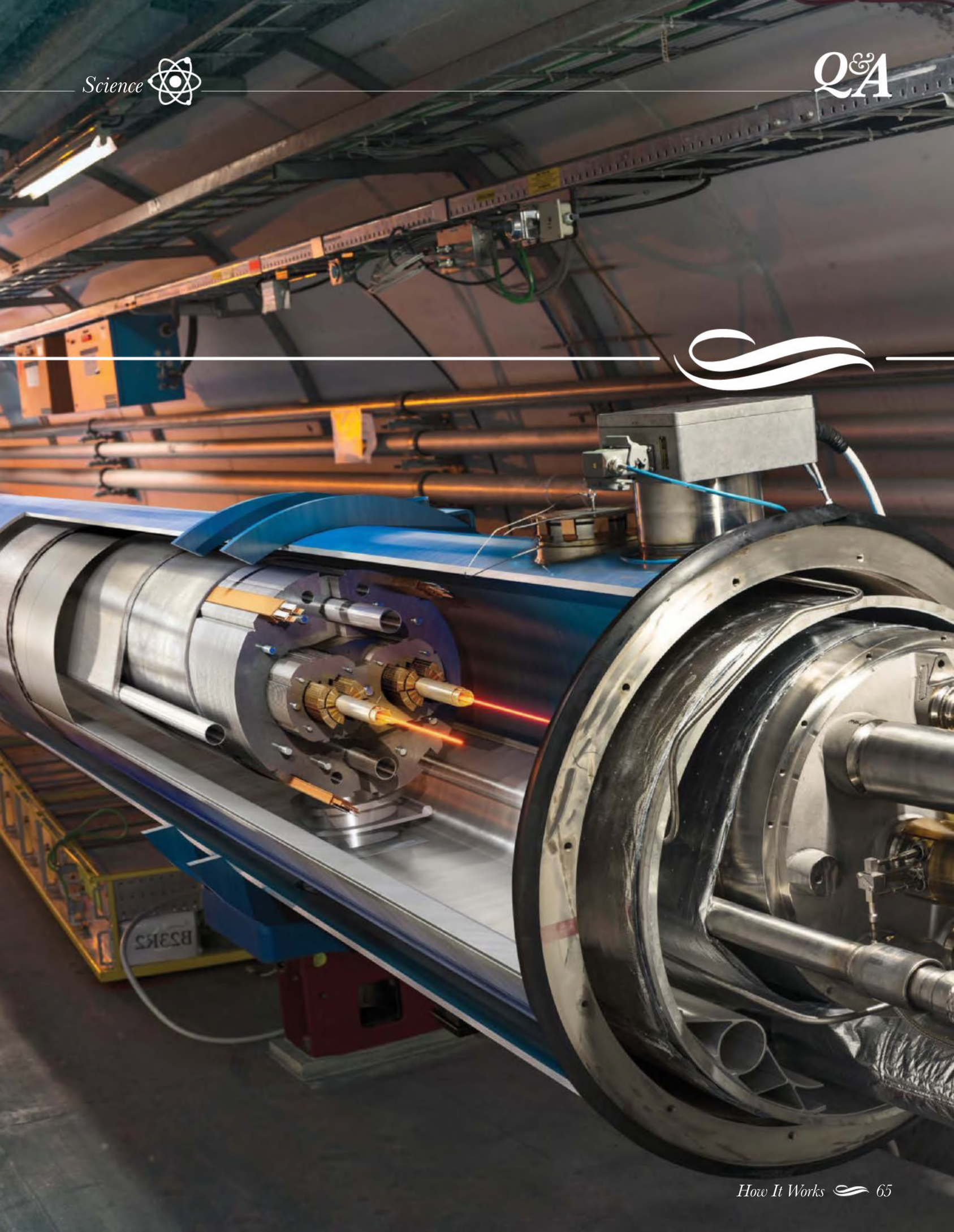


Does staring at a computer screen damage your eyesight?

A twenty-year study of 4,500 children in the US recently concluded that there was no link between those who spent the most time in front of a TV or computer and the ones that went on to become shortsighted. But another study found that computer use may increase the risk of glaucoma, particularly if you are already shortsighted to begin with. Glaucoma is a disease where the fluid doesn't flow out of the iris properly, increasing the pressure in the eye and eventually damaging the optic nerve. Regular eye tests should catch this early on though, and it can be treated quite easily with eye drops.

> *"A study found that computer use may increase the risk of glaucoma, particularly if you are already shortsighted to begin with"*

Science



Are there more than five human senses?

Discover the ten senses you never knew you had

The five classic human senses get all of the attention, so it might surprise you to know that there are several more senses working away quietly in the background in your body. Take something as simple as sitting down to eat your dinner. All five senses are active, taking in the sight and smell of the food on your plate, the taste and feel as you put it into your mouth, and the sound as you chew. But without your other senses, the experience of eating that meal would not be the same.

The act of sitting at the table and getting the food from the plate to your mouth is a sensory feat. You can't keep an eye on your limbs all the time, so the positions of your joints and the tension in your muscles is constantly measured, enabling you to eat without having to closely watch what you are doing. In order to stay balanced as you reach across the table, sensory information is quietly gathered by specialist structures in the inner ear.

Once the food has reached and is inside your mouth, one set of sensors provide information about the temperature, and another set of specialist nerves called nociceptors quickly alert you as to whether the mouthful is dangerously hot or particularly cold. At the same time, the blood and the fluid surrounding your central nervous system are monitored to make sure that levels of carbon dioxide and oxygen remain within normal limits, and your breathing rate is subconsciously adjusted.

As your stomach starts to fill up, stretch sensors feed back to the brain, turning down the signals that are telling you to keep eating, and when the part-digested food starts to hit your small intestine, sensors trigger the production of a hormone that flicks the switch to tell you that you have had enough. The build-up of waste products is also closely monitored and long after your meal has been completed, sensors will alert you when it is time to get rid of anything that is left over.

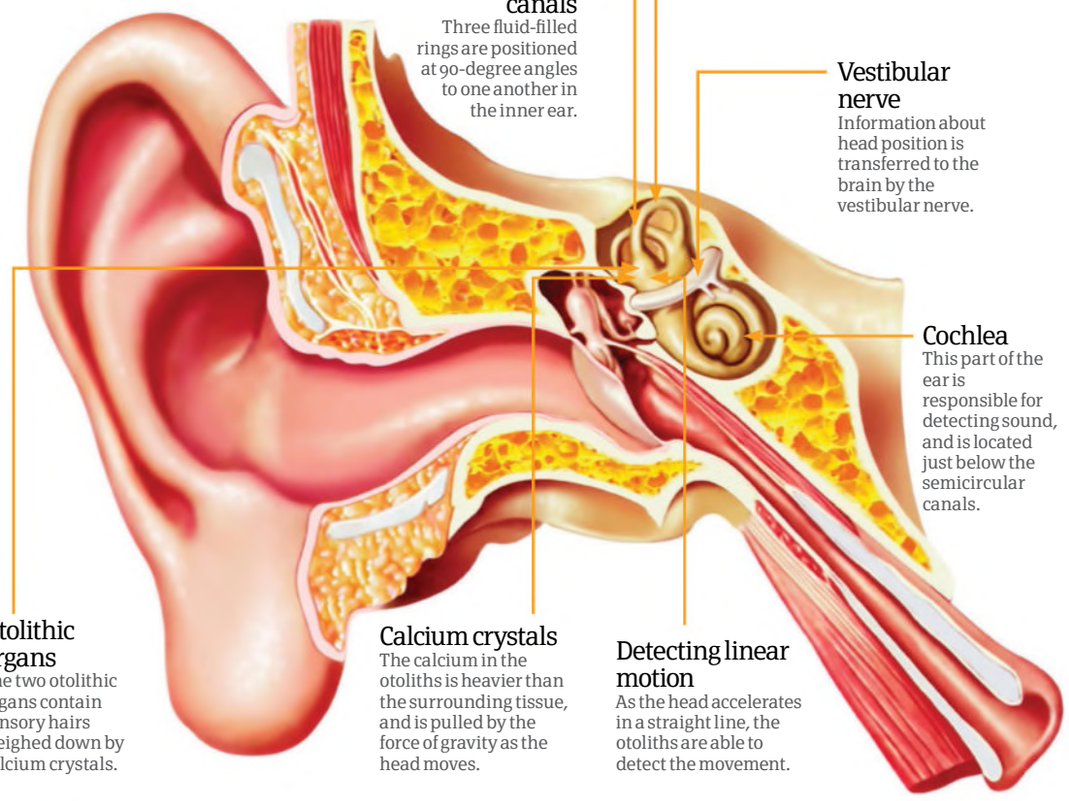
So while the traditional five senses are the ones that we rely on most in our conscious interactions with the world around us, there are several more that work quietly in the background as we go about our daily lives.

Balance (equilibrioception)

Our sense of balance is handled by the vestibular system in the inner ear, and provides vital feedback about head position and movement. Inside the ear there are three semicircular canals; each is filled with fluid. At one end of each canal is a bulge supporting a series of sensitive hairs. As you move your head, the fluid moves too, bending the tiny hairs and sending information about head rotation to the brain. There are also two organs called otoliths on each side of the head. These contain sensory hairs weighed down by calcium crystals that help to tell which way is up.

Staying balanced

The inner ear contains specialised structures that detect head movements



Semicircular canals
Three fluid-filled rings are positioned at 90-degree angles to one another in the inner ear.

Detecting head rotation
As the head rotates, the fluid in the semicircular canals moves.

Vestibular nerve
Information about head position is transferred to the brain by the vestibular nerve.

Cochlea
This part of the ear is responsible for detecting sound, and is located just below the semicircular canals.

Otolithic organs
The two otolithic organs contain sensory hairs weighed down by calcium crystals.

Calcium crystals
The calcium in the otoliths is heavier than the surrounding tissue, and is pulled by the force of gravity as the head moves.

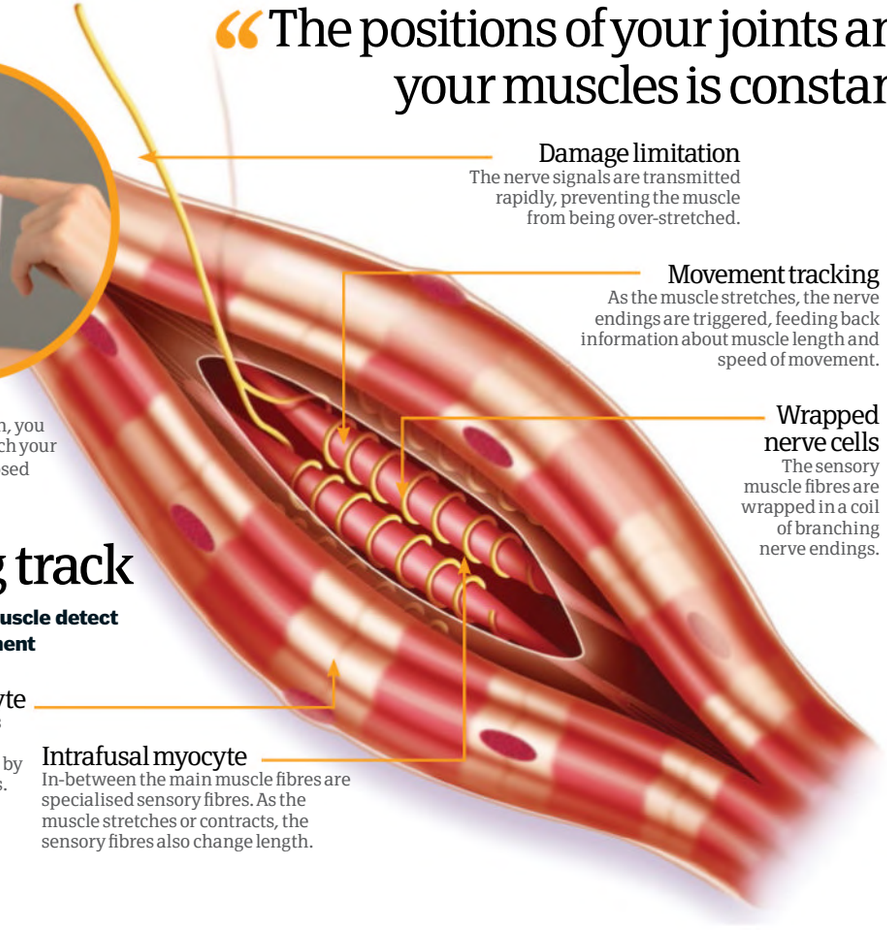
Detecting linear motion
As the head accelerates in a straight line, the otoliths are able to detect the movement.

> "The positions of your joints and the tension on your muscles is constantly measured"

Without proprioception, you wouldn't be able to touch your nose with your eyes closed

Keeping track

Fibres inside the muscle detect stretch and movement



Damage limitation
The nerve signals are transmitted rapidly, preventing the muscle from being over-stretched.

Movement tracking
As the muscle stretches, the nerve endings are triggered, feeding back information about muscle length and speed of movement.

Wrapped nerve cells
The sensory muscle fibres are wrapped in a coil of branching nerve endings.

Extrafusal myocyte
The main muscle fibres are responsible for contraction, controlled by incoming nerve signals.

Intrafusal myocyte
In-between the main muscle fibres are specialised sensory fibres. As the muscle stretches or contracts, the sensory fibres also change length.

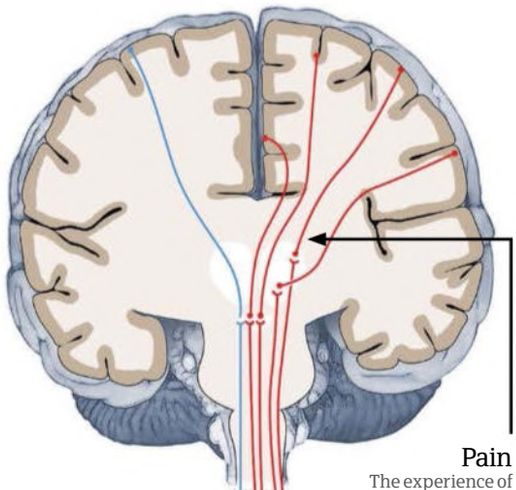
Movement (proprioception)

Even the simplest movements would be a challenge without this sense; proprioception allows us to keep track of the position of our bodies in space without looking. This enables us to make the tiny adjustments that keep us from falling over when we are standing still, helps us to judge the distance each time we take a step, and allows us to coordinate complex movements like riding a bike or playing the piano. The receptors responsible are found in the joints, muscles and skin, and help to relay information about the angle and position of each joint, and the tension on our tendons and muscles, providing the brain with constant feedback.

Pain (nociception)

This sense allows us to tell the difference between a harmless touch and potential damage to keep our bodies safe

Specialised nerve endings called nociceptors are found in the skin and organs. Unlike normal sensory nerves, these are not activated by low-level stimulation, and instead wait until the temperature, pressure or level of a toxic substance is enough to cause the body harm. Activation of these nerves can trigger a swift withdrawal reflex, prompting us to move away from the harmful stimulus, and in the long term it acts as a deterrent, teaching us to avoid whatever it was that caused the unpleasant sensation in the first place. The ability to sense damaging stimuli is different from the feeling of pain, and the sensation that we are all familiar with involves a significant amount of further processing in the brain.



Pain
The experience of pain is more than just the nerve signals, and involves emotions, memories and other higher-level brain processing.

Into the spinal cord
The signal is rapidly transmitted towards the spinal cord, passing through a cluster of nerve cell bodies.

Pain receptor
Nociceptors are only activated if tissue damage is imminent, alerting the body to potential danger.

Heat
Some nerves respond specifically to heat, becoming active at temperatures above 40-45 degrees Celsius (104-113 degrees Fahrenheit).

Cold
Other nerves respond to cold temperatures, and start to fire when temperatures drop below five degrees Celsius (41 degrees Fahrenheit).

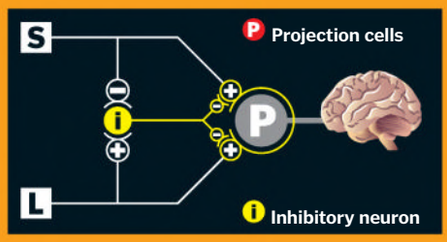
Pressure
Some nociceptors respond to pressure, triggering when parts of the body are dangerously compressed.

Chemical
Some nociceptors respond to chemical signals of tissue damage, like the presence of acid, or the lack of oxygen.

Towards the brain
The incoming signal can induce a rapid withdrawal reflex just by reaching the spinal cord, but the feeling of pain relies on signals travelling onwards to the brain.

Numbing the pain

Have you ever put your finger in your mouth after shutting it in a door, or grabbed hold of your foot after stubbing your toe? Incoming signals from our other senses can switch off pain signals, preventing some of them from reaching the brain.



Pain gate
Nociceptive (pain-detecting) nerves send their signals towards the spinal cord before they go on to the brain, but in order to reach the brain they have to travel through a biological gate.

Inhibition of pain
Touch-sensitive nerves pass their messages through the same region as the pain signals. These nerve cells are larger and faster, and are able to close the gate, overriding the pain signals.

Pain signal
Without the input from the large nerve fibres, the gate is opened. This allows pain messages travelling along the smaller nerve fibres to pass through the spinal cord and onwards towards the brain.

Time (Chronoception)

Internal clocks help us to keep track of time

Even without a watch, we have a sense of the passage of time, but our body clock is not like any normal timepiece. The suprachiasmatic nucleus in the brain is the master clock, and it governs our daily cycle, or circadian rhythm. This 24-hour clock controls daily peaks and troughs in our hormone levels, influencing many behaviours, from eating to sleeping. For shorter tasks, scientists think that we might have several internal stopwatches keeping time inside our brains. As yet, the parts of the brain responsible for keeping these rhythms have not been discovered.

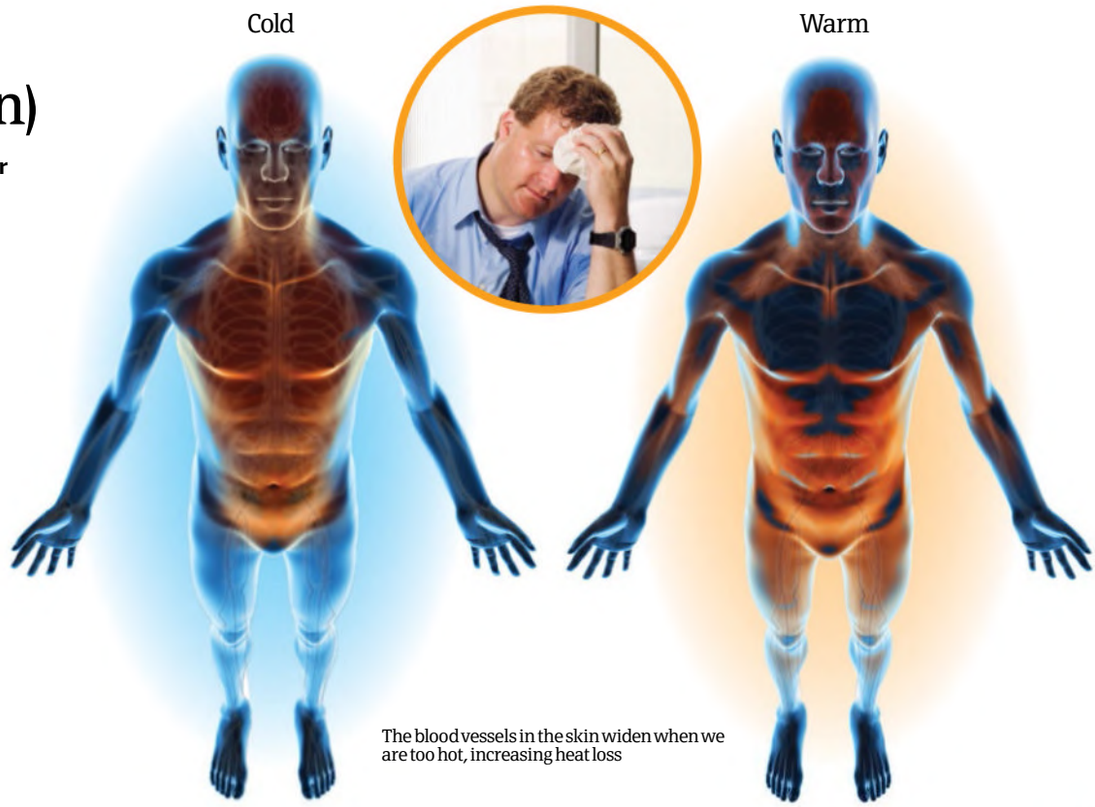
Our sense of time is not always reliable, and changes depending on our mood and environment

Temperature (thermoception)

An internal thermostat keeps our body temperature at a constant 37°C (98.6°F)

It is crucial for our bodies to be able to detect heat and cold, firstly to ensure that our internal organs are kept at the right temperature to function properly, and secondly to prevent us being damaged by extremes. We are able to detect the temperature of our extremities by a series of nerves in the skin, while our core body temperature is monitored by a part of the brain known as the hypothalamus.

As warm-blooded animals, we generate huge amounts of heat as we burn sugars to release energy. This helps to keep us warm, but in order to maintain a constant temperature, adjustments need to be made continually to make up for changes in the environment or changes in our level of activity. For immediate changes in body temperature, the brain orders the body to shiver or sweat, and for more long-term regulation, the production of thyroid hormone is ramped up or down, altering the rate at which we burn sugars and generate heat.

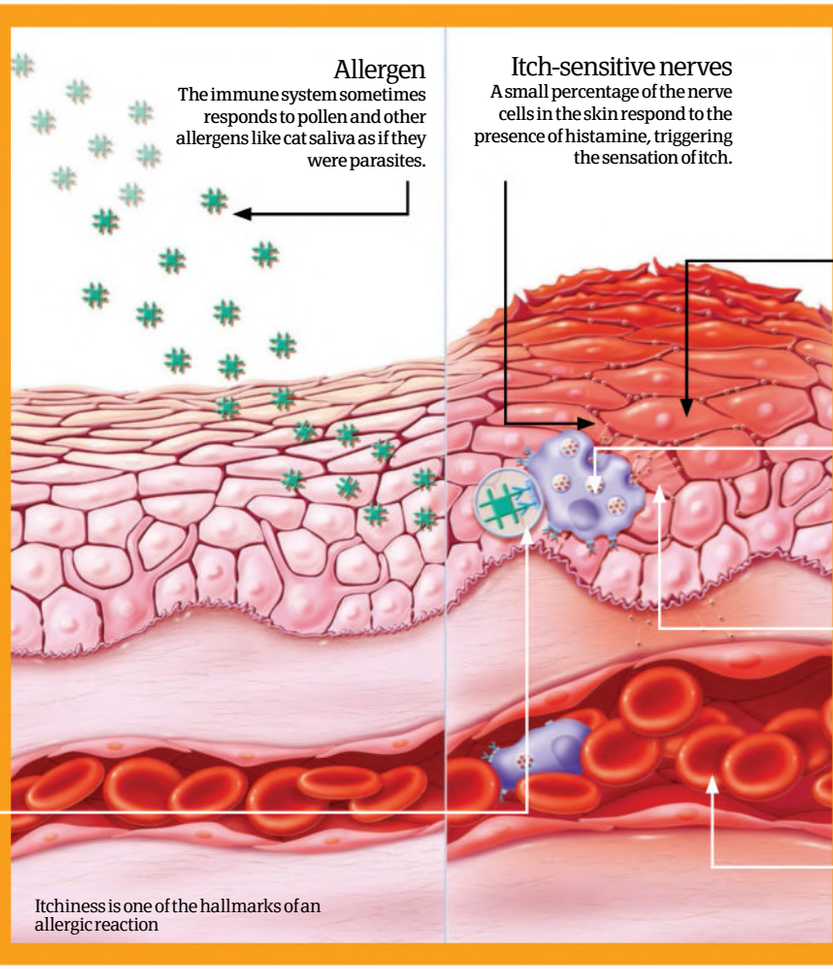


The blood vessels in the skin widen when we are too hot, increasing heat loss

Itchiness

This unusual sensation is closely related to pain

Itchiness is the body's way of alerting us to parasites and irritants. It prompts a reflex scratch response, which scientists think is to draw our attention to that area of the body so any irritant can be eliminated. The exact science of itching is still unclear, but one of the most well studied culprits is a molecule known as histamine. Parasites like biting insects and worms often produce chemicals known as proteases, which help them to break through the barrier of the skin. These proteases trigger white blood cells to release histamine, which in turn activates our body's itch-sensitive nerve cells.



Itchiness is one of the hallmarks of an allergic reaction

Allergic itch

Sometimes the body gets it wrong and releases histamine in response to harmless allergens

Extra sensitive
Other chemicals released during the inflammatory response sensitise the nerve endings, making them fire more easily and magnifying the sensation of itchiness.

Mast cell
These specialised immune cells behave like sentry towers in the skin. Their normal function is to respond rapidly to the presence of parasites.

Histamine
This small molecule is responsible for the itchiness associated with allergic reactions.

Leaky vessels
Histamine also makes local blood vessels leaky, allowing more white blood cells to enter the area.

How are we affected by neurotransmitters?

Are our moods and emotions really just brain chemistry?

Messages are passed from one nerve cell to the next by chemical messengers called neurotransmitters. Each has a slightly different effect and by looking at what happens when neurotransmitter levels change, we are discovering that different combinations play a role in a range of complex emotions.

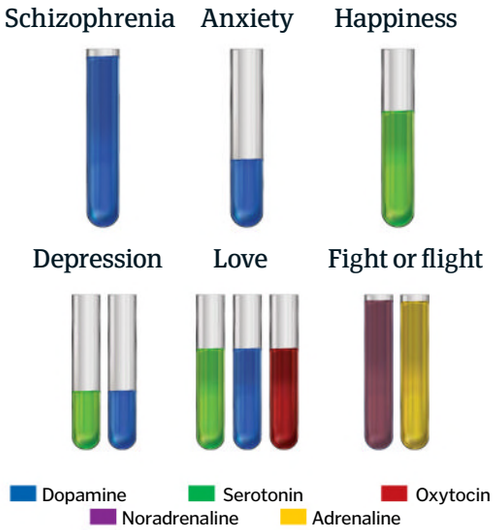
Acetylcholine excites the nerve cells that it touches, triggering more electrical activity. It plays a role in wakefulness, attention, learning and memory, and abnormally low levels are found in the brains of people with dementia caused by Alzheimer's disease.

Dopamine is a chemical that also excites nerve cells. It plays a vital role in the control of movement and posture, and low levels of dopamine underlie the muscle rigidity that exists in Parkinson's disease. Dopamine is also used in the brain's reward circuitry and is one of the chemicals responsible for the good feelings that are normally associated with more addictive behaviour types.

Noradrenaline is similar in structure to the hormone adrenaline and is involved in the 'fight or flight' response. In the brain, it keeps us alert and focussed. In contrast, GABA reduces the activity of the nerves that it interacts with and is thought to reduce feelings of fear or anxiety.

Serotonin is sometimes known as the 'happy hormone' and transmits signals involved in body temperature, sleep, mood and pain. People with depression have been found to have lower serotonin levels than normal, though raising serotonin levels with antidepressant medications does not always help.

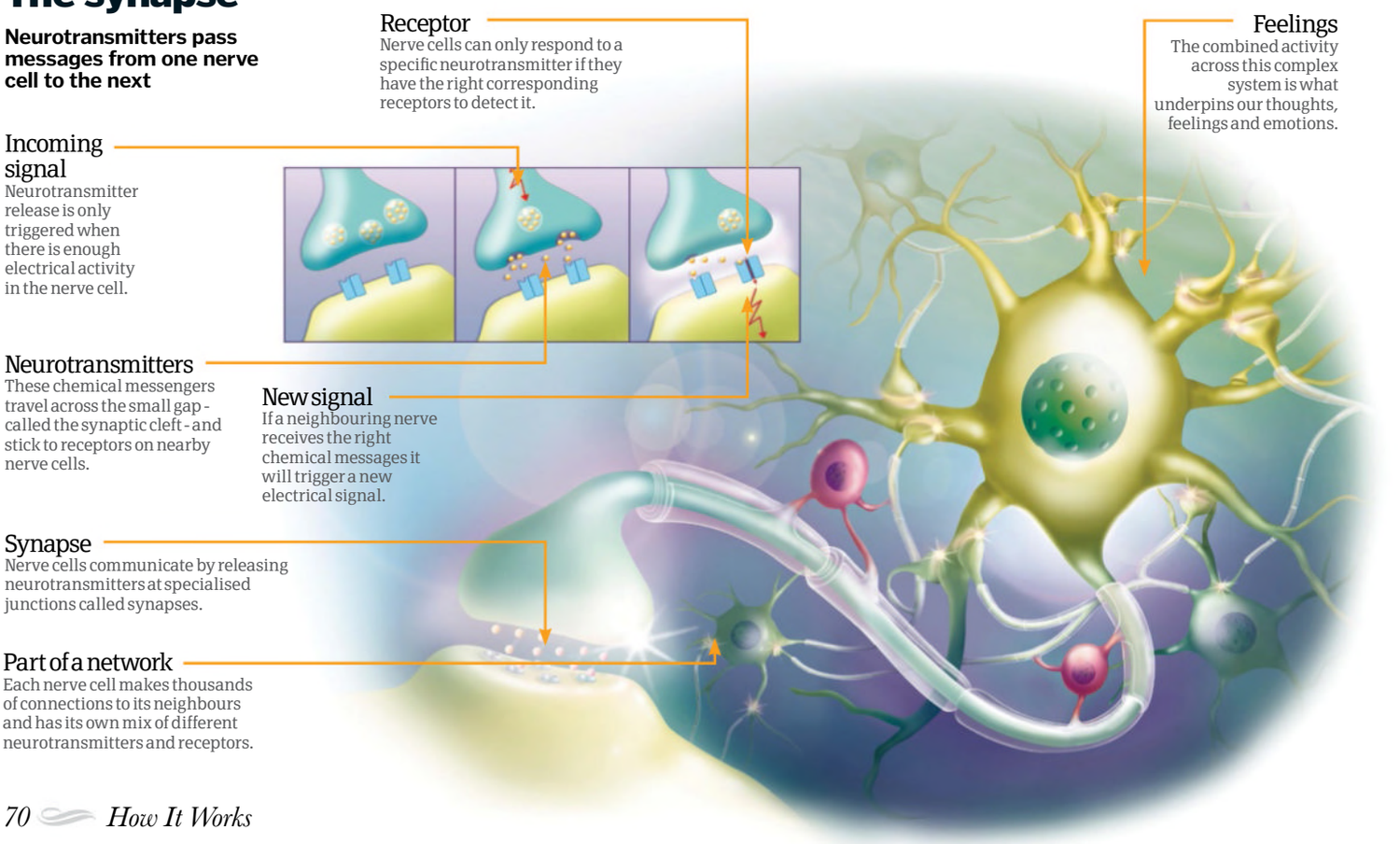
There are many more neurotransmitters in the brain and other chemicals like hormones can also influence the behaviour of nerve cells. It is these interactions that are thought to underlie the huge range of human emotions.



Different levels of neurotransmitters have been associated with different mental states

The synapse

Neurotransmitters pass messages from one nerve cell to the next



Why does popping candy pop?

Discover the science behind this sweet's sizzling sensation

Pop Rocks candy bounces in your mouth when high-pressure carbon dioxide bubbles are released as it melts on your tongue

Popping candy explodes on the tip of your tongue, a sensation either loved or loathed by those with a sweet tooth. The secret to its unique fizz, crackle and pop is actually all down to how it is made.

In fact, popping candy is created in a similar way to traditional boiled sweets. Sugar, corn syrup, water and flavouring are all mixed together and then heated so that the water boils off. If the resulting sugar syrup solution would be left to cool at this stage, you'd end up with regular hard sweets. But in order to give the candy its unique popping potential, the molten mixture is exposed to high-pressure carbon dioxide gas at about 40 times atmospheric pressure. This causes small bubbles of gas to form within the solution. As this is then cooled, the pressure is released, causing the candy to shatter into small pieces of rock. However, each piece still contains tiny high-pressure bubbles. When you then place the candy on the tip of your tongue, and it begins to melt, the trapped pressurised bubbles are released, creating a unique sizzling sound and the sensation of it bursting and bouncing around your mouth.

What is the diving reflex?

Find out how it enables you to swim underwater

The diving reflex is a physiological response that enables all mammals, including humans, to dive underwater for extended periods of time on just one breath. Once triggered, it slows and shuts down parts of the body in order to conserve energy and ensure survival.

It all happens in stages. The body's first response, after you've held your breath or been submerged in cold water, is to slow the heart rate down, known as bradycardia. This enables more oxygen to reach the organs, as less is needed in the bloodstream.

Eventually the body's circulatory system will start to constrict your capillaries, redirecting blood from the extremities, so that more is allocated to the vital organs such as the heart and brain.

At this stage you're likely to experience cramping in your arms and legs, due to a lack of oxygen in these areas. The latter stage, blood shift, generally only occurs if you're free-diving at depths of a few hundred feet. This essentially causes the lungs to fill with plasma, helping to prevent them from collapsing under the pressure.

Holding your breath elicits the diving reflex, which enables you to conserve oxygen

How is hair transplanted?

How this surgical technique battles baldness

Male pattern baldness is common, although in some people it can lead to concerns over appearance and even a severe loss of confidence. Most choose to accept it, but others are fighting the balding process. Modern science has recently updated ancient techniques, meaning that hair transplants can now reliably restore normal hair patterns.

Patients are carefully screened before undergoing hair transplantation, similar to patients before any cosmetic procedures. While hair transplants can restore self-confidence, it's important that they aren't used to fix problems in patients' lives that can't be solved through a change in appearance alone.

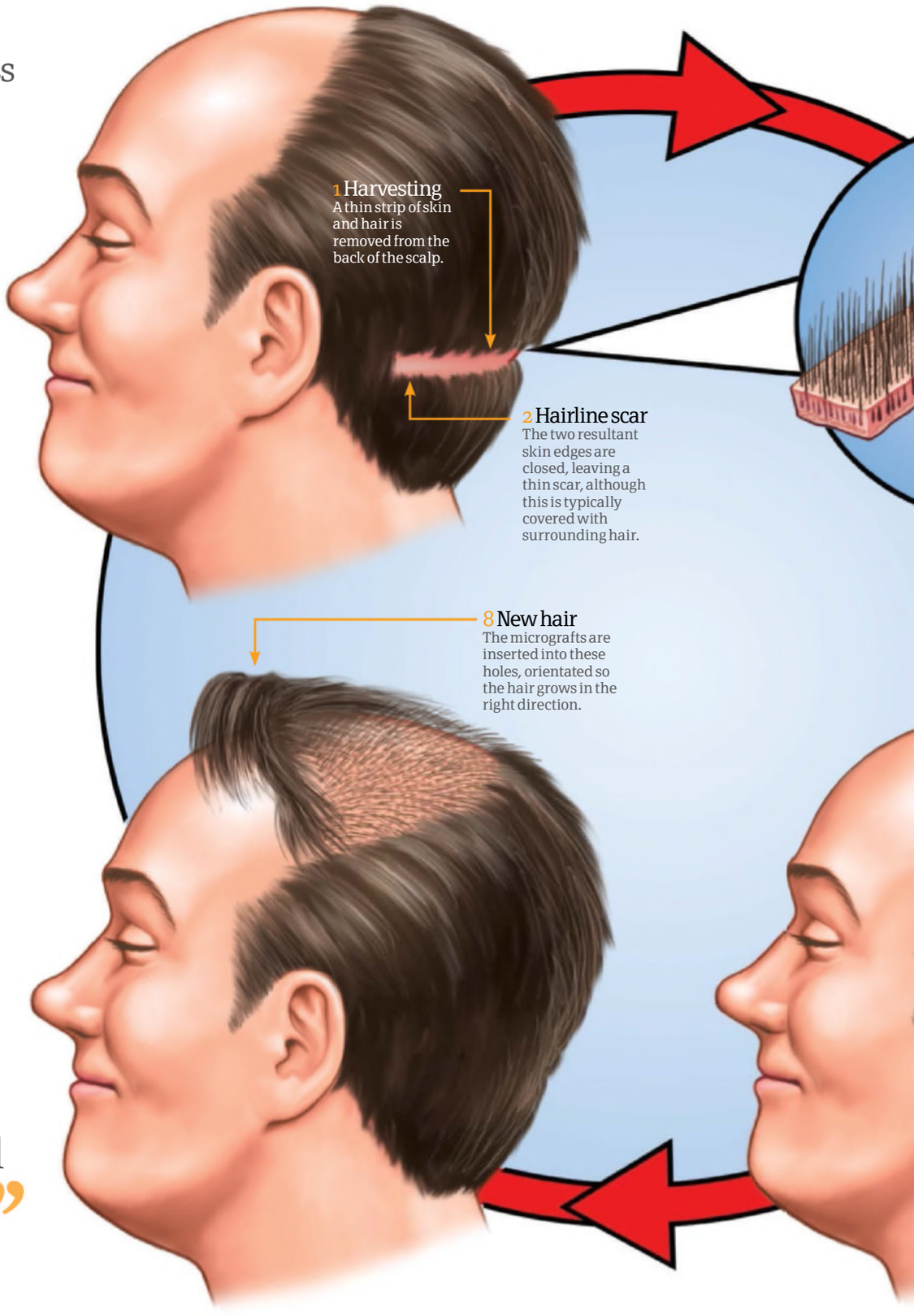
Hair transplants have been practiced as far back as the 19th century. However, it is only in the last 20 years that modern techniques have led to reliable and realistic results. Currently, two techniques are used the most. The first involves taking a thin strip of hair from the back of the scalp, removing the hair follicles and implanting them to the front of the hairline. The second doesn't involve removing a strip; rather, small units of two to four follicles are removed and then transplanted in the required area.

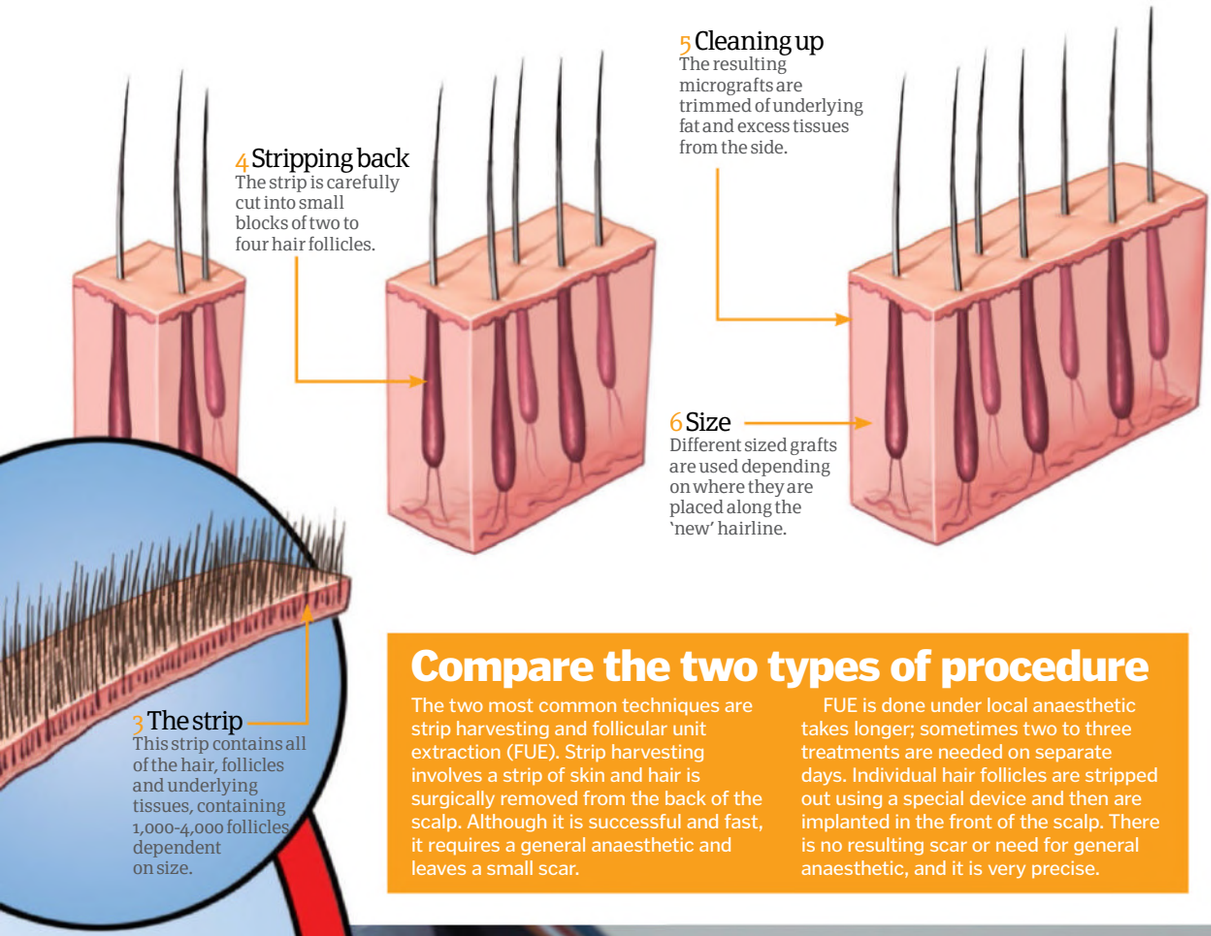
These techniques have become so sophisticated that the direction of the hair follicle is controlled when implanting it in the new site. This gives a natural hair-growth direction and a realistic pattern. These procedures aren't without risks, though. They can be painful, and as with any surgical wound, infection can set in. There is also no guarantee of success as baldness can recur. However, it is a generally successful procedure and can restore lost confidence.

> "Modern science has recently updated ancient techniques"

How to perform a hair transplant

The basic steps in performing a strip harvest of hair, the most commonly used method





Compare the two types of procedure

The two most common techniques are strip harvesting and follicular unit extraction (FUE). Strip harvesting involves a strip of skin and hair is surgically removed from the back of the scalp. Although it is successful and fast, it requires a general anaesthetic and leaves a small scar.

FUE is done under local anaesthetic takes longer; sometimes two to three treatments are needed on separate days. Individual hair follicles are stripped out using a special device and then are implanted in the front of the scalp. There is no resulting scar or need for general anaesthetic, and it is very precise.

How hair is lost

The most common type of baldness is male pattern baldness, which can affect 50 per cent of men over the age of 50. Typically, the hair on the temples thins while the hair on the top of the head recedes. It usually takes around ten years for the hair to recede fully, leaving a small rim around the sides and back.

Changes in signalling of the male sex hormone dihydrotestosterone (DHT) is primarily responsible. The hairs on the head become susceptible to it, which causes thinning and then hair loss. Why the chest or beard hair isn't affected is unknown. This type of age-related baldness can affect women too, but is less common.

Different types of hair loss also exist. These include patchy hair loss on the scalp (leaving tufts), loss of all body hair (head, chest, arms and legs), and universal hair loss (all hair including eyebrows and eyelashes).

Hair transplant science has improved greatly in the last 20 years

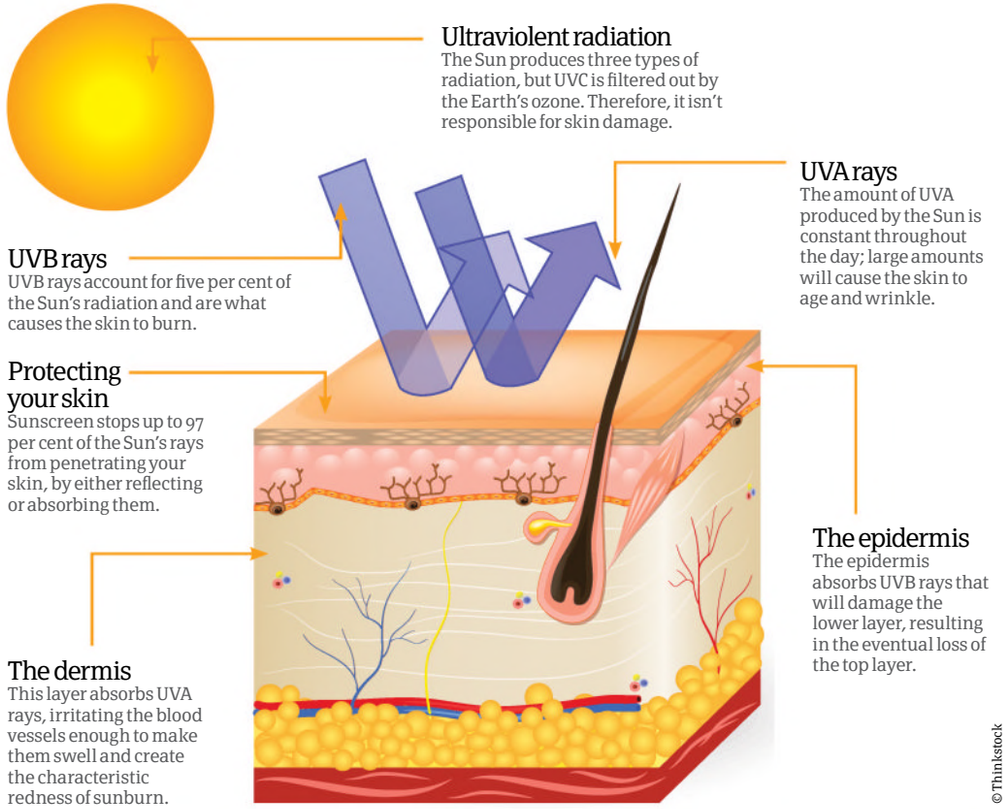
How does sunscreen work?

See how this clever substance protects our skin from harmful UV rays

The dangers of the Sun's rays have long been appreciated by humanity. The ancient Greeks slathered themselves with olive oil, while ancient Egyptians used extracts of rice and jasmine that are still present in modern day skincare products.

Whether it is in the form of a spray, lotion, gel or wax, modern sunscreen works by combining ingredients that either block or absorb the Sun's dangerous ultraviolet (UV) rays. Minerals such as zinc oxide reflect UV rays directly, whereas organic chemicals such as avobenzone absorb UV radiation into their chemical bonds, and then gradually release it as heat. The Sun Protection Factor, or SPF, indicates how well the sunscreen will block the Sun's UVB rays, which are responsible for burning the skin. An SPF 15 sunscreen will prevent your skin from burning for 15 times longer than it usually takes for you to burn, but will only block out around 93 per cent of UVB rays.

The chore of rubbing on sunscreen may soon be a thing of the past, however. There is currently a race to develop a pill that will provide full UV protection, based on a compound produced by the algae that live inside coral. Scientists hope to see this product for sale on the market in the coming years.



Why do cats go crazy for catnip?

The oil that stimulates a cat's sensory neurons

There is an oil found in the catnip plant (nepeta cataria) called nepetalactone. Researchers believe that when this oil enters a cat's nasal tissue, it binds to protein receptors that stimulate sensory neurons. This leads to a response in neurons in a certain part of the brain known as the olfactory bulb which projects to other brain regions; regions that not only mediate emotional responses to stimuli (consequently causing a behavioural response), but also regulate neuroendocrine responses, making the cat react to an artificial cat pheromone. It doesn't affect all cats, but many react by rolling around, flipping over, becoming hyperactive and sometimes acting aggressively, before experiencing a come down ten minutes later.

What are the physics of the cricket ball?

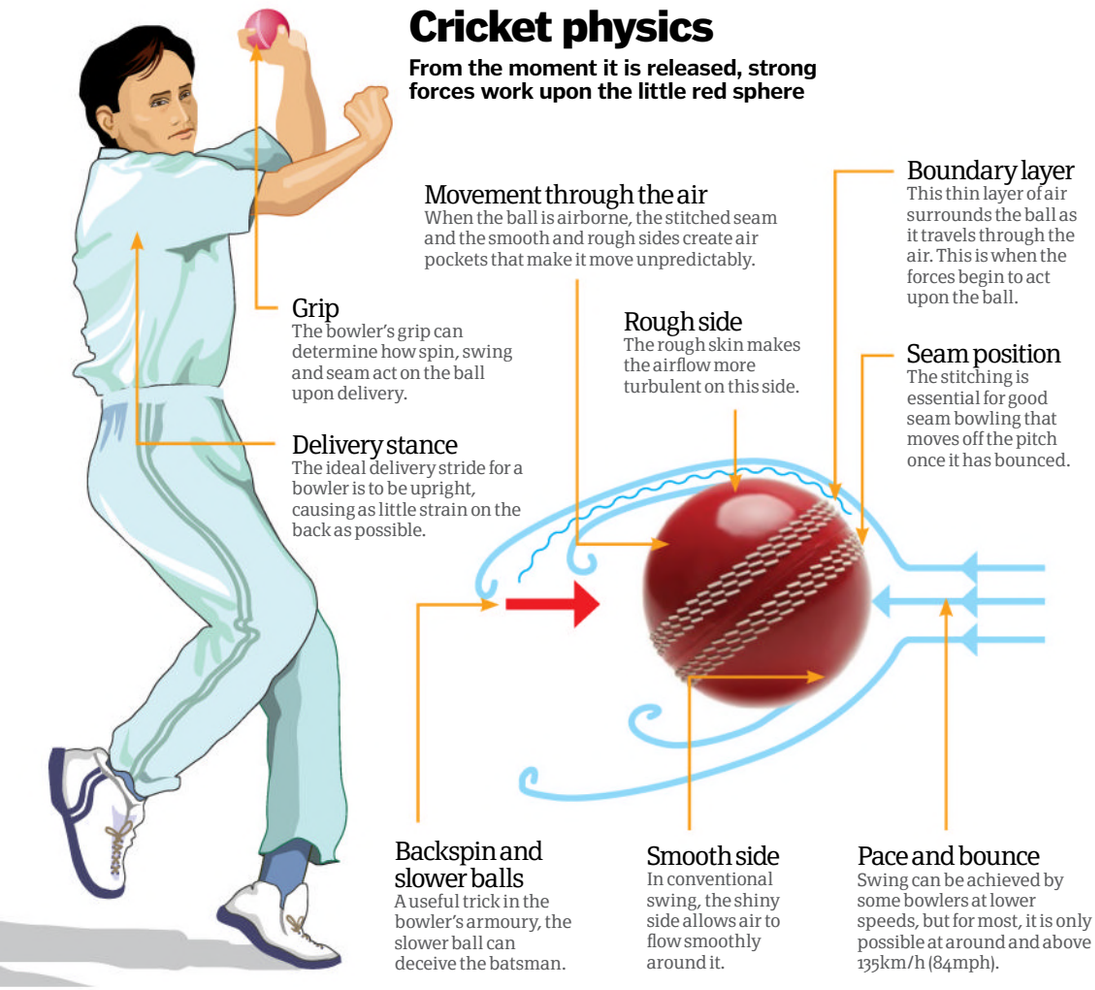
In a game of fine margins, physics can make all the difference

The movement of a cricket ball is unique within the sporting world. When the ball is delivered, a layer of air known as a 'boundary layer' forms over the ball. This is where the physics come into play. By angling the seam – the stitched part in the middle – the bowler can alter the pressure of the forces on the ball and choose which way the delivery will go. The aerodynamics can be varied further by the bowler changing the pace of the ball and where the ball bounces. These deliveries are known as 'cutters' to cricket fans and the practice is called seam bowling. Spin is another weapon in the bowler's armoury. Spin bowlers use their wrist or fingers to put revolutions on the ball to allow it to spin fiercely once it has pitched. Slow spin works better on dry and dusty pitches where the ball can skip off the pitch.

Side forces also act on the ball in swing bowling. When one side of the ball becomes rougher than the other, that half becomes less streamlined. Bowlers frequently use this to their advantage to move the ball sideways in the air in order to confuse batsmen into playing false and poorly timed shots. The effect of swing can be exaggerated even further by shining one side of the ball, although using anything other than your cricket whites to rough the ball up is considered unsporting.

Cricket physics

From the moment it is released, strong forces work upon the little red sphere



The mystery of reverse swing

Reverse swing, where the ball swings in the opposite direction to the conventional way, is a rare delivery that can dismiss even the most experienced batsmen. Made famous by the likes of Wasim Akram and Imran Khan, the cricket ball can become almost unplayable. Readily achievable at bowling speeds of over 135 kilometres (84 miles) per hour, reverse swing works best when the ball is old and rough. Now the ball is not shiny so it will move in the opposite way to what is expected from a conventional swing. The boundary layer is affected quicker, allowing an in-swinging bowler to bowl out-swinging deliveries and vice-versa. As the bowler doesn't change his grip, there is no hint to the batsman that the ball will move the other way. It is said that overcast and humid weather can aid swing bowling, but further research into this remains inconclusive. If a bowler masters reverse swing, the odds will be in his favour.

James Anderson is England's premier swing bowler, making the ball reverse swing at high speeds

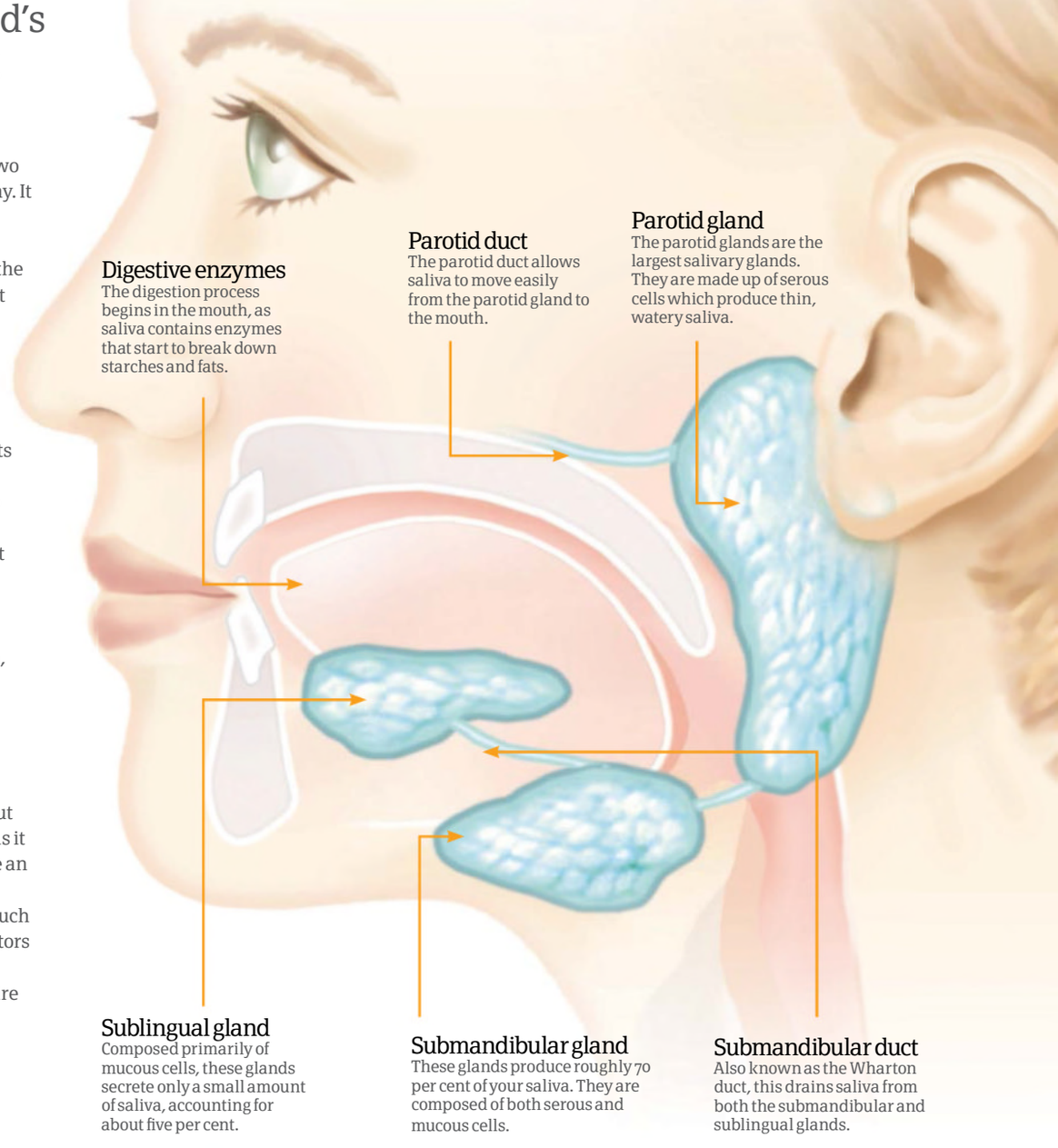
What is saliva?

Find out this frothy liquid's vital role in maintaining human health

Humans can produce an incredible two litres (half a gallon) of saliva each day. It is made up of 99.5 per cent water, so how is it able to perform so many important functions in our mouths? The answer lies in the remaining 0.5 per cent, which contains a host of enzymes, proteins, minerals and bacterial compounds. These ingredients help to digest food and maintain oral hygiene.

As soon as food enters the mouth, saliva's enzymes start to break it down into its simpler components, while also providing lubrication to enable even the driest snack to slide easily down the throat. Saliva is also important in oral health, as it helps to protect teeth from decay and also controls bacterial levels in the mouth to reduce the risk of infection. Without sufficient saliva, tongue and lip movements are not as smooth, which, in extreme cases, can make it very difficult to speak.

With advanced scientific techniques and research, an individual's saliva can reveal a great deal of information. New studies have shown that a saliva test can be used to find out whether a person is at risk of a heart attack, as it contains C-reactive protein (CRP). This can be an indicator of heart disease when found at elevated levels in the blood. A saliva test is much less intrusive than a blood test and gives doctors a rough estimate of the health of a patient's heart. What's more, saliva contains your entire genetic blueprint. Even tiny amounts, equivalent to less than half a teardrop, can provide a workable DNA sample that can be frozen and thawed multiple times without breaking down.



Digestive enzymes
The digestion process begins in the mouth, as saliva contains enzymes that start to break down starches and fats.

Parotid duct
The parotid duct allows saliva to move easily from the parotid gland to the mouth.

Parotid gland
The parotid glands are the largest salivary glands. They are made up of serous cells which produce thin, watery saliva.

Sublingual gland
Composed primarily of mucous cells, these glands secrete only a small amount of saliva, accounting for about five per cent.

Submandibular gland
These glands produce roughly 70 per cent of your saliva. They are composed of both serous and mucous cells.

Submandibular duct
Also known as the Wharton duct, this drains saliva from both the submandibular and sublingual glands.

Saliva can actually help wounds to heal

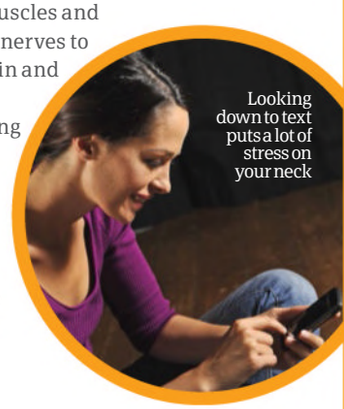
Can saliva speed up healing?

Many animals do it instinctively, but it turns out that there is a benefit to humans licking their wounds. A study found that there is a compound in human saliva, namely histatin, which can speed up the healing process. Scientists conducted an experiment using epithelial cells from a volunteer's inner cheek, creating a wound in the cells so that the healing process could be monitored. They created two dishes of cells, one that was treated with saliva and one that was left open. The scientists were astounded when after 16 hours the saliva-treated wound was almost completely closed, yet the untreated wound was still open. This demonstrated that saliva does aid the healing of at least oral wounds, something that has been suspected but unproven until this study.

Could you have 'text neck' syndrome?

How staring at a smartphone can affect your spine

Whether you're trying to get to the next level of Angry Birds, or having an emoji-filled text conversation with your friends, looking at your smartphone for long periods of time could be doing serious damage to your neck. As we tend to hold our phones at chest or waist height, we tilt our heads forward to be able to see the screen. This isn't so bad if you're just checking the occasional message or weather update, but with smartphone users spending an estimated two to four hours a day looking down at their phones – equivalent to one or two months a year – the problem gets much worse. The average human head weighs around 5.4 kilograms (12 pounds), but when it is angled downwards, the effective weight applied to your spine increases. This can put an enormous amount of stress on your neck, shortening and tightening the muscles and compressing the nerves to cause intense pain and spasms. Doctors recommend taking regular texting breaks and doing neck stretches, or even switching to making phone calls instead.



Looking down to text puts a lot of stress on your neck

Pain in the neck

How the weight on your spine changes as you tilt your head

> "Doctors recommend taking regular texting breaks and doing neck stretches"

Tilt angle	0 degrees	15 degrees	30 degrees	45 degrees	60 degrees
Weight applied to spine	5.4kg (12lb)	12.2kg (27lb)	18.1kg (40lb)	22.2kg (49lb)	27.2kg (60lb)

How does sticky tape work?

Discover the hidden forces that make gift-wrapping a possibility

The adhesive on sticky tape is a viscoelastic material, meaning that it behaves both like a solid and a liquid. When you apply pressure to it, it flows like a liquid, finding its way into any tiny gaps in the surface it is being stuck to. Then, when you leave it alone, it turns back into a solid, allowing it to lock into those gaps like a piece of a jigsaw puzzle to hold itself in place. However, before you even apply any pressure, another force has already got to work. The molecules of the adhesive are dipoles, meaning they have one positively charged side and one negatively charged side. This makes the molecules act like tiny magnets, creating an electrostatic attraction when they come into contact with another surface. These weak sticking bonds are known as van der Waals forces, which are also used by geckos to stick to walls. When you peel off the tape, this bond is broken, but will continue to work again and again until the adhesive surface gets too clogged up with dust and dirt.

A scanning electron micrograph of the adhesive side of sticky tape

What is cellulite?

Learn why 98 per cent of all cellulite occurrences are in women

Although it has physically existed for a while, the term cellulite was largely unheard of before the 1960s. Also known as gynoid lipodystrophy by scientists, cellulite has undergone extensive research, with the aim of finding out what causes these unsightly bumps to form on our skin.

Two types of cellulite have been identified. Primary cellulite has no causal factors and forms naturally when enlarged fat cells push into the outer skin layer, causing an uneven 'dimpled' surface to form. Secondary cellulite forms either when the skin is damaged by infections or by extensive and rapid weight loss, which can leave the skin loose, as it contracts very slowly.

Men are just as capable of going through these processes as women, which begs the question of why cellulite formation in women is so much more common. To find the answer, scientists had to look more closely at how the formation of fat tissue and skin structure differed between the sexes. They found that men's fat tissues are entangled in one singular mass, allowing them to grow outward evenly. Meanwhile, women's fat tissues are constructed in a side-by-side formation, which means that when the fat content grows, they have no option but to push upward, before pressing against the skin and forming cellulite.

There is also a hormonal difference between the sexes that contributes to this. Oestrogen could be a factor in cellulite formation, as it interacts with fat and skin. After puberty, this hormone makes the female body store surplus fat to help prepare it for pregnancy. Oestrogen also helps explain why cellulite levels differ between women and between the sexes, as some women have more oestrogen than others, while men have very little oestrogen at all.

Cellulite treatments

A number of possible treatments have been trialled to help both men and women rid themselves of cellulite. A procedure using lasers has been performed with good results. This actually requires minor surgery, with a laser fitted to the end of a cannula (a very fine metal tube) inserted under the skin. The laser can then be used to divide the fibrous bands that hold the fat cells together, helping to reduce the 'orange peel' appearance and smooth out the skin. The laser can also stimulate the production of collagen, helping to keep the skin tight.

Laser treatments aim to be a more permanent solution to cellulite, unlike some of the other treatments available. These include ultrasound therapy, which claims to melt away fat and even out cellulite. Unfortunately, this treatment's results only lasts for a few months. Topical caffeine treatments have been proposed, which aim to decrease fat levels by speeding up metabolism, but these methods have been met with mixed reviews.

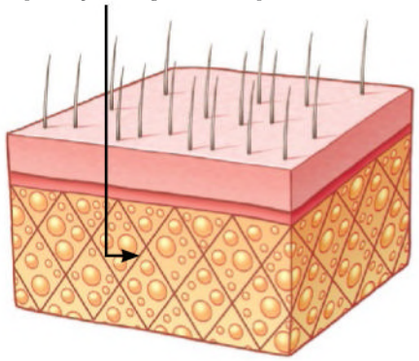
Laser treatment of cellulite has yielded promising results

Under the skin

See the differences between men and women's fat cells

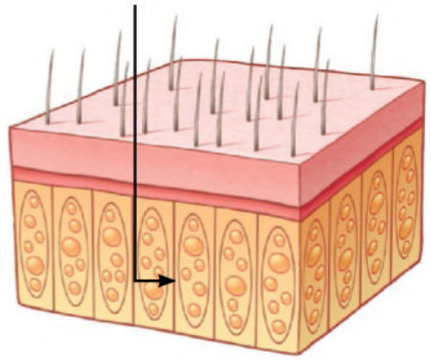
Crisscross collagen

Within a male, the skin's collagen holds fat cells in place by forming a crisscross pattern.



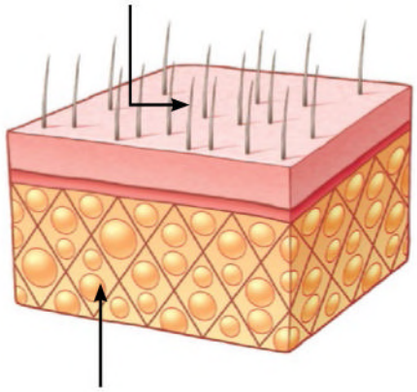
Collagen bands

Within a female, the skin's collagen forms a circular structure around the fat cells.



No visible cellulite

In spite of the enlarged fat cells, the male's skin surface shows little or no sign of any cellulite.

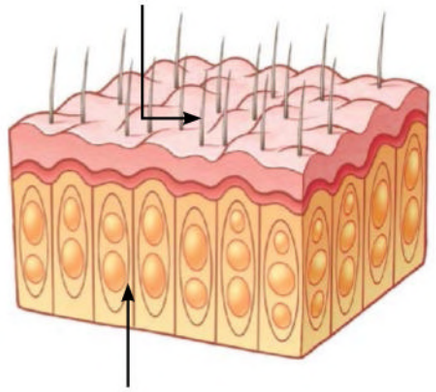


Male cell enlargement

When males put on weight, the fat cell collagen chambers stretch evenly due to their structure, resulting in no change to the skin's surface.

Irregular skin surface

Cellulite has formed due to the enlarged fat cells stretching the collagen chambers out toward the surface.



Female cell enlargement

When females put on weight, the fat cells cause the collagen chambers to push up into the skin, causing cellulite to form.

What causes a dry cough?

Find out what triggers a dry cough and how it helps to keep your airways clear

Coughing is an automatic defence reflex that helps to keep your airways and lungs clear. There are two different types; a productive wet cough, which produces mucus or phlegm, and a dry cough, considered nonproductive.

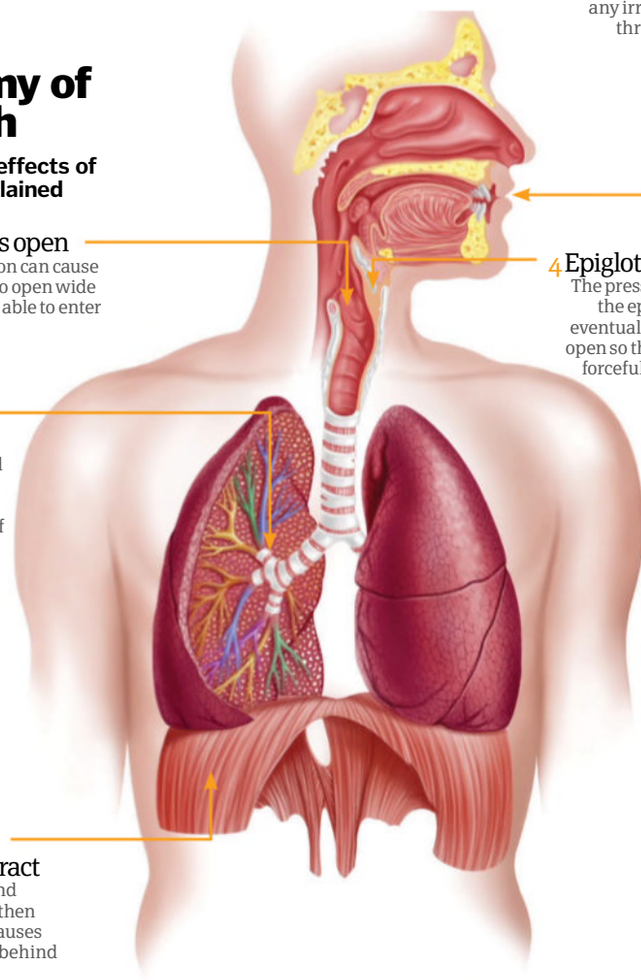
A dry or tickly cough can erupt from the chest for a number of reasons. It occurs when the throat and upper airways become inflamed, most commonly the result of an infection such as cold or flu, but it can also be triggered by irritants (such as dust, pollen or pet hair) or pollutants in the air. The body assumes this inflammation is a foreign object partially blocking the airway and initiates the cough reflex in order to remove it.

The vocal chords within the trachea open wide to allow more air into the lungs. The epiglottis at the top of the throat will then close off the windpipe while the abdominal and rib muscles contract. This increases the pressure behind the epiglottis, which opens to expel the air at up to 160 kilometres (100 miles) per hour.

> "A dry or tickly cough can erupt from the chest for a number of reasons"

Anatomy of a cough

The physical effects of coughing explained



1 Vocal chords open
A tickling sensation can cause the vocal chords to open wide so that more air is able to enter the lungs.

2 The lungs expand
The lungs expand with extra air as the epiglottis closes at the top of the throat.

3 Abdominal muscles contract
The abdominal and rib-cage muscles then contract, which causes pressure to build behind the epiglottis.

4 Epiglottis opens
The pressure behind the epiglottis will eventually cause it to open so the air can be forcefully expelled.

5 Dry coughing
The air will push out of the lungs at up to 160km/h (100mph) in an effort to dislodge any irritants in the throat or lungs.

How does laser hair removal work?

Does this technique really banish unwanted hair for good?

Laser hair removal isn't cheap; a single treatment of a large area can cost in the region of £640 ($1,000)

Laser hair removal works by firing a specific concentrated light beam at the undesired hair, with a wavelength that targets melanin responsible for hair colour and the hair bulb, where living cells divide to build the hair shaft. The laser uses your hair to absorb heat, which causes inflammation to form around the follicle, effectively killing it. As the hairs are not targeted individually, the process is much quicker to carry out than electrolysis, but may cause damage to the skin if it is not carried out correctly. If you are relatively pale with dark hair this treatment should work very well, however, its limitations lie with people that do not have contrasting hair and skin colours. This means that less of the laser beam is absorbed into the hair, making the treatment much less effective. Even when this technique works it is rarely permanent; patients need between one and four treatments a year to maintain it. This is because at any one time, a number of your hairs will be in the resting phase of growth, meaning that they won't be affected by the laser treatment and will grow back again.

What is the Large Hadron Collider?

The upgrades and discoveries of the most powerful particle smasher on the planet

The world's most powerful particle accelerator is back, and it's better than ever. After being shut for two years of planned repairs and maintenance, the Large Hadron Collider (LHC) is smashing particles together at a record-breaking 13 tera-electronvolts, almost double the energy it was using in 2013.

Researchers at CERN hope this vastly improved energy output will allow more intricate studies of the Higgs boson – a particle that could explain why matter has mass – which was famously discovered in 2012. The increased energy should mean that Higgs boson particles are generated more frequently (it should be able to generate ten times as many as during the LHC's first run), helping researchers measure them more accurately and probe their rare decays. Furthermore, researchers hope that a more powerful LHC will be able to safely conduct more extreme experiments, which scientists believe will better simulate the conditions of the early universe.

In July 2015, the LHC's latest discovery was made: the pentaquark. This not only represented a brand new particle, but also gave researchers a way to group together quarks (the constituent particles of protons and neutrons) in a brand new pattern. This in turn could help us understand how these subatomic particles are formed.

Physicists have also set their sights on finding dark matter, which is known to make up around 85 per cent of all matter in the universe, but whose nature is unknown. The only reason we know it exists is due to its gravitational effects, holding the universe together. Scientists have theories about the characteristics of the particles required for dark matter, but it may be that they uncover something else entirely. This is what makes the LHC experiments so exciting; no one really knows what it will find between now and 2018, when the next set of upgrades have been scheduled to occur.

"This vastly improved energy output will allow more intricate studies of the Higgs boson"

Higher energy beams
One of the most significant improvements is the energy of collisions, which will now be 13 tera-electronvolts compared to eight tera-electronvolts in 2012.

Thinner beams
As beam widths decrease with increasing energy, the LHC's beams will now be more tightly focused to allow more collisions and interactions during experiments.

There are several possible layouts of the quarks inside a pentaquark; further research is needed to determine their exact structure

What is anxiety?

How our brains trigger a fight or flight response

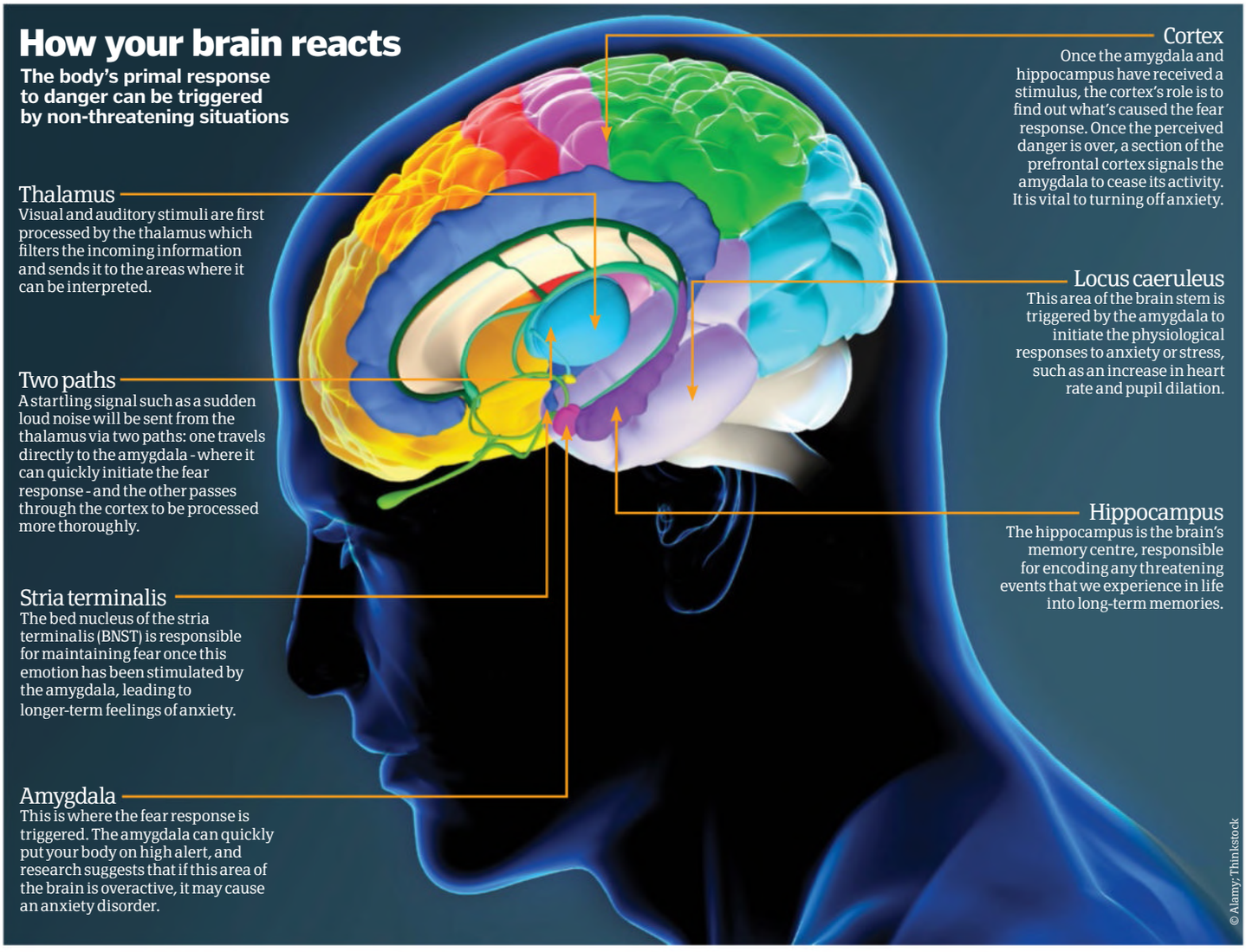
Anxiety affects a huge number of people and can be so severe that it stops many sufferers from leaving their homes or doing their jobs. In the US, over 40 million people aged 18 or over endure an anxiety related disorder, while in the UK one in 20 people are affected. Some researchers believe that modern day technology has influenced the rise of anxiety related conditions; we are constantly on high alert with texts, emails, social media and news updates.

Anxiety is a natural human response that serves a purpose. From a biological point of view, it functions to create a heightened sense of awareness, preparing us for potential threats. In a way, it's nature's panic button.

When we become anxious our fight or flight response is triggered, causing our bodies to flood with epinephrine (adrenaline), norepinephrine (noradrenaline) and cortisol, which help increase your reflexes and reaction speed. Your body prepares itself to deal with danger by increasing the heart rate, pumping more blood to the muscles and by getting the lungs to hyperventilate.

At the same time, the brain stops thinking about pleasurable things, making sure that all of its focus is on identifying potential threats. In extreme cases, the body will respond to anxiety by emptying the digestive tract by any means necessary, as this ensures that no energy is wasted on digestion.

Some people who suffer anxiety find it hard to leave the house



How do Bunsen burners work?

Find out how its flame reaches temperatures of up to 1,200°C

Bunsen burners are typically fuelled with natural gas, which is almost pure methane, CH_4

Robert Bunsen invented the Bunsen burner in the mid-19th century as a means to an end. The German chemist's work focused on emission spectra, which is the bright light produced by different elements when they are heated in a flame. To carry out this experiment he required a hot, clean flame, which gave him the idea for the Bunsen burner. A modern Bunsen burner consists of a straight metal tube, measuring about 13 centimetres (five inches) long, attached to a base stand. A thin rubber tube known as a gas hose connects to the bottom and supplies gas to the Bunsen. The metal collar works to adjust the amount of air that enters the tube by altering the size of the air hole at the base. By allowing air and therefore oxygen to mix with the gas, a hotter and more complete reaction occurs, causing a very hot, blue flame to be produced. The Bunsen still has an abundance of laboratory applications today, including sterilisation and fixing cells to microscope slides.

Why does foam form?

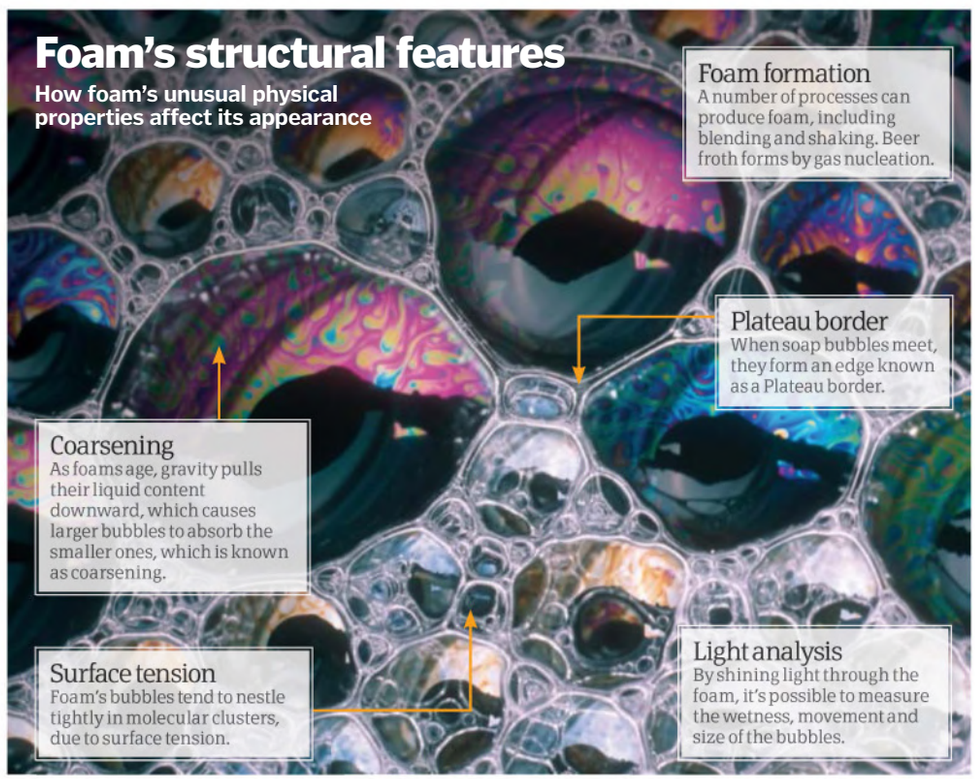
Popping the mystery behind this strange substance

Foams are made up of thousands of tiny bubbles and have a wider range of applications than you would expect. They are used to fight fire, separate ores and manufacture vehicles; one type has even been used to neutralise anthrax.

Upon handling foam, its physical state is somewhat unclear. Although it has qualities of all three states of matter, typical liquid foam is 95 per cent gas and five per cent liquid. Foams contain a surfactant, which prevents the bubbles from immediately popping by keeping them separate and repelling water.

Foam is far more rigid than you would expect, which is due to something known as jamming. This phenomenon occurs because the foam bubbles are incredibly tightly packed, meaning the bubbles can't move around each other when they are compressed. The pressure within the bubbles will continue to increase as they are further compressed, making the foam appear even more solid.

A study into foam optics and mechanics was conducted on the International Space Station between 2009 and 2010 in order to look at foam stability and foam coarsening, along with how microgravity affects a liquid's 'foamability'.



How do suntans develop?

Find out how our skin reacts to being exposed to the Sun

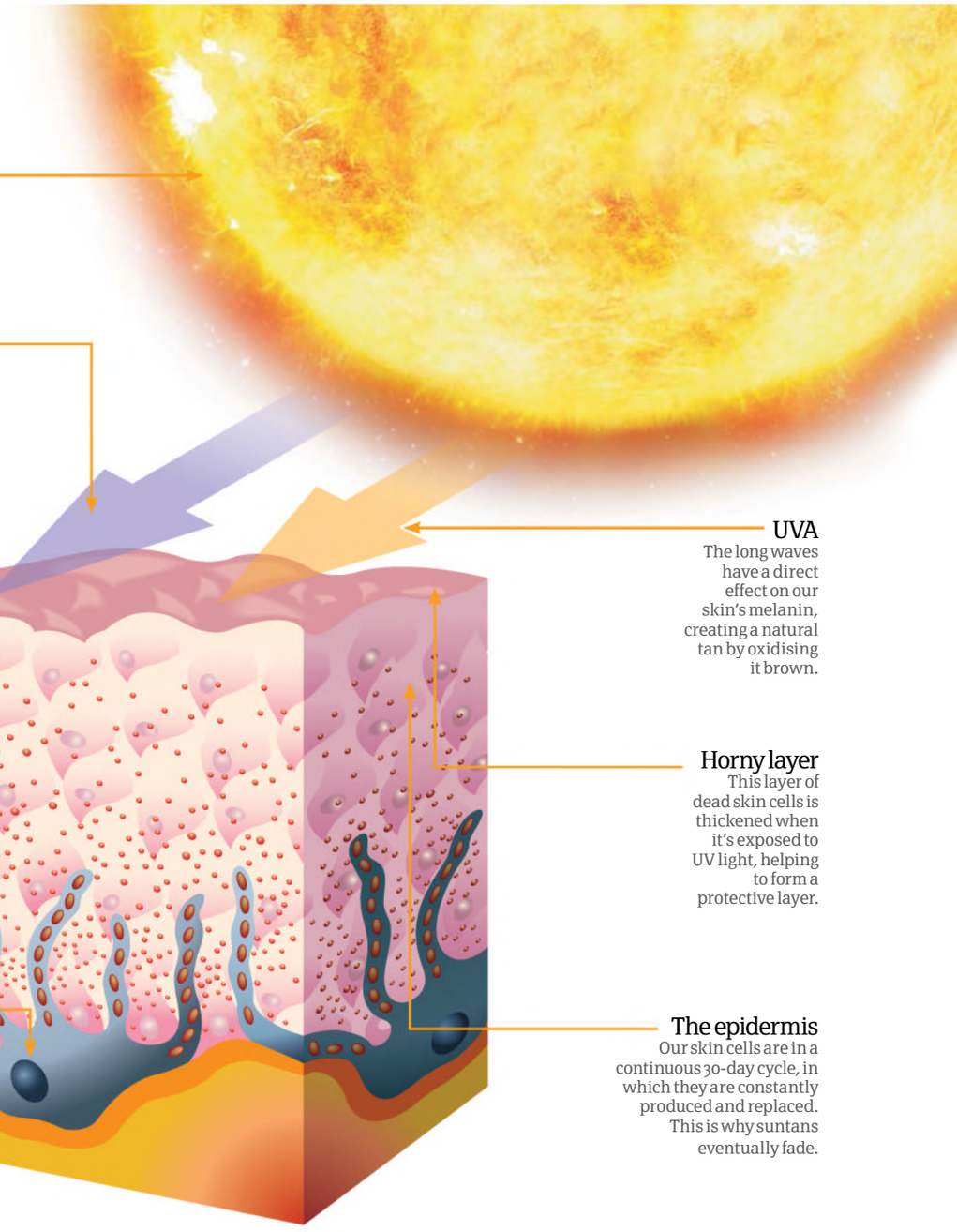
Medical professionals continue to warn us about the dangers of exposing our skin to too much sunlight. In spite of this, many of us still spend too long sunbathing in the hope of achieving the even bronzing that so many celebrities flaunt.

When we expose our skin to strong sunlight or a sunbed, the UV radiation we absorb prompts melanocytes in our skin to react by producing more melanin pigment. Melanin is the pigment responsible for our skin's colour and it protects the cells by absorbing UV radiation that would otherwise damage skin cells. People with naturally darker skin have more melanin and so are inherently better protected against sunlight. Nevertheless, excessive UV exposure damages melanoyctes' DNA, which can lead to a deadly form of skin cancer known as melanoma.

Recent science suggests the process of tanning has addictive qualities. An experiment using mice showed that as well as producing melanin, UV radiation produced pleasure chemicals called endorphins, which are also produced after a person ingests addictive drugs.

The tanning process

Learn the locations of important structures within the skin that play a role in creating a tan



The Sun
The Sun produces UVA, UVB and UVC light, but the UVC is mostly blocked out by the Earth's atmosphere.

UVB
These short waves cause the melanocytes to initiate the production of melanin. UVB also promotes the synthesis of vitamin D.

UVA
The long waves have a direct effect on our skin's melanin, creating a natural tan by oxidising it brown.

Melanin
This pigment browns when it absorbs UVA light. It also increases in size and then surrounds each skin cell.

Horny layer
This layer of dead skin cells is thickened when it's exposed to UV light, helping to form a protective layer.

Melanosomes
These are produced within the melanocytes and contain the enzyme tyrosinase, which synthesises melanin.

Melanocytes
These are specialised skin cells. They are responsible for the production of melanosomes and can send them to the surrounding skin cells.

The epidermis
Our skin cells are in a continuous 30-day cycle, in which they are constantly produced and replaced. This is why suntans eventually fade.

Why do we get cravings?

Is a child destined to develop a taste for all things sweet?

Hunger and cravings are two very different things. While one is about survival, the other satisfies the nagging need for something sugar-filled.

It's believed we all develop a taste for sweetness in infancy, which is said to stem from the predominant sweet taste of our mother's milk; when we taste it, the brain's reward centres light up, causing us to derive pleasure from this experience. As we continue to consume our mother's milk this pleasure is reinforced, which could explain how our sugar cravings originate. What's more, our mothers' diet can influence our preferences for certain foods. Scientists have found that flavours are transmitted from mother to baby via the amniotic fluid surrounding the foetus in the womb. Once born, the probability of the child disliking the flavours they have already experienced is reduced.

Our gut also plays a large role in cravings. The gut contains an almost separate autonomous system that governs the digestion lining. This vast network of 100 million neurones constantly samples the ingested food, relaying this information to the brain. This endless conversation can cause our appetite and cravings to change. The gut bacteria are also heavily involved; when they break down large quantities of fibre, they produce a specific compound that is sent to the brain, triggering it to feel full and satisfied from the recently ingested meal.

So should we consider cravings as a sign of food addiction? Although high-sugar and high-fat foods exhibit some of the hallmarks of addiction, the consensus is that it's actually the behaviour around eating these foods that we are addicted to.

People commonly crave the sweet taste and melt-in-the-mouth texture of chocolate

Can the latest technology stop cravings?

There's a microchip that aims to control cravings, developed by Kings College London's Centre for Bio-Inspired Technology. Once implanted in the body, the chip will use electrodes to monitor the signals passing between the gut and the brain. By 'listening' to the communication between the two organs, the microchip will be able to recognise signals for cravings and alter these before they reach the brain. Ghrelin is the body's hunger-inducing hormone. By using a ghrelin antagonist, scientists aim to suppress this hormone's activity, stopping cravings from ever materialising. This research has implications for the cravings of other substances too. Scientists have hypothesised that due to the similarities between this system and the system responsible for craving nicotine and alcohol, it may be possible to switch off these cravings as well as those related to food.

Tricking our senses

Does a spoon's colour change the way yoghurt tastes? In reality it doesn't, but the colour of cutlery can alter how you think something tastes. A recent study fed a group of volunteers the same yoghurt using a white and a black spoon. The results showed that the yoghurt was perceived to taste sweeter on the white spoon. Altering the spoon's weight was then tested. The lighter spoons caused the participants to feel the yoghurt was denser and more luxurious. Scientists are unsure what mechanism causes these bizarre results, and want to carry out further research into why we make these associations.

How do fireworks make shapes?

The chemistry behind the spectacular patterns in the sky

Modern fireworks can burst into hearts, smiley faces and even a representation of the planet Saturn. The shape comes down to the construction of the firework's shell (container) and the arrangement of the exploding stars (pyrotechnic pellets) within them. As aerial shells are often spherical, they tend to explode symmetrically. Arranging the stars into the desired shape on a piece of card within the shell makes them explode outwards in that pattern.

Manufacturers also use multi-break shells that have different compartments inside them, often with stars of various colours and compositions. When these are placed and fused in a specific order, they will explode in sequence to create recognisable patterns and shapes in the sky. However, it's not an exact science; many displays will fire several copies of the same firework at the same time so that at least one of them creates the desired shape in the audience's line of sight.

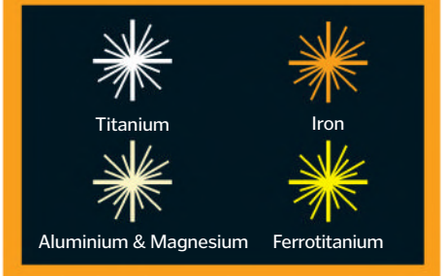
The first shaped fireworks appeared in the early 1990s to welcome returning American troops

Sparkler science

The chemical composition of sparklers consists of three important components: an oxidiser, a binder and a metal fuel. These three substances are bound together in a paste, which is then coated onto the iron wire that forms the sparkler's main body.

A powdered metal is essential, as it helps produce sparks that generate the famous glittery effect and can also colour the sparkler. Aluminium, titanium and magnesium all produce bright, white sparks, whereas iron will burn with a characteristic orange hue. When iron and titanium are combined they form an alloy called ferrotitanium, which produces golden yellow sparks when it burns.

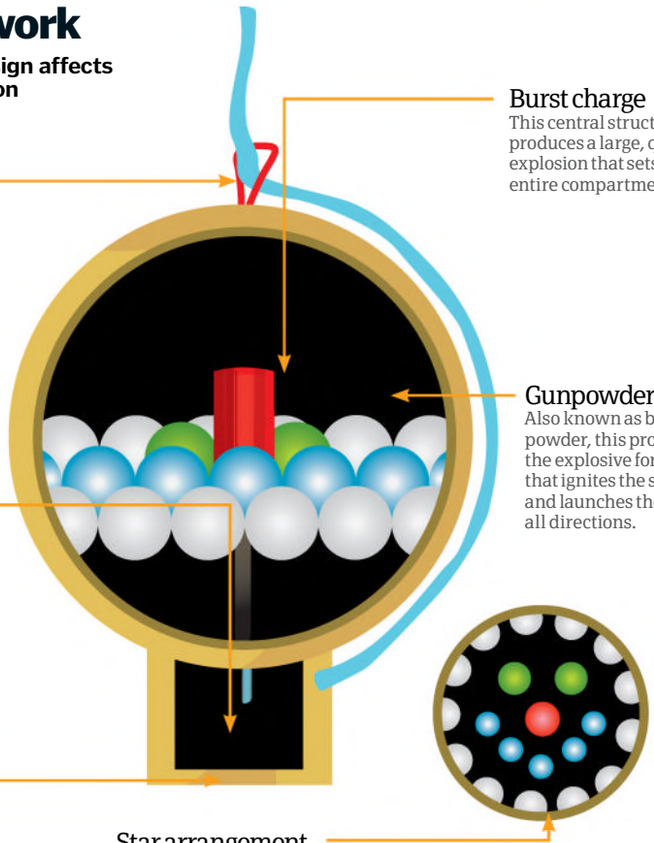
For even more colours, salts of various metals can be added to sparklers, which is often the technique used for creating coloured fireworks. Copper salts produce green-blue, barium salts create green and strontium salts produce red.



Powdered metals react with oxygen to produce metal oxides, which burn with specific colours

Inside a firework

See how the internal design affects the shape of the explosion



Burst charge
This central structure produces a large, quick explosion that sets the entire compartment off.

Fuse
This initial fuse ignites other, smaller fuses within the firework. In public displays, these are lit by electrical contacts called wirebridge fuseheads.

Gunpowder
Also known as black powder, this provides the explosive force that ignites the stars and launches them in all directions.

Timed fuse
This section ignites the burst charge once the firework has reached the appropriate altitude.

Lifting charge
The initial explosion sends the shell soaring into the air without detonating the main compartment.

Star arrangement
Different chemicals are added to create a range of colours, while the shape is determined by the arrangement of small, combustible pellets.

What is keratin?

The secret behind some of nature's toughest materials

Keratin is a protein found in humans and animals alike. There are two main types and each has a slightly different structure. Alpha keratin, which is the main structural component of hair, skin, nails, hooves and the wool of animals has a coiled shape, whereas the tougher beta keratin, found in bird beaks and reptile scales, consists of parallel sheets. Both are composed of amino acids – the building blocks of all proteins that make up a large proportion of our cells, muscles and other tissues.

The flexibility of the keratin depends on the proportion of different amino acids present. One particular amino acid, called cysteine, is responsible for forming disulphide bridges that bond the keratin together and give it its strength. The more cysteine the keratin contains, the stronger the bonds will be, so more can be found in rigid nails and hooves than in soft, flexible hair. Incidentally, it's the sulphur within cysteine that creates the strong odour of burning hair and nails.

Curly hair has more bonds between amino acids in the protein chain that makes up keratin

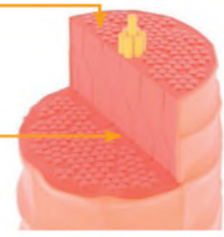
Alpha keratin

How this protein makes up your hair

Alpha helix
Keratin is made of coils of amino acids held together by peptide bonds to form polypeptide chains.

Protofibril
Three alpha helices twist together to form a protofibril, the first step towards creating a hair fibre.

Microfibril
An 11-stranded cable is formed by nine protofibril joining together in a circle around two more protofibril strands.



Macrofibril
Hundreds of microfibrils bundle together in an irregular structure to create a macrofibril.

Hair cell
These macrofibrils join together within hair cells, making up the main body of the hair fibre called the cortex.

What's inside dust?

From skin cells to space rocks, there's a long list of particles lying around your home

It's a myth that dust in our homes is only made up of dead skin. In fact, it contains an average of 9,000 different species of microbes, alongside a powdery potion of animal hairs, pollen, decomposing insects, fabric fibres and much more. The majority actually comes from outside, having been blown in through windows and doors or carried in on your clothes or shoes. The rest comes directly from the people, animals or objects inside the house.

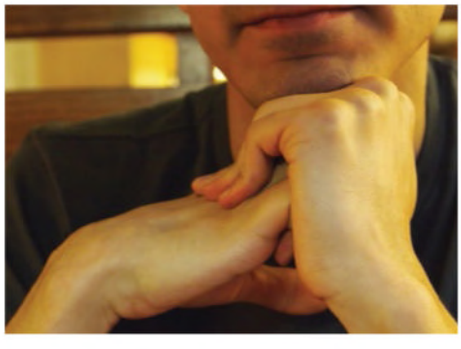
Thousands of different species of bacteria and fungi are commonly found in dust, as well as tiny creatures called dust mites, which produce allergens. However, among all of these disgusting things, you might also find something to treasure. Dust has been found to contain tiny particles of space dust called micrometeorites, which were once part of comets and asteroids, and you should be able to pick them out using a very strong magnet.

A coloured scanning electron micrograph of household dust containing pet hair, insect remains and pollen

Household dust is mostly harmless and 80 per cent of it can be removed by cleaning regularly

Why are bicycles much more stable when moving?

There is no definitive explanation behind a moving bike's uncanny ability to stay upright. Experts agree that it is linked to bikes' ability to steer into a fall and right themselves, with even riderless bikes able to recover from a sideways push. For a long time, it was believed that the wheels created stability through the gyroscopic effect: the tendency for a spinning object to resist movement in certain directions. A second idea was that the direction of travel aligns the bikes wheels a bit like when pushing a shopping cart. Researchers, however, disproved these theories in 2011 by building a bike which negated both effects. A pair of counter-rotating wheels cancelled out the gyroscopic effect and the steering axis lay behind the front wheels, yet the moving bike was still stable. The research team concluded that although both effects may have an impact, neither were vital to a bike's stability.



What makes my joints crack so often?

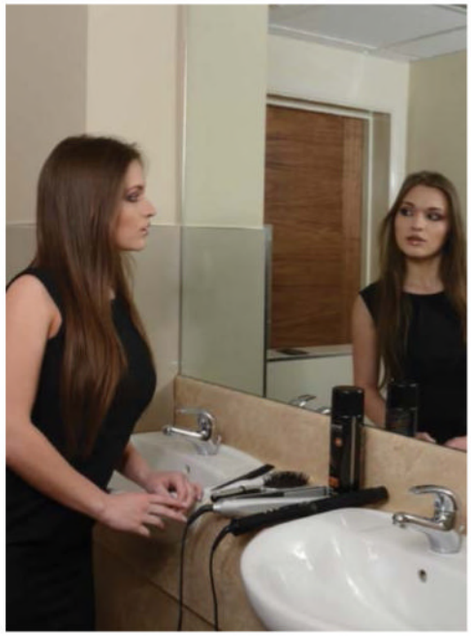
There are a few different reasons why your joints may crack. Joints are lubricated by a fluid called synovial fluid, which contains gases like carbon dioxide, nitrogen and oxygen. When you move the joint, gas bubbles are quickly released and make a popping sound. Popping noises may also come from tendons and ligaments moving or tightening as the joint moves. Sometimes joints crack more often after surgery or if you have arthritis, which can cause rough joint surfaces and worn cartilage. Despite what you may have heard, cracking joints don't indicate a problem unless they're also accompanied by pain, swelling, or loss of function or motion. Purposely cracking your knuckles, however, may lead to swollen joints and a weaker grip.

Are we able to digest sweetcorn?

Although unchewed sweetcorn appears to be able to pass through the digestive system completely unchanged, it has actually been partly digested. The inside of the corn kernel is made up mostly of starch, and is easily digestible, but the outside is made from tough plant fibre called cellulose. Humans lack the digestive enzymes required to break down cellulose, so if you don't chew your sweetcorn properly it will pass through your digestive system whole. Digestive enzymes are able to diffuse across the membrane, breaking down some of the starch inside and releasing sugar molecules into the gut, but from the outside it looks almost exactly the same.

Why do we have blood types?

The short answer is that we still don't know. There an incredible 33 different blood-group systems in humans, but the most commonly talked about is the A, B, O system, which has four types. Depending on your genetics, your red blood cells are coated in A antigens, B antigens, both A and B antigens, or neither (in which case you are blood type O). We know these factors affect blood transfusion, but the real reason behind different blood types seems to be related to the spread of infection; for example, people with blood type O are more susceptible to bubonic plague, but are better protected against malaria.



Why do reflections appear reversed in the mirror?

Mirrors appear to reverse things from left to right because of our perceptions. Our bodies are roughly symmetrical, so the reflection of your left hand looks just like your right hand. For this reason, we tend to assume that mirrors reverse left and right. But if you hold up an asymmetric object in front of a mirror, for example a saucepan, left and right are not reversed. The right-hand side of the saucepan (for instance the handle) is still on the right, and the left-hand side is reflected on the left. Instead, a mirror inverts front and back.

How does acupuncture work?

Whether acupuncture really works is a matter still debated in medical and scientific communities. This is because designing medical trials to test acupuncture is challenging. A good trial would pit the treatment against a harmless placebo, and neither the patients nor the doctors would be aware of which they were receiving or administering. In the case of acupuncture, this is near impossible.

In order to get around this, the trials use 'sham acupuncture', either inserting the needles in nontraditional places, or pretending to insert them while in reality just holding the needles against the skin. In these tests, acupuncture was found to be more effective than the sham and the placebo for relieving pain associated with headaches, osteoarthritis, back and neck pain, but for other conditions such as rheumatoid arthritis, and shoulder pain, there was no convincing evidence that it works. One idea is that it might stimulate the production of endorphins, the body's natural painkillers.

What causes indigestion?

Indigestion (also known as dyspepsia) is a pain in your stomach after eating. It's caused by the acid in your stomach coming into contact with the lining of the digestive system (the mucosa). This lining is sensitive and can be irritated by the harsh acid, which breaks it down and can also cause it to swell, leading to the discomfort you feel.

Indigestion is most often triggered by eating, but can also be caused by smoking, drinking, stress or certain medications. It is often treated with antacids, which neutralise the acid made by your stomach and helps relieve the pain.

Why do voices change during puberty?

We speak by pushing air through two elastic vocal cords attached to cartilage in a structure known as the larynx, or voice box. The tissue in the voice box responds to the male sex hormone testosterone, so when levels rise during puberty it triggers thickening and growth. Just like the thicker strings on a guitar make a lower sound when they vibrate, the thickening of the vocal cords can alter the pitch of a boy's voice by up to an octave.

What is the difference between heat and temperature?

Heat (measured in joules) is the amount of thermal energy (molecular movement) something has and it can vary depending on the mass of the object; if the object has a large mass, its thermal energy will also be large as it has a lot of molecules, while a smaller object will have less thermal energy as it has fewer molecules. Temperature, however, is a measure of the relative thermal energy of something; it's the degree of hotness or coldness, measuring the average kinetic energy in the molecules of an object.

Temperature is not dependent on the mass of an object, so objects of different sizes could have the same temperature, but they'd have different heats. For instance, a mug of tea may have the same temperature as a bath of hot water, but as the bath has more water, it takes more energy to get its molecules to that temperature, and therefore it has more heat.

Why does coffee make me dehydrated but tea doesn't?

Caffeine in general – whether it's in tea, coffee, or soda – is definitely dehydrating. However, when you consume these beverages you're also consuming water, which seems to ultimately counteract any dehydrating effect. Studies have given us conflicting information, though there appears to be a limit. According to the Mayo Clinic, if you consume more than 500 milligrams of caffeine per day on a regular basis, you could be at risk of dehydration. As long as you drink a variety of beverages and drink whenever you're thirsty, you shouldn't have a problem. Although it might seem that you have to urinate more frequently when you drink coffee, you'd probably have to go just as often if you were drinking an equivalent amount of plain water.

Why does your heart pump twice for every beat?

The human heart has four chambers; two atria at the top of the heart, which collect blood returning from the body and lungs, and two larger ventricles at the bottom, which pump blood back out again.

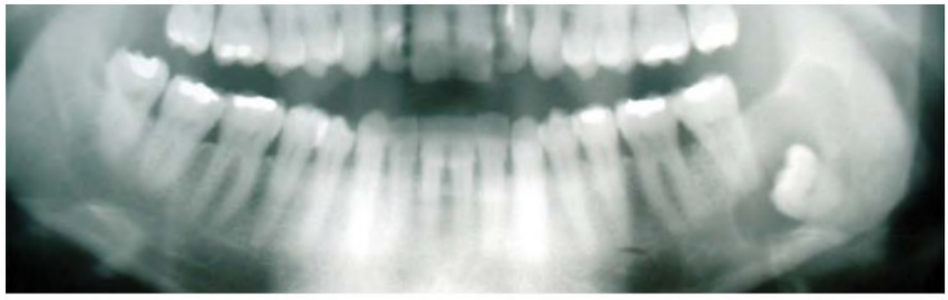
The heart has its own biological pacemaker, which triggers a rhythmic electrical wave that spreads across the muscle. It starts at the top and travels down the walls of the two atria, making them squeeze and transferring the blood into the ventricles. Valves then snap shut to prevent the blood moving back, making the 'lub' sound of the heartbeat.

The electrical impulse moves down to the bottom of the heart through specialist cells in the middle, and then comes up in a wave, making the ventricles contract and forcing blood towards the body and the lungs. Then a second set of valves snap close, making the 'dub' sound of the heartbeat.

Why do we need protein?

Proteins form the molecular machinery that makes the human body work, from the structure of our muscles, skin and bones, to the digestive enzymes that break down our food. They are made from long chains, folded into three-dimensional structures, and are constructed using around 20 different building blocks known as amino acids.

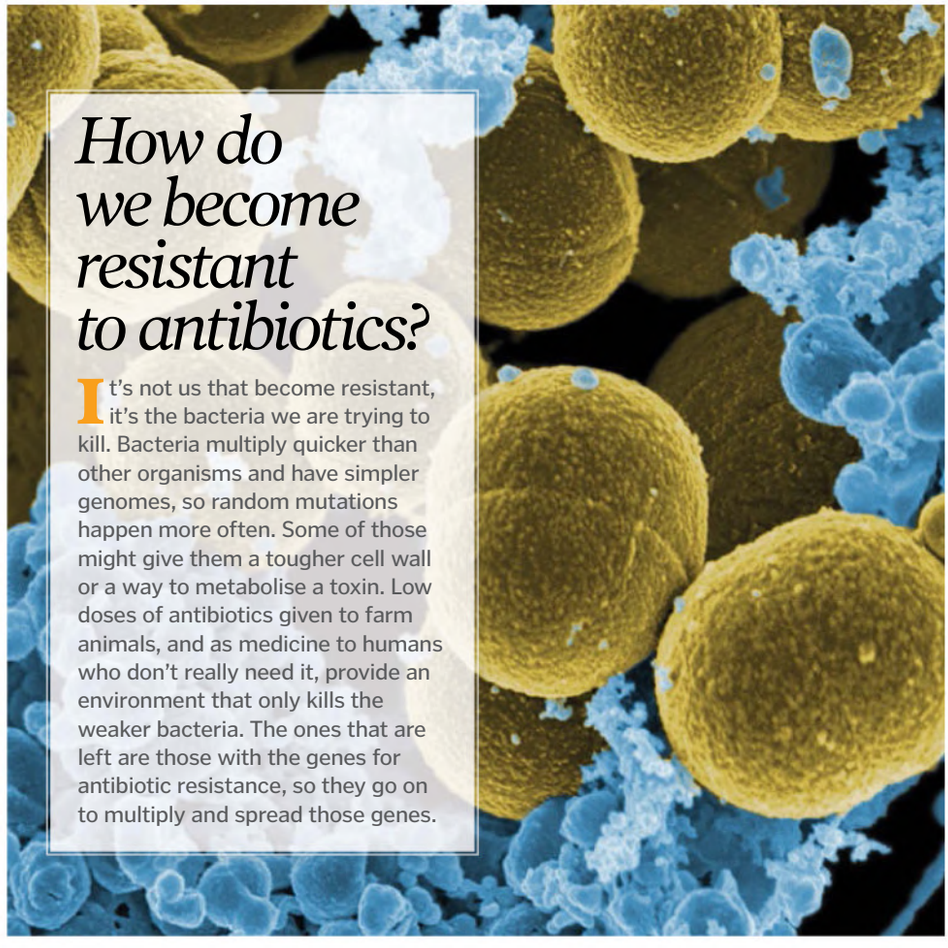
All living things use the same 20 or so amino acids, so we are able to use the proteins from plants and animals as a source for the building blocks we need to construct our own bodies. However, unlike fat and carbohydrate, the human body cannot store excess protein, so we need to eat it every day in order ensure a steady supply of the amino acids we need for growth and repair. The liver is able to convert some amino acids into others, but around eight of them are known as 'essential' and can only be obtained from our diets.



Why do some people have wisdom teeth?

If you trace human evolution right back to our early ape-like ancestors, you'll find that they had much larger heads and jaws than we do now. Their teeth would have been used for biting, crushing and grinding food well before we had developed the means to chop and cook it. As we evolved and our diets changed, our teeth were no longer our primary tool, and as our brains grew larger, our jaws became shorter.

Today, we no longer need our wisdom teeth, and for many people they are a problem. Our jaws are small, and wisdom teeth don't always have space to come through straight. They often need to be removed because they are causing pain, or damaging the surrounding teeth. Around 35 per cent of the population do not have any wisdom teeth at all, and there is some debate as to whether they will eventually disappear all together.



How do we become resistant to antibiotics?

It's not us that become resistant, it's the bacteria we are trying to kill. Bacteria multiply quicker than other organisms and have simpler genomes, so random mutations happen more often. Some of those might give them a tougher cell wall or a way to metabolise a toxin. Low doses of antibiotics given to farm animals, and as medicine to humans who don't really need it, provide an environment that only kills the weaker bacteria. The ones that are left are those with the genes for antibiotic resistance, so they go on to multiply and spread those genes.

Why are some people left-handed?

Around ten per cent of the general population is left handed, and according to archaeological evidence, this proportion has remained the same for around 5,000 years. A mathematical model developed by Northwestern University has a possible explanation.

Humans are a competitive species, and historically we fought hand-to-hand to settle disputes. In direct competition, left-handers have the advantage because their stance is unusual, and in one-on-one sports like fencing and baseball, there are many more left-handed athletes than you might expect.

If this were the only affecting factor, the numbers of left and right-handed people would eventually even out. However, even more important to humans than competition is co-operation. As a social species, one of our defining characteristics resides in the use of tools.

Left-handed people are at a disadvantage when using tools designed for right-handed people, and in golf, a sport where there is no direct competition and a heavy reliance of specialist tools, left-handers are under-represented. This balance between the advantage of novelty in competition and the disadvantage of difference in co-operation is thought to be the reason that some of the population is left-handed.

Space

What if two planets collided?

The Solar System may seem calm now, but long ago it was a chaotic and violent place…

The planets in our Solar System currently orbit the Sun in stable orbits, always far enough away from the other planets to avoid a collision. This isn't always the case, though. Planets can and do collide, usually either when they are very young or very old.

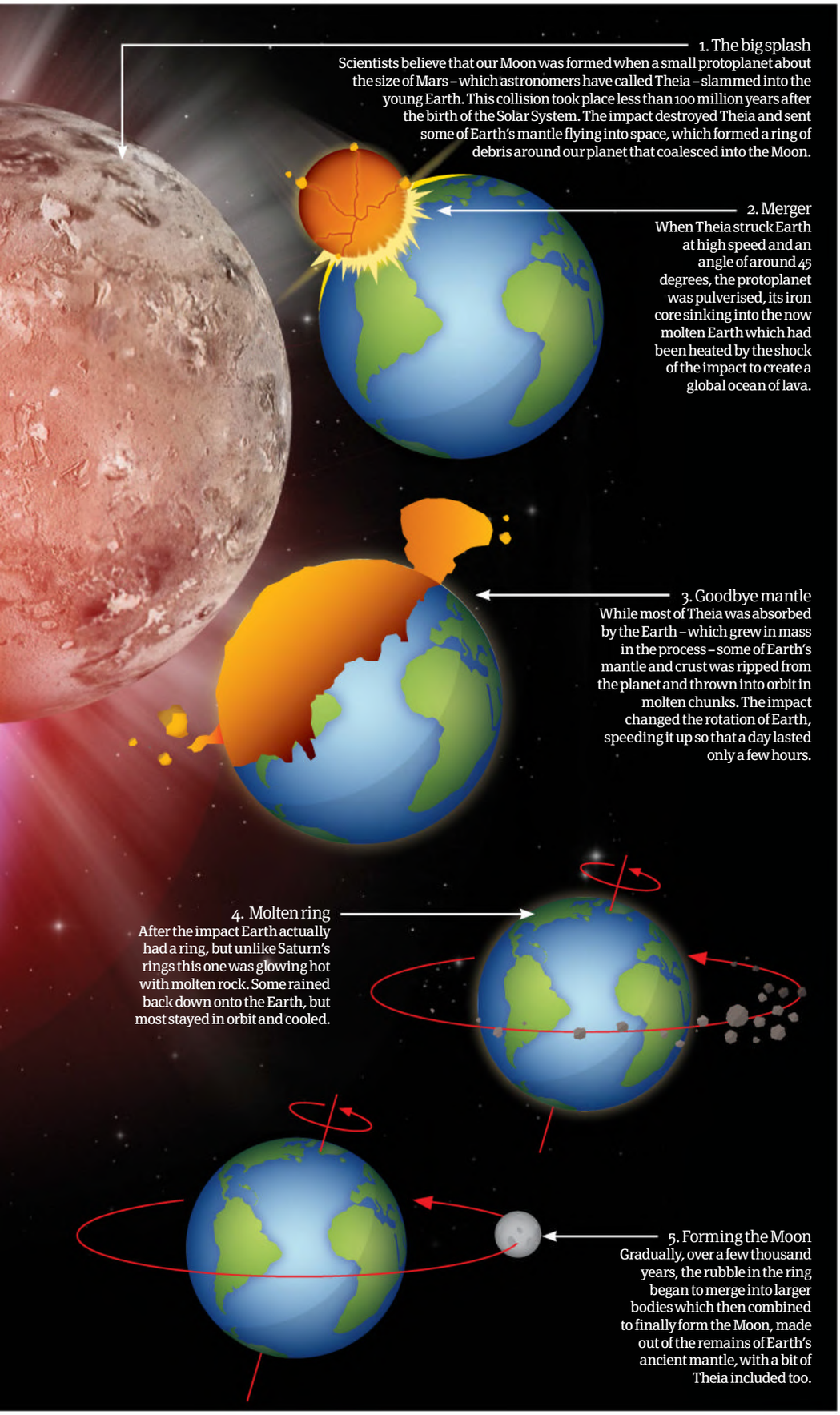
Planets are made through collisions: young stars are surrounded by discs of gas and dust particles that collide and stick together, going on to form progressively larger chunks. A young planetary system can have dozens of 'protoplanets' flying around on unstable orbits. These crash and smash into each other, the debris from the collisions coalescing into larger and larger bodies.

Earth is probably the result of many violent collisions, the last of which formed the Moon. Scientists using NASA's Spitzer Space Telescope have witnessed the dusty debris clouds that are the aftermath of such a collision around the star HD 172555, where two planets crashed at 36,000 kilometres (22,400 miles) per hour.

Some of the planets grow so large that they begin to siphon hydrogen away from the gaseous dust disc around their young parent star. Their accelerated growth soon sees them become gas giant planets, like Jupiter. However, as they steal gas from the disc around them, these planets lose angular momentum and begin to migrate inwards towards their star, steamrolling anything in their way. Smaller planets that are in the gas giant's path can be flung in all directions: some will collide with each other, or with their star, or be thrown out of their planetary system altogether.

Now, fast-forward billions of years to the death of these stars. Most will end their lives by becoming red giants, before casting off their outer layers in a planetary nebula, leaving behind a white dwarf. As the star swells into a red giant, it swallows the innermost planets, while those planets outside its grasp see their orbits widen due to the giant's lower mass. This can cause planets, comets and asteroids to collide. We see evidence for this in the form of the debris from these collisions contaminating the surface of the white dwarf.

Beyond the scale of solar systems, some truly cosmic collisions take place between entire galaxies. The Andromeda galaxy is currently heading straight for our Milky Way and is due to collide in about four billion years. It might sound like the plot of a science fiction blockbuster, but mergers such as these are common in the universe and are key to galaxy evolution.



> "Planets can and do collide, usually either when they are very young or very old"

The giant impact hypothesis

The main evidence for the theory that the Moon was formed by a giant impact comes from lunar rocks returned to Earth during the Apollo missions. These rocks contain ratios of oxygen isotopes (atoms of a given element that have a different number of neutrons) that are almost exactly the same as those found in Earth's mantle. This suggests that the Moon is made from material that came from our own planet's mantle. Material in those Moon rocks was also found to have once been molten long ago, and an impact would have provided the necessary energy to efficiently melt rock.

Although the impact theory is now widely accepted, a number of puzzling problems remain. For example, some believe there should be more evidence of debris material from Theia found in the Moon rocks. Also, the rocks contain so-called volatile elements (materials that evaporate easily in relatively low temperatures) such as water, which were embedded in the rocks when they formed, yet the heat of an impact should have evaporated them. However, these puzzles remain as details to be ironed out, rather than serious threats to the impact theory.

A 77g (2.7oz), golf-ball-sized piece of Moon rock that was collected by astronaut Dave Scott during the Apollo 15 mission

This is an artist's impression of the asteroid collision around the star NGC 2547-ID8, which released a huge cloud of dust

Asteroid collisions

Space rock smash-ups happen once per year in the asteroid belt

Forget the asteroid chase scene in *The Empire Strikes Back* – the asteroid belt is really quite empty – you could be standing on one asteroid and not be able to see another! Even so, that doesn't stop them from bumping into each other. And when they do, it can be dramatic.

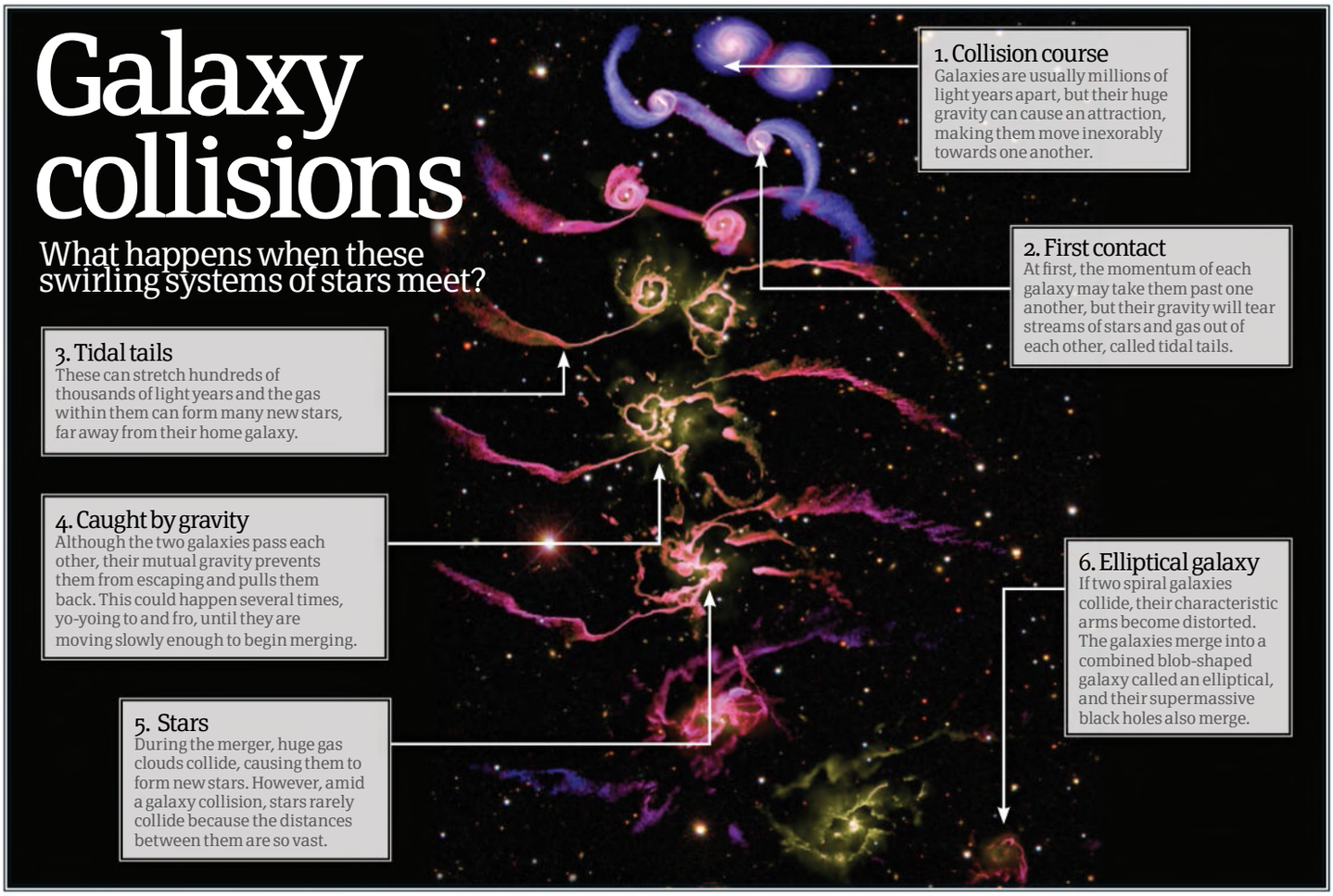
In 2010 the Hubble Space Telescope spotted something mysterious in the asteroid belt: a strange, X-shaped object with a long tail like a comet. The tail was asteroid dust, believed to be released when a 122-metre (400-foot) wide asteroid collided with a smaller asteroid, about 4.6 metres (15 feet) across, which struck it at a velocity of 17,700 kilometres (11,000 miles) per hour. Astronomers suspect impacts like this could happen between minor asteroidal bodies in the asteroid belt about once per year on average.

Some asteroids come in groups or families. The families are believed to be chunks of the largest member of the family, smashed off in an impact. For example, Vesta – one of the largest asteroids in the Solar System – has a family of smaller asteroids, while a rare type of meteorite found on Earth, called HED (howardite-eucrite-diogenite) meteorites, are believed to come from this family as well. Sometimes collisions can send asteroids larger than these small meteorites our way too, and when that happens they can endanger life on Earth.

Asteroid collisions happen around other stars, too. In 2012 a star called NGC 2547-ID8 suddenly found itself having much more dust around it than it used to have, released by a giant asteroid impact. Spitzer saw the infrared emission from this dust, which contains sand-sized grains that are grinding themselves down even smaller.

Galaxy collisions

What happens when these swirling systems of stars meet?



1. Collision course
Galaxies are usually millions of light years apart, but their huge gravity can cause an attraction, making them move inexorably towards one another.

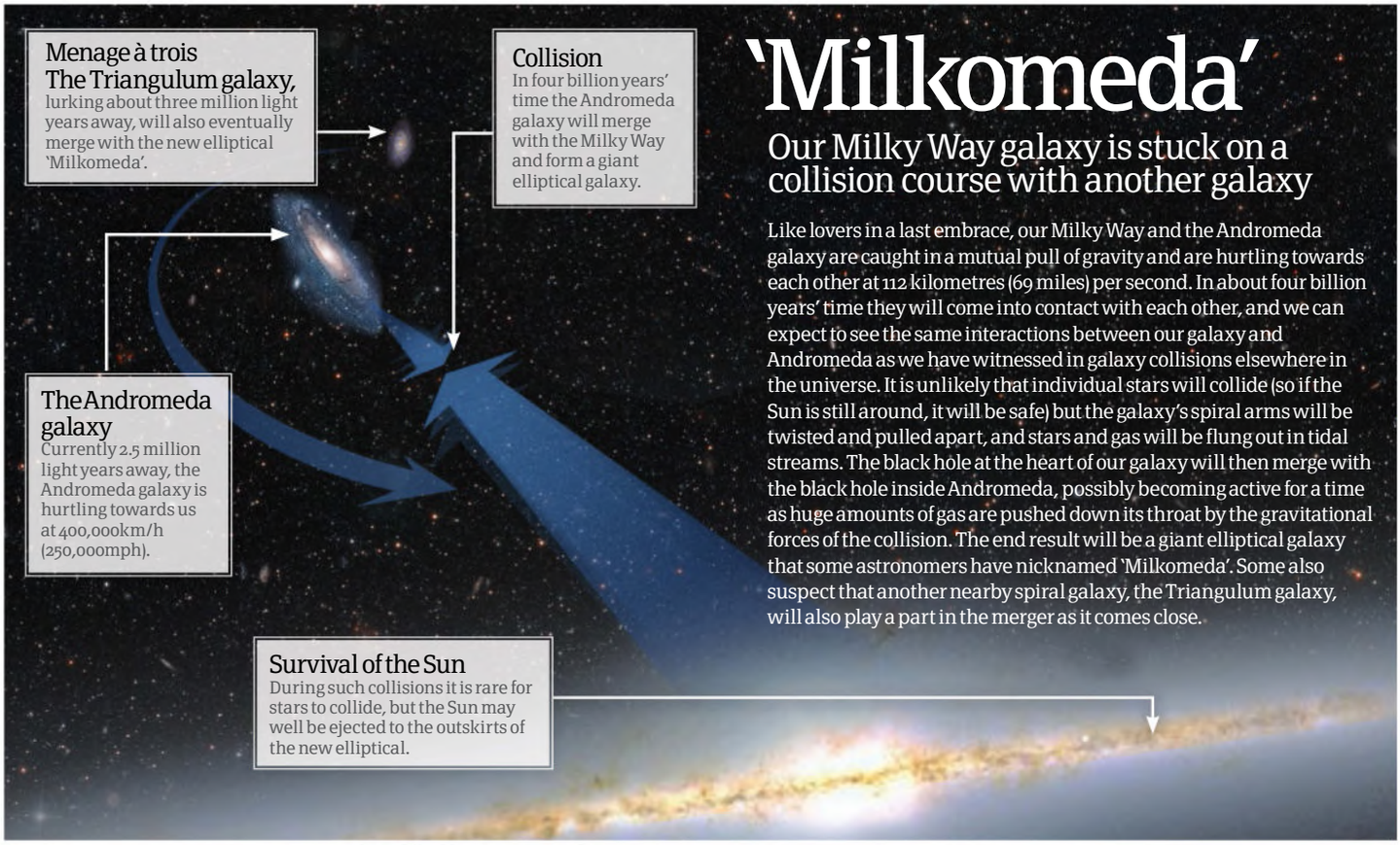
2. First contact
At first, the momentum of each galaxy may take them past one another, but their gravity will tear streams of stars and gas out of each other, called tidal tails.

3. Tidal tails
These can stretch hundreds of thousands of light years and the gas within them can form many new stars, far away from their home galaxy.

4. Caught by gravity
Although the two galaxies pass each other, their mutual gravity prevents them from escaping and pulls them back. This could happen several times, yo-yoing to and fro, until they are moving slowly enough to begin merging.

5. Stars
During the merger, huge gas clouds collide, causing them to form new stars. However, amid a galaxy collision, stars rarely collide because the distances between them are so vast.

6. Elliptical galaxy
If two spiral galaxies collide, their characteristic arms become distorted. The galaxies merge into a combined blob-shaped galaxy called an elliptical, and their supermassive black holes also merge.



'Milkomeda'

Our Milky Way galaxy is stuck on a collision course with another galaxy

Like lovers in a last embrace, our Milky Way and the Andromeda galaxy are caught in a mutual pull of gravity and are hurtling towards each other at 112 kilometres (69 miles) per second. In about four billion years' time they will come into contact with each other, and we can expect to see the same interactions between our galaxy and Andromeda as we have witnessed in galaxy collisions elsewhere in the universe. It is unlikely that individual stars will collide (so if the Sun is still around, it will be safe) but the galaxy's spiral arms will be twisted and pulled apart, and stars and gas will be flung out in tidal streams. The black hole at the heart of our galaxy will then merge with the black hole inside Andromeda, possibly becoming active for a time as huge amounts of gas are pushed down its throat by the gravitational forces of the collision. The end result will be a giant elliptical galaxy that some astronomers have nicknamed 'Milkomeda'. Some also suspect that another nearby spiral galaxy, the Triangulum galaxy, will also play a part in the merger as it comes close.

What will we see?

Earth's night sky will change dramatically over the next four billion years

Present day

We can see the Milky Way and the Andromeda galaxy spanning three degrees in the sky. However, Andromeda has a blueshift meaning it's moving towards us.

The encounter begins

As the Andromeda galaxy gets nearer it will grow larger in our sky. Its invisible gravitational force will begin to distort the shape of the Milky Way.

Collision!

As the spiral arms of the two galaxies collide their structures are completely disrupted. From Earth we will see the Milky Way become misshapen and tangled.

Starburst

During the merger huge gas clouds collide, creating the conditions for a burst of star formation. In the night sky we will see more nebulae and bright star clusters light up.

Black holes

The black holes in each galaxy edge their way towards each other. From Earth, we will see two galactic cores, getting closer until they merge.

The end result

Eventually the star formation ends, the black holes merge, the spiral arms are destroyed, and the two galaxies form a blob of stars called an elliptical galaxy.

Could we farm on alien planets?

Mars and the Moon could be new places to grow food

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

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

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

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

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

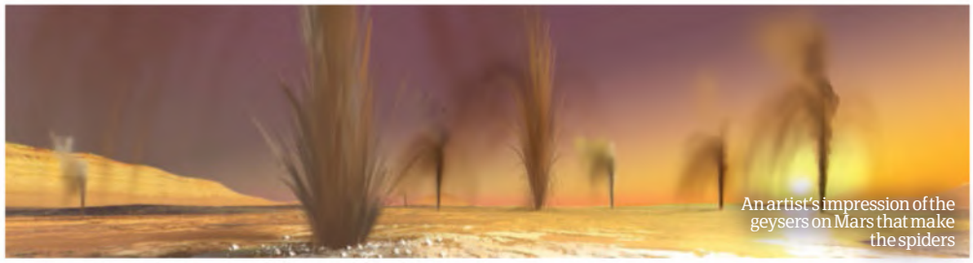
What are Mars' spiders?

These aren't David Bowie's backing group, but creepy patterns found in Martian ice

At Mars's south pole, in the middle of winter, the temperature can plummet as low as -125 degrees Celsius (-193 degrees Fahrenheit), which is chilly enough for carbon dioxide gas in the atmosphere to freeze out as a layer of dry ice (what we call frozen carbon dioxide). When spring comes around, this frost evaporates explosively! The darker ground below the dry ice absorbs the warmth of sunlight at a faster rate than the ice does. The warmer ground warms the dry ice from the bottom up, causing it to turn back into carbon dioxide gas – a process called sublimation. As the gas heats up it expands and forces its way through the ice above, burrowing its way to the surface by carving out channels that converge at a spot where the gas and dirt it carries with it burst out into the air as a geyser of dirty carbon dioxide gas.

It is these channels, some of which are 300 metres (984 feet) across, that create the impression of a spider web. Scientists suspect that the dwarf planet Pluto might also have spiders, formed by geysers of nitrogen instead of carbon dioxide. Pluto has a bright ice cap that is in sunlight at the moment, and the New Horizons spacecraft will be looking for the spiders from Pluto when it flies past in July.

Spider patterns seen at Mars's south pole by NASA's Mars Reconnaissance Orbiter



An artist's impression of the geysers on Mars that make the spiders

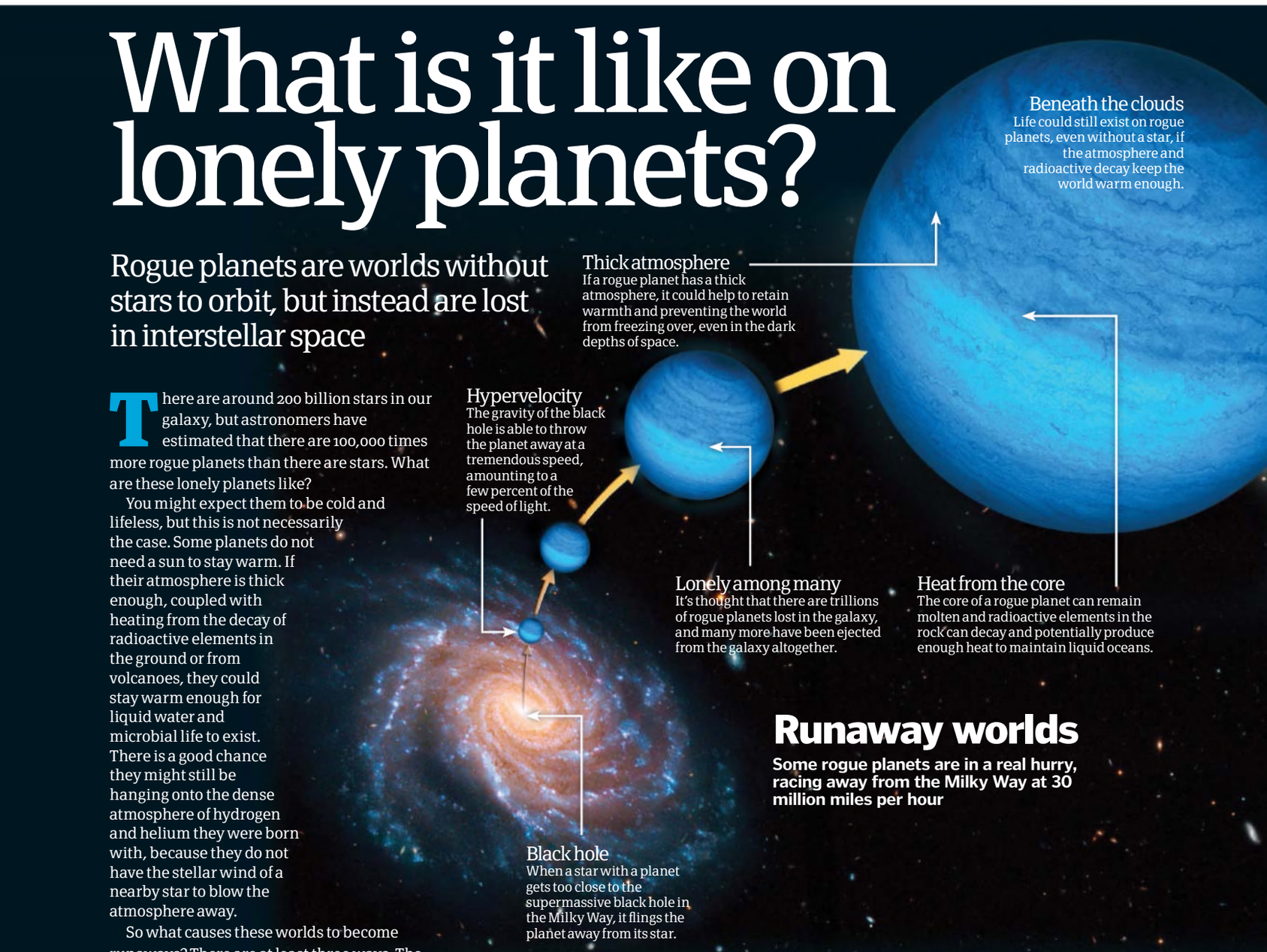
What is it like on lonely planets?

Rogue planets are worlds without stars to orbit, but instead are lost in interstellar space

There are around 200 billion stars in our galaxy, but astronomers have estimated that there are 100,000 times more rogue planets than there are stars. What are these lonely planets like?

You might expect them to be cold and lifeless, but this is not necessarily the case. Some planets do not need a sun to stay warm. If their atmosphere is thick enough, coupled with heating from the decay of radioactive elements in the ground or from volcanoes, they could stay warm enough for liquid water and microbial life to exist. There is a good chance they might still be hanging onto the dense atmosphere of hydrogen and helium they were born with, because they do not have the stellar wind of a nearby star to blow the atmosphere away.

So what causes these worlds to become runaways? There are at least three ways. The first is that they could be born alone – some of the biggest gas giants are very similar to brown dwarfs, which are failed stars that form like stars, direct from a collapsing gas cloud. Another way is that a star that wanders too close to the black hole at the centre of the Milky Way could have its planet pulled away from it and sent hurtling through space and out of the galaxy at 48 million kilometres (30 million miles) per hour. Finally, planets can be kicked out of solar systems by larger planets migrating in their orbits. The migrating planet's gravity forces other, smaller worlds out of the planetary system. Some astronomers even think our Solar System once had five giant planets, but that one was ejected as the others migrated.

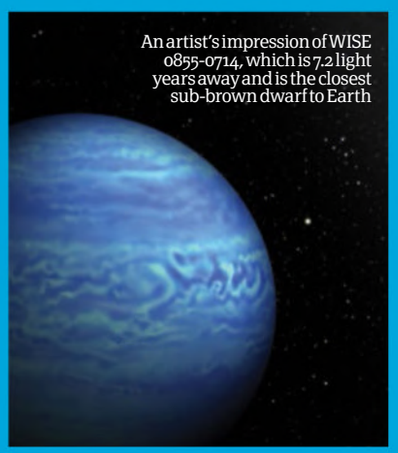


Runaway worlds

Some rogue planets are in a real hurry, racing away from the Milky Way at 30 million miles per hour

Brown dwarfs: overgrown planets or failed stars?

Brown dwarfs are gas giants that are too small to become a star – they cannot reach the temperatures and pressures within their core to begin fusing hydrogen into helium. The smallest brown dwarfs are about 13 times the mass of Jupiter, and anything smaller should be a planet, but the dividing line is blurred. Some rogue planets have formed like a star or a brown dwarf, condensing out of a cloud of gas. Astronomers call these sub-brown dwarfs, and the closest one found so far is called WISE 0855-0714 and is about 7.5 light years away. Its mass is between three and ten times the mass of Jupiter. Astronomers have found many planets with the same mass orbiting stars. WISE 0855-0714 is a cold object, with temperatures between minus-13 to minus-48 degrees Celsius (8.6 and minus-54.4 degrees Fahrenheit).



An artist's impression of WISE 0855-0714, which is 7.2 light years away and is the closest sub-brown dwarf to Earth

What colour are the planets?

Discover the science behind the colours in our Solar System

Of the eight planets in our Solar System, only two can't be seen unaided from Earth – Uranus and Neptune. And even then, unless you're observing through a telescope, the physical appearance of almost all planets will be difficult to perceive. Except of course Earth's neighbouring planet, Mars, which even ancient cultures correctly documented as being red, as its orange-red glow is distinguishable from Earth.

Space missions and scientific advancements in the last century have greatly improved our perception of the planets, including those closest and farthest away from the Sun. As a result we are now finally able to identify a planet's true colour and – more importantly – understand why it appears as such.

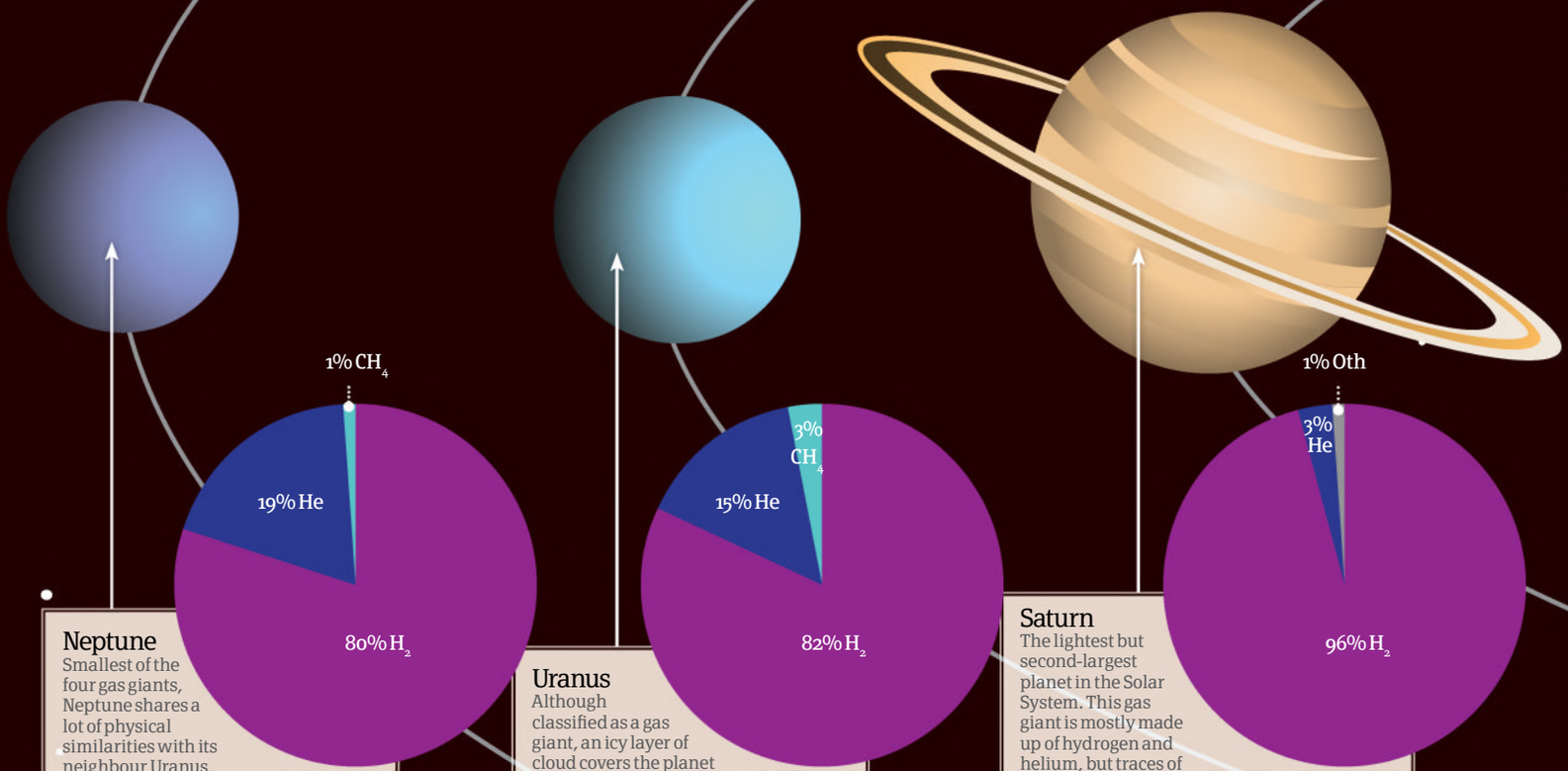
The colour of each planet is determined by what they made up of, and in some instances, how their atmospheres absorb and reflect light from the Sun.

The four terrestrial planets, which have solid rock surfaces, are mostly grey or reddish-brown in appearance due to elements such as iron found on the surface. However, the surface of Venus is difficult to detect from space, as a dense atmosphere and thick clouds of acid surround it. The sulphur present in the clouds reflects the light and gives Venus its noticeable yellow colouring. A similar principle applies when it comes to determining the colours of the four gas giants. Uranus and Neptune, for example, appear to us as blue because methane gas present in their atmospheres absorbs red light, enabling them to only reflect blue.

Planetary colour palette

Here's how each planet is coloured, with each colour indicative of a certain element

- Hydrogen (H_2)
- Carbon dioxide (CO_2)
- Helium (He)
- Nitrogen (N_2)
- Oxygen (O_2)
- Methane (CH_4)
- Sodium (Na)
- Argon (Ar)
- Other gases (Oth)



Neptune

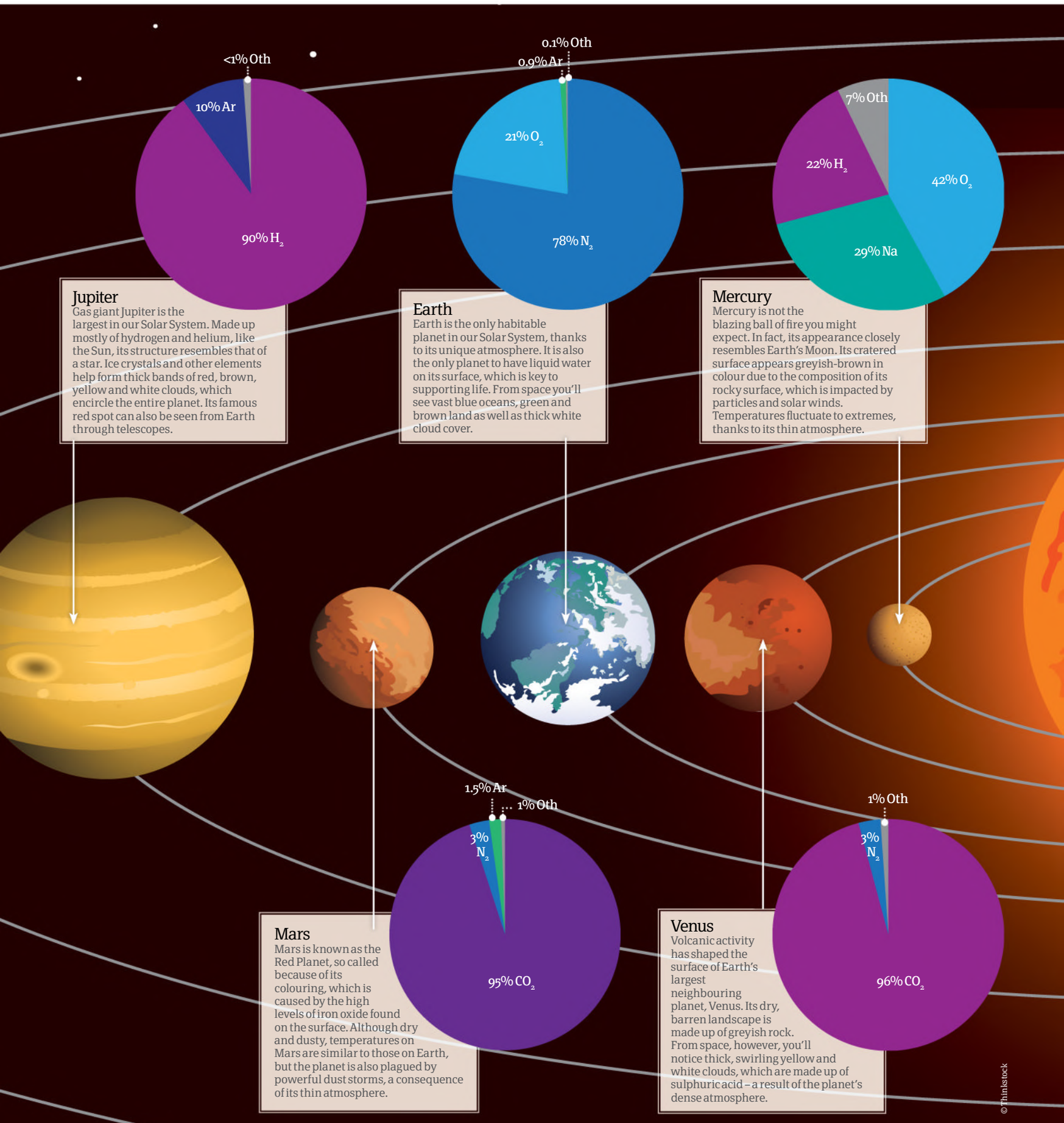
Smallest of the four gas giants, Neptune shares a lot of physical similarities with its neighbour Uranus, including its blue colouring. It's considered the windiest planet, with speeds recorded at around 2,414km/h (1,500mph). Extreme storms are also known to occur in its atmosphere and the planet also features a giant storm spot like Jupiter.

Uranus

Although classified as a gas giant, an icy layer of cloud covers the planet Uranus. The coldest planet in our Solar System, temperatures at cloud level drop to below -220°C (-364°F). Methane in its atmosphere gives Uranus its distinct turquoise appearance; as red light is absorbed, only green-blue light is reflected.

Saturn

The lightest but second-largest planet in the Solar System. This gas giant is mostly made up of hydrogen and helium, but traces of ammonia, phosphine, water vapour and hydrocarbons in its atmosphere give the planet its distinct yellowish-brown colour. Saturn's famous rings, which are primarily made up of water ice, share a similar hue, but also vary in colour depending on density and the presence of other materials.



Jupiter

Gas giant Jupiter is the largest in our Solar System. Made up mostly of hydrogen and helium, like the Sun, its structure resembles that of a star. Ice crystals and other elements help form thick bands of red, brown, yellow and white clouds, which encircle the entire planet. Its famous red spot can also be seen from Earth through telescopes.

Earth

Earth is the only habitable planet in our Solar System, thanks to its unique atmosphere. It is also the only planet to have liquid water on its surface, which is key to supporting life. From space you'll see vast blue oceans, green and brown land as well as thick white cloud cover.

Mercury

Mercury is not the blazing ball of fire you might expect. In fact, its appearance closely resembles Earth's Moon. Its cratered surface appears greyish-brown in colour due to the composition of its rocky surface, which is impacted by particles and solar winds. Temperatures fluctuate to extremes, thanks to its thin atmosphere.

Mars

Mars is known as the Red Planet, so called because of its colouring, which is caused by the high levels of iron oxide found on the surface. Although dry and dusty, temperatures on Mars are similar to those on Earth, but the planet is also plagued by powerful dust storms, a consequence of its thin atmosphere.

Venus

Volcanic activity has shaped the surface of Earth's largest neighbouring planet, Venus. Its dry, barren landscape is made up of greyish rock. From space, however, you'll notice thick, swirling yellow and white clouds, which are made up of sulphuric acid – a result of the planet's dense atmosphere.

How will NASA blow up asteroids?

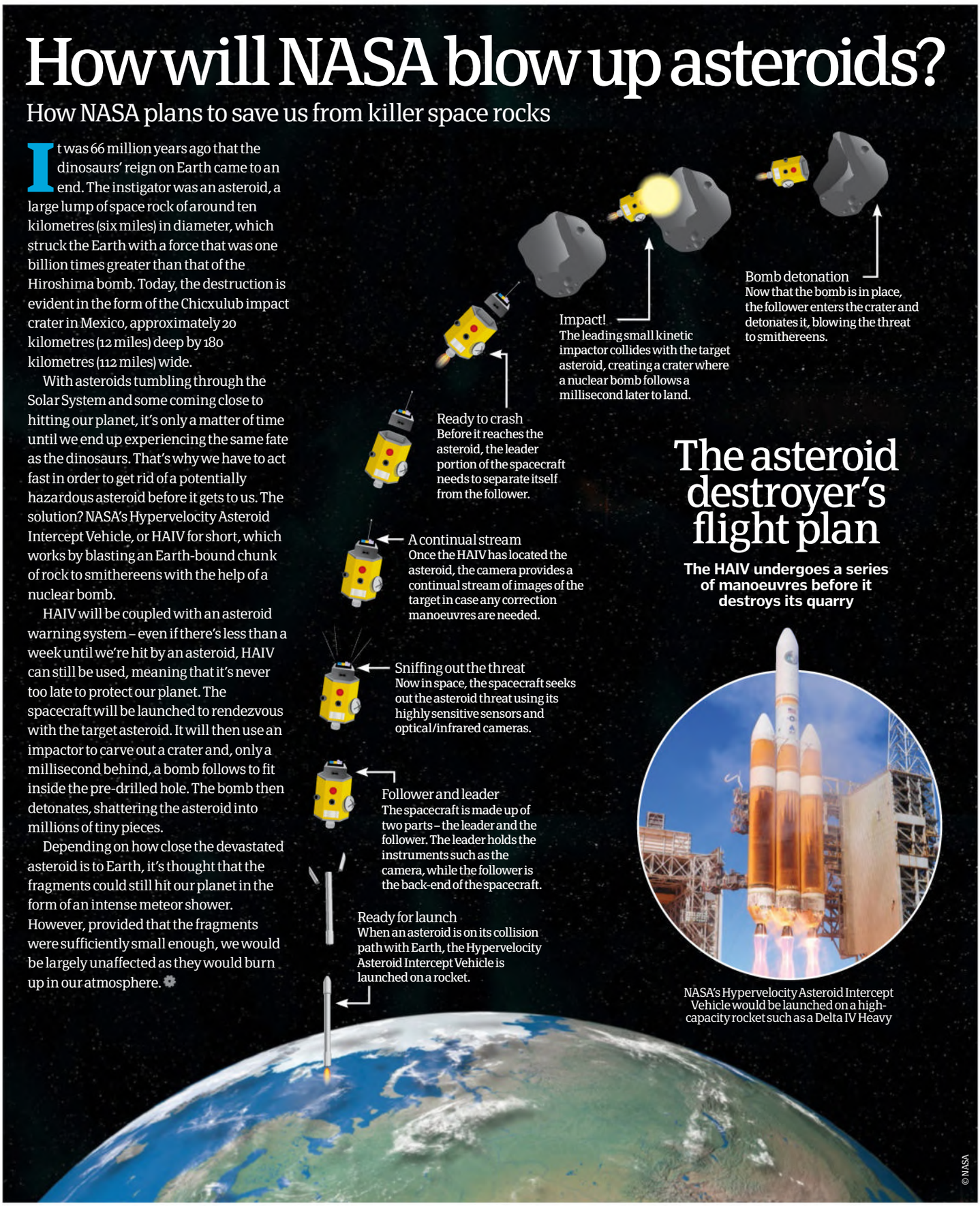
How NASA plans to save us from killer space rocks

It was 66 million years ago that the dinosaurs' reign on Earth came to an end. The instigator was an asteroid, a large lump of space rock of around ten kilometres (six miles) in diameter, which struck the Earth with a force that was one billion times greater than that of the Hiroshima bomb. Today, the destruction is evident in the form of the Chicxulub impact crater in Mexico, approximately 20 kilometres (12 miles) deep by 180 kilometres (112 miles) wide.

With asteroids tumbling through the Solar System and some coming close to hitting our planet, it's only a matter of time until we end up experiencing the same fate as the dinosaurs. That's why we have to act fast in order to get rid of a potentially hazardous asteroid before it gets to us. The solution? NASA's Hypervelocity Asteroid Intercept Vehicle, or HAIV for short, which works by blasting an Earth-bound chunk of rock to smithereens with the help of a nuclear bomb.

HAIV will be coupled with an asteroid warning system – even if there's less than a week until we're hit by an asteroid, HAIV can still be used, meaning that it's never too late to protect our planet. The spacecraft will be launched to rendezvous with the target asteroid. It will then use an impactor to carve out a crater and, only a millisecond behind, a bomb follows to fit inside the pre-drilled hole. The bomb then detonates, shattering the asteroid into millions of tiny pieces.

Depending on how close the devastated asteroid is to Earth, it's thought that the fragments could still hit our planet in the form of an intense meteor shower. However, provided that the fragments were sufficiently small enough, we would be largely unaffected as they would burn up in our atmosphere.



The asteroid destroyer's flight plan

The HAIV undergoes a series of manoeuvres before it destroys its quarry

NASA's Hypervelocity Asteroid Intercept Vehicle would be launched on a high-capacity rocket such as a Delta IV Heavy

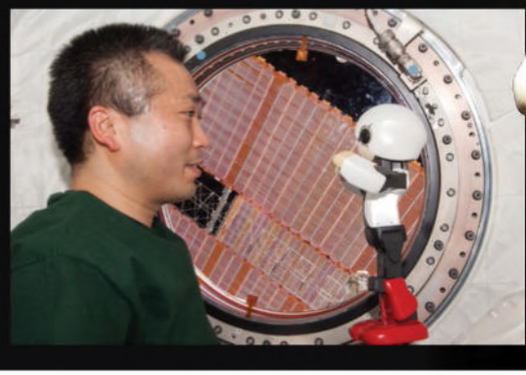
How do robots keep astronauts company?

Meet Kirobo, the Japanese robot living on the ISS

Feelings of loneliness are often hard to avoid when you're in space. Astronauts who stay on the International Space Station (ISS) for extended periods often struggle with this feeling. Sometimes, their psychological issues can be harder to deal with than living in microgravity or sleeping upright.

To combat this, Japanese scientists designed a robot with the aim of providing psychological support. It was named Kirobo, which is derived from the Japanese word for hope ("kibo") and robot. Kirobo stands 34 centimetres (13.4 inches) tall and weighs one kilogram (2.2 pounds). It has a clever voice-recognition system and can produce its own sentences with the help of an advanced language-processing system, and its own built-in voice synthesis software.

These innovative systems were actually designed by Toyota, which plans to use the technology to develop other robots' conversational abilities. The Kirobo experiment also aimed to see how humans and robots might live alongside each other during longer space missions, which may take place in the future. Kirobo has now returned to Earth after an 18-month stay aboard the ISS.



US Astronauts Reid Wiseman and Barry Wilmore during their spacewalk outside the ISS to make repairs

Can a spaceship be repaired in orbit?

Who fixes the ISS when it 'breaks down'?

Astronauts and cosmonauts aboard the International Space Station perform spacewalks regularly to make repairs. In early 2015, two American astronauts spent about 20 hours over the course of three spacewalks installing cables. NASA is also testing technology on the ISS that will eventually be used to repair existing satellites in orbit, using both humans and robots. This technology is part of a campaign to enable spacecraft repair while in space, which will help further exploration beyond our current capabilities. The Apollo 13 mission in 1970 required the astronauts aboard to make a life-saving repair so they could return safely to Earth after an on-board explosion aborted their mission to the Moon. At the time, they were about 322,000km (200,000mi) from Earth. So in short, spacecraft repairs in orbit are definitely possible.

What are active galaxies?

The powerful galaxies that swallow their surroundings

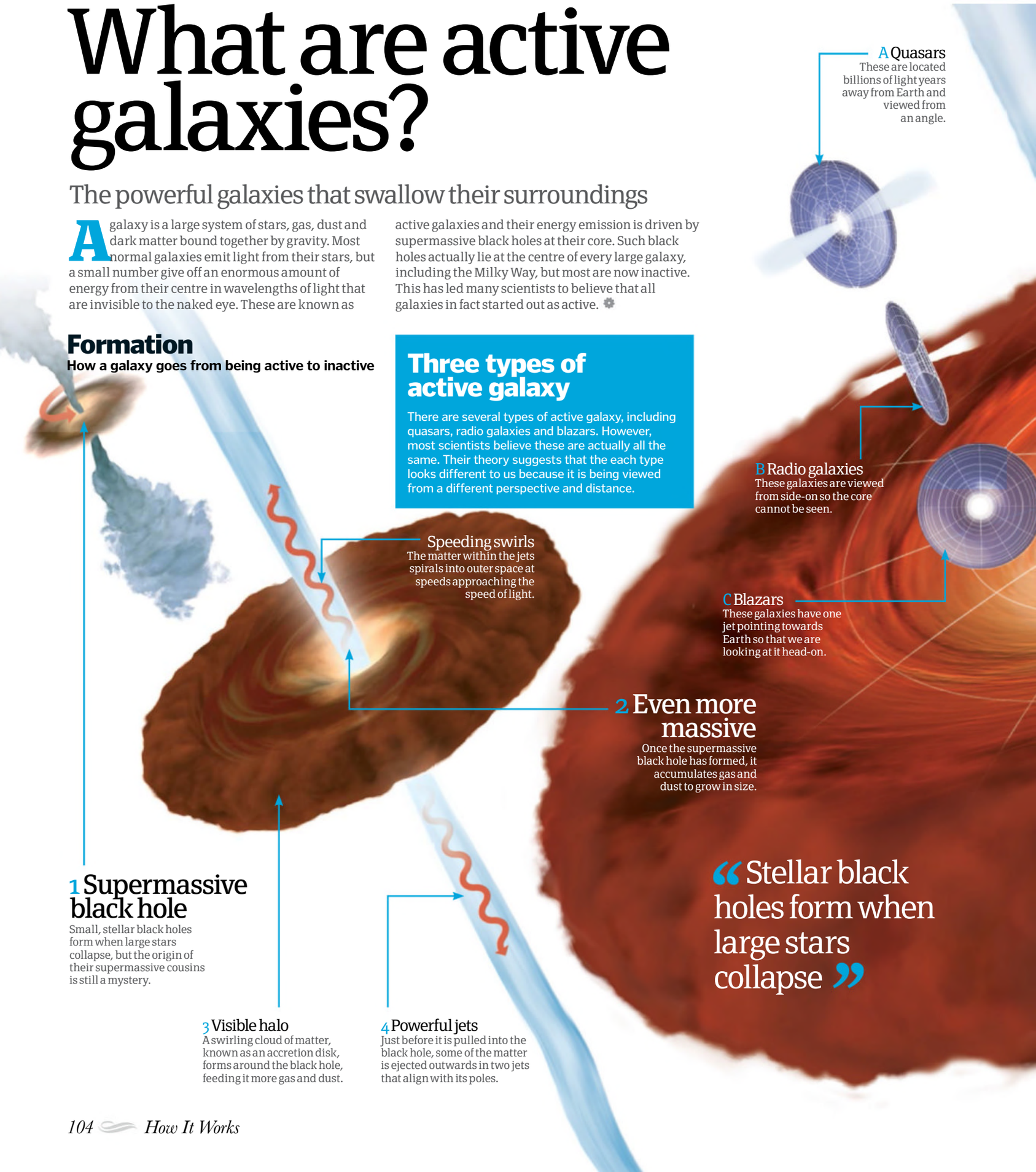
A galaxy is a large system of stars, gas, dust and dark matter bound together by gravity. Most normal galaxies emit light from their stars, but a small number give off an enormous amount of energy from their centre in wavelengths of light that are invisible to the naked eye. These are known as active galaxies and their energy emission is driven by supermassive black holes at their core. Such black holes actually lie at the centre of every large galaxy, including the Milky Way, but most are now inactive. This has led many scientists to believe that all galaxies in fact started out as active.

Formation

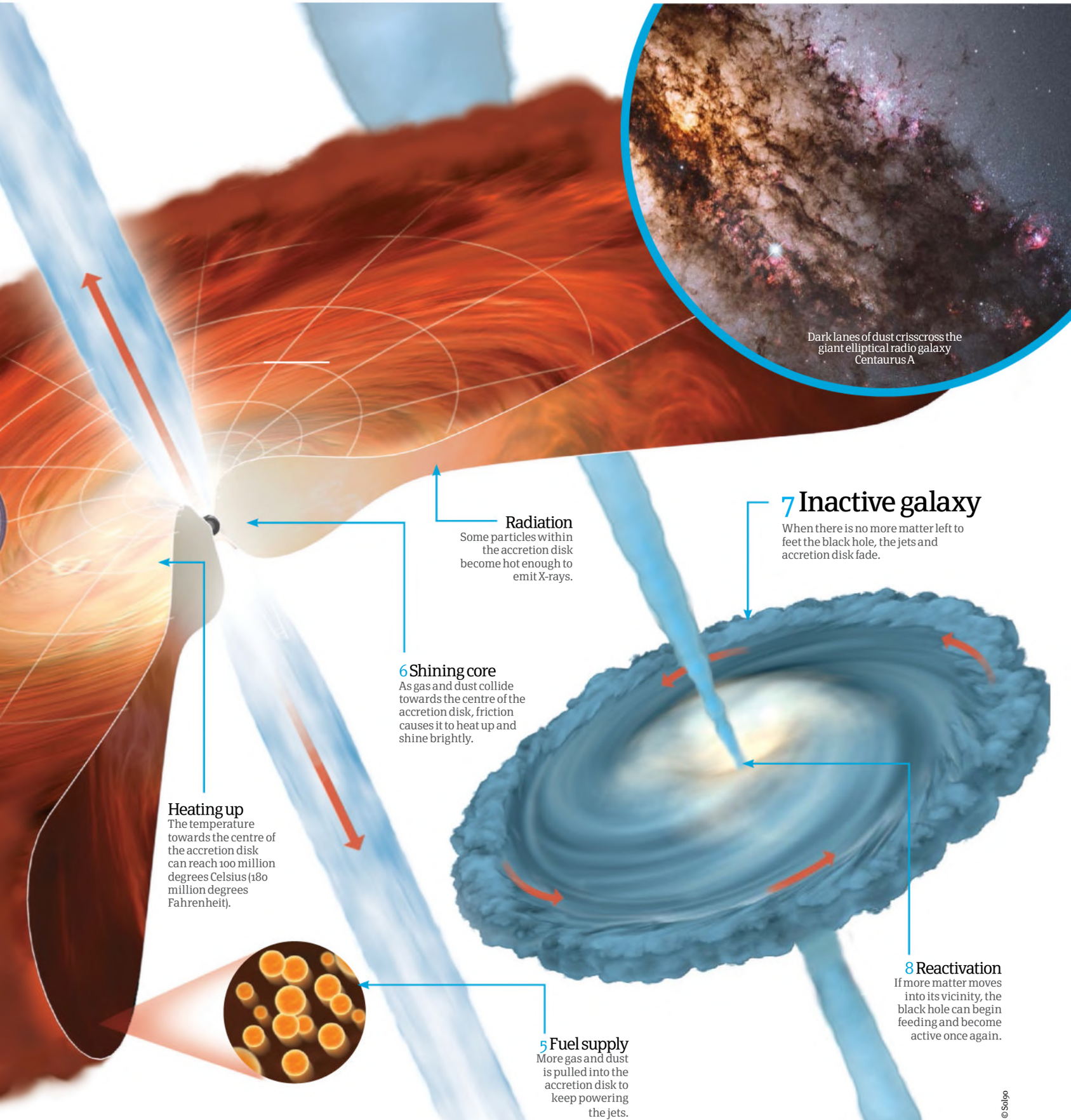
How a galaxy goes from being active to inactive

Three types of active galaxy

There are several types of active galaxy, including quasars, radio galaxies and blazars. However, most scientists believe these are actually all the same. Their theory suggests that the each type looks different to us because it is being viewed from a different perspective and distance.



> "Stellar black holes form when large stars collapse"



Dark lanes of dust crisscross the giant elliptical radio galaxy Centaurus A

Radiation
Some particles within the accretion disk become hot enough to emit X-rays.

7 Inactive galaxy
When there is no more matter left to feet the black hole, the jets and accretion disk fade.

6 Shining core
As gas and dust collide towards the centre of the accretion disk, friction causes it to heat up and shine brightly.

Heating up
The temperature towards the centre of the accretion disk can reach 100 million degrees Celsius (180 million degrees Fahrenheit).

8 Reactivation
If more matter moves into its vicinity, the black hole can begin feeding and become active once again.

5 Fuel supply
More gas and dust is pulled into the accretion disk to keep powering the jets.

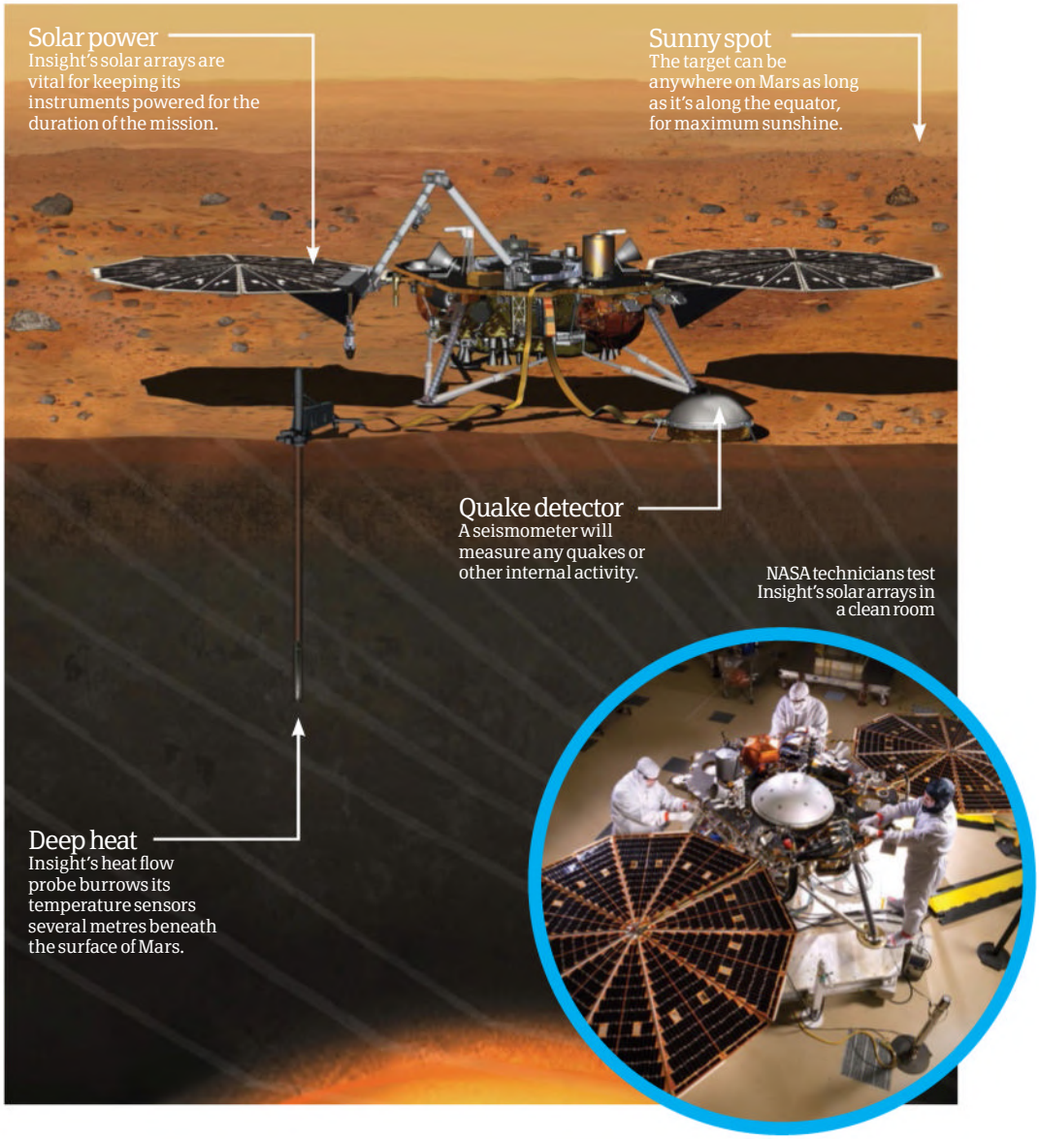
What is the new Mars lander?

NASA's next mission will offer clues about the formation of the Solar System

We might have sent over a dozen rovers, landers and orbiters to Mars, but that doesn't mean we are done sending probes to the Red Planet – we still have a lot to discover.

NASA's InSight (Interior Exploration using Seismic Investigations) lander is planned to launch in March 2016 and will touch down on the Martian surface just six months later. As the acronym suggests, its two-year mission will involve peering deep beneath the Martian crust at a landing site near the equator to study Mars' internal processes and structure, as well as any tectonic activity and meteorite impacts.

This is much more than figuring out what Mars is made of or even the history of this one planet. Geologically, Mars is practically inert compared to a planet like Earth, as it has no plate tectonics, and so there is a much more complete history of how it has evolved over the last few billion years. Therefore by investigating Mars's interior, scientists will be able to gain a much better understanding of how all of the terrestrial planets formed.




Titan, with its polar vortex (below), shrouded in the haze of its thick atmosphere

Is Titan Earth's toxic twin?

It's bitterly cold and shrouded in a choking natural 'smog', but Titan is more like Earth than you'd think

Venus is often referred to as 'Earth's evil twin' because despite having similar characteristics and evolutionary starting line, it went on to become the inhospitable world that it is today. However, a team of scientists from University College London (UCL) have dubbed the giant moon Titan 'Earth's toxic twin' for a few slightly different reasons.

Saturn's biggest natural satellite is the only other place in the Solar System where it rains, has rivers and surface oceans – of liquid hydrocarbons (like ethane and methane), rather than water. These were recorded during descent of the Huygens probe, the only spacecraft to have successfully landed on any celestial body in the outer Solar System, in 2005.

The team at UCL has found that in Titan's dense, hazy atmosphere there is also a polar wind that works in a similar way to that of Earth's, driving around seven tons of nitrogen and methane gases out of the atmosphere and into space every day. It's thought that both Mars and Venus could feature similar polar winds, and it also begs the question: if so many worlds are similar to Earth in this Solar System alone, how long can it be before we find another planet capable of supporting life?

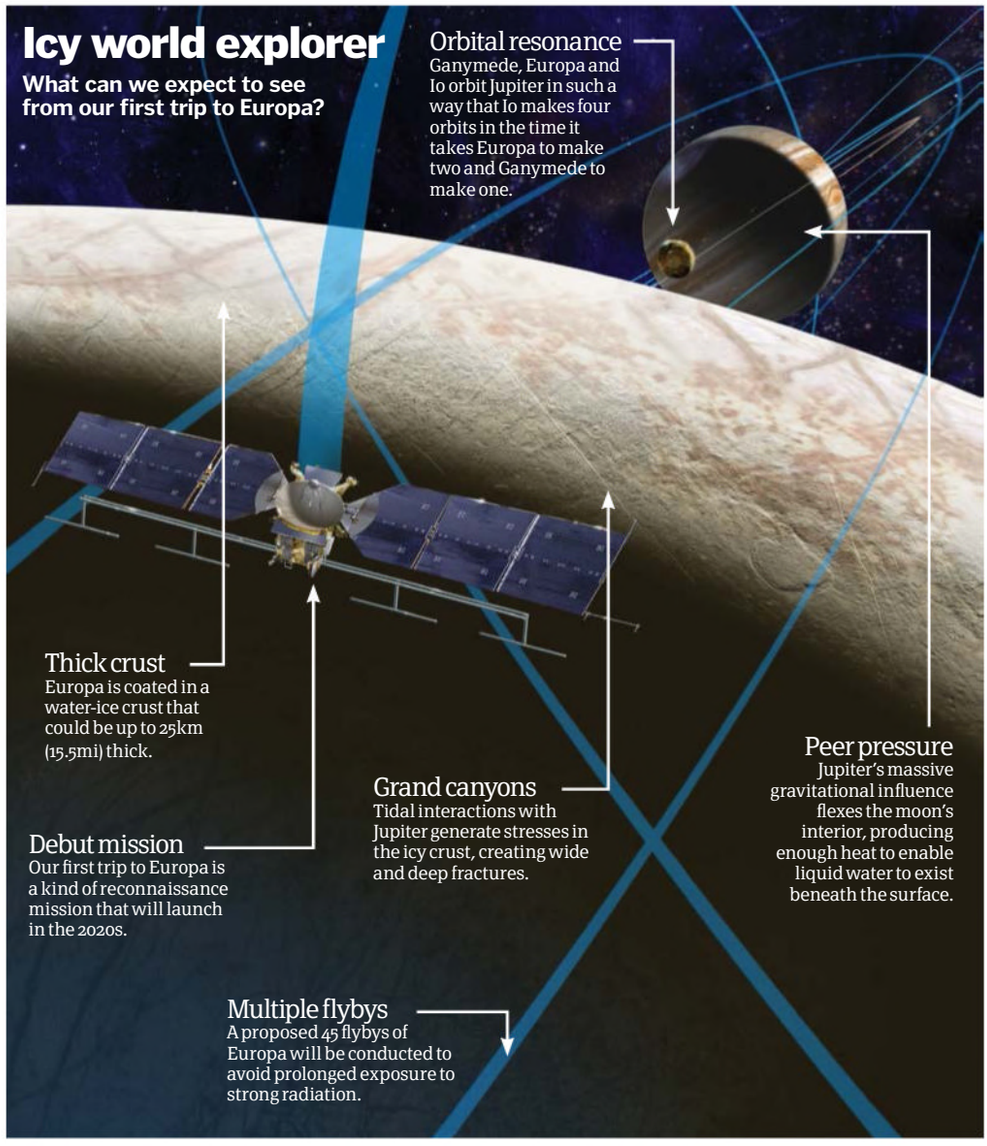
What is the aim of NASA's Europa mission?

Here's why Jupiter's icy moon is next on NASA's hit list

In May, following federal allocation of funds for the coming year, NASA announced the selection of a series of scientific instruments it would use to investigate potential life on an icy moon, along with a 2020s mission to Europa. This is one of Jupiter's largest natural satellites and, courtesy of its role in various science fiction novels and films, perhaps one of the most famous objects in the Solar System.

Europa isn't just the next logical stepping-stone from Mars into the outer Solar System though: it's a frozen world at the surface with an icy crust, and there's strong evidence for a large sub-surface water ocean beneath it. In many ways it's a remarkably similar place to the lakes found beneath the kilometres-thick ice of Antarctica, where several space agencies (including NASA) have conducted experiments for years, so this isn't a wholly alien environment to us. Furthermore, life has been found in sub-surface Antarctic lakes that have been devoid of any sunlight for tens of thousands, or even millions of years. This means Europa has the potential to be habitable, even if life never occurred on it.

The current proposal is for a hardy probe that can withstand the intense radiation belts around Jupiter to make the 600 million-kilometre (373 million-mile) journey to the gas giant. Here it will orbit Jupiter and perform 45 flybys of Europa – swooping as low as 25 kilometres (16 miles) above the surface – scanning the moon to determine the thickness of the ice and where its subsurface lakes might be found. If the reconnaissance mission is a success, scientists could follow up with a landing mission and a probe to send beneath the ice crust to search for life in the frigid depths.



What is the squid rover?

NASA's calling it the 'Soft-Robotic Rover with Electrodynamic Power Scavenging' – but the concept of this aquatic rover was inspired by the squid and so the catchier 'squid rover' has stuck. It certainly resembles this terrestrial mollusc.

The squid rover will plummet into the dark and cold depths of Europa's sub-surface oceans, where no nuclear or solar-powered rover can hope to survive. It will 'scavenge' its power from its environment, using two tentacle-like appendages to electrolyse the water around it. It will then produce hydrogen and oxygen gas to provide the fuel for its propulsion systems, as well as generating electricity for both communications and alien life-seeking scientific instruments.

This technology is very much in the concept phase, but NASA is taking its development seriously. If successful, the squid rover would solve the problem of powering a craft so far away from the Sun. On top of that, it would be an effective propulsion system through the sub-surface oceans, which are suspected to lie beneath the icy surface of many outer Solar System worlds.

This soft-bodied rover will search for habitable environments in sub-surface oceans on other worlds

How are exoplanets found?

Discover how we are able to spot alien worlds now and in the future

Scientists had suspected that exoplanets – planets beyond our Solar System – had existed for several hundred years, long before the first confirmed detection was made. Over the years some claimed to have discovered an exoplanet, but it wasn't until 1992 that the detection of a planetary-mass object orbiting a type of star – known as a millisecond pulsar – was confirmed.

That observation took the power of the giant Arecibo radio telescope in Puerto Rico and some out-of-the-box thinking to detect – techniques that are now standard procedure in the search for distant worlds. But it's actually possible to detect exoplanets from your own back garden with a few specialised pieces of astronomy kit and particularly dark night skies.

It's not surprising, however, that it's the big ground-based and space observatories run by various government agencies and organisations around the world, that have made nearly 2,000 confirmed detections to date. Most of these discoveries have been made by space telescopes at their vantage point 1.5 million kilometres (932,057 miles) away from Earth's obscuring atmosphere. Hubble, which had been in orbit for two years by the time the first exoplanet was confirmed, has discovered a handful of these and has contributed to the discovery of many others, but it isn't the most successful exoplanet hunter. That particular gong goes to NASA's Kepler spacecraft, a specialised alien-world hunter that successfully passed the 1,000 confirmed exoplanets milestone earlier this year.

Of course, the total number of exoplanets we've discovered so far is a drop in the ocean: the Gaia telescope was launched in late 2013 to map a billion stars, or about one per cent of our own galaxy, and will help in the search for new worlds by finding the host stars that they orbit. However, given that there's an estimated average of one planet for every star in the Milky Way, we've still got a long way to go.

Exoplanet hunting

These are – or will be – the most powerful telescopes searching for new worlds

Spitzer Space Telescope
With a few clever hardware adjustments, this infrared instrument has been repurposed as a planet hunter.

The Hubble Space Telescope
Hubble is a valuable asset in exoplanet hunting, but its technology is old and will soon be decommissioned.

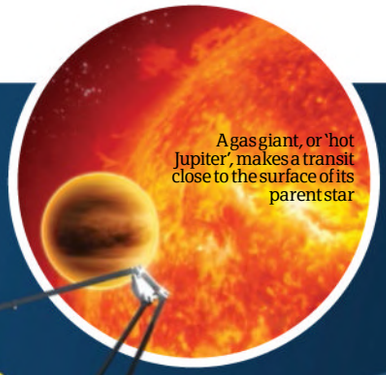
Kepler space observatory
Despite a failure that threatened the entire mission, Kepler has continued planet hunting and has clocked up the most confirmed exoplanet discoveries to date.

Terrestrial observatories
The European Southern Observatory (ESO) in Chile has some of the best ground-based telescopes in the world.

> "It's actually possible to detect exoplanets from your own back garden with a few specialised pieces of astronomy kit and particularly dark night skies"

Detection methods

Building a top-notch observatory with current technology is half the battle: it's not just a matter of pointing your telescope and hoping to see something. This is because planets don't emit any light of their own, they can be thousands of light years from us and they're usually found orbiting stars, which means they're lost in the bright starlight. Astronomers have developed several techniques to detect exoplanets indirectly, in other words, by making observations that infer the existence of a planet. By far the most successful is the transit method, which measures the miniscule decrease in the levels of light from a star when an orbiting planet passes in front of it. It has its limitations, of course, but this method accounts for over two thirds of confirmed exoplanet detections.



A gas giant, or 'hot Jupiter', makes a transit close to the surface of its parent star

Wide-Field Infrared Survey Telescope (WFIRST)

Its primary science will be to answer questions about dark energy, but it will also search for solar systems like our own.

James Webb Space Telescope (JWST)

This hotly anticipated observatory will launch in 2018 and sees in visible wavelength to infrared in unprecedented resolution.

Advanced Technology Large-Aperture Space Telescope (ATLAST)

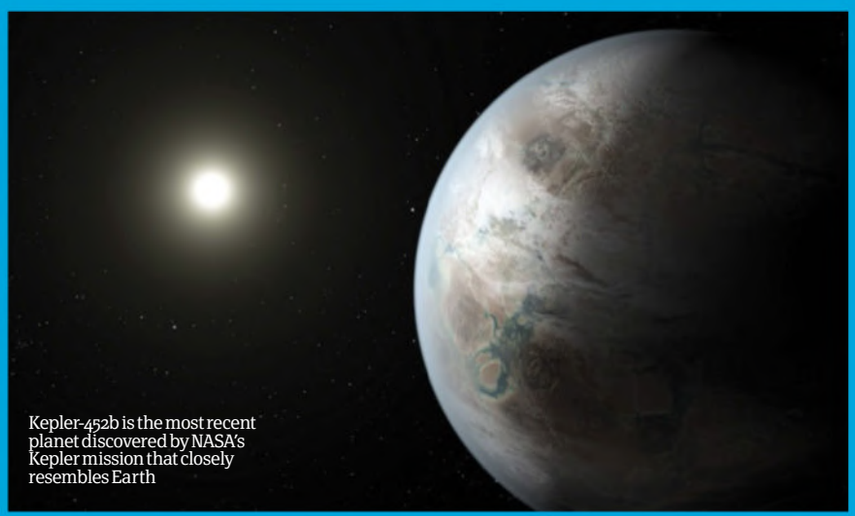
A potential successor to Hubble and the JWST, the ATLAST mission would search for biosignatures (signs of life) on other worlds in our galaxy.

Transiting Exoplanet Survey Satellite (TESS)

Due to launch in 2017, TESS will survey the nearest and brightest stars to us, providing targets for further observation.

Earth's bigger and older cousin

NASA's Kepler mission has recently discovered a planet that closely resembles Earth and orbits within a 'habitable zone' – an area around a star where it's warm enough for water to be liquid. It may therefore offer just the right conditions for supporting life. Named Kepler-452b, the planet is 60 per cent larger in diameter than Earth and is considered a super-Earth-size planet. Its mass and composition have not yet been determined, but previous research suggests that planets the size of Kepler-452b have a good chance of being rocky. While it is larger than Earth, its 385-day orbit is only five per cent longer because the planet is five per cent farther from its parent star, Kepler-452, than Earth is from the Sun. Kepler-452 is six billion years old, 1.5 billion years older than our Sun, but has the same temperature, is 20 per cent brighter and has a diameter ten per cent larger. The Kepler-452 system is 1,400 light years away in the constellation Cygnus.



Kepler-452b is the most recent planet discovered by NASA's Kepler mission that closely resembles Earth

What is space salad?

How to grow vegetables that are out of this world

Deliveries of fresh fruit and vegetables are rare on the ISS, so astronauts' diets mostly consist of pre-packaged, non-perishable foods. However, thanks to the Vegetable Production System, or Veggie, being used on board, this is starting to change.

The Veggie plant growth chamber uses plant pillows: small bags of slow-release fertiliser and a clay-like soil that is also used on baseball fields. These pillows are placed in a reservoir of water and have wicks inserted into them to draw the liquid into the soil. Plant seeds are glued onto these wicks to make sure they grow the right way up in the zero gravity environment – that the roots grow down into the soil and the shoots pop out the top of the pillows.

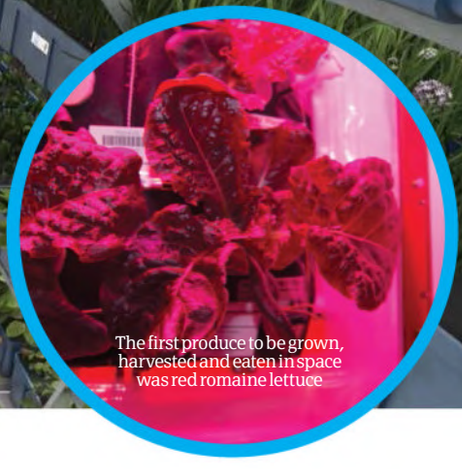
At the top of the chamber, LEDs provide light for photosynthesis as well as a sense of direction to keep the shoots growing upwards. A mixture of red and blue light is used as these are the colours of light plants use most, but the resulting purple hue makes the plants appear grey and unappetising. Therefore, to make their crops look more appealing, the astronauts can switch on additional green LEDs, which combine with the red and blue to create a more natural white light. The first Veggie crop was harvested in 2014 but it had to be frozen and returned to Earth for analysis to make sure it was safe to eat. Once approved for consumption, a second crop was grown and on 10 August 2015, the Expedition 44 crew became the first humans to sample space-grown produce.

Veggie benefits

Growing vegetables on the ISS doesn't just have nutritional benefits for the crew; it can also improve their psychological wellbeing too. A bit of greenery provides some relief from the metallic, lifeless environment of the space station and allows the astronauts to form a connection with a living thing. This will be particularly important for the deep space missions to an asteroid, and then Mars, that NASA is currently planning. For small crews, living in a confined space with limited communication for an extended period of time, having a little piece of Earth to care for will help them cope with the stressful and isolated environment, as well as provide them with a sustainable food source. The tech used in the Veggie system is also proving useful much closer to home, with countries such as Dubai using it to maintain a controlled plant-growing environment in their hot and dry climates.

Growing plants in space has nutritional and psychological benefits for astronauts

Future spacecraft heading on deep space missions could have entire gardens on board



The first produce to be grown, harvested and eaten in space was red romaine lettuce

The history of space food

1962-1964
The first space foods were pastes that were squeezed from tubes and cubes of dehydrated food that were rehydrated by saliva in the mouth.

1965-1967
NASA's Gemini missions had freeze-dried meals, including shrimp cocktail and butterscotch pudding, which were rehydrated by injecting water into the packet.

1968–1972
The Apollo missions were the first to have hot water, which made rehydrating food easier, and utensils in the form of spoons.

1973-1979
The Skylab space station had a dining table, onboard refrigeration, food warming trays and 72 different food items.

1980-1999
Astronauts on the Space Shuttle missions could design their own menus and heat their food in an onboard oven.

2000-today
On the ISS, the menu consists of frozen, refrigerated and ambient foods, and sometimes meals designed by celebrity chefs.

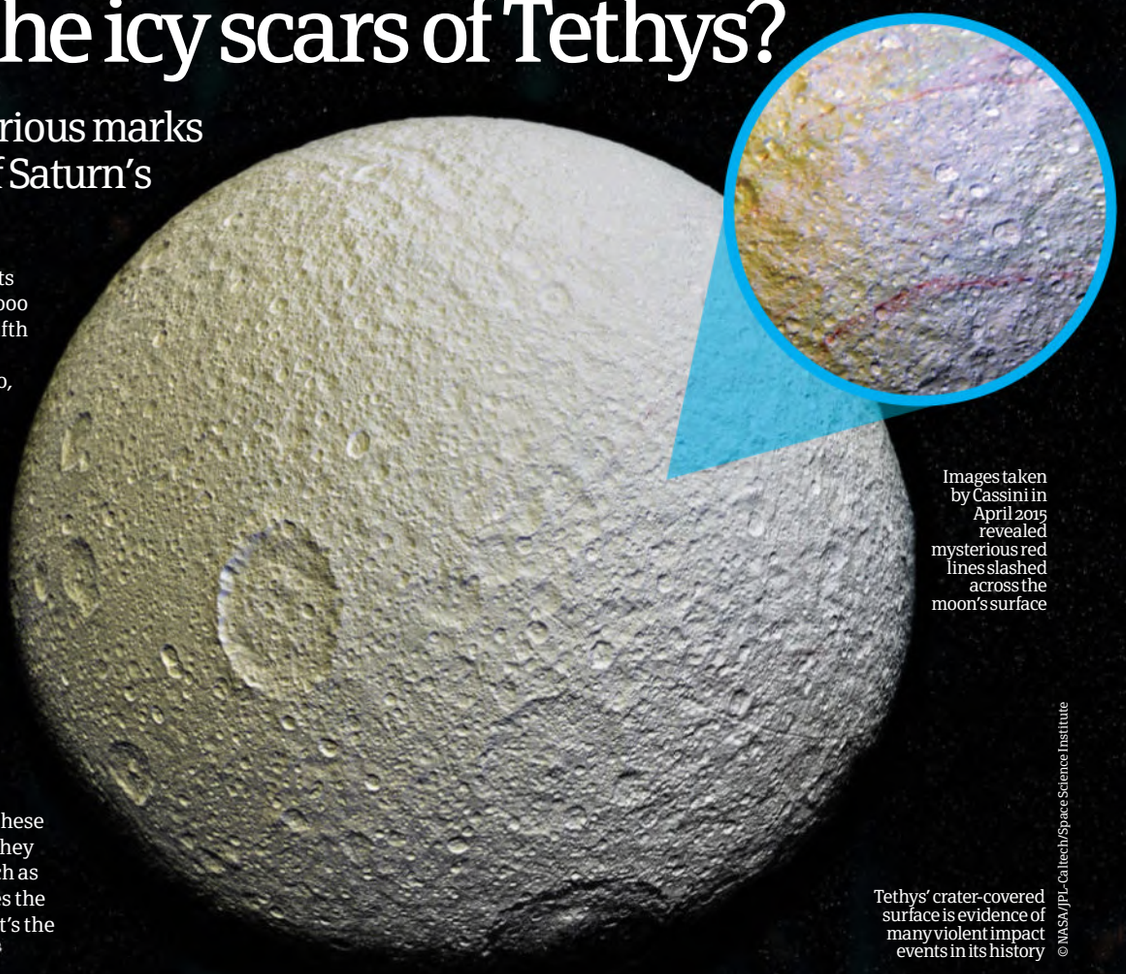
What are the icy scars of Tethys?

The craters and mysterious marks covering the surface of Saturn's battered moon

Composed mainly of ice, Tethys orbits Saturn at a distance of around 295,000 kilometres (183,305 miles). It is the fifth largest of all of Saturn's satellites and has two tiny companions, Telesto and Calypso, which are both less that 32 kilometres (20 miles) across, held in place by Tethys' gravity. It is merely one of 62 moons orbiting the ringed planet, but it has a compelling story.

Tethys has taken an unprecedented number of hits during its lifetime, which have given it an almost sponge-like appearance. It has a particularly noticeable crater known as Odysseus, which covers nearly five per cent of the entire moon's surface – which is equivalent to a crater bigger than Russia on Earth.

Enhanced-colour images from NASA's Cassini probe have recently highlighted scar-like red arcs across Tethys' surface. These marks must be relatively young because they seem to have formed over old features such as craters. Scientists are not sure what causes the strange red colour, but one theory is that it's the result of chemical impurities in the ice.



Images taken by Cassini in April 2015 revealed mysterious red lines slashed across the moon's surface

Tethys' crater-covered surface is evidence of many violent impact events in its history

How do water bears fare in space?

Take a look at the first animal to survive in outer space

The tardigrade is sturdy enough to handle anything. These small yet robust animals, just half a millimetre (0.02 inches) long, can be found anywhere from the beyond-freezing conditions of the South Pole to the high pressures of the ocean floor. What's more, they can survive more than ten years without food or water, in conditions just above absolute zero to over 150 degrees Celsius (302 degrees Fahrenheit). Scientists call such hardy creatures extremophiles.

Being so tough makes the tardigrade the perfect astronaut and, in 2007, a group of these so-called 'water bears' made the journey into space aboard the European Space Agency's Foton-M3 mission. True to form, these resilient creatures withstood the harsh combination of extremely low pressure, cold temperatures and intense radiation – capable of damaging DNA – with only slight signs of wear and tear when they returned to Earth ten days later. The tardigrade became the first animal to survive exposure to space. Another group of tardigrade astronauts then headed into space onboard NASA's Space Shuttle Endeavour to visit the International Space Station as part of Project BIOKIS, which among other things sought to learn more about how these creatures can naturally defend themselves from the extreme stresses caused by the conditions in space.

Tardigrades, also known as 'water bears', are extremely hardy animals

What are temperatures like in space?

What are the hottest and coldest temperatures in space, and where can we find them?

Absolute zero

-273.15°C (-459.67°F)

The lowest temperature possible, zero degrees Kelvin.

Elements

-272.2°C/-457.96°F

Lowest freezing point

Helium will remain liquid right down to near absolute zero.

-40°C/-40°F

Equilibrium

The point at which both the Celsius and Fahrenheit scales have the same value.

-38.83°C/-37.89°F

Mercury freezes

Your thermometer will be useless in the depths of an Antarctic winter.

0°

Space tech

Earth

450 picokelvin

Coldest recorded temperature

A team of scientists from MIT cooled sodium gas to a fraction above absolute zero.

-93.2°C/-135.8°F

Coldest place on Earth

This was measured in eastern Antarctica by a NASA satellite, so is not an official Guinness world record.

Celsius: -250, -200, -150, -100, -50, -40

Fahrenheit: -400, -328, -200, -148, -40, 0, 32

Solar System

-240°C/-400°F

Lunar craters

The Moon is cold enough anyway, but there are craters on its surface in permanent shadow that never rise above this temperature.

-48°C/-54°F

Coldest brown dwarf star

Sub-stellar objects can achieve surprisingly low temperatures, including this record-breaking neighbour of ours that is just 7.2 light years away.

0°

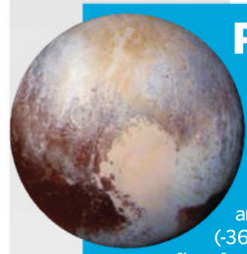
Milky Way

-272°C/-458°F

Deep space refrigerator

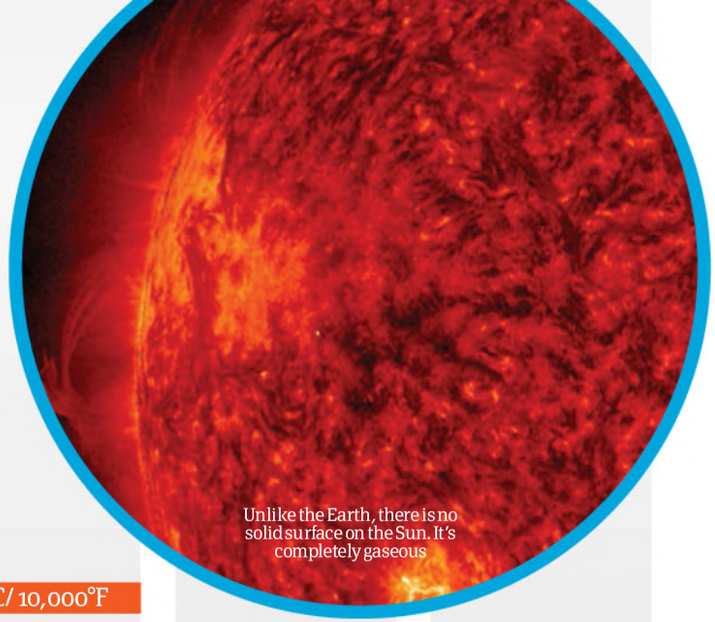
The Boomerang nebula 5,000 light years from Earth, is the coldest natural place in space.

Universe



Pluto's icy heart

From a distance of 450,000 kilometres (280,000 miles) away, New Horizons' Long Range Reconnaissance Imager (LORRI) took four photos to create this composite colour image of Pluto, revealing some curious details. The heart-shaped Tombaugh region (named after the astronomer who discovered Pluto in 1930) is split into two lobes in this image, and it's thought that temperatures as low as -223 degrees Celsius (-369 degrees Fahrenheit) cause nitrogen to precipitate as snow and flow from one side of the region to the next in massive glaciers. The team at New Horizons mission control also think that this vast area acts as a kind of reservoir that feeds both its geological and atmospheric activity.



Unlike the Earth, there is no solid surface on the Sun. It's completely gaseous

-1,538°C/-2,800°F

Iron melts

Under intense pressure, such as at the Sun's core, iron will remain in a liquid state even at extreme temperatures.

2,200°C/3,992°F

Atmospheric re-entry

The heat shield on NASA's new Orion capsule will protect its crew from blistering temperatures when re-entering the Earth's atmosphere.

3,093°C/5,600°F

Rocket boosters

The temperature within the booster of NASA's Space Launch System – the most powerful rocket booster ever built – during tests.

70.7°C/159.3°F

Hottest place on Earth

The Lut desert in Iran achieved this record in 2005. It was measured by satellite.

Heat of the Big Bang

In the first few moments of its formation, the universe was pretty toasty to say the least, with a temperature in excess of four trillion degrees Celsius (7.2 trillion degrees Fahrenheit). The universe was so hot and dense that protons and neutrons could not exist, but their constituent elementary particles formed a quark-gluon plasma. This so-called "quark soup" was 250,000 times hotter than the Sun's core, but it cooled as the universe expanded. At 100 seconds after the Big Bang, the universe was at one billion degrees Celsius (1.8 billion degrees Fahrenheit), but it took 380,000 years before the first hydrogen and helium atoms could form.

5.5 trillion°C/ 9.9 trillion°F

Hottest recorded temperature

This gong goes not to a star or even a supernova, but was briefly generated by the man-made particle accelerator, the Large Hadron Collider.

5,500°C/ 10,000°F

Surface of the Sun

Hot enough to boil iron.

24,000°C/ 43,232°F

Core of Jupiter

The immense pressure at Jupiter's core from this massive planet, makes it a massive five times hotter than that of the Sun's surface.

15,000,000°C/ 27,000,000°F

Core of the Sun

Not surprisingly, this is the hottest place in the Solar System, where each of the fusion reactions take place.

55,000,000°C/ 99,000,032°F

Supernova gas

The energy of a supernova can heat the gas surrounding it to blistering temperatures.

100 billion°C/ 180 billion°F

Core of a newly-formed neutron star

Massive stars that collapse sometimes leave behind these incredibly hot and dense remnants.

°C	°F
50	
100	212
150	300
200	392
400	
600	
800	
1,000	1,000
2,000	1,832
3,000	5,000
4,000	
5,000	
6,000	
7,000	
8,000	
9,000	
10,000	10,000
100,000	100,000
1 million	1 million
10 million	18 million
100 million	180 million
1 billion	18 billion
1 trillion	1.8 trillion
1 quadrillion	1.8 quadrillion
1 quintillion	1.8 quintillion
1 sextillion	1.8 sextillion
1 septillion	1.8 septillion
1 octillion	1.8 octillion
1 nonillion	1.8 nonillion
1 decillion	1.8 decillion

Planck temperature

142,000,000,000,000,000,000,000,000,000,000°C (255,000,000,000,000,000,000,000,000,000,000°F)

The hottest (theoretical) temperature of matter achievable.

What would happen if the ISS had to be evacuated?

In case of emergency, astronauts on the International Space Station can take refuge or return to Earth on board the Soyuz escape capsules. One or two Soyuz spacecraft remain docked with the station at all times, with each accommodating up to three people. Since the ISS' launch in 1998, its crew have never had to make an emergency return to Earth. In January 2015, a suspected ammonia leak forced American astronauts to shelter temporarily in the Russian section of the ISS. Close encounters with space debris have also forced crew to move to Soyuz as a precautionary measure three times, but no collisions occurred.

Is there sound in space?

Sound exists as waves that travel through air, but in space there's no air through which these waves can travel. However, in 2013 a NASA physicist announced that he had recorded sounds in interstellar space. Don Gurnett used an instrument that detects the electromagnetic vibrations that electrons make as they travel through plasma. They aren't sound waves, but they do pulse at similar frequencies. Once the data was recorded and processed, it could be heard as sound. Gurnett was seeking proof that Voyager 1 had left the heliosphere. It picked up audible tones that were very low at around 300 hertz as it travelled inside, thanks to bursts of plasma called solar storms. Once the ship left the heliosphere and began travelling through interstellar medium, the frequency changed to between two and three kilohertz because the gas there is denser. So there is not true 'sound' in space, but you can hear something if you have the right knowledge and instrumentation.

How do we measure the distance to galaxies?

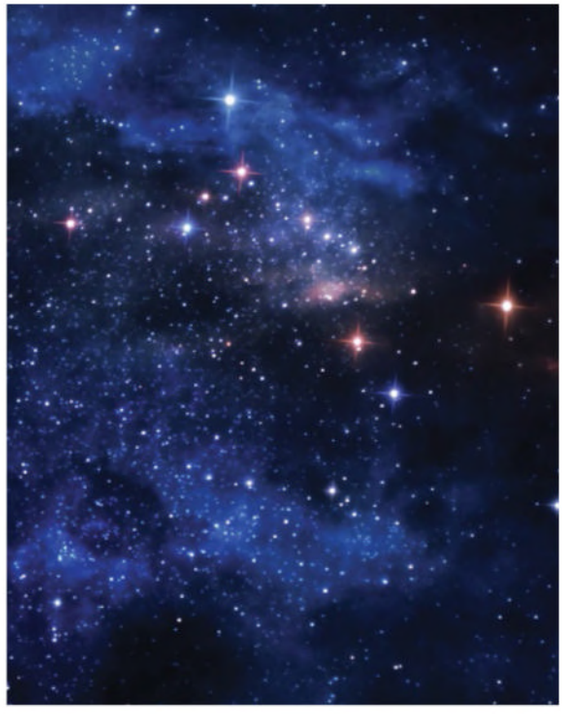
Astronomers estimate the distances to far-away galaxies by measuring the brightness of their stars. The easiest way of doing this is to find a special type of star called a Cepheid variable, whose brightness varies over time. US astronomer Henrietta Leavitt discovered over 100 years ago that the period of these fluctuations relates to Cepheid variable stars' true brightness. By comparing the star's true brightness to how bright it appears from Earth, its distance can then be calculated. Edwin Hubble used this method in 1923 to make the first accurate measurements of how far away the Andromeda galaxy is.

Why can't we feel the Earth's spinning?

You can! The Earth's rotation generates a centrifugal force pulling upward, acting to partially balance out the force of gravity pulling us down, but it's very subtle. At the equator, you weigh 0.346 per cent less than at the poles. That's a difference of only about 250g (8.8oz). The Earth's rotation also causes the Coriolis effect, which deflects the wind in opposite directions in the northern and southern hemispheres. Westerly or southwesterly winds in Britain are due to the Coriolis effect, so you could say you feel the Earth spinning when the wind in your face is from the west or southwest.

How do we know dark matter exists if we can't see it?

Nobody has seen dark matter, but astronomers can detect its presence from the gravitational pull it exerts on other objects, such as stars or galaxies. Dark matter has mass but does not emit or absorb electromagnetic radiation, so it is invisible to telescopes. But the movements of distant galaxies suggest that something with a very large mass is altering their paths by exerting a gravitational force on them. We know relatively little about dark matter, but some believe it could be made up of a new type of subatomic particle called a WIMP (weakly interacting massive particle), although no experiment has yet proven that these exist.



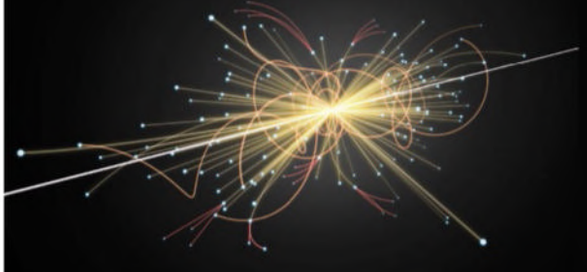
How long could we survive if the Sun died?

If the Sun suddenly died, Earth would be transformed into a cold, dark, lifeless planet in a matter of weeks or months. Without the Sun's energy, no photosynthesis could occur, spelling the end for all plant life within weeks. The Earth's surface temperature would drop off, reaching temperatures below freezing within a few days. With no plants around, plant-eating species would be next to go as they exhausted food supplies. If they could endure the cold, meat-eating species including humans could survive for a while, although their food would soon run out too. From then onwards, how long humans could survive for would depend on their ingenuity and technology. A nuclear fusion reactor for instance, might enable us to sustain ourselves. However, in reality, the Sun's death will occur over millions of years and our star will first increase in intensity and dry out the planet's water, ending all life on Earth long before its own death.

Why can we see the Moon in the daytime?

The Moon is the second-brightest object in the sky and incredibly reflective of the Sun's rays. This means the reflected light can penetrate the scattered blue light of the sky. Though it may seem that the Sun rises in the east while the Moon sets in the west, the Sun and the Moon are only opposite each other in the sky when the Moon is at its full stage. In theory, the Moon is almost always visible in daytime, except when it's too close to the Sun (during a new moon) or too far away (during a full moon).

What is the smallest thing in the universe?



The concept of size breaks down at the tiniest scales, but scientists think the smallest possible size for anything in the universe is the Planck length, about a millionth of a billionth of a billionth of a billionth of a centimetre across!

How long could a stranded astronaut survive on the Moon?

How long a stranded astronaut could survive on the Moon would depend very much on the supplies they had with them, particularly oxygen. While the average human can survive for a few weeks without food and about three days without water, just 16 minutes of oxygen deprivation typically leads to irreparable damage to the brain and ultimately death within 30 minutes. The longest Moon mission to date was Apollo 17, during which astronauts spent 75 hours on the lunar surface. Had their lander been unable to return into orbit, they would only have had enough oxygen to last them a few days. If we return to the Moon for a longer mission, astronauts may extract water and oxygen by melting ice hidden deep inside the Moon's craters, allowing them to survive for much longer.

Why do stars twinkle?

Stars twinkle when it appears there are variations in their brightness. Astronomers call this phenomenon atmospheric scintillation, and it's caused by motion in the atmosphere. Specifically, changes in atmospheric temperature cause small fluctuations in the air's density. As starlight passes through the atmosphere, it's refracted, or slightly alters direction, creating a twinkling effect. Atmospheric scintillation is more obvious when viewing stars closer to the horizon, because there's a thicker layer of atmosphere.

Astronomers compensate for atmospheric scintillation by using special adaptive optics on the most sophisticated telescopes. Space-based observatories like the Hubble also allow us to view stars and other objects without atmospheric scintillation.

Transport


QUANTUM OF THE SEAS

What is the future of commuting?

Explore the cutting-edge technology set to change the way we travel

How long do you spend commuting every day? The average journey time is a soul-sucking 60 minutes, which amounts to over a year of our lives travelling to and from work. Whether it's via road, train or even sky, the commuter experience is blighted by traffic and human or technological errors, leading to delays and expensive fares to supplement archaic modes of transport.

However, the daily slog could be about to change for the better. Thanks to a raft of new technology, we'll see vast improvements to the speed and safety of a commute over the next 50 to 100 years, through improving current transit systems and implementing entirely new modes of transport in the future. These range from faster, more efficient bus services, to sophisticated capsule-based transport that will turn a three-hour journey into a thirty-minute intercity blast.

The future of commuting will also benefit the environment thanks to the development of cleaner, greener vehicles. Electric and hybrid engines are an increasingly popular choice in passenger cars, and the technology is transcending into other forms of transport including motorbikes, buses and even helicopters. This means we'll be producing fewer emissions on our journey to work and we won't be relying on the Earth's diminishing supply of oil to power our various forms of transport. In fact, some forms of transport are likely to produce more energy than they actually use!

Of course, electricity isn't the only source powering commuter vehicles both now and in the future. Innovative forms of travel include linear electric motors for Elon Musk's Hyperloop and maglev technology for Israel's skyTran. We also can't forget the 'number two' Bio-Bus in the UK that's currently transporting passengers between the cities of Bath and Bristol, thanks to the biomethane gas produced from human waste!

No matter what way you look at it, the international workforce of the future has little to fear. They'll be able to relax, sipping coffee as their autonomous car does all the steering, or reclining in a levitating pod that soars above the city. Over the next few pages, take a glimpse into the exciting future of travel but in the meantime, always remember to mind the gap between the train and platform edge!

Building better buses

Bus rapid transit, or BRT, is billed as the future of urban transport. The system aims to efficiently ferry passengers around busy urban environments in a cost-effective way, and BRT vehicles travel on dedicated bus-only lanes that are segregated from regular vehicle carriageways, reducing delays due to traffic. All bus stop platforms are at the same height as the floor of the bus for easy access for wheelchair and pram users, and passengers pre-pay for the bus electronically; significantly reducing the amount of time a bus remains stationary at stops. This means BRT can provide a speedier service, ensuring commuters spend less time in the place they don't want to be – the bus.

Signal priority
Some rapid bus systems use signal priority transmitters to hold a green light long enough for the bus to get through an intersection.

Bus stop platform
These are the same level as the bus floor, making it easier for passengers to get on and off.

New and improved Underground systems

The London Underground is a vital transport network for Britain's capital city, and Transport for London has plans in place to improve the services for its customers. All-new trains are being rolled out on the Piccadilly Line, with the Bakerloo, Central, and Waterloo and City lines following shortly after. The new trains will be air conditioned to make journeys more comfortable, with walk-through carriages to allow for extra room during peak periods of travel. The lines' signalling systems will also be upgraded, helping to eliminate delays. The introduction of a 24-hour service for central London is the first step to improved commutes for Londoners.

The new train design for London promises to deliver faster, more frequent journeys

Driverless pods

These small electric vehicles call on the same cool technology piloted by other driverless car projects, using sensors, lidar and navigation equipment to transport one or two passengers autonomously to their destination via road or pavement. Think this is a technological advancement of the future? Think again. Driverless pods are already being trialled in several UK towns and cities including Oxford and Milton Keynes.

Driverless pods are currently spearheading the automotive industry's autonomous vehicle push

Off-board ticketing
This enables customers to pay for their bus tickets before they get on, ensuring the bus can get moving quicker again after a stop.

Doors
As customers have already paid for their journey at the stop, they can quickly board the bus using any of its doors.

Engines
Many BRT systems are powered by hybrid diesel-electric engines to reduce pollution.

Mod cons
Rapid-transit buses can feature free on-board Wi-Fi and reading lights, as well as high-back chairs and footrests for comfort.

Bike rack
Some buses have built-in bike racks inside, making the bus a convenient commute option for cyclists too.

Seating
Seats can be positioned to face inwards, providing more legroom and extra standing room for commuters.

Zero emission motorbikes

They're the ideal form of transport to zip one or two people at a time through busy city streets, but internal combustion-engine motorcycles are still damaging the environment in the same way cars do. However, with electric car sales on the rise, the same technology is being applied to their two-wheeled counterparts with the introduction of eco-friendly electric motorbikes. Some models can offer an impressive range of up to 300 kilometres (185 miles) per charge, which is ample for cutting through the traffic-laden city streets.

The Hyperloop

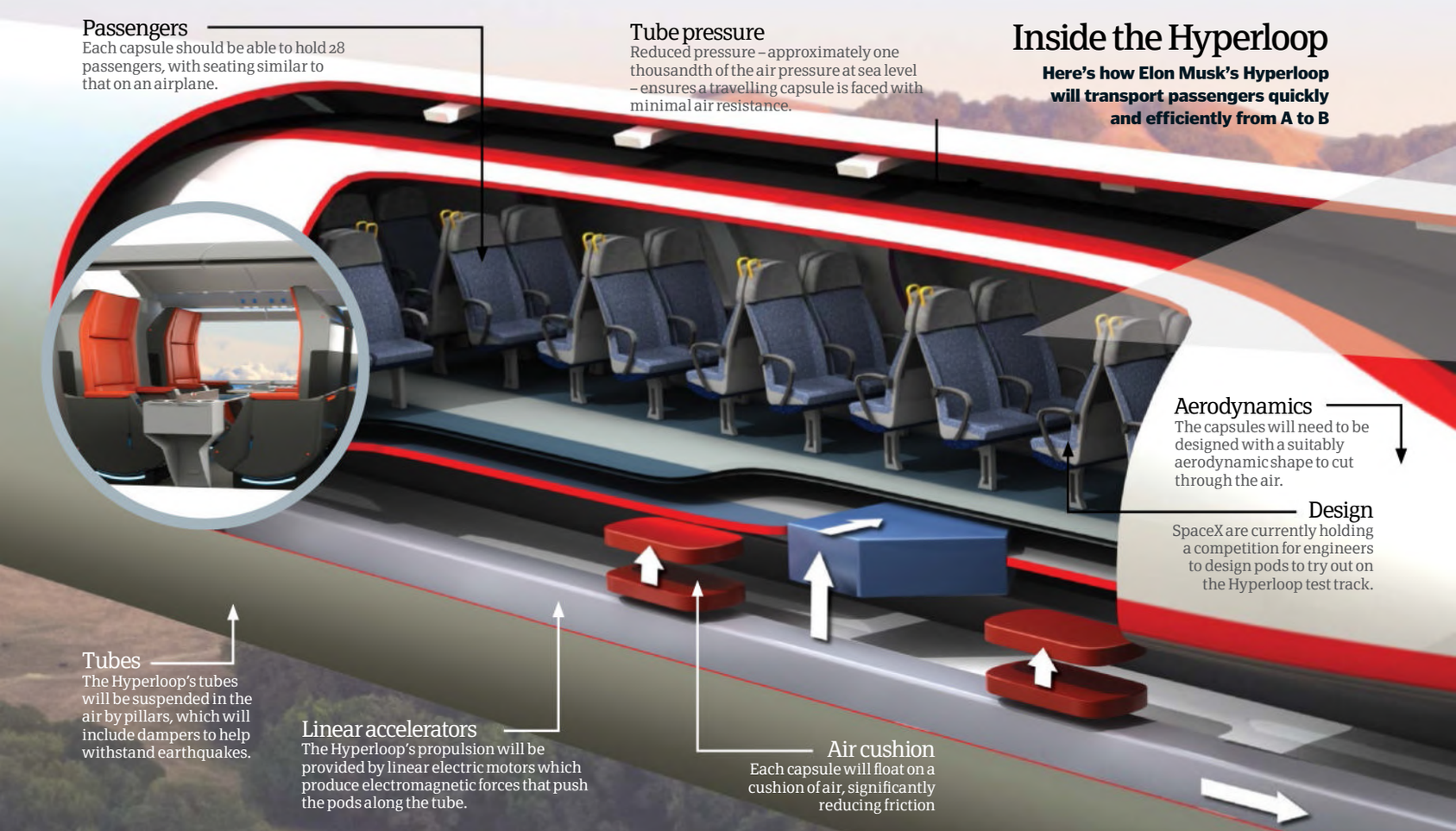
Elon Musk's fascination with revolutionising the way we travel doesn't just include the electric Tesla road vehicle or SpaceX rockets. The entrepreneur's most innovative idea yet focuses on a high-speed super shuttle called the Hyperloop. This Futurama-style tube concept is billed as a high-speed transport system for both people and cargo, capable of whizzing between San Francisco to Los Angeles – a total distance of around 600 kilometres (372 miles) – in just 35 minutes. The unconventional design involves pods travelling through a tube at almost the speed of sound. To achieve such an incredibly quick journey between the two Californian cities, the Hyperloop's tubes will be depressurised to significantly reduce atmospheric drag on the pods as they zip through. Musk ruled out using a complete vacuum, however, since this would be difficult to maintain and even so much as a tiny crack in the tube would completely stop the whole system working.

The pods will have aluminium ski-like fixtures that will have high-pressure air pumped through them, allowing the capsules to levitate on a cushion of air, similar to an air hockey table. These skis will pass through tracks of linear induction motors positioned throughout the tube which will electromagnetically accelerate or decelerate the pods as required.

An eight-kilometre (five-mile) test track of the Hyperloop system is due to be built in California next year. If the project is a success, we could soon see a super-quick form of transport for people and goods that doesn't cost lots to run, making Hyperloop one of the most exciting advancements to occur in the travel industry.

Inside the Hyperloop

Here's how Elon Musk's Hyperloop will transport passengers quickly and efficiently from A to B



Passengers
Each capsule should be able to hold 28 passengers, with seating similar to that on an airplane.

Tube pressure
Reduced pressure – approximately one thousandth of the air pressure at sea level – ensures a travelling capsule is faced with minimal air resistance.

Aerodynamics
The capsules will need to be designed with a suitably aerodynamic shape to cut through the air.

Design
SpaceX are currently holding a competition for engineers to design pods to try out on the Hyperloop test track.

Tubes
The Hyperloop's tubes will be suspended in the air by pillars, which will include dampers to help withstand earthquakes.

Linear accelerators
The Hyperloop's propulsion will be provided by linear electric motors which produce electromagnetic forces that push the pods along the tube.

Air cushion
Each capsule will float on a cushion of air, significantly reducing friction

A taxi service in the sky

Personal helicopters aren't the only next-gen form of travel whisking passengers away from street level. SkyTran, which has a pilot project currently in development in Israel, is a monorail-like system with pods suspended six to nine metres (20 to 30 feet) above the ground and provides high-speed, low-cost transport for its users. Passengers simply summon a pod to a station via an app on their smartphone and it takes them where they want to go. The system works using maglev technology which utilises magnets in the rail to levitate the two-person pods so they are not in direct contact with the track, reducing friction. The cutting-edge technology, developed with NASA's Ames Research Center, means that the pods generate their own levitation as they move, only requiring an initial burst of power to start and stop. A 500-metre (1,640-foot) test track will be built at the campus of Israel Autospace Industries, where the pods will be able to reach speeds of up to 70 kilometres (43.5 miles) per hour. If the trial is successful, this all-new form of transport will be installed in the heart of Tel Aviv, before being introduced to cities across the world.

SkyTran's pilot project will demonstrate a network of high-speed, low-cost transport

Personal helicopters

Traffic is swelling on roads around the world and in Brazil the wealthy are looking to avoid this altogether – by taking to the skies in personal helicopters. As such, novel designs such as the Volocopter are becoming increasingly popular among the urban elite. Key to the success of vehicles like the manned Volocopter, which can carry up to two passengers at a time, is that they are capable of a vertical take-off or landing, making it very useful in tightly packed cities where space is at a premium. The Volocopter is powered by electric motors, making it quieter and more environmentally friendly than a conventional helicopter. The lack of an internal combustion engine also eliminates the vibrations and the high noise level associated with helicopters, meaning the Volocopter is much more comfortable for its occupants.

German company e-volo's Volocopter is an electrically powered VTOL aircraft

Solar power

The Hyperloop looks set to harness the Sun's energy by installing solar panels along the roof of the tube.

Speed

The capsules will whiz through the Hyperloop at a top speed of about 1,223km/h (760mph) – just below the speed of sound.

Air compressor

A large compressor fan will be mounted to the front of each capsule to help direct air toward the back and out of the pod's path.

Journey times from LA to San Francisco

What is an AirBoard?

Meet the smallest one-person aircraft in the world

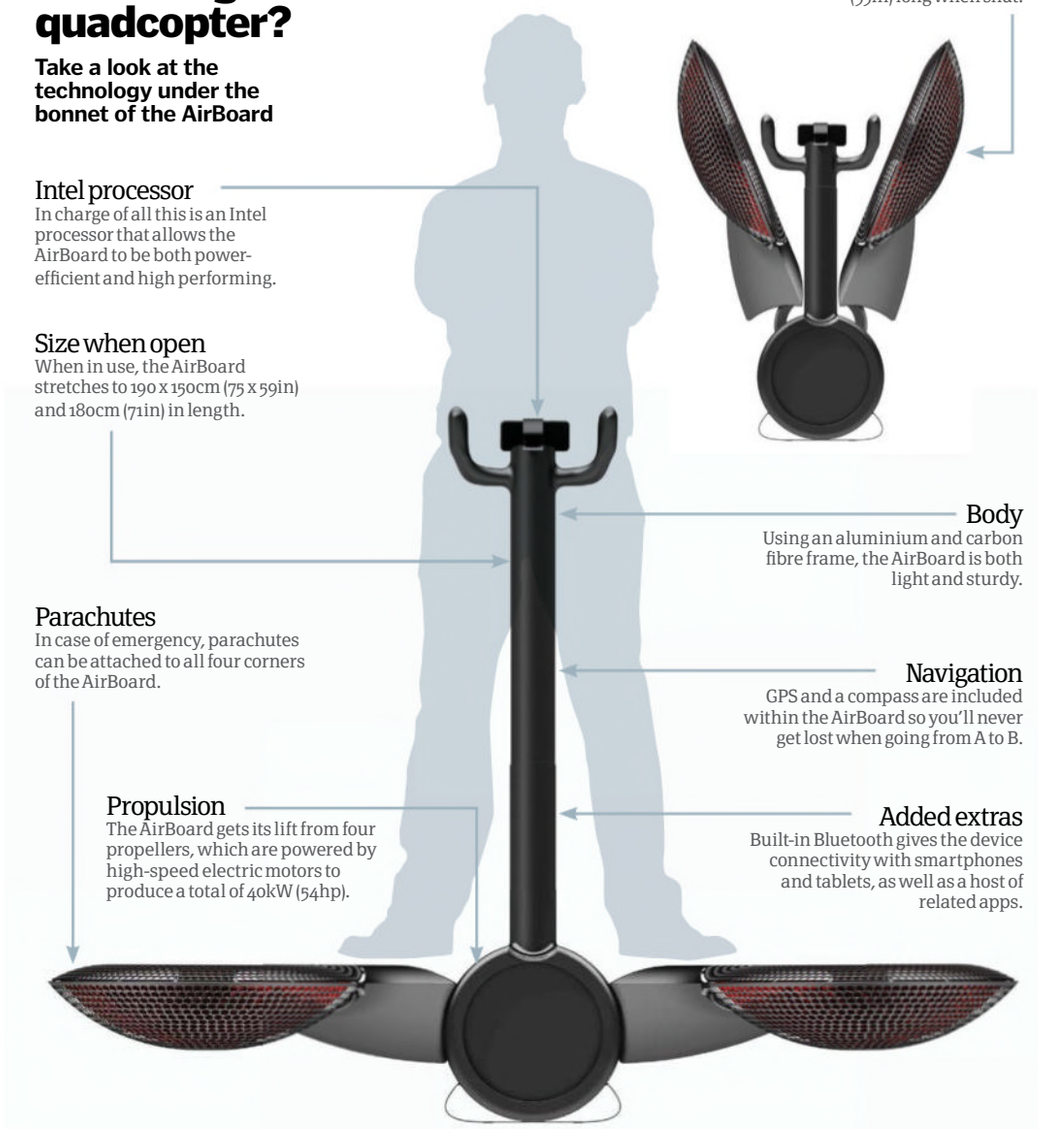
Ever wanted to fly but don't have the time or money to train as a pilot? The new AirBoard could be the answer. The smallest one-person aircraft in the world, it can carry the weight of a single person using its powerful battery. The AirBoard is classified as an ultralight quadcopter aircraft and it's small enough to fit in the boot of your car.

Its thrust is provided by four high-speed electric motors that each power a propeller. The drive system is managed by an Intel processor chip that incorporates a ground collision sensor to keep the board at a set height above the ground. This system comes into its own when you take the AirBoard into the great outdoors. Designed for both urban and rural use, the quadcopter will hover over nearly all ground, whether it's a snowy plain, water, rocky terrain or just in the street.

The device is easy to control, requiring the user to merely lean in the direction they want to go. For safety, the board's altitude is limited to a tame 1.5 metres (4.9 feet). The AirBoard's qualities make it ideal for recreational use but its features also make it potentially useful in search and rescue for the emergency services and perhaps even espionage for the military.

What makes an ultralight quadcopter?

Take a look at the technology under the bonnet of the AirBoard



The contenders

More tiny aircraft proving that bigger isn't always better

Messerschmitt Me-328

It may have never made it past the prototype stage, but the Messerschmitt Me-328 is the smallest pulsejet fighter of all time. It would have been used by Nazi Germany as a parasite fighter launched off larger aircraft.

Bumble Bee II

The tiny 2.7m (8.8ft)-long Bumble Bee II is listed by the *Guinness Book Of Records* as the smallest aircraft ever made, but it was sadly destroyed in a crash in 1988.

Bede Bd-5

The Bede BD-5 is considered the smallest civilian jet but not the world's smallest aircraft. Its first flight was in 1971 and despite its 3.8m (12.5ft) length it can reach a top speed of 483km/h (300mph).

XF-85

A prototype parasite fighter like the Me-328, the American XF-85 Goblin was the world's smallest jet fighter. At 2,050kg (4,519lb) when loaded, it is significantly heavier than the civilian aircraft on the list, mainly due to its four machine guns.

How do parking meters work?

Find out how these dreaded machines police our parking 24 hours a day

Since the first parking meter was installed in Oklahoma in 1935, they have spread throughout the world, as cars became the dominant mode of transport. In the UK alone, parking meters provide revenue in the region of £500 million ($762 million) each year, just from on-street parking.

For cash payments, the meter identifies each inserted coin by conducting a set of pre-programmed tests, which include weighing the coin and testing its physical properties using electrical currents or lasers. This helps to distinguish between the different types of metal that are used to create the coins.

In America, the process is often simplified by accepting only one type of coin, most commonly the quarter. Parking meters in the US commonly only monitor one space; modern versions do this with the help of special sensors that use lasers to determine when the space has been vacated. Once it is vacated the clock is automatically reset to zero, so that another car can't use someone else's parking time for free. Individual parking meters are largely being replaced by modern pay-and-display meters, as they take up less space and can be powered by solar energy.

More and more parking meters are now accepting electronic payments, and some even use pre-loaded smart cards

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

How is crop dusting conducted?

Million-dollar planes keep our farms pest- and weed-free

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

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

What's inside the ultimate cruise ship?

Discover the amazing tech on board the latest colossal cruise ships

Cruise ships are getting bigger and bigger, with the latest vast vessels able to transport the entire population of a small town to new and exciting destinations. Cruise line Royal Caribbean International is leading the way when it comes to building the world's largest floating hotels, with their Allure of the Seas and Oasis of the Seas ships taking the top two spots. However, as well as making their ships bigger, they are also striving to make them smarter, with their latest vessels featuring state-of-the-art technology to enhance the cruising experience. The Quantum of the Seas and its sister ship the Anthem of the Seas may 'only' be the joint-third largest in the world, but it's the gadgets and gizmos on board that set them apart from the rest. With robotic bartenders, virtual balconies and a whole host of interactive art on board, these cruise ships offer the ideal holiday for tech fans.

Learn to surf or bodyboard on the ship's top deck

92m (300ft) high

The North Star viewing capsule can put you at eye-level with the Statue of Liberty

This ship is as long as five Boeing 747 jets

347.8m (1,141ft) long

1 Roboscreens

The large venue at the back of the ship is called Two70°, because its floor-to-ceiling glass walls offer 270-degree panoramic views. However, at night, the space is transformed as 18 projectors cast 12K resolution scenes onto the windows. Six 2.5-metre (eight-foot) 'Roboscreens' can also be choreographed to move independently or in unison to enhance the evening's shows.

2 Surf simulator

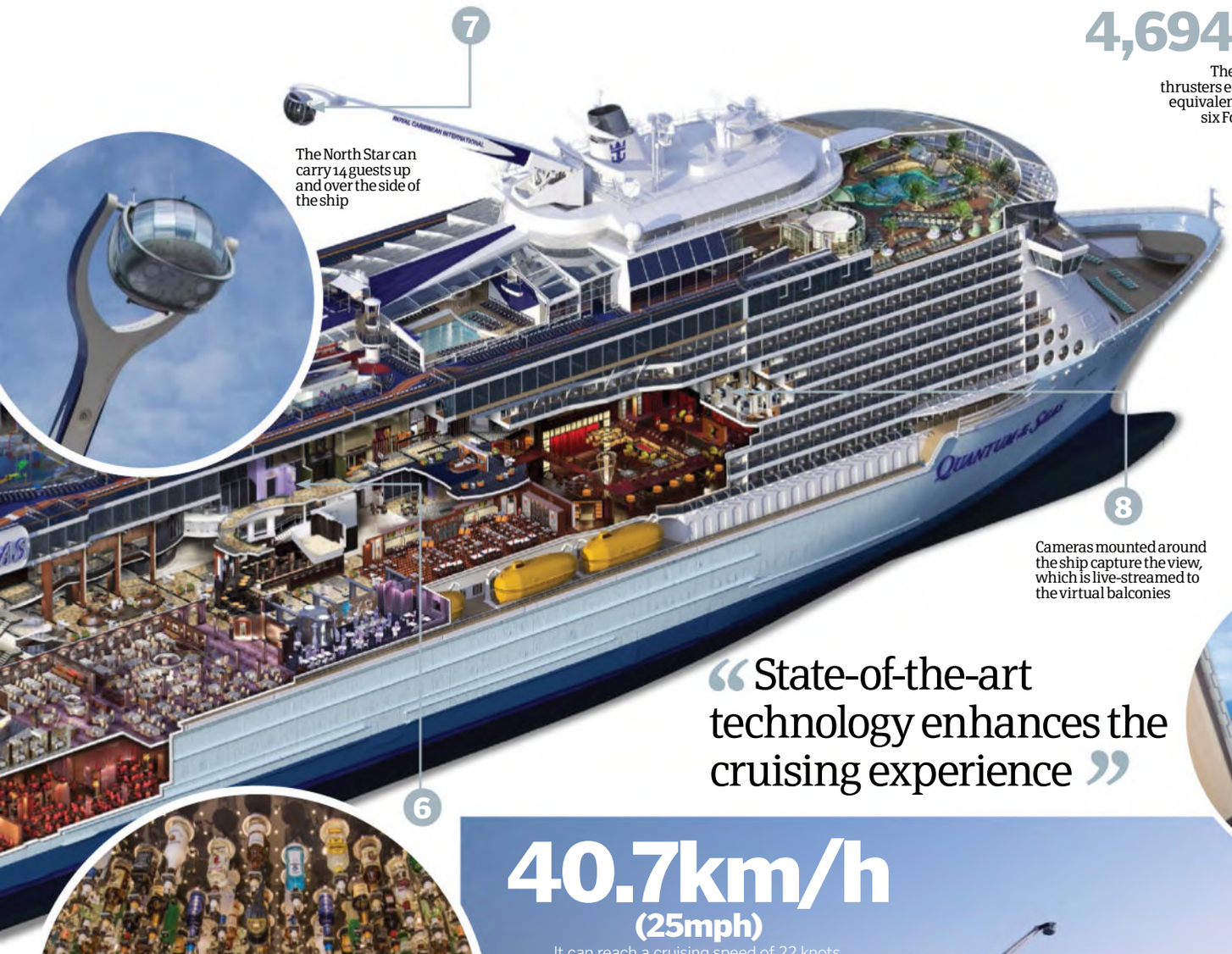
Test your surfing skills on board the ship with the FlowRider surfing simulator. This powerful machine pumps out 272,800 litres (72,057 gallons) of water per minute at speeds of 48-64 kilometres (35-40 miles) per hour, creating a smooth wave that you can surf or bodyboard, even when the surrounding ocean is as calm as a pond.

3 Skydiving simulator

The first skydiving simulator at sea enables you to experience freefall without having to jump out of a plane. The seven-metre (23-foot) tall vertical wind tunnel contains a fan capable of generating windspeeds of around 209-282 kilometres (130-175 miles) per hour, creating a cushion of air on which you can float.

4 App planner

When you climb on board, the free Royal iQ app enables you to track your luggage, so you know when it has been delivered to your cabin. It works by tracking the RFID (radio-frequency identification) tag on your bag, which uses electromagnetic fields to transmit data about your luggage's current location. The app also provides information about what activities you can do both on and off the ship.



4,694bhp

The ship's four bow thrusters each produce the equivalent horsepower of six Formula One cars

The North Star can carry 14 guests up and over the side of the ship

Cameras mounted around the ship capture the view, which is live-streamed to the virtual balconies

"State-of-the-art technology enhances the cruising experience"

40.7km/h (25mph)

It can reach a cruising speed of 22 knots, beating Usain Bolt's average speed

5 Connectivity

Stay in touch with your friends and family back home with the super-fast internet on board. Satellites launched by tech company O3b Networks beam signals directly to the ship, delivering more bandwidth to the Quantum-class vessels than all the other cruise ship in the world combined. This enables you to upload photos, stream video and even compete with gamers all over the world in the Xbox Live suite.

6 Robot bar

Human bartenders have been replaced by robots at the high-tech Bionic Bar. You order your drink via an app on a tablet, choosing from the menu or creating your own concoction from a long list of ingredients. One of the two robot arms will then mix your drink, mimicking a human bartender's action to shake, stir or strain it.

7 Viewing capsule

You can get a breathtaking bird's-eye view of the ship and its surroundings by boarding the North Star viewing capsule. The glass pod is located on the end of a long arm fixed to the top deck. It can lift you 91 metres (300 feet) above sea level to give you a 360-degree view while at sea or in port.

8 Virtual balconies

Even if you can't afford to upgrade to an outside cabin with a balcony, you can still experience stunning views from your room. The interior cabins feature virtual balconies, using two-metre (80-inch) high-definition 4K LED screens to display the sights and sounds of the outside world in real-time.

How do twin-clutch gearboxes work?

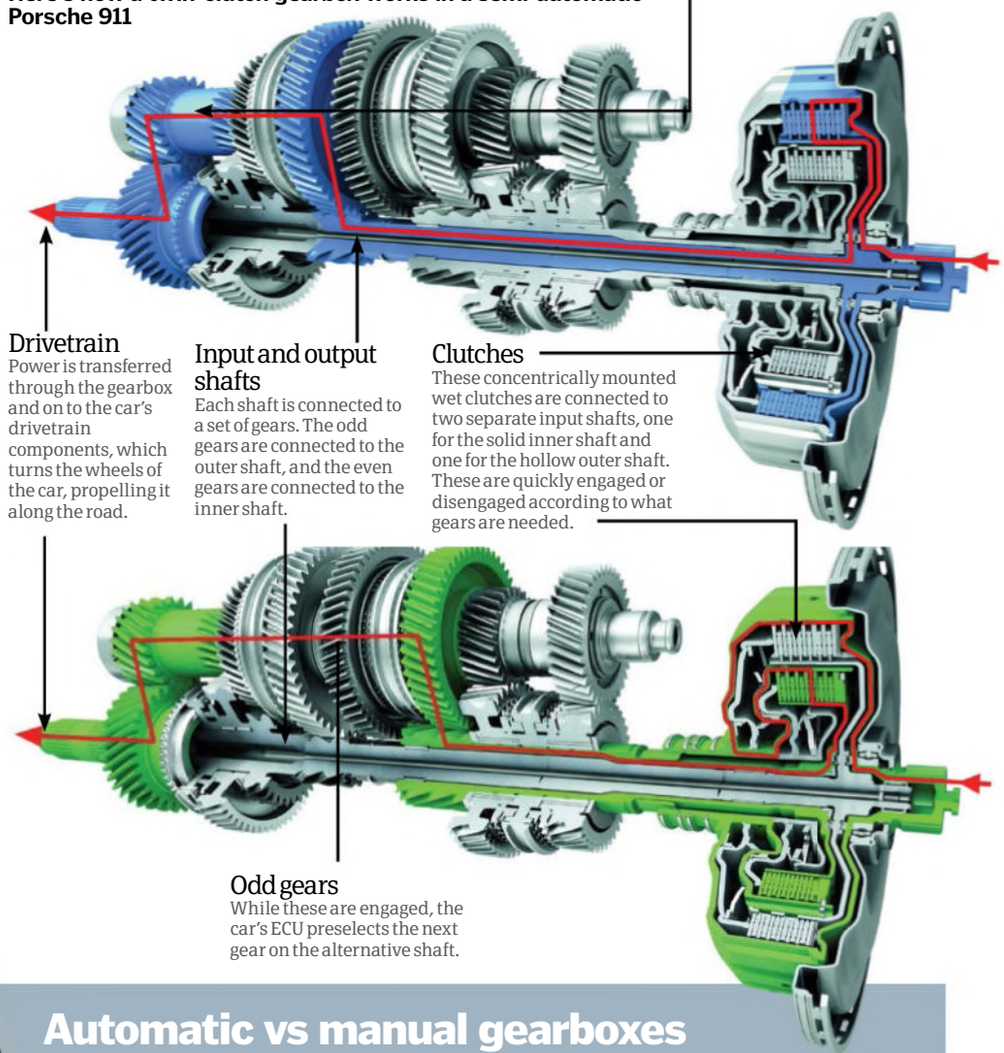
They are a common feature in today's supercars and here's why

As supercars get faster and faster, with 0-100-kilometre (0-62-mile)-per-hour times of less than three seconds, manufacturers are now looking at ways of making gains for their cars to cover even more ground in even less time. An area that has been developed a lot in supercars in recent years are gearboxes, where a lightning-quick gear change is absolutely essential if the car is to maintain linear power delivery when accelerating to 100 kilometres (62 miles) per hour and far beyond.

To provide this super-quick shift, manufactures such as Porsche, Audi and Lamborghini have produced a complex yet exquisite 'double-clutch' semi-automatic gearbox that substantially reduces the time it takes to shift up or down a gear. This technology works by effectively splitting the gearbox in two, with a concentrically mounted clutch on the end of two separate input shafts. The odd gears are on one shaft and the even gears are on the other. When a new gear is selected, the supercar's on-board computer preselects the next gear needed on the other shaft according to driving style and conditions, so when it is time to change gear, the cog in question takes mere milliseconds to engage with the drivetrain, making sure that mighty power from the engine is fed to the wheels as efficiently and quickly as possible.

Inside a twin-clutch gearbox

Here's how a twin-clutch gearbox works in a semi-automatic Porsche 911



Automatic vs manual gearboxes

The purists will always favour the better driver involvement offered from the physical 'throw' action when changing gears with a gear stick, but the reality is that, as cars become ever faster and more powerful, automatic gearboxes are inevitably the future. The reason for this is threefold: they allow for quicker gear changes as we've just discovered, plus they're more economical as the car's on-board computer will always select new gears to keep fuel usage down, while a human can become lazy or forget to change gear according to these parameters. Then there's the safety and comfort factor: as cars produce more power, a bigger clutch is needed to transfer the power to the gearbox, which usually results in a very heavy clutch pedal on supercars. An automatic gearbox takes away the clutch pedal, meaning you can drive the car in comfort without giving your left thigh an excessive workout!

Q&A

What are unmanned ships?

The world's first full-sized autonomous ship will only have drones for company

Named after the famous ship that once took pilgrims from England to America, the Mayflower Autonomous Research Ship (MARS) will have a much lonelier journey. Powered by renewable wind, ocean current and solar energy, it will replicate this historic journey with no crew, using only GPS and onboard collision avoidance systems in order to navigate.

Two sails will enable it to move at 37 kilometres (23 miles) per hour, but on calmer days these will be stowed away so that more light can reach the solar panels. These will then power an electric motor with a top speed of 23 kilometres (14 miles) per hour.

The ship will gather meteorological, oceanographic and climate data using a team of onboard drones, and is due to set sail from Plymouth, UK in 2020, the 400th anniversary of its namesake's voyage. It will take seven to ten days to cross the Atlantic.

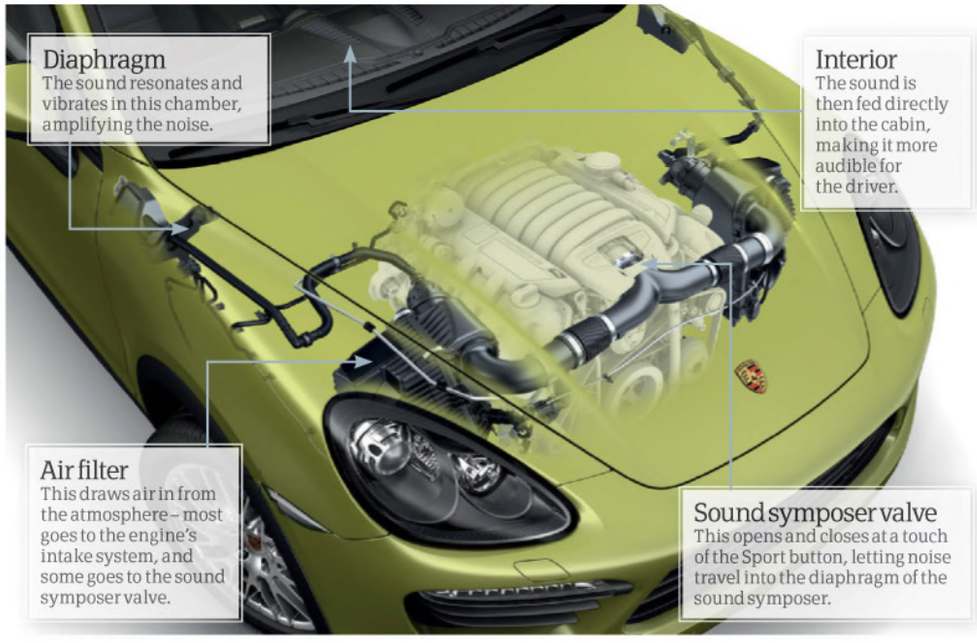
Plymouth University, Shuttleworth Design and MSubs have developed the vessel

What are sound symposers?

These simple devices make sports cars sound even better

As sports car engines have become cleaner, they have also become quieter, particularly as vehicles switch to turbocharged engines in order to keep emissions down. However, some owners still want to hear the roar of that hard-working engine during performance driving, and it's here where the introduction of a sound symposer saves the day.

In essence, a sound symposer projects noise – but not fumes – from the exhaust straight into the cabin of a car. Inside the Porsche 911, an acoustic channel picks up vibrations from the engine, which are reinforced by a membrane and transmitted as sound into the cabin. To deactivate this, drivers can depress the Sport button, which closes a valve in the channel and reduces the roar of the engine.



What's the science behind racing simulators?

These high-tech simulators are almost as good as the real thing

We have all played on driving simulators in arcades or on games consoles at home, but what was once a bit of fun is now a serious business – and a crucial part of a professional racing driver's preparation for any major competition.

The science behind these sophisticated modern-day race simulators lies within the human vestibular system, which comprises the small canals and bones in the inner ear. The utricle and saccule organs in the vestibular system help humans detect linear acceleration in three directions: vertical (for example, gravity), lateral (sway), and longitudinal (surges forward or backwards). In addition, three fluid-filled semi-circular canals are oriented in three planes to sense yaw, pitch and roll. As a person's body is moved about, tiny hair cells in the vestibule and semi-circular canals stimulate the vestibular nerve, helping the brain to interpret nerve impulses resulting from these six primary movements.

This is where the genius of new driving simulators come in: the movements of the simulator are designed to arouse a driver's vestibular nerves, creating a driving experience that's more true-to-life. As well as a real and working dashboard, the simulator is fitted with pedals that are hydraulically weighted the same as the car they're testing, and it's the same for the power steering 'feel' too. As for the graphics, they are displayed on a huge eight-metre (26-foot) screen and have a projection and resolution rate five times faster than that of a multiplex cinema, offering razor-sharp and, crucially, time-accurate images of the circuit that is being tested.

This all means simulators are a great way to get much needed practice on a circuit ahead of a race – particularly if it's a track that the driver has never visited before – and all done in familiar surroundings despite never actually sitting in a car. The accuracy of the facility means that time spent in the simulator is very nearly as good as doing the time in the cockpit itself, ensuring that the driver can enter a race buoyed by as much experience behind the wheel as possible.

Pedals
These feature vehicle-grade hydraulics and haptic actuators for accurate response and feel.

The lifestyle of a pro racing driver

You may think there's little else to the job of a professional racing driver than simply pulling up to the starting line and completing numerous laps of a circuit, but as Porsche's World Endurance Championship driver Nick Tandy tells us, you have to be 'race fit' to be able to pilot a modern race car.

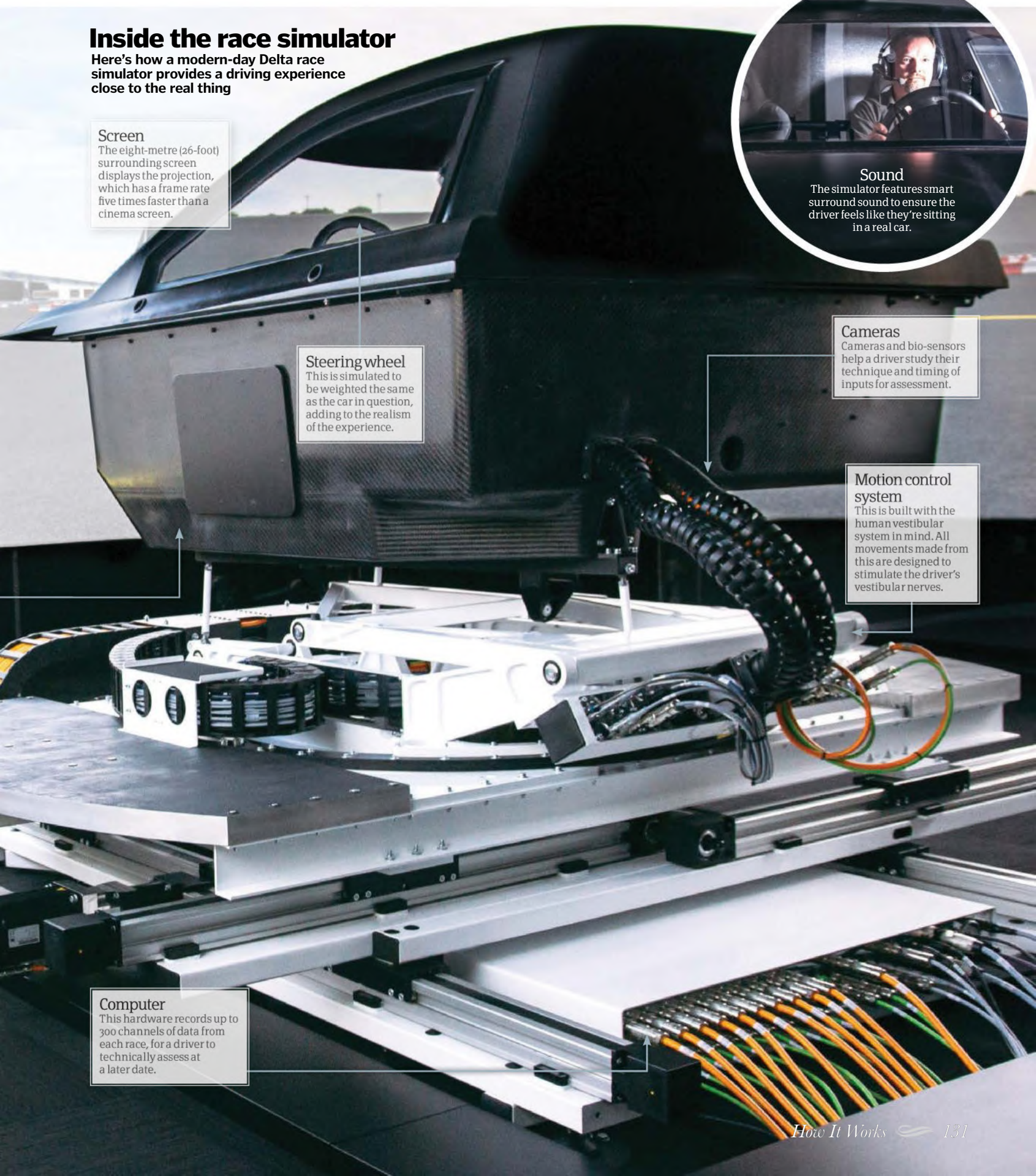
With cars even more powerful and capable of pulling high g-forces through every twist and turn of a race, the driver needs to be mentally and physically fit enough to handle these constraints on the body, particularly in an endurance race such as the Le Mans 24 Hours.

As such, pro drivers have intense fitness regimes and strict diet plans, with performance training to help improve reaction times and their acclimatisation to extreme heat. It doesn't end there, either: tactics are an important part of professional racing and drivers work hard to be attuned to the best setups of their car and driving style in all conditions, during every stage of a race.

Drivers need to be physically fit to withstand intense forces on the track

Inside the race simulator

Here's how a modern-day Delta race simulator provides a driving experience close to the real thing



Screen
The eight-metre (26-foot) surrounding screen displays the projection, which has a frame rate five times faster than a cinema screen.

Steering wheel
This is simulated to be weighted the same as the car in question, adding to the realism of the experience.

Sound
The simulator features smart surround sound to ensure the driver feels like they're sitting in a real car.

Cameras
Cameras and bio-sensors help a driver study their technique and timing of inputs for assessment.

Motion control system
This is built with the human vestibular system in mind. All movements made from this are designed to stimulate the driver's vestibular nerves.

Computer
This hardware records up to 300 channels of data from each race, for a driver to technically assess at a later date.

How do aircraft toilets work?

The powerful vacuum system that flushes your waste at 30,000 feet

The incredibly loud and powerful suction of aircraft toilets might make you jump when you press the 'flush' button, but it is there for a good reason. The conventional toilet you are familiar with wouldn't be practical on a moving jet as the toilet bowl full of water would be likely to spill during turbulence. As this water, with the help of gravity, is required to flush out the waste, another system had to be developed to empty the bowl more effectively.

Until 1982, electric pumps were used to send a blue sanitising liquid into the toilet bowl with every flush and push out the waste. However, this required hundreds of gallons of the stuff to be carried on every flight, taking up lots of weight and space. Nowadays, most aircraft use vacuum toilets, which only use very small quantities of sanitising liquid for the purpose of cleaning the bowl. The waste is removed using powerful suction created by a vacuum in the pipes, but don't worry, unless you are able to perfectly seal the bowl with your backside, you won't get stuck to the seat!

Vacuum toilet tech

What happens to your waste when you go to the loo in the sky?

2. Flush
When the toilet is flushed, a valve underneath opens and the vacuum in the pipes sucks the waste out.

3. Sanitising liquid
At the same time, a small amount of blue sanitising liquid is deposited into the toilet bowl to clean it.

4. Waste tank
The waste and sanitising liquid are sucked into the waste tank and remain there for the duration of the flight.

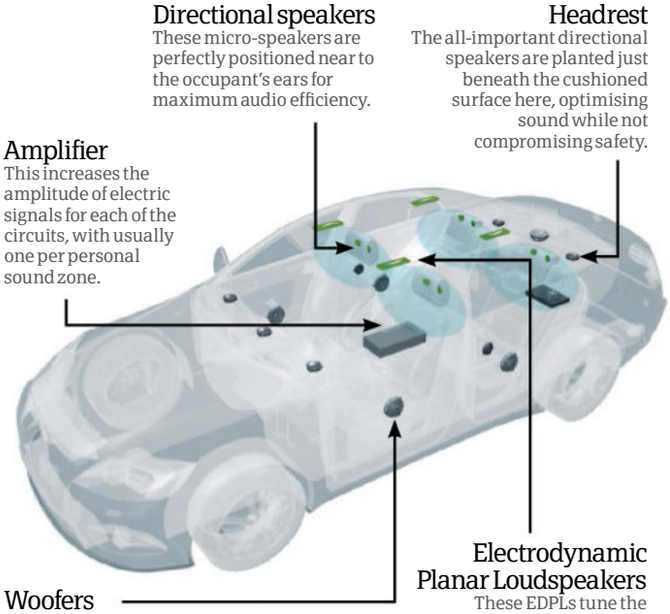
1. Vacuum generator
A pump draws the air out of the pipes and the waste tank to create a vacuum effect.

6. Rinse line
Another pipe accessible from the outside of the aircraft allows water to be pumped into the waste tank to rinse it out.

5. Drain valve
When on the ground, a drain valve on the outside of the aircraft is opened and the waste is vacuumed out of the tank.

How will car audio technology evolve?

Listen to music in your own personal sound zone



Directional speakers
These micro-speakers are perfectly positioned near to the occupant's ears for maximum audio efficiency.

Headrest
The all-important directional speakers are planted just beneath the cushioned surface here, optimising sound while not compromising safety.

Amplifier
This increases the amplitude of electric signals for each of the circuits, with usually one per personal sound zone.

Electrodynamic Planar Loudspeakers
These EDPLs tune the acoustics to ensure the passenger's audio experience is optimised for their location in the vehicle.

Woofers
These amplify the low-frequency bass for each personal sound zone, removing a 'tinny' acoustic effect.

Ever had to endure a car journey with nothing but the tedious resonance of your parents' favourite music for company? Thanks to cutting-edge technology currently being piloted in the automotive industry, passengers of the future could be able to listen to their own music thanks to personal sound zones. The technology works by placing more small yet powerful micro-speakers in the headrest of a seat, so the sound is nearer to the head of each individual passenger – but there's more. A filter matrix then modifies the wave field of the standard car audio speakers and headrest speakers to the desired frequency of the occupant, providing cross-talk cancellation (CTC) against other sounds.

Aside from being able to listen to your own music, this breakthrough in audio technology presents a host of benefits to the occupants of any vehicle. For example, with the sound zones, any navigation prompts to the driver will have little impact on the audio experience of others, and incoming calls can effectively be 'passed' through the car to the intended recipient.

The Immortus will be a 40kW composite roadster, weighing around half a ton

Can cars be solar powered?

Inspired by post-apocalyptic movies, the Immortus can drive on sunshine alone

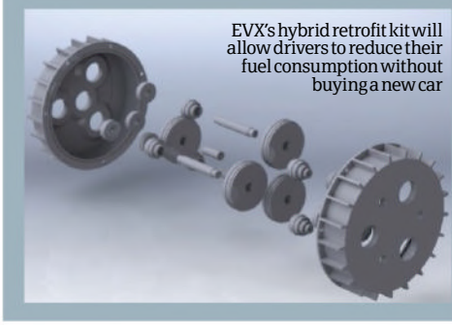
This limited edition, solar-electric sports car is the brainchild of a small electric vehicle company called EVX, which is currently working on a prototype that should be ready by the end of 2016. The car will absorb the Sun's energy via almost seven square metres (75 square feet) of photovoltaic cells spread across its roof, and will also feature a plug-in electric powertrain, complete with a lithium-ion battery pack. Measuring five by two metres (16.4 by 6.6 feet) it will be by no means small, with enough room for two occupants plus hand luggage.

By combining a fully charged battery and the Sun's rays, the Immortus will have a range of over 550 kilometres (342 miles) when travelling at 85 kilometres (53 miles) per hour. However, if you slow the average speed down to 60 kilometres (37 miles) per hour, it will be possible for the Immortus to keep going all day, limited only by the availability of sunshine. Its ability to store power while in motion will be hugely significant, helping it to deliver excellent performance when needed, reaching a top speed of over 150 kilometres (93 miles) per hour with combined electric and solar energy.

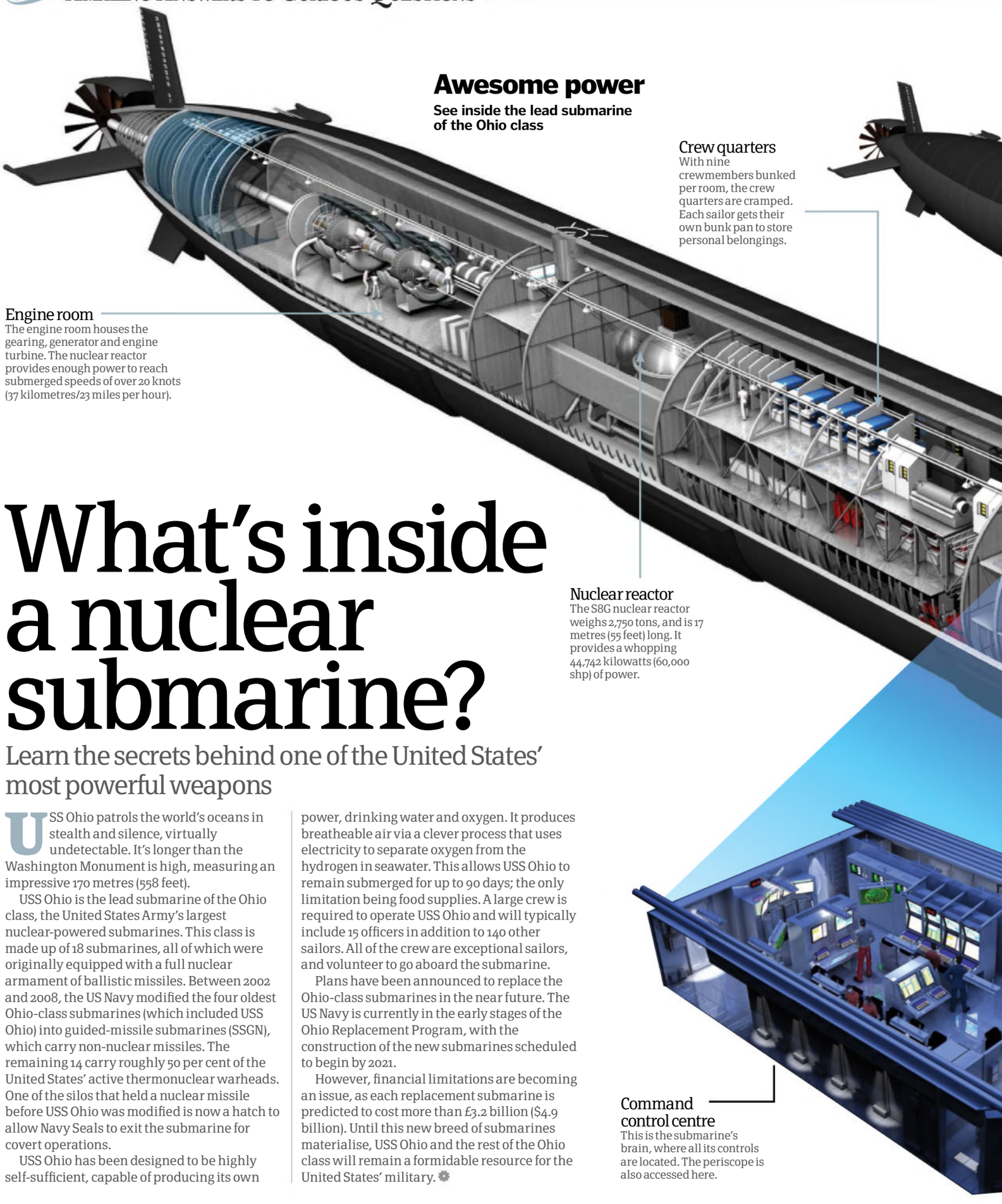
There is still much work to be done before the Immortus can become a reality; EVX are seeking funding of almost £1 million ($1.5 million) in order to start production. Once they have obtained this funding they are expected to make only 100 units, which will retail for an estimated £326,000 ($500,000). At least prospective buyers will save on fuel!

Inspiring future technology

While designing the solar car technology that will feature in the Immortus, EVX have identified several innovations that could be incredibly useful to car manufacturers around the world. One such technology is a hybrid retrofit kit, which will convert petrol-powered vehicles into plug-in hybrids, giving owners the ability to make older cars environmentally friendly. This kit will also increase acceleration after breaking and turn conventional two-wheel drive cars into four-wheel drive. EVX have also theorised a lightweight, air-cooled battery box, which is essential for the Immortus and could soon be applicable to the aeronautic and mining industries, as they are likely to rely on electric technology in the future. The designers also want to develop small cameras to replace wing mirrors, as this will reduce air resistance and make future electric cars even more efficient.



EVX's hybrid retrofit kit will allow drivers to reduce their fuel consumption without buying a new car



What's inside a nuclear submarine?

Learn the secrets behind one of the United States' most powerful weapons

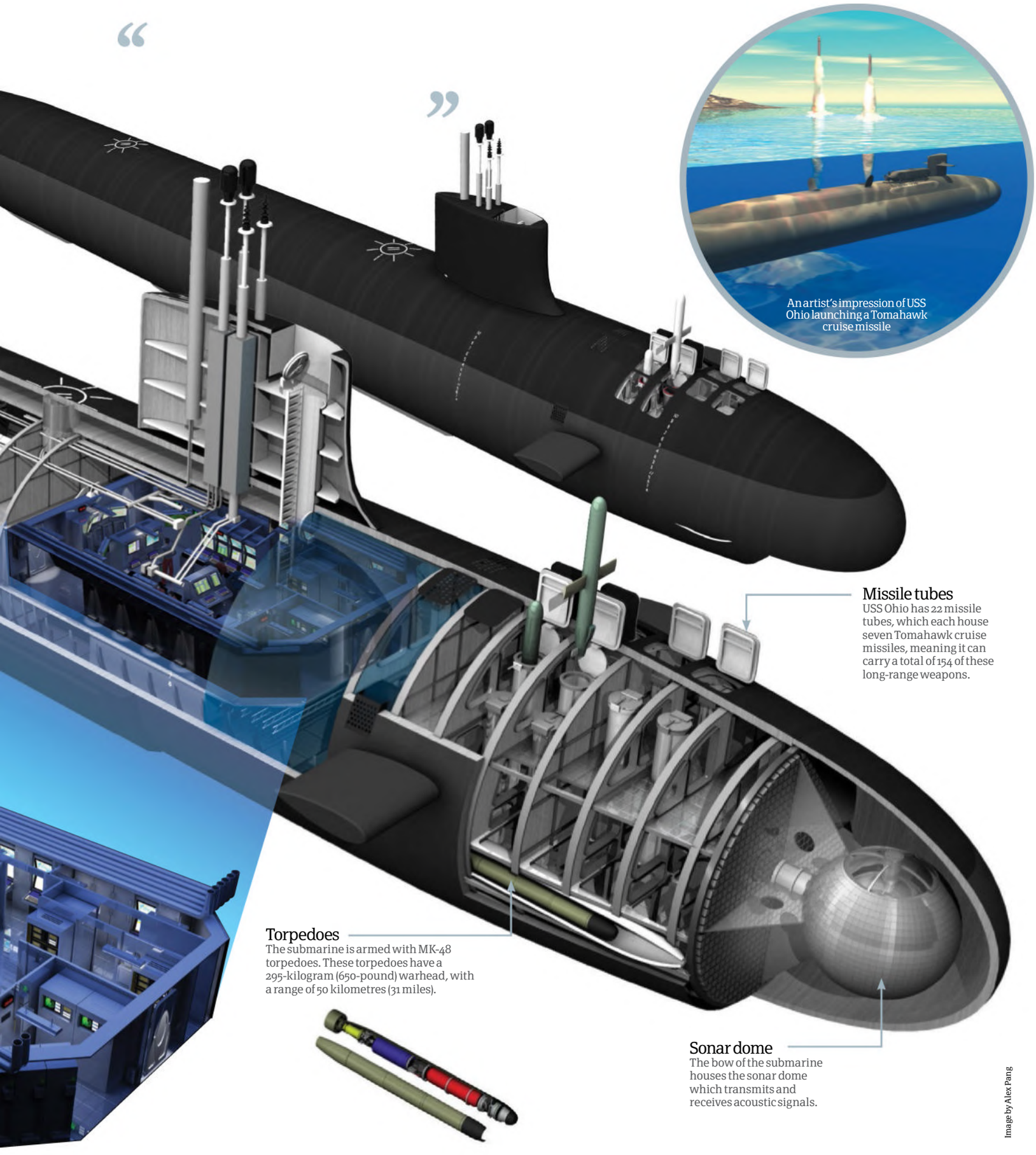
USS Ohio patrols the world's oceans in stealth and silence, virtually undetectable. It's longer than the Washington Monument is high, measuring an impressive 170 metres (558 feet).

USS Ohio is the lead submarine of the Ohio class, the United States Army's largest nuclear-powered submarines. This class is made up of 18 submarines, all of which were originally equipped with a full nuclear armament of ballistic missiles. Between 2002 and 2008, the US Navy modified the four oldest Ohio-class submarines (which included USS Ohio) into guided-missile submarines (SSGN), which carry non-nuclear missiles. The remaining 14 carry roughly 50 per cent of the United States' active thermonuclear warheads. One of the silos that held a nuclear missile before USS Ohio was modified is now a hatch to allow Navy Seals to exit the submarine for covert operations.

USS Ohio has been designed to be highly self-sufficient, capable of producing its own power, drinking water and oxygen. It produces breatheable air via a clever process that uses electricity to separate oxygen from the hydrogen in seawater. This allows USS Ohio to remain submerged for up to 90 days; the only limitation being food supplies. A large crew is required to operate USS Ohio and will typically include 15 officers in addition to 140 other sailors. All of the crew are exceptional sailors, and volunteer to go aboard the submarine.

Plans have been announced to replace the Ohio-class submarines in the near future. The US Navy is currently in the early stages of the Ohio Replacement Program, with the construction of the new submarines scheduled to begin by 2021.

However, financial limitations are becoming an issue, as each replacement submarine is predicted to cost more than £3.2 billion ($4.9 billion). Until this new breed of submarines materialise, USS Ohio and the rest of the Ohio class will remain a formidable resource for the United States' military.



An artist's impression of USS Ohio launching a Tomahawk cruise missile

Missile tubes
USS Ohio has 22 missile tubes, which each house seven Tomahawk cruise missiles, meaning it can carry a total of 154 of these long-range weapons.

Torpedoes
The submarine is armed with MK-48 torpedoes. These torpedoes have a 295-kilogram (650-pound) warhead, with a range of 50 kilometres (31 miles).

Sonar dome
The bow of the submarine houses the sonar dome which transmits and receives acoustic signals.

Image by Alex Pang

What's inside a NASCAR hauler?

How this 18-wheeler transports race cars and more

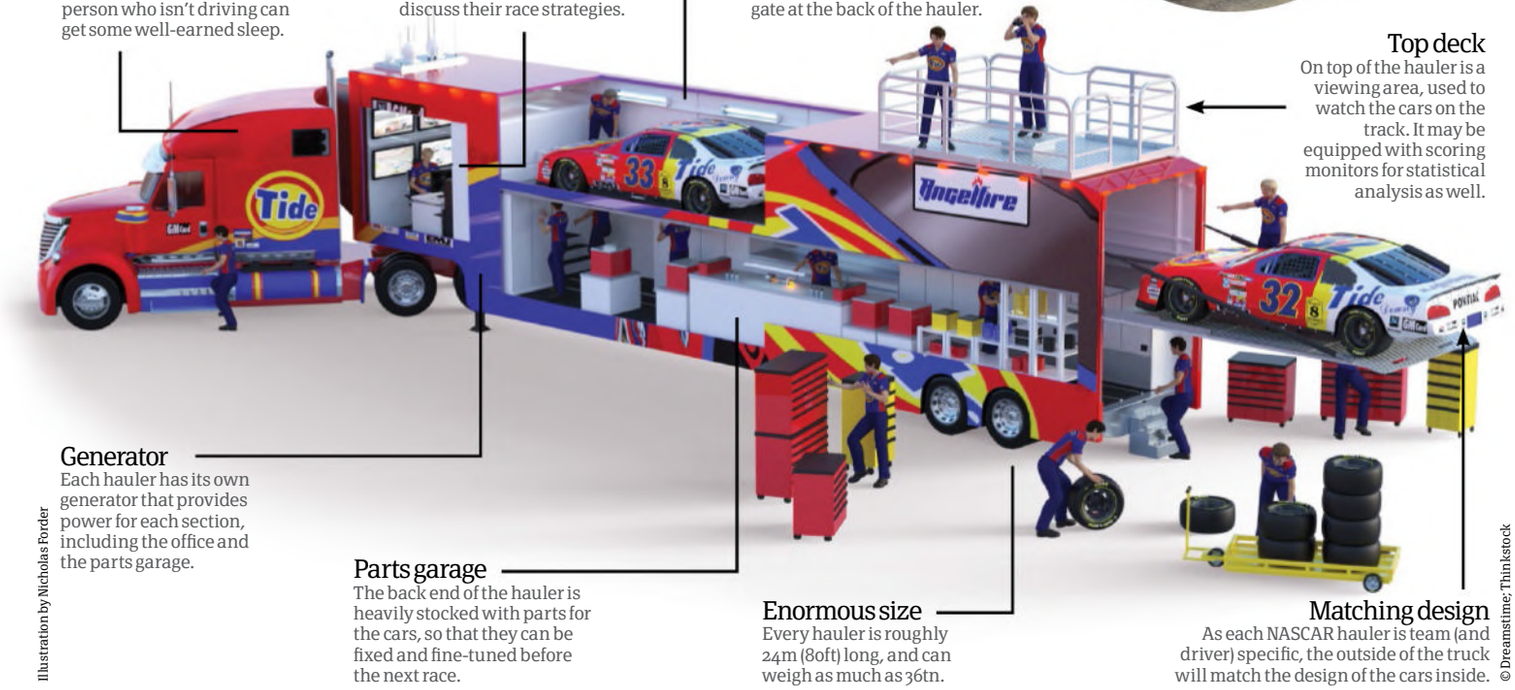
Over the years NASCAR has become a huge part of American sporting culture. Founded in 1947, it now sanctions more than 1,200 races across America, Canada, Mexico and Europe.

Getting the highly specialised race cars from one race to another presents the teams with a problem. You won't see a race car being driven on normal roads, and since the NASCAR races are so spread out across America, they have to be transported in a specialised hauler to each race venue. These haulers do much more than simply transport the cars; they function as repair shops, restaurants, meeting rooms, viewing platforms and storage facilities.

As every racetrack on the calendar is different, each NASCAR team will alter the setup of their cars depending on the conditions. This means that every car has to return to the team's base after each race before it can be transported to the next. Once it gets back to base, every single item on board the hauler is removed, before being either cleaned or replaced and then loaded back on. This equates to around 10,000 items – comparable to packing and unpacking a four-bedroom house every week for 38 weeks a year. Without the haulers, the drivers would have no feasible way of transporting their cars, and would likely be ill-prepared for their next race.

Inside the race shop on wheels

Discover just how much these haulers can store inside them



Sleeper cab
The front cabin has two beds behind the driver and passenger seats, so that the person who isn't driving can get some well-earned sleep.

Fully equipped office
Towards the front of the hauler is the office area, so the team have somewhere to discuss their race strategies.

Car bay
This level of the transporter holds two race cars, which are loaded using a hydraulic lift gate at the back of the hauler.

Top deck
On top of the hauler is a viewing area, used to watch the cars on the track. It may be equipped with scoring monitors for statistical analysis as well.

Generator
Each hauler has its own generator that provides power for each section, including the office and the parts garage.

Parts garage
The back end of the hauler is heavily stocked with parts for the cars, so that they can be fixed and fine-tuned before the next race.

Enormous size
Every hauler is roughly 24m (80ft) long, and can weigh as much as 36tn.

Matching design
As each NASCAR hauler is team (and driver) specific, the outside of the truck will match the design of the cars inside.

Illustration by Nicholas Forder

How does the CYG-11 fly and float?

This clever new craft could change the tide for future travel

The travel industry is no stranger to vehicles that can multi-task when it comes to operating on various terrains and atmospheres. We've previously seen amphibious vehicles or even planes that can land or take off on sea, but the CYG-11 craft has gone one step further by being able to either fly in the air or 'float' on the water's surface. The Chinese-built CYG-11 'seaplane' is able to do this thanks to clever re-engineering of a small propeller plane (which takes care of the flying side of its duties), enabling the craft to 'float' on a cushion of air above the sea.

What this means is that this type of craft offers the opportunity for owners to save on money and space because it means they don't need to purchase both a boat and a plane for their travels. It also opens up a new way of getting to destinations that were previously difficult to reach. The floating aspect of the seaplane works by drawing on the wing-in-ground effect, increasing lift and reducing drag when an aircraft's wings are close to the ground. This is done simply by mounting the wings lower down on the fuselage of the aircraft, enabling the plane to effectively float on a cushion of air.

The CYG-11 craft can reach a top speed of 250km/h (155mph)

What are airless tyres?

Will Michelin's new airless tyre design end the fight against flat tyres?

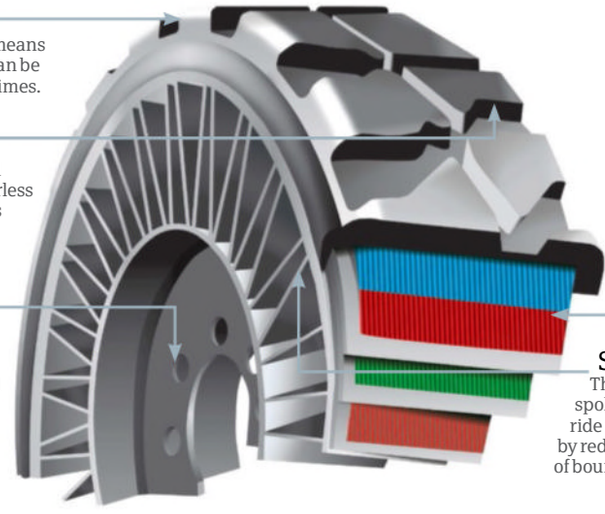
Michelin's airless tyre design promises to put an end to frustrating slow punctures and dangerous high-speed blow-outs. Their new 'Tweel' is a combined wheel and tyre assembly in a single, tough unit, primarily designed for commercial use in landscaping, agriculture and construction. If successful, the designers hope to implement the technology in other vehicles.

Solid, air-free tyres have existed for a while but as they are incredibly hard, the vehicle bounces when travelling over rough terrain. The Michelin Tweel combats this by compressing when driving on rugged roads. Another advantage is that it's much more eco-friendly than current air-filled pneumatic tyres, as it is made of a plastic resin that can be repeatedly recycled. This means these tyres will have very little environmental impact even when they are replaced.

We are many years away from seeing this type of wheel design on road cars, but the prospect of flat tyres becoming a thing of the past will excite all motorists.

Inside an airless tyre

See the features that make the Tweel so durable



How does the Panama Canal work?

This engineering marvel is getting an upgrade a century later

When the Panama Canal first opened in August 1914, many considered it to be the greatest engineering feat ever accomplished. It allowed ships travelling between New York and San Francisco to cut their journey by a colossal 12,669 kilometres (7,872 miles), as they no longer had to go around the southernmost point of South America. Roughly 27 million kilograms (60 million pounds) of dynamite were used to excavate and construct the canal, along with 3.8 million cubic metres (135 million cubic feet) of concrete.

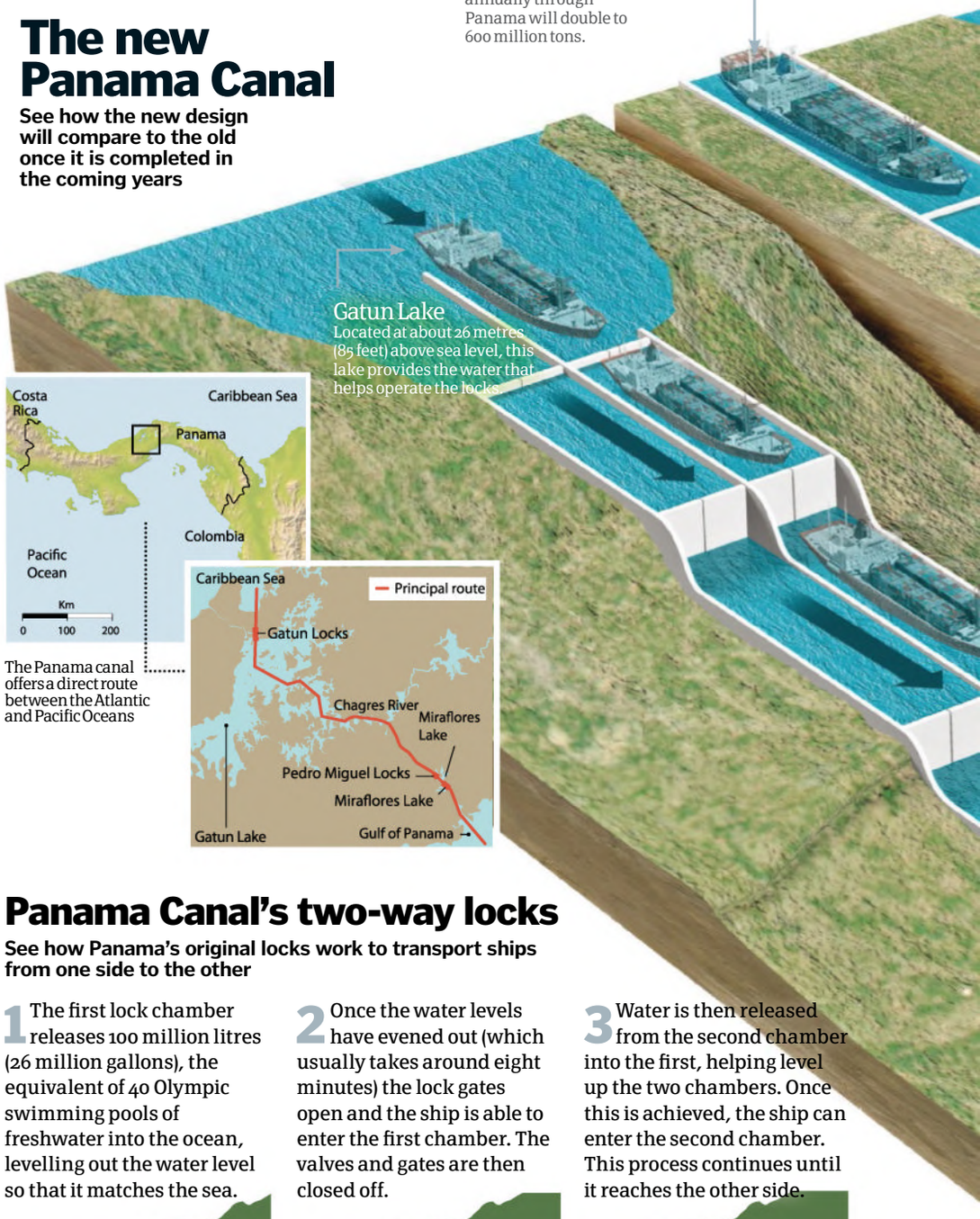
Traffic in the world's oceans has quadrupled over the past 20 years; mammoth cargo ships now transport 95 per cent of imported goods to American shores. Due to this, it was decided that the canal needed some serious renovation and expansion to keep pace with the modern shipping industry. More than 100 studies were conducted to find out what would be the most appropriate plan of action, taking into account the environmental impact of the changes and the technical engineering that would be required.

A £3.5 billion ($5.25 billion) project has been devised, which will involve four major components: a Pacific access channel, an additional set of locks, improvements to the water supply and enhanced navigation channels. Once complete, the canal will be able to support a third lane of traffic, and will be roomy enough to allow ships almost three times the current maximum size permitted, carrying 2.5 times the number of containers. Passage through the new locks will not be cheap for the largest vessels, which currently pay hundreds of thousands of dollars to pass through.

The renovations were scheduled to be completed in 2015, but a considerable number of issues have resulted in delays. Nevertheless, the canal's improvements will have a huge impact; trade will become more efficient as it will require less time, money and fuel to get products to American ports. Much of the intercontinental traffic will no doubt flock to Panama to take advantage of this, boosting American economy much like it did when it opened in 1914.

The new Panama Canal

See how the new design will compare to the old once it is completed in the coming years

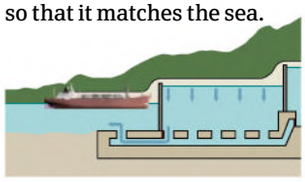


The Panama canal offers a direct route between the Atlantic and Pacific Oceans

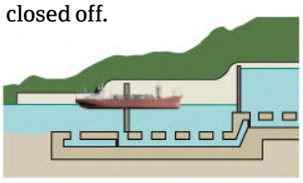
Panama Canal's two-way locks

See how Panama's original locks work to transport ships from one side to the other

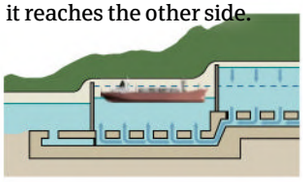
1 The first lock chamber releases 100 million litres (26 million gallons), the equivalent of 40 Olympic swimming pools of freshwater into the ocean, levelling out the water level so that it matches the sea.

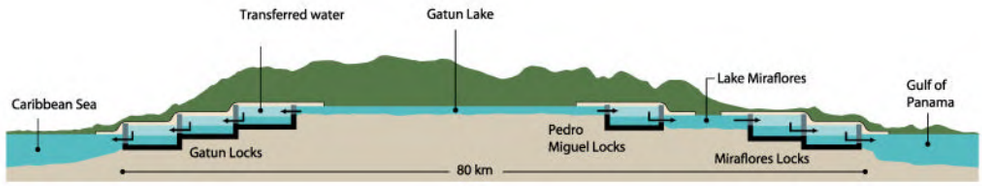


2 Once the water levels have evened out (which usually takes around eight minutes) the lock gates open and the ship is able to enter the first chamber. The valves and gates are then closed off.



3 Water is then released from the second chamber into the first, helping level up the two chambers. Once this is achieved, the ship can enter the second chamber. This process continues until it reaches the other side.





Competition for Panama?

The Panama Canal is starting to face fierce competition from around the world. Egyptian president Abdel Fattah el-Sisi announced plans to add an extra lane to the Suez Canal, which runs through Egypt to connect the Mediterranean Sea with the Red Sea, in 2014. It was completed in a third of the originally estimated time and has allowed two-way traffic, doubling the canal's capacity to an average of 97 ships each day. It has also slashed transit time almost in half, from 18 hours to 11.

The Suez is not the only canal trying to get in on the action; there is likely to be a new contender in the coming years. One Chinese entrepreneur has announced plans for a £33 billion ($50 billion) Nicaragua Grand Canal, which would connect the Atlantic to the Pacific through Lake Nicaragua. This canal would be 278 kilometres (173 miles) long and able to accommodate some of the biggest ships in the world, carrying enormous containers. Construction is planned to take five years, but at the time of writing it has not yet started.

Reusable water
60 per cent of the water drained from each new chamber will be reused, making the new locks much more efficient and eco-friendly.

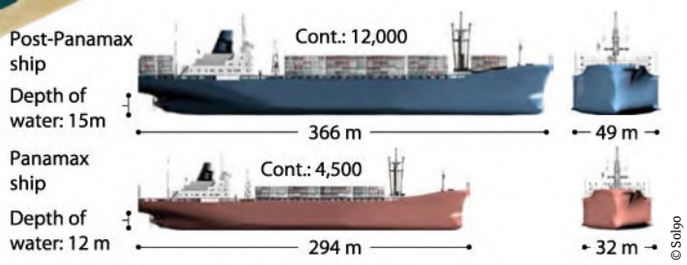
Deeper channels
Extensive dredging of the current canal will make it significantly deeper, helping it to accommodate much larger vessels.

Fast transit time
The canal is 82 kilometres (51 miles) long, and allows ships to go from the Atlantic to the Pacific in just over eight hours.

Global significance
Roughly three per cent of world maritime commerce flows through Panama Canal, which will no doubt rise when the new locks open.

Wider locks
The new locks will be 55 metres (180 feet) wide, allowing the gigantic Post-Panamax ships through the canal.

Excellent safety
There have only been 38 shipping accidents reported since 2002, an average of one per 4,000 voyages via the canal.



Do astronauts go through customs when returning from space?

Yes, but not simply because they're returning from space. Currently astronauts spending time on the International Space Station must travel to and from the Baikonur Cosmodrome in Kazakhstan because they launch on the Russian Soyuz spacecraft. They go through international customs like everybody else. There are customs forms filled out for the Apollo 11 astronauts, but it was for novelty purposes only. It's likely that the forms were created as a joke by a Customs Services District Director in Hawaii (the closest state to the splashdown location) and later signed using an autopen.

What is solar panel parking?

Electric and hybrid cars are becoming much more of a common sight on the roads, with many plug-in charging stations now visible in car parks and service stations around the globe. However, there's a new technology now available that enables these cars to be charged without the need for a mains power supply, instead drawing on energy from the Sun.

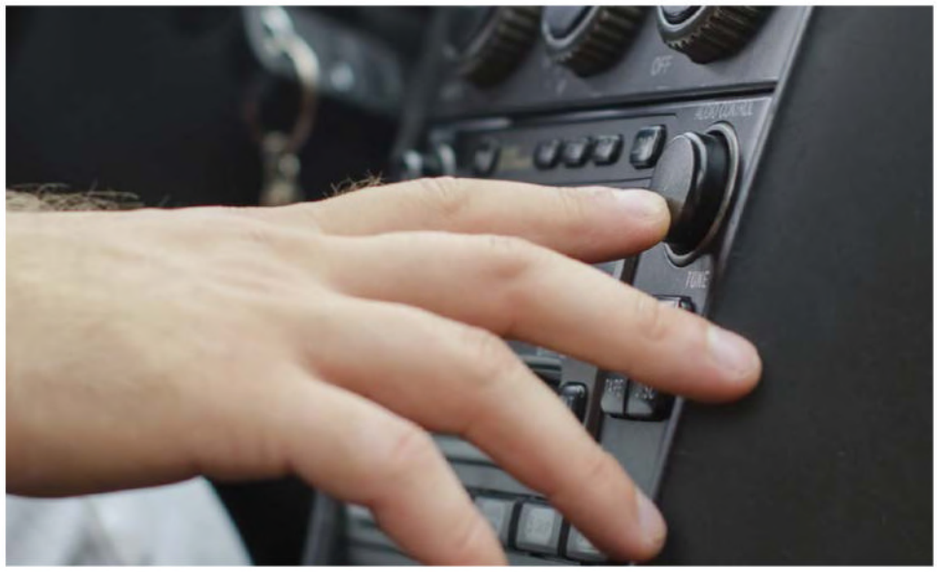
This system of solar panel parking works by converting daylight energy into electric energy, trickle-charging cars ready for use. Photovoltaic panels mounted to the roof of the parking lot or carport absorb the Sun's rays and convert the solar energy into electric energy compatible with the automobile, which is fed in via an adaptor to the car's standard electric charging port.

However, while this can reduce costs of electricity charging at the mains, photovoltaic panels are not yet efficient enough to convert all the solar energy they receive into electricity, so several hours of solar charge won't power a car for a long period of time. The technology is in its infancy, though, and could well provide a framework for the future of regenerative-fuelled motoring.

Swinging your arms as you walk helps to conserve energy

Why do we swing our arms when we walk?

It was originally thought that arm swinging might help with balance, but so far the science has not managed to demonstrate enough evidence to prove that idea. However, there is another possible explanation. Analysis of oxygen consumption when people walk and swing their arms reveals that the swinging motion actually helps to save energy. One study found that when people swung their arms as they walked, they used up to eight per cent less oxygen than when they kept their arms by their sides, indicating that their muscles were burning less fuel.



Why do you lose radio signals in a tunnel?

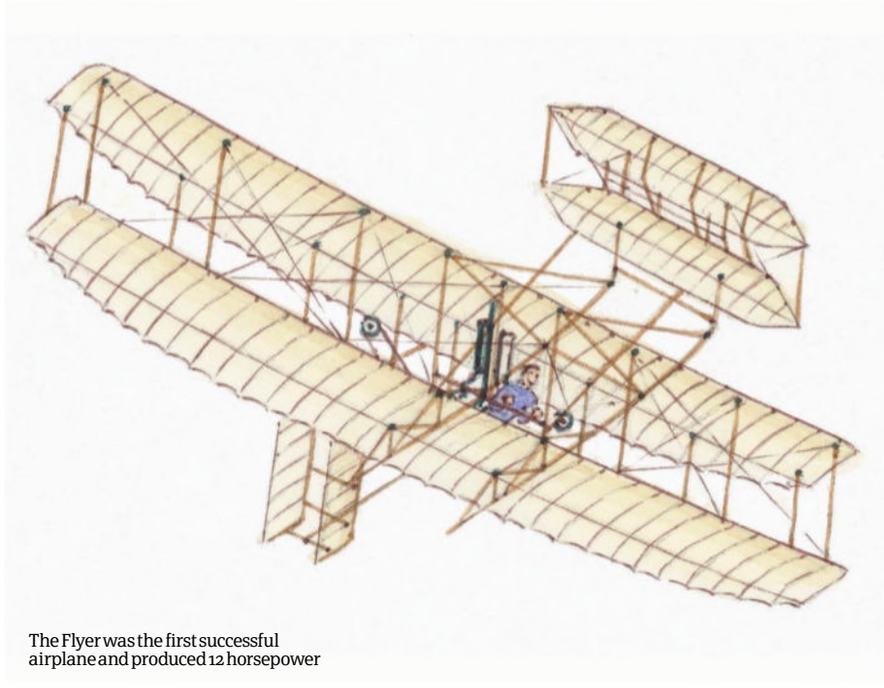
When you are travelling in a vehicle listening to a radio station that broadcasts on medium wave (AM), the signal will weaken or cut out when you go through a tunnel. However, when you are listening to a radio station that broadcasts on high frequency (FM), the signal remains strong. This is because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

How do monorails work?

Most monorail trains use wheels running over a single guide rail, with horizontal wheels clamping it to the rail on either side. But some use maglev technology to float above the track. There are two main types: electromagnetic suspension (EMS) and electrodynamic suspension (EDS). Maglev trains accelerate using magnetic coils built into the side of the track. These create an overlapping pattern of alternating north and south magnetic fields. The train rapidly alternates the direction of its own magnetic coils to attract the front of the train to the next coil along the rail.

How many horsepower did the Wright Brothers' plane have?

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



The Flyer was the first successful airplane and produced 12 horsepower

Why are bicycles much more stable when moving?

There is no definitive explanation behind a moving bike's uncanny ability to stay upright. Experts agree that it is linked to bikes' ability to steer into a fall and right themselves, with even riderless bikes able to recover from a sideways push. For a long time, it was believed that the wheels created stability through the gyroscopic effect: the tendency for a spinning object to resist movement in certain directions. A second idea was that the direction of travel aligns the bikes wheels a bit like when pushing a shopping cart. Researchers, however, disproved these theories in 2011 by building a bike which negated both effects. A pair of counter-rotating wheels cancelled out the gyroscopic effect and the steering axis lay behind the front wheels, yet the moving bike was still stable. The research team concluded that although both effects may have an impact, neither were vital to a bike's stability.

How does salt melt ice on the roads?

We spread granulated salt on icy roads because it lowers the freezing and melting temperature of water. When water cools to zero degrees Celsius (32 degrees Fahrenheit) or below, it freezes into ice. But when you add salt, the water must be at a much lower temperature to freeze. For example, a 20 per cent salt solution would freeze at -16 degrees Celsius (three degrees Fahrenheit). If you sprinkle salt on ice that's formed on the road, it will dissolve into the liquid water film on the surface of the ice and ultimately melt it. There is a limit, however; if the road temperature is lower than minus-nine degrees Celsius (15 degrees Fahrenheit), the salt cannot penetrate the surface of the ice to begin the process of melting it. Some places add calcium fluoride to their road-salt mixture at these colder temperatures, which allows for melting at slightly lower temperatures.

Why does tarmac have that mirage effect, even if it's not a particularly hot day?

Although they're often associated with deserts and summer temperatures, it doesn't have to be a particularly hot day for you to see a mirage on dark tarmac – just a sunny, dry one. Mirages are caused by waves of light passing through layers of air that have different densities, then refracting – or bending – towards the densest layer of air. In an inferior mirage, the layer of air on the surface is warmer than the air above it, creating an image below that of the actual object. This is why you can often see mirages on road surfaces because tarmac heats up quickly on a sunny day.

This image was taken in Apeldoorn, the Netherlands, in May, when the average high temperature is 13°C (55.4°F)

© Thinkstock

How do emergency vehicle lights work?

Fixed to the top of police, fire and ambulance service vehicles, flashing blue lights are deployed in the event of an emergency. Their bright flashes grab the attention of other road users from a distance, allowing them to take evasive steps in good time to make sure the emergency vehicle can pass through safely and quickly, even in heavy traffic, which is crucial when responding to an emergency call.

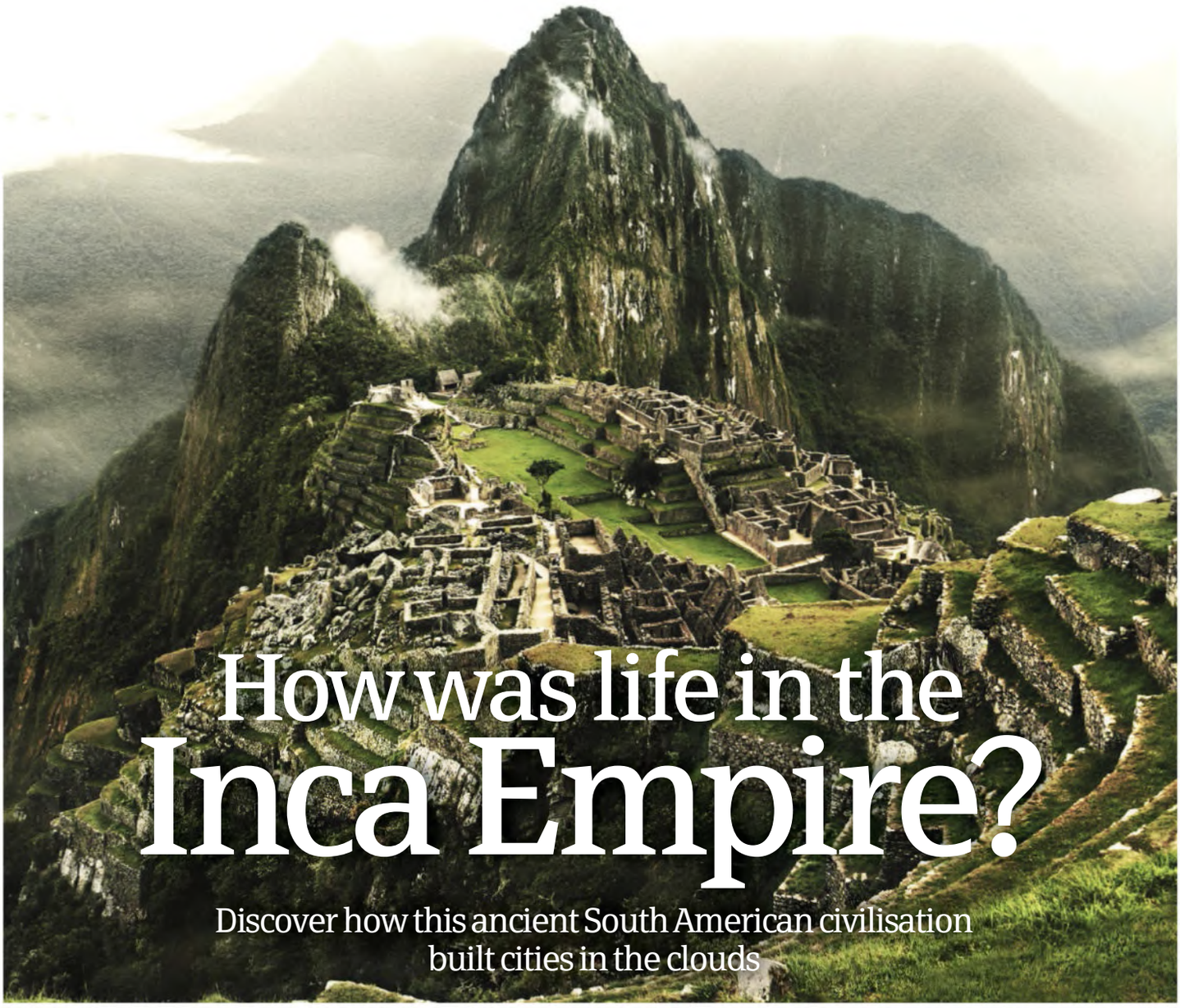
Although brighter, more efficient blue LED lights are now commonplace on modern police cars, ambulances and fire engines, the old-fashioned method of using a see-through unit with a single light bulb inside has long been a trusted ally of the emergency services – and its magic is in the illusion it creates.

Of course, bulbs can't keep flashing on and off for long periods or they'll blow, so the illusion is created by a rotating base with a vertical reflector affixed to it, moving around a fixed light bulb. The reflector redirects light outward from one side, while blocking the light out to the other. When the base is rotated fast, this creates the 'on-off' illusion of a flashing blue light atop an emergency vehicle.

Why do returning space ships land in the sea?

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

History



How was life in the Inca Empire?

Discover how this ancient South American civilisation built cities in the clouds

In less than a century the Incas built an empire that stretched over 3,862 kilometres (2,400 miles) along the west coast of South America, making it the largest nation in the world at that time. Not only did they do this without the wheel, horses, or a formal written language, they also had to navigate deserts, rainforests and the highest mountain range on the continent, the Andes.

The civilisation's ruler was known as the Sapa Inca, who led from the capital of Cuzco in present-day Peru. King Pachacuti was the first leader to expand beyond this region in the early 15th century, sending his army to conquer new territories. Inca warriors were fearless, well-disciplined and skilled at using a number of weapons, but it was the organisation of the Inca government that really made their conquests a success.

The Incas called their empire Tawantinsuyu ("the four parts together"), as they divided it into the northeast, southeast, northwest and southwest regions. Each region had its own governor and group of local administrators to oversee the settlements and report back to the Sapa Inca. When new areas were conquered, Inca officials were sent to facilitate the spread of their customs, language and general way of life, resulting in the iconic settlements we see today.

However, in 1532, the Inca Empire collapsed just as quickly as it had started. Spanish conquistadors, led by Francisco Pizarro, took advantage of the rebellions and epidemics of European diseases that were rife in the region at the time, and took the land for their own.

Examples of the Inca way of life still live on, as many villagers dwelling in the Andes speak the Quechua language and farm the land as the Incas did 500 years ago. Some Inca cities also managed to escape destruction by the Spanish. One of the best-preserved sites is Machu Picchu, located 2,430 metres (7,972 feet) above sea level. There are several theories about the site's purpose, but one popular idea is that Machu Picchu was a royal estate for the Sapa Inca. This ancient city in the clouds is now a UNESCO World Heritage Site that gives tourists a glimpse into the past.

Anatomy of an Inca warrior

The fierce soldiers that helped expand the Inca Empire

Feathers
Helmets were adorned with brightly coloured feathers. The number of feathers distinguished military ranking.

Helmet
High-ranking warriors wore helmets made of copper or bronze, but regular fighters had wooden headgear.

Jewellery
High-ranking warriors wore plates of gold, silver or bronze on their chests, and gold or silver earplugs to stretch their lobes.

Shield
Shields came in a variety of shapes, made from wood covered in leather or hide, and were mainly used by high-ranking soldiers.

Tunic
Made from thick, padded cotton with plates of stone or metal on the back and front, the tunic provided protection against wooden and stone weapons.

Weapon
The Incas used a variety of weapons depending on their position in the battle, including spears, slingshots, bows, clubs and axes.

Fringes
Fringes of wool were tied around the biceps, ankles and below the knees, which was believed to strengthen the limbs.

Colours
Tunics were designed with specific colours and insignia corresponding to the region of the army.

Sandals
Footwear was crafted from untanned llama hide or braided fibre, helping them walk for miles into battle.

Messenger service

As their empire expanded, the Incas built a vast network of roads and bridges to connect their settlements. However, as they had no wheeled vehicles or horses, journeys were made on foot using llamas or alpacas to carry any heavy supplies. One important use for these roads was the delivery of verbal messages, as the Incas had no written language. Runners were located at stations along each route and would pass on their message when they reached the next station, a bit like a relay race. They would mostly deliver news of invasions, uprisings, or the Sapa Inca's death, but occasionally recorded information that needed to be sent. This was done using a quipu, a rope with a series of strings suspended from it. The colour of each string indicated what was being counted, such as how many soldiers were available for war, and the number of knots denoted the amount.

The quipu was used to record everything from the length of a ruler's reign to how many crops a settlement produced

Manual labour

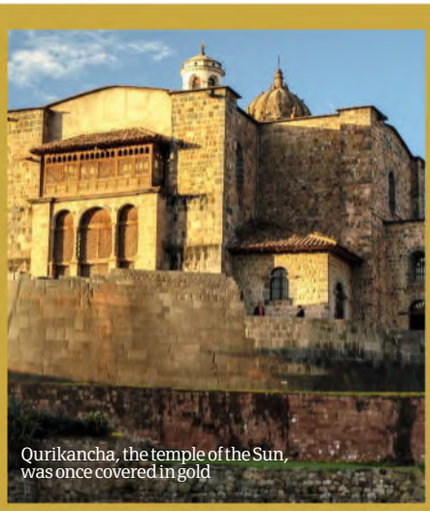
The families at the bottom of the Inca hierarchy were mainly farmers. As there was no currency, land was allocated to each family by the state and in return they would pay tax in the form of food and textiles. These families could only keep some of the food they produced for their own use, as the rest was divided between offers for the gods and the state. Every adult was also required to spend part of each year working for the state, helping to build houses and roads or by joining the army. The Incas also used their building skills to find clever ways to farm uneven mountain slopes. One solution was to cut terraces into the hillside and build walls to keep the soil in place.

Terracing helped to extend the farmland and prevented soil from being washed away

Inca architecture

How the Incas built impressive structures and simple homes

The Incas were excellent stonemasons, constructing buildings that were uniform in design, incredibly stable and pleasing to the eye. The clean lines and trapezoidal windows and doorways in their structures soon became recognisable as their settlements spread west across South America. Grand palaces and humble homes were built in much the same way, and could only be differentiated by their size and the quality of the stone finish. Some more ambitious designs also featured curved walls and gold sheeting, but most buildings were much simpler. Homes were typically built in a kancha, an enclosure of several single-room structures built around a courtyard and enclosed by a wall.



Qurikancha, the temple of the Sun, was once covered in gold

Sun worship

The Incas worshipped several nature gods, including a Moon goddess and a god of thunder, as they were believed to control the natural world and prevent disasters such as floods and droughts. However, one of their most important gods was Inti, the Sun god and giver of heat and light. Inca rulers were regarded as Inti's representative on Earth and the Incas considered themselves the 'children of the Sun'. Their religious ceremonies took place according to the movements of the Sun, with offerings of food, drink, and animal and human sacrifices made to Inti. Most buildings, doors and windows were constructed to align with the sunrise and other astronomical events, and temples were also devoted to the Sun god. One of the most sacred buildings, the Qurikancha temple in the capital of Cuzco, was once covered in gold to reflect the Sun's light and represent its power.

Building materials

Inca houses were built from stone blocks shaped using harder stones and bronze tools. These blocks could weigh many tons and were moved using a system of ropes, logs, levers and ramps. It could take many months to build a single wall.

Grand structures
Stone blocks were cut so precisely that they interlocked perfectly, and no mortar was necessary to hold the walls together.

Simple dwellings
Smaller stones were set into place with mud, or dried mud bricks called adobe were used instead.

> "Grand palaces and humble homes were built in much the same way"

Housing

Take a look inside a traditional Inca abode

On the map

Growth of the Inca Empire

1. Puerto Princesa River, Philippines
2. Phong Nha, Vietnam
3. Križna Jama Cave, Slovenia
4. Rio Secreto, Mexico

What is honey hunting?

Discover the terrifying lengths people will go to to satisfy their sweet tooth

A colony of wild bees in Kathmandu Valley, Nepal

Honey is the world's most common natural sweetener, and from as early as Palaeolithic times – 2.6 million years ago – our early Hominin ancestors were harvesting it from wild bees. Today, honey hunting is still practised by traditional cultures in Africa, Asia, South America and Australia.

However, it's in Nepal where this ancient practice is perhaps demonstrated at its most dramatic, as at least five different species of honeybee can be found nesting on the formidable cliff faces of the Himalayan Mountains. Still at the heart of life, honey is used in tea by the villagers and sold to Japan, China and Korea for use in traditional medicine. As a testament to its importance, the Gurung people of Nepal even sacrifice a sheep to the mountain gods in the hope that they will deliver a good honey harvest in return.

Each region of Nepal has its own distinctive honey hunting technique, but all of them involve lighting a fire under the nest to 'smoke out' the bees, leaving the hive exposed. Men with rope ladders descend the cliff face armed with baskets and poles, while others keep watch, raising or lowering the daring honey hunter's ladder up to 91 metres (300 feet) above the ground. A basket on a pole is held under the hive, while another pole with a sharp blade neatly cuts out the honeycombs, letting them drop into the basket below.

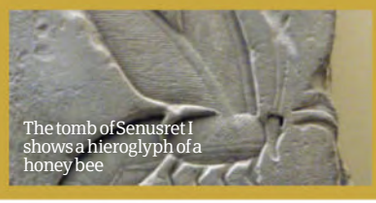
Requiring huge skill, patience and self-control, the honey hunter can take up to three hours harvesting just the one hive.

Bee-keeping in Ancient Egypt

Honey had special significance in Ancient Egypt, and was used in medicine, ointments, wine and food. Some temples contain reliefs showing beehives and how beekeepers used the technique of smoking out bees while they collected the honeycomb. The bees themselves were named 'tears of Ra', as it was believed they were created by the sun god weeping.

The oldest written reference to honey is from 5500 BCE, and by 3500-3100 BCE the fertile banks of the Nile were so perfect for beekeeping that Lower Egypt was called 'Bee Land'. Its ruler took the title 'bjtj', which means 'he of the bee'.

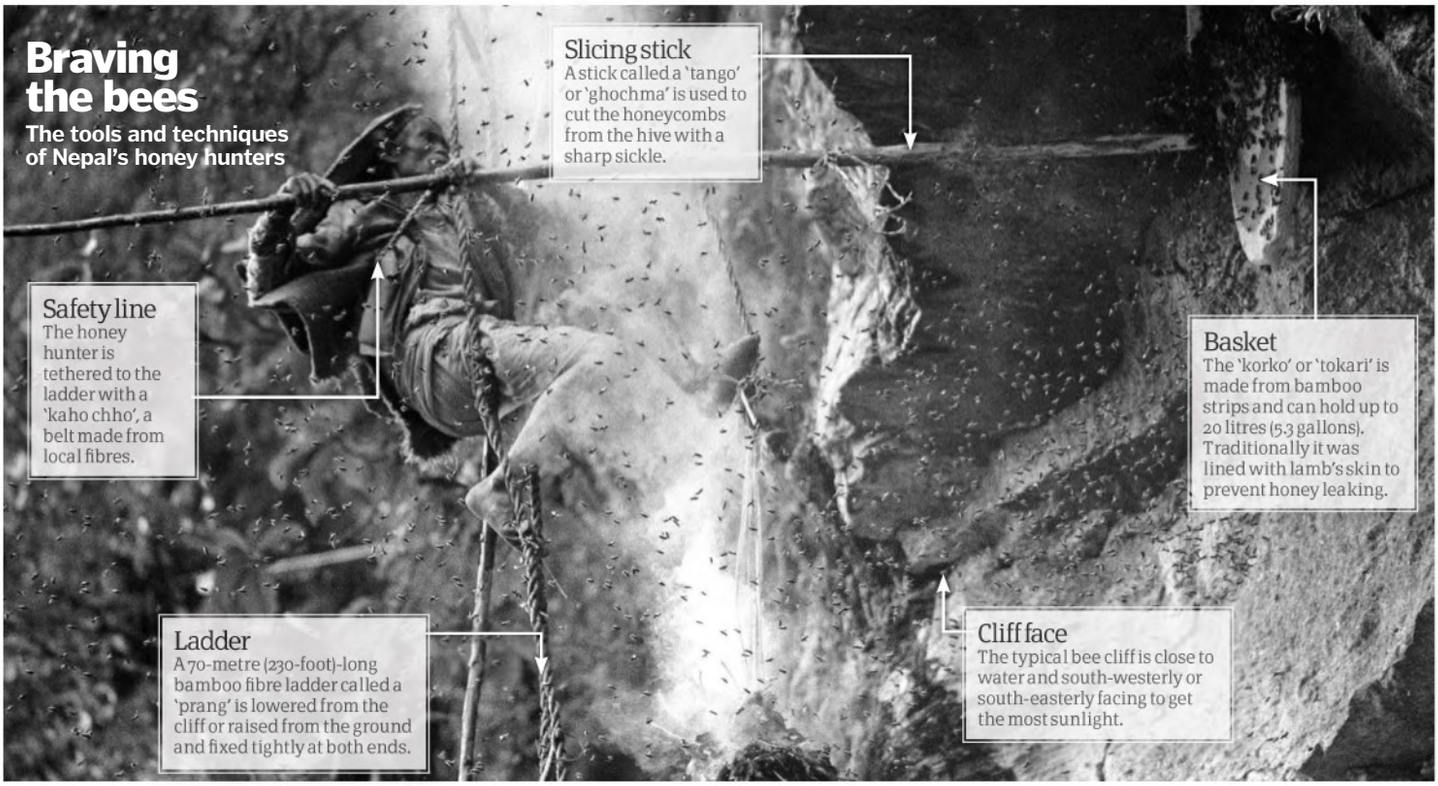
Although they had domesticated beehives, Egyptians also valued wild honey. The Pharaoh (whose title included 'Sedge and Bee', to symbolise the grasses of Upper Egypt and the honey of Lower Egypt) would send armed guards to protect honey hunters on their expeditions into the desert, while the official Sealer of the Honey ensured quality control in the finished product.



The tomb of Senusret I shows a hieroglyph of a honey bee

Braving the bees

The tools and techniques of Nepal's honey hunters



Slicing stick
A stick called a 'tango' or 'ghochma' is used to cut the honeycombs from the hive with a sharp sickle.

Safety line
The honey hunter is tethered to the ladder with a 'kaho chho', a belt made from local fibres.

Basket
The 'korko' or 'tokari' is made from bamboo strips and can hold up to 20 litres (5.3 gallons). Traditionally it was lined with lamb's skin to prevent honey leaking.

Ladder
A 70-metre (230-foot)-long bamboo fibre ladder called a 'prang' is lowered from the cliff or raised from the ground and fixed tightly at both ends.

Cliff face
The typical bee cliff is close to water and south-westerly or south-easterly facing to get the most sunlight.

How was ocean depth first measured?

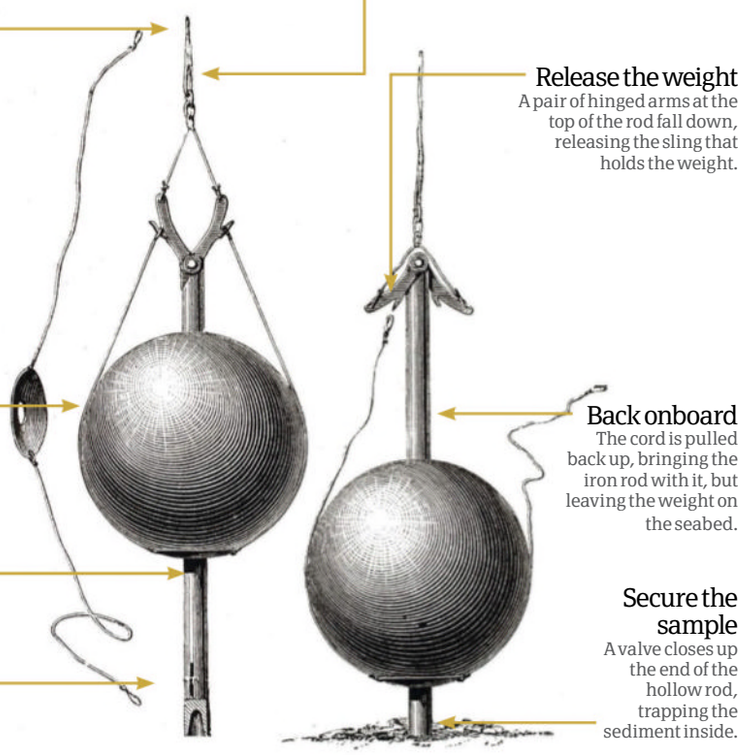
Explore the clever methods used to take the first measurements of the sea floor

The first evidence of humans attempting to measure the depth of the oceans can be seen in Egyptian tomb paintings from 1800 BCE. The images show a man on a boat dipping a sounding pole (a long rod used to measure depths) into the water and measuring how far it goes in before it reaches the bottom. This technique didn't change much for the next several thousand years, with the pole simply switched for a rope with a weight on the end.

Most of the measurements were taken in shallow areas to identify near-shore hazards for shipping, but in 1872 the first wide-scale study of the world's oceans began. On its four-year expedition, the HMS Challenger took 360 depth readings of the sea floor using a variety of sounding devices. These devices used a weight to pull a sounding line to the seafloor and collected samples from the seabed in the process. The findings helped to identify underwater mountain ranges and trenches, as well as thousands of new marine species, forming the basis of modern oceanography. However, it wasn't until 1914 that sonar was first used to take more accurate measurements.

The Brooke's sounding apparatus

How this deep-sea sounding device worked



How did people stay clean?

The gruesome practices that were once considered healthy!

1 Urine mouthwash
Ammonia, a common ingredient of household cleaners, is also found in urine, and so the Romans used it to clean their clothes. However, they also believed its stain removing powers could clean and whiten teeth, and so they regularly gargled with it as mouthwash.

2 Toilet closets
In medieval houses, toilets were basically a bowl covered by a slab of wood with a hole in the middle. They could usually be found in closets called garderobes, and people would often keep their clothes in their as the smell helped to keep moths away.

3 Rotten teeth
The Tudors knew that sugar rotted their teeth, but because sugar was so expensive and therefore a sign of wealth, Tudor women would deliberately blacken their teeth to make them look rotten!

4 Hair-raising treatments
A common treatment for baldness in the 17th century was to mix potassium salts with chicken droppings and rub it into the scalp. Alternatively, one method for removing hair involved creating a paste from eggs, vinegar and cat dung.

5 Mouse-skin eyebrows
During the 18th century, it was unfashionable for women to have thick eyebrows, so they would shave them off and replace them with ones made from mouse skin. Pale make-up was also popular – but deadly – and contained poisons such as lead and mercury.

What's inside the Washington National Cathedral?

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

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

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

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

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

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

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

What to look out for

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

Darth Vader

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

Cathedral Carousel

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

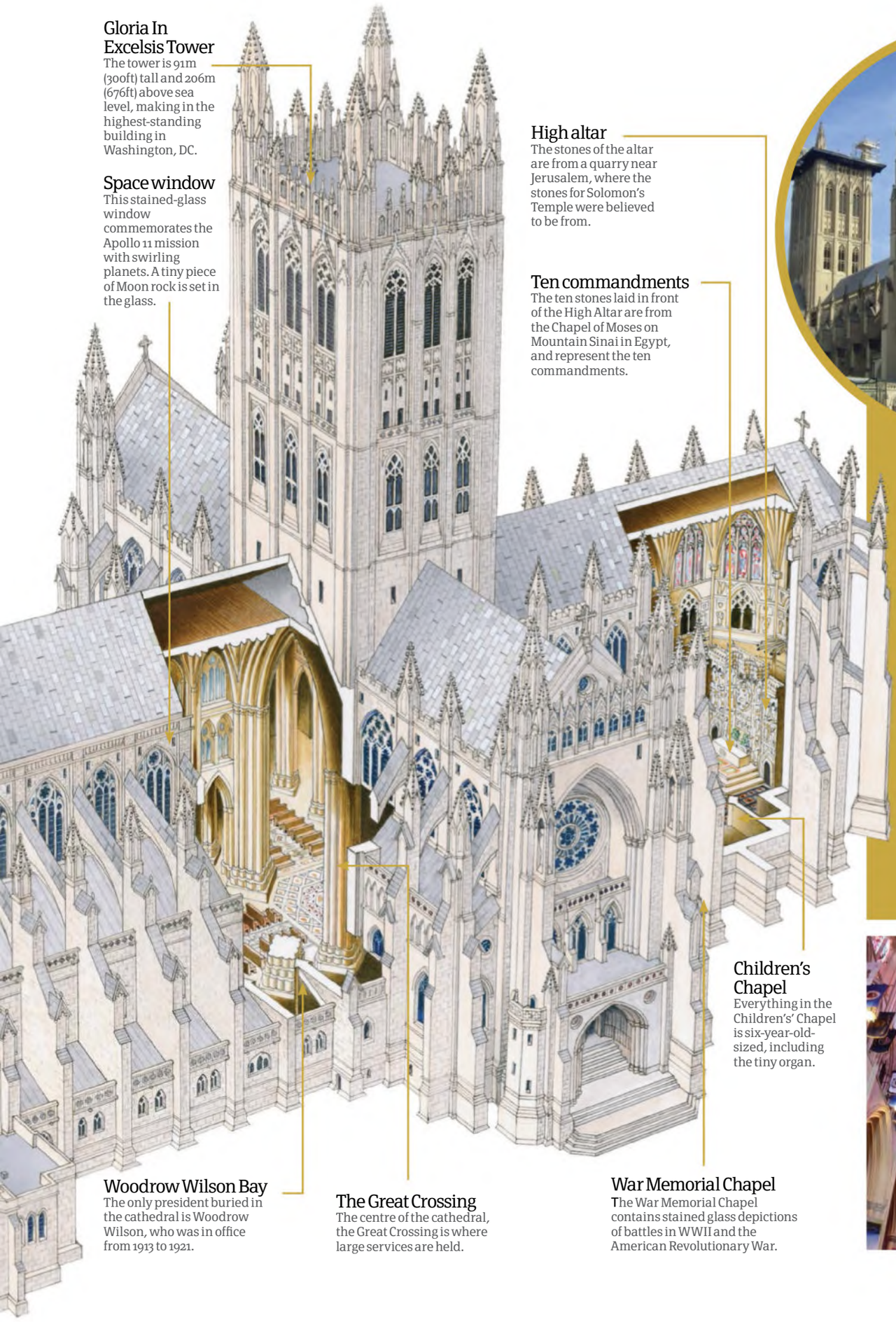
A rare all-wood carousel with a brass pipe organ, it has 24 hand-carved and brightly painted animals and two chariots for seating, which rise and fall as the carousel rotates around the centre pole, which is driven by a petrol engine.

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

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

West facade

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



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

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

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

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

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

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

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

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

Cathedral vs quake

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

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

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

How was the post-WWII housing crisis solved?

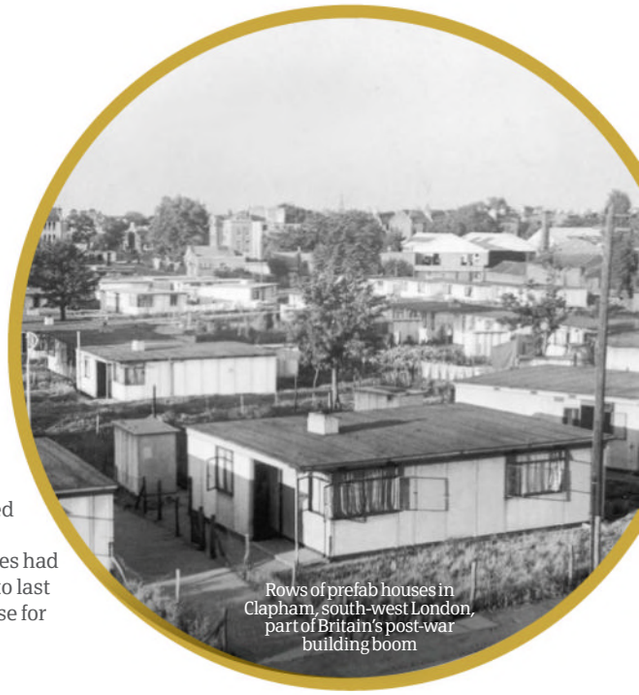
How this prefabulous plan solved the post-war housing crisis

As soon as war began in 1939 house building in Britain effectively stopped, with all efforts directed towards fighting the war. By the end of World War II, many thousands of Britons had been made homeless by German bombings during the Blitz and were living with friends or family. Some were even forced to squat in unused buildings and Underground stations.

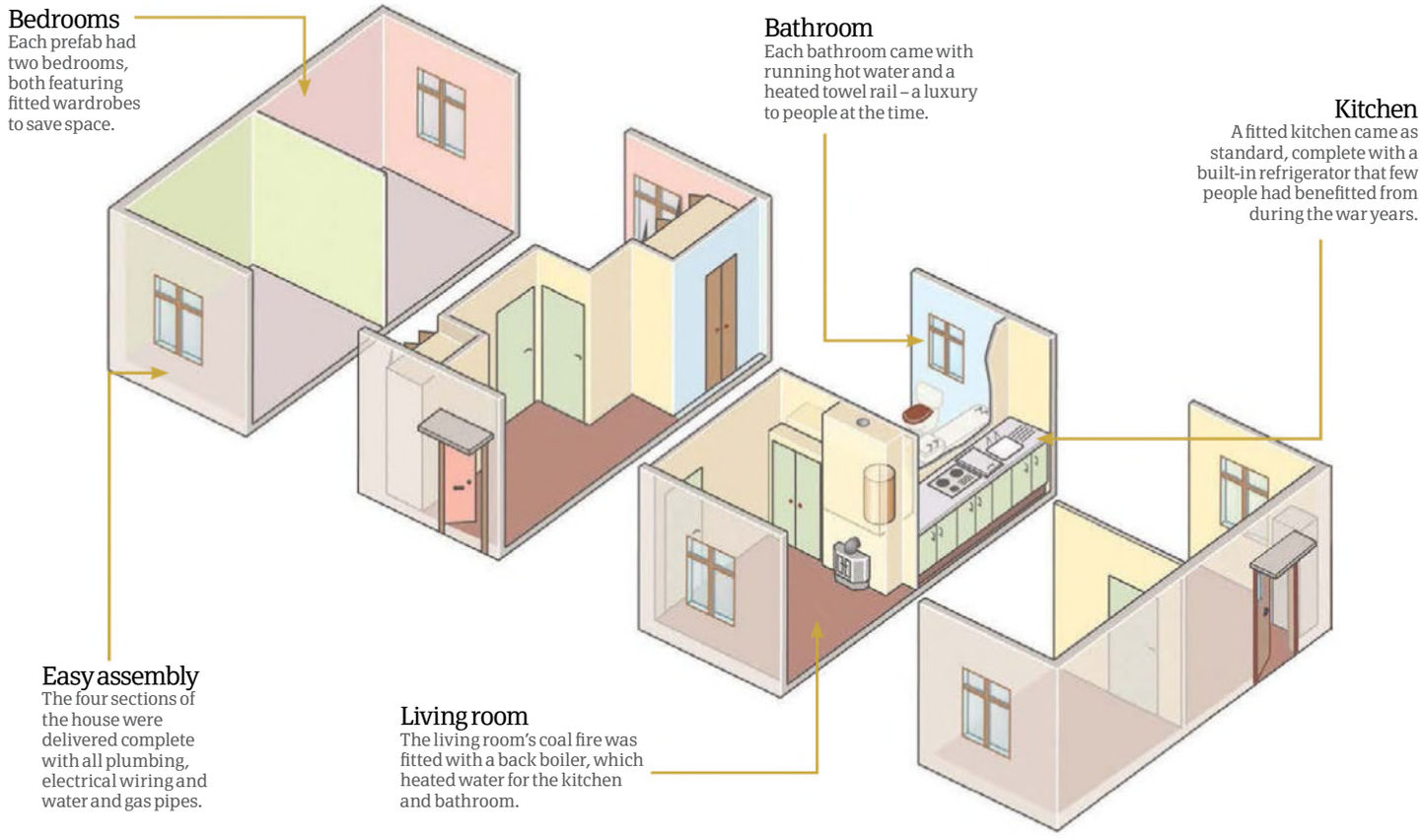
To address the housing shortage, Winston Churchill, who was the Prime Minister at the time, decided he would make use of the vast array of munitions factories and turn them into housing factories instead. He proposed the large-scale production of prefabricated buildings, which could quickly provide houses while the country began to rebuild after the war.

One of the most popular prefab designs was the aluminium Type B2, which took only 12 minutes to manufacture as four separate sections. The pieces were then transported to their final destination on the back of a lorry, where they could be assembled quickly and efficiently.

By 1949 more than 156,000 prefabricated homes had been built. These homes had been designed to last for around ten years but many remained in use for much longer, with some still being occupied throughout the early 2000s.



Rows of prefab houses in Clapham, south-west London, part of Britain's post-war building boom



How was wine made in Ancient Israel?

Thousands of grapes and a whole lot of manpower was needed to make the Israelites' favourite beverage

Israel's hot, sunny climate and mountainous landscape makes it the perfect place for growing grapes. In ancient times, it was situated along a wine-trading route, which brought winemaking knowledge and influence to the area. People would drink about a litre of wine a day, so knowing how to make lots of wine fast was a very good skill to have.

The ancient Israelites harvested the grapes at the height of summer, and then brought them to 'wine presses' cut into the rocky ground for fermentation. First, they were tipped into what was called a 'treading pool' where vineyard workers would tread on the grapes with their bare feet to crush them. The juice would then flow through a channel into a vat, where the fermentation process would take place.

The yeast on the skin of the grapes would react with the sugars in the juice and turn them into alcohol. Once fermentation was over, the wine would be collected in leather bags called wineskins or big jars called amphorae. These were often coated with resin, which helped to preserve the wine and gave it a woody flavour. Olive oil was then poured on top of the wine to prevent exposure to the air, and the jars were sealed with more resin or clay. The wine would be stored in cool, dark cellars for months or even years, and eventually sold in Israeli markets or exported to foreign lands.

An ancient wine press

Many of these have been excavated in Israel, which give us an idea as to how wine was made

Vat
Here the fermentation process would take place, with the juice bubbling away for several days.

Channel
The juice from the crushed grapes flowed through this channel into the fermentation vats.

Jars
Once the bubbling stopped, the wine was poured into clay jars like these and sealed with olive oil, clay or resin.

Rock
The limestone rock in Israel is perfect for wine presses, as it's easy to cut and holds liquid well.

Treading pool
The grapes were poured into a large pool, where they were crushed under foot.

Filter
Dried shrubbery or other plant fibres were used to filter the grape juice.

Why do some wines taste better with age?

Tannins are a group of molecules found in grape stems, skins and seeds that are produced by the grapevine to help defend against hungry critters. They make unripe grapes taste bitter, meaning that if animals or people try to eat one, they'll soon be put off. Tannins also bind to the proteins in your saliva that make it slimy, leaving your mouth feeling dry. When wine is first bottled, it will taste very bitter and very dry.

However, over time small amounts of oxygen leak through the cap and react with the tannins. This changes their molecular structure and means that they will no longer bind to the salivary proteins. Instead, they will linger pleasantly on your gums, cheeks and tongue. As the wine ages, it also becomes much less bitter. The older the wine, the richer and more complex it becomes. But beware – leave it too long and its fruitiness will disappear completely!

Tannins also affect the colour of wine. The older they are, the deeper the colour

Who invented the pencil sharpener?

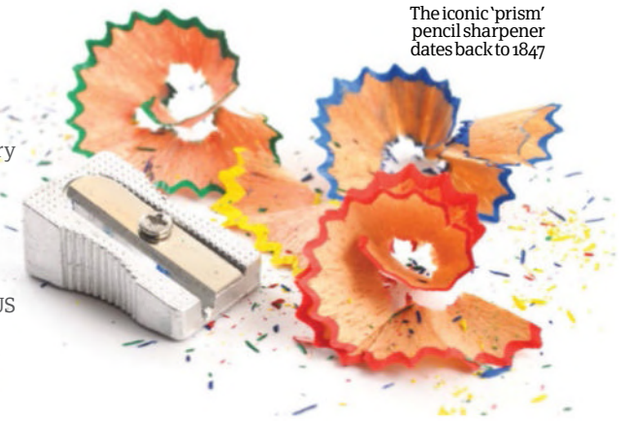
Discover the French engineers and the American tycoon behind the pencil sharpener

Although the exact origins of the pencil are uncertain, its growing popularity demanded a far less time-consuming and far more precise method of sharpening it than to slash away with a knife.

The first attempt came in 1828 from French mathematician Bernard Lassimone, who placed two blades at 90 degree angles on a block of wood, but this method of grinding down the pencil to a point wasn't any faster than the traditional method.

The mechanism we're familiar with today came in 1847 from another Frenchman, Therry des Estwaux, who invented a cone-shaped device with a single blade that when turned would neatly and evenly shave away at the pencil on all sides.

The French may have paved the way, but it was America that made waves. In the 1850s, US inventor Walter K Foster mass-produced a similar cone design and by 1857 his company was cranking out 7,200 sharpeners a day.



The iconic 'prism' pencil sharpener dates back to 1847

When did the 'butcher crocodile' roam Earth?

The 'Carolina Butcher' topped the food chain 231 million years ago

When the supercontinent Pangaea was breaking apart, 2.7-metre (nine-foot) tall, sharp-toothed creatures roamed the area that would become North Carolina in North America. Palaeontologists have recently discovered parts of the skeleton belonging to Carnufex carolinensis, an ancestor of today's crocodiles. Nicknamed the 'Carolina Butcher', it is believed to have used its blade-like teeth to slice flesh from its prey, likely to have been armoured reptiles and the early relatives of large mammals. As its forearms were so short, it is also suspected the creature walked on two legs, much like a T-rex.

A 3D model of the creature was created from scans of its fossils

How were drones used in WWII?

How UAVs first took to the skies over 70 years ago

Now synonymous with distant pilots soaring high above a battlefield they will never see first hand, the roots of today's sleek and sophisticated unmanned aerial vehicles (UAVs) actually stretch back almost a century.

With World War I (1914-1918) providing a crucible for technological innovation, experiments began in unmanned flight. The result was an American 'aerial torpedo' called the Kettering Bug. A forerunner to the modern guided missile, it could carry an explosive warhead at up to 80 kilometres (50 miles) per hour. A timer could be set, shutting off the engine and dropping the wings so that it could plummet like a bomb, but military planners were wary of flying these inaccurate explosives over their own lines.

In the run up to World War II (1939-1945), Britain's Royal Navy experimented with fitting wooden biplanes with radio control so that they could serve as target practice – building up vital skills for the coming conflict, which would see air superiority play a pivotal role.

In 1933, a modified floatplane called Fairey Queen was tested as the first flightless drone aircraft. It crashed on two out of three trials, but in 1934, Queen Bee, a modified Tiger Moth aircraft, followed with greater success.

Training gunners on these rudimentary models wasn't a very realistic simulation, but a solution was soon to come from the United States in the form of British-born actor Reginald Denny, and his Radioplane Company. After years of trying desperately to interest the US Navy in the Radioplane-1, Denny succeeded in 1939 and over the course of the war some 15,374 models of Radioplane were built.

Fast, agile and durable, Radioplanes were fitted with responsive radio control and were better able to mimic the speed and agility of the enemy's fighters.

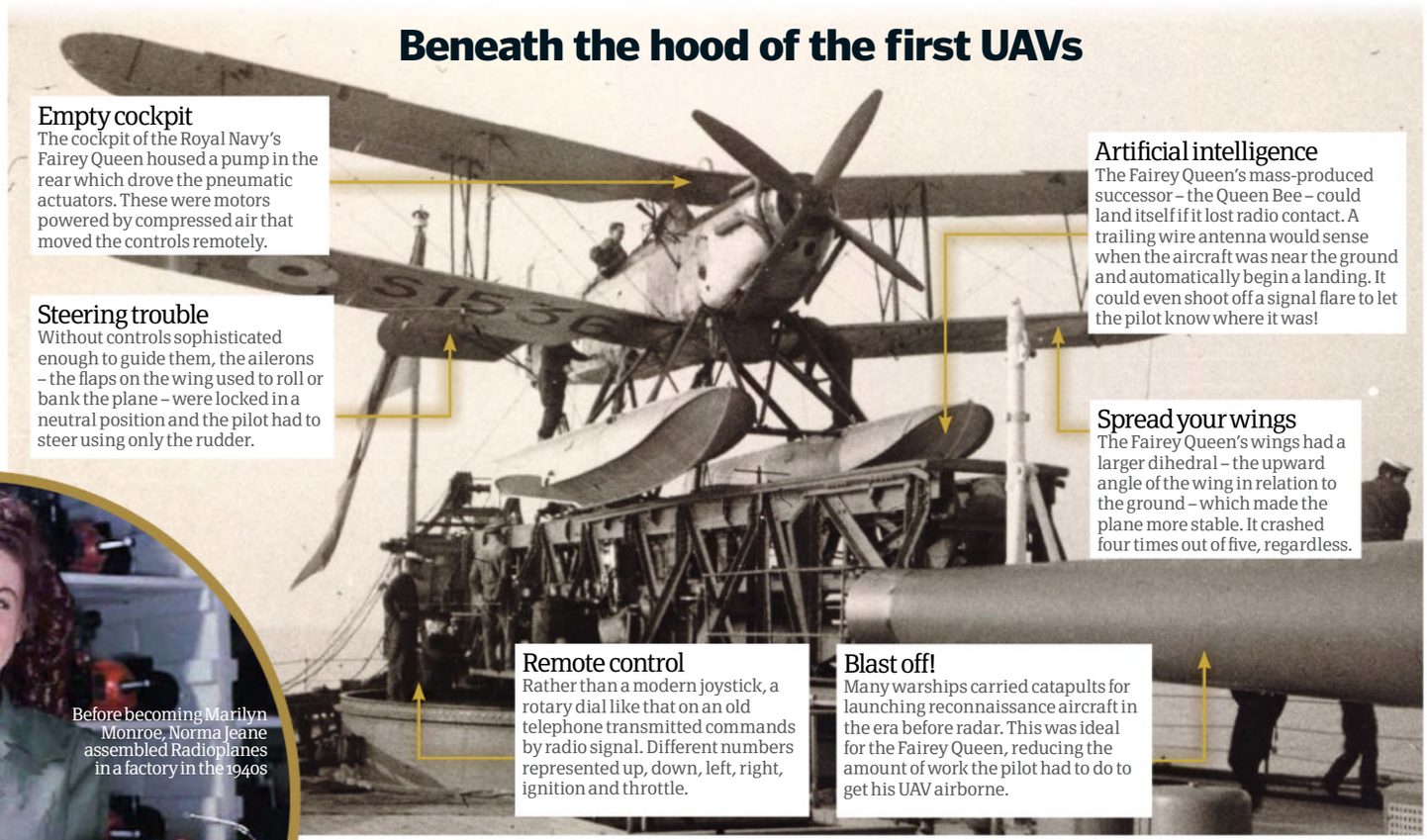
Drones that fight

While 'aerial torpedoes' represented the destructive capability of drone technology – the end result being Nazi Germany's V-1 and V-2 rockets – the seeds of the concepts for modern UAVs were also sewn behind the red banners of the Third Reich.

Dr Fritz Gosslau proposed Fernfeuer in 1939 – a vision for a remotely-piloted plane, which could drop its payload and then return to base. Plans for Fernfeuer were halted in 1941, but paved the way for development of the V-1 flying bomb.

In March 1944, the US Navy deployed the TDN-1 assault drone in the fight against Japan. On 19 October 1944 it successfully dropped bombs over targets in the Pacific. Unlike the planned Fernfeuer and current UAVs though, TDN-1 had no way of flying home.

Beneath the hood of the first UAVs



Empty cockpit
The cockpit of the Royal Navy's Fairey Queen housed a pump in the rear which drove the pneumatic actuators. These were motors powered by compressed air that moved the controls remotely.

Steering trouble
Without controls sophisticated enough to guide them, the ailerons – the flaps on the wing used to roll or bank the plane – were locked in a neutral position and the pilot had to steer using only the rudder.

Artificial intelligence
The Fairey Queen's mass-produced successor – the Queen Bee – could land itself if it lost radio contact. A trailing wire antenna would sense when the aircraft was near the ground and automatically begin a landing. It could even shoot off a signal flare to let the pilot know where it was!

Spread your wings
The Fairey Queen's wings had a larger dihedral – the upward angle of the wing in relation to the ground – which made the plane more stable. It crashed four times out of five, regardless.

Remote control
Rather than a modern joystick, a rotary dial like that on an old telephone transmitted commands by radio signal. Different numbers represented up, down, left, right, ignition and throttle.

Blast off!
Many warships carried catapults for launching reconnaissance aircraft in the era before radar. This was ideal for the Fairey Queen, reducing the amount of work the pilot had to do to get his UAV airborne.

Before becoming Marilyn Monroe, Norma Jeane assembled Radioplanes in a factory in the 1940s

What was inside a Huey?

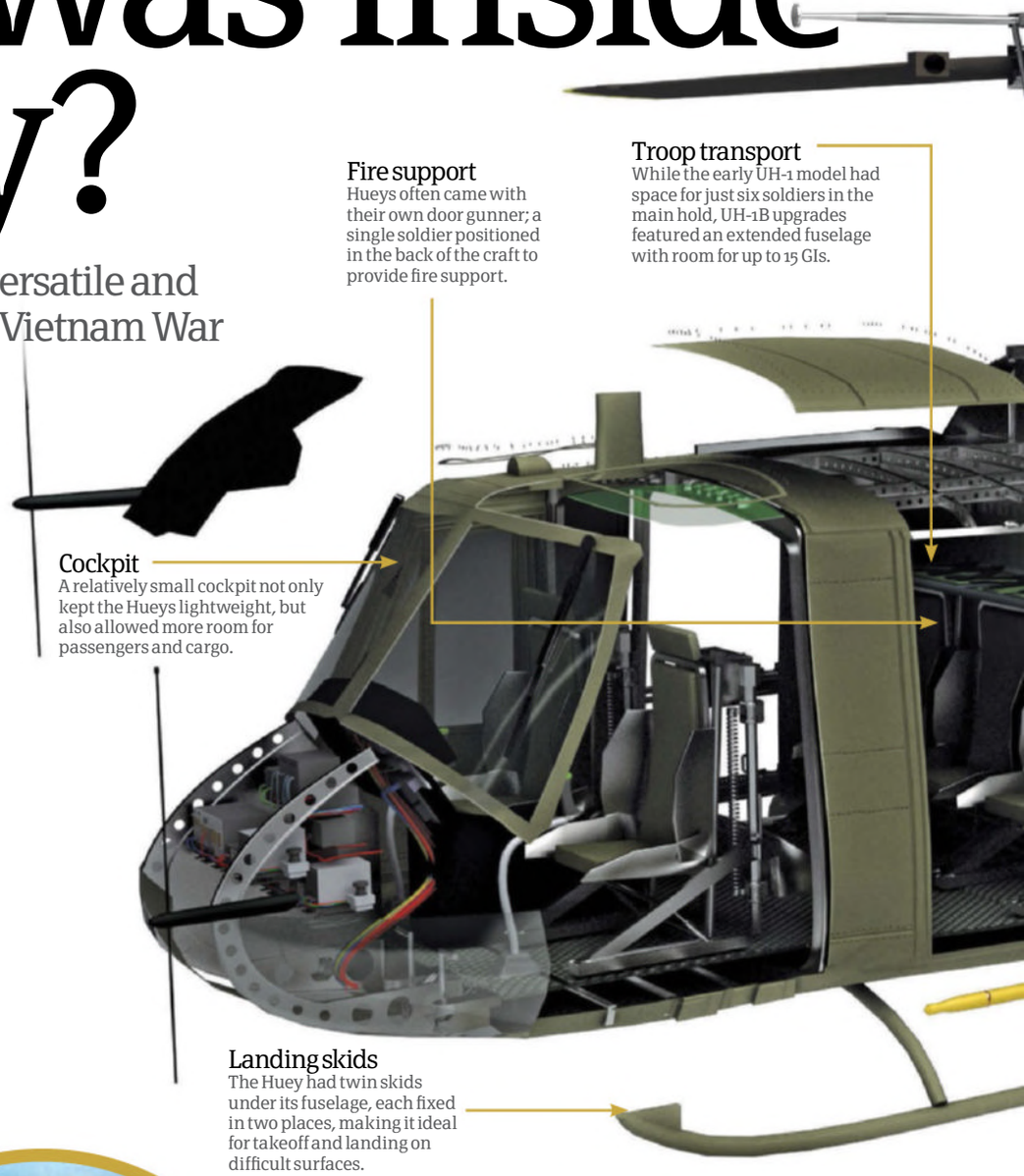
Take a look at one of the most versatile and recognisable vehicles from the Vietnam War

Among the most iconic vehicles of American operations in Vietnam was the multi-functional Bell UH-1 Iroquois helicopter, better known as Huey. With a flexible design, the helicopter was constantly adapted as a rapid troop transport, medevac, supply transport, as well as a gunship. In Vietnam, the American forces were able to strike deep into enemy territory using Hueys, which had an effective range of up to 510 kilometres (317 miles). Parachute drops were hardly ever used during the entire war, mainly due to the hazards of dropping men over thick jungle. Helicopters, on the other hand, were able to deploy units more precisely in designated clearings.

At the Battle of Ia Drang (1965), Hueys were used to drop US troops within Viet Cong territory, but due to the sheer number of soldiers required for the operation, the transports had to make multiple trips between the landing zone and their base. Once the fight began, many of the vehicles then turned to re-supply and evacuation missions as casualties mounted and ammunition ran low. The versatility of the Huey's simple fuselage, its wide doors and large flat base, proved ideal for housing either injured troops or crates of supplies.

However, many Hueys had little to no armament, making them ideal targets for Viet Cong fighters. Over 1,000 were lost during the war, either through accident or enemy attacks, though many of the craft also came armed. Door gunners equipped with either carbines or mounted medium machine guns were often positioned in the hold, poised to defend the Huey or provide fire support for troops below. Later versions of the Huey also came loaded with 30-calibre machine guns and even rocket pods, with which they could assault enemies on the ground.

During its lifetime, more than 16,000 Bell UH-1 models were produced, with 7,000 seeing active service between 1955-1976. Many are still used today by military and civilian organisations worldwide.



Fire support
Hueys often came with their own door gunner; a single soldier positioned in the back of the craft to provide fire support.

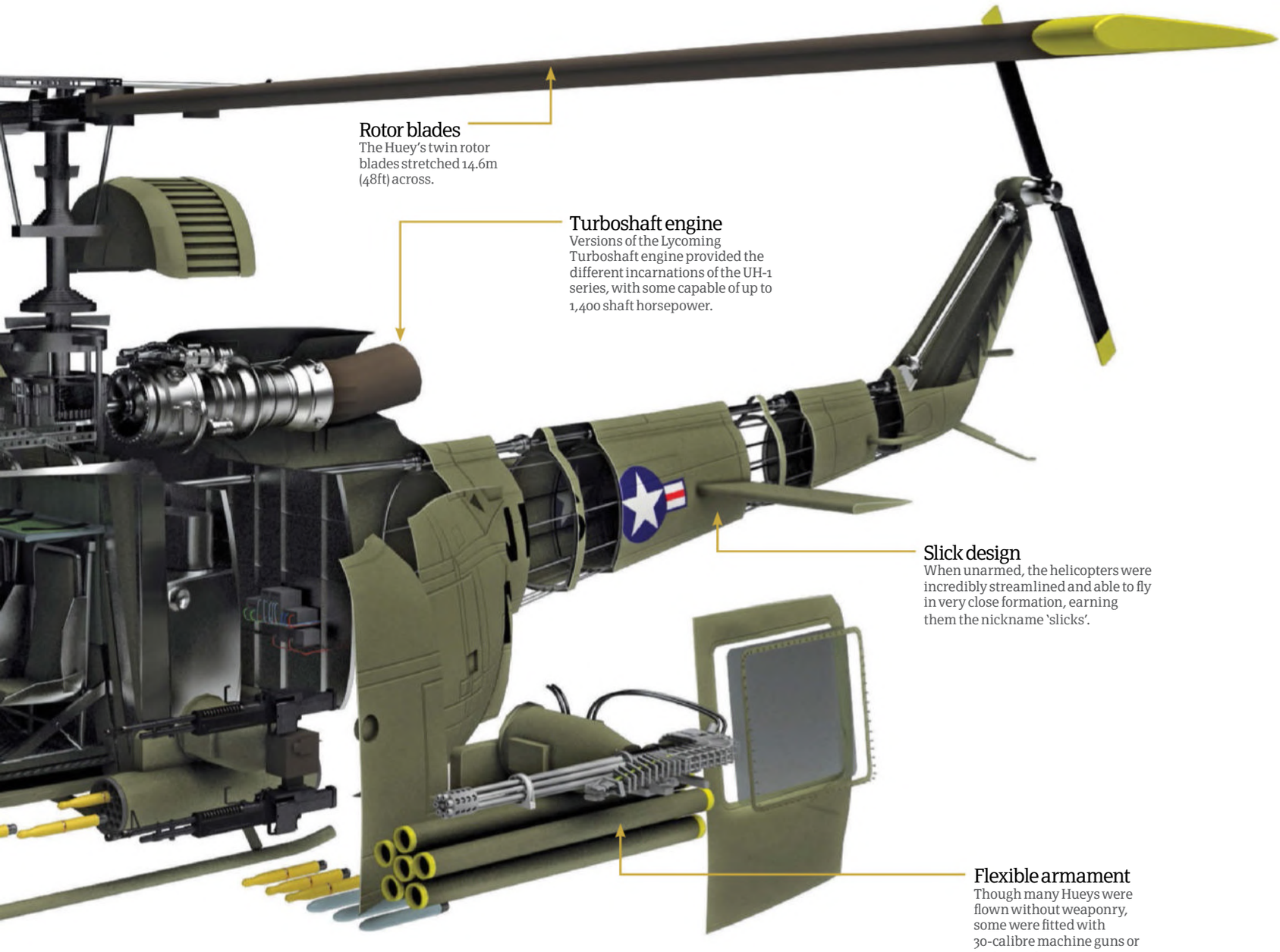
Troop transport
While the early UH-1 model had space for just six soldiers in the main hold, UH-1B upgrades featured an extended fuselage with room for up to 15 GIs.

Cockpit
A relatively small cockpit not only kept the Hueys lightweight, but also allowed more room for passengers and cargo.

Landing skids
The Huey had twin skids under its fuselage, each fixed in two places, making it ideal for takeoff and landing on difficult surfaces.

Huey helicopters prepare to transport troops during Operation Wahiawa, South Vietnam

Here a UH-1D is pictured during the Battle of Ia Drang in 1965



Rotor blades
The Huey's twin rotor blades stretched 14.6m (48ft) across.

Turboshaft engine
Versions of the Lycoming Turboshaft engine provided the different incarnations of the UH-1 series, with some capable of up to 1,400 shaft horsepower.

Slick design
When unarmed, the helicopters were incredibly streamlined and able to fly in very close formation, earning them the nickname 'slicks'.

Flexible armament
Though many Hueys were flown without weaponry, some were fitted with 30-calibre machine guns or rocket pods.

The modern 'Super Huey'

Bell's UH-Y1, also called the Yankee and the 'Super Huey', is one of the latest stages in the evolution of the Huey. With all the flexibility, reliability and efficiency of the original UH, this 21st-century beast of the air packs in the most up-to-date military-grade tech. As well as a night-vision-compatible cockpit and an electronic warfare self-protection suite, this modern Huey also notably has two twin rotor blades, unlike the original UH series.

Also different to the original Hueys, the UH-1Y craft have vastly improved safety and protective features, including a crashworthy fuel system and energy-absorbing landing gear. Capable of carrying heavier payloads and flying further than its predecessor, the UH-1Y was deployed in Afghanistan in 2009 where it was utilised by the US Marine Corps.

US Marine Corps pilots landing a UH-1Y during training exercises in Pendleton, California

How did Ancient Greek sculptors work?

Learn the ancient methods of the Greeks who cast legends into stone

Ancient Greece was a civilisation full of drama, majesty and legend that is evident in the art they left behind. However, many of the statues that we know are actually copies of Roman origin – we owe the Romans a lot for their preservation of art that would otherwise have been lost forever!

Greek sculptors would begin their craft with a few blocks of stone – this was often marble or limestone that was readily available in Greece.

The tools and techniques that the stonemasons used have changed very little over thousands of years and are similar to the ones worked with today. Marble was the most popular to use, but sculptors would pick their blocks for their workability rather than beauty.

These large statues of stone are incredibly heavy and so the sculptors would employ a few tricks to reduce weight and enhance stability. Statues would often have an extra support, such as tree trunk or column, to provide a solid foundation for the figure on the plinth than just its two feet. Masons would sometimes hollow-out the inside of a sculpture in order to keep weight at a minimum.

Once statues were finished, they would often be adorned with bronze accessories such as spears and jewellery. The eyes would be inlaid with glass or bone to bring them to life and some statues had bronze discs on the head, known as 'meniskoi' to prevent birds from defacing the figure.

Bronze sculpture

Bronze is an alloy made of roughly ninety per cent copper and ten per cent tin; copper was readily available around the Mediterranean and tin was imported. Early Greek sculptors used a method known as 'sphyrelaton' – meaning 'hammer-driven' – to create their masterpieces. Sculptors would hammer a sheet of the metal over a piece of wood carved into the desired shape, then fix the different pieces together.

As time moved on, lost-wax casting then became the most popular technique for bronze statuary. This involved various different ways of using wax and clay to create moulds, then heating so that the wax melted to leave a recess into which the molten bronze could be poured.

Bronze could also be re-used, melted down and turned into something new. This means that there are few Ancient Greek bronze sculptures left for us to find, and the ones that we do have are incredible pieces of history.

These 2,500 year old bronze statues were found in the sea near Riace, Italy in 1974

Making of a masterpiece

The steps taken by Ancient Greeks to create their iconic sculptures

How have fridges evolved?

The ingenious methods humans have used to keep food cool

1700 BCE — **1400 BCE** — **400 BCE** — **1805** — **1748** — **1920s**

1 Ice houses
Zimri-Lim, the king of Mari in Syria, ordered the construction of an ice house, which no previous king had ever built. Ice was collected from nearby mountains and stored in pits in the ground so it would remain cool. Ice houses were still used in the UK and USA right up until the 20th century.

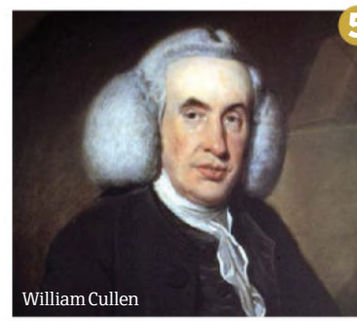
2 Evaporative coolers
Without access to ice, ancient Egyptians stored wine in earthenware jars called amphorae. They would leave the amphora outside during the cool nights, and slaves would sprinkle them with water. The cold wind caused the water to evaporate, slowly cooling the wine inside.

3 Yakhchal
To store ice in the desert, Persians built mud brick domes. In winter, water was led into channels underground and left to freeze. The ice was moved into the yakhchal, which had two parts: the dome and a pit. Warm air rose, leaving cold air underground to chill the ice.

4 Ice box
The ice harvesting industry took off in the 19th century and it became common for people to have an ice box in their home. They were made of wood, lined with metal and insulated with straw or cork. Ice was delivered every few days and placed inside to keep food from spoiling.

5 Artificial refrigeration
Artificial refrigeration was first demonstrated by Scottish chemist William Cullen, but in 1834 US inventor Jacob Perkins built the first refrigerating machine. However, early fridges were expensive and used toxic gases as refrigerants, making any faulty leaks deadly.

6 Domestic fridges
Early domestic fridges were still dangerous and cost more than a car, but soon a much safer refrigerant chemical called Freon was developed and the fridge soon became a common feature of most kitchens. Over the next few decades, they became even cheaper and more eco-friendly.



William Cullen

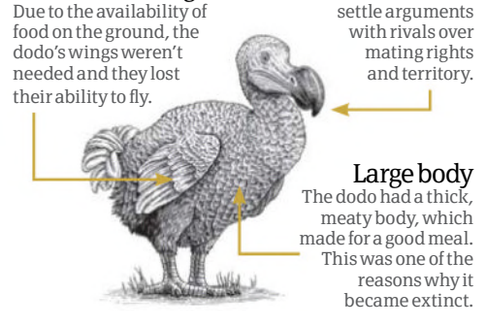
Jacob Perkins

Why did the dodo die out?

From thriving to non-existent in less than 100 years

One of the most famous extinction cases in history, the dodo once inhabited the island of Mauritius in the Indian Ocean, where it thrived due to an abundance of food and a total lack of threat from predation.

The bird was in many ways a victim of its own evolution, as over time it lost the ability to fly due to the abundance of food available to forage for on the ground. Their wings withered away while the body grew bigger and heavier. When Dutch sailors arrived in Mauritius at the end of the 16th century, the dodo made for a quick and nutritious meal – and they could be hunted with ease. Without any natural predators, the bird was too trusting. Eggs and chicks soon came under fire when the explorers began to bring foreign animals with them. Rats, dogs and cats raided their nests, while colonisation destroyed their habitat. This is likely to have been the fastest extinction in history and underlines just how quickly human interaction can ruin the lives of a native species.



What was it like inside a Japanese castle?

Whether at peace or at war, life was hard for the population it protected

A medieval Japanese castle was not only the geographical centre of a ruler's territory; it was also their most important structure. The population relied on the castle to defend them when war began; during times of peace they would either work to maintain the castle, grow food for its army or fight for it in distant campaigns.

Extremely strict rules were enforced on the locals; if a man was away fighting a campaign, his wife would be forced to make repairs to the castle if it was damaged by the weather. The daimyo's (ruler's) needs were always the priority. If a single person failed to complete their task, a punishment would be imposed on the entire company.

When war began, the daily lives of both the garrison and the general population drastically changed, as the castle was quickly converted into an active military headquarters. All available personnel would immediately be tasked with fortifying the castle, typically by either replastering the castle walls, constructing extra palisades (defensive fences of wooden stakes) or by deepening the ditch that surrounded the castle's walls. If the battle was lost, everyone inside the castle was at risk of execution.

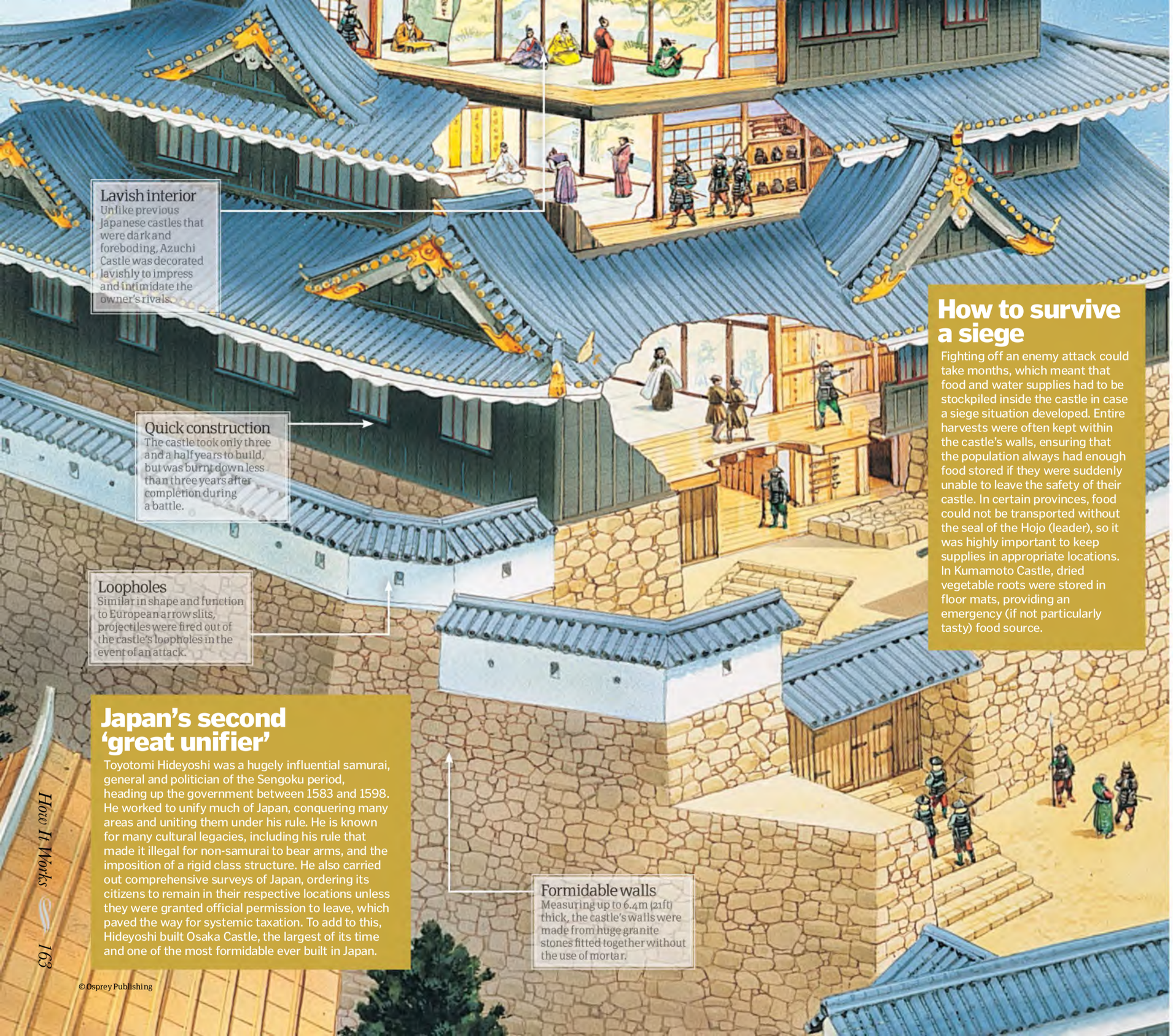
Historic castles, such as Matsumoto pictured here, are listed as National Treasures in Japan

Hip roof
This type of roof design is known as irimoya, and features a hip and gable structure. The sides of the roof slope down and then turn up slightly.

Novel location
Azuchi Castle was built at a great height to give a wide view of an approaching enemy, whereas most Japanese castles were built at the base of a mountain surrounded by dense vegetation.

Main keep
Azuchi Castle's main keep was an impressive seven stories high, and is thought to have been the largest wooden building in the world when it was built.

Gable
Decorative gables are thought to have been a prominent feature of the design on the outer castle, and were more elaborate than its contemporaries.



Lavish interior
Unlike previous Japanese castles that were dark and foreboding, Azuchi Castle was decorated lavishly to impress and intimidate the owner's rivals.

Quick construction
The castle took only three and a half years to build, but was burnt down less than three years after completion during a battle.

Loopholes
Similar in shape and function to European arrow slits, projectiles were fired out of the castle's loopholes in the event of an attack.

Formidable walls
Measuring up to 6.4m (21ft) thick, the castle's walls were made from huge granite stones fitted together without the use of mortar.

How to survive a siege

Fighting off an enemy attack could take months, which meant that food and water supplies had to be stockpiled inside the castle in case a siege situation developed. Entire harvests were often kept within the castle's walls, ensuring that the population always had enough food stored if they were suddenly unable to leave the safety of their castle. In certain provinces, food could not be transported without the seal of the Hojo (leader), so it was highly important to keep supplies in appropriate locations. In Kumamoto Castle, dried vegetable roots were stored in floor mats, providing an emergency (if not particularly tasty) food source.

Japan's second 'great unifier'

Toyotomi Hideyoshi was a hugely influential samurai, general and politician of the Sengoku period, heading up the government between 1583 and 1598. He worked to unify much of Japan, conquering many areas and uniting them under his rule. He is known for many cultural legacies, including his rule that made it illegal for non-samurai to bear arms, and the imposition of a rigid class structure. He also carried out comprehensive surveys of Japan, ordering its citizens to remain in their respective locations unless they were granted official permission to leave, which paved the way for systemic taxation. To add to this, Hideyoshi built Osaka Castle, the largest of its time and one of the most formidable ever built in Japan.

What's the secret of Abu Simbel?

The incredible tale behind one pharaoh's tribute to himself

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

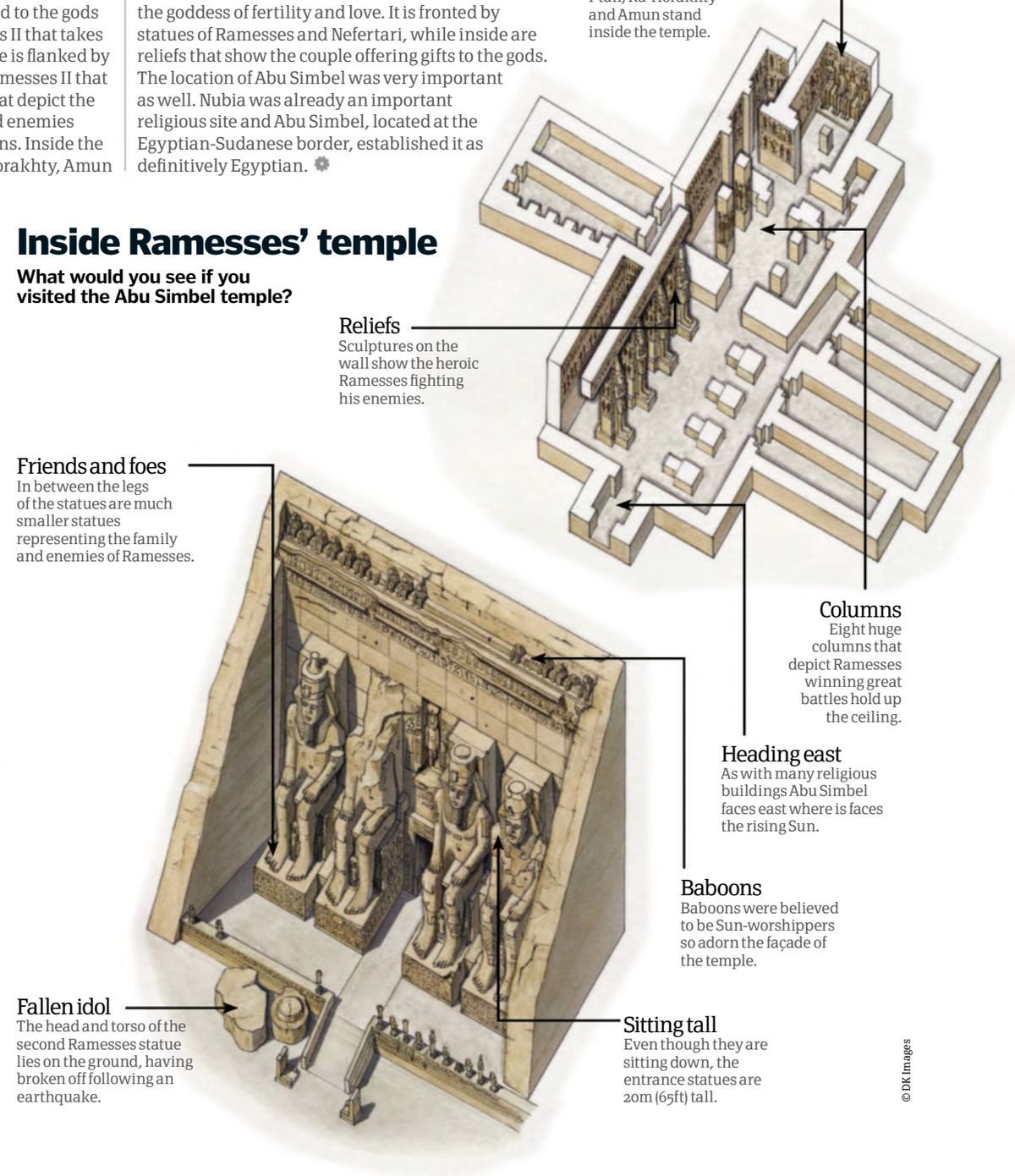
Moving on up

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

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

Inside Ramesses' temple

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



Who were USA's first firemen?

How the USA's volunteers put the fight in firefighter

Today, firefighters are brave heroes who come to our rescue with efficiency and professionalism, but that hasn't always been the case. During the late 18th century and early 19th century, firefighters in the USA didn't have such a good reputation. Rather than being employed by the government, they were typically volunteers who had been let off military service or jury duty, and were required to buy their own uniforms and equipment.

Firehouses became like social clubs and when news of a fire broke, the volunteers would race those from other fire companies to reach the scene first, dragging heavy hand-operated water pumps with them. These competitions often resulted in the firefighters battling each other instead of the fire!

Soon, local gangs began associating themselves with the firehouses, and the firefighters became involved in party politics. This resulted in even more violence, with the firefighters sometimes starting fires themselves. One particularly lethal confrontation in 1856 became known as the Know-Nothing riot, and saw several people killed at Lexington Market in Baltimore.

By the mid-19th century, insurance companies and the Republican Party were lobbying for a professional fire service and when horse-drawn, steam-powered water pumps became available, the volunteers were replaced with paid fire departments.

Helmet
The reinforced dome helmets made from specially treated leather had an angled brim so that water could run off the back.

Beard
Firefighters would soak their beards in water, bite them, then breathe through them to prevent themselves from inhaling fumes from the fire.

Red shirt
Bright red, bibbed shirts helped people identify the firefighters, and they soon became a symbol of elevated social status.

Speaking trumpet
Excited and noisy crowds would often come to watch the firefighters at work, so they used brass speaking trumpets to relay commands.

Hose
The leather hose had seams were held together by metal rivets to stop it rupturing under the pressure of the water.

Leather boots
Knee-high leather boots were worn mainly to keep the firefighters warm and dry, rather than protect them from the flames.

Fighting fires by hand

Before steam-powered fire engines, firefighters used hand-operated pumps to douse fires with water. These machines on wheels would be pulled through the streets by horse or by the firefighters themselves. Some had to be filled by hand, with so-called 'bucket brigades' of local helpers fetching water from nearby sources, but others were equipped with a suction hose that could draw water directly from municipal hydrants.

The firefighters would then pump the long levers up and down to operate a set of pistons inside. The movement of the pistons would alternately suck water out of the main tank and force it into a separate chamber. The air trapped inside the chamber would maintain a constant pressure helping to spray the water out through a hose. It requires an exhausting 60 strokes per minute to pump the water effectively, so teams of firefighters would take turns to operate the machine for a few minutes at a time.

What were armoured trains?

Discover how railways went to war in the 19th and 20th century

The explosion of rail travel in the 19th century changed warfare. Now armies depended upon railways to mobilise and to supply, from dispatching troops and vehicles to the front line to keeping them well-stocked with munitions, medicine and other sundries. Railways became pivotal to the war effort, so they had to be protected.

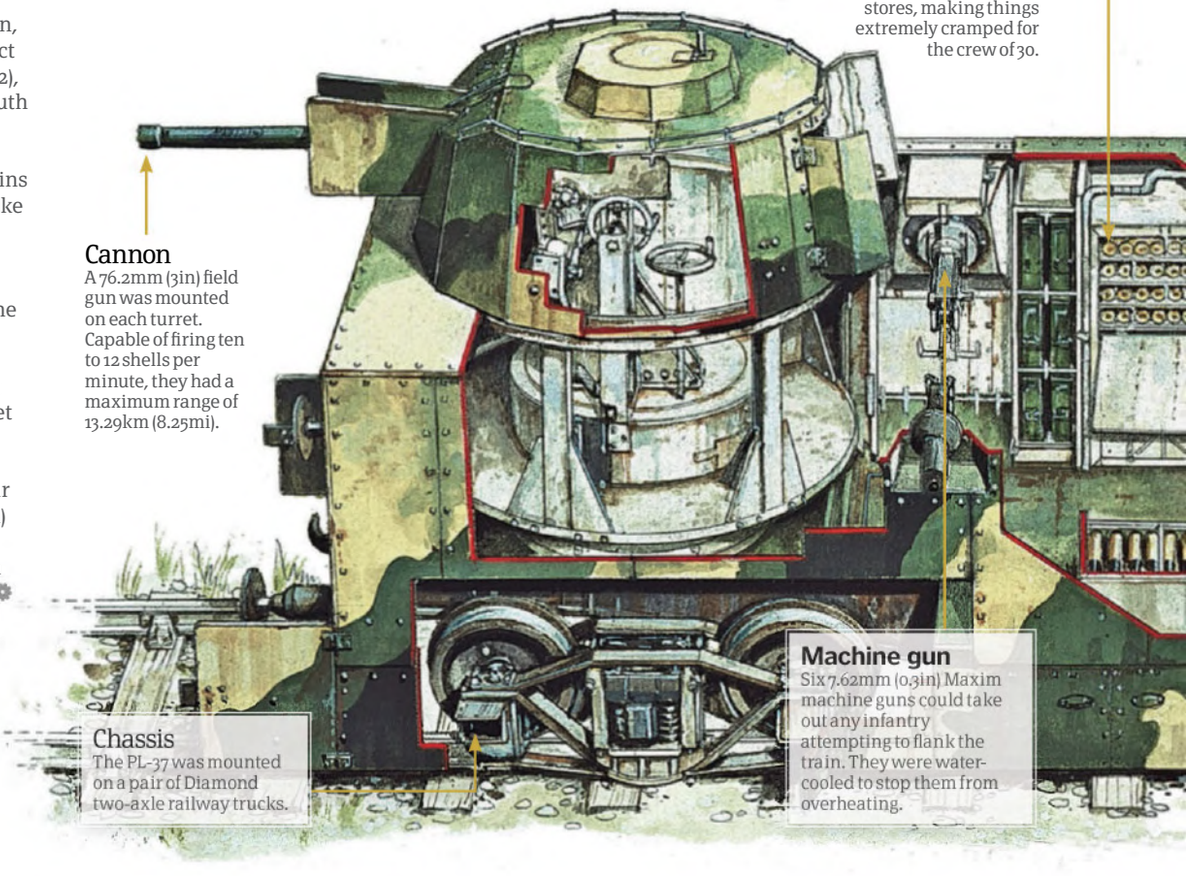
The first improvised armoured trains appeared in 1848 for use by the Austro-Hungarian army in quelling the revolutions that gripped the empire that year. Nearly two decades later they proved their strategic worth in the American Civil War of 1861 to 1865 when armoured trains protected the Union-held rail lines of Baltimore from Confederate saboteurs.

In June 1862, Confederate General Lee ordered that a cannon be mounted on a railway carriage, kick-starting the evolution of the armoured train as a means to not just protect the railway, but as an offensive weapon in itself, able to advance rapidly toward the lines and unleash a powerful artillery barrage.

It was over wide-open spaces where armoured trains really came into their own, and the British Empire used them to protect its far-flung interests, such as in Egypt (1882), Sudan (1885) and India (1886), as well as South Africa during the Boer War (1899-1902). By World War I (1914-1918), Britain and its continental neighbours saw armoured trains as best deployed against irregular forces like those they had faced in their colonial campaigns, and too vulnerable for use against professional armies.

Although a few models saw service on the Western Front, it was on the Eastern Front where armoured trains remained vital thanks to the poor infrastructure and vast distances of the Russian Empire. The Soviet Union inherited the previous regime's enthusiasm for rail-mounted combat and they were a feature of the Russian Civil War (1917-1920), the Polish-Soviet War (1919-1921) and the Eastern Front of World War II (1939-1945), where they saw service as both frontline artillery and anti-aircraft guns.

Soviet railwaymen work on an armoured train in the depot during WWII



> "Railways became pivotal to the war effort"

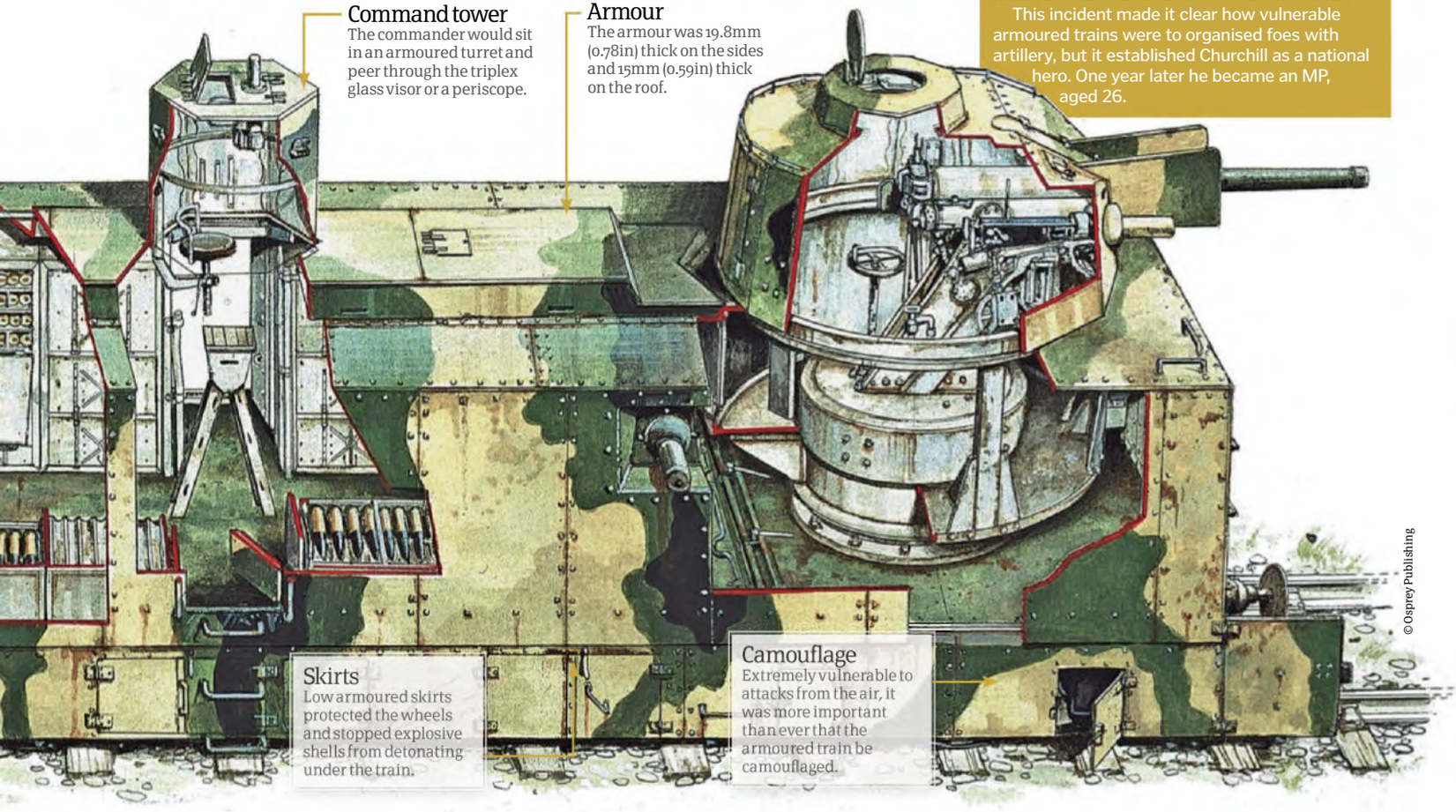
The railway warlord of China

When the Communists emerged victorious in the Russian Civil War, many defeated nationalist 'Whites' fled to China – and they brought their trains with them!

The vastness of China and the widespread nature of the fighting after the overthrow of the emperor in the Xinhai Revolution (1911) was ideal territory for armoured trains and they became most closely associated with Manchurian warlord Zhang Zuolin.

As well as the 'White' trains and volunteers, including at least three generals and an entire cavalry regiment, Zhang employed Russian engineers to create similar armoured trains for his army. Fittingly, Zhang was assassinated in his train on 4 June 1928 when a bomb was planted on a railway bridge.

The wreckage of Zhang Zuolin's train after his assassination



Churchill in his military uniform, four years before his scrape in South Africa

Winston Churchill's armoured train

Before he entered politics and then history, swashbuckling young cavalry officer-turned-war reporter Winston Churchill was captured along with 50 British soldiers when their armoured train was ambushed by a well-armed Boer militia in South Africa.

On 15 November 1899 they blocked the line with rocks and then opened fire with two field guns, taking out the train's naval gun. "The troops, who had maintained a hopeless fight with great courage, were overpowered," wrote The Manchester Guardian on 17 November. "Mr Churchill was last seen advancing with a rifle among the Dublin Fusiliers. He is believed to have surrendered himself to cover the retreat."

This incident made it clear how vulnerable armoured trains were to organised foes with artillery, but it established Churchill as a national hero. One year later he became an MP, aged 26.

How did the Anasazi live?

Who built these incredible cave cities in the Colorado desert?

When European Americans first explored Chaco Canyon in New Mexico in 1849 they must have thought they'd found a mythical lost city. Against the canyon wall were the ruins of vast five-storey homes, a warren of around 800 rooms like an entire town within a single set of walls. Among the debris were ceramic cylinders and broken pottery, evidence of dams and irrigation trenches that diverted water, and a network of roads nine metres (30 feet) wide.

The Anasazi, whose name comes from the Navajo word for 'ancient enemies' or 'ancient ones', built numerous similar settlements across the Four Corners region at the intersection of what is Utah, New Mexico, Arizona and Colorado today, from as early as the 10th century.

Then at some point before the end of the 13th century, this mysterious culture suddenly moved from their multi-storey 'great houses' and into caves that had been carved into the seemingly inaccessible orange-brown cliff-faces of southern Colorado. Just as ambitious as their original homes, these cliff dwellings had several rooms connected by ladders and walls of sandstone blocks. By the 14th century these new dwellings were empty too; the reason for the Anasazi's sudden migration may also be responsible for their sudden disappearance.

Facing competition from other tribes over dwindling water supplies, the Anasazi may have gathered their scattered communities into more defensible positions – literally with their backs to the wall. From there they may have left, heading further south in search of swollen rivers or plentiful rainfall well away from the arid cliffs and canyons of the Colorado desert.

A city on the edge

How the Anasazi lived

Plaster
The sandstone blocks that made up the walls were often coated in a 'plaster' of mud.

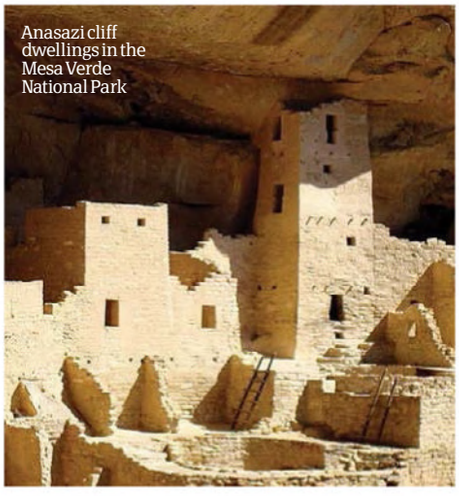
Wooden frames
Anasazi homes used ponderosa pine wood for supports.

T-shaped door
T-shaped doors were a common Anasazi motif, but the significance of them is a mystery.

Ladders
The Anasazi moved between levels with ladders; these could be pulled up behind them for protection.

Kiva
Meaning 'world below', the Kiva was used as a meeting and ceremonial room and was lined by stone benches.

Roof
The Kiva roof contained a hole that could be used as an entrance and also provided ventilation for the fire pit below.



Anasazi cliff dwellings in the Mesa Verde National Park

Anasazi riches

Though the Anasazi cities and cliff dwellings are confined to a relatively small area, this ancient Native American culture had a network of trade that stretched as far west as the Californian coastline and as far south as Mexico. Thanks to their valuable mines, the Anasazi were able to import goods as diverse and luxurious as parrots, seashells and copper bells from the Gulf of Mexico in exchange for turquoise, which was used in jewellery and mosaics. Relics and funeral masks made from glistening green Anasazi turquoise have been found as far away as the Mayan city of Chichen Itza, taking pride of place in the elaborate tombs of Mexico's Yucatán Peninsula.

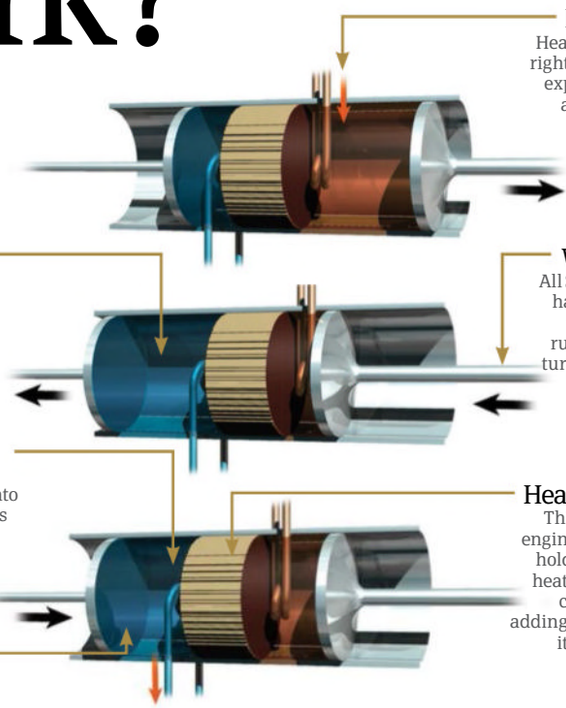
An Anasazi turquoise pendant

How did stirling engines work?

How does this 200-year-old design convert heat into mechanical energy?

A Scottish clergyman named Robert Stirling invented the Stirling engine in 1816. He hoped to create an engine that was safer and more efficient than its steam-powered rivals, which had already existed for roughly a century. The release of the Stirling engine was met with much enthusiasm, but the rise of internal combustion engines saw it sidelined by many companies.

Stirling engines work by repeatedly cooling and heating the same volume of gas, using its expansion and compression to move two pistons and drive an engine. This mechanism is experiencing somewhat of a revival, as it is perfect for use in solar plants where it can produce continuous power as the Sun warms the solar panels. They can also run backwards to create super coolers for use in superconductivity and electronics research.



What was the Caspian Sea Monster?

Why this monstrous Russian aircraft worried the West for so many years

Dubbed the "Caspian Sea Monster" by US Intelligence, this 92-metre (301-foot) long Russian ekranoplan (a mixture of airplane and hovercraft) was spotted during the height of the Cold War in 1966 by an American spy satellite while it scanned the Caspian Sea.

Initially it baffled the West due to its odd shape and intimidating size, which made it poorly suited for traditional sea to air flight. The Sea Monster's actual function was to fly very close to the water or ground, producing a cushion of air that increased its lift and made it more efficient than a traditional aeroplane. This phenomenon is known as 'ground-effect' and could have allowed the vehicle to fly low enough to be undetectable by enemy radar at the time, ferrying hundreds of troops and armoured vehicles across the water in secret. The only model of the Caspian Sea Monster was unfortunately crashed in 1980 after a pilot error, and was much too heavy to recover from its watery grave. Plans were made to deploy over 100 similar planes during the 1990s, but the end of the Cold War also put an end to these developments, leaving only a handful of ekranoplans in existence.

This gigantic aircraft was capable of reaching speeds of 500 kilometres (311 miles) per hour

What was Vostok 6?

How the first woman was sent into space

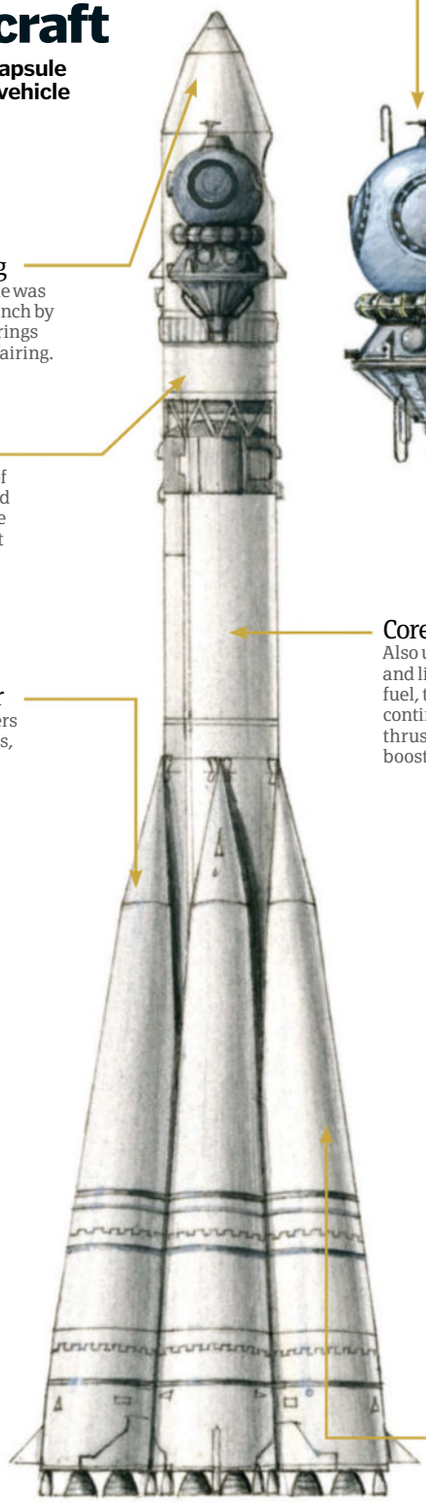
The Soviet Union achieved many firsts in the quest to explore space. They launched the first artificial satellite, Sputnik, in 1957, sent the first animal, Laika the dog, beyond Earth's atmosphere in the same year, and then launched the first human into orbit, Yuri Gagarin, four years later. However, they weren't ready to stop there, and so in 1963 they beat America to yet another space race milestone – sending the first woman into space.

Valentina Tereshkova was a textile factory worker and keen skydiver before starting cosmonaut training in 1962. She was chosen for her excellent parachuting skills, as she would be required to eject from her Vostok 6 spacecraft when returning to Earth and parachute down separately. Just one year later, at the age of 26, she was ready for her mission, uttering the words "Hey, sky! Take off your hat, I'm coming!" just before launch.

However, Tereshkova wasn't actually alone in space, as two days earlier Vostok 5 had launched onto the same orbital path. It was originally intended for both spacecraft to be piloted by women, with Tereshkova at the controls of Vostok 5, but male astronaut Valery Bykovsky ended up in the capsule. The two spacecraft came within five kilometres (three miles) of each other in orbit, and Bykovsky reported that Tereshkova hummed songs to him via radio link before they drifted apart and the connection was lost. After Bykovsky had completed 82 obits of Earth and Tereshkova had done 48, both cosmonauts successfully returned to Earth on the same day. Tereshkova was almost unconscious when she landed, but by the following day she was well enough to film a re-enactment. She soon became a global celebrity, but it would be 19 years before another woman, Svetlana Savitskaya, would follow in her footsteps.

Tereshkova's spacecraft

The Vostok 6 capsule and its launch vehicle



Vostok 6 capsule
The spherical capsule contained a 2.3m (7.5ft) wide pressurised cabin, with an ejection seat for Tereshkova to sit in.

Air supply
Tanks of compressed nitrogen and oxygen provided breathable air for Tereshkova and propulsion for the spacecraft.

Instrument section
The conical module underneath the capsule contained the Earth-return rocket and thermal control systems.

Payload fairing
The Vostok 6 capsule was shielded during launch by two petal-like coverings called the payload fairing.

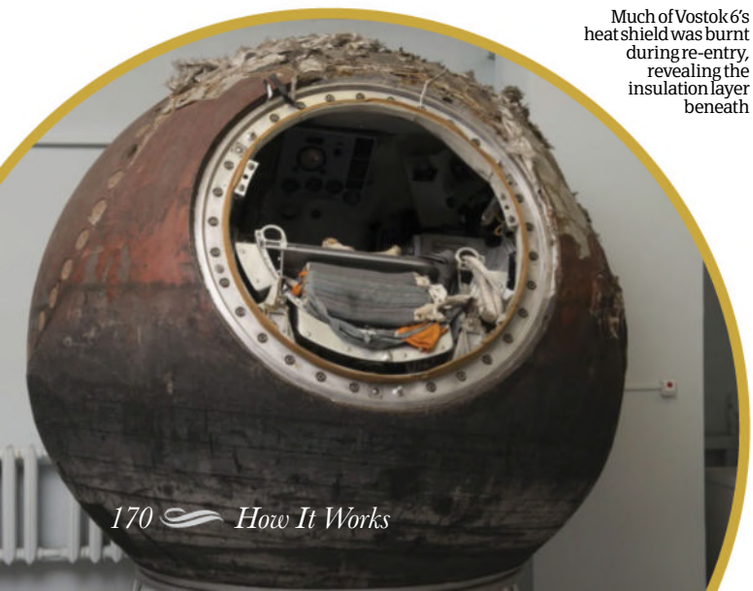
Final stage
The upper section of the rocket contained the Vostok 6 capsule and helped insert it into orbit.

Core stage
Also using kerosene and liquid oxygen as fuel, the middle section continued to provide thrust when the boosters fell away.

Rocket booster
The Vostok's boosters used RD-107 engines, which had been developed from the world's first intercontinental ballistic missiles.

First stage
Each of the four boosters had a rocket engine at the base, and were fuelled by kerosene and liquid oxygen.

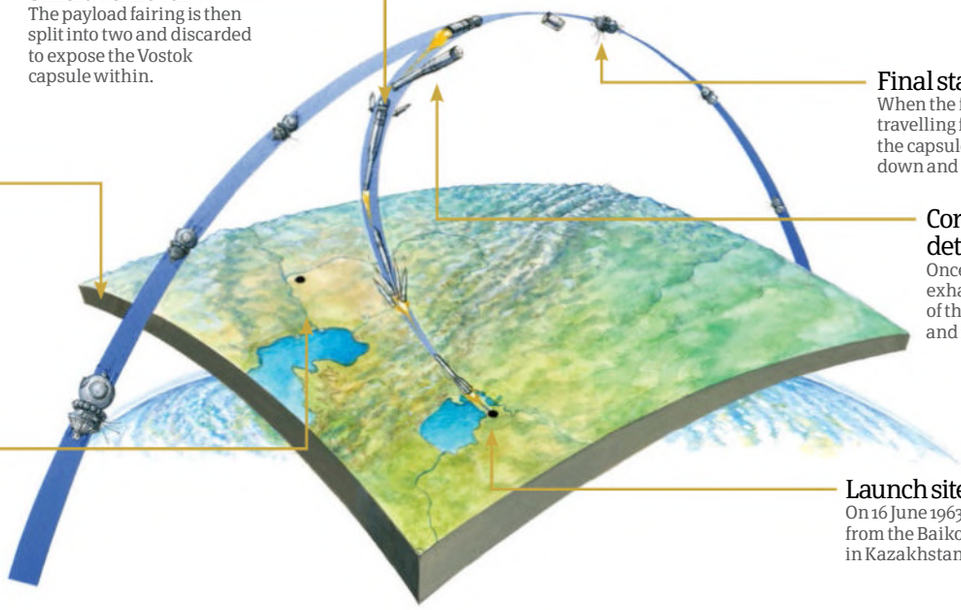
> "The two came within three miles of each other"



Much of Vostok 6's heat shield was burnt during re-entry, revealing the insulation layer beneath

Lift-off

How Vostok 6 was launched into space



Shield removal
The payload fairing is then split into two and discarded to expose the Vostok capsule within.

Final stage separation
When the final stage is travelling fast enough to deliver the capsule into orbit, it is shut down and separated.

In orbit
The Vostok 6 capsule goes on to complete 48 orbits of the Earth, reaching a maximum altitude of 231km (144mi).

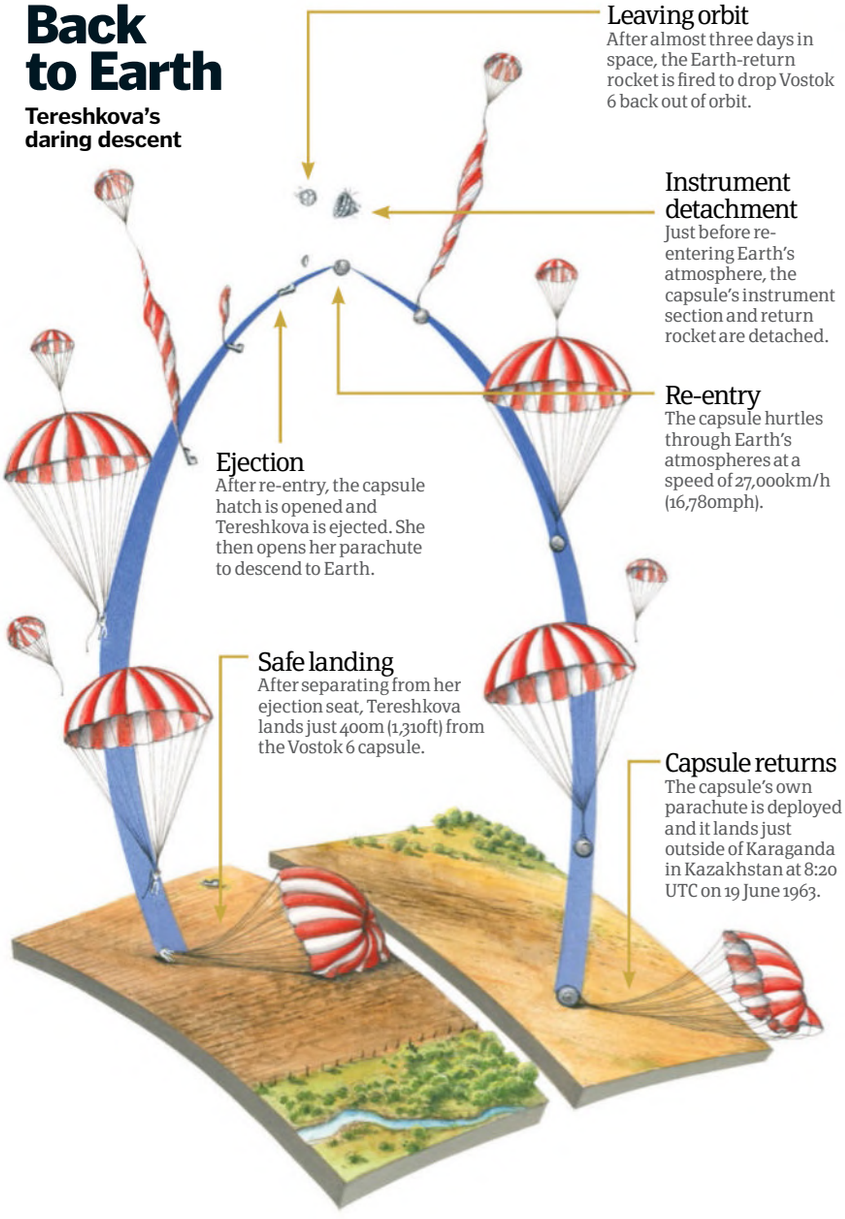
Core stage detachment
Once its fuel supply is exhausted, the core stage of the rocket detaches and falls back to Earth.

Booster separation
Several minutes after launch, the four rocket boosters run out of fuel and are detached, falling back to Earth.

Launch site
On 16 June 1963, Vostok 6 launches from the Baikonur Cosmodrome in Kazakhstan at 9:29:52 UTC.

Back to Earth

Tereshkova's daring descent



Leaving orbit
After almost three days in space, the Earth-return rocket is fired to drop Vostok 6 back out of orbit.

Instrument detachment
Just before re-entering Earth's atmosphere, the capsule's instrument section and return rocket are detached.

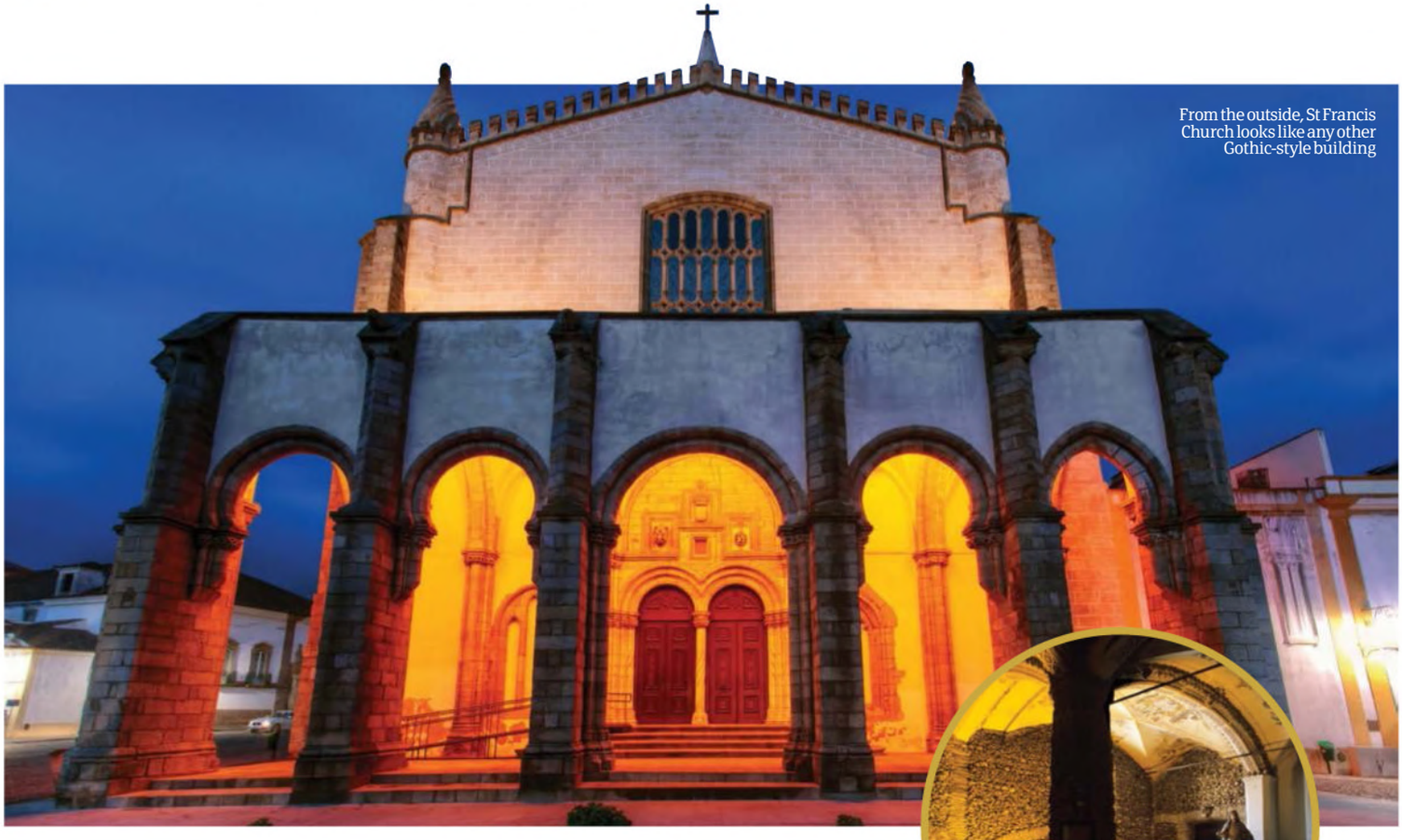
Re-entry
The capsule hurtles through Earth's atmospheres at a speed of 27,000km/h (16,780mph).

Ejection
After re-entry, the capsule hatch is opened and Tereshkova is ejected. She then opens her parachute to descend to Earth.

Safe landing
After separating from her ejection seat, Tereshkova lands just 400m (1,310ft) from the Vostok 6 capsule.

Capsule returns
The capsule's own parachute is deployed and it lands just outside of Karaganda in Kazakhstan at 8:20 UTC on 19 June 1963.

Tereshkova's call sign for the mission was 'Chaika', Russian for 'seagull'. She had one embroidered on her spacesuit



From the outside, St Francis Church looks like any other Gothic-style building

What is the Chapel of Bones?

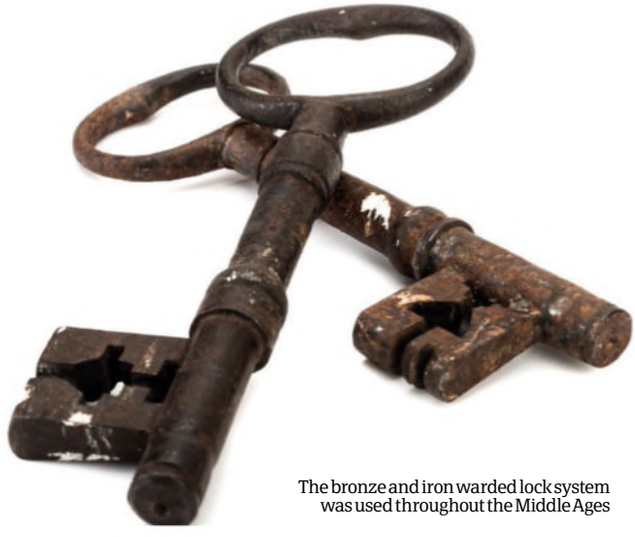
The bones act as a reminder of the transience of life

The outside of St Francis Church in Evora, Portugal looks just like any other Renaissance church. But step inside and you will discover a dark secret hidden within its walls – a chapel made out of bones. The Capela dos Ossos, or 'Chapel of Bones', was built by a group of Franciscan monks in the 16th century. When the city's cemeteries became overcrowded, the remains of thousands of deceased people were brought to the church for storage. This was normal practice for the time, but rather than hide them away in underground tombs, the monks decided to put the bones on display. They believed that this monument would help to remind their fellow brothers of their own mortality.

The walls and central pillars of the chapel were covered with cement, and then the bones and skulls of around 5,000 skeletons were pressed into them. Two desiccated corpses were also hung from the ceiling by ropes. No one really knows who these two skeletons belong to, but some people believe they are those of an adulterous man and his son, cursed by a jealous wife.

Who invented the first keys?

One of the earliest known examples of a key and lock system was used in Egypt 4,000 years ago. The simple mechanism consisted of a wooden bolt secured to the door, with several wooden pins gripping it into position. The wooden key resembled a toothbrush in shape and featured pegs at the end that, when inserted into the lock, pushed the pins upwards to release the bolt. However, this offered little security, as any key could open any lock. To solve this problem, the Romans developed the warded lock, often made of iron or bronze. Notches and grooves called wards were cut into the keyhole, so that only keys cut with corresponding notches and grooves could fit into it. Warded locks still weren't particularly secure though, as instruments could be fashioned to fit the wards and pick the lock, but they still remained in use for centuries. After a few more attempts at developing a more secure system, it wasn't until the 1800s that American Linus Yale and his son Linus Yale Jr developed the spring-driven pin-tumbler lock that is still commonly used today.



The bronze and iron warded lock system was used throughout the Middle Ages

What were original rugby balls made from?

Produced close to the school from which its name derives, the rugby ball was originally made from pigs' bladders, which is why they have such an unconventional shape. In the 19th century, shoemakers Richard Lindon and William Gilbert began making balls for the pupils at Rugby School by blowing up the bladders and encasing them in stitched leather. The bladders were even inflated manually – a clearly unpleasant task.

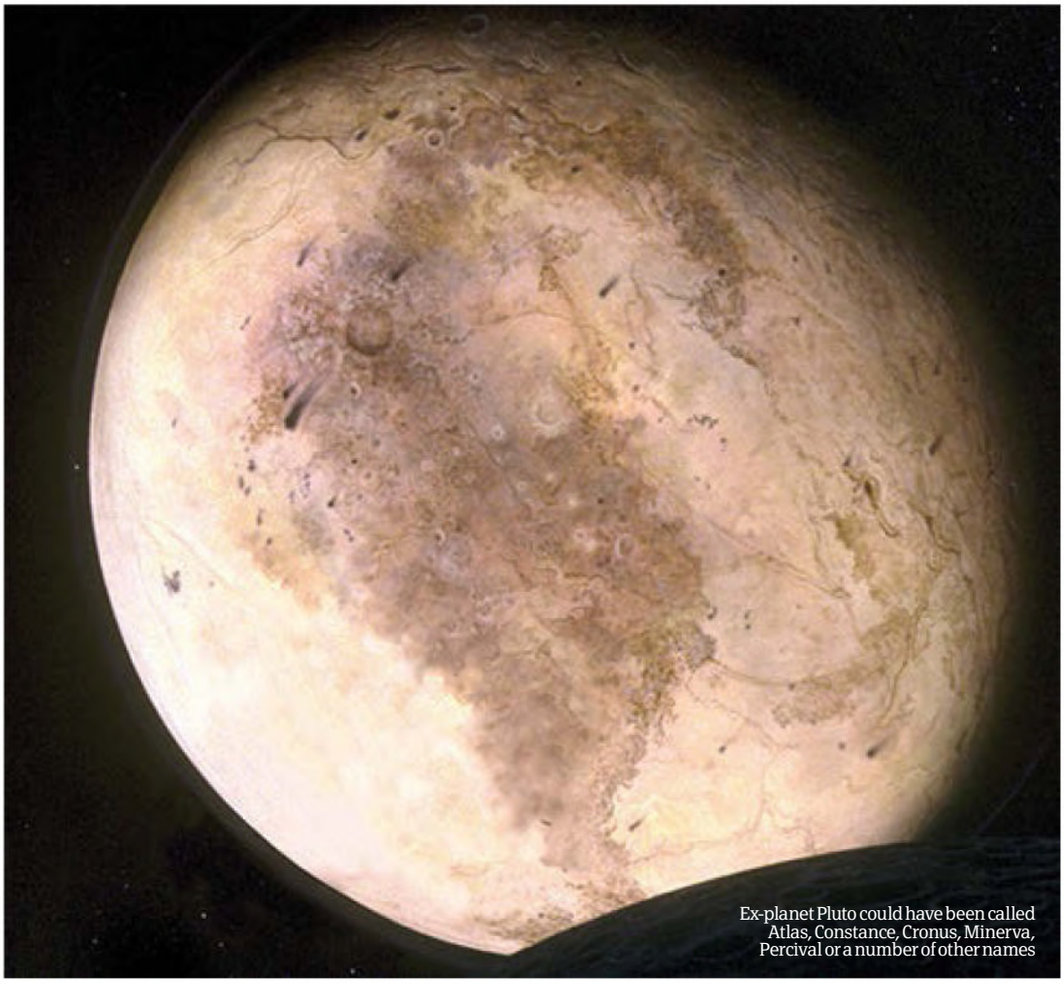
As each pig came with a different-sized bladder, practically this meant the original rugby balls came in a variety of sizes, but the characteristic oval shape only emerged later. It wasn't even until 1845 that rugby rules, written by the pupils of the school, were established. By 1892, specifications for the ball were written into the game, stating among other things that it be hand-sewn with eight stitches per inch and have a weight of 368.5 grams (13 ounces).

Originally, rugby balls were less oval and more rounded in their shape

Gold has been used as a currency by cultures across the globe

Has gold always been so valuable?

Gold has been prized throughout human history due to its scarcity, combined with a unique selection of properties that led to its use as a currency. Gold is rare, making up just five parts per billion of the Earth's crust. It is also difficult and expensive to extract, and so only very limited quantities can be mined every year, making it a stable currency. Gold is remarkably unreactive and so does not oxidise like silver or iron. Therefore, gold coins do not lose or gain weight over time. While other metals such as aluminium, platinum or silver look quite similar, gold is the only yellow metal, rendering it instantly recognisable. Gold's attractive appearance has also made it a popular material for jewellery and other adornments. Due to gold's malleability, it is possible for it to be moulded into different shapes and divided easily.



Ex-planet Pluto could have been called Atlas, Constance, Cronus, Minerva, Percival or a number of other names

Why were the names of the planets chosen?

Planetary names in our Solar System are derived from mythology – except for Earth, which comes from Middle English. Since five of the planets can be seen by the naked eye, they have been called many things depending on the culture over the centuries before their current names became standard. Uranus (previously thought to have been a star) is the only planet whose name comes from Greek rather than Roman mythology. Neptune's discoverers argued over who could name it, while former planet Pluto's name was suggested by an 11-year-old in the UK. There were no planetary naming rules until 1919, when the International Astronomical Union (IAU) formed. The IAU is currently in charge of naming all celestial objects.

How did speech evolve?

Speech and language are two separate things, but their evolution is linked. Humans are different from other primates because our larynx (voice box) is lower down in our throats. Scientists think that this might have helped early humans to sound bigger and scarier than we really were. Having a low larynx means that we can move our tongues much more freely and make a much wider range of sounds. In the animal kingdom, whales use their vocal repertoire to signal their membership of a family group – individuals learn songs from one another, making it easy to spot an outsider. One hypothesis is that early human speech was used in much the same way, evolving as a mechanism to detect people who didn't belong.

Human speech is made possible by our unusual anatomy

How many people are in the average family tree?

This depends on how far back you look, and what you think of as an 'average' family. The number of children per family varies widely from country to country and from generation to generation. For example, in the UK, the average number of children in each family in 2012 was 1.7, while in the 1970s it was 2.4. Worldwide, the figures were 2.5 children in 2012, compared with five in 1960.

As you can see, it is hard to define the 'average' family tree. However, there is one universal truth about families – everyone has two biological parents – so you could ask, how many ancestors do I have?

You have two parents, four grandparents, eight great grandparents, 16 great-great grandparents, and so on. For every generation you add double the number of ancestors as the previous generation. Assuming the average generation length is around 25 years, if you go back just 250 years in history, your family tree will contain around 2,047 people.

> "Prehistoric men are believed to have had thick beards for protection"

Hans Langseth, pictured here in 1912, grew his beard to a record-setting 5.33 metres (17.5 feet) long

What is the history of the beard?

Beards are currently trendy, but their popularity has cycled. Prehistoric men are believed to have had thick beards for protection from both the elements and other men during fights. They also may have been an intimidation factor, as they made the jaw look bigger and more menacing. Beards have often been said to project a strong sense of masculinity, and a big beard was a sign of honour in ancient times. Cutting off one's beard was used as a punishment. Then things changed around the time of Alexander the Great, in the mid-300s BCE. He banned beards on his soldiers because he feared that enemies could use them to pull them in for attack. In the Middle Ages, it was considered highly offensive to touch another man's beard and could lead to a duel. In the 18th century, beards fell out of favour, then returned during Victorian times. Beard wearing has had – and will continue to have – many different influences, including politicians, celebrities, religion and societal changes.

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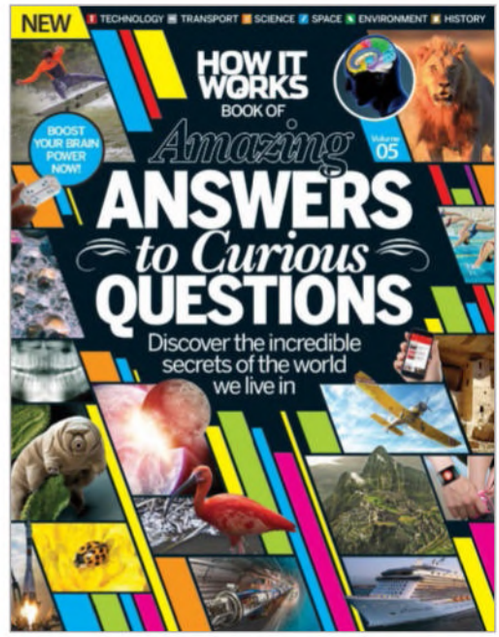

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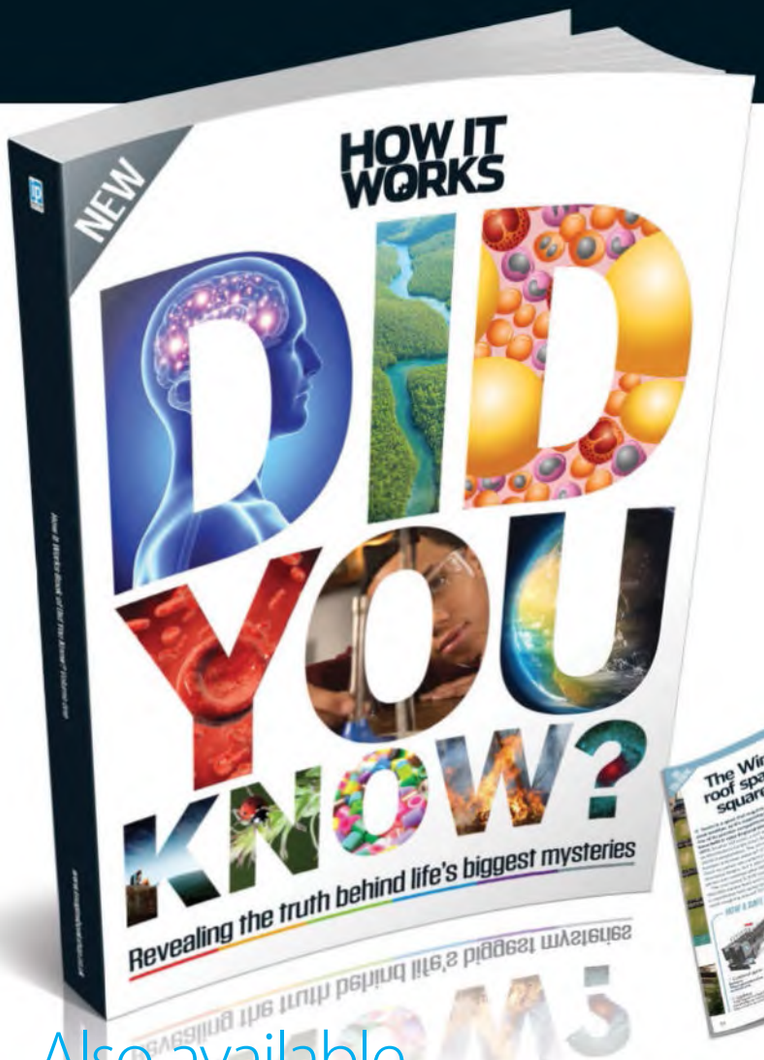

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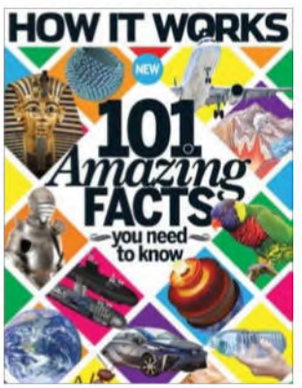

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