THE MAGAZINE THAT FEEDS MINDS

HOW IT WORKS

SCIENCE | ENVIRONMENT | TECHNOLOGY | TRANSPORT | HISTORY | SPACE

INSIDE

GRAVITY
THE FORCE THAT PULLS YOU BACK TO EARTH

UNDERWATER WONDERS
HOW THE PLANET'S BIGGEST BEASTS SURVIVE THE DEEP

A great white's bite force is more than 18,000 Newtons

Orcas can live for over 50 years

Some jellyfish are 95% water

The sperm whale can hold its breath for up to 90 minutes

+ LEARN ABOUT
- ANGER
- SPLEENS
- MOSAICS
- FIREBOATS
- INSTAGRAM
- 3D GLASSES
- HANDBRAKES
- CLEANROOMS

MUSCLE CARS
THE ENGINEERING INSIDE A POWERFUL STREET RACER

BIRTH OF THE SOLAR SYSTEM
Where did all the planets come from?

3.2 BILLION PIXEL CAMERA
What's inside the world's biggest digital camera?

EXOSKELETONS
Which animals wear their skeletons on the outside?

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IMAGINE PUBLISHING

HOW IT WORKS

ISSUE 38

WELCOME

The magazine that feeds minds!

Get in touch

Have YOU got a question you want answered by the How It Works team? Get in touch via...

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FEED YOUR MIND!

While over 70 per cent of the surface of the planet is covered by ocean, amazingly 95 per cent of it has never been explored, which only serves to deepen our fascination with this alien part of our world. To satisfy your curiosity with this diverse and often inhospitable environment, this issue we're exploring the anatomy of the enormous creatures that call these dark depths their home. Find out why being bigger is definitely better for the wonders that inhabit our planet's oceans, and learn about the physiology of the marine giants that can withstand the immense pressure of a one-kilometre (0.6-mile) dive and hold their breath for well over an hour! You'll meet all kinds of mammoth mammals and gigantic fish, along with other species – including a crab the size of a car and a whale that weighs the same as 36 African elephants!

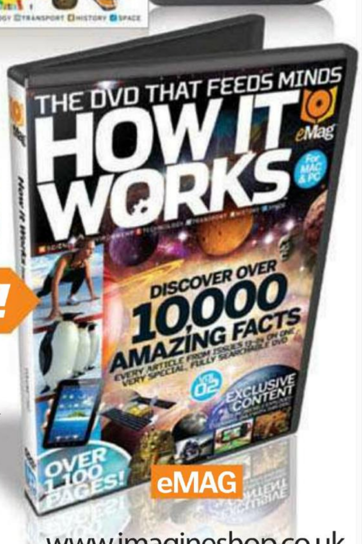
Also this issue, on page 40 you can learn about gravity, the powerful force that not only keeps our feet planted firmly on the ground, but helped to create the ground in the first place. Indeed, gravity is key to the formation of all planets, which you can read about in more detail in our excellent 'Birth of the Solar System' feature over on page 54.

Enjoy the issue.

Helen

Helen Laidlaw
Editor

THE WORLD OF HOW IT WORKS



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Meet the team...

Dave
Ed in Chief
Muscle cars have certainly come a long way since their heyday in Fifties and Sixties America. It was a real eye-opener to see how their all-round engineering has stepped up a gear.

Robert
Features Editor
Breaking through the myth to reach a kernel of truth about velociraptors was a high point for me. Films like *Jurassic Park* have truly warped our perception of this turkey-sized dino.

Ben
Features Editor
Having visited The Rock myself, an insight into the history of Alcatraz as an island, military institution, high-profile federal prison and, finally, a tourist attraction was a riveting read.

Adam
Senior Sub Editor
Not since my Physics GCSE have I pondered gravity in any great detail. The big feature in Science, however, has made me see it in a whole new light – where would we be without it?

THE SECTIONS

The huge amount of info in each issue of **How It Works** is organised into these sections

ENVIRONMENT
The splendour of the natural world explained

TRANSPORT
Be it road, rail, air or sea, you'll find out about it in Transport

HISTORY
Your questions about how things worked in the past answered

SCIENCE
Explaining the applications of science in the contemporary world around us

TECHNOLOGY
The wonders of modern gadgetry and engineering explained in depth

SPACE
From exploration of our Solar System to deep-space adventures

WITH THANKS TO...

How It Works would like to thank the following organisations for their help

DK · NASA · SCIENCE PHOTO LIBRARY

CONTENTS

The magazine that feeds minds!

MEET THE EXPERTS

Find out more about the writers in this month's edition of **How It Works...**

Michael Simpson
Instagram

Michael's article on Instagram technology betrays his obsession with technology and gadgets. While not working as an ecologist in BC, Canada, he also writes on science fiction and fact.

Dave Roos
Science of gravity

We may not be able to see it, but this issue science writer Dave reveals how great an impact the force of gravity has on everything in our world – in fact, without it Earth wouldn't be here in the first place!

Mike Anderiesz
Self-service checkouts

Technology writer Mike may not always get on with the latest method to pay for our shopping – and, let's face it, he's not alone – but he does know a thing or two about how self-checkouts work.

Lynsey Porter
Free radicals

This month biology expert Lynsey explains the science of some unusual molecules called free radicals, revealing why they can be harmful to our bodies and what we can eat to keep them in check.

Tom Harris
Quest for the Higgs boson

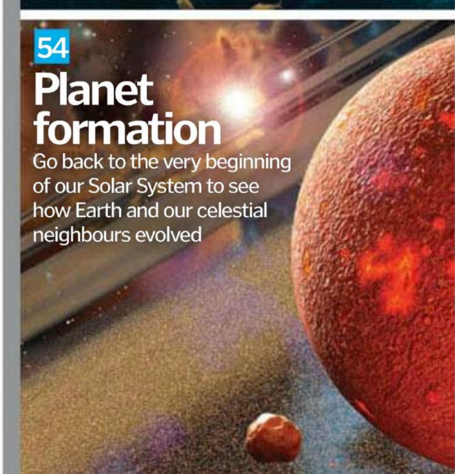
This issue How It Works regular Tom is taking a closer look at the decades-long journey to discovering the elusive Higgs subatomic particle and why being certain is a science unto itself.

How does Instagram edit and share our photos?
Go to page 36 to find out!

12 UNDERWATER WONDERS

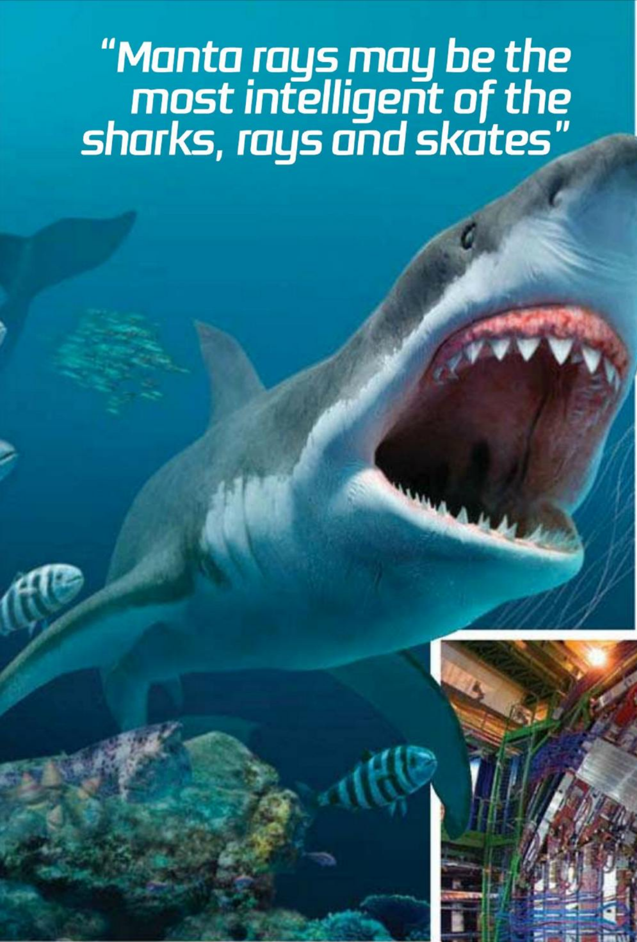
Meet the ocean giants

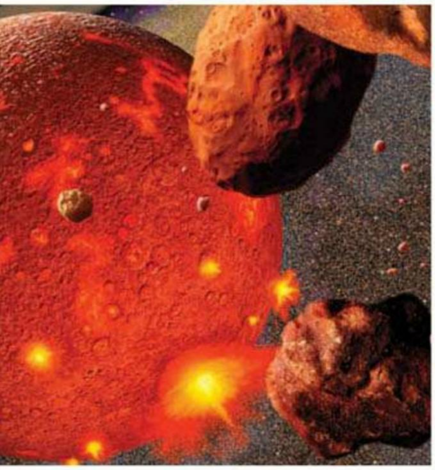
Take a moment to ponder how the sea's biggest beasts can support such immense bodies and satisfy their mighty appetites in order to survive the deep blue yonder

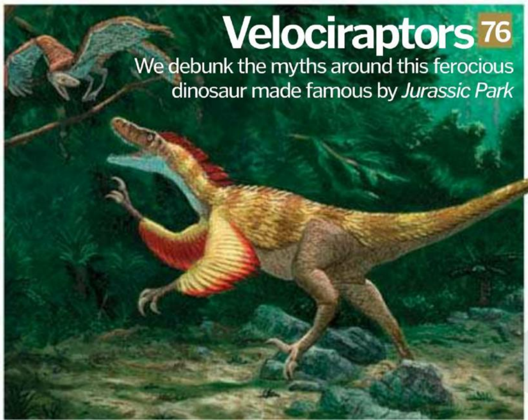


54 Planet formation
Go back to the very beginning of our Solar System to see how Earth and our celestial neighbours evolved

26 Mega drills
How do these giant mechanical moles burrow through a mountain range?


"Manta rays may be the most intelligent of the sharks, rays and skates"





REGULARS

Mars's alien wilderness caught on camera

The Curiosity Rover, NASA's $2.3bn explorer, touches down on the Red Planet and begins its landmark mission by transmitting stunning full-colour panoramas back to Earth

After an epic eight-month voyage across 566 million kilometres (352 million miles) of space, NASA's Curiosity Rover finally touched down on Mars, instigating celebrations around the world. From NASA's Jet Propulsion Laboratory (JPL) at the California Institute of Technology where the vehicle was designed and built, through to the deserts surrounding the European Space Observatory's Paranal Observatory in Chile where it was tested, the news has taken the world by storm, marking a momentous milestone in humanity's exploration of other planets.

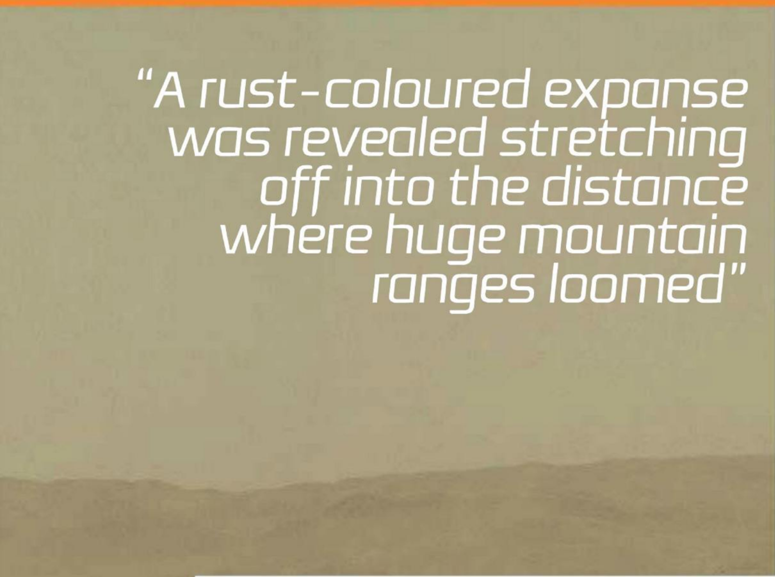
After a hair-raising seven-minute descent through the Red Planet's atmosphere that culminated in Curiosity landing just 2.4 kilometres (1.5 miles) from its scheduled target zone, the rover then proceeded to wow both professional and layman astronomers alike by beaming back eerie black-and-white and then full-colour photographs of Mars's landscape. Strewn with pebbles, rocks and dust, a rust-coloured expanse was revealed stretching off into the distance where huge mountain ranges loomed over the region known as the Gale Crater – a remnant from a massive asteroid collision.

After taking in the sights Curiosity then synced up with its control centre on Earth allowing a four-day systems upgrade to begin. This upgrade – best described as a brain transplant – allowed NASA engineers to switch the rover out of its flight stage and activate two critical functions: the ability to drive and to use its geochemistry laboratory – the latter critical for obtaining samples to analyse.

The primary location for Curiosity's sampling is a rock formation called Mount Sharp, a large array positioned at the heart of the Gale Crater roughly 11 kilometres (seven miles) from the landing zone. The rocky layers of Mount Sharp are believed by NASA scientists to hold key details of Mars's geological history and, therefore, it's hoped that by analysing samples from here we will be able to determine whether life did exist – or at least could have once existed – on our celestial neighbour.

At the time of writing, Curiosity is undertaking a series of 'health checks' prior to embarking on its scientific mission proper, which entails putting the nuclear-powered, six-wheeled vehicle's systems and instrumentation through a painstaking series of small-scale tests. Once these are completed, Curiosity will be cleared for full-scale operation and will proceed with its task, sending a host of data and imagery back to Earth and perhaps confirming, once and for all, if there was ever life on Mars.

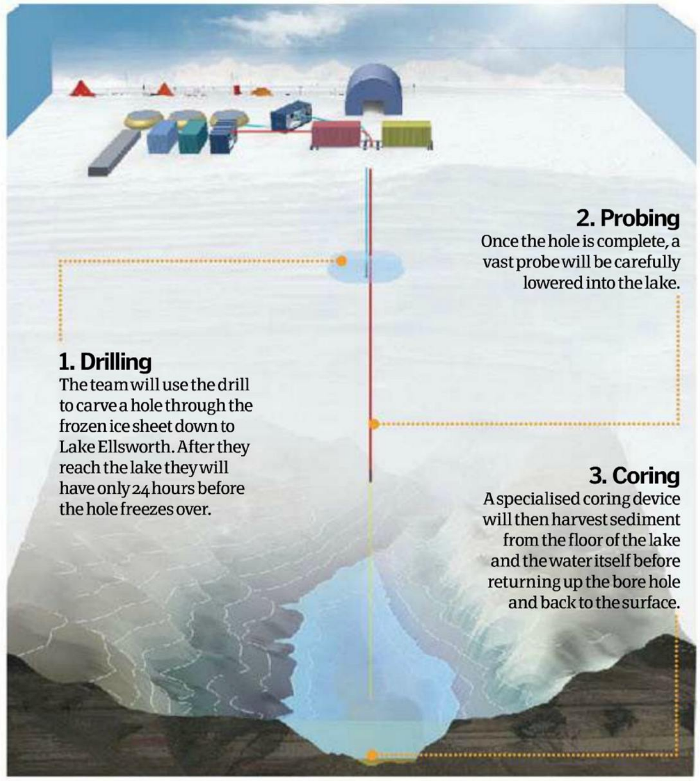
A view of the Gale Crater from above, with the target landing area marked by an ellipse



"A rust-coloured expanse was revealed stretching off into the distance where huge mountain ranges loomed"

President Obama makes a call to congratulate the MSL team after touchdown

© Pete Souza



© Subglacial Lake Ellsworth Consortium

NASA engineers celebrate after Curiosity successfully touches down on Mars

4x © NASA

Drill en route to seek new life in Antarctica

Ancient ice lake's secrets set to be revealed

A ship carrying a revolutionary deep-ice drill has set sail from the UK for Antarctica, marking the launch of one of the most adventurous and difficult science missions in years.

The drill, which has been created by engineers from the British Antarctic Survey and the National Oceanography Centre over a three-year period, has been designed so that it can successfully cut through over three kilometres (two miles) of solid ice down to a subglacial lake.

Lake Ellsworth is the target destination as it lies completely encased within the ice and is believed to have been isolated for roughly half a million years. If this is true, then the body of water is expected to harbour radical microbial life, as yet not recorded on Earth. If microbial life is found, it will provide scientists with incredibly valuable data on how species can adapt to some of the harshest environments.

The project's scientists need to ensure the drill remains as sterile as possible, as any contamination could adversely affect any microbes in the lake. As such, aside from being transported in a sterile container vessel, when in use the drill will employ a series of filters and ultraviolet systems to help minimise contaminants. Drilling operations are set to begin in December 2012.

New mags land on Imagine's online hub

Imagine Publishing's latest titles make their digital debut

Imagine Publishing's groundbreaking digital magazine supersite – **www.greatdigitalmags.com** – has just bolstered its portfolio of amazing titles with the brand-new **Fantasy Artist**, a premium publication offering readers the essential tips and tricks to maximise their digital art skills. Stuffed with insider secrets from digital-painting experts, 65 pages of Photoshop and painting guides as well as over three hours of video tutorials on a free DVD, **Fantasy Artist** is a one-stop shop for amateur and professional artists alike.

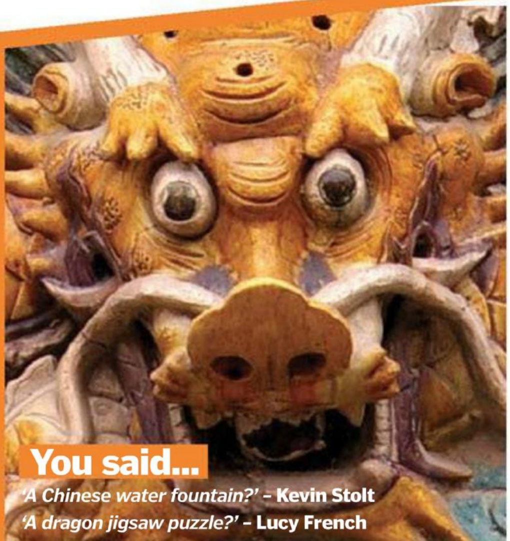
If that wasn't enough, **www.greatdigitalmags.com** has also just welcomed the latest issue of Imagine's stellar new knowledge title **All About Space**, the most awe-inspiring space mag currently on the market. This month **All About Space** has an eye-opening feature on black holes, a day-in-the-life-of guide focused on the Paranal Observatory – home to the amazing Very Large Telescope (VLT) – and an in-depth look at the next-generation space stations set to radically transform our ability to explore the cosmos.

GLOBAL EYE NEWS

WHAT ON EARTH IS IT?

A close-up look at the world!

Each month we post weird images on **www.howitworksdaily.com**. Find out what they are now...



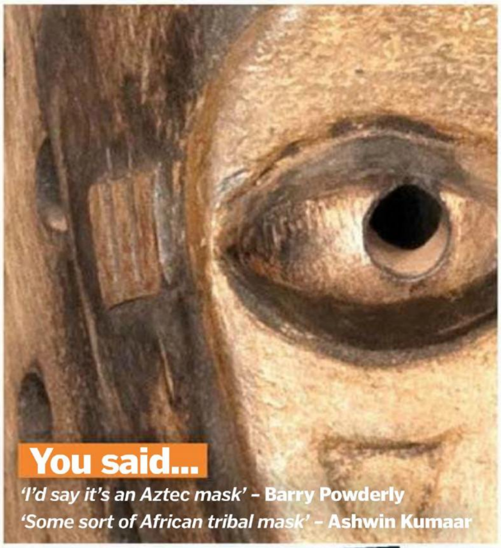
You said...

'A Chinese water fountain?' – **Kevin Stolt**
'A dragon jigsaw puzzle?' – **Lucy French**

A: Nine-dragon wall

© Jakub Halun

This is a detail taken from a nine-dragon wall located in the Forbidden City, Beijing, China. Nine-dragon walls are a type of screen wall that feature, as you'd expect, nine different Chinese dragons. They are principally used to shield key entranceways to palaces and gardens. The first description of a nine-dragon wall comes from Chinese philosopher Confucius's *Analects*, written in the 5th century BCE.



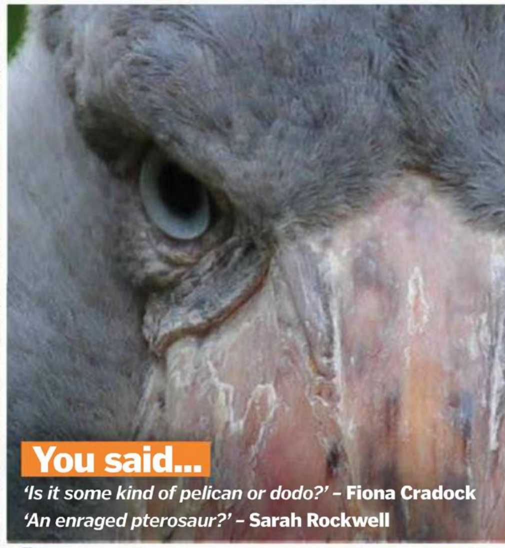
You said...

'I'd say it's an Aztec mask' – **Barry Powderly**
'Some sort of African tribal mask' – **Ashwin Kumaar**

A: African ritual mask

© Roman Bonnefoy

As many of you point out, this is an African ritual mask from the Bambara tribe in Mali. Historically ritual masks in most African cultures took on a religious/supernatural element, with the mask supposedly transforming its wearer from a human being into a spirit capable of contacting deceased ancestors or even gods. The Dogon people of Mali had 78 different masks, each purportedly representing one of their deities.



You said...

'Is it some kind of pelican or dodo?' – **Fiona Cradock**
'An enraged pterosaur?' – **Sarah Rockwell**

A: Shoe-billed stork

© Olaf Oliviero Riemer

This evil-looking chap is a member of the Balaeniceps rex species of birds known as shoebills, which are native to east Africa. They are distinctive due to their massive, shoe-shaped beak, which can grow over 30 centimetres (11.8 inches). Adult males tend to be grey, while females and juveniles are brown.

To get involved, visit WWW.HOWITWORKSDAILY.COM to make your guess now!

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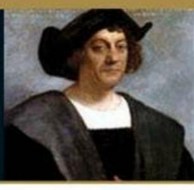
THIS DAY IN HISTORY

6 SEPTEMBER: How It Works issue 38 goes on sale, but what

394 CE Christian Roman Emperor Theodosius I defeats the pagan usurper Eugenius at the Battle of the Frigidus.

1492 Christopher Columbus (right) sets sail from the Canary Islands, his final port of call before crossing the Atlantic.



1620 The Pilgrims sail from Plymouth, England, on the Mayflower to settle in North America.

1781 The Battle of Groton Heights takes place during the American War of Independence, resulting in a decisive British victory.

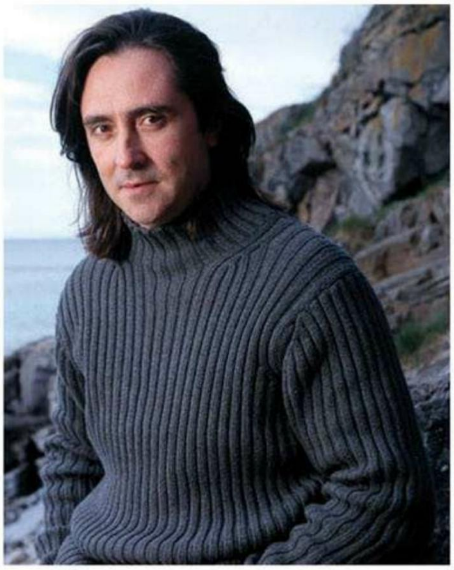
1870 Louisa Ann Swain becomes the first woman in the USA to cast a vote legally.

The story of Britain

Top author and broadcaster Neil Oliver reveals the origins of the British Isles

How It Works: With *A History Of Ancient Britain* in mind, tell us about the challenges of piecing together a narrative from fragmentary evidence.
Neil Oliver: When you embark on something with the title *A History Of Ancient Britain* obviously you are opening yourself up to having to find a way to navigate from the human occupation of the earliest times – as much as half a million years ago (maybe even up to a million years ago) – and then that human habitation being interrupted by numerous ice ages, right on through to the first Roman contact. So, it was daunting to say the least!

What I tried to do is to tell very much a human story. I aimed to keep it as simple as I could to try to get across the idea that Britain's story is a very, very long one. That it is a story told in part by human beings – some exactly the same as us and others that are more distant relatives – but [ultimately] it is a story about people.



HIW: How far back are we talking for Britain's earliest inhabitants and what impact did the people of pre-Roman Britain have on its landscape?
NO: Well, the oldest human remains, in terms of actual bones, are from Boxgrove Man in Sussex. He, or she – it's only one shinbone and a couple of teeth so it's impossible to specify – lived approximately 500,000 years ago and occupied a very different kind of Britain. A Britain that would have been populated by woolly rhinos and hyenas. That is the earliest proof of a human form we have, a species called Homo heidelbergensis, which is our cousin, if you like – a common ancestor to Homo sapiens.

But even earlier than that on the east coast of England there have been finds of tools – human-made hand axes – and food remains which go back as far as 900,000 years. So again, we are talking about a much earlier species. There has also been, more recent than Boxgrove, occupation by Neanderthals who were in Britain and north-western Europe approximately 25,000 years ago, where [eventually] as a species they became extinct.

As to the impact those species would have had it's very difficult to tell. However, human beings have always had an impact on their environment. I think that right up until the advent of farming, where people engage in forest clearing and open up the land for crops, the impact was very artificial. They would have had fire and perhaps it would have been in their interests to clear areas of woodland – maybe to instigate some sort of regrowth where they could attract animals to hunt – but broadly speaking the impact would have been [minimal].

"With the ice gone, the land started to rise up again"

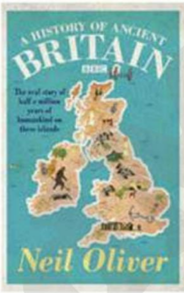
HIW: What effect did the last ice age have on Britain and the people who lived here?
NO: The last ice age probably began around 25,000-30,000 years ago. And by roughly 18,000-20,000 years ago that ice age would have been at its peak. So we are talking about glaciers and ice sheets as much as [0.8 kilometres] half a mile thick, an enormous weight of ice that pushed the landmass down into the sea. The ice was moving too and it was an incredibly powerful force in terms of sculpting the landscape, so many valleys and mountains were scoured out at this time.

By about 15,000 years ago the climate began to warm up again and the ice started to melt into the sea. The ice was fully gone by 10,000-12,000 years ago and it left a barren landscape – very much like a building site where all vegetation was completely cleared. There was no wildlife – even the big animals like the mammoth couldn't survive – so it was like a blank slate. The blank slate was gradually repopulated, first by plants, then animals like deer, and with these animals you get interest from humans. So bands of hunters from what we'd now call the European Continent would have walked dry-shod back into what would have been the British Peninsula, as at that time Britain was still a part of Europe.

You then began a long period of time when, with the ice gone, the land started to rise up again. At the same time you have rising sea levels [due to all the meltwater]. So you get a jockeying of position between the land and the sea, with sometimes the former winning and sometimes the latter. Interestingly, that process is still occurring to this day with the north coast of Scotland rising up out of the sea and the south of England – like the other end of a see-saw – slowly dipping into it.

Eventually, about 8,000 years ago, there was an event off the coast of Norway – a massive sub-sea collapse of a land ridge. This pushed a tsunami across the North Sea to Britain where it hit the eastern seaboard. It was this event that finally separated Britain from mainland Europe. From that point on the British Isles were born.

HIW: What are you currently working on?
NO: I've just completed work on a TV series and a new book, both called *The Vikings*. I think we're all quite familiar with the story of Vikings arriving in Britain and attacking the monasteries, however this project is all about looking at how wide-ranging the Vikings and the people of Scandinavia were. From about the 9th century to the 11th century CE, you had Swedish Vikings going through Russia, and then the Middle East, looking for Indian and Chinese silk and Arabic silver. You had the Norwegian Vikings heading west to Iceland, Greenland and eventually North America 500 years before Columbus. There are also the Danish Vikings who had such an impact on Britain and in northern Europe, and even Vikings raiding coastlines in the Mediterranean. So it's a project to help make all of us more aware of how much the Scandinavian people contributed to the shaping of Europe and, indeed, the world.



Neil Oliver's *A History Of Ancient Britain* is out now in hardback and in paperback from 11 September 2012. Neil's new BBC Two TV series and affiliated book *The Vikings* are due to be released this autumn.

else happened on this day in history?

1952 Canada's first television station, CBFT-TV, airs in Montreal.

1968 The landlocked country of Swaziland in southern Africa becomes independent.

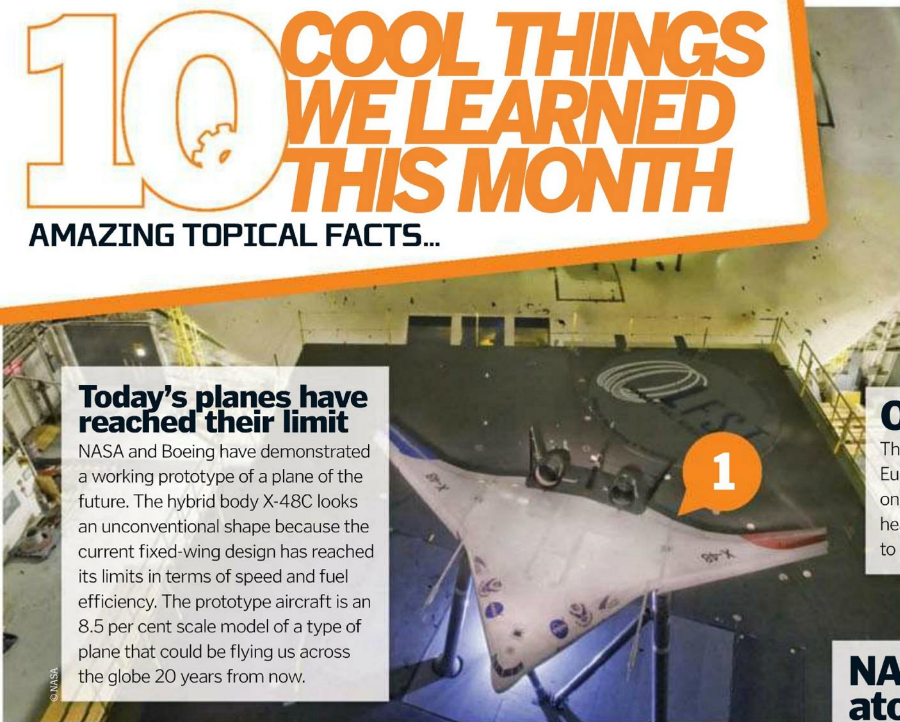
1991 The USSR recognises the independence of the Baltic states Estonia, Latvia and Lithuania.

1997 The funeral of Diana, Princess of Wales, takes place in London, England.

2009 SuperFerry 9 sinks off the Zamboanga Peninsula, Philippines. All but ten of the 971 passengers are saved.

10 COOL THINGS WE LEARNED THIS MONTH

AMAZING TOPICAL FACTS...



© NASA

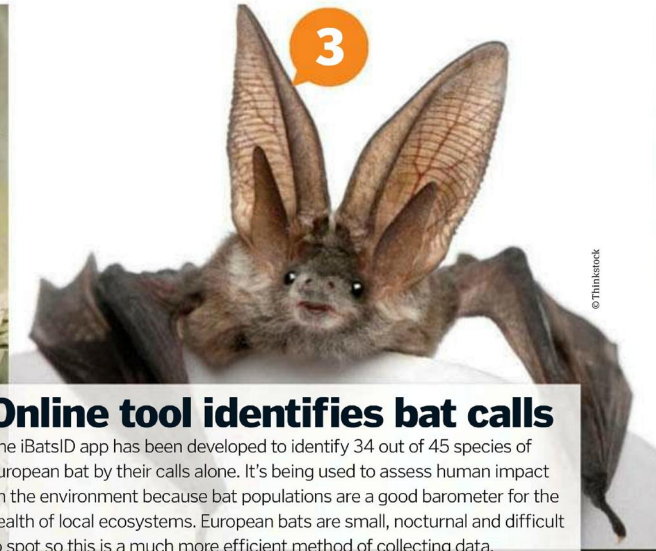
Today's planes have reached their limit

NASA and Boeing have demonstrated a working prototype of a plane of the future. The hybrid body X-48C looks an unconventional shape because the current fixed-wing design has reached its limits in terms of speed and fuel efficiency. The prototype aircraft is an 8.5 per cent scale model of a type of plane that could be flying us across the globe 20 years from now.

© Getty

Squid glow in Japan

Watasenia scintillans, aka the firefly squid, is common in the western Pacific and famously found washed up in Toyama Bay, Japan, due to the area's topography. They have bioluminescent glands in their tentacles, so when they're deposited in their thousands on the beaches, nightfall sees an eerily beautiful blue light display along the waterline. They're also edible, although we wouldn't advise eating anything washed up like this.



© Thinkstock

Online tool identifies bat calls

The iBatsID app has been developed to identify 34 out of 45 species of European bat by their calls alone. It's being used to assess human impact on the environment because bat populations are a good barometer for the health of local ecosystems. European bats are small, nocturnal and difficult to spot so this is a much more efficient method of collecting data.

© NASA

NASA is 40 atoms from perfection

NASA has created the Gravity Probe B, an incredibly precise gyroscope – the world's *most* precise gyroscope, in fact. Not only that, it's just 40 atoms' thickness away from being a perfect sphere. This form means that scientists can use the Gravity Probe B to test the laws of modern physics laid down by the likes of Albert Einstein.

© SPL

Stone can float

A 26,000-square-kilometre (10,000-square-mile) volcanic raft of rock has been found floating off the coast of New Zealand. It's comprised largely of pumice, which is less dense than water and so floats. It's believed to most likely have originated from the seamount Monowai, near Tonga, which has been active recently.

© Thinkstock

Traffic can be bad for the heart

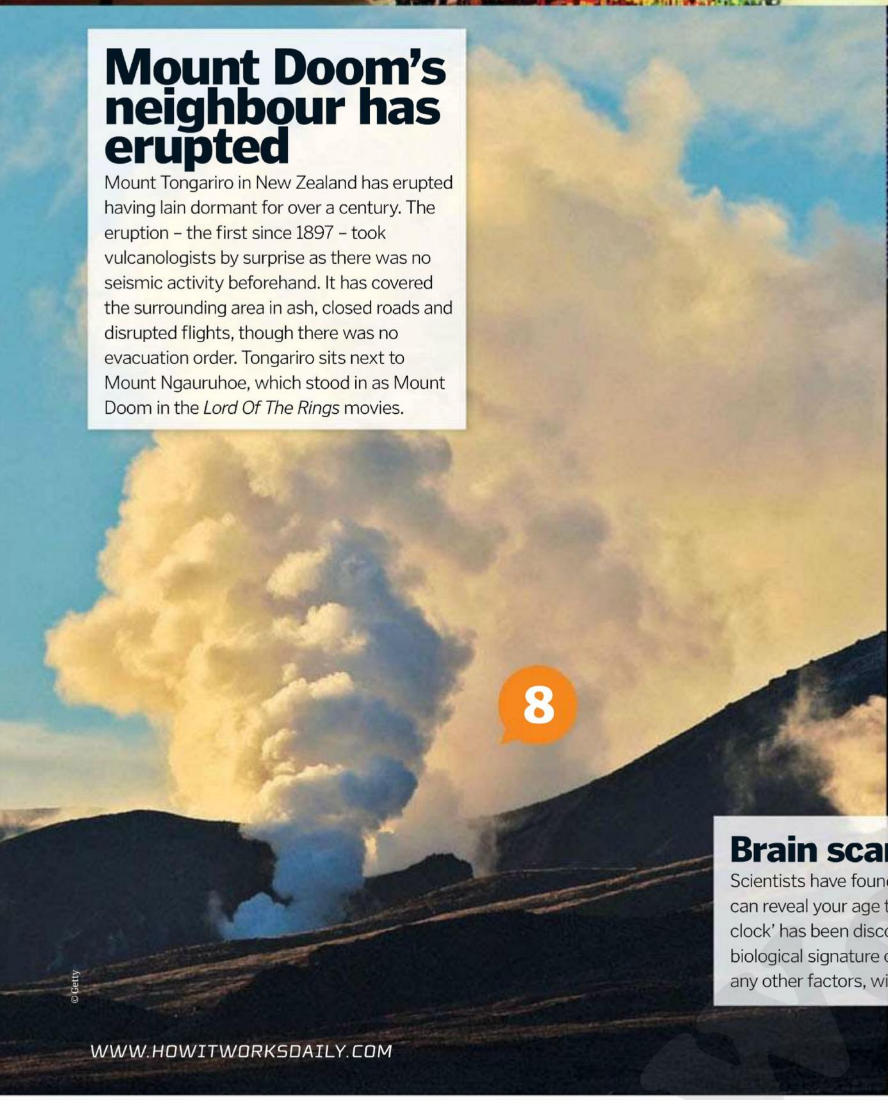
Leeds researchers have shown that carbon monoxide gas – commonly found in exhaust fumes, smog, cigarettes and faulty boilers – can disrupt the heart's rhythm. Carbon monoxide is already known to be deadly at high concentrations because it replaces oxygen being transported in the blood, but the Leeds University team's research suggests even low levels can damage the heart by unsettling its rhythm, which itself is potentially fatal.

"The closing ceremony took 93 lorries to move the actual set into the arena"

7 Closing ceremony took 210,000 hours of preparation

Over 3,500 volunteers practised for around 60 hours each for the London Olympics 2012 closing ceremony. That's a total of 210,000 hours, or 24 years' worth of preparation for a three-hour event – around two and a half hours of practice for every second! The closing ceremony took 93 lorries to move the actual set into the arena, which included the 'audience pixels' built in to the seating – 634,500 of them creating the largest video screen ever.

© Getty



8 Mount Doom's neighbour has erupted

Mount Tongariro in New Zealand has erupted having lain dormant for over a century. The eruption – the first since 1897 – took vulcanologists by surprise as there was no seismic activity beforehand. It has covered the surrounding area in ash, closed roads and disrupted flights, though there was no evacuation order. Tongariro sits next to Mount Ngauruhoe, which stood in as Mount Doom in the *Lord Of The Rings* movies.

© Getty

9 Sprites are real

No, not the high fantasy fairy creatures but an as-yet unexplained phenomenon that happens around 80 kilometres (50 miles) above Earth. The vertical flashes of red and blue light happen so fast that they've never been deliberately caught on video until now. NASA scientists and Japanese TV company NHK filmed them from a satellite at 10,000 frames per second as part of a study.

© NASA

10 Brain scans can reveal age

Scientists have found that a simple MRI scan of the brain can reveal your age to within a year. A 'developmental clock' has been discovered in the organ that gives a reliable biological signature of age, regardless of environmental or any other factors, with a 92 per cent rate of accuracy.

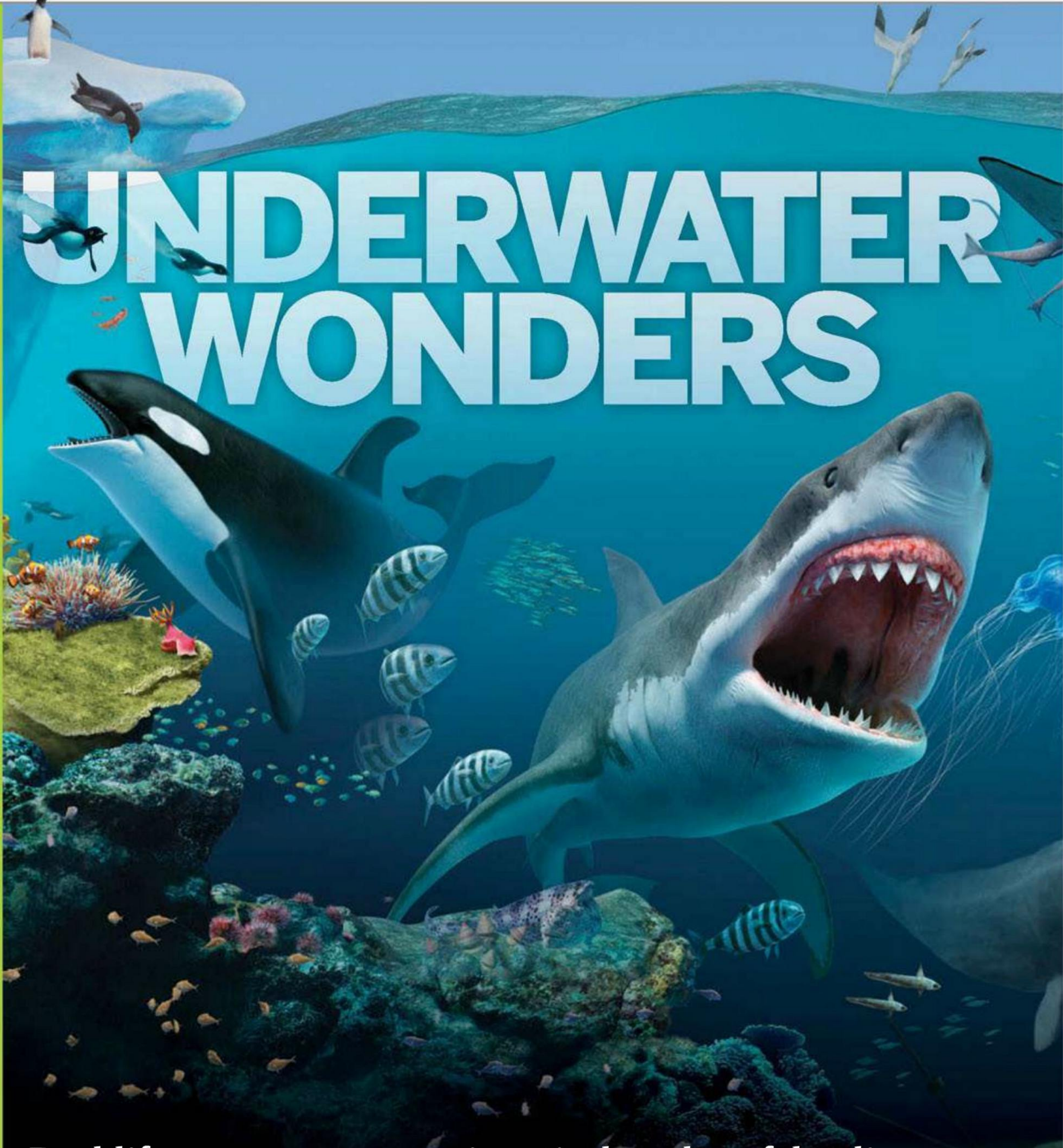
© SPL

Welcome to... ENVIRONMENT

With 70 per cent of Earth's surface covered by water, it's no wonder marine life has grown so diverse and, indeed, huge, but how do the giants of the sea survive? Also discover why some animals play dead, how our coasts are continually changing and meet the critters with skeletons on the outside.

LEARN MORE

UNDERWATER WONDERS



Real-life sea monsters so gigantic they dwarf the dinosaurs

The open ocean is an extremely dangerous place to live. There are no trees to hide in, no burrows you can dig. Death surrounds you in three dimensions and everything larger than you is a predator. To survive, you have to think big. For some species, this means living as part of a large school of fish. For others, it means actually becoming genuinely, truly enormous. Tiny fish are eaten by small fish. Small fish are eaten by larger fish and so on. In every size bracket, natural selection favours the larger animal over the smaller one. Over millions of years, animal species tend to grow gradually larger and larger until they are too big to fit in anyone's mouth.

Being big is easier in the sea than on land because the buoyancy of water supports an animal evenly around its body, instead of just through the soles of its feet. An African elephant, for instance, can't grow much larger than ten tons without fracturing its own legs. A blue whale, meanwhile, will weigh this much before it's three months old.

Sea giants can get by with much smaller skeletons and their bones don't need to be so strong as they aren't subject to so much shock loading. But the density of water also presents some challenges. It's much harder to move through water than air, so streamlining is essential. A blue whale is 60 times longer than it is wide, compared with only 3.5 times for a

1. BIG

Oarfish
15m (49ft) long and eel-like in appearance. Rare sightings of these normally deepwater fish may have given rise to legends of sea serpents.

2. BIGGER

© Zac Wolf

Whale shark
The largest verified specimen was 12.7m (41.5ft) long, but there are unconfirmed reports of whale sharks that reach a staggering 18m (59ft)!

3. BIGGEST

© Dmitry Bogdanov

Leedsichthys problematicus
Fossils of this fish from 155 million years ago show it was 22m (72ft) long, making it the largest known fish ever to live.

DID YOU KNOW? In 2010 in New Hampshire, 150 people were stung by a single dead lion's mane jellyfish which had disintegrated

Japanese spider crab

Claws that can straddle a car

Binomial name: Macrocheira kaempferi

Type: Crustacean

Diet: Carnivore, eg shellfish and carrion

Average life span in the wild: 80 years

Weight: 19kg (42lb)

Size: 3.8m (12.4ft) claw to claw

Worldwide distribution: Southern coast of Japan

Amazing fact: Those huge legs are quite fragile; indeed, almost three-quarters of Japanese spider crabs have a leg missing. This isn't a problem because they can survive with up to three legs missing and the walking legs can grow back when the crab moults to a new carapace.

1 Japanese spider crab = 1 child

The largest animal ever to have lived

Binomial name: Balaenoptera musculus

Type: Mammal

Diet: Filter feeder, eg krill, copepods

Average life span in the wild: 80 years

Weight: 180,000kg (396,832lb)

Size: 30m (98ft)

Worldwide distribution: Throughout the world's oceans, in five to seven main populations

Amazing fact: A newborn blue whale is the same size as a full-grown adult hippopotamus at 2.7 tons. They drink 400l (700 pints) of milk every day and put on 90kg (198lb) of weight on a daily basis for the first seven months of their life.

1 blue whale = 36 African elephants

Blue whale

Lion's mane jellyfish

A tangled cloud of floating stingers

Binomial name: Cyanea capillata

Type: Scyphozoan

Diet: Carnivore, eg plankton, small fish

Average life span in the wild: 1 year

Weight: 25kg (55lb)

Size: 2.5m (8.2ft)-diameter bell; 30m (98ft)-long tentacles

Worldwide distribution: Arctic, north Atlantic and north Pacific

Amazing fact: The largest lion's mane jellyfish ever found washed up in Massachusetts Bay, USA, back in 1870. Its tentacles were 36m (118ft) long, making it longer than a blue whale and possibly the longest animal ever recorded.

1 lion's mane jellyfish = 1 child

hippo. The rear third of the whale's body provides the muscle to drive the 7.5-metre (25-foot) tail fluke up and down. Why does an animal with no natural predators need to cruise at 32 kilometres (20 miles) per hour? One reason is that it makes it much harder for barnacles to attach. It's ironic that an animal as large as a whale should be threatened by something as small as a barnacle, but if enough take hold, the extra drag drastically increases the energy required to swim.

Food is the limiting factor for all large sea creatures. Light doesn't penetrate far in water so there are no grassy plains for large herbivores to graze. Instead the ocean is a thin soup, with the occasional chunk of meat bobbing in it. You can chase after the chunks, but catching them requires more energy, which means you need more food and so on.

The largest animals in the sea have found it is more lucrative to swallow the 'soup' instead. This is a mixture of unicellular organisms, fish larvae and shrimp, ie plankton. They are too small to swim against the current, so it's just a matter of straining them from the water. The lion's mane jellyfish can do this while expending virtually no energy. It swims slowly up by pulsing its bell and then relaxes to drift down again like a parachute. As it does, its tentacles billow out like hair to cover a wide area and prey gets speared by its stinger cells. Most large whales, along with the whale shark and the manta rays, adopt a slightly more active strategy by either swimming at speed into a dense cloud of plankton or taking huge gulps to suck them in, and then filtering them through a mesh of fibres made from modified teeth or gill bars. Different animals have different sized filter meshes that trap a particular size of plankton. Whales and whale sharks trap only the relatively large krill (a kind of shrimp) and crab larvae. A ton of krill contains about 450 thousand calories – which is about a tenth as much as a ton of chocolate – and an adult blue whale needs 3.5 tons of krill a day.

Very large animals need to protect their young to give them time to grow big enough to fend off predators. Whales are mammals so the embryo develops inside its mother to protect it. Great white sharks and manta rays have abandoned the usual fishy strategy of laying eggs on the seabed and copied mammals; the eggs are retained inside the female and hatch as live 'pups'. The mating and birthing of the whale shark has never been , but they are believed to use the same technique. Even the giant Pacific octopus will guard her nest of eggs until they hatch. Her month-long vigil is the last thing she does though because the exertion kills her – to compensate she lays around 100,000 eggs in one go!

Huge fish have other tricks normally reserved for mammals too. Large sharks and manta rays have a low surface area compared to their body size so they don't lose as much heat. This makes them effectively warm-blooded and allows them to maintain a more active lifestyle even in colder seas.

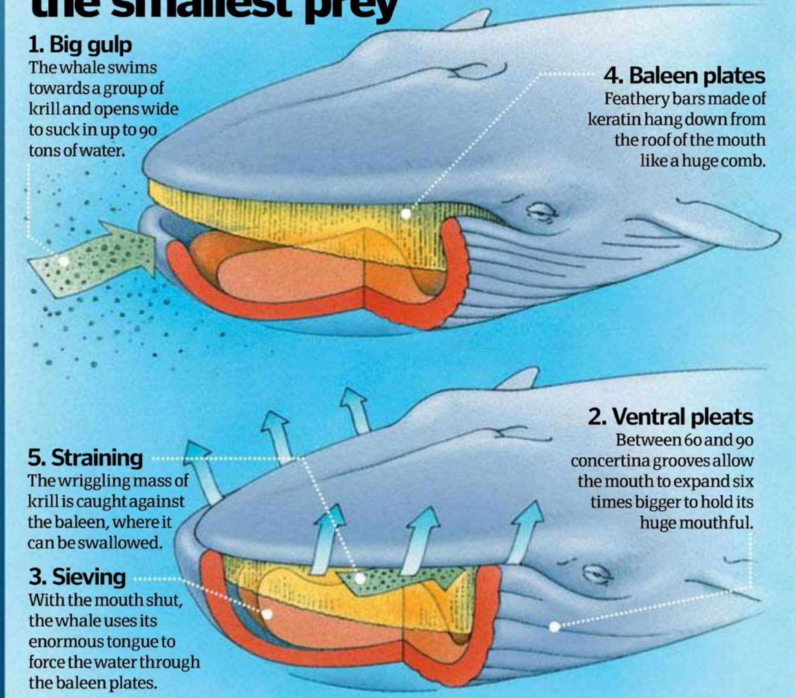
The best-studied ocean giants are those that live in fairly shallow water – above 200 metres (656 feet) – where most of the plankton is. But there are very large animals including squid that live in the perpetual blackness beyond. If you are an air-breathing mammal like a sperm whale that feeds on these squid, you face a unique challenge. To feed you need to dive to depths of up to three kilometres (1.9 miles), but to breathe you need to return to the surface. The pressure change in a round-trip is almost 300 atmospheres! Sperm whales have three times more myoglobin in their muscles to store more oxygen and their ribcage is flexible so that the lungs collapse under pressure and reduce the amount of nitrogen that dissolves into the blood. Despite this, the skeletons of older whales show pitting from the decompression effects of repeated dives.

> "The hungriest creatures in the ocean are the killer whales"

Supersized diets

Large animals have big appetites. Exactly how big depends on how fast you burn energy. At the bottom of the scale are the invertebrates. Jellyfish can grow to be huge, but their body is about 95 per cent water and they move very slowly. Eating just 0.04 per cent of their body weight is enough to sustain them. Blue whales, at the other end of the scale, have a warm-blooded body to support as well as a complex brain. But the hungriest creatures in the ocean are the killer whales. Their extremely active, predatory lifestyle means they need 3.7 per cent of their body weight each day to survive; when your body weighs six tons, that's a lot of fish!

How the largest animal eats the smallest prey



How much do they eat a day?

...and how many cheeseburgers would that equate to?

Blue whale: 3,600kg (7,937lb) eg krill	= 16,667
Killer whale: 227kg (500lb) eg fish, sharks	= 1,051
Great white shark: 30kg (66lb) eg fish, seals	= 138.9
Giant Pacific octopus: 1kg (2.2lb) eg crabs	= 4.6
Lion's mane jellyfish: 100g (3.5oz) eg plankton	= 0.46

The shark with the biggest bite

Binomial name: Carcharodon carcharias

Type: Elasmobranch fish

Diet: Carnivore, eg tuna, dolphins

Average life span in the wild: 30 years

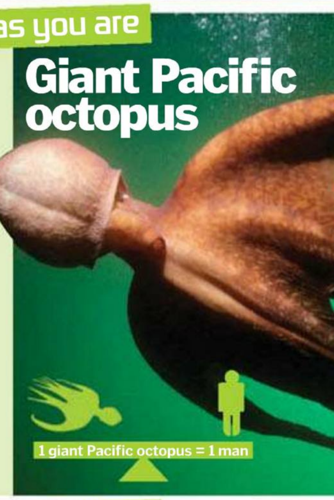
Weight: 1,900kg (4,189lb)

Size: 6m (19.7ft)

Worldwide distribution: Tropical and temperate seas, eg off South Africa, Australia and USA

Each arm is as long as you are

Giant Pacific octopus



Binomial name: Enteroctopus dofleini

Type: Cephalopod

Diet: Carnivore, eg fish, molluscs

Average life span in the wild: 3-5 years

Weight: 15-70kg (33-154lb)

Size: 4.3m (14.1ft) arm span

Worldwide distribution: Coastal waters of the north Pacific

Amazing fact: Its huge size isn't enough to keep this octopus safe. Seals, sperm whales and even sea otters all prey on them. Their short life span is an adaptation to compensate for high predation. All their energy is expended in a single huge spawning of 100,000 eggs.

Super-smart king of the gliders

Giant oceanic manta ray

Binomial name: Manta birostris

Type: Elasmobranch fish

Diet: Filter feeder, eg plankton, shrimp

Average life span in the wild: 27 years

Weight: 1,300kg (2,866lb)

Size: 6.7m (22ft)

Worldwide distribution: Shallow water of the western Pacific and Indian Ocean

Amazing fact: Manta rays may be the most intelligent of the sharks, rays and skates, as their brain-to-body ratio is much higher than other fish. A network of blood vessels called the rete helps to keep their brain warm.

900KG

HEAVIEST TURTLE

The largest turtle ever found was a leatherback that washed up on a beach in Wales in 1988. It was 2.75 metres (nine feet) long and at least 100 years old when it died.

DID YOU KNOW? *Lobsters don't seem to age and can grow almost indefinitely. The biggest ever caught was over 1m (3.2ft) long!*

Great white shark

Amazing fact: Great white sharks have two stomach compartments and can store food in one compartment for days or weeks without digesting it. Great whites have been found with shoes, wigs, newspapers, licence plates and even cannon balls in their stomachs.

Whale shark

The world's largest fish

Binomial name: Rhincodon typus

Type: Elasmobranch fish

Diet: Filter feeder, eg krill, crab larvae

Average life span in the wild: 80 years

Weight: 9,000kg (19,842lb)

Size: 9.7m (32ft)

Worldwide distribution: Tropical seas worldwide

Amazing fact: According to the Whale Shark & Oceanic Research Center, there are several reports of whale sharks three or four times bigger than the norm. Indeed, in 1994 a shark caught off the coast of Taiwan allegedly weighed almost 36 tons!

What does it take to sustain a whale shark?

Mouth
When a whale shark is feeding, its mouth can gape 1.5m (4.9ft) wide. This creates tremendous suction that makes it impossible for small animals to swim out of the way. Whale sharks have over 300 rows of teeth but each tooth is quite small and they don't appear to serve any purpose.

Gills
The real business of feeding occurs at the gills. As well as extracting oxygen from the water, the gills have ten filter pads (see picture) that sieve out anything over 2-3mm (0.08-0.12in). Although efficient, sometimes the pads can become blocked and the shark must 'cough' to clear them.

Brain
Whale sharks have quite small brains compared to other sharks. Brain tissue requires a lot of energy, so big brains must earn their keep. These sharks don't actively hunt, and their huge size keeps them safe from most predators, so they don't need the same cunning as other shark species.

Skeleton
Sharks have cartilage rather than bone, and no ribcage. Whale sharks beached in shallow water are quickly crushed to death by their own body weight. In the open sea, though, a cartilage skeleton saves weight because it has half the density of bone. This makes the whale shark a much more efficient swimmer.

Skin
10cm (3.9in)-thick skin provides a rigid covering that maintains the shark's streamlined shape; when we swim, the water causes our skin to ripple, which leads to drag. Shark skin is also covered with tiny placoid scales. Each one is structured like a tooth, with enamel, dentine and a pulp cavity; the scales reduce microturbulence.

Liver
Instead of a swim bladder, sharks use an oil called squalene to maintain buoyancy. This is stored in the liver and, since oil isn't as light as gas, the whale shark needs lots of it – indeed, the liver can weigh up to two tons! Fishermen in Kenya hunt whale sharks for their liver and the oil from a single shark can last them for years.

Ones that got away!

Meet a few more behemoths of the deep

Seven-arm octopus
Heavier than the giant Pacific octopus, but with shorter tentacles. It actually has eight arms altogether but keeps one coiled up out of the way, except when it's mating.

Colossal squid
Thought to grow up to 14m (45.9ft) long, an adult specimen has never been found. It has the largest eyes in the animal kingdom.

Sperm whale
This 40-ton cetacean has the largest brain of any animal ever to have lived and has teeth that weigh 1kg (2.2lb) each. Its diet includes the colossal squid.

Giant clam
The biggest bivalve mollusc. They can weigh up to 200kg (441lb) and live on a combination of filter feeding and photosynthesis from symbiotic algae.

Brisingid starfish
Midgardia xandaros is the biggest starfish. Its slender arms can be up to 1.4m (4.6ft) long. Most starfish have five arms while some, like the one pictured, have 12 or more!

Giant isopod
Bathynomus giganticus might look like a garden woodlouse, but this relative can weigh up to 1.7kg (3.7lb) and reach 76cm (29.9in) long; that's the size of a newborn baby!

"The shockwave from the eruption could have punched a hole in the cloud deck"

The Sarychev Peak eruption

Snapped by NASA in a remote part of Russia, this volcano photo has sparked a heated debate among scientists…

On 12 June 2009, the International Space Station happened to be passing the northern part of the Kuril Islands, a Russian archipelago in the north-west Pacific, just as the Sarychev Peak was erupting explosively for the sixth time since 1946.

This photo was immediately taken by an enthusiastic astronaut, which excited vulcanologists not just because of the early stage of Sarychev's eruption, but because of several interesting features that can be observed at once in the same image. The characteristic plume that's rising from the caldera is mainly composed of ash that has been able to 'mushroom' naturally on the relatively calm day. Curiously, this has been capped with a white head of steam called a pileus cloud, a result of air rising quickly in a strong updraft and cooling into condensation.

On the ground, there are several columns of molten material winding their way down from the peak which are known as pyroclastic flows; these are superheated currents of rock and gas made fluid by water vapour. The flows are extremely hot (read: up to 1,000 degrees Celsius/1,832 degrees Fahrenheit) and travel very fast, at around 200 metres (656 feet) per second. Their speed, deadly temperature and unpredictability make them especially dangerous in more populated areas.

What scientists can't quite figure out is the round hole in the cloud above the volcano. To the untrained eye, it would appear that the plume is having an effect on the cloud mass above it. That is a possibility, as the shockwave from the eruption could have punched a hole in the cloud deck or evaporated it as the hot ash rose. But it could easily have been pure coincidence. Sheets of cloud form in these regions where the ocean surface is cool and move with the wind. But when they come into contact with an island, they're forced upwards into a dry layer of air, which causes them to break up.

43KM

TALLEST TERRESTRIAL PLUME

The highest known volcanic plume on Earth was caused by the 1815 eruption of Mount Tambora, Indonesia (the biggest eruption on record). The ejecta thrust into the stratosphere affected global weather for a whole year.

DID YOU KNOW? *The Kuril Islands belonged to Japan until after WWII, when Russia evacuated all 17,000 Japanese inhabitants*

Space volcanoes put things into perspective

In 2001, the unmanned spacecraft Galileo was making a flyby of Jupiter's moon Io when it passed through what NASA thought to be a cloud of sulphur dioxide at the time. It was only as the data was transmitted back to mission control that scientists realised what it was: the Tvashtar volcano had erupted, spouting a plume of ash and particles that reached 500 kilometres (310 miles) into space. That dwarfs the biggest recorded plume on Earth and makes it the largest volcanic eruption plume ever recorded in the Solar System. This plume might have been matched by some of Yellowstone Park's eruptions millions of years ago.

© NASA

"The Devil's Marbles started life nearly 2 billion years ago"

What are the Devil's Marbles?

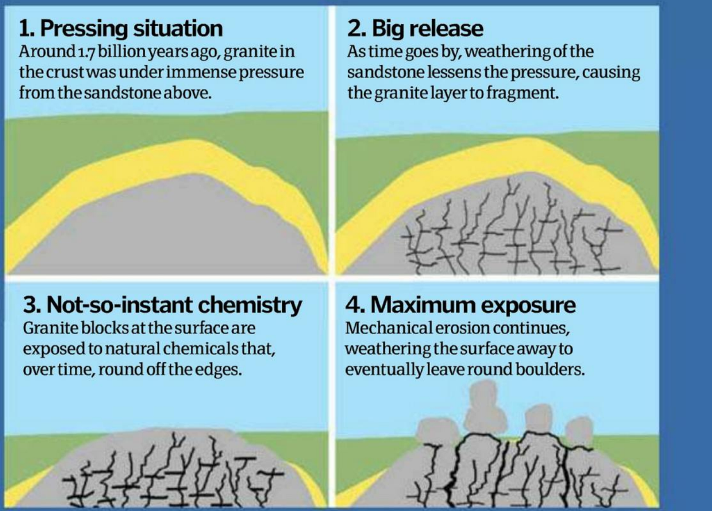
Part of Australia is littered with odd boulders, but where did they come from?

You can understand how this odd natural feature got its name: in the middle of Australia's Northern Territory wilderness, near the town of Wauchope, hundreds of rounded boulders are strewn conspicuously across the arid landscape. Some are piled in heaps, while others are poised atop rocky outcrops in a seemingly deliberate attempt to balance them. The Aboriginal owners of this 1,800-hectare (4,453-acre) reserve call it Karlu Karlu, which is also derived from a traditional belief that a supernatural being placed the boulders for its own unfathomable amusement. And while the reality might not involve the paranormal, the science is just as interesting…

The Devil's Marbles started life nearly 2 billion years ago as the magma cooled in the Earth's crust to form the igneous rock granite. On top of the granite, a thick sedimentary layer of sandstone formed that compressed the granite under its immense weight. Over millions of years, the sandstone gradually eroded, simultaneously releasing the pressure and causing the granite to expand and then crack into roughly cube-shaped blocks.

Once the sandstone was completely eroded, the angular blocks of granite were subject to erosion themselves. But granite is a significantly harder material than sandstone, so the boulders you can see now are a lot more resistant to the same chemical and mechanical weathering. A combination of water and acidic chemicals naturally present in the atmosphere rounds off the points of the blocks to leave smoother rocks, while the great difference in day and night temperatures expands and contracts the rock forms, peeling off layers to leave the 'marbles' we see today.

Marbles in the making



Aussie rocks

Wave Rock
This distinctive Australian rock is found near Perth, Western Australia. It's shaped like a 14-metre (46-foot)-high wave and is 110 metres (361 feet) long.

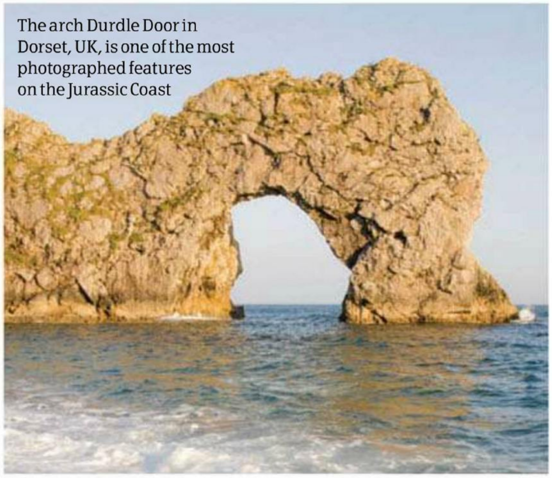
Uluru
Easily Australia's most well-known rock, Uluru (formerly Ayers Rock) is 348 metres (1,142 feet) high, and is Earth's biggest monolith.

Mount Augustus
The less-known Mount Augustus is much bigger than Uluru, at 860 metres (2,820 feet) high, but is a monocline, rather than a monolith.

"Coastal erosion is a very slow process, but scientists believe that climate change is speeding things up"

What is coastal erosion?

Our coastlines are constantly changing – building up and breaking down. Learn about the amazing processes reshaping our shores right now…


The arch Durdle Door in Dorset, UK, is one of the most photographed features on the Jurassic Coast

Water is not given enough credit for the role it plays in shaping Earth. Tectonic plates and volcanic eruptions are often cited as the culprits for most land features, but it is water and wave action that shapes and constantly reshapes the coastlines of our world.

When a wave crashes on the shore it carries sediments that are suspended in the water, and it pushes larger sediments along the ground too. When a wave recedes it also takes sediment with it and this is rarely done at an equal rate.

If a wave deposits more sediment than it takes away it builds up, causing coastlines to extend. Alternatively, when more sediment is being removed than added, the coastline recedes or erodes. Coastal erosion is responsible for some of the most amazing landforms we know today from the Twelve Apostles in Australia to the White Cliffs of Dover in England.

The type of coastline that is created from erosion varies greatly depending on any number of factors including the strength of the wave action and wind, sediment composition of the coastline and the types of rock in the vicinity.

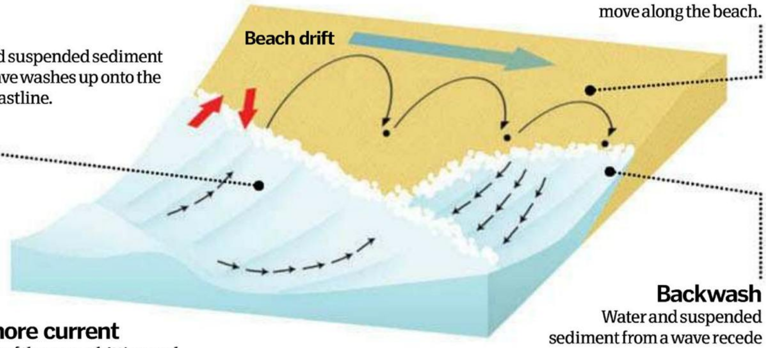
Coastal erosion is a very slow process taking hundreds of years, but scientists believe that climate change is speeding things up. Climate change has caused a rise in sea levels and storm frequency and severity – both of which play a key role in erosion. Indeed, the UK's Environment Agency has estimated that the British coastline could erode anywhere from 67-175 metres (220-575 feet) over the next 100 years.

Longshore drift explained

A longshore, or littoral, drift occurs when a wave crashes on the beach at an angle and then flows back at a right angle. When repeated, this action causes the sediment brought in by the waves to be pushed along the shore in a zigzag motion

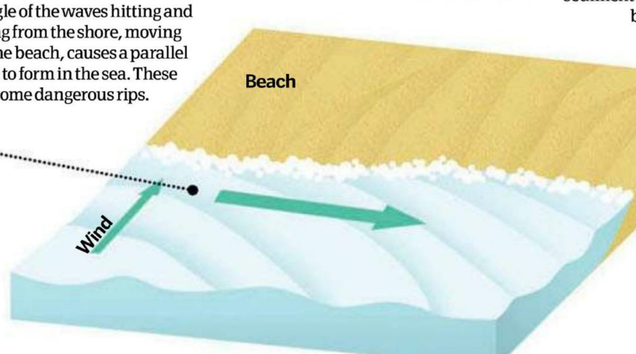
Sediment
Sediment is washed ashore and pulled back into the ocean at differing rates. During a longshore drift the angle of the waves causes the sediment to move along the beach.

Swash
Water and suspended sediment from a wave washes up onto the beach/coastline.

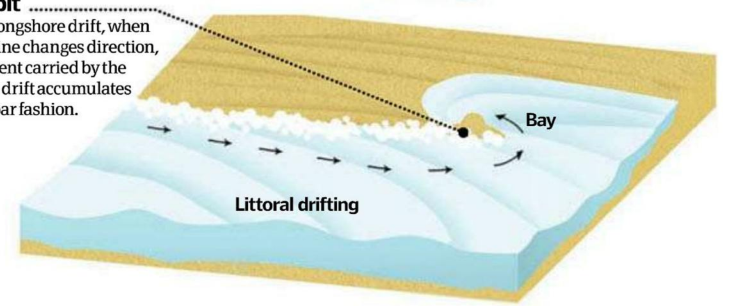


Backwash
Water and suspended sediment from a wave recede back into the ocean.

Longshore current
The angle of the waves hitting and receding from the shore, moving along the beach, causes a parallel current to form in the sea. These can become dangerous rips.



Sand spit
During a longshore drift, when the coastline changes direction, the sediment carried by the longshore drift accumulates in a sandbar fashion.



More than one way to wear a rock…

Corrosion
This chemical-based erosion occurs only with certain types of rock such as chalk or limestone, which are high in calcite. The acidity of the seawater causes a chemical reaction in the mineral, eating away at it.

Abrasion
This occurs when the sediment suspended in the water (eg sand) is thrown against the shore by waves. The sediments grind against the land, weakening the structural integrity of the coastline.

Hydraulic action
Wave action compresses tiny air pockets within the rock, which eventually causes cracks to form. The cracks get bigger and bigger over many years and eventually develop into caves and so on.

Attrition
Continued wave action hurls stones and other material at the land, which smooths and breaks up the rocks on the coast, dislodging them from. These in turn collide with other rocks on the shore.

AMAZING VIDEO!

SCAN THE QR CODE FOR A QUICK LINK

Watch a cliff collapse due to coastal erosion

www.howitworksdaily.com

DID YOU KNOW? *During a storm, a wave can hit the coastline with a force of six tons per square centimetre!*

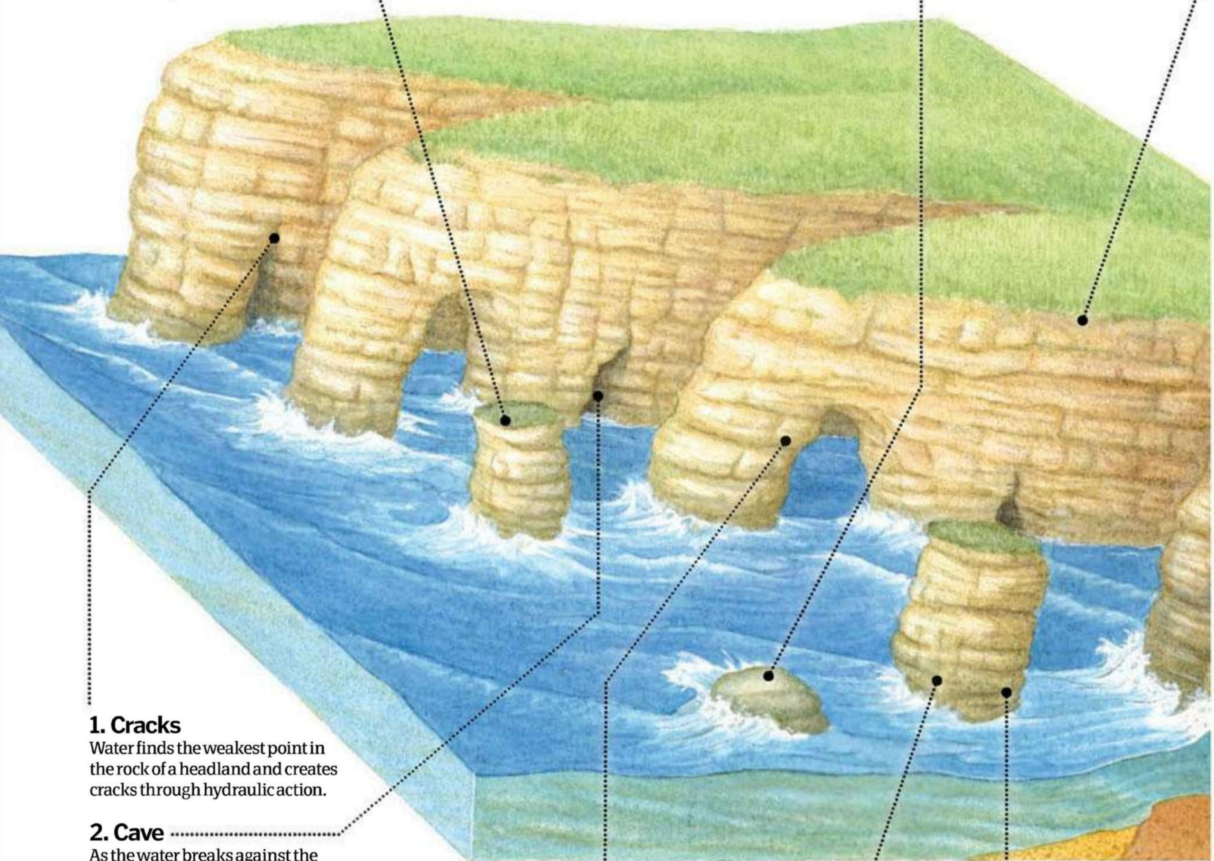
Sea stack formation

Discover how these rocky towers develop and what fate awaits them in the long term…

6. Top of stack
Sea stacks are a popular nesting site for seabirds as they are isolated and difficult for predators to reach.

7. Stump
The stack gets eroded away further until it leaves just a stump, which is often covered at high tide.

8. Headland
Harder-density rocks remain jutting out into the ocean where the coastline has receded behind it, usually creating bays.



© Thinkstock

1. Cracks
Water finds the weakest point in the rock of a headland and creates cracks through hydraulic action.

2. Cave
As the water breaks against the cracks, they open out into a small cave, which becomes larger and larger as time goes by.

3. Arch
Wave action from both sides of the cave causes it to break open forming an arch-shaped structure.

4. Stack
Eventually the meeting point of the tip of the arch and the headland will collapse, leaving a free-standing stack, separated entirely from the headland.

5. Rock type
Medium-density rocks like sedimentary or volcanic rocks usually form sea stacks; softer rocks like clay erode too quickly.

ON THE MAP

Erosion landmarks

1 The Twelve Apostles (sea stacks): Victoria, Australia
2 Dungeness Spit (sea spit): Washington, USA
3 Azure Window (arch): Gozo, Malta
4 Moeraki Boulders (stumps): Otago, New Zealand
5 White Cliffs of Dover (cliffs): Strait of Dover, UK
6 Farewell Spit (sea spit): South Island, New Zealand

Australia's Twelve Apostles are some of the most famous sea stacks in the world

The different shapes of coastlines

Bay
Bays are inlets of water that form between headlands. They have low-energy wave action.

Atoll
Atolls can be ring or horseshoe-shaped coral reefs surrounding an inner lagoon. They are formed when a fringing reef develops around an island; the island gradually subsides into the water due to erosion.

Delta
These occur where a river flows into another body of water like the ocean. The river's flow, which carries sediment, is stemmed so the sediment builds up around the river mouth.

Fjord
A narrow inlet of water surrounded by a steep shoreline. Fjords form when a glacier cuts a deep valley into bedrock. The glacier recedes and the valley floods with water.

Fringing reef
Fringing reefs are coral reefs that develop around an island, creating – as the name suggests – a fringe. Coral polyps build on top of one another to form huge living structures.

Blowhole
These occur when a sea cave is developing and a small hole forms on top of the headland. Wave action forces water up through the hole, up to several metres high.

STRANGE BUT TRUE
GOLD TEETH

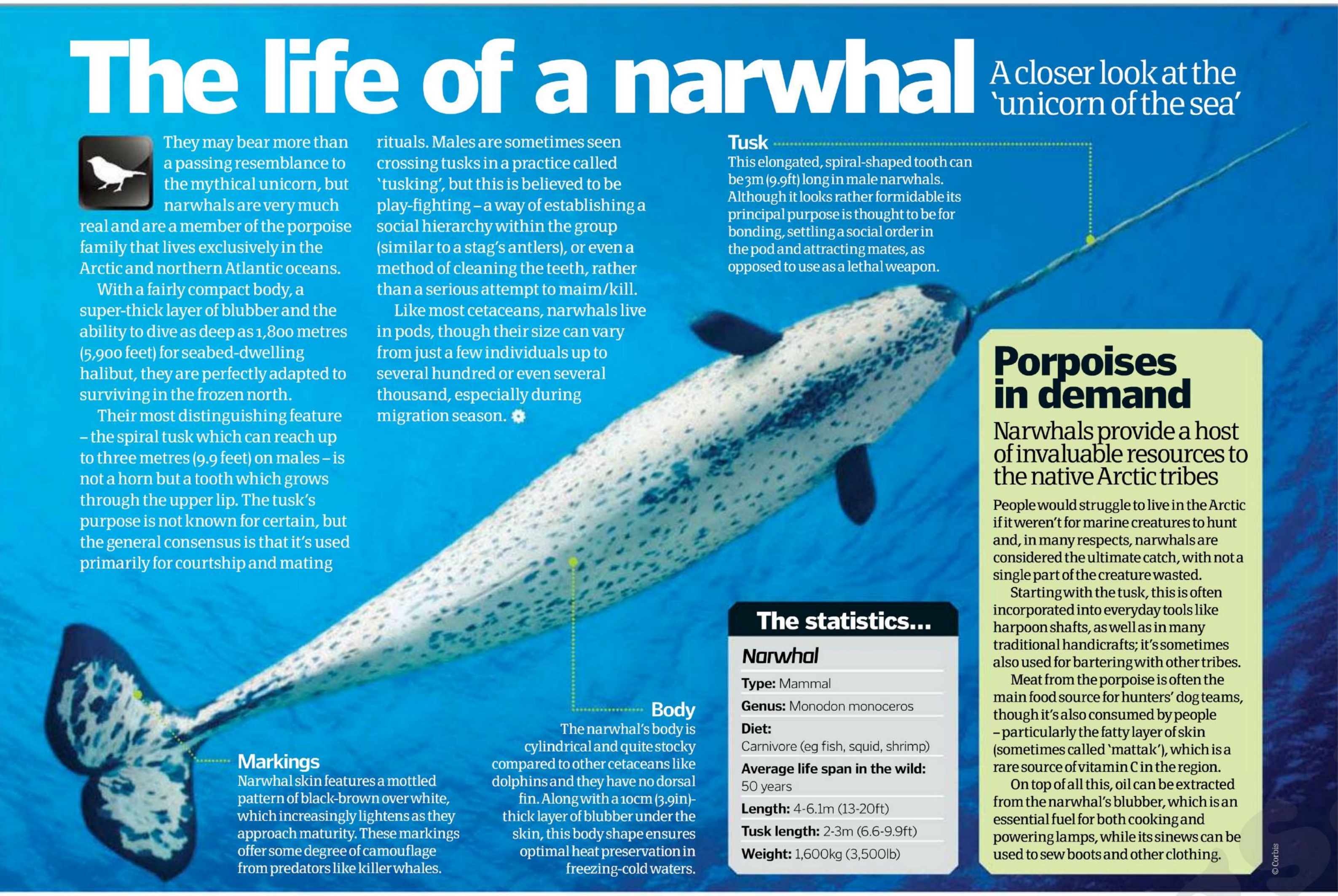
HORN VS TUSK

In medieval Europe the narwhal's spiral tusks were sold as 'unicorn horns' at more than ten times their weight in gold. Though a protected species today they're still hunted for their unusual elongated teeth, which can fetch thousands of dollars.

DID YOU KNOW? Red flour beetles can play dead for up to 20 minutes in the presence of the Adanson's house jumper spider

The life of a narwhal

A closer look at the 'unicorn of the sea'



They may bear more than a passing resemblance to the mythical unicorn, but narwhals are very much real and are a member of the porpoise family that lives exclusively in the Arctic and northern Atlantic oceans.

With a fairly compact body, a super-thick layer of blubber and the ability to dive as deep as 1,800 metres (5,900 feet) for seabed-dwelling halibut, they are perfectly adapted to surviving in the frozen north.

Their most distinguishing feature – the spiral tusk which can reach up to three metres (9.9 feet) on males – is not a horn but a tooth which grows through the upper lip. The tusk's purpose is not known for certain, but the general consensus is that it's used primarily for courtship and mating rituals. Males are sometimes seen crossing tusks in a practice called 'tusking', but this is believed to be play-fighting – a way of establishing a social hierarchy within the group (similar to a stag's antlers), or even a method of cleaning the teeth, rather than a serious attempt to maim/kill.

Like most cetaceans, narwhals live in pods, though their size can vary from just a few individuals up to several hundred or even several thousand, especially during migration season.

Tusk
This elongated, spiral-shaped tooth can be 3m (9.9ft) long in male narwhals. Although it looks rather formidable its principal purpose is thought to be for bonding, settling a social order in the pod and attracting mates, as opposed to use as a lethal weapon.

Markings
Narwhal skin features a mottled pattern of black-brown over white, which increasingly lightens as they approach maturity. These markings offer some degree of camouflage from predators like killer whales.

Body
The narwhal's body is cylindrical and quite stocky compared to other cetaceans like dolphins and they have no dorsal fin. Along with a 10cm (3.9in)-thick layer of blubber under the skin, this body shape ensures optimal heat preservation in freezing-cold waters.

The statistics...

Narwhal

Type: Mammal
Genus: Monodon monoceros
Diet: Carnivore (eg fish, squid, shrimp)
Average life span in the wild: 50 years
Length: 4-6.1m (13-20ft)
Tusk length: 2-3m (6.6-9.9ft)
Weight: 1,600kg (3,500lb)

Porpoises in demand

Narwhals provide a host of invaluable resources to the native Arctic tribes

People would struggle to live in the Arctic if it weren't for marine creatures to hunt and, in many respects, narwhals are considered the ultimate catch, with not a single part of the creature wasted.

Starting with the tusk, this is often incorporated into everyday tools like harpoon shafts, as well as in many traditional handicrafts; it's sometimes also used for bartering with other tribes.

Meat from the porpoise is often the main food source for hunters' dog teams, though it's also consumed by people – particularly the fatty layer of skin (sometimes called 'mattak'), which is a rare source of vitamin C in the region.

On top of all this, oil can be extracted from the narwhal's blubber, which is an essential fuel for both cooking and powering lamps, while its sinews can be used to sew boots and other clothing.

© Corbis

Why do some animals play dead?

Learn about the critters that feign death in order to live another day

Perhaps one of the most peculiar behaviours witnessed in the animal kingdom, tonic immobility is an involuntary reflex where a creature experiences total paralysis and, essentially, appears dead. Often demonstrated by sharks and some bony fish when turned on their backs, the animal enters a cataleptic state – much like the proverbial 'rabbit caught in the headlights'. Whether it's your world being flipped 180 degrees or a car hurtling towards you, it's believed this condition is the result of some form of sensory overload. Left to their own devices, most fish will 'come to' within 15 minutes and return to normal, however certain chemicals can be used to speed up the process.

Although an animal might look dead when in a tonic state, there's a distinction to be made between tonic immobility – which is outside a creature's control – and thanatosis, which is an instinctual behaviour where death is actively feigned. This is seen across mammals (eg opossum – hence 'playing possum') to reptiles (eg grass snake) and insects (eg pselaphid beetle). Most use the technique as a defence to deceive predators, or members of their own species, into thinking they're already dead, but a few actually use it as a means of predation. For example, the pselaphid beetle tricks ants into carrying it back to their nest, where it will dine on the colony's eggs and larvae.

There has been some research into whether humans can experience tonic immobility and recent studies suggest we can in extremely traumatic situations, where we essentially 'switch off' from a life-threatening situation. Most likely our brains trigger this response to try and reduce psychological damage.

The prairie ringneck snake, found in North America, often coils and rolls onto its back when threatened to appear as if it's dead

© Thinkstock

"As well as protecting the creature, an exoskeleton also creates a watertight barrier"

Animals with exoskeletons

Why do some critters have their skeletons on the outside?

The rhinoceros beetle is considered by many as the world's strongest creature, able to carry up to 850 times its own weight!

It might come as a surprise but 98 per cent of the animals on Earth don't have a backbone, and 95 per cent don't have any bones at all. So how do all these creatures support and protect themselves? Well, many invertebrates – and all arthropods – have a protective external casing called an exoskeleton. This literally means 'outside skeleton' and its role is to cover the animal's soft tissues and also provide a rigid structure to which the creature's muscles can attach.

Insect exoskeletons are made of chitin, which is embedded into a kind of tough protein matrix. Chitin is a nitrogen-based biopolymer – similar, at least in function, to keratin, which is the stuff our hair and nails are made of. Arthropods such as crustaceans, meanwhile, have additional calcium carbonate in their exoskeletons for extra armour plating.

As well as supporting and protecting the creature, an exoskeleton also creates a watertight barrier that prevents the animal from drying out. The exterior of an exoskeleton can also contain sensory hairs or bristles, while some animals can secrete various pheromones and chemicals onto the surface of their shell as a means of repelling predators.

Though an exoskeleton consists of flexible leg joints to enable the creature to move about, once it's formed this armour does not expand with the rest of the body. Therefore, the animal will eventually outgrow it. At this point a process called ecdysis, or moulting, takes place whereby the creature will shed its overly tight outer skin in order to make way for a new one.

There are three main types of skeletal system in the animal kingdom: exoskeletons (on the outside), endoskeletons (on the inside, like humans) and hydrostatic skeletons, which are a bit different as they have no real framework but rather maintain their shape by the pressure of fluid in their bodies. Examples of creatures with hydrostatic skeletons include slugs, worms and jellyfish.

Which creatures have exoskeletons?

Scorpion
Baby scorpions start out all soft and squishy, riding around on their mothers' backs, but their exoskeletons soon harden. One unusual trait about the scorpion's exoskeleton is that it glows fluorescent under ultraviolet light.

Spider
The discarded cuticle left behind after a spider has outgrown its exoskeleton and wriggled out is complete with all the legs and you can even see the fine hairs on its body.

DID YOU KNOW? *Unlike other crustaceans which shed their entire exoskeleton in one go, woodlice only shed half at a time*

In Chinese medicine, cicada shells, or slough, are used to treat certain ailments

Outgrowing your shell

Until an arthropod reaches maturity, its body will continue to grow. The exoskeleton, however, does not. Whenever the shell begins to feel tight – maybe once or twice a year – it's time to grow a new one and dispose of the old. This process of moulting is known as ecdysis.

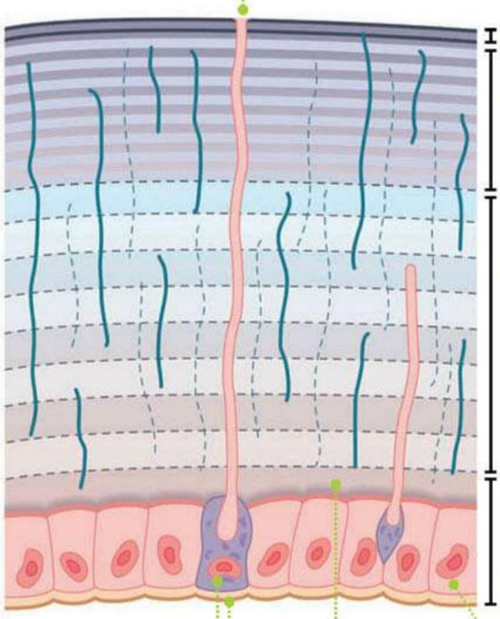
The new soft exoskeleton is produced beneath the old one, and when the time's right the old cuticle will separate from the body, enabling the animal to slip out.

Once the outer shell is cast off, the creature needs to temporarily inflate its new soft body as much as possible to create room for growth before the cuticle becomes hard again. This rapid expansion is achieved by the transferral of fluids from the animal's soft body parts to other areas. Insects that breathe through tracheal tubes can also pump up their bodies by taking in extra air.

The hardening and darkening of the cuticle is a process called sclerotisation. Superficial hardening can take a few hours, whereas permanent structural integrity and colouration can take a number of days or even weeks. Before the new exoskeleton has toughened up, the pale-bodied creature remains quite soft and is therefore very vulnerable to predators. As a result the animal will often hide away until its new shell has fully hardened.

Arthropod exoskeletons

All arthropods have an exoskeleton, aka cuticle, which consists of two main protective layers: the thin, waterproof outer epicuticle and the thicker chitinous procuticle just below it...



Epicuticle
A thin, waxy layer, the epicuticle is both water and solvent-resistant. It contains no chitin and makes up the hard exterior of the exoskeleton.

Hardened exocuticle
The thick procuticle layers are made of chitin, which is like nature's plastic. Compacted layers of this structural biopolymer produce the exoskeleton's characteristic hardness.

Flexible endocuticle
Located below the exocuticle is a criss-crossing network of further chitinous layers, which together form the tough yet flexible endocuticle layers.

Procuticle
The procuticle is made up of two main layers: the exocuticle and the endocuticle. The procuticle contains chitin microfibres bound by a protein matrix, each layer aligned differently for strength.

Epidermis
Below the cuticle layers is the epidermis, which is a single layer of secretary cells from which the epicuticle is produced.

Dermal gland
Found in the epidermis, the dermal glands are responsible for producing predator-repelling chemicals, which are released on the surface of the exoskeleton through minute ducts.

Crab
A crab's broad protective plate across its back is called the carapace. The decorator crab's exoskeleton comes in handy for disguise too, as it features tiny hooks onto which coral attaches. The coconut crab (above), meanwhile, is so big it can spend a whole month shedding its shell and waiting for the new one to harden.

Millipede
Its long, tubular exoskeleton is reinforced by hard minerals. Toxic chemicals can also be secreted onto the surface of the outer shell to deter predators or when millipedes feel threatened.

Spiny African flower mantis
A mantis will moult between five and ten times during its lifetime, and usually it will stop growing and shedding once it's an adult with fully functioning wings.

Lobster
Crustacean exoskeletons are reinforced with calcium and made up of plates. Hormones that originate from the lobster's eye tell it when it's time to shed its shell. When a chef boils a lobster its outer skin will turn from blue-black to bright red. This is because certain pigments in the exoskeleton turn red when exposed to heat.

Welcome to... TECHNOLOGY

A mountain can be a big obstacle, but for a mighty tunnel-boring machine it's just another day at the office, as you'll see here. Also learn the workings of smartphone projectors, self-checkouts, 3D glasses, Instagram and more.

LEARN MORE

MEGA DRILLS

Burrowing through a mountain range requires a little more digging power than a couple of pickaxes. Here How It Works takes a closer look at the giants of the tunnelling world

Tunnel-boring machines (TBMs) – sometimes known as 'mega-moles' within the industry – are pieces of drill-mining equipment used to excavate long tunnels, such as those used by cars and trains in hilly and mountainous regions. They can be configured to bore through a surprising variety of materials, ranging from sand, through to earth and even solid rock.

Each tunnel-boring machine consists of three key components: a cutterhead, hydraulic bracing system and an excavating conveyor, as well as a host of other elements (see 'Tunnel-boring machine breakdown' overleaf for details).

The cutterhead comprises a circular metal face interspersed with discs that, when the cutterhead rotates – and it can turn a full 360 degrees – are forced against the tunnel face under immense pressure. In this process the cutter discs roll over the surface, loosening the material – whether it's rock or soil – into small segments referred to as chips. As the chips are created, they fall into large bucket lips, which are openings in the cutterhead that lead to a series of sheltered hoppers. Once the hoppers receive the excavated material they discharge it onto a vast conveyor belt system that extends backwards through the central body of the tunnel-boring machine.

At the rear of the TBM the belt deposits the material into a back-up area, which tends to be an enlarged cavern within the tunnel system with access to the surface. Here the chips are scooped up by a tracked or wheeled loading unit and placed into a 'muck truck', a large dump vehicle that specialises in traversing the tunnel system to the surface where the material can be dropped off for further processing or relocation.

Importantly, the overall extraction process greatly relies on a TBM's ability to remain stable within the tunnel it is mining. This is made possible due to radially mounted hydraulic braces, which are fixed to the mega drill's body, pushing outwards into the tunnel's walls. These braces simultaneously stabilise its

KEY DATES
GOTTHARD BASE TUNNEL (GBT)

1999 Excavating activities begin for the GBT with blasting works starting at Sedrun, Switzerland.

2003 After being awarded the contract, Herrenknecht delivers four Gripper TBMs and begins drilling.

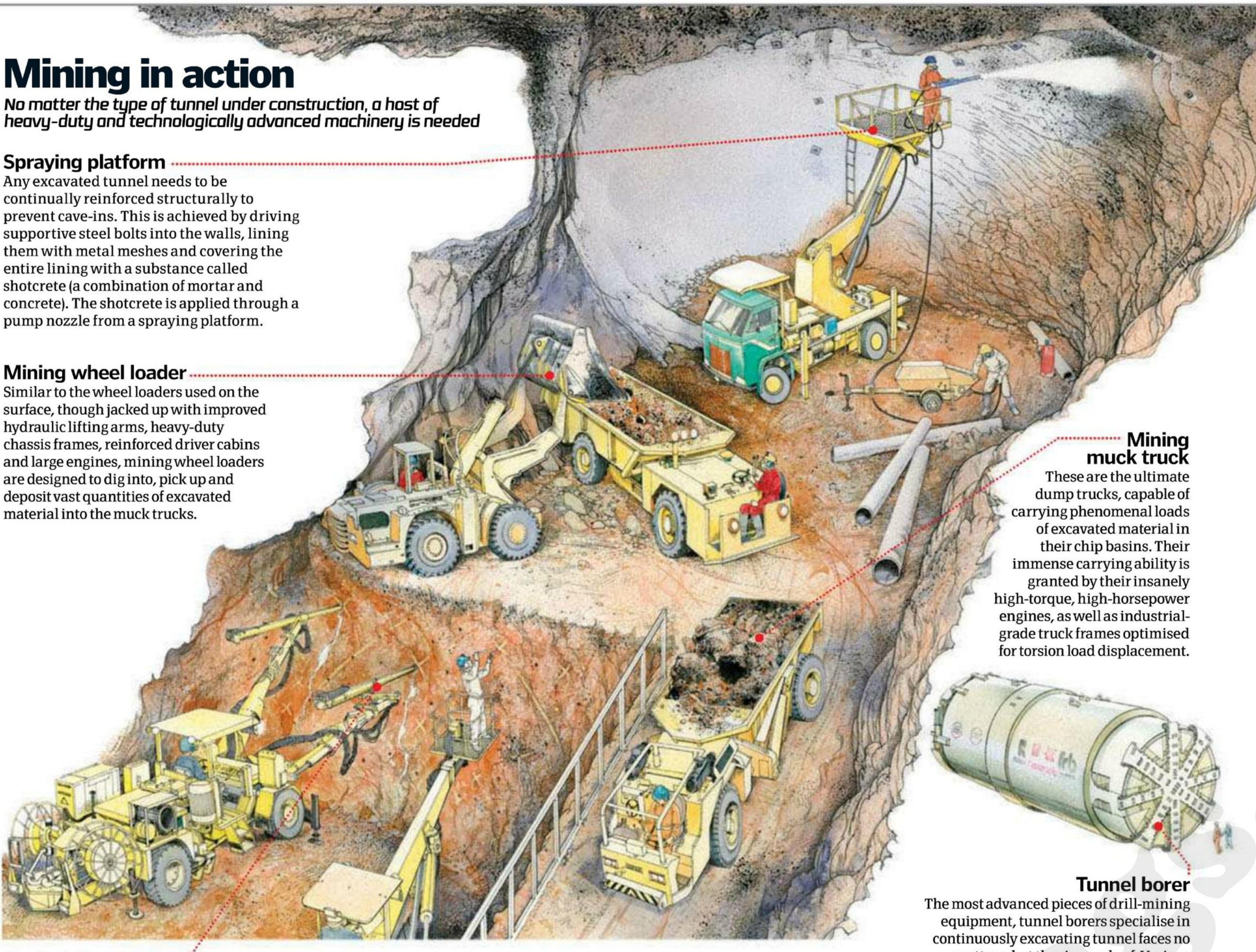
2006 The Gripper TBMs on the northern and southern sections reach their first target nine months ahead of schedule.

2009 Mechanised tunnelling is completed in the north.

2010 The main breakthrough of the eastern tunnel is completed between Sedrun and Faido.

2011 The main breakthrough of the western tunnel is completed between Sedrun and Faido.

DID YOU KNOW? *The first railway tunnel through the Gotthard region was completed in 1882*



Mining in action

No matter the type of tunnel under construction, a host of heavy-duty and technologically advanced machinery is needed

Spraying platform
Any excavated tunnel needs to be continually reinforced structurally to prevent cave-ins. This is achieved by driving supportive steel bolts into the walls, lining them with metal meshes and covering the entire lining with a substance called shotcrete (a combination of mortar and concrete). The shotcrete is applied through a pump nozzle from a spraying platform.

Mining wheel loader
Similar to the wheel loaders used on the surface, though jacked up with improved hydraulic lifting arms, heavy-duty chassis frames, reinforced driver cabins and large engines, mining wheel loaders are designed to dig into, pick up and deposit vast quantities of excavated material into the muck trucks.

Mining muck truck
These are the ultimate dump trucks, capable of carrying phenomenal loads of excavated material in their chip basins. Their immense carrying ability is granted by their insanely high-torque, high-horsepower engines, as well as industrial-grade truck frames optimised for torsion load displacement.

Tunnel borer
The most advanced pieces of drill-mining equipment, tunnel borers specialise in continuously excavating tunnel faces no matter what they're made of. Various types are manufactured ranging in size, length and material expertise (eg sand, earth, rock, etc). The largest TBM in the world has a cutterhead 19.3m (63.3ft) across!

Shaft drill
These allow their operator to use a series of drill shafts/booms to penetrate tunnel faces with acute precision. The drills – which are akin to manual jackhammers – extend from the vehicle's body on long hydraulic arms and, powered pneumatically, drive their drill bits into the rock/earth to break it up.

position so it can push forward, while also supporting the structure of the tunnel. Once braced, a series of hydraulic cylinders extend from the TBM's body and press the cutterhead's disc cutters firmly against the tunnel face, allowing a new stretch to be cleared.

While drill mining is, of course, the primary purpose of a TBM, it also acts as a platform for many of the safety procedures needed to secure a tunnel during the building process.

These include installing rock anchors, metal meshes, steel beam supports and, at the rear of the TBM, the necessary pumps and nozzles required to inject shotcrete – a mortar/concrete wet mix used to line and reinforce tunnel walls. All these tasks are performed in the 'working area' of the TBM, a large segment positioned just behind the cutterhead where ring erectors, anchoring drills and wire-mesh installers semi-automatically secure a freshly excavated tunnel to make it safe for tunnel workers to proceed.

Boring history

Prior to mechanised boring machines, tunnels were made through a mixture of explosives and manual labour, with men and machine alike locked in an incredibly dangerous game of knock and run. The introduction of the first boring machines didn't improve things much either, with the early systems relying on water compressors to supply them with pressurised air to drive their drills into the earth. The machines broke down frequently and, due to their cumbersome and inaccurate nature, led to many accidents deep within mountain excavations.

Other early systems, such as the 1853 Wilson's Patented Stone-Cutting Machine, just failed to work at all. Famously, engineer Charles Wilson's contraption, which had been employed to help drill out the Hoosac railroad tunnel in Massachusetts, USA, cut through just three metres (9.9 feet) of rock before breaking and falling to bits. The tunnel was eventually completed 20 years later using traditional methods and it, as well as the remains of Wilson's machine, can still be seen there to this day.

"Each TBM has three key parts: a cutterhead, hydraulic bracing system and excavating conveyor"

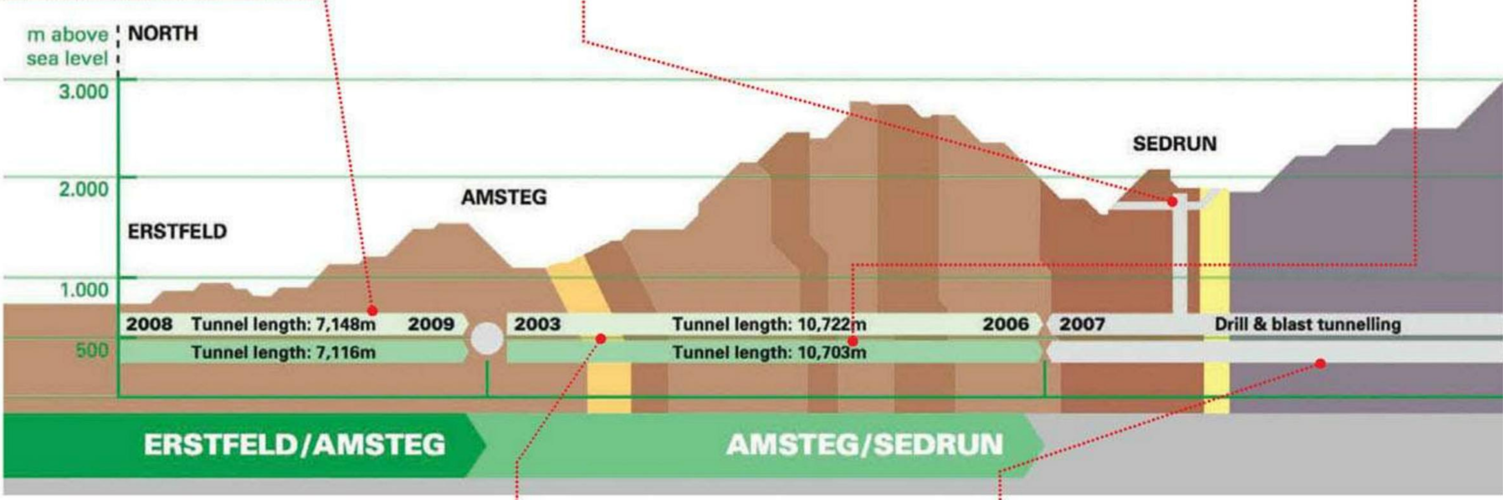
Boring the Gotthard Base Tunnel

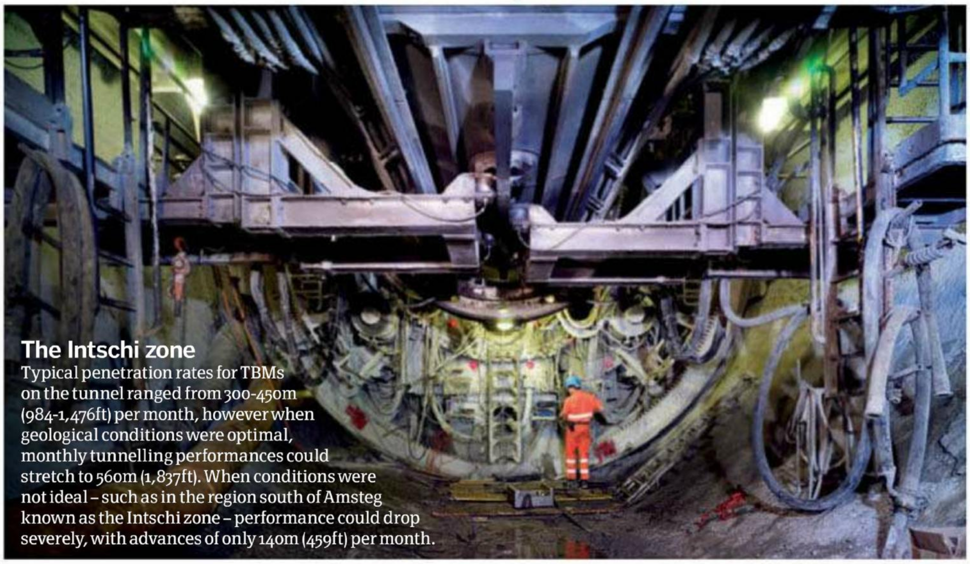
Officially the world's longest railway tunnel, the GBT stretches a total 152km under the Swiss Alps. Here we look at how this engineering marvel was built...

Record breaker
Due to the vast cutterhead diameter of the Herrenknecht Gripper TBMs, in 2008 a new world record was set by a northern unit, drilling through 56m (184ft) of earth between Erstfeld and Amsteg in 24 hours. What's more, when the TBM in question made the breakthrough into the Amsteg tunnel centre, it had only deviated from the ideal drill line by 4mm (0.15in) horizontally and 8mm (0.3in) vertically!

Fire in the hole!
Tunnel construction began proper in 1999 at Sedrun, a small settlement 1,405m (4,610ft) above sea level. From here engineers set up a construction control centre and began blasting operations. This allowed large access and supply tunnels to be excavated down to the tunnel's position, as well as a ventilation shaft for the supply of fresh air. Drilling operations began at Amsteg and Bodio in 2003.

Water logged
In 2005 the engineers in the western tube hit the longest delay of the project due to a combination of loosened rock and mountain water suddenly infiltrating the cutterhead. After a failed attempt to clear the cutterhead by hand, engineers had to solidify the loose soil ahead by injecting it with cement and bentonite. The cutterhead was eventually cleared and, five months later, boring resumed.





The Intschi zone
Typical penetration rates for TBMs on the tunnel ranged from 300-450m (984-1,476ft) per month, however when geological conditions were optimal, monthly tunnelling performances could stretch to 560m (1,837ft). When conditions were not ideal – such as in the region south of Amsteg known as the Intschi zone – performance could drop severely, with advances of only 140m (459ft) per month.

Zurich to Milan
With drilling operations now complete the tunnel is set to be fully equipped and ready for its public opening in 2017. When opened the Gotthard Base Tunnel will enable passengers to travel from Zurich, Switzerland, to Milan, Italy, in just two hours 40 minutes, which is a whole hour less than the current route allows.

GO FIGURE
GBT IN NUMBERS

How many of these could fit end-to-end in the world's longest railway tunnel?

23 THOUSAND ANACONDAS

13 THOUSAND NARROWBOATS

345 TUNNEL-BORING MACHINES

DID YOU KNOW? *Trains will travel at up to 250km/h (155mph) through the Gotthard Base Tunnel*

Epicentre

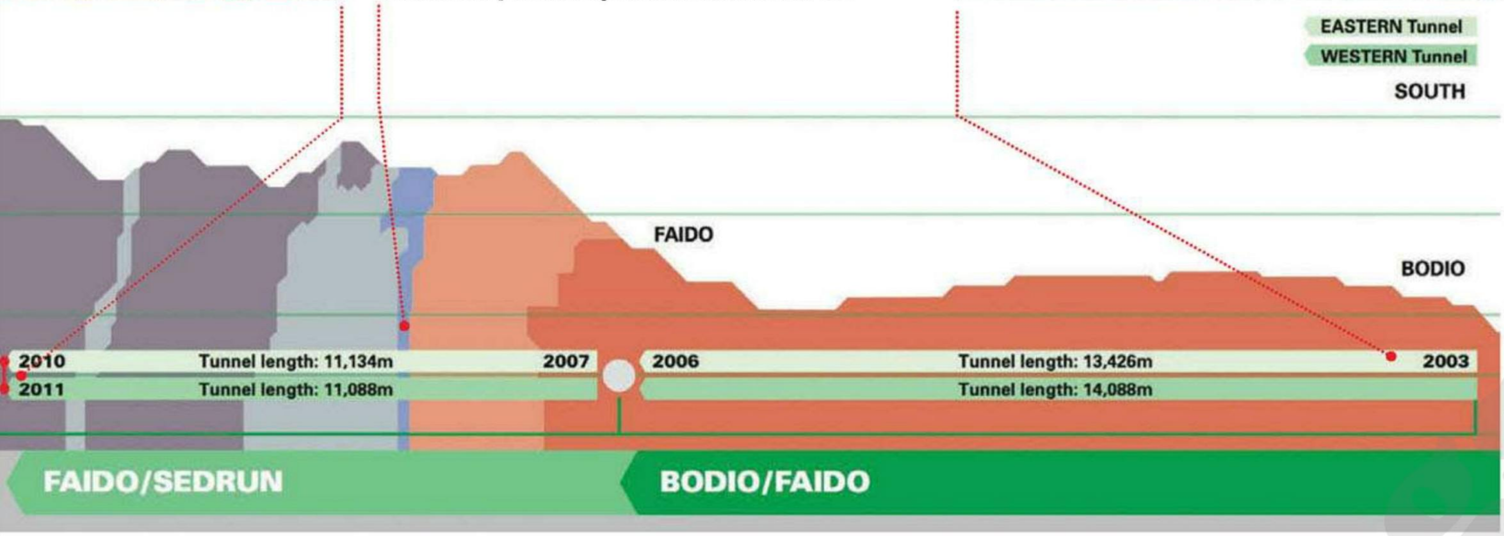
Both main breakthroughs – the joining up of the north and south excavations – occurred in 2010 and 2011, respectively, at the epicentre of the tunnel, about 28km (17.5mi) from either end. Deep within the Swiss Alps, and under more than 2,000m (6,562ft) of rock, the joining of both east and west tunnels was a momentous achievement for all those involved and marked the end of the drilling operation.

Devil's basin

Not far from Faido lies the Piora Basin, a funnel-shaped region consisting of sugar-grained dolomite and water, under a huge pressure of 150 bars. When inclined drills were used to probe the area back in 1996, a deadly jet of water and dolomite exploded out. This led to speculation that boring through the area could be immensely dangerous. Luckily, after reports came through that the basin culminated in a gypsiferous cap-rock above the tunnel's depth, both southern TBMs passed through the area without issue in 2008.

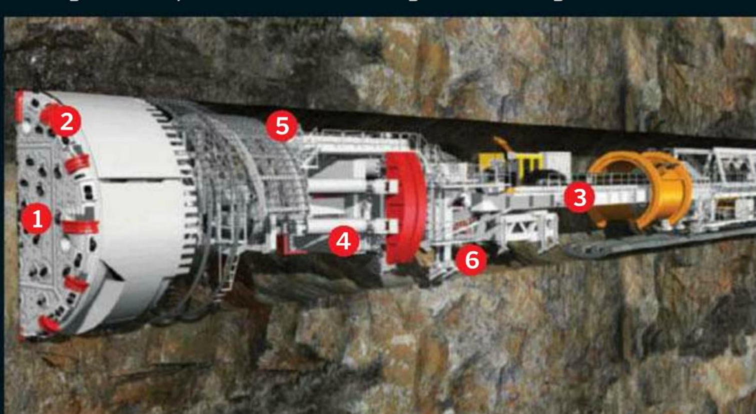
Kakirite zone

The two southern tunnel-boring machines that began drilling at Bodio hit a major obstacle after only 200m (660ft) of operation, running into a geological disturbance region known as a kakirite zone. This area was made of material too soft for the Gripper TBMs to process as usual, which specialise in drilling through hard rock. As such, every metre of the tunnel that was excavated needed to be reinforced prior to boring.



Tunnel-boring machine breakdown

Get to grips with the key components of these burrowing behemoths – or mega-moles – from the cutterhead through to the walking device



1. Cutterhead
All the excavation tools are mounted in the cutterhead at the front of the TBM, which also supports the tunnel face.

2. Disc cutters
These roll in concentric circles over the tunnel face. The contact pressure crushes the rock/earth.

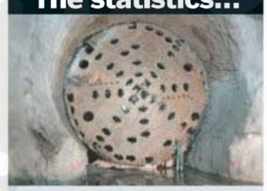
3. Conveyor belt
The system's buckets deposit the excavated rubble behind the cutterhead onto a conveyor belt system.

4. Thrust cylinders
These drive the rotating cutterhead against the tunnel face.

5. Roof bolting unit
This part can rotate around the machine's axis and drills holes into the rock for receiving metal bolts.

6. Walking device
The rear of the bore and the back-up systems rest on these moving feet.

The statistics...



Gotthard Base Tunnel

Construction start: 2003

Maximum altitude above sea level: 550m (1,804ft)

Total length of tunnels/ shafts: 151.8km (94.4mi)

Tube diameter: 8.8-9.6m (29-31ft)

Maximum overburden: 2,500m (8,200ft)

Tunnel borers: 2 x south / 2 x north (Herrenknecht Grippers)

Construction end: 2016

"The fluid turns solid much in the same way that custard does when heated"

How does liquid armour stop bullets?

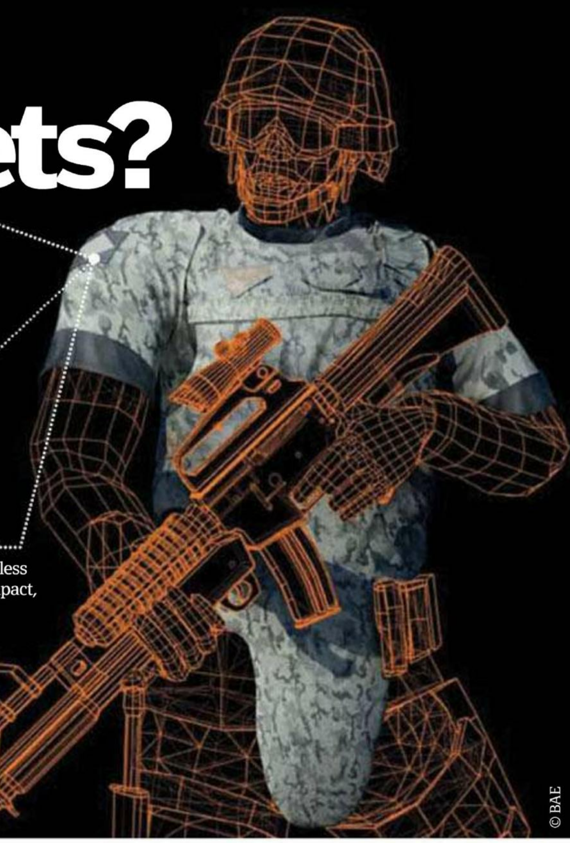
Why this revolutionary protective gear takes Kevlar to a whole new level

While Kevlar armour offers good stopping power against standard rounds, the material is both stiff and heavy, making it hot and uncomfortable to wear – especially considering that over 30 layers of it are used in an average suit! It is battle proven at stopping bullets, but it often does so at the expense of its own structural integrity, warping the armour so it's unusable in the future.

Liquid armour goes a long way to tackling these issues by splicing traditional Kevlar layers with a shear-thickening fluid. The fluid acts as an impact energy displacement layer, hardening upon a bullet's impact and spreading its force out over a larger area than if it were just Kevlar. The fluid turns solid much in the same way that custard does when heated, starting off with a runny consistency, only to become thicker and more dense as it is warmed up.

The liquid's chemical composition, however – which remains top secret – catalysed by the intense heat of the bullet, allows the hardening process to take place instantaneously. Critically, once the round has been stopped by the armour, the liquid layer returns to its fluid state, reducing warping and therefore improving the longevity of the kit.

In addition to providing superior impact resistance, due to the fewer Kevlar layers needed, the overall thickness of the liquid armour is reduced by nearly half. As a result, it's considerably more comfortable to wear than standard all-Kevlar suits.



Thinner
The liquid armour is 45 per cent slimmer than standard Kevlar suits.

Stronger
With a third less Kevlar layers, the liquid armour still provides superior stopping power.

Tougher
The liquid armour is also less prone to warping post-impact, extending its life span.

© BAE

How do computers stay cool?

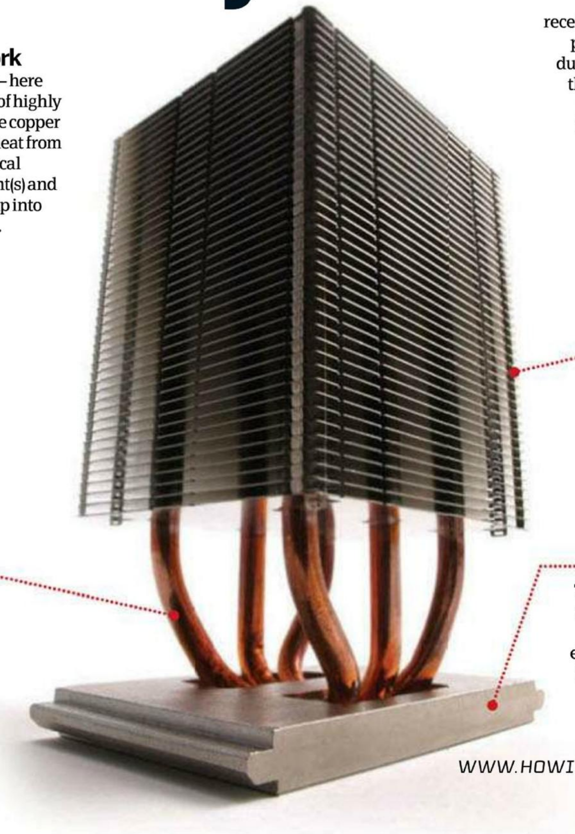
Learn how heat sinks help a computer reach its full potential

Heat sinks are passive cooling components commonly found in PCs. They consist of a series of metal plates, pipes, pins and lattices that work together to absorb heat from electrical components through conductivity then dissipate it into the environment.

Conduction, which is the central operating principle of heat sinks, occurs when two objects with different temperatures are placed in contact with each other. When they touch, the hotter object's faster-moving molecules transfer a portion of their energy to the colder object's less-active molecules.

Not surprisingly, for conduction to take place optimally, the two objects must be made out of a material that is a good conductor. Metals, for the most part, are very effective and, as such, form the base material for almost all heat sink devices. Aluminium alloys and copper are probably the two most commonly used metals on commercial heat sinks as they offer a favourable thermal conductivity-to-cost ratio.

If we take a computer's central processing unit (CPU) as an example component, its mounted heat sink operates by attaching itself to the CPU's small surface area (ie the top of the chip) and then transfers the generated heat away via a series of pipes into a lattice. The lattice, due to its considerable surface area, allows for a balanced and more rapid radiation of the heat into the surrounding system, which enables the processor to remain at a stable and efficient operating temperature.



Pipework
The pipes – here made out of highly conductive copper – receive heat from the electrical component(s) and funnel it up into the lattice.

Lattice
The aluminium lattice receives heat from the copper pipes via conduction and, due to its structure, spreads the energy out over a large surface area, radiating it into the surrounding air.

Plate
The base plate of the sink makes contact through a thermal adhesive to the electrical component(s). It is securely attached via a bracing system of clips and/or push pins.

© Thinkstock

"Colour is introduced to the image by the LED's white light being broken down into RGB via a prism filter"

Inside the Galaxy Beam

How does this smartphone device double up as a video projector?

Samsung's Beam is one of the latest smartphones in the manufacturer's Galaxy range of devices. The phone itself offers a 10.2-centimetre (four-inch) TFT screen, 1GHz dual-core CPU and the usual list of connectivity and storage options. However, what separates it from the pack is that it also comes equipped with an integrated projection system capable of blowing up the screen's display to a rather sizable 127 centimetres (50 inches).

The projector's integration is possible due to it being based on the advanced Digital Light Processing (DLP) system made by Texas Instruments. This differs from standard units as it can reflect a binary data pattern (video or image) with a speed, precision and efficiency greater than most spatial light modulators. It achieves this through a revolutionary array of 2 million tiny mirrors, or digital micromirror devices (DMDs), each of which is just one-fifth the width of a human hair. The hinge-mounted mirrors are controlled via bit-streamed binary data entering the DMD unit from the DLP processing chip, the information ultimately dictating their angle of tilt.

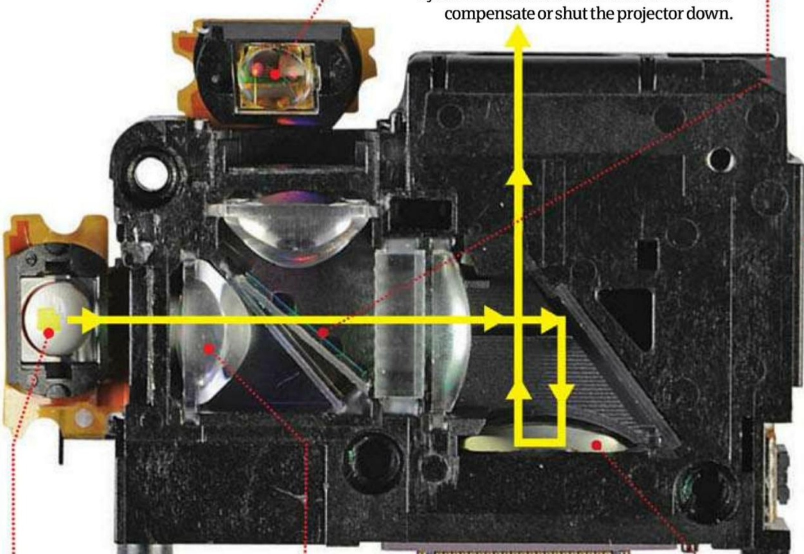
The Beam uses a single white LED as a light source. This illuminates the DMD mirrors, which – adapting to the pixel arrangement of the video/image that's embedded in the code – individually tilt so the pattern is replicated – each mirror acting as a real-world pixel. So if a specific pixel in the image needs to be black, the corresponding DMD mirror would tilt away from the light source. Colour is introduced to the image by the LED's white light being broken down into RGB via a prism filter prior to reaching the mirrors. As such, upon leaving the device, a colour, highly detailed image can be reproduced from just binary data.

The Beam's projector unit is manufactured by Texas Instruments

Anatomy of the DLP projector

How It Works takes a closer look at the Galaxy Beam's primary feature

= Direction of light



Infrared transmitter/receiver
As the Beam's projector is housed within a plastic casing (rather than invar), an infrared transmitter and receiver are also included. These are used to monitor the system's optical path length in the event of the heat or humidity creating lens displacement. If this occurs the IR system can detect it and shift the mirrors to compensate or shut the projector down.

Filter
On its own the DMD unit reflects white light into light, dark and grey pixels. For colour to be added, prior to the white light from the LED reaching the DMDs, it must pass through a wedge mirror prism to be split into RGB.

Light
For the DLP system to work a light source is needed (for the DMDs to reflect). In the Beam's DLP system a single white LED is used.

Optics
For the light from the white LED to be focused correctly it must pass through a series of lenses. This ensures it hits the DMDs just so and is therefore projected correctly on leaving the device.

DMD unit
The DMD unit is a rectangular array of 2 million hinge-mounted microscopic mirrors, each just one-fifth the width of a human hair. The bit-streamed image code entering the DMD unit from the DLP chip directs the mirrors' movement so that each reflects either a light, midtone or dark pixel.

1. SIMPLE

Shutter 3D glasses
These black out the left then right eye views in quick succession using a battery-powered liquid crystal system.

2. SIMPLER

Polarised 3D glasses
By filtering out wavelengths with opposite polarising filters to the projection, each eye sees a slightly different image to get a 3D composite.

3. SIMPLEST

Anaglyph 3D glasses
Chromatically opposing colours filter out parts of each frame, resulting in two images that are fused by the brain into one.

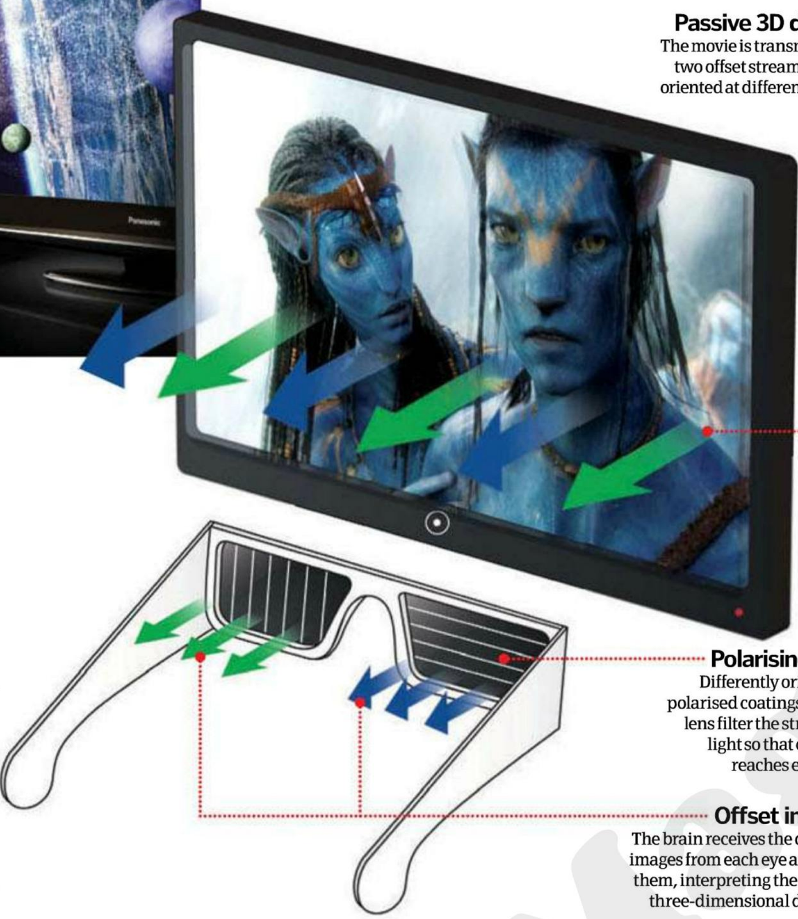
DID YOU KNOW? Panasonic, Sony and Samsung promote active 3D, while LG and Vizio favour passive 3D

Active vs passive 3D glasses

See through the technology that enables us to watch films in three dimensions

Polarising 3D

How passive glasses use a trick of the light to create the illusion of 3D



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Both active and passive 3D glasses are used with display devices that show a movie as two offset streams of imagery. For a viewer, essentially this means that each eye receives slightly differing information, which – without conscious thought – the brain combines to form a sequence of three-dimensional images.

However, the method that the glasses employ to achieve this differs somewhat. First, with active shutter 3D the streams are displayed as an alternating sequence of matching frames so rapidly that it looks like they are transmitted together. The glasses respond to wireless signals from the display device by applying voltage to a liquid crystal layer in each lens successively. This basically makes the lenses 'wink' at the speed at which frames are swapped.

Passive 3D glasses, on the other hand, have no circuitry and essentially just filter light. Passive displays show two streams of images simultaneously as light waves aligned at different angles. The glasses act as polarising filters that reflect back the light wave matching the alignment of their polarisation.

If working correctly, both types of glasses ideally ensure that each eye only ever sees one stream of footage and the brain does the rest of the work, fusing the two streams into a 3D scene.

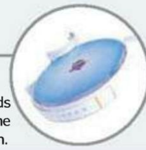
KEY DATES
WIRELESS WEB

1985 The US FCC allows anyone to freely transmit radio signals on the 900MHz, 2.4GHz and 5.8GHz frequency bands.

1997 The Institute of Electrical and Electronics Engineers (IEEE) agrees a common standard for data transmission: 802.11.

1999 The IEEE releases the first widely adopted wireless standard – 802.11a – which grants a transmission up to 54Mbps.

2004 New routers have nominal maximum throughput speeds of 300Mbps, kick-starting the online multimedia revolution.


© Sapido

2009 Over 15 tech companies form the Wireless Gigabit Alliance (WiGig) to promote superfast 60GHz wireless technologies.

DID YOU KNOW? Marketed transfer speeds of wireless routers are rarely achieved due to distance and interference

Wireless routers explained

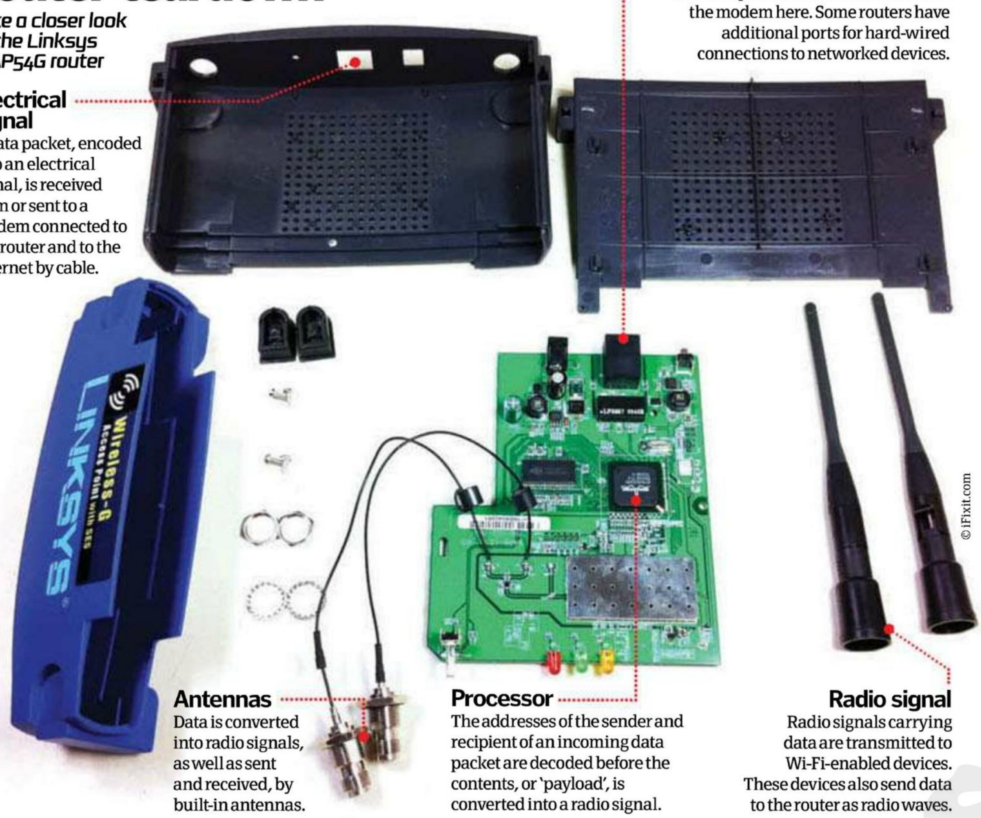
What happens inside the magic boxes that get us online over thin air?

Wireless routers have revolutionised information access on the go. Yet there is nothing revolutionary about how they work. Internet data is essentially sent and received like over-the-air (OTA) television broadcasts, except in reverse. OTA signals are broadcast as radio waves and picked up by antennas attached to television sets. Each antenna converts the waves into electrical signals and sends them down wires to be turned into images by the TV.

Wireless routers do things the other way around. They receive electrical signals from a modem connected to a cable on an internet service provider's network. These signals contain information in the form of data packets. A processor in the router decodes each packet's digital label or 'header'. This contains the unique numerical internet protocol (IP) addresses of the sender and intended recipient. A packet's payload of data (an email, for example) is then converted into a radio signal by the router and broadcast on the 2.4GHz or 5GHz frequencies via antennas. Wireless network adaptors in Wi-Fi-enabled devices intercept this transmission and convert it back into electrical signals.

Router teardown

Take a closer look at the Linksys WAP54G router



© iFixit.com

Electrical signal
A data packet, encoded into an electrical signal, is received from or sent to a modem connected to the router and to the internet by cable.

Ethernet port
The data packet enters the router from the modem here. Some routers have additional ports for hard-wired connections to networked devices.

Antennas
Data is converted into radio signals, as well as sent and received, by built-in antennas.

Processor
The addresses of the sender and recipient of an incoming data packet are decoded before the contents, or 'payload', is converted into a radio signal.

Radio signal
Radio signals carrying data are transmitted to Wi-Fi-enabled devices. These devices also send data to the router as radio waves.

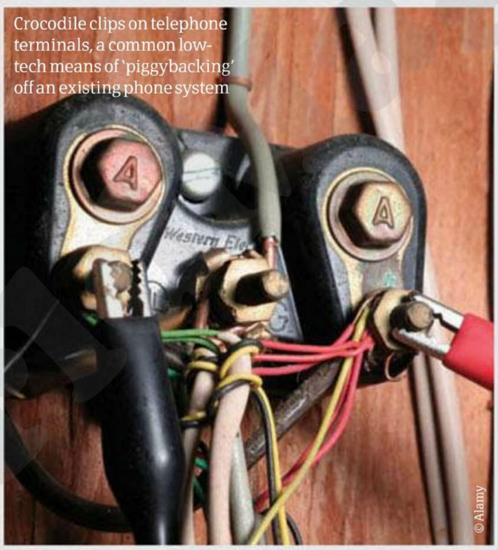
How are telephones tapped?

Tech that lets people listen in on others' phone calls

Phone tapping enables people to listen in on conversations. It can be achieved in a variety of ways, each requiring different techniques and tools. Regardless of the method, all tapping techniques rely on exploiting a phone's internal cabling, microphones and speakers.

The most basic method is to manipulate a person's phone line outside their home or office. This is achieved by attaching a gateway phone onto the line by 'piggybacking' off the device's cabling. This works as phones transmit audible noises (such as the human voice) as a fluctuating electrical current through their wires, which are encoded and decoded via handsets' microphones and speakers. As such, by simply adding a splitter to any line and then plugging in another phone – ideally with its microphone wire disconnected – a line's activity can be heard remotely. The advantage of this technique is that it's incredibly easy to carry out and requires little in the way of equipment. The main downside is that physical access is needed to the line both before and during tapping operations.

The second, slightly more complex method of tapping a telephone involves installing a 'bug' in the handset. The bug is actually a minuscule radio transmitter that either through direct connection to the handset's wiring – the same piggybacking process as before – or via the addition of a microscopic microphone of its own, is capable of picking up and transmitting a conversation and then broadcasting it wirelessly on a specific frequency to a receiver. This option enables someone to remotely monitor a phone's activity without having to be in the locale, however it does require a greater level of access to the physical handset in the first instance.


Crocodile clips on telephone terminals, a common low-tech means of 'piggybacking' off an existing phone system
© Alamy

"Instagram's services are delivered by over 25 64-bit computers with powerful processors"

Inside Instagram

Discover the tech behind the billion-dollar app that adds retro effects to your photos in seconds

Everybody knows that social-networking services thrive on constant interaction with a large and diverse community of users. The smartphone-based photo-sharing app Instagram has taken only two years to master this, securing over 50 million snappers worldwide and a highly publicised $1 billion (£638 million) takeover by Facebook.

Ironically, given its value according to Facebook, Instagram runs on a version of the free Linux operating system Ubuntu. Free doesn't mean limited though: Instagram's services are delivered by over 25 64-bit computers with powerful processors, each connected to the same server infrastructure that supports Amazon's websites.

Day and night these computers manage the mass of descriptive information, or metadata, in user profiles and photos using another piece of free software called PostgreSQL. This database system gives Instagram users on-demand access to specific data, such as photo locations, using keywords and hashtags.

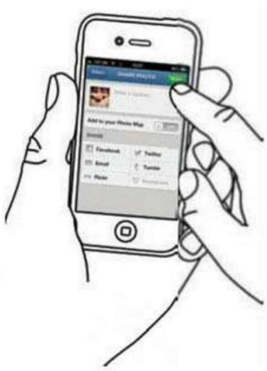
At the frontend, the Instagram app allows uploaded photographs to be modified using filters that produce effects such as converting colour to black and white or boosting contrast. When a user picks a filter, Instagram runs a mini-program called a script. This employs mathematical algorithms that determine which colours the pixels in a picture should be to create the desired result.

Instagram can even expand beyond the app thanks to its application programming interface (API). The API is essentially a software socket that allows third-party programs to plug in to core information including image metadata and tags. The results include cool extensions like This is Now (http://now.jit.su), a website delivering real-time feeds of Instagram photos from major cities around the world.

Instagram filters produce a number of different effects, from giving a photo a focal point to adding depth of field or aesthetically ageing a shot

Key features behind the app

Filters
Every detail in a photo is determined by the colour of its pixels. When a filter is applied, a software script changes these where necessary to achieve the desired finish, eg Lo-Fi.



Metadata
If you write a caption for a photo, it's saved as part of the image's metadata – coded information that includes the time and location of where the picture was captured.

Search
When looking for friends to add to your Instagram network, the app sends a query to the service's massive database, which is stored across a series of powerful servers.

Instagram timeline
A focus on the major milestones in the app's history

July 2010
Kevin Systrom – one of Instagram's founders – uploads the very first photo to a prototype app called Codename.

October 2010
Instagram is officially launched in Apple's App Store as an iOS app for the iPhone and its popularity snowballs.

April 2012
Instagram is released on the Android platform for phones running Android 2.2 or above and supporting OpenGL ES 2.

April 2012
Facebook buys Instagram for $1 billion ($638 million) in cash and stock, pending approval by the US Federal Trade Commission.

July 2012
Two years after the first image was uploaded to Codename, over 50 million 'Instagramers' have shared more than 1 billion photos.

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"Data passes back and forth between the till and its host computer or data centre"

SELF-SERVICE CHECKOUTS

Some people may dislike them but there's no arguing these machines are revolutionising the way we shop

Self-service checkouts have been steadily rising in number since British supermarket giant Tesco introduced the technology in the UK in 2010, with the aim of making paying for groceries much more efficient. From less than 100,000 terminals throughout the world back in 2008 to nearly half a million installed today, they have gone through many changes in this short period, vastly improving in speed and accuracy.

Self-service checkouts come in many shapes and sizes, depending on the floor space available, but usually consist of four main sections: the barcode scanner, touchscreen display, bagging area and the payment terminal.

Barcode scanners feature a wipe-friendly surface and see-through panel over which items are passed to be logged. Beneath this panel are components that illuminate, scan, convert and then decode the barcode, swiftly passing data back and forth between the till and its host computer or data centre. Items that can't be barcoded (for example, loose fruit and veg) can be selected manually via a touchscreen display.

Loose items must also be weighed using a pressure pad that matches the item against its expected weight. If this does not happen, the customer and supervisor are both alerted with the now-familiar 'unexpected item in the bagging area' warning. Otherwise, it's simply a matter of paying, using a combination of debit/credit card reader, note reader and coin counter to check and verify the payment.

Despite improvements in accuracy and speed, the advantages of self-checkouts are debated. Certainly, one operator monitoring up to six tills means lower staff costs. However, for some consumers human interaction is a vital part of the shopping experience and, in busy periods, you can end up waiting longer than normal if the machine has a fault.

Tesco was the first retailer to introduce self-checkouts to the UK high street

KEY DATES
TILLS THROUGH TIME

1879 The cash register is invented in the US by the saloon owner James Ritty.

c.1880 A paper roll is added to keep a physical record of till transactions.

1906 Inventor Charles F Kettering (right) introduces the first motorised cash register.

1973 This year sees the first cash register controlled by a built-in microprocessor.

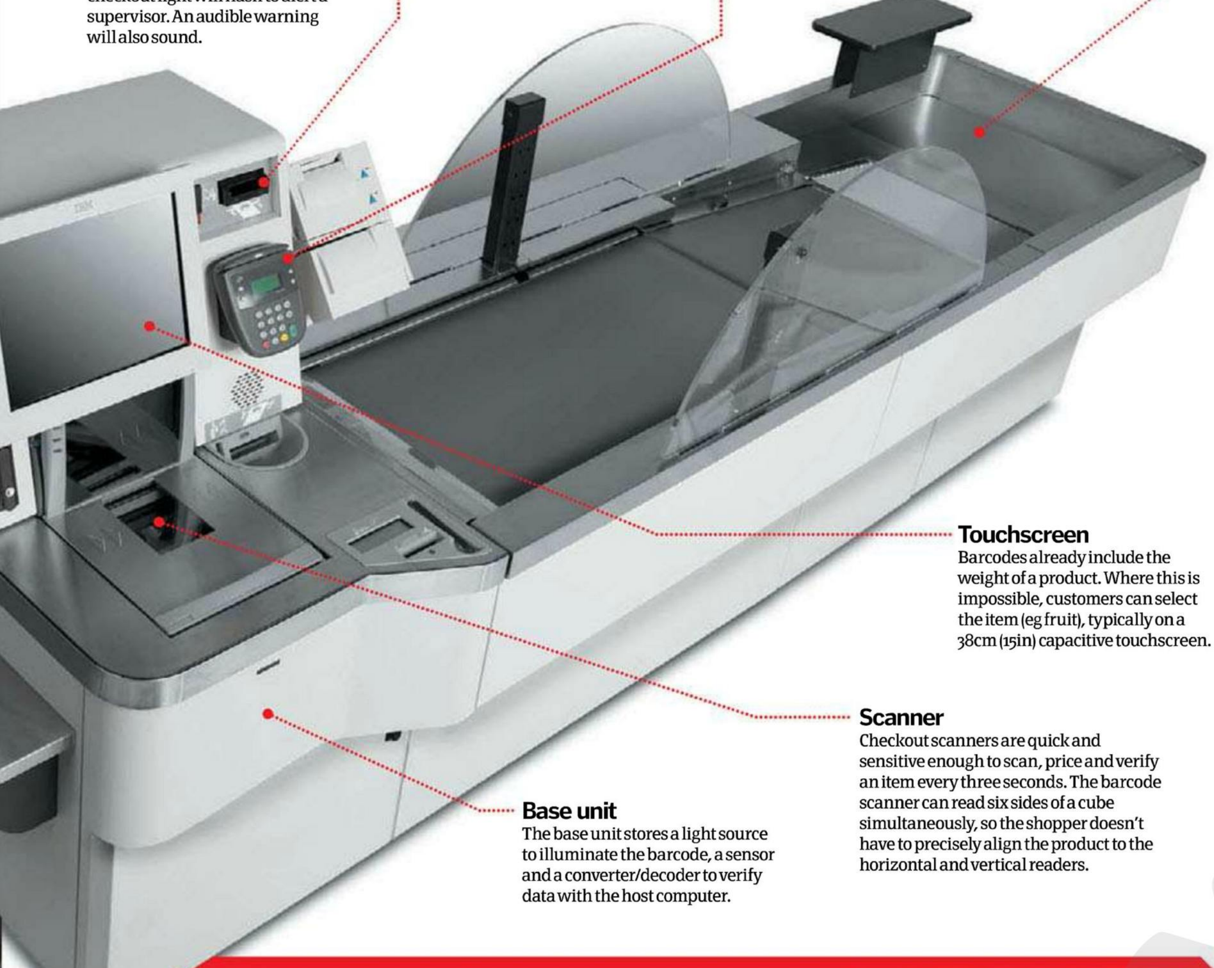
1974 The first UPC barcode is introduced, on a pack of Wrigley's chewing gum.

2010 Self-service checkouts begin to appear in UK supermarkets.

DID YOU KNOW? *'Unexpected item in the bagging area' is such a well-known phrase in Britain now that it's a T-shirt slogan!*

Check out a checkout

We look at some of the key features that make these DIY devices so convenient



Alert system
If a problem is detected, the checkout light will flash to alert a supervisor. An audible warning will also sound.

Note reader
Despite their widespread use, note readers are still prone to rejecting notes and coin counters to bouncing change out of the collection tray.

Card reader
Debit/credit card readers are now commonplace and, barring recent network failures, impressively reliable.

Bagging area
A weighing scale linked to a product database verifies the expected weight for each selected item that arrives in the bagging area.

Touchscreen
Barcodes already include the weight of a product. Where this is impossible, customers can select the item (eg fruit), typically on a 38cm (15in) capacitive touchscreen.

Scanner
Checkout scanners are quick and sensitive enough to scan, price and verify an item every three seconds. The barcode scanner can read six sides of a cube simultaneously, so the shopper doesn't have to precisely align the product to the horizontal and vertical readers.

Base unit
The base unit stores a light source to illuminate the barcode, a sensor and a converter/decoder to verify data with the host computer.

Black and white all over

Barcodes were first developed in the US in the late-Forties, but achieved acceptance with the Universal Product Code (UPC) introduced in 1974 for Wrigley's chewing gum. The UK version (known as UPC-A) consists of a strip of black bars and white spaces above a sequence of 12 numbers, the first six defining the manufacturer, five for the product and a final check digit to ensure the code has been scanned correctly. The bars and spaces are merely a machine-friendly representation of the readable UPC number, designed so it can be illuminated, scanned and checked by the till at high speed.

Once the sale is concluded, barcode data is used in a number of different ways, from controlling stock levels to updating loyalty points and creating a profile of each customer's shopping habits for future marketing. Barcodes have not just made shopping quicker and easier but also helped cement supermarkets' dominance over the last few decades.

Stand and deliver?

Supermarkets know only too well the threats self-service checkouts pose, not just from committed fraudsters (who have been known to use counterfeit barcode stickers) but otherwise 'honest' customers, tempted by the control they now have over what used to be handled by a real person. However, there are significant security safeguards in each of the key areas of weighing, bagging and paying, as well as constant monitoring by both human and CCTV eyes, to prevent theft.

When an error is detected (for instance, an item scanned but not bagged), there are both audible and visual warnings to alert both the customer and supervisor. Despite this, research suggests up to a third of all customers have stolen items at self-service tills, using anything from tampering with the scales to bagging without scanning, or simply walking off without paying. Retailers are understandably cagey about revealing exactly how many customers get away with it though.

Welcome to... SCIENCE

Gravity might be invisible, but it affects everything from galaxies to single atoms. Find out how here. Elsewhere learn how the shelf life of certain foods can be extended with radiation, how the Higgs boson was found, plus what happens to the body when we get cross.

LEARN MORE

HOW GRAVITY WORKS

Unravel the mysterious force that formed the stars and keeps our feet on the ground

Of all Isaac Newton's revolutionary discoveries, perhaps none was more ambitious than unravelling the enigma of gravity. In the 1660s, Newton saw an apple fall to the ground and dared to ask, "Why?" Why doesn't the apple drift slowly upward? Why does water always seek the lowest place? Why does the Moon stay in orbit and not catapult into space? In his day, it was a question of near-religious significance.

Instead of meditating on divine mysteries, Newton drew up formulas. His law of universal gravitation, as presented in his 1687 treatise *Principia*, states that every particle of matter in the universe attracts every other particle of matter in the universe with a measurable force called gravity (named for the Latin 'gravitas', or weight). The strength of the gravitational force increases with mass and decreases with distance. In other words, the larger the object, the more gravity it exerts, and the closer you are to the object, the greater the pull.

Here is Newton's brilliantly simple formula for calculating the force of gravity between two objects, where m_1 and m_2 are the masses of the two objects, r is the distance between the two objects' centres of gravity, and G is the universal gravitational constant: $F = G\frac{m_1 m_2}{r^2}$

Perhaps the most surprising thing about Newton's law is its universality. Though it can be difficult to conceive, not only is there a gravitational attraction between the apple and the Earth, but there's also a gravitational attraction between you and the apple. Essentially, any two objects that have mass – whether cosmically huge like a galaxy or infinitely small like an atom – exert a gravitational force on each other.

If that's true, though, why don't we swerve toward the street when a large truck passes, or get pinned to the base of a skyscraper? Because that 'big G' in Newton's equation is actually incredibly small – roughly 6.67×10^{-11} Newtons (square

THE STATS

GRAVITY IN NUMBERS

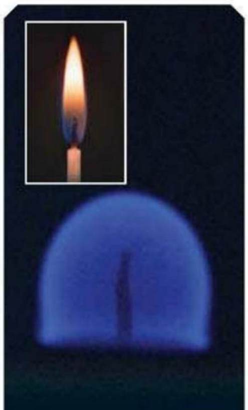
ACCELERATION OF GRAVITY ON EARTH $9.8m/s^2$

GRAVITATIONAL CONSTANT (G) $6.67 \times 10^{-11} Nm^2/kg^2$

TERMINAL VELOCITY OF A SKYDIVER ~60m/s

ACCELERATION OF GRAVITY ON THE SUN $274m/s^2$

DID YOU KNOW? *The value of the universal gravitational constant ('big G') wasn't measured until 70 years after Newton's death*



Microgravity

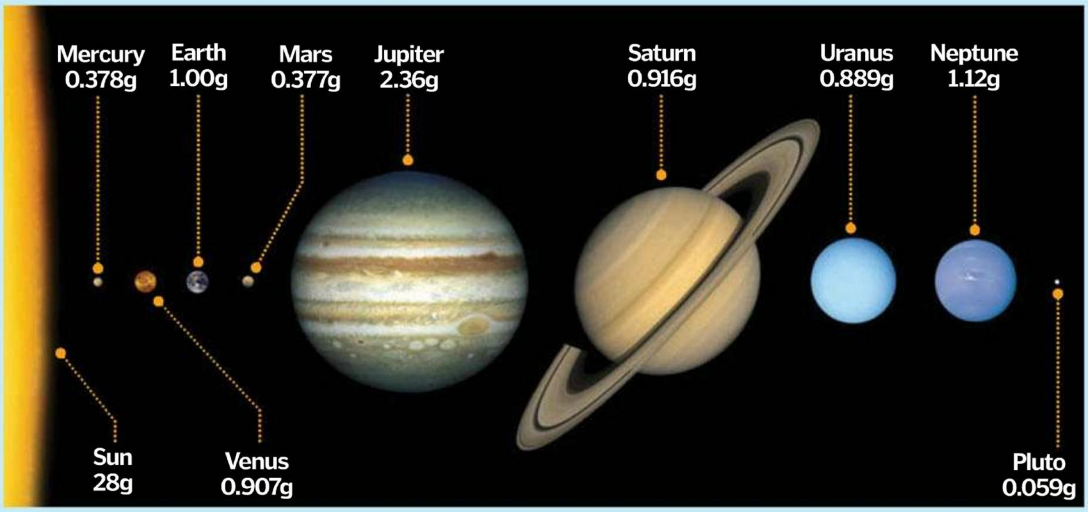
Scientists use the orbiting ISS to conduct experiments in the weakened gravity 370 kilometres (230 miles) above the Earth's surface. In a microgravity environment, flames aren't drawn upward by convection currents. The steady, slow-burning flame of microgravity allows scientists to better understand the process of combustion both on our planet and beyond…

Gravity through the Solar System

As Newton theorised back in the 17th century, every particle of matter exerts a gravitational pull on every other particle of matter. If you concentrate a large amount of matter in one place, it will create a much greater gravitational pull than a loose smattering of particles.

Mass is the measurement of how much matter is in a particular object. The greater the mass, then the more gravitational influence it will possess. Every planet, moon, star and galaxy in the universe has a different mass and therefore generates a unique gravitational pull.

The mass of the Earth pulls a falling object toward the ground at a rate of $9.8m/s^2$ ($32.2ft/s^2$). In contrast, the mass of the Sun is 333,000 times greater than the Earth. As a result, a falling object near the surface of the Sun would be pulled downward at a rate approaching $274m/s^2$ ($899ft/s^2$), 28 times faster than on our planet.



Gravity is the weakest force of nature, which is why a magnet can easily 'defy' it to pick up metal objects below

metres/kilograms); yes, the decimal point is 11 digits to the left. Unless the combined mass of the two objects is very, very large, the force of gravity between them is undetectable.

The Earth qualifies as a very, very large object with a mass of 5.97219×10^{24} kilograms (1.31664×10^{25} pounds). In comparison, your mass (not weight) is probably closer to 70 kilograms (154 pounds). If you plug the Earth's mass into Newton's equation as m_1, your mass as m_2, and then use the radius of Earth for r, you get an answer of 686 Newtons (154.2 pounds force).

That is the gravitational force between you and our planet – in other words, the force that your mass exerts through gravity, aka your weight on the surface of the Earth. If you were to run the same numbers at a jumbo jet's cruising altitude of around 12,200 metres (40,000 feet) above sea level, however, you would actually exert a whole two Newtons less, because there is a greater distance between your centre of gravity and the centre of the Earth. ▶

How orbits work

There are over 900 satellites currently orbiting the Earth. But how do they stay in orbit without any engines? Satellites in orbit don't require power as they're really in controlled freefall. A satellite is launched into space in the nose of a rocket. That rocket must provide enough thrust to escape the surface gravity. Once in space, the satellite is released on a perpendicular trajectory. But instead of flying away from the planet, the satellite 'falls' into an elliptical orbit determined by the long-distance gravitational pull of the planet.

> "Little g is critical because it explains why objects fall to the Earth at a consistent rate"

Thanks to Newton's second law of motion, we know that force equals mass multiplied by acceleration (expressed as f = ma). Using Newton's gravity equation on page 40, we figured out the gravitational force between you and the Earth. Since we know the combined mass of you and the Earth, we can then solve the acceleration of gravity (a = f/m). The answer, $9.8m/s^2$ ($32.2ft/s^2$), is also known as 'little g'. Little g, like big G, is a constant, but it's only a constant for objects on or near the surface of the Earth. This means that little g on, say, the Moon or near the Sun is a whole different story.

Little g is critical because it explains why objects fall to the Earth at a consistent rate, even when they are of wildly different masses. For instance, if you push a BMW Sedan and a bowling ball off the top of the Burj Khalifa hotel in Dubai – currently the tallest building in the world – they will both hit the ground at exactly the same time. The only exceptions are objects with low mass and a lot of surface area, like a feather or a parachute, which float down slowly as the result of upward drag. This wouldn't be the case, however, in an airless environment – for example, a laboratory vacuum or the surface of the Moon – where, believe it or not, the feather and the bowling ball would fall at precisely the same rate.

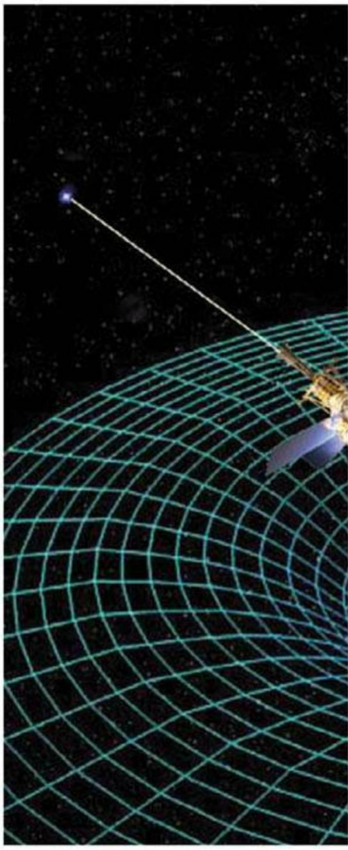
Notice that gravity is the force of attraction between *two* objects; that is, it's a two-way process. Not only are you attracted to Earth with a force of 686 Newtons (154.2 pounds force), but the Earth is attracted to you with an equal force. In fact, if you fall out of a tree and accelerate toward the Earth at $9.8m/s^2$ ($32.2ft/s^2$), the Earth also accelerates towards you. But that's impossible, right? The world doesn't jostle out of orbit every time some klutz tumbles out of a tree. The difference is in the rate of acceleration. If a = f/m and f is 686 Newtons, then the rate of acceleration gets slower and slower as mass gets bigger and bigger. Yes, the Earth technically accelerates towards you and every other falling object, but that rate of acceleration is so tiny – and the Earth's inertia and momentum so great – that no wiggle is remotely detectable.

While Newton's universal law of gravitation gives us the physics to calculate the force and acceleration of gravity just about anywhere in the universe, it doesn't explain what gravity is and how it works at an atomic level.

Albert Einstein took up that challenge with his general theory of relativity, published in the early-20th century, which explained gravity as a curve in the space-time continuum. Beyond our three-dimensional universe, Einstein argues, is a fourth dimension of space and time. Objects with large masses, like planets, can warp the space-time dimension like a bowling ball on a trampoline. If you try to roll a marble across the trampoline, it will be drawn toward the bowling ball. The same is true for planets as they swirl in orbit around a huge celestial body like the Sun, or a cosmic beam of light that bends as it passes a black hole.

But even Einstein's revolutionary theory didn't explain the mechanism at work in gravity. What is it, exactly, that carries this force between two objects? Today, many physicists believe that the gravitational interaction is carried by undetectable, massless particles referred to as gravitons. Others talk of gravitational waves – barely detectable shockwaves of gravitational force created by the collision of neutron stars or the explosion of a supernova.

Despite the limits of our understanding, what began as an apple falling from a tree in the 17th century has led to remarkable insight into the mysterious forces that guide the universe. Gravity, the force that keeps our feet firmly on the ground and dictates global tides with the passing of the Moon, appears to be the same ancient force that bound together primordial cosmic elements to form the first stars and galaxies. If nothing else, it's something to mull over the next time you're falling out of a tree…



What goes up…

A fun way to experience weightlessness on Earth is to leave it momentarily. The flight of this motorbike follows a parabolic curve – the same path flown by NASA aircraft to ready astronauts for zero-gravity

Acceleration
Cruising across flat ground, the bike experiences normal gravity as it reaches a speed of around 104km/h (65mph).

Horizontal to vertical
When the bike hits the 45-degree ramp, it's forced upward against gravity, increasing the gravity force – G force – felt by the rider.

Liftoff
The second the motorbike is airborne, the force of gravity drops to zero, giving the rider a weightless sensation.

True weightlessness
At the top of the parabolic arc, the rider experiences the closest thing to true weightlessness on Earth, minus the drag of air resistance.

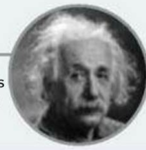
KEY DATES
GRAVITY TIMELINE

1543
Nicolaus Copernicus placed the Sun as the gravitational centre of our Solar System.

1604
Galileo Galilei (right) uses his inclined plane experiments to measure the acceleration of falling objects.

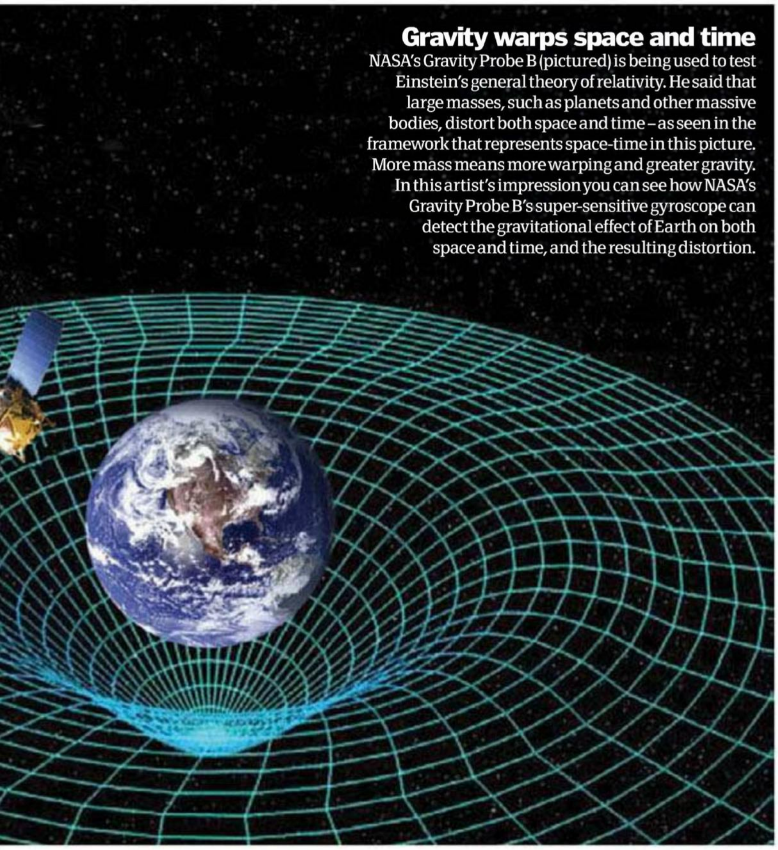
1687
Isaac Newton publishes his *Philosophiae Naturalis Principia Mathematica*, containing the law of universal gravitation.

1915
Albert Einstein (right) publishes his theory of general relativity, which explains gravity as a disturbance in the space-time continuum.

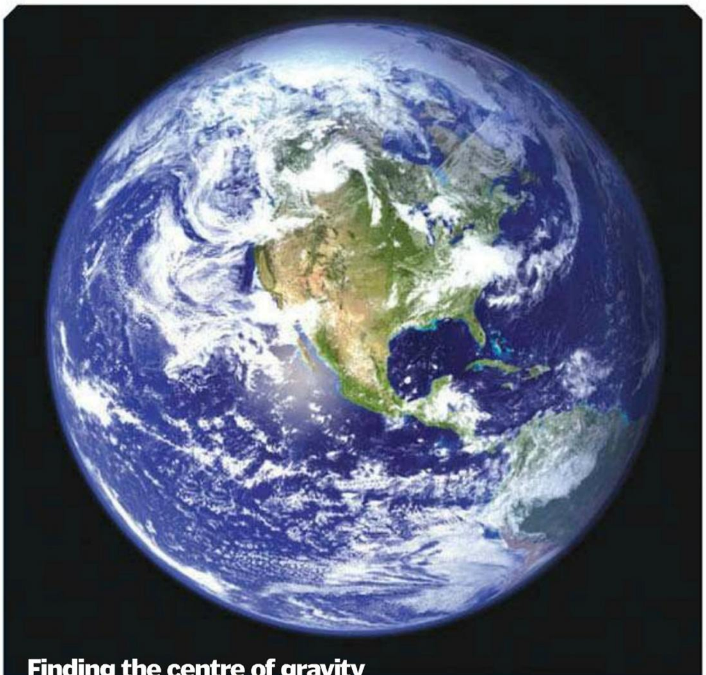


1976
A rocket probe confirms Einstein's theory that gravity slows the passing of time.

DID YOU KNOW? Due to topographical features, the gravity of the Hudson Bay area in Canada is the lowest on Earth



Gravity warps space and time
NASA's Gravity Probe B (pictured) is being used to test Einstein's general theory of relativity. He said that large masses, such as planets and other massive bodies, distort both space and time – as seen in the framework that represents space-time in this picture. More mass means more warping and greater gravity. In this artist's impression you can see how NASA's Gravity Probe B's super-sensitive gyroscope can detect the gravitational effect of Earth on both space and time, and the resulting distortion.

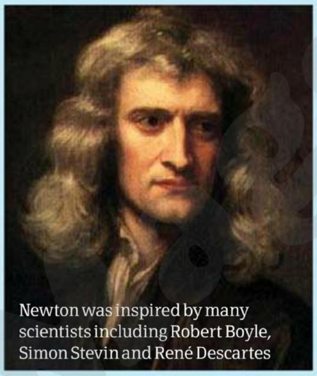


Finding the centre of gravity
To calculate the acceleration of gravity, you need to know the distance between the centres of gravity of object one and object two. But how do you work out these centres of gravity? For a sphere like the Earth, it's easy. The centre of gravity is the exact centre of the sphere. The distance, then, between your centre of gravity and the Earth's centre of gravity is equal to the Earth's radius. For odder shapes like an apple or the human body, the centre of gravity is defined as the average centre of the object's mass. In practice, you can locate the centre of gravity of any object by finding its balancing point.

Coming down
With a take-off speed of 104km/h (65mph), a bike launched from a 45-degree ramp travels 22m (70ft) before gravity pulls it back to Earth.

Landing
On the bike's landing, the rider experiences greater than normal gravity. An inclined landing ramp decreases the G force.

Measuring gravity
Thanks to Newton, gravity is a measurable force. Not coincidentally, the international standard unit of force is called a Newton (N). On Earth's surface, roughly 0.98N equals the downward force of gravity on 100 grams of mass. Likewise, one kilogram of mass exerts a downward force of 9.8N. To calculate the force of gravity, physicists use the formula $f = ma$ (force = mass x acceleration). Since the acceleration of gravity is $9.8m/s^2$ on Earth – ie little g – we can easily calculate the Newton force of any mass. The average person's mass is 70 kilograms, which multiplied by 9.8 gives you 686N – the force by which gravity keeps us all securely grounded.


Newton was inspired by many scientists including Robert Boyle, Simon Stevin and René Descartes

A hammer vs a feather

Newton's law of universal gravitation states that an object with greater mass will exert a greater gravitational force. But force is not the same as acceleration. The question of which object lands first is a matter of acceleration. When you do the maths, you find that every object – regardless of its mass – has the same acceleration of gravity near the Earth's surface. Take a look:

$$a = f/m; \text{ or } a = (m \times 9.8m/s^2)/m; \text{ or } a = 9.8m/s^2$$

The only reason the feather falls slower on Earth is air resistance. In a perfect vacuum like space, in contrast, the feather and the hammer land at precisely the same time.

EARTH'S OXYGEN PRODUCED BY MICROBES	50%	MICROBES IN 1L OF SEAWATER	1bn	MICROBES IN 1G OF SOIL	1bn
SOIL MICROBE TYPES	1mn	EARTH'S BIOMASS THAT IS MICROBIAL	60%	YEARS MICROBES HAVE BEEN ON EARTH	3.8bn

DID YOU KNOW? *With over a million users, SmartWater is currently believed to be protecting in excess of 20 million items*

Preserving food with radiation

How does firing gamma rays at food extend its shelf life?

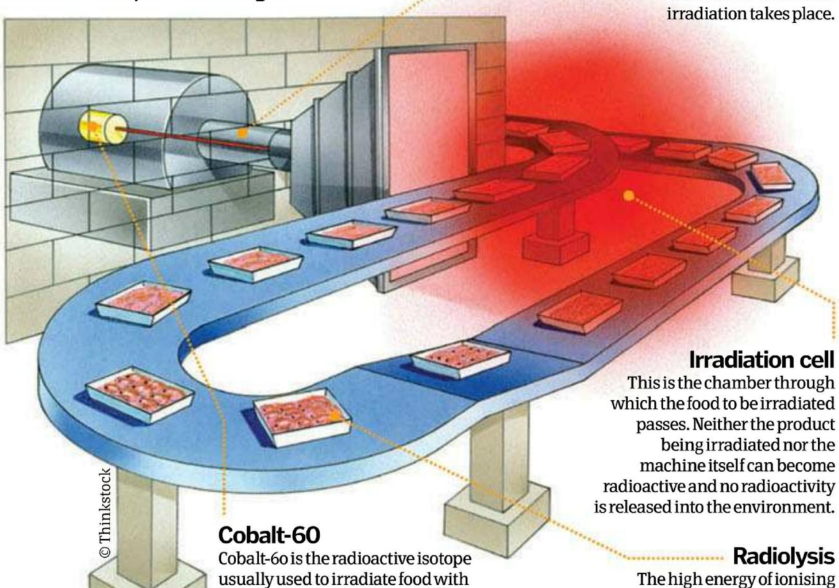
Food irradiation is a form of preservation that involves carefully exposing foodstuffs to ionising radiation for a specific length of time in order to destroy any harmful bugs and pathogens that could be lurking on your fruit and veg.

Ionising radiation is a kind of energy emitted by elements with an unstable electrical charge – either positive or negative. The high-frequency, high-energy waves of gamma radiation can penetrate a variety of different materials, drastically altering their chemical makeup, which is why ionising radiation is dangerous to humans.

Ionisation involves bombarding atoms with radiation such as gamma rays to dislodge the electrons in orbit around the nuclei, which results in the atoms becoming charged, or 'ionised'. The atoms are then called ions. The chemical bonds in ionised bacteria are irreversibly damaged. Once that happens the cell's genetic instructions stop working, which means harmful bacteria can no longer reproduce.

The irradiation process

A closer look at the production line which employs some clever science to make sure our food lasts longer



© Thinkstock

Electron beam
A stream of high-energy electrons is fired out of an electron gun. Machine operators remain behind a thick concrete wall while irradiation takes place.

Irradiation cell
This is the chamber through which the food to be irradiated passes. Neither the product being irradiated nor the machine itself can become radioactive and no radioactivity is released into the environment.

Cobalt-60
Cobalt-60 is the radioactive isotope usually used to irradiate food with gamma rays. This naturally occurring isotope spontaneously decays to its stable state. When not in use it is stored in water, which absorbs the radiation.

Radiolysis
The high energy of ionising radiation striking a microbe breaks the chemical bonds in the bacteria; this process is called radiolysis. When this happens the cell can no longer develop and/or multiply.

What is SmartWater?

The technology that uses chemical signatures to tag and identify our most treasured possessions to deter thieves

Whenever stolen goods are retrieved by the police, determining their rightful owner can be nigh-on impossible. Today, however, SmartWater Technology Ltd uses a chemical solution called SmartWater and forensic science techniques to do exactly this.

SmartWater contains taggants: identifying ingredients that can be cross-referenced like a barcode to establish their source. By 'marking' an item with a unique blend of SmartWater, the owner can then be identified.

The solution consists of a liquid polymer. Polymers are large molecules with repeating chains of smaller units called monomers. And in the same way that your DNA contains polymers that define you,each SmartWater solution contains a unique combination of 24 rare synthetic compounds to make each batch distinct. Retrieved stolen items are scanned with a mass spectrometer, revealing the mass of individual components and ultimately the molecular composition of a sample, which can then be traced to the owner via a database.

SmartWater is resistant to extremes of temperature and sunlight, so it's almost impossible to remove from a marked item

© 3x images courtesy of SmartWater Technologies Ltd

MILESTONES
MARKING MOMENTOUS MOMENTS IN SCIENCE

5 facts: Higgs boson

1 ESSENTIAL TO EVERYTHING
Without the Higgs boson (or an equivalent mechanism), particles would be energy without mass, making it impossible for them to form atoms. Consequently, the universe would be entirely devoid of matter.

2 HIGGS IS BIG
Big by subatomic standards, anyway. CERN scientists reported the suspected Higgs boson was 125.3 gigaelectronvolts (GeV), which is about 133 times heavier than a proton.

3 HOW SURE IS 'PRETTY SURE'?
Particle physicists report certainty in terms of sigma – the likelihood of random chance yielding the same results. CERN scientists put the chance that this was not a new particle at 1 in 550 million, a 5.9-sigma certainty.

4 GONE IN A ZEPTOSECOND
One of the trickiest qualities of the Higgs (if it exists) is that it decays almost immediately. Within a zeptosecond (that's a thousandth of a billionth of a billionth of a second) of appearing, it's gone.

5 DATA OVERLOAD
A single second of LHC activity yields 1,000 terabytes of data – more than all the books in all the world's libraries. The 4 July discovery entailed analysis of more than 300 trillion collisions.

THE DISCOVERY OF THE HIGGS BOSON

In 1964, a bunch of physicists had a wild idea about how the universe works. 48 years and one £2.6bn laboratory later, it looks like they were bang on…

In 1913, Danish physicist Niels Bohr revealed the inner world of the atom: a positively charged nucleus orbited by negatively charged electrons. This only led to more questions, like what was in those particles, and why did they behave the way they did?

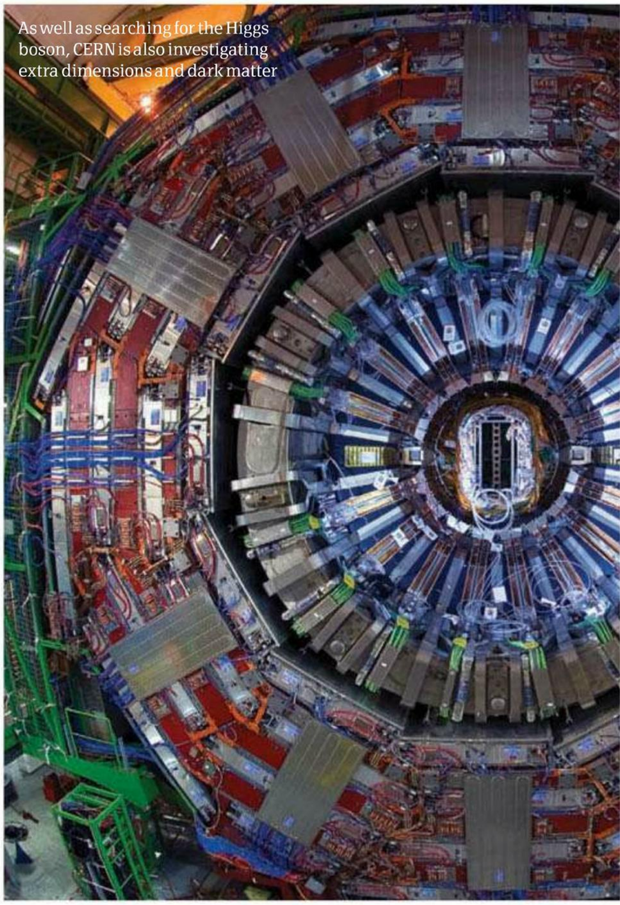
New subatomic particle discoveries, such as the neutron (1932) and the muon (1937), added pieces to the puzzle. By the early-Sixties, the hot game in town was devising a maths-based theory to explain how it all fitted together. But leading theories tripped on a basic question: where does mass come from?

In 1964, three separate groups of physicists arrived at the same answer: particles gain mass by moving through an invisible field, formed less than a second after the Big Bang. In a 1966 follow-up paper, one of the crowd – Scottish physicist Peter Higgs – elaborated on how it all might work. In the Higgs mechanism, the invisible Higgs field imparts mass to particles by way of force-carrying particles called Higgs bosons.

The Higgs mechanism is a cornerstone of the Standard Model, a theory of how fundamental forces work on the subatomic level. To validate the model, physicists needed evidence of the Higgs field – clear detection of a Higgs boson.

Higgs-hunting means rapidly colliding particles together to reproduce the immense amounts of energy that followed the Big Bang. The energy of these collisions transforms into subatomic particles. A Higgs particle is especially tricky to identify as, if it exists, it immediately decays into other particles. The search requires computers to pore over trillions of collisions looking for decay patterns that match the theoretical profile of the Higgs.

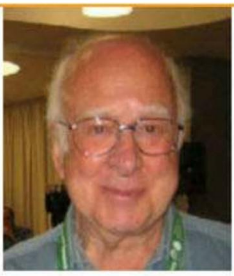
In the Nineties, high-energy collisions in CERN's Large Electron-Positron Collider (LEP) yielded proof of Z and Y bosons – also predicted in the Standard Model – but no conclusive evidence of a Higgs. CERN dismantled the LEP in 2000, and in 2008 replaced it with the more powerful Large Hadron Collider (LHC). On 4 July 2012, physicists reported that the LHC had detected a previously unknown boson that matches the predicted mass and behaviour of the elusive Higgs.


As well as searching for the Higgs boson, CERN is also investigating extra dimensions and dark matter

JOURNEY TO THE HIGGS BOSON

We look at some of the key events on the path to uncovering this tiny particle

1964
Peter Higgs and associates propose the mechanism that suggests such a particle as the Higgs boson could exist.



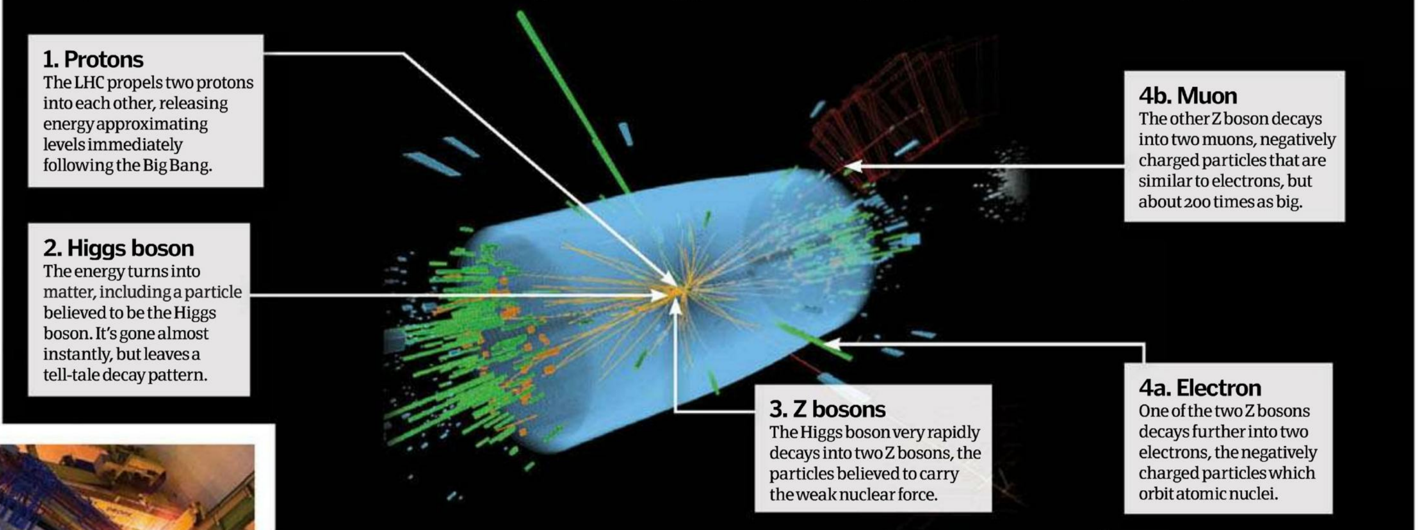
1967
The Higgs mechanism is shown to be compatible with the electroweak theory and therefore the Standard Model of physics.

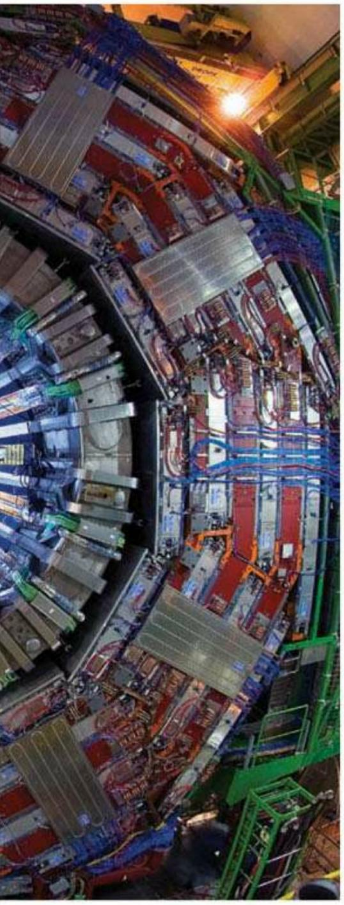
1971
The world's first particle accelerator – the Intersecting Storage Rings (ISR) – is built at CERN, Switzerland. However it's not advanced enough to observe Higgs-scale events.

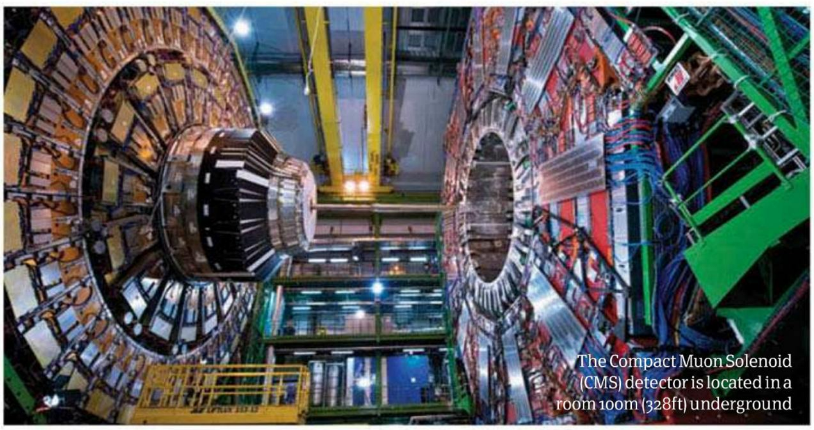
1989
The Large Electron-Positron Collider (LEP) is built. It eventually generates data which hints that a Higgs-like particle had been observed with a mass of 115GeV.

Particle collision step-by-step

This is a proton collision recorded by the CMS detector in May 2012. One of many events analysed in the Higgs hunt, the collision showed the results of a possible Higgs boson decaying into other subatomic particles






The Compact Muon Solenoid (CMS) detector is located in a room 100m (328ft) underground

The 'God particle'

In the fervour around the search for the Higgs, this 'God particle' nickname got the public's attention, but journalists soon realised it's best not used near physicists…

The name comes from the title of a 1993 book on particle physics co-authored by the Nobel Prize-winning physicist Leon Lederman. Lederman says the working title was *The Goddamn Particle*, a reference to the frustrating effort to find the missing piece. His publisher proposed the more polite alternative, and Lederman saw the name as a metaphor: the particle helps us simplify our understanding of the universe.

Like many physicists, Peter Higgs is embarrassed by the term. In an interview with *The Guardian* newspaper, he explained that, while he's not a believer himself, he sees the name as a potentially offensive misuse of the concept of 'God'. The particle is not an ultimate creator and its existence has no inherent religious implications.

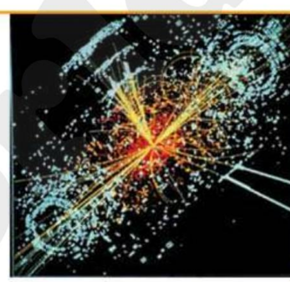
The future of Higgs?

Physicists have no specific applications or objectives in mind for the Higgs. Their only goal has been to understand the universe better. The Higgs may usher in a new era of discovery, however. Future observations could help scientists identify or predict additional particles and phenomena, including extra dimensions and the nature of dark matter. In 2013, the LHC will shut down for a major equipment upgrade, nearly doubling the energy of its collisions… and possibly showing us something completely unexpected.

2008
The Large Hadron Collider (LHC) is finished, becoming the world's highest-energy particle accelerator. It resumes the search for the Higgs boson.

2010
The six original authors of the 1964 papers receive the JJ Sakurai Prize for Theoretical Particle Physics.

2011
CERN reports that if the Higgs boson exists it is most likely to have a mass constrained to the range of 115-130GeV.



2012
Two teams at the LHC independently confirm they have found an unknown boson whose behaviour is consistent with the Higgs. The boson has a statistical probability of 5.9 sigma – 0.9 over the formal level required to announce a new particle discovery.

"As anger is controlled by the emotional part of the brain an angry person can lose control"

What makes you get angry?

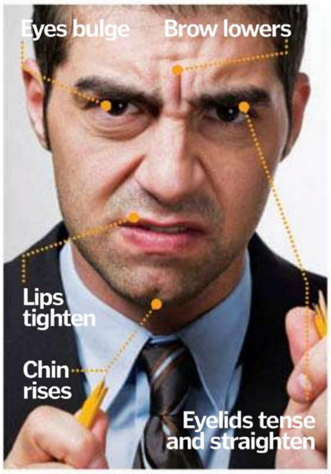
Learn what happens when someone loses it…

Anger is one of the six universal emotions experienced by humans – the others being happiness, fear sadness, disgust and surprise. Our emotions are the largely unconscious physical responses we have to stimuli.

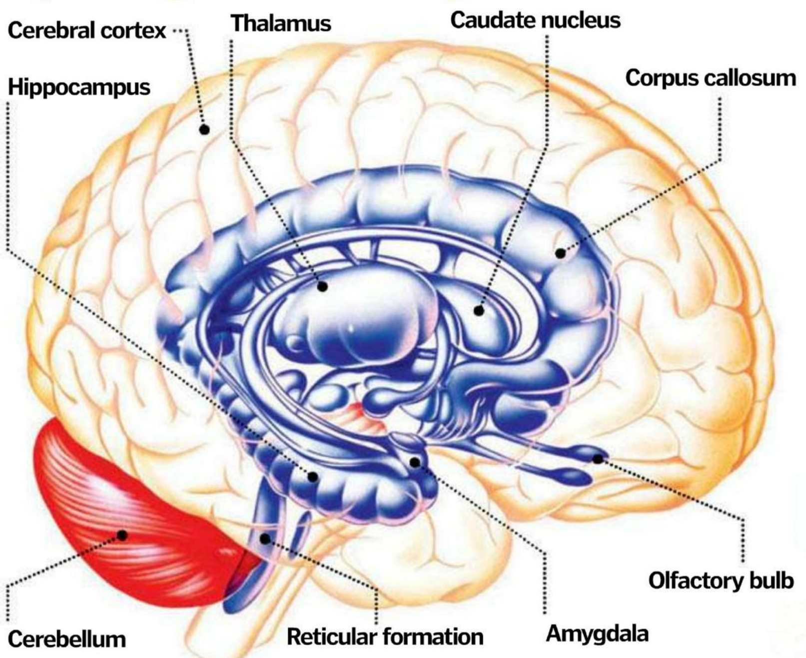
While we use the cerebral cortex in the brain to think logically and make judgements, anger is controlled by the limbic system, a group of structures buried lower down in the primitive regions of the brain. A sophisticated network of nerve pathways controls instinct and governs such emotions as fear and rage. We get angry to protect ourselves from danger if something threatens us, our belongings or anyone that we care about.

Within the limbic system is the amygdala, a structure in which we store our emotional memories. Anger is a primitive form of self-preservation and it's the limbic system that invokes our natural instincts such as the fight-or-flight response to fear. When a stimulus triggers the amygdala, a flood of hormones – such as adrenaline – is produced automatically to warn the body to prepare for action. Because anger is controlled by the emotional centre of the brain – rather than the 'thinking' part – an angry person can temporarily lose control of their actions as well as the things they say. This is why we often refer to someone as 'losing it' when they get really mad.

We exhibit anger in a variety of ways, including facial expressions, raising of the voice and more aggressive behaviour. We communicate this emotion for others to read and respond to.



Exploring the limbic system



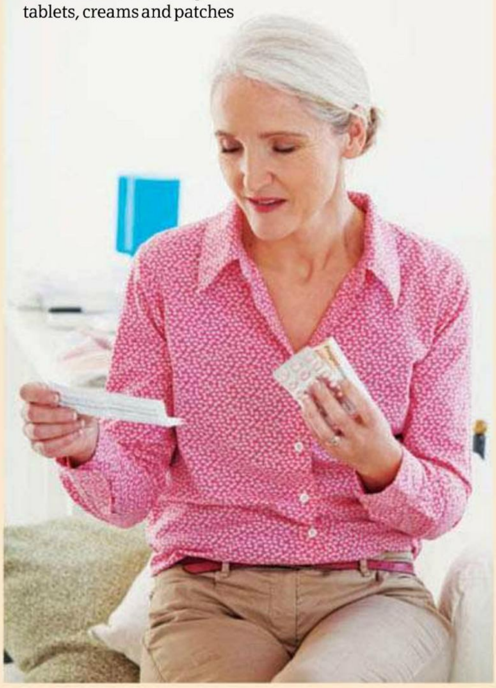
Understanding the menopause and HRT

How does HRT help women going through 'the change'?

As a woman gets older her reproductive system becomes less and less responsive to hormonal stimulation. Over a period of time, known as the menopause, she will produce less and less oestrogen, which eventually stops her four-weekly ovulation cycle. The menopause can last several years with the last period usually occurring around the age of 51 in developed countries.

Menopause reduces the levels of two significant hormones produced in a woman's ovaries: oestrogen and progesterone. Oestrogen helps to regulate things like bone density and body temperature. Therefore, a reduction in oestrogen can cause thinning of the bones (known as osteoporosis) and hot flushes. Progesterone, meanwhile, is key to the health of the womb and preparing a woman's body for pregnancy, and a lack of progesterone in the system generally increases a woman's risk of endometrial (womb) cancer.

To counteract falling hormone levels – including oestrogen and progesterone – HRT can supplement the body's natural hormones with synthetic ones either in the form of pills, creams or transdermal skin patches impregnated with hormones.


HRT is administered in several forms including tablets, creams and patches

Frequent exposure
1 We are exposed to free radicals in the environment every day – alcohol, tobacco smoke, household chemicals and even radiation from the Sun all contain radicals.

Take it easy
2 Although exercise is extremely beneficial for the body in many respects, lots of strenuous activity can actually increase production of these harmful molecules, so don't overdo it!

Eat your fruit and veg
3 Research has shown that eating a varied diet with plenty of fruit and vegetables helps your body fight against the effects of free radicals – generally limiting the damage they can cause.

What's the charge?
4 Free radicals can have positive, negative or zero charge, hence why they bond with other molecules. As a result they can affect our cells in different ways.

Free as a bird
5 The reason 'free' often precedes 'radical' is because the reactive molecules will float freely until they find another molecule to exchange electrons – which is when they start causing damage.

DID YOU KNOW? *Berries are some of the best food you can eat to keep free radicals in the body in check*

What are free radicals?

Often blamed for ageing, and even serious illnesses such as cancer, what exactly are these atoms and how do they affect the human body?

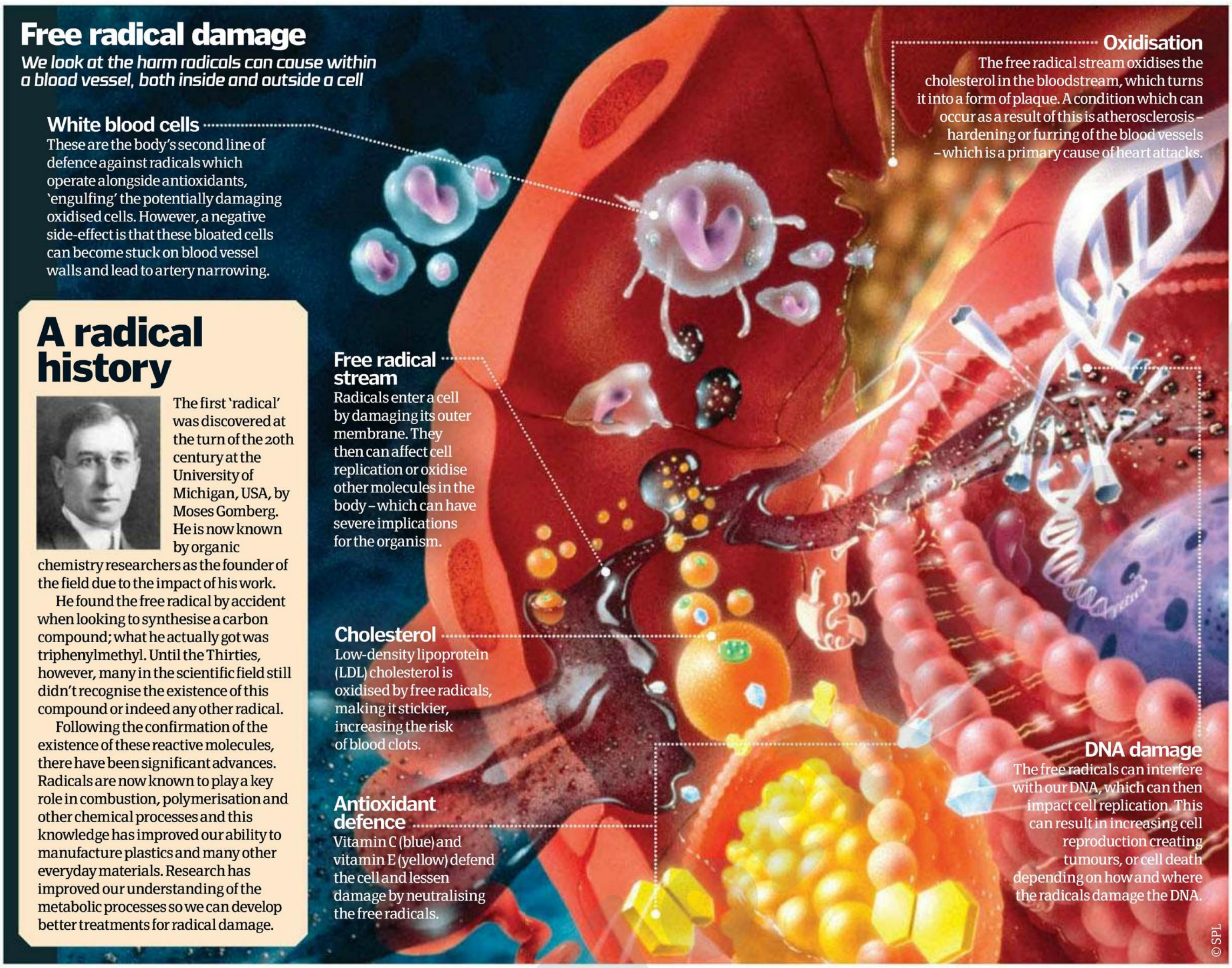
Free radicals – also known simply as radicals – are singular atoms, or a group of atoms, with an odd number of electrons. As they have an uneven number of electrons, they are consequently unstable. To stabilise themselves, they constantly look to react with other molecules either by stealing an electron, donating an electron, or just merging with the molecule entirely.

In the human body this can often cause damage or even cell death, which affects major functions. Consequently the body has to defend itself against these molecules to limit potential damage, and it does so using antioxidants – which neutralise the free radicals – as well as the natural immune system. Typical antioxidants are vitamins, which often must be sourced through diet as the body can't synthesise them; this is one of the major reasons why daily consumption of fruit and vegetables is so important. Berries, grapes, kale, sweetcorn and beetroot are just a few of the antioxidant-rich foods we can eat.

No human can avoid free radicals no matter what their lifestyle as they are a natural result of cell metabolism. Radicals, such as superoxide, are present within the body as they and their by-products play an important role in a number of biological processes we couldn't live without.

There is a leading school of thought that posits free radicals are a key contributor to ageing. This theory states that damage caused by free radicals stealing electrons from other cells accumulates over time and reduces cell function, causing the overall organ to grow less efficient.

Free radical damage has also been associated with more serious ailments like strokes, heart disease and cancer and there's evidence that cognitive diseases such as Parkinson's and Alzheimer's may be exacerbated by radicals.



A radical history

The first 'radical' was discovered at the turn of the 20th century at the University of Michigan, USA, by Moses Gomberg. He is now known by organic chemistry researchers as the founder of the field due to the impact of his work.

He found the free radical by accident when looking to synthesise a carbon compound; what he actually got was triphenylmethyl. Until the Thirties, however, many in the scientific field still didn't recognise the existence of this compound or indeed any other radical.

Following the confirmation of the existence of these reactive molecules, there have been significant advances. Radicals are now known to play a key role in combustion, polymerisation and other chemical processes and this knowledge has improved our ability to manufacture plastics and many other everyday materials. Research has improved our understanding of the metabolic processes so we can develop better treatments for radical damage.

SIZE **7.6 x 12.7 x 2.5cm** WEIGHT **200g**

TOTAL RED PULP 75% TOTAL WHITE PULP **25%** PERCENTAGE OF CARDIAC OUTPUT IT RECEIVES ~5%

DID YOU KNOW? *Around 15 per cent of us have an extra spleen – a small sphere close to but separate from the principal organ*

How the spleen works

Perhaps not as well known as famous organs like the heart, the spleen serves vital functions that help keep us healthy

The spleen's main functions are to remove old blood cells and fight off infection. Red blood cells have an average life span of 120 days. Most are created from the marrow of long bones, such as the femur. When they're old, it's the spleen's job to identify them, filter them out and then break them down. The smaller particles are then sent back into the bloodstream, and either recycled or excreted from other parts of the body. This takes place in the 'red pulp', which are blood vessel-rich areas of the spleen that make up about three-quarters of its structure.

The remainder is called 'white pulp', which are areas filled with different types of immune cell (such as lymphocytes). They filter out and destroy foreign pathogens, which have invaded the body and are circulating in the blood. The white pulp breaks them down into smaller, harmless particles.

The spleen is surrounded by a thin, fragile capsule and so is prone to injury. It sits beneath the lower ribs on the left-hand side of your body, which affords it some protection, but car crashes, major sports impacts and knife wounds can all rupture the organ. In the most serious cases, blood loss can endanger the person's life, and in these situations it needs to be removed by a surgeon. Since this reduces the body's ability to fight infections, some people will need to take antibiotics to boost their immunity for the rest of their lives.

The immune system

Although the red blood that flows through our bodies gets all the glory, the transparent lymphatic fluid is equally important. It has its own body-wide network which follows blood vessel flow closely and allows for the transport of digested fats, immune cells and more…

Spleen
One of the master co-ordinators that staves off infections and filters old red blood cells. It contains numerous lymphocytes that recognise and destroy invading pathogens present in the blood as it flows through the spleen.

Thymus
A small organ that sits just above the heart and behind the sternum. It teaches T-lymphocytes to identify and destroy specific foreign bodies. Its development is directly related to hormones in the body so it's only present until puberty ends; adults don't need one.

Tonsils
These are masses of lymphoid tissue at the back of the throat and can be seen when the mouth is wide open. They form the first line of defence against inhaled foreign pathogens, although they can become infected themselves, causing tonsillitis.

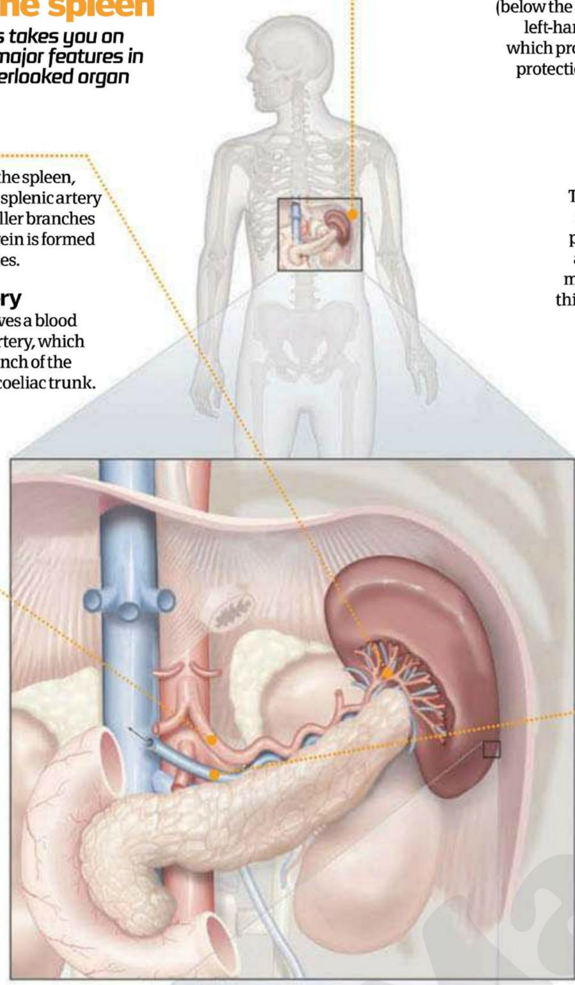
Adenoids
These are part of the tonsillar system that are only present in children up until the age of five; in adults they have disappeared. They add an extra layer of defence in our early years.

Bone marrow
This forms the central, flexible part of our long bones (eg femur). Bone marrow is essential as it produces our key circulating cells, including red blood cells, white blood cells and platelets. The white blood cells mature into different types (eg lymphocytes and neutrophils), which serve as the basis of the human immune system.

Lymph nodes
These are small (about 1cm/0.4in) spherical nodes that are packed with macrophages and lymphocytes to defend against foreign agents. These are often linked in chains and are prevalent around the head, neck, axillae (armpits) and groin.

Inside the spleen

How It Works takes you on a tour of the major features in this often-overlooked organ



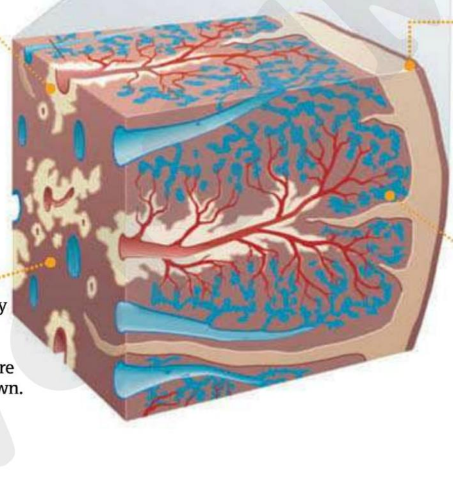
Location
The spleen sits underneath the 9th, 10th and 11th ribs (below the diaphragm) on the left-hand side of the body, which provides it with some protection against knocks.

Hilum
The entrance to the spleen, this is where the splenic artery divides into smaller branches and the splenic vein is formed from its tributaries.

Splenic vein
The waste products from filtration and pathogen digestion are returned to the main circulation via this vein for disposal.

Splenic artery
The spleen receives a blood supply via this artery, which arises from a branch of the aorta called the coeliac trunk.

© Alamy



White pulp
Making up roughly a quarter of the spleen, the white pulp is where white blood cells identify and destroy invading pathogens.

Splenic capsule
The capsule provides some protection, but it's thin and relatively weak. Strong blows or knife wounds can easily rupture it and lead to life-threatening bleeding.

Red pulp
Forming approximately three-quarters of the spleen, the red pulp is where red blood cells are filtered and broken down.

Sinusoid
Similar to those found in the liver, these capillaries allow for the easy passage of large cells into the splenic tissue for processing.

"The intensity of the core's fission events is directly related to the intensity of its Cherenkov radiation"

EXPLORE A NUCLEAR REACTOR'S CORE

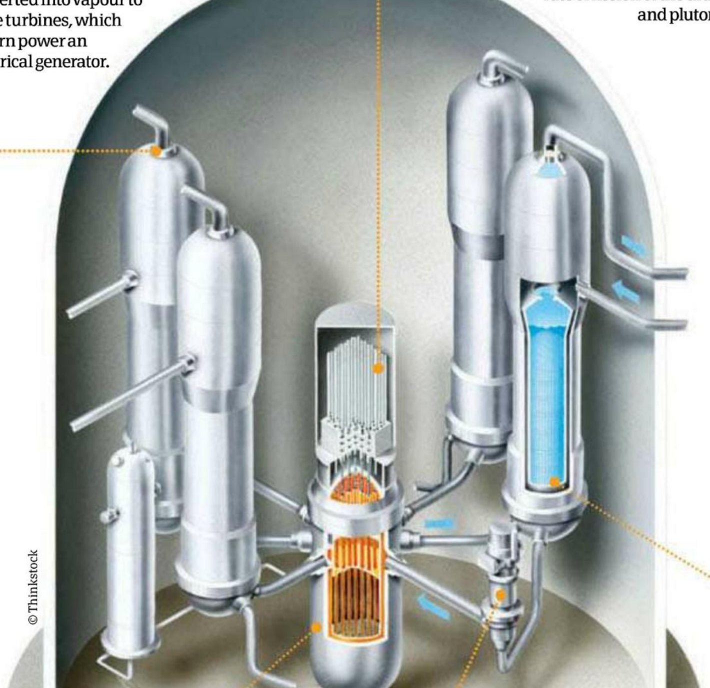
What goes on within the core and why does it glow?

This image shows a nuclear reactor's core surrounded by Cherenkov radiation. Cherenkov radiation is a unique phenomenon where electromagnetic charged particles – such as electrons – emitted from a nuclear reactor's core travel faster through its coolant (pressurised water) than the phase velocity of light. This process causes the particles to polarise the water molecules, which then proceed to rapidly descend back to their ground state, expelling photons – hence the perceived blue-white illumination – and intensifying observed radiation levels. As such, the intensity of the core's fission events is directly related to the intensity of its generated Cherenkov radiation.

For a closer inspection of a core's main features and processes, check out the 'Inside a nuclear reactor' boxout below.

Inside a nuclear reactor

What are the main components?



HEAD 2 HEAD
NUCLEAR POWER PLANTS

1. BIG


© Chuck Szmurlo

Bruce Nuclear Generating Station

With a net capacity of 4,748 megawatts, it outputs over 36,180 gigawatt-hours of energy a year in Canada.

2. BIGGER


© Douche Quentin

Gravelines Nuclear Power Station

With a 5,460-megawatt net capacity, it outputs over 36,625 gigawatt-hours of energy a year in France.

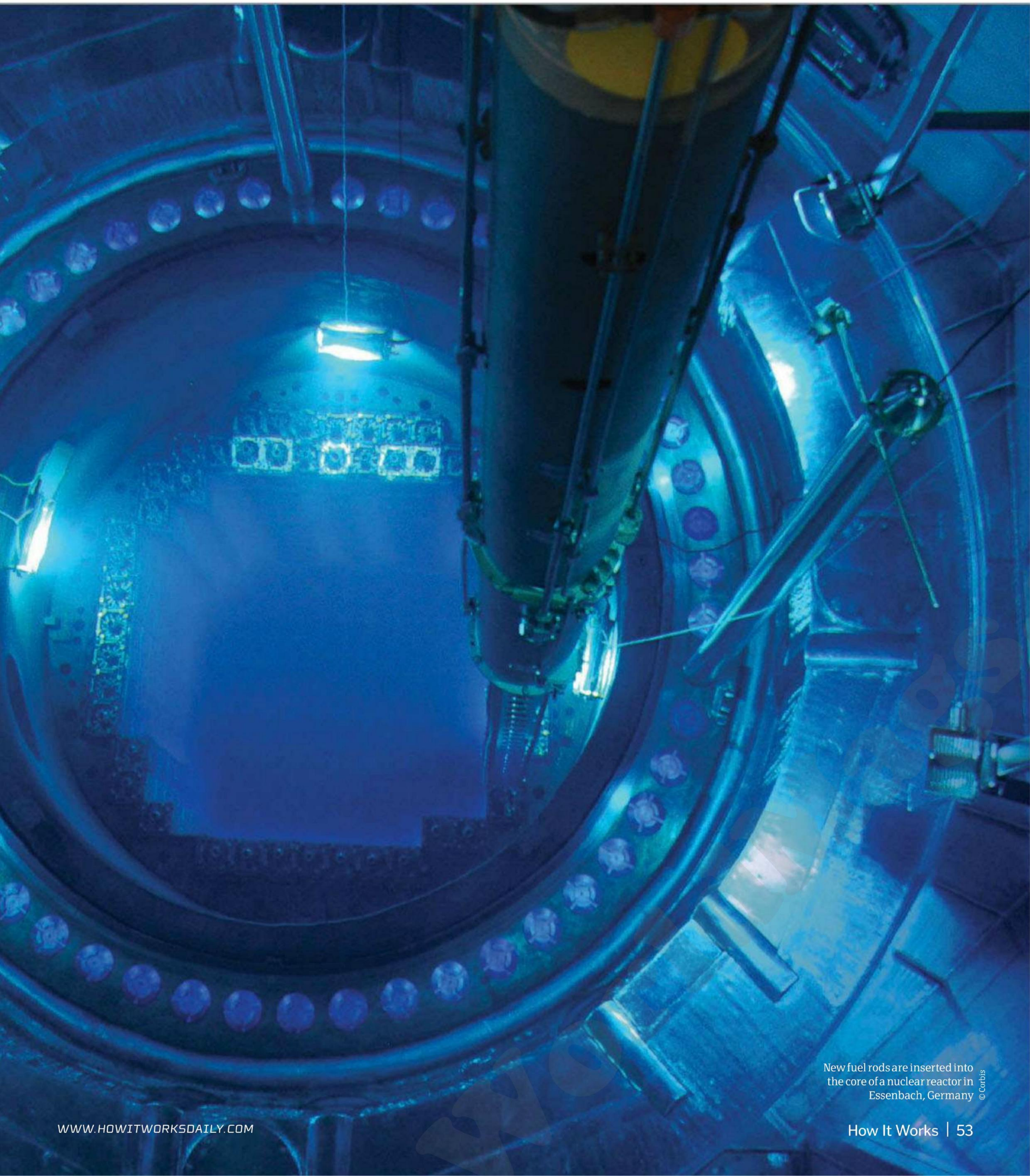
3. BIGGEST


© Daisuke Yamagishi

Kashiwazaki-Kariwa

Located in Niigata, Japan, this has a net capacity of 7,965 megawatts and outputs 50,790 gigawatt-hours of energy each year.

DID YOU KNOW? *Nuclear power plants currently supply 14 per cent of the world's electricity*



New fuel rods are inserted into the core of a nuclear reactor in Essenbach, Germany © Corbis categories explained: Exploration | Solar System | The universe | Astronomy | General

Welcome to... SPACE

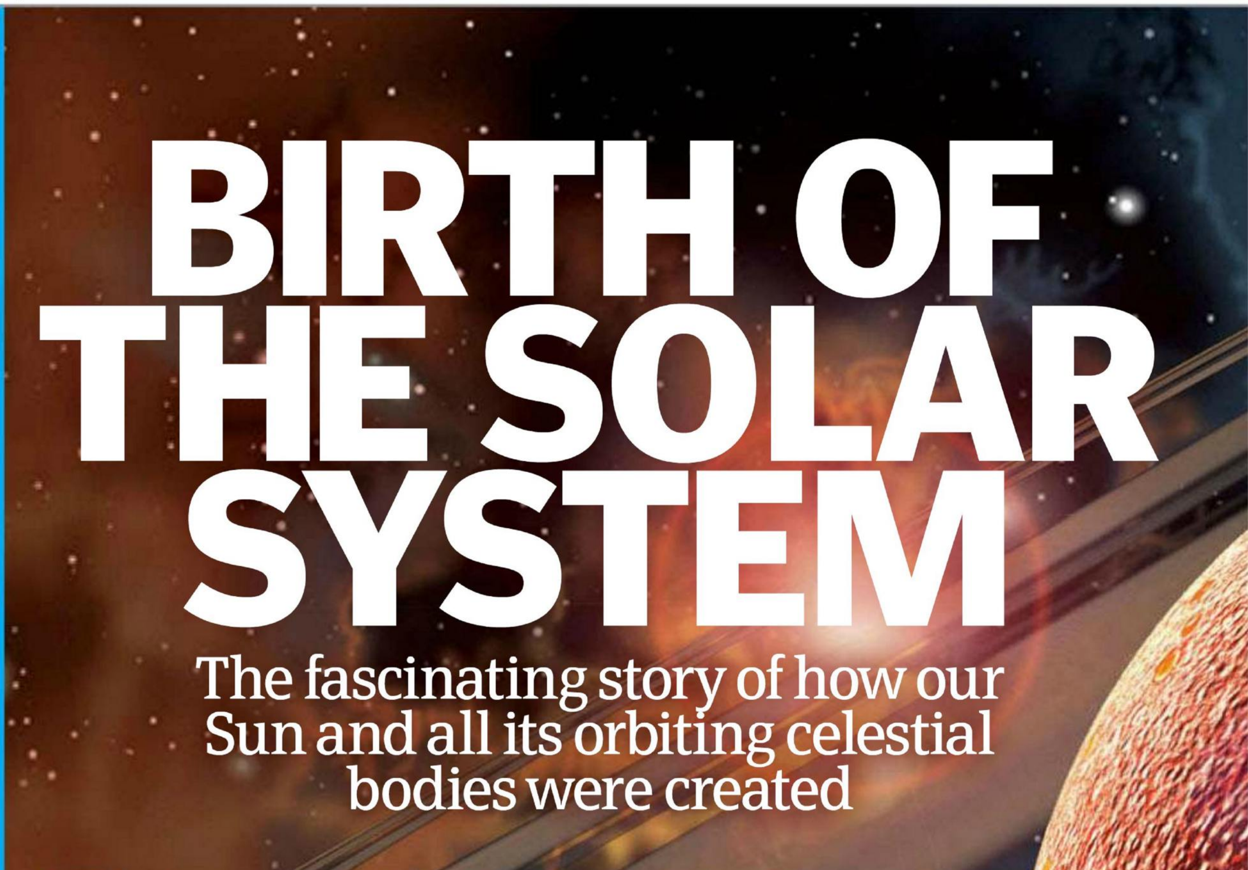
It can be difficult to imagine a time when Earth, the Sun and the rest of our Solar System didn't exist, but here we're going way back to reveal how it all began and what the future may hold. Also learn how cleanrooms are kept spotless and why NASA is firing metal balls at its own space shuttles.

59 Cleanrooms

63 Helix Nebula

64 LSST

LEARN MORE



BIRTH OF THE SOLAR SYSTEM

The fascinating story of how our Sun and all its orbiting celestial bodies were created

Until 500 years ago, the Earth was at the centre of the universe and had been since the dawn of time. Orbiting the Earth was the Sun, Moon, stars and planets of Mars, Mercury, Venus, Jupiter and Saturn. Then, in the 16th-17th centuries, the three astronomers Copernicus, Kepler and Galileo turned two millennia of scientific belief on its head with the theory of heliocentrism – the idea that the Earth and planets revolve around the Sun: in other words, the Solar System. The notion was vehemently opposed by the Church until the 18th century, when a growing number of prominent members of society began to question conventional wisdom. It allowed French scientist Pièrre-Simon Laplace to formulate one of the first origin of the Solar System theories that had a hard scientific basis. His Nebular Hypothesis first appeared in his 1796 book *Exposition Of A World System*, which suggested that the Solar System was originally a spinning cloud of gas that condensed to form the Sun and the planets – not exactly light years from the way most astronomers believe the Solar System came to be today.

20th-century physics and mathematics allowed for more cohesive theories as to the origins of the planets, but one idea they all had in common was that their creation started with a nebula. In the wake of Edwin Hubble's discovery that the Milky Way was just one of many galaxies in the cosmos, the Accretion Theory was proposed. Soviet astronomer Otto Schmidt suggested that the Sun in its present form had moved through a cloud of stellar particles and emerged on the other side surrounded by an envelope of gaseous dust. The Accretion Theory was modified by Raymond Lyttleton in 1961, but it still couldn't explain how the planets were formed from this material to everyone's satisfaction. Other explanations were put forward, including McCrea's Protoplanet Theory, in which a nebula collapsed and dust particles gathered to form protoplanets, and Capture Theory, where material from a protostar was captured by the Sun and eventually collapsed to create planets.

Although no origin of the Solar System theory is a certainty, it's Laplace's model that prevails today, albeit in a modified form. Modern Laplacian Theory kicks off with an ancient supernova, 5 billion years ago, which threw out a spectrum of elements and gas that collided with a hydrogen and helium nebula, seeding our embryonic Solar System. We can see this happening in other parts of our galaxy and beyond.

This cloud of material that included nitrogen, oxygen, iron and silica (all components vital for building an Earth-like planet) rotated slowly at first, but – under the force of its own gravity – gathered towards a central point, spinning faster and faster according to centripetal acceleration (the same force that causes a pirouetting ballerina to spin more rapidly when pulling their arms into the body). A denser cloud meant motes of dust could more easily coalesce to form small clumps that, in turn, grouped together over millions of years to form an enormous body at the centre – a protostar. The protostar was cold enough to collapse under its increasing mass and, as it did, a nuclear chain reaction was triggered that ignited it into a star similar to the Sun we know today.

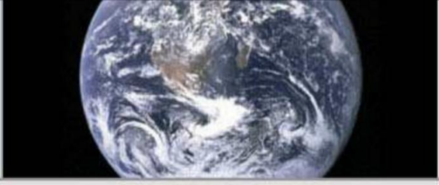
But what of the planets? How did they form and why does each differ so much? It's hard to believe that ▶

STRANGE BUT TRUE

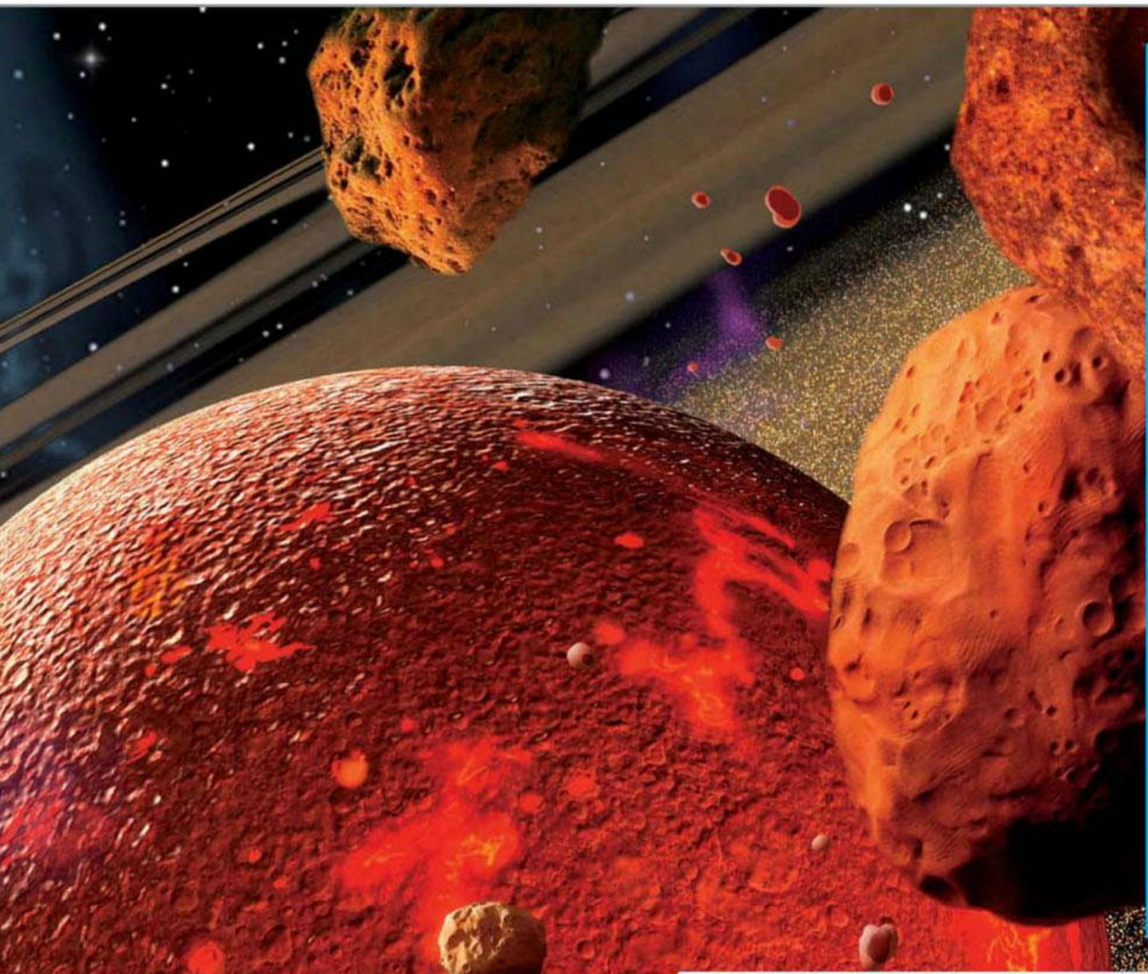
IRON-RICH EARTH

IRON IS EXTREMELY RARE

The metal iron is the fourth-most abundant element found on our planet, forming nearly 15 per cent of Earth; indeed, it makes up nearly 80 per cent of the core. Yet surprisingly, iron comprises only a shade over 0.1 per cent of the Solar System.



DID YOU KNOW? *In billions of years our Sun will become a black dwarf, which is a white dwarf that's lost all its heat*



Planets on the move

The position of each of the planets is no mere coincidence. The gravity of the growing planets within the gaseous disc that formed around the new Sun in the early Solar System perturbed the gas around them, either removing or adding angular momentum. The lower-mass terrestrial planets experienced a lower rate of migration than the four massive Jovian planets in the outer Solar System, although only very rarely does migration cause a planet to move outward rather than inward. Planetary migration is also affected by the gravity of other celestial bodies (like Saturn's influence on Jupiter) as well as heavy asteroid bombardment in the first billion or so years of Earth's existence.

How the planets arrived at their current locations isn't known for certain, but it's probable that the terrestrial planets of Mercury, Venus, Earth and Mars migrated inward to their current positions in the inner Solar System, while the Jovian giants led a more complicated dance, moving inward from ice-forming regions and then back out again. It explains why the Asteroid Belt contains both bone-dry and water-ice objects. It's certain too that while the planets are stable in their current configuration, an ageing Sun and a collision with the nearby Andromeda galaxy billions of years from now will see planetary orbits change and, in all likelihood, Earth's ejection from the Solar System.

What is the Kuiper Belt?

In 1992, the Kuiper Belt was discovered. Similar in form to the Asteroid Belt, it's around 4.5-7.5 billion kilometres (2.8-4.6 billion miles) from the Sun, is 20 times wider and contains up to 200 times more mass. Where the Asteroid Belt is composed of small rocky minerals and metals, the Kuiper Belt is made up mostly of chunks of frozen methane, ammonia and water ice. It's a remnant of the early Solar System and space scientists suspect some comets originate from here. Two moons – Saturn's Phoebe and Neptune's Triton – are also suspected to have been planetesimals from the Kuiper Belt. After Pluto was declassified to a dwarf planet in 2006, it became the largest-known feature of the Kuiper Belt, although it was only the second biggest dwarf planet after icy Eris, which is 27 per cent larger than Pluto.

"It's hard to believe that these massive celestial bodies were originally nothing but gaseous dust"

these massive celestial bodies were originally nothing but gaseous dust, but this is believed to be the case.

As the protostar collapsed and its angular rotational speed increased, what was left of the dust concentrated around the equatorial region to form a circumstellar disc. When the protostar went nuclear to become our Sun, an enormous blast of solar wind spread the dust evenly across over 6 billion kilometres (3.7 billion miles) of space.

The inner planets of the Solar System (Mercury, Venus, Earth and Mars) were all formed from the material that spread across the first 400 million kilometres (250 million miles). At this range it was too hot for molecules like water and methane to condense, so only heavier minerals and metals like iron and nickel clumped together. Like the protostar that became the Sun, they bound as motes of dust before forming larger rocks and, over millennia, developed into planetesimals – the seeds that would become the first four rocky planets from the Sun. Because of the scarcity of these heavier elements (ie hydrogen, helium and oxygen make up 99 per cent of the Milky Way compared to iron's 0.1 per cent), these planets could not grow very large compared to the four outer planets, which total 99 per cent of the planetary mass orbiting the Sun.

Between the inner and outer Solar System lies a vast strip of asteroids that was once believed to be a single planet that inhabited the orbital region between Mars and Jupiter, smashed apart by a colossal collision. At least, there seemed to be enough rocky mass to support the theory when German astronomer Heinrich Olbers proposed this idea in 1802. But since then, scientists have discovered not only that the Asteroid Belt would form a body only four per cent the size of Earth's Moon, but that the differing chemical compositions of the asteroids indicate they never came from a single body. Today, it's thought that the Asteroid Belt is simply a remnant of the original coalescing nebula, which was prevented from forming a planet by the mighty pull of nearby Jupiter's gravity.

Past the Asteroid Belt is the frost line. Here, at about 523 million kilometres (325 million miles) from the Sun and beyond, temperatures plummet to -120 degrees Celsius (-184 degrees Fahrenheit) – cold enough for gaseous compounds to solidify. There were enough of these volatile compounds to form giants Jupiter, Saturn, Uranus and Neptune. They grew massive enough to capture the lightest elements of helium and hydrogen, with Jupiter and Saturn taking the lion's share. By the time Uranus and Neptune had grown enough to hold onto the nebular gas, Jupiter and Saturn had claimed most of it.

We'll give an honourable mention to Pluto because for 76 years from the point of its discovery, it was considered a planet. However, due to finding many other similar-sized bodies orbiting the Sun – including the distant and super-icy Eris – it was reclassified as a dwarf planet. It's been suggested that Pluto was once an escaped moon of Neptune that was knocked out of its previous orbit by Triton, Neptune's current largest moon. It's now believed to be a member of the Kuiper Belt, which is similar in origin to the Asteroid Belt, only much bigger and located at the very fringes of the Solar System.

The Solar System in the making…

1 Giant molecular cloud A giant body of nebular particles begins to group together and, over time, forms larger and larger clumps.

2 Sun formation The Sun forms from these clumps and throws off a massive coronal ejection that helps seed the planets.

Going for a spin

In astronomy, angular momentum is the amount of spin or orbital motion any celestial object possesses. It's calculated through multiplying mass by velocity by the distance from the object that celestial body is spinning around. It's a vitally important component of understanding the formation of our Solar System, because angular momentum dictated the initial spin of the molecular cloud that created the Sun and all of the planets. Thus, it played a major role in the initial distribution of the planets, their orbits and axial rotation. Ultimately, it had a huge hand in the form life took here on Earth.

Solar System timeline

4.59 billion years ago
The Solar System forms as the Sun goes nuclear

4.3 billion years ago
Earth's satellite, the Moon, forms

2 billion years ago
Complex cellular life appears on Earth

Now 2012
Humans are the dominant species on our planet

1.5 billion years' time
The Sun expands; Earth is now uninhabitable

DID YOU KNOW? It's believed our Moon most likely formed from a massive collision between Earth and another celestial body

3 The inner planets

Mercury, Venus, Earth and Mars – the iron and nickel terrestrial planets closest to the Sun – steadily gain mass as they're bombarded by meteorites.

4 The outer planets

Jupiter, Saturn, Uranus and Neptune are among the first planets to form, amassing enough material to achieve gravities that attract the light gases like helium and hydrogen abundant in the early Solar System.

5 Planetary migration

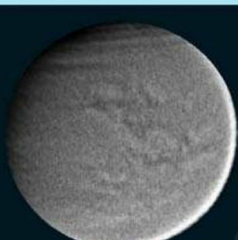
The planets move around a great deal on the same plane – Jupiter in particular, which migrated across what's now the Asteroid Belt before settling in its current position.

6 Today

This is a relatively calm period in the history of the Solar System, but over the billions of years to come, planets will either be consumed by a growing Sun or ejected from the Solar System.

4.8 **billion years' time**
The Sun becomes a red giant

6.5 **billion years' time**
Saturn's moon Titan becomes habitable



10 **billion years' time**
The Sun sheds its outer gaseous layers

13 **billion years' time**
The Sun becomes a white dwarf

15 **billion years' time**
Life in the Solar System is now impossible

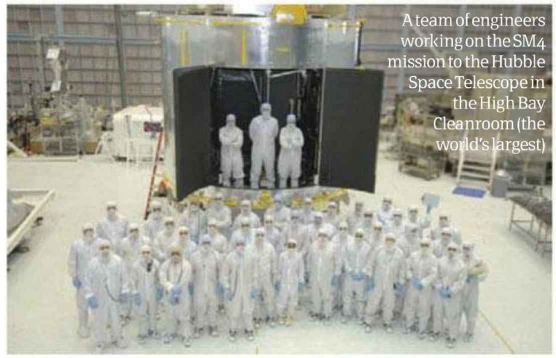
HIDDEN ATTRACTION

Despite once being considered pretty barren, the ZOA actually hides what is referred to as the 'Great Attractor', a colossal, mysterious gravity anomaly over 10,000 times the mass of the Milky Way, slowly pulling our galaxy towards it.

DID YOU KNOW? *The largest cleanroom on the planet is found at the Goddard Space Flight Center, Maryland, USA*

How cleanrooms stay pristine

Why do these rooms need to be so spotless when engineers work on space equipment?



A team of engineers working on the SM4 mission to the Hubble Space Telescope in the High Bay Cleanroom (the world's largest)

A cleanroom is a secured environment where the level of particulate matter in the atmosphere is strictly controlled. All pollutants such as dust, chemical vapours, airborne microbes and aerosols are permanently monitored and eradicated by an internal conditioning system, which includes a combination of filters (HEPA and ULPA), extraction fans, airlocks, air showers and protective clothing for its workers.

Via this system, a controlled number of particles per cubic metre (and of a specific size) can be ensured, with higher-class facilities capable of delivering smaller and fewer particles. For instance, an ISO 1 cleanroom – the highest grade; there are nine in total – allows no more than two two-micrometre particles per cubic metre. For perspective, a typical urban environment has 35 million particles of all sizes per cubic metre.

Cleanrooms are used by NASA when building, testing and integrating spacecraft components to ensure no contamination or damage is inadvertently done to the sensitive and expensive equipment – technology that once launched into space cannot be decontaminated. Indeed, while tiny specks of dirt may seem insignificant, past experiences and studies have shown that even the tiniest piece of pollen, sand, hair or flake of skin can imbalance a star-tracking unit, damage an exhaust port or even lead to a spacecraft's thruster becoming blocked.

As such, whenever a NASA engineer comes into work on the latest space technology, far from simply hanging up their coat and getting down to business they must first change into their protective clothing, pass through an air shower – essentially a human-sized hand-dryer that removes any particles stuck to the suit, proceed through a secure airlock equipped with extraction fans, and then finally pass through a temperature and humidity-controlled room to the assembly area. Only then, and under the constant filtering process of a laminar flow filtration system, can they begin work.

Cleanroom engineers prepare a Science Instrument Control and Data Handling Unit

The galactic plane of the Milky Way can obscure around one-fifth of the extragalactic sky at night

Why does the Zone of Avoidance look so empty?

What is this region in space and why do stars and even entire galaxies appear to shun it?

The Zone of Avoidance (ZOA) is a narrow band in the night sky in which very few galaxies can be seen. To reflect this barren-looking region, astronomers nicknamed the band the 'Zone of Avoidance', as compared to other parts of the sky, celestial bodies seem to be actively avoiding this patch of space.

Interestingly, however, the ZOA is actually a misnomer of sorts, as while it is true that very few galaxies are visible within it, it's not because they are not there or are intentionally 'avoiding' it, but rather that they are obscured by the interstellar matter of our own galaxy, the Milky Way.

This occurs as the interstellar dust, attenuation (loss of flux intensity) and stars in the plane of the Milky Way – referred to as the galactic plane – obstruct approximately 20 per cent of the extragalactic sky at visible wavelengths. As a result, this combination of factors makes it extremely difficult to discern cosmic phenomena accurately. For instance, it's hard not to confuse foreground stars with background galaxies.

Recent developments in space astronomy have made good headway in exploring this obscured part of the night sky by employing surveys of it at longer wavelengths than visible light, such as in infrared. At these wavelengths, attenuation is almost entirely eradicated, making probing the ZOA more viable. In light of this, many galaxies have now being discovered there – Maffei 1 and 2 and Dwingeloo 1 to name just three – and more are being found each year.

4x © NASA

"For every kilogram of shielding placed on a shuttle, it costs NASA tens of thousands of dollars extra"

What goes on in the Hypervelocity Gun Lab?

Why is NASA shooting objects at thousands of miles per hour in its New Mexico facility?

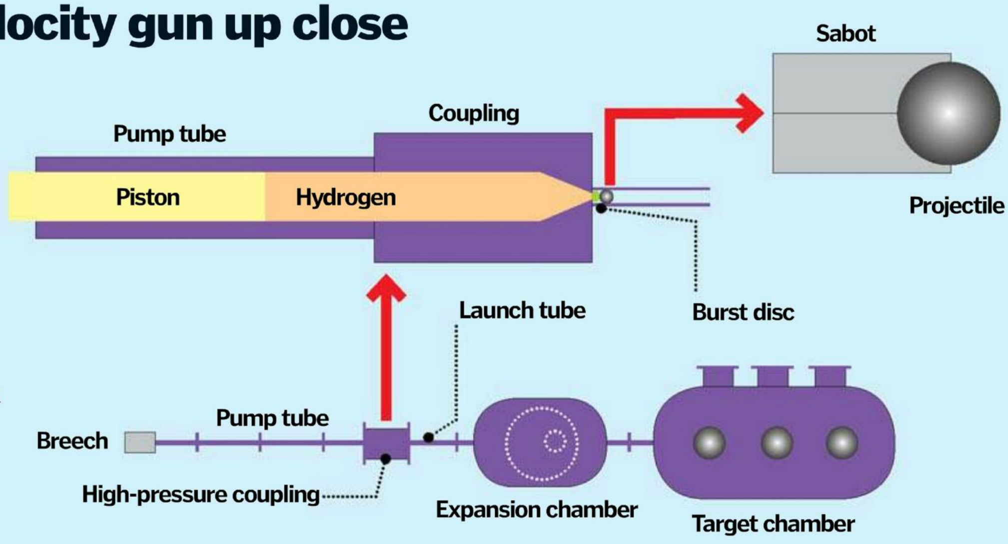
In 1996, a briefcase-sized piece of debris from the French rocket Ariane I collided with the military reconnaissance satellite Cerise in Earth's orbit. It was travelling at nearly 50,000 kilometres (31,000 miles) per hour – fast enough to vaporise part of Cerise's stabilisation boom and send the satellite spiralling into an erratic trajectory. Fortunately, ground control was able to set Cerise back on track so it could continue its mission. However, this could have been disastrous for a manned craft or space station like the ISS, which had its own near-miss with a fragment of the Russian satellite Cosmos 2251 that was travelling at 26,000 kilometres (16,155 miles) per hour, earlier in 2012.

NASA is well aware of the dangers of the space junk that our half-century of spaceflight has left in orbit. The Space Surveillance Network in Colorado Springs, USA, monitors thousands of orbital objects travelling at an average 33,000 kilometres (21,000 miles) per hour. Large chunks can be avoided so the biggest threat to any mission is from the smaller pieces of debris – those between two and ten centimetres (one to four inches) in diameter that zoom around the Earth like super-accelerated bullets and number in the tens of thousands, yet are too small to track.

For every kilogram of shielding placed on a shuttle, it costs NASA tens of thousands of dollars extra, so the precise amount required for any mission is calculated at the White Sands Test Facility in New Mexico. This cutting-edge shooting gallery is home to four enormous guns with 36-metre (118-foot) barrels that can propel aluminium ball bearings at similar speeds to those which can be reached in orbit. NASA engineers will fire many of these at shuttle casings until they find one whose armoured outer layers prevent the pressure wall from being punctured.

The hypervelocity gun up close

The gun's mechanism is simple but effective. A piston is driven into a compression chamber by 1.8 kilograms (four pounds) of gunpowder, which squeezes the hydrogen inside to 7,000 kilograms-force per square centimetre (100,000 pounds-force per square inch). This propels the aluminium sphere in a plastic sabot down the barrel. A steel stripper rips the shell off and the sphere enters the target tank (with air pumped out to replicate the vacuum of space) and hits the target. A digital camera that captures 100 million frames a second records the impact to the nanosecond.



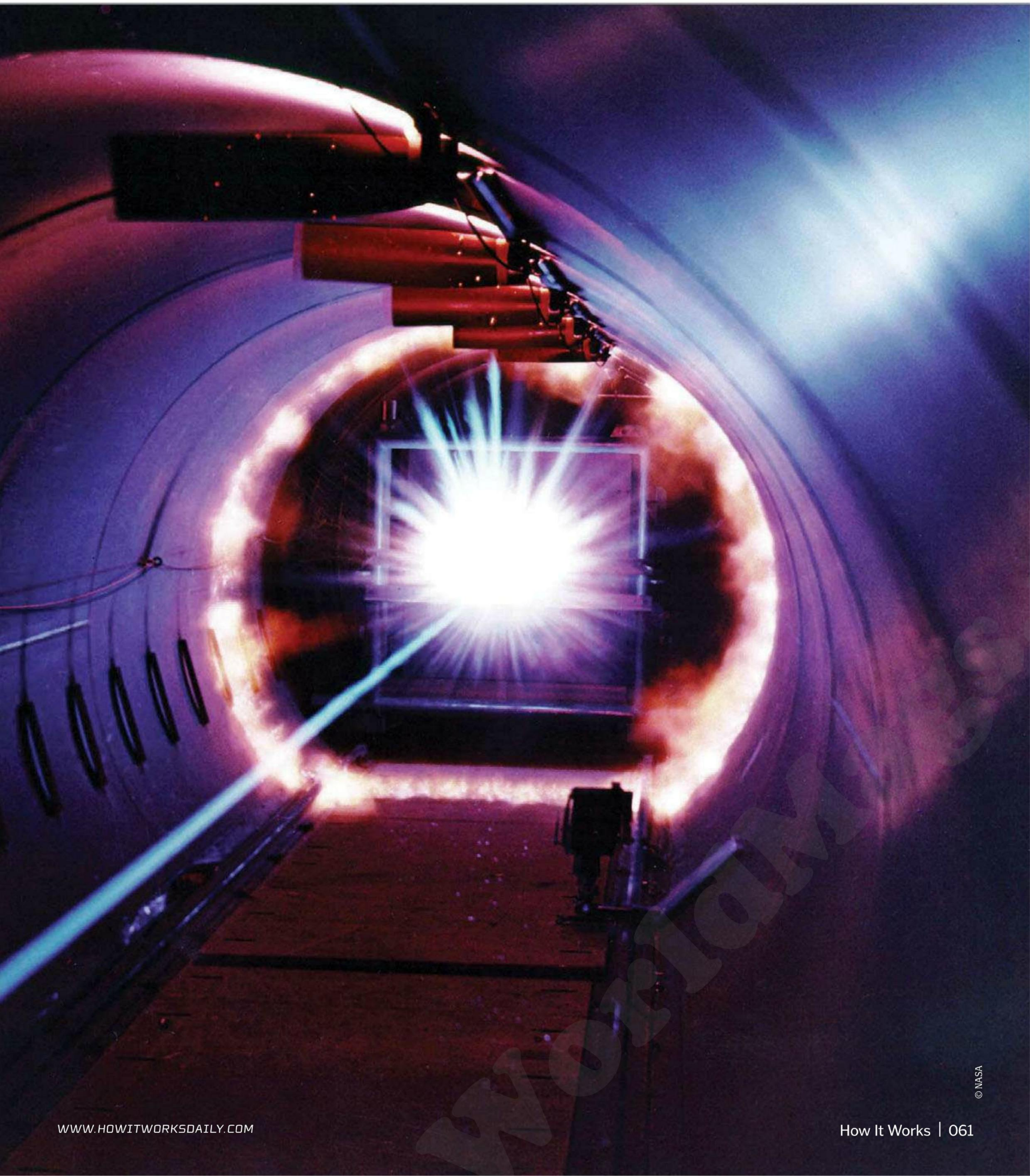
HEAD 2 HEAD
SPACE JUNK CULPRITS

1. MESSY
Russia
Russia and its former Soviet incarnation has ejected nearly 6,000 carrier rockets, satellites and other expended junk into near-Earth space.

2. MESSIER
USA
The United States of America has left marginally more of the junk in orbit than Russia: 27.5 per cent compared to 25.5 per cent.

3. MESSIEST
China
China's relatively recent expansion into space has seen the country shoot to the top of the space polluters, responsible for 40 per cent of the debris.

DID YOU KNOW? *A single layer of one-50th of an inch-thick aluminium can improve shuttle puncture odds from 1:62 to 1:1,000*



© NASA

THE STATS
NGC 7293

COMETARY KNOTS **~20,000**
EXPANSION RATE 40km/s
RADIUS (IN LIGHT YEARS) **2.87**
YEAR OF DISCOVERY 1824
INNER TEMP (IN KELVIN) 1,800
AGE **12,000 years old**

DID YOU KNOW? *'Planetary nebula' is a misnomer coined by early astronomers who saw fuzzy discs that looked like gas planets*

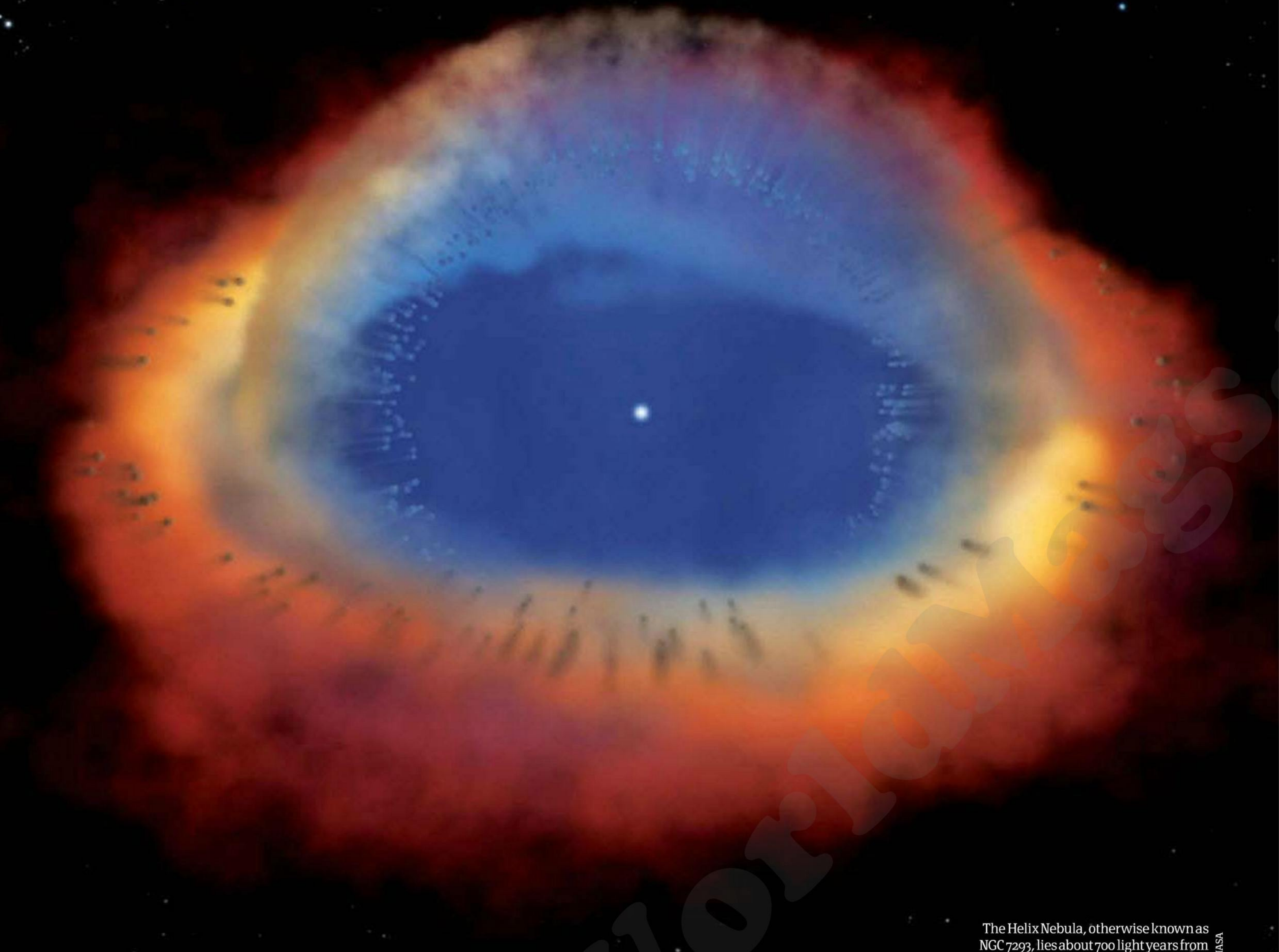
The Helix Nebula up close

Find out why scientists have been intently studying this planetary nebula

The nearest planetary nebula to Earth is the Helix Nebula, which began expanding around 12,000 years ago. It's roughly 700 light years from our world, which makes it easily viewable from the Hubble Space Telescope stationed in low Earth orbit, but still far away enough to make its three-dimensional shape troublesome to figure out. And NASA scientists – being the voraciously curious academics that they are – just had to know what shape the Helix Nebula actually is…

When a Sun-like star is dying, it doesn't have the mass to go supernova and so it throws off layers in huge coronal mass ejections (CMEs) until it becomes a bright shell of expanding gas known as a white dwarf. The shapes that the 1,000 or so catalogued nebulas form as the star ejects its outer shell are as varied as snowflakes – a fact that NASA is struggling to explain. The proximity of the Helix Nebula made it a prime candidate for closer inspection, so NASA compiled images of it from Hubble and terrestrial telescopes around the globe. This is the 3D image they came up with as a result of the intense study: a poached egg-shaped nebula with a bulbous blue inner sphere surrounded by gas.

Fringed around the inner sphere are thousands of cometary knots – so-called because these tight bundles of gas and dust bear some resemblance to comets with their trailing tails. These knots were used as 'markers' to create the image, along with measurements of the speed and direction that the nebular material is moving. The dying star located at the centre of the Helix Nebula is causing the dust particles and gas that encircle it to glow brightly, or fluoresce.



The Helix Nebula, otherwise known as NGC 7293, lies about 700 light years from Earth towards the Aquarius constellation

"It will be able to capture light instantaneously from a mammoth area of the night sky"

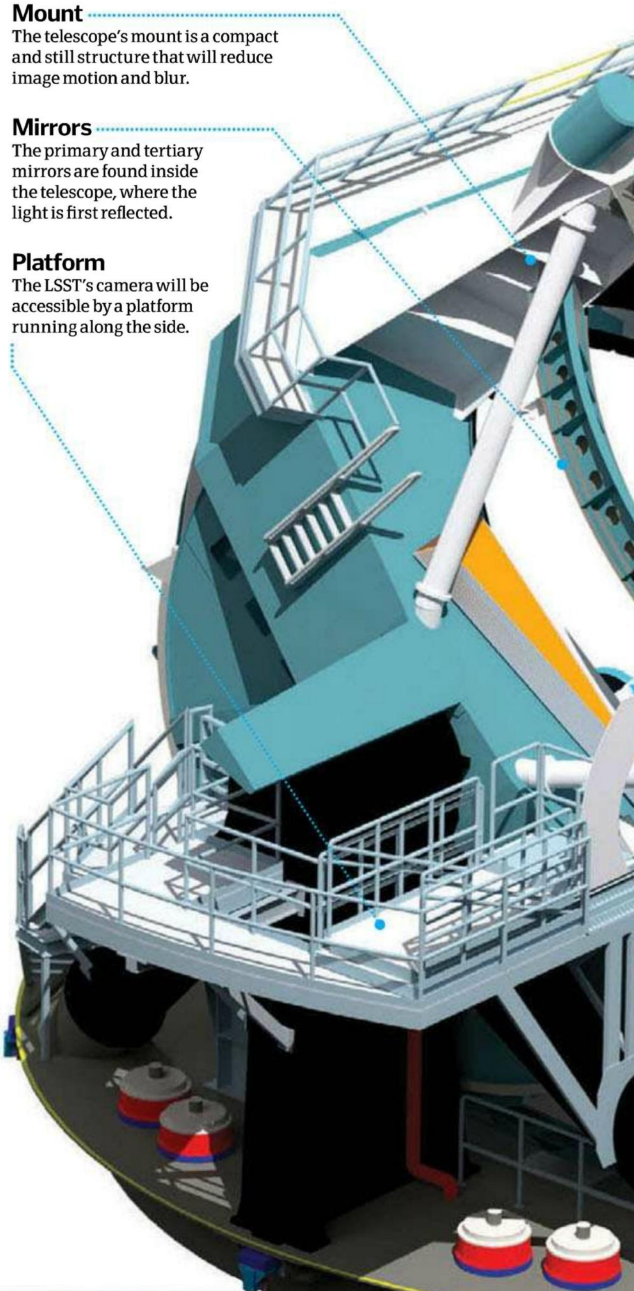
Earth's largest digital camera explained

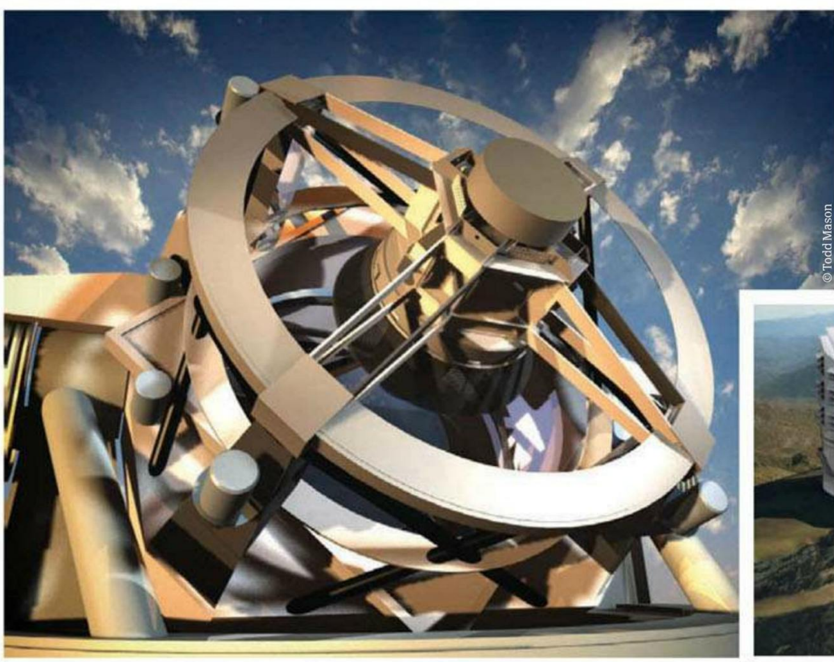
What makes the Large Synoptic Survey Telescope such an astronomical marvel?

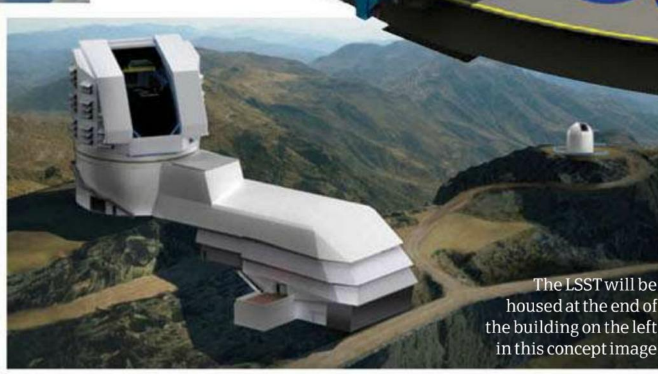
At an altitude of 2,660 metres (8,730 feet) on the El Peñón peak in northern Chile, construction is underway of one of the most remarkable telescopes ever to be devised. The Large Synoptic Survey Telescope (LSST) is unprecedented in size, and with an aperture of 8.4 metres (27.4 feet) it will be able to capture light instantaneously from a mammoth area of 320 square metres (3,440 square feet) in the night sky with its staggering 3.2-billion-pixel digital camera (the biggest on the planet).

The four parts of its name are representative of the major features of the telescope. 'Large' refers to the enormous primary mirror that will provide astronomers with an unrivalled view of the night sky. 'Synoptic' is the movie-like window on the universe the LSST will unveil by taking over 400,000 16-megapixel images every night, allowing astronomers to see videos of celestial objects that change or move rapidly. 'Survey' is the immediate release of data to the public, allowing numerous studies to be made by anyone including mapping the mass of dark matter in the cosmos and tracking the closest asteroids to Earth. 'Telescope', somewhat predictably, refers to the entire structure that will house all of this incredible technology.

Unusually for such a huge telescope, the LSST project is the work of a non-profit private organisation known as the LSST Corporation, which has raised funding through both private pledges and national grants. Construction of the telescope in its high-altitude position – perfect for clear views unhindered by the atmosphere – began back in November 2007, and as of July 2012 the LSST has entered its final design phase. It is set to be completed in 2014 and initially is expected to run until 2024.




© Todd Mason


The LSST will be housed at the end of the building on the left in this concept image

5 TOP FACTS
LSST GOALS

Find dark matter
1 The Large Synoptic Survey Telescope will detect signatures of dark energy and dark matter by measuring weak gravitational lensing present in deep space.

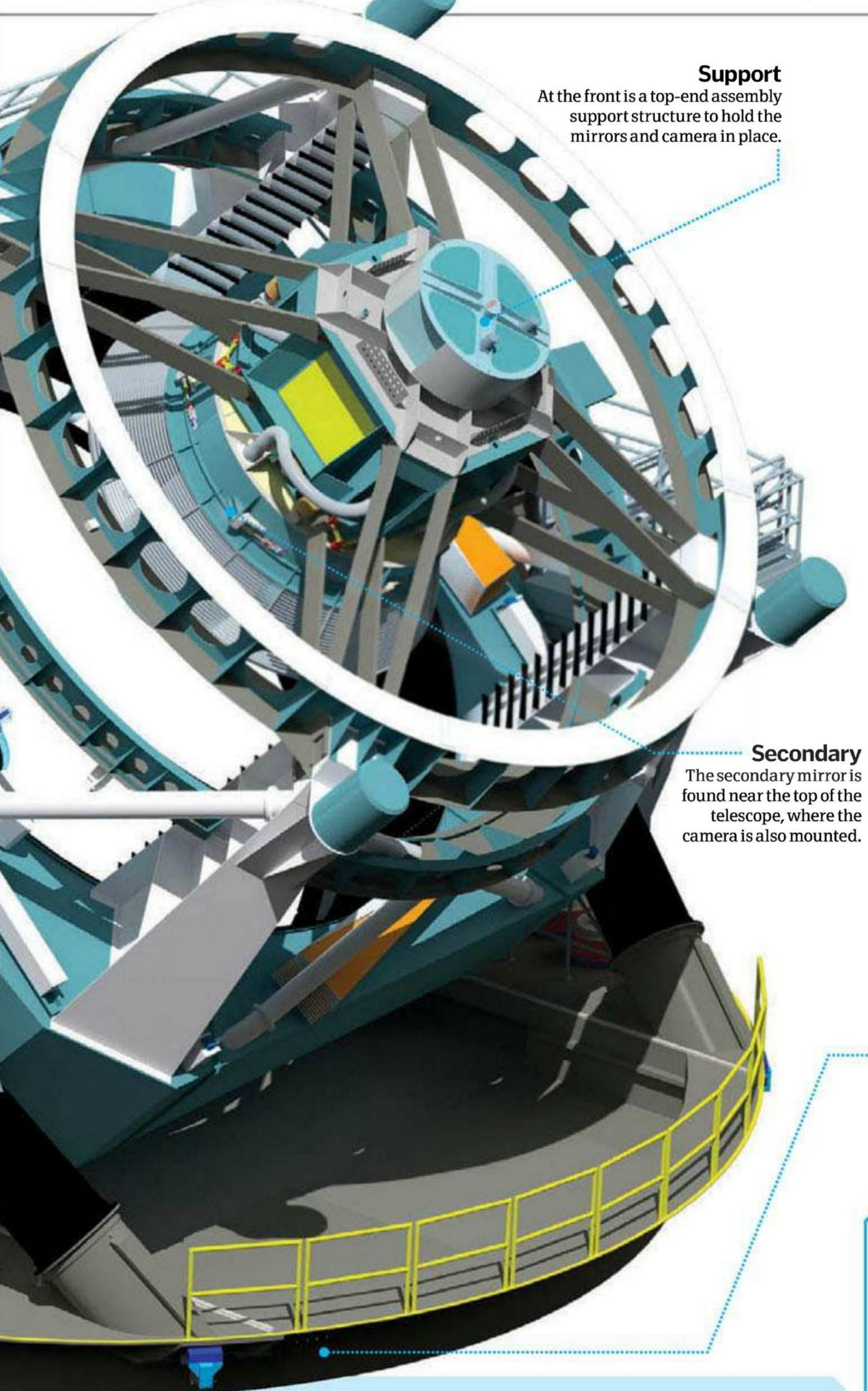
Track asteroids
2 In under a minute the LSST will be able to find objects that are merely 140 metres (460 feet) wide in the Asteroid Belt, helping us to chart potentially dangerous near-Earth objects.

Record movies
3 The rapid image-capturing and processing power of the telescope will enable it to watch superfast events in the universe unfold, such as novas and supernovas.

Map the Milky Way
4 The ability of this massive telescope to capture the entire night sky in just three days will be crucial in our continued attempts to map out our galaxy.

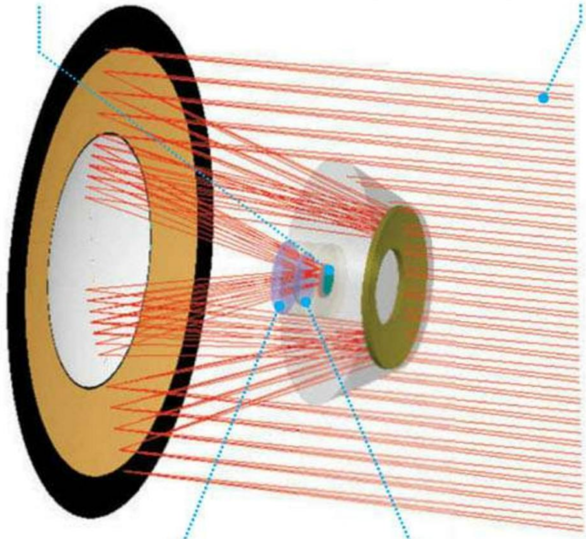
Make new discoveries
5 The incredible imaging power of this telescope and its wide field of view mean that it is highly expected to make numerous unprecedented cosmic discoveries.

DID YOU KNOW? *Software billionaire Bill Gates kick-started funding for the LSST by pledging $10m to the project in 2008*



Capturing an image

How will the LSST camera snap 3,200-megapixel shots?



The telescope

Unlike most other giant telescopes, the LSST will use three mirrors rather than two to capture images. Light is first collected onto an 8.4-metre (27.6-foot) primary mirror, before being reflected onto a 3.4-metre (11.2-foot) secondary mirror. It is then reflected again onto a five-metre (16.4-foot) tertiary mirror in the centre of the primary mirror. Both the secondary and tertiary mirrors are spherical, which allows the light to be intensely focused. The arrangement of this trio gives the LSST an exceptionally wide field of view, enabling it to survey the entire southern sky in just three days performing two observations a night.

The data

There's lots of revolutionary tech inside the LSST, but one of the most important bits is the imaging sensors it will use. Capable of capturing light from ultraviolet to infrared, these sensors will produce 30 terabytes of data every night. After a decade of observations it will have produced over 100 petabytes (100 million gigabytes) of data, which will require 250 teraflops of power to process – about 100,000 home PCs!

The camera

You might be impressed when you see a professional photographer with a camera the size of your arm, but imagine one that was the size of a car…

The largest digital camera ever constructed, the LSST's camera will measure about 1.6 x 3 metres (5.2 x 9.8 feet) and weigh in at around 2,800 kilograms (6,200 pounds). Inside, a variety of 16-megapixel silicon detectors will combine to produce a whopping image resolution of 3.2 gigapixels, or 3.2 billion of your regular pixels, across a 320-square-metre (3,440-square-foot) field of view.

The camera will sit in the middle of the telescope and will operate at approximately -100 degrees Celsius (-148 degrees Fahrenheit) to get the optimal performance out of its detectors.

Welcome to... TRANSPORT

Think of a sunset and a car hurtling down an endless road somewhere in the American Midwest and you'll probably be picturing a muscle car – here we look under the hood of some of the new kids on the block. Also see how handbrakes stop a car, why fireboats are much more than just marine fire engines and meet BAE's latest unmanned aerial vehicle to take to the skies.

LEARN MORE

MUSCLE CARS EVOLVED

How It Works explores how the latest generation of North American muscle cars is obliterating years of European engineering with a bevy of sophisticated technology

For decades, despite their prestige and beauty, North American muscle cars were dismissed by automotive pundits as nothing more than straight-line dragsters. Machines that while delivering bucketloads of raw power, time and again fell short of the all-round performance and engineering delivered by their European counterparts. Critics would joke to boredom about the inability to turn, brake or even survive for more than a few hours in Mustangs and their like, ignoring these vehicles' craft and many strengths.

Of course, there was an element of truth to the critics' claims – turning certainly hasn't been a strong capability of muscle cars in the past – however, as of 2012, things have radically changed. A new generation of muscle cars is smashing through the walls of European supercar dealerships and then leaving their current offerings in the dust, out-accelerating, out-manoeuvring and out-gunning prestige marques in every way that matters. Far from dumb brutes, today's muscle cars are some of the most technologically refined and advanced vehicles on the planet, not just giving big players like Ferraris, Porsches and Jaguars a run for their money, but leaving them in the scorched remains of a horizon-busting burnout.

Letting this new breed of automotive beast take the spotlight in this feature, **How It Works** examines three of the most iconic muscle cars currently in production. We reveal their power, performance and – most importantly of all – the technology that's transforming them into some of the best cars on Earth. So you might want to strap yourself in, as you're in store for one heck of a wild ride...

Be afraid, be very afraid... The Shelby GT500 can even outpace a Ferrari California

AMAZING VIDEO! SCAN THE QR CODE FOR A QUICK LINK

Watch Jay Leno take the Shelby GT500 for a spin

www.howitworksdaily.com

DID YOU KNOW? *The Shelby GT500 is manufactured in Flat Rock, Michigan, USA*

Shelby GT500

The ultimate Mustang, the Shelby GT500 is obscenely fast and likely to give you an adrenaline rush like no other

Let's get the unsurprising facts out of the way first. The 2013 Shelby GT500 is equipped with the most powerful production V8 engine in the world and also the most efficient one in America, producing more than 485 kilowatts (650 brake horsepower). These two achievements are made possible by an all-aluminium block, 2.3-litre (0.6-gallon) supercharger, upgraded cooling system, larger engine fan, redesigned air cooler, higher-flow intercooler pump and a 36 per cent increase in the capacity of the intercooler's heat exchanger. That's impressive – 325 kilometres (202 miles) per hour impressive – but not something that is particularly shocking for arguably one of the most iconic muscle cars ever.

What *is* surprising is the way the GT500 converts that immense power into refined performance. After all, strapping 650 horses to a chassis raises myriad problems, none more so than that of ensuring solid traction and handling. The GT500 deals with these issues through a launch control system – an electronic configurator that enables drivers to set specific rpm launch points – along with a Torsen limited-slip differential and AdvanceTrac steering-assist. Combined, all this advanced tech allows this modern Mustang to maximise the amount of raw power put down, as well as control it while cornering.

Further, the Shelby GT500 complements its all-round performance by the inclusion of a top-of-the-range braking system. Accompanying the 48-centimetre (19-inch) front and 51-centimetre (20-inch) rear forged-aluminium alloys is a new Brembo-made system of rotors and callipers (with six pistons at the front), as well as a series of composite brake pads oriented towards sharp acceleration and deceleration manoeuvres. These, along with a four-profile traction control setup plus an SVT-designed set of Bilstein shock absorbers, ensure excellent handling on the road as well as on the track.

Engine
The supercharged, intercooled 5.8l (1.5ga), 32-valve V8 petrol engine outputs 485kW (650bhp), which enables the GT500 to accelerate from 0-97km/h (0-60mph) in just 3.5 seconds.

Brakes
35.6cm (14in) Brembo vented rotors with six-piston callipers in the front and 30cm (11.8in) vented rotors with a single-piston calliper at the rear help the GT500 stop rapidly.

Electronics
A four-profile traction control setup along with a Bilstein electronically adjustable damper system delivers excellent handling on both road and track.

The statistics...

Shelby GT500

Length: 4,780mm (188.2in)
Height: 1,400mm (55.1in)
Weight: 1,746kg (3,850lb)
Engine: 5.8l (1.5ga) V8
Transmission: Tremec six-speed manual
0-100km/h (0-62mph): 3.5sec
Power: 485kW (650bhp)
Efficiency: 8.5km/l (24mpg)

4x © Ford Motor Company

"Today's muscle cars are some of the most technologically refined and advanced vehicles on the planet"

Chevrolet Camaro

The Camaro specialises in pouncing on European supercars and taking out their performance stats with lethal efficiency

As you'd expect from one of the biggest names in muscle car production, the Chevrolet Camaro is pretty fast. Achieving 0-97 kilometres (0-60 miles) per hour in 5.2 seconds, it could keep up with a Jaguar XK with ease, but unlike Camaros of old, today's models boast tech that make it not just a pacy machine, but one that can handle most terrains – and without consuming vast quantities of hydrocarbons to boot.

Critical to this is the StabiliTrak electronic control system. This consists of four speed sensors on each wheel, a rotation rate sensor on the wheelbase, a steering angle sensor on the steering wheel, a brake-operating hydraulic unit and a master control unit in the engine bay. Combined, these components monitor every manoeuvre and make instant adjustments to maintain maximum traction.

How this works is best explained with a theoretical manoeuvre. If a driver has to corner sharply to the left and then immediately right at high speed, the steering angle sensor detects the initial input and transmits it to the master control unit. At the same time, the Camaro's rotation rate sensor – which measures the car's lateral speed and rotation around its centre line – determines its projected potential for straight-line drift and also communicates this to the control unit. The brains of the system act upon the feedback, adjusting the car's rear-left hydraulic brake, slowing its rotation and aiding a smooth cornering manoeuvre. To avoid oversteer, when the car's steering wheel is turned back to the right to take the next bend, StabiliTrak gauges the rotation speed of the front-left wheel and repeats the process, this time reducing the right-hand turning force and preventing the vehicle's back-end from spinning out.

The other notable engineering feat on the reborn Camaro is GM's Active Fuel Management (AFM) technology. This electronic system automatically deactivates four out of the vehicle's eight cylinders when cruising at speed to conserve fuel and boost miles-per-gallon economy. This is a lot more complex than it sounds, as the engine control module (ECM) has to automatically reprogram the cylinders' firing pattern each time a deactivation takes place.

For example, if a Camaro is sustaining a cruise speed with light throttle response, the ECM will – ideally – deactivate cylinders one and seven on the engine's left bank, plus four and six on the right, creating a four-cylinder firing order of eight, two, five and three. However, if cylinder one is undertaking a combustion event when the AFM is called on, then the ECM automatically detects this and, rather than forcing deactivation, bumps the deactivation on to the next cylinder (ie cylinder eight), which in turn rearranges the deactivation pattern for optimum efficiency.

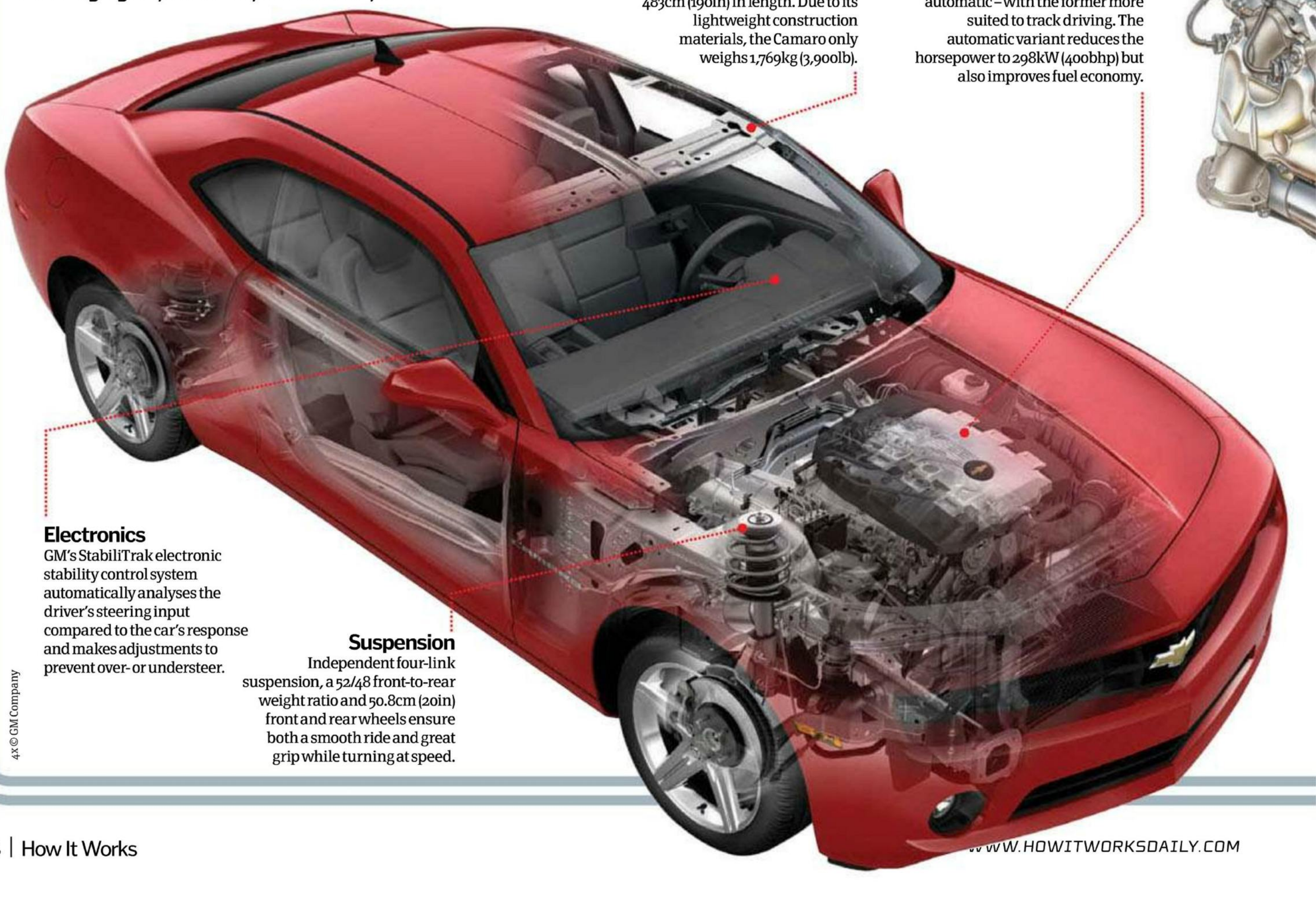
The statistics...

Chevrolet Camaro

Length: 4,837mm (190.4in)
Height: 1,360mm (53.5in)
Weight: 1,769kg (3,900lb)
Engine: 6.2l (1.6ga) V8
Transmission: Six-speed manual
0-97km/h (0-60mph): 5.2sec
Power: 318kW (426bhp)
Efficiency: 9.77km/l (27.6mpg)

Anatomy of a Camaro

Check out our illustrative cutaway of this famous Chevy, which highlights just some of its advanced features



Engine
The 6.2l (1.6ga) V8 engine in the Camaro is quite something. Thanks to improvements such as an enlarged cylinder bore of 10.3cm (4in) and a stroke length of 9.2cm (3.6in), the block can output up to 318kW (426bhp).

Chassis
The body is made from aluminium and measures in at 483cm (190in) in length. Due to its lightweight construction materials, the Camaro only weighs 1,769kg (3,900lb).

Transmission
A six-speed transmission comes in two flavours – manual and automatic – with the former more suited to track driving. The automatic variant reduces the horsepower to 298kW (400bhp) but also improves fuel economy.

Electronics
GM's StabiliTrak electronic stability control system automatically analyses the driver's steering input compared to the car's response and makes adjustments to prevent over- or understeer.

Suspension
Independent four-link suspension, a 52/48 front-to-rear weight ratio and 50.8cm (20in) front and rear wheels ensure both a smooth ride and great grip while turning at speed.

KEY DATES
DODGE CHALLENGER

1959
The first car with the Challenger name was the limited-edition 1959 Dodge Silver Challenger. It packed a six-cylinder V8 engine.

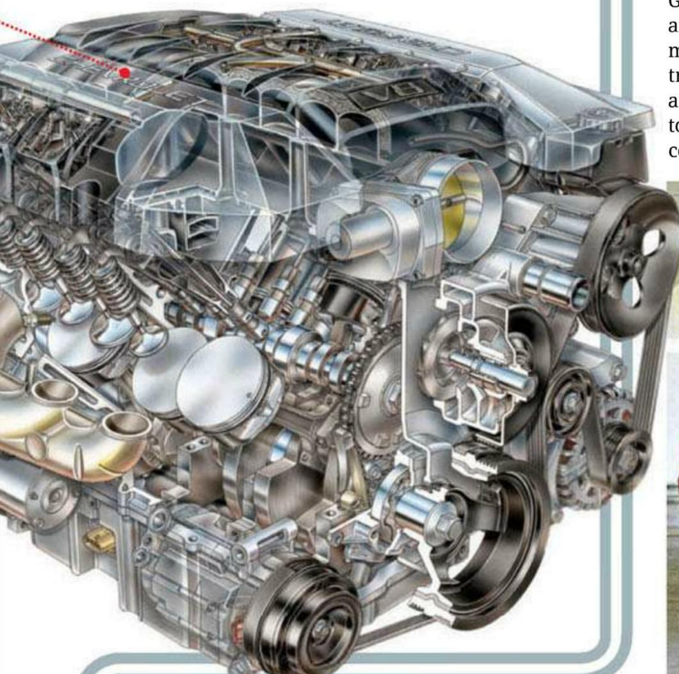
1970
Built to rival the Mustang and Camaro, the first-gen Challenger sold well with 76,935 made in its first year, but it was slated by critics.

1978
The next time the Challenger name was used by Dodge was in 1978, rebranding the Mitsubishi Galant Lambda for a US audience.

2008
Arguably the true successor to the Seventies model, the SRT Challenger was longer and taller than the original and packed a 6.1-litre (1.6-gallon) V8.

DID YOU KNOW? A 1977-era Chevrolet Camaro featured in the 2007 film *Transformers*, with modern variants in the two sequels

The Camaro hits 97km/h (60mph) in an impressive 5.2 seconds



Dodge Challenger

The Dodge SRT8 sends out a challenge not just to other muscle cars, but any vehicle that dares to take it on

Where the new Shelby GT500 and Chevrolet Camaro partner their raw power with unseen and subtle advanced technologies, the Dodge Challenger struggles more to shake off its muscle car heritage than perhaps any other.

Indeed, aside from the cart-breaking frenzy of the giant 6.4-litre (1.7-gallon) V8 engine – a block capable of outputting more torque than a Lamborghini Gallardo – the on-road stability granted by automatic electronic rain brakes, tyre pressure monitors, antilock vented brake discs and a steering assist computer is second to none. With added responsiveness delivered by independent front and multi-link rear suspension, the Challenger specialises in providing the user with critical information to help maximise the driving experience.

Central to this is the Challenger's Electronic Vehicle Information Center (EVIC). The EVIC consists of a trip computer, G-force indicator, two speed timers, 0.2-kilometre (eighth-mile) and 0.4-kilometre (quarter-mile) automatic log, and a multimedia information centre. This, partnered with Dodge's trapezoidal systems gauges – which includes a digital compass and temperature sensor, allows for the vehicle's performance to be closely monitored and then tailored dependent on driving conditions, the terrain and the driver's skill level.

The statistics…

Dodge Challenger SRT8

Length: 5,021mm (197.7in)
Height: 1,450mm (57.1in)
Weight: 1,886kg (4,160lb)
Engine: 6.4l (1.7ga) V8 SRT HEMI
Transmission: Six-speed manual
0-97km/h (0-60mph): 3.9sec
Power: 350kW (470bhp)
Efficiency: 8.14km/l (23mpg)

The Challenger comes with a G-force indicator as well as 0-97km/h (0-60mph) and 97-0km/h (60-0mph) timers

2x © Death Writer

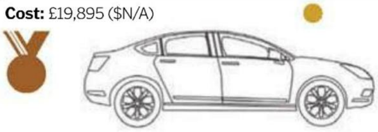
Flexing their muscles…

HIW pits the Shelby GT500 against a Citroën C5 and Ferrari California to see which car makes the best all-round ride

Key: 1st, 2nd, 3rd

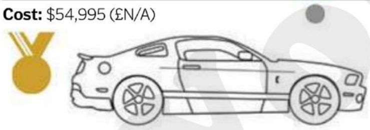
Citroën C5

Weight: 1,670kg (3,682lb)	1st
Efficiency: 14.9km/l (42.2mpg)	1st
Engine size: 1.6l (0.4ga)	3rd
Power: 115kW (154bhp)	3rd
Max torque: 240Nm (177lbf/ft)	3rd
0-100km/h (0-62mph): 8.2sec	3rd
Top speed: 209km/h (130mph)	3rd
Cost: £19,895 ($N/A)	1st



Shelby GT500

Weight: 1,746kg (3,850lb)	3rd
Efficiency: 8.5km/l (24mpg)	2nd
Engine size: 5.8l (1.5ga)	1st
Power: 410kW (650bhp)	1st
Max torque: 600Nm (443lbf/ft)	1st
0-100km/h (0-62mph): 3.5sec	1st
Top speed: 325km/h (202mph)	1st
Cost: $54,995 (£N/A)	2nd



Ferrari California

Weight: 1,731kg (3,817lb)	2nd
Efficiency: 6.7km/l (19mpg)	3rd
Engine size: 4.2l (1.1ga)	2nd
Power: 360kW (483bhp)	2nd
Max torque: 505Nm (372lbf/ft)	2nd
0-100km/h (0-62mph): 3.8sec	2nd
Top speed: 312km/h (194mph)	2nd
Cost: £142,865 ($223,055)	3rd

“Handbrakes offer a greater level of safety and reliability than the more complex hydraulic types”

©Alamy

Cherrypickers explained

How do these portable mechanical platforms help get people to out-of-reach places?

Cherrypickers are a type of mechanical lifting device in which a series of telescopically extending, hydraulically powered arms can raise a platform to great heights. The arms of the picker originate from a stabilising base, which is commonly a large truck so that the picker can be easily transported, while the arms extend up to the bucket. The cherrypicker's movement can be controlled from a base-mounted panel – common for firefighting, where the fire officer needs their hands free to put out a blaze – and also from a bucket-mounted one. The latter panel allows the operator a greater degree of fine control over their position once up in the air.

While the term 'cherrypicker' has become a general name for any sort of mechanical lifting device, technically it only applies to those with these hydraulic, telescopic arms. Scissor lifts, aka pantographs, which use folding supports in an X pattern, are not cherrypickers and can be powered by pneumatic or mechanical means, as well as hydraulics. Though scissor lifts might provide more vertical lifting power, they don't possess the ability to move horizontally, so they're restricted to lifting in a single vertical plane.

How handbrakes stop a vehicle

A closer look at the essential safety feature that can stop a car dead

A handbrake is an additional braking mechanism installed on all commercial vehicles that's completely separate from foot pedal-operated brakes. The role of the handbrake is to both supply an emergency means of stopping if the primary brakes fail – eg if the brake fluid leaks – and also as a parking assist tool. The latter ability is especially useful if a driver needs to park their vehicle on a steep incline.

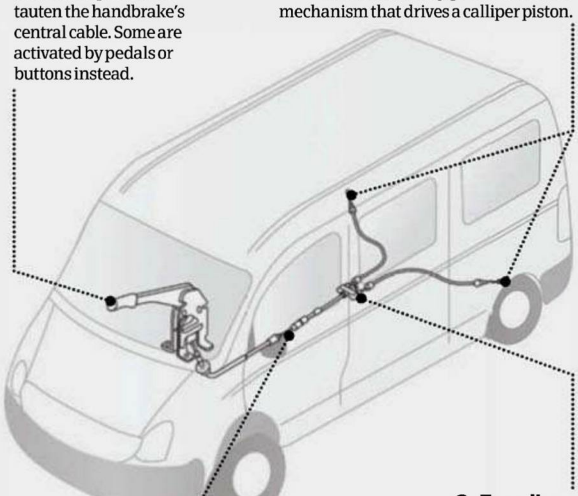
Critically, handbrakes are purely mechanical braking tools, relying on a series of levers, cables and screws to activate a car's wheel brakes. In being designed this way, they offer a greater level of safety and reliability than the more complex, if more powerful, hydraulic types. As shown in the diagram below, the handbrake system originates at the front of the vehicle – typically perceived by the user as a lever – and culminates at the rear wheels where the brakes engage to stop a car in its tracks.

Handbrake in action

See how your vehicle's handbrake works

1. Lever
Most handbrakes employ a manual lever, which can be drawn upwards to tauten the handbrake's central cable. Some are activated by pedals or buttons instead.

4. Brakes
With drum brakes the split cables go directly to the rear wheels' brake shoes; while with disc brakes, they go to a corkscrew mechanism that drives a calliper piston.



2. Cable
Attached to the lever is a brake cable (multiple cables are used in some cases), which when the lever is drawn up passes through a force-amplification mechanism.

3. Equaliser
With the small force generated by the lever greatly increased, the central cable passes through an equaliser, a U-shaped device that splits the cable – thus the force – into two.

Jetstream 31 UAV

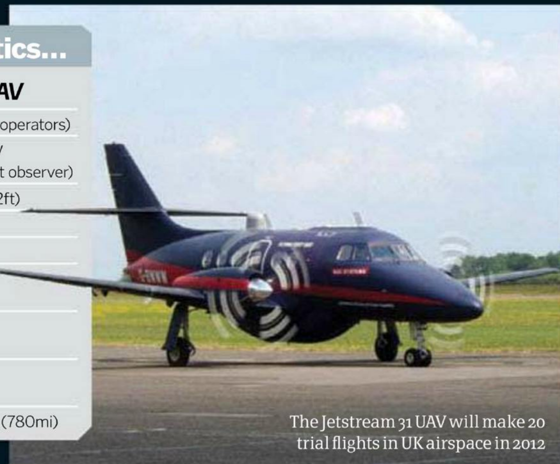
HIW explores BAE's 'Flying Test Bed' to discover how the next generation of unmanned aerial vehicles will work

The Jetstream 31 UAV, or the Flying Test Bed, is an unmanned (also known as uninhabited) aerial vehicle designed by BAE Systems to trial a new series of smart, autonomous flight-control, navigation and detection systems. The systems are designed to provide a clear technological roadmap for the development of next-generation UAVs capable of routinely flying in controlled airspaces – such as those commonly shared by civilian jetliners. However, for the dream of autonomous aircraft to become a reality, strict safety protocols must first be met. Read on to find out how the Jetstream 31 UAV is going a long way to realising them…

The statistics…

Jetstream 31 UAV

Air crew: 2 (systems operators)
Ground crew: 2 (UAV commander, flight test observer)
Wingspan: 15.8m (52ft)
Length: 14.3m (47ft)
Height: 5.1m (17ft)
Max speed: 411.9km/h (256mph)
Cruise speed: 313.8km/h (195mph)
Max altitude: 7,315m (24,000ft)
Max range: 1,255km (780mi)


The Jetstream 31 UAV will make 20 trial flights in UK airspace in 2012

The big three

To fly solo in shared airspace, any future UAV must always play it safe

1 Weather avoidance
If the jet can't detect bad weather, it could easily fly into a storm. To avoid this, the Jetstream uses a variety of cameras, sensors and electrical systems to continuously sweep the surrounding atmosphere and cloud forms.

2 Object avoidance
With future UAVs set to fly in shared civilian airspace, they need to be able to adequately avoid other aircraft and obstacles. The Jetstream 31 does this with an aircraft identification antenna (AIA) to pick up transponder signals, which then initiates a course change. If no signal is identified, on-board cameras can give a visual contact.

3 Emergency landing
In the worst-case scenario a UAV must be able to land without causing danger. The Jetstream uses belly-mounted sensors and radars to detect buildings and life on the ground, selecting only clear areas to touch down.

Testing times

We break down a standard trial run of BAE's Flying Test Bed

2x © BAE

5 TOP FACTS
UAVS IN FOCUS

Military
1 UAVs are most commonly used in national militaries, operating typically as remotely piloted drone aircraft that can relay real-time battlefield footage back to a command station.

Civilian
2 Increasingly, UAVs are being used in the civilian sphere too. A good example is firefighting, where remotely piloted drones are flown into burning buildings to assess stability.

Rotorcraft
3 While the majority of UAVs are fixed-wing aircraft – either with or without engines – rotorcraft designs, such as the MQ-8B Fire Scout, are gaining popularity in the battlefield.

Reaper
4 The most deadly UAV is the MQ-9 Reaper. Designated as a 'hunter-killer', this is capable of scanning, identifying and then taking out targets with powerful Hellfire missiles.

Toy
5 Interestingly, UAVs are beginning to be made as toys, with small hobby units such as the Parrot AR.Drone enabling users to pilot them remotely via their smartphones.

DID YOU KNOW? The Jetstream 31 UAV has already flown thousands of miles without any human assistance

"The largest fireboat in the world can pump up to 50,000 gallons of water per minute"

Fireboats explained

How do these unique vessels extinguish blazes out at sea?

Fireboats, just like land-based fire engines, specialise in redistributing water on a large scale from a store (such as those delivered through fire hydrants) onto a large blaze. Critically a major distinction is that while terrestrial fire engines must be physically attached to a water source via a large tube, fireboats do not, as they are installed with pumping mechanisms that can draw seawater directly from their native environment.

The pumps themselves are installed within the base of the fireboat's hull, sucking water into the vessel and depositing it into a system of internal pipes and valves for redistribution. On average, the pumps can take in upwards of 37,854 litres (10,000 gallons) of water per minute into the boat's water-firing nozzles. But the current largest fireboat in the world – the RAnger 4200-class Three Forty Three – can pump up to a staggering 189,270 litres (50,000 gallons) per minute!

The distribution nozzles, which are also known as water cannons, are controlled either manually by the firefighters – with the individual nozzles swivelling on a platform – or remotely from the control station through a series of hydraulics. The pressure the water is fired at is also dictated from the control room and can be varied to deliver a wide variety of arcs and spray patterns best suited to the job at hand.

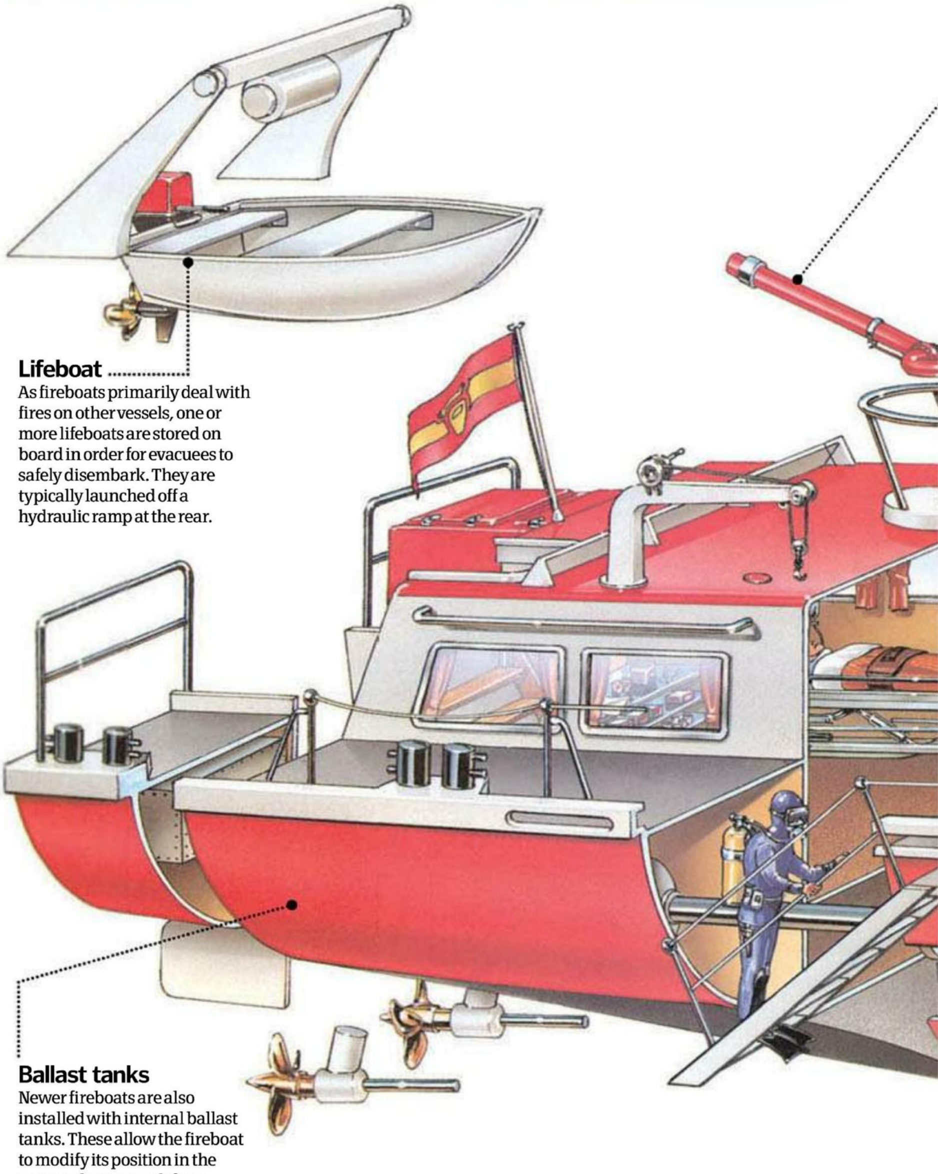
In order for a fireboat to effectively put out ship fires – or indeed those in a harbour or on coastline – and rescue anyone who's trapped, it needs to be able to position itself so that both are easily achieved. This is obviously handled in the first instance by steering it effectively – hence the raised control station – however it's also aided by an internal ballast system.

The ballast system enables the fireboat to raise or lower itself according to the deck level of the stricken ship, creating better firing lines from its cannons and allowing, where possible, for evacuees to board directly from the other vessel. The addition of on-board lifeboats and diving equipment allows for traditional ferrying operations too, in situations where close positioning of the fireboat is not possible.

Despite their name, fireboats do much more than putting out fires, operating not just as marine fire engines, but also as ambulances and anti-terrorism units. The latter role has grown specifically over the last decade and, as such, modern fireboats are installed with an advanced suite of detectors that can sweep for and pick up signs of chemical, biological, radiological, nuclear and explosive agents in the local atmosphere. To protect the crew in the case of a foreign agent being detected, the control room has its own integrated air supply, which is screened continuously by a series of high-efficiency particulate air (HEPA) filters.

On a final note, depending on the country of origin, certain fireboats may also be configured for ice-breaking operations. This essentially requires the vessel to be built with a double hull, with both hull layers strengthened at the bow, stern and waterline with extra steel plates and the interior augmented with a number of watertight compartments.

The Phoenix fireboat cruises in San Francisco Bay, USA



Lifeboat
As fireboats primarily deal with fires on other vessels, one or more lifeboats are stored on board in order for evacuees to safely disembark. They are typically launched off a hydraulic ramp at the rear.

Ballast tanks
Newer fireboats are also installed with internal ballast tanks. These allow the fireboat to modify its position in the water to better reach fires, stranded civilians or the deck of smaller/bigger vessels.

HEAD 2 HEAD
FIREBOAT SHOWDOWN

1. BIG

Phoenix
With a displacement of 146 tons and able to pump up to 24,226 litres (6,400 gallons) of water at a high pressure, the Phoenix is a formidable firefighter.

2. BIGGER

©Joshua Sherurcij

William Lyon MacKenzie
The MacKenzie delivers a displacement of 200 tons and the ability to not only tackle fires but also smash through pack ice.

3. BIGGEST

© Peter Stehlik

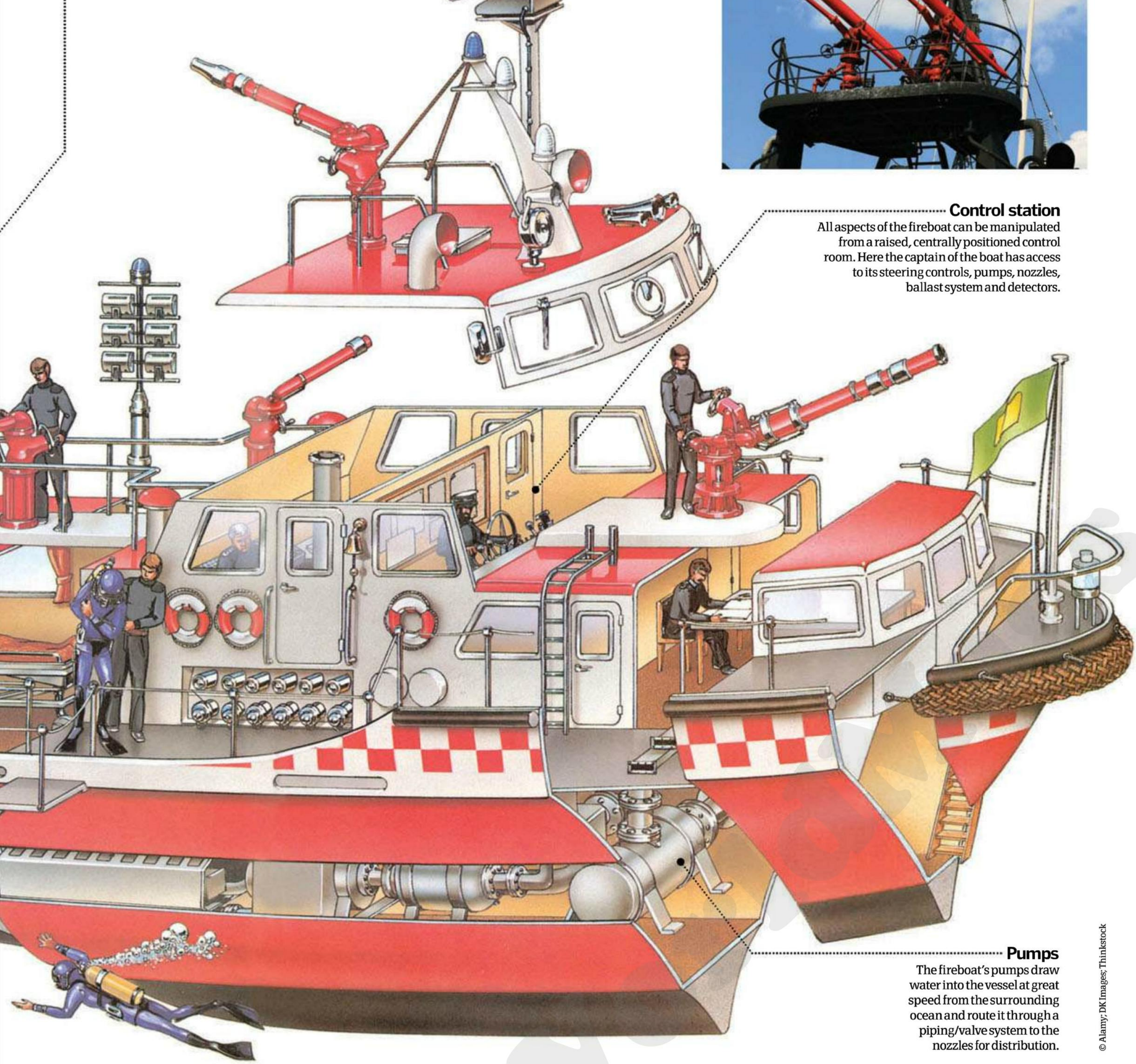
Three Forty Three
Blowing all rivals out of the water, this 500-ton firefighting beast can pump 189,270 litres (50,000 gallons) of water a minute.

DID YOU KNOW? In 1940, British fireboat the Massey Shaw rescued 500 troops from Dunkirk, France

Nozzle
The nozzles – or cannons – of the fireboat receive water from the pumps and project it at high power in the direction of the blaze. Their power can be modified to suit each fire.

Detectors
Modern fireboats are equipped with a host of detectors that can sweep for signs of chemical, biological, radiological, nuclear and explosive agents.

Modern fireboats are equipped with advanced radars and chemical agent detection sensors



Control station
All aspects of the fireboat can be manipulated from a raised, centrally positioned control room. Here the captain of the boat has access to its steering controls, pumps, nozzles, ballast system and detectors.

Pumps
The fireboat's pumps draw water into the vessel at great speed from the surrounding ocean and route it through a piping/valve system to the nozzles for distribution.

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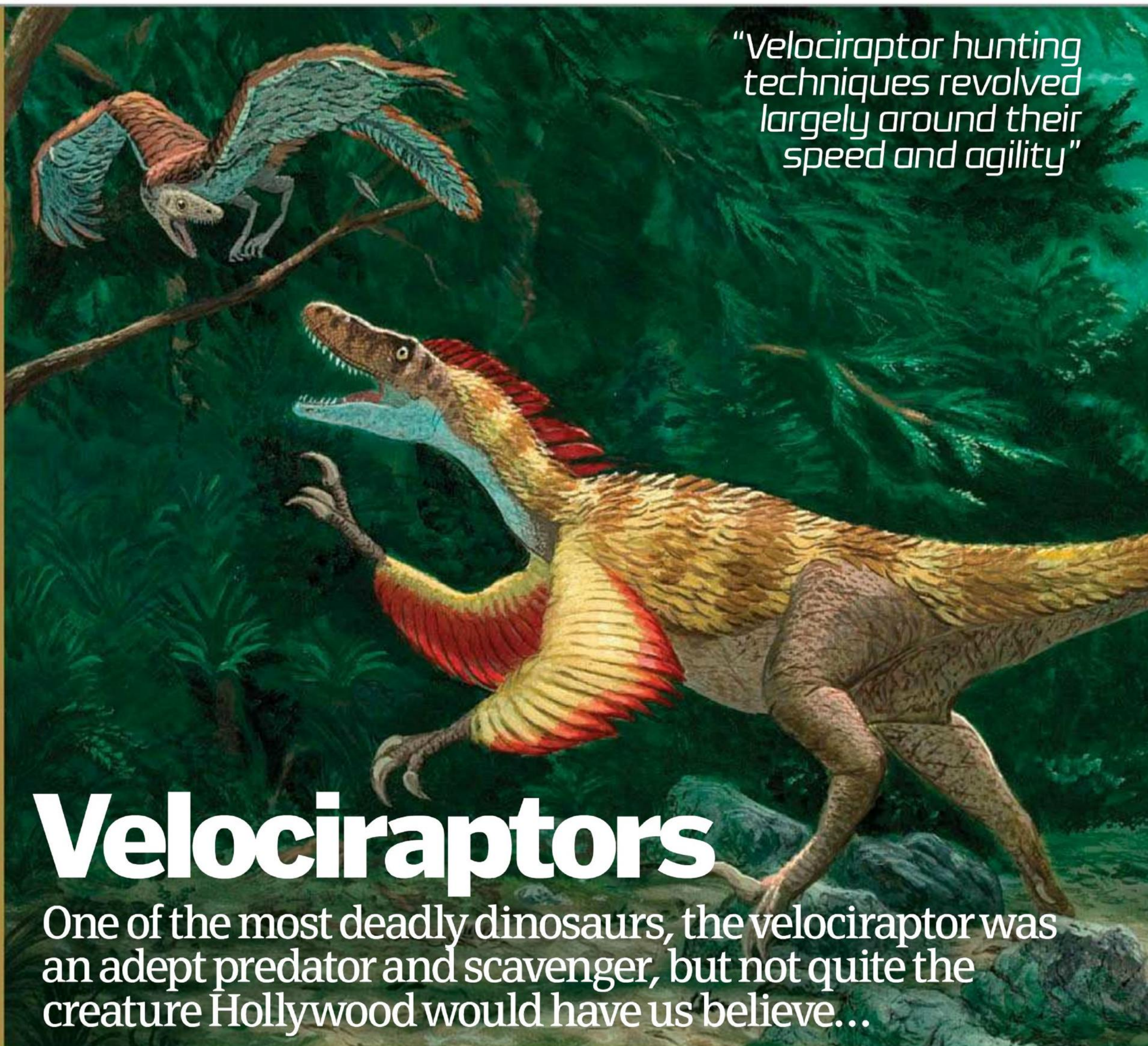
Velociraptors debunked



Welcome to... HISTORY

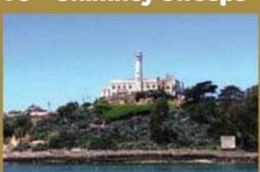
They are one of the most memorable characters from the Nineties blockbuster *Jurassic Park*, but how accurately were velociraptors portrayed? Also in History, take a tour around the world's most famous prison, Alcatraz, based on an island off California, before heading to the Victorian era to gen up on the hazardous vocation of chimney sweeping.

78 Mosaics

79 Chimney sweeps

80 Alcatraz prison

LEARN MORE



"Velociraptor hunting techniques revolved largely around their speed and agility"

Velociraptors

One of the most deadly dinosaurs, the velociraptor was an adept predator and scavenger, but not quite the creature Hollywood would have us believe…

Velociraptors have been ingrained in public consciousness since the 1993 movie *Jurassic Park* showcased them as the most fearsome of apex predators. Smart, lethal and bloodthirsty, the velociraptors of the film arguably stole the show. However, the movie was famed for its indulgence of artistic licence, with palaeontologists bemoaning the lack of historical accuracy.

So what were these dinosaurs really like? Velociraptor, of which there are two verified species – V mongoliensis and V osmolskae, was a genus of dromaeosaurid ('running lizard') theropod dinosaur that lived in the Late Cretaceous period, about 75-71 million years ago. They were two metres (6.6 feet) long, just under a metre (three feet) high, feathered and bipedal, running on two of their three toes per foot. They were native to modern-day central Asia (notably Mongolia), where they built large, ground-based nests to protect their young.

Velociraptors, though often living in close proximity to one another, were largely solitary and, while certain finds suggest they could have teamed up while chasing their quarry, they were not pack hunters, with evidence showing they would fight among themselves for feeding rights. In addition, their staple diet consisted of animals of equal size and weight to themselves or those smaller than them, with very little evidence suggesting they would attempt to bring down larger dinosaurs, such as the Tyrannosaurus rex à la *Jurassic Park*.

Velociraptor hunting techniques revolved largely around their speed and agility. They could accelerate up to 64 kilometres (40 miles) per hour and pounce long distances, as well as grip prey firmly with their unique, sickle-shaped claws (notably their enlarged 'killing claw'). These traits were partnered with a tendency to ambush prey, rather than tackle their victims face on or from long range (see the 'Slash or subdue?' boxout for more). Interestingly, however, while there's no doubt that velociraptors hunted live prey, unearthed fossilised evidence suggests they were also incredibly active scavengers, with the species frequently feeding on carrion (pterosaur bones have been found in velociraptor guts, for instance) and carcasses left over by other predators.

Velociraptors died out along with the remaining species of dromaeosauridae in the run up to, and as a result of, the Cretaceous-Tertiary mass-extinction event that occurred approximately 65.5 million years ago. Despite this, elements of their anatomy and appearance can still be seen today – albeit in heavily evolved forms – in many species of bird.

5 TOP FACTS VELOCIRAPTOR MYTHS

Feathered fiend
1 Contrary to popular depictions of velociraptors in films such as *Jurassic Park*, they would have in fact been covered in feathers, a trait that's been passed down to today's birds.

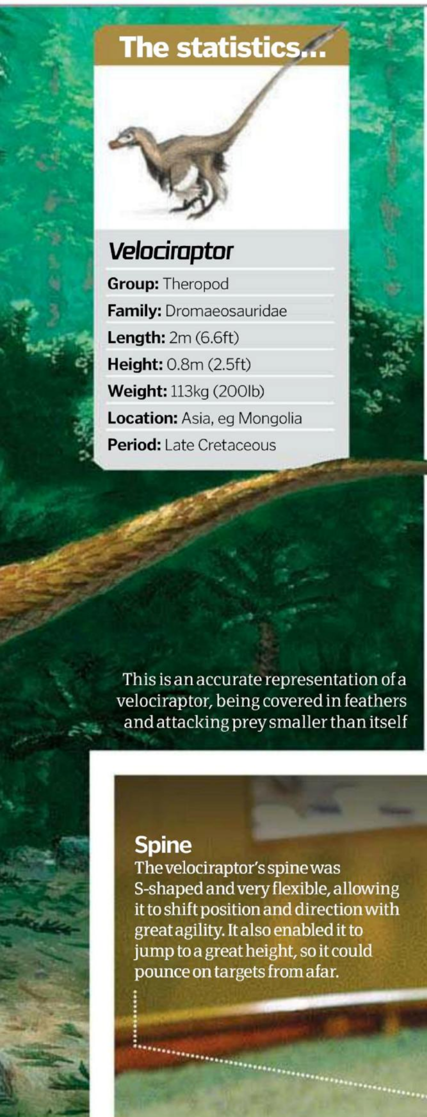
Size matters
2 Another falsehood perpetuated by Hollywood movies is the size of velociraptors. Far from being over three metres (9.9 feet) long, they were much closer to two metres (6.6 feet).

Pack hunters
3 Velociraptors didn't tend to hunt in packs. Evidence suggests various individuals did chase prey at the same time, but would then squabble among each other for 'first dibs'.

American citizens
4 Another myth perpetuated by the *Jurassic Park* franchise is that velociraptors lived in what is now the Americas. In fact, remains have only ever been discovered in central Asia.

'Philosoraptor'
5 Unlike the super-intelligent velociraptors depicted in *Jurassic Park* – eg opening closed doors with their claws – they were likely only as smart as a primitive opossum.

DID YOU KNOW? Modern-day hawks and eagles attack their prey in a similar way to velociraptors



The statistics...

Velociraptor

Group: Theropod
Family: Dromaeosauridae
Length: 2m (6.6ft)
Height: 0.8m (2.5ft)
Weight: 113kg (200lb)
Location: Asia, eg Mongolia
Period: Late Cretaceous

This is an accurate representation of a velociraptor, being covered in feathers and attacking prey smaller than itself

Slash or subdue?

Did velociraptors use their sickle-shaped claws to disembowel prey or for some other purpose?

The majority of non-avian theropod dinosaurs are characterised by razor-sharp serrated teeth and talon-like recurved claws, the velociraptor being no exception. Armed with a bounty of claws on both its hands and feet, the velociraptor at first glance seems to be the perfect killing machine, capable of rapidly chasing down prey before shredding their flesh with one of their knife-like tools. Well, that was at least the commonly accepted theory among palaeontologists until late in 2011, before a new study by a team of international dinosaur experts suggested an entirely different use for them.

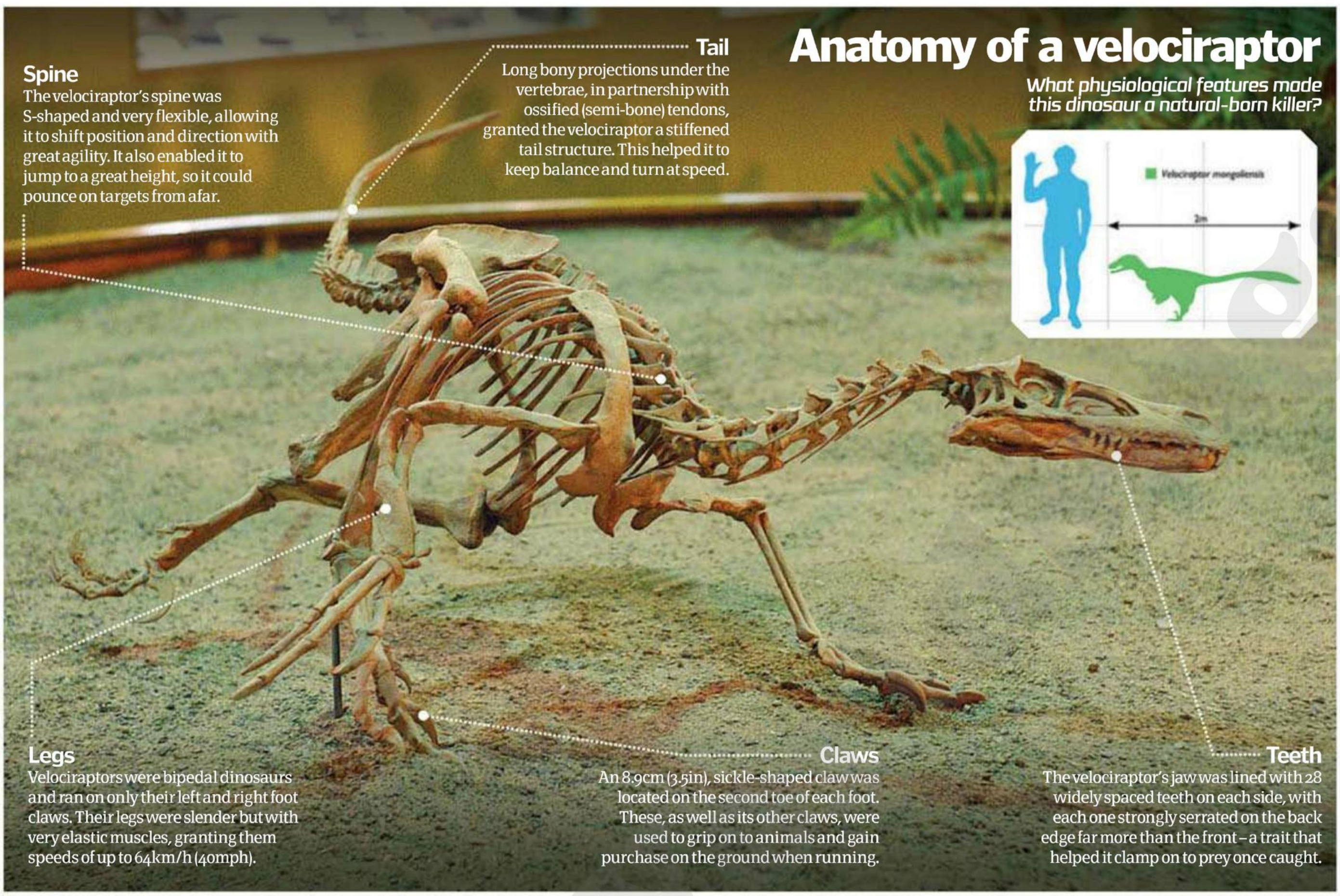
The study suggested that far from their claws – specifically the velociraptor's much-touted 'killing claws' – being used to shred and slice prey in order to kill them prior to consumption, they were far more likely to be used in a similar way to the talons of modern-day hawks and eagles. This entails the birds using their talons as a gripping tool, snaring prey of a lesser body size, pinning them down with their own body weight and then often consuming them live with their beaks.

This theory is seemingly backed up by the velociraptor's feet showing morphology consistent with a grasping function, supporting a prey immobilisation model rather than the originally assumed combative one.

A fossilised claw from a velociraptor. Recent evidence has emerged that has challenged the idea that this was used as a slashing weapon

Anatomy of a velociraptor

What physiological features made this dinosaur a natural-born killer?



Spine
The velociraptor's spine was S-shaped and very flexible, allowing it to shift position and direction with great agility. It also enabled it to jump to a great height, so it could pounce on targets from afar.

Tail
Long bony projections under the vertebrae, in partnership with ossified (semi-bone) tendons, granted the velociraptor a stiffened tail structure. This helped it to keep balance and turn at speed.

Legs
Velociraptors were bipedal dinosaurs and ran on only their left and right foot claws. Their legs were slender but with very elastic muscles, granting them speeds of up to 64km/h (40mph).

Claws
An 8.9cm (3.5in), sickle-shaped claw was located on the second toe of each foot. These, as well as its other claws, were used to grip on to animals and gain purchase on the ground when running.

Teeth
The velociraptor's jaw was lined with 28 widely spaced teeth on each side, with each one strongly serrated on the back edge far more than the front – a trait that helped it clamp on to prey once caught.

"Capstans still exist today, but they're usually driven by a motor or hydraulics"

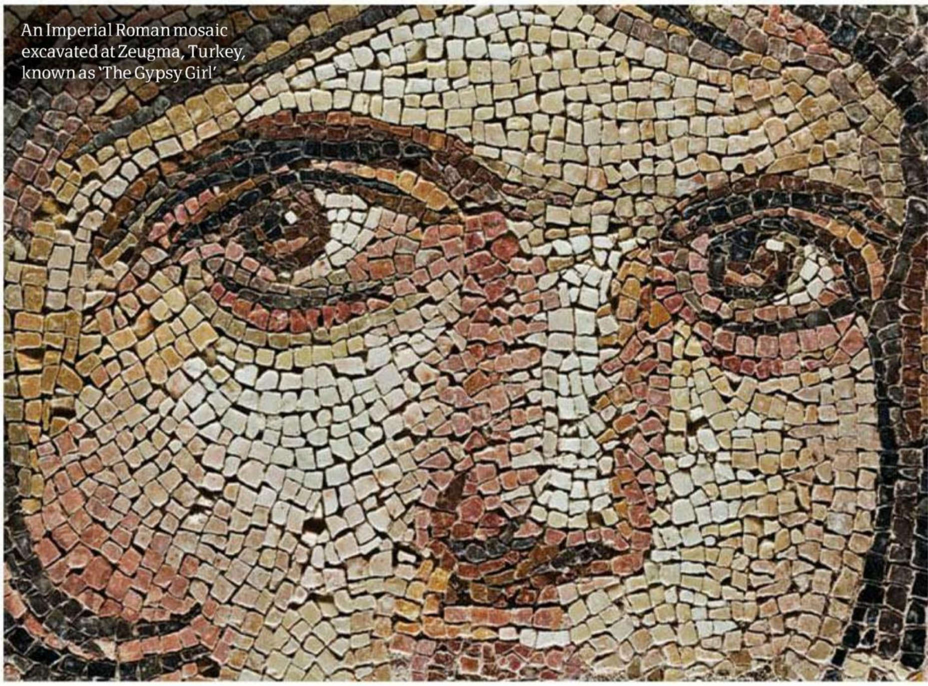
How mosaics were made

This ancient art dates back 5,000 years, but how were mosaics pieced together?

The first examples of decorative mosaics were found in a temple in modern-day Iraq and dated from 3000 BCE. Since that time, civilisations across the world have used mosaics. Romans named individual tiles 'tesserae', which were small pieces of stone, beads or any material that could be arranged to form an image. Colours were achieved using carefully selected stone or shell and, for more elaborate examples, coloured glass and stone coated in gold leaf.

In floor mosaics, a ground layer called statumen was packed with small pebbles onto which 25 centimetres (ten inches) of mortar called rudus was poured. A finer-grade rudus, known as nucleus, was poured on top of that and the design was etched into the surface, before the tesserae were set in place.

Mosaics were applied using one of three techniques: direct application to the surface for 3D objects; indirect application to a backing, before being transferred to a surface; or double indirect, a more complex indirect method in which the tiles could be laid as they would appear in the final work.



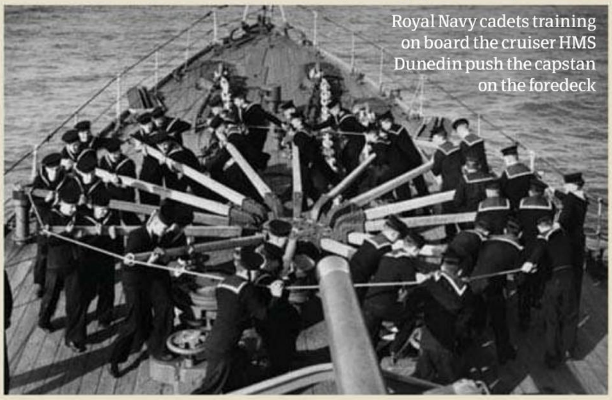
An Imperial Roman mosaic excavated at Zeugma, Turkey, known as 'The Gypsy Girl'

Nautical capstans explained

Once vital to sailing ships, what functions did these lifting devices serve at sea?

Capstans are mechanical pulleys with a vertical axle. On classic sail ships, they're used to apply tension to ropes in order to hoist and hold sails in place. Early timber capstans had a basic ratchet with which to hold the force applied by the sailors, who levered the rope around the capstan by inserting metal bars through the top and hauling it around in a clockwise direction.

Come the Industrial Revolution (circa 1750-1850) the greater forces at play meant capstans made completely of iron were forged with gears in the head, which were designed to lift anchors and other heavy objects when turned anticlockwise. Capstans still exist today, but they're usually driven by a motor or hydraulics – especially in larger vessels where the elbow grease of several sailors can be replaced several times over at minimal cost. A winch is a form of nautical capstan that is used on smaller sailing boats and this is still generally powered by hand.



Royal Navy cadets training on board the cruiser HMS Dunedin push the capstan on the foredeck

A capstan works in much the same way as a windlass, but the latter is based around a horizontal axle instead

419.7m

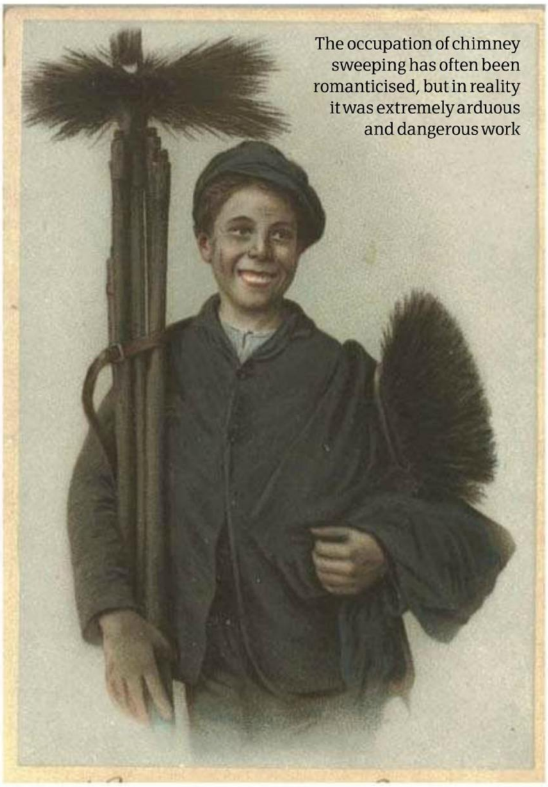
KING OF THE CHIMNEYS

The world's tallest chimney/flue gas stack belongs to the GRES-2 Power Station in Kazakhstan. It's known as the 'Cigarette Lighter' and its height is used to more effectively disperse pollutants.

DID YOU KNOW? *Chimney sweeping is still a profession today, but it's much more hi-tech, often using specialised cameras*

How did people sweep chimneys?

Why was this iconic trade of the 19th century in such high demand?



The occupation of chimney sweeping has often been romanticised, but in reality it was extremely arduous and dangerous work

The big cities of the 19th century – the likes of Paris, London and New York – were grim places to live in many ways. With mains gas and electricity available only in the latter half of the century and only to the well off, heating homes hadn't changed much in centuries. Solid fuels like wood and coal were burned in thousands of fireplaces, belching thick black smoke into the air, the heavier particles of which eventually settled to coat the city in a filmy black layer.

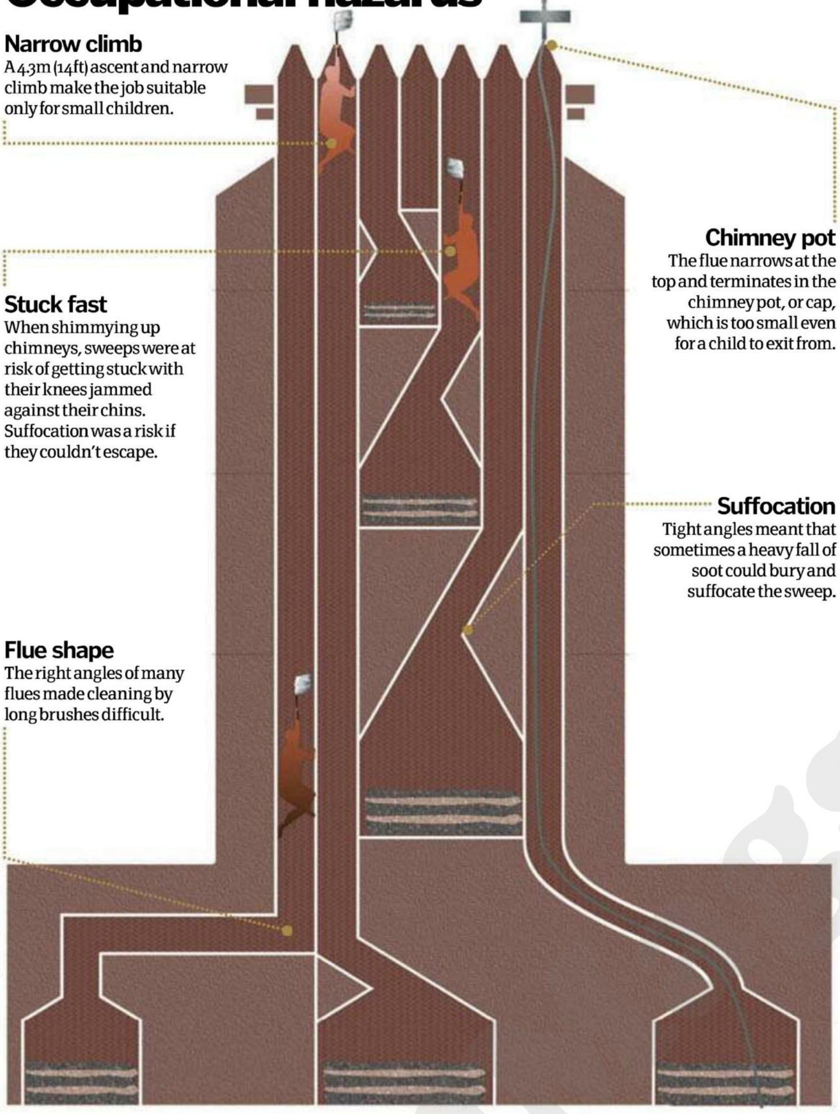
The smoke also coated the inside of the chimney – the flue – in soot and a tarry by-product called creosote. Over time, soot could thicken to the point of blocking the chimney, while the creosote could potentially ignite and send the whole building up in flames. It was the chimney sweep's job to help prevent this.

A master sweep would take on several apprentices to help him clear the soot with brushes. As the spaces the sweeps had to climb up were often tight – indeed, as little as 23 centimetres (nine inches) wide in places – small boys and girls were chosen.

These children – usually orphans from the local workhouse – were bound to the chimney sweep master until they reached adulthood. They would learn how to climb the treacherous bends and ascents of various chimneys and risk their lives on a daily basis. A long brush was used when possible, but often it didn't have the clearance and, besides, the chimney needed to be scraped smooth because the combined soot and flammable creosote content was a saleable commodity in itself.

Four years after London's Great Smog of 1952 – sometimes called the Big Smoke – the Clean Air Act was passed in the UK that, for the most part, put an end to the chimney sweep trade.

Occupational hazards



A sweep wasn't so lucky...

As well as being ill-treated by their masters and often living in appalling conditions, a chimney sweep's apprentice risked their life every day. Narrow spaces meant they could get stuck, suffocate or fall to their death.

Worse still were the effects of the soot they worked with. Asthma and chest conditions were rife in the occupation, and there was also chimney sweep's cancer, a scrotal squamous-cell carcinoma brought on by sweat accumulating soot around the groin. It produced sores that, in puberty, could invade the testes and eventually move up to the abdomen where it would prove fatal.

The brutality of a chimney sweep apprentice's life was recognised by many peers of the time and, in some places, sending kids up chimneys was forbidden. Regulation finally outlawed the use of children as sweep apprentices in 1875.

"Alcatraz gained its reputation because of its geographical location and its notorious inmates"

What made Alcatraz prison so secure?

How did The Rock earn its fearsome reputation?

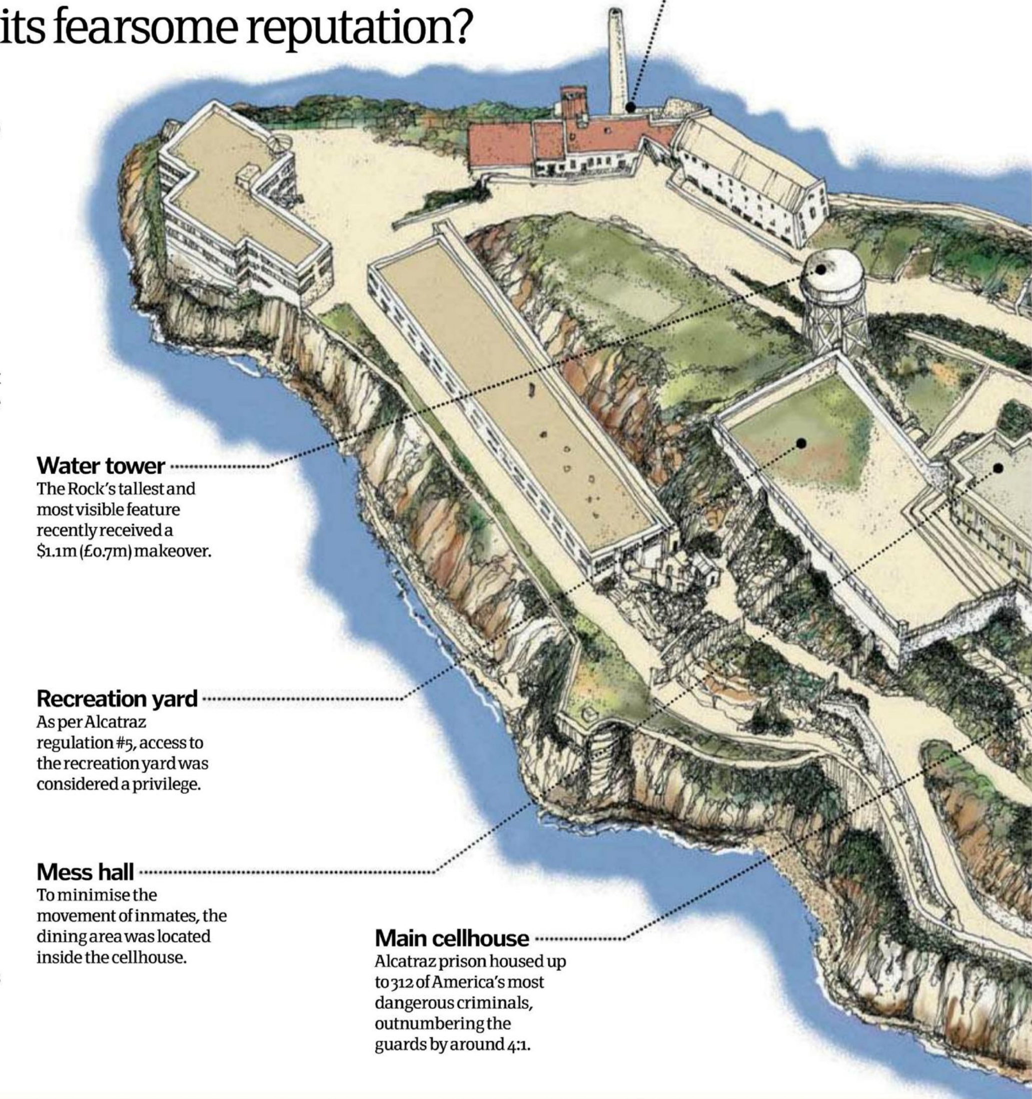
Even when it was named La Isla de Los Alcatraces in 1775, no one had anything nice to say about this nine-hectare (22-acre) island. It was barren, with hardly any soil or vegetation, no beaches, and a layer of guano coated its surface. The stratified rock made it difficult for people to build on and steep cliffs encircled by deadly currents made access a nightmare. It remained untouched for nearly another century before the US began to see the features for which the island had been shunned in a more positive light.

In 1859, Camp Alcatraz was established by the US Army as a garrison for 200 soldiers and armaments, but despite enduring the American Civil War, its guns were never fired. Alcatraz proved far more useful as a military prison for deserters, insubordinates and, of course, Confederate sympathisers.

A new block was built in 1909, which was modernised into a maximum-security prison when the army turned The Rock over to the Federal Bureau of Prisons in 1934. It's during the following 30-year period that Alcatraz became the most famous penitentiary in American – if not world – history.

Alcatraz gained its reputation because of its geographical location, its maximum-security status and its notorious inmates. Only 300 of the most disruptive and high-risk of federal prisoners were detained there, held under conditions so strict that anything other than food, medicine, shelter, legal representation and letters to family was considered a privilege to be earned by good behaviour.

Security was tight; only the elite of officers were posted at Alcatraz and prison procedures were run with military precision. Even if an inmate did manage to breach the walls, they still had a chilly stretch of water with treacherously strong currents to navigate before they reached the mainland. Alcatraz prison was closed in 1963 after a review concluded that operations were too expensive and its novel location had encouraged a 'circus' atmosphere.



Powerhouse
The military prison had a maintenance tunnel that led from the cellhouse to the powerhouse. This was sealed by the prison authorities in 1934.

Water tower
The Rock's tallest and most visible feature recently received a $1.1m (£0.7m) makeover.

Recreation yard
As per Alcatraz regulation #5, access to the recreation yard was considered a privilege.

Mess hall
To minimise the movement of inmates, the dining area was located inside the cellhouse.

Main cellhouse
Alcatraz prison housed up to 312 of America's most dangerous criminals, outnumbering the guards by around 4:1.

No one escapes from The Rock...

Busting out of this max-security island prison was no mean feat

Over its three decades of operation, 36 prisoners made 14 escape attempts from Alcatraz, of which only five got away and all of these were presumed drowned. One of the better-known attempts was the 1946 'Blastout', where six inmates overpowered a guard, broke into the gun gallery and seized control of the cellhouse, from which they discovered they couldn't escape. A siege ensued that lasted for two days and cumulated in a gun battle with the guards, aided by the US marines, who ultimately dropped grenades into the cellhouse to recapture it.

But perhaps the most famous attempt was depicted by the Clint Eastwood film *Escape From Alcatraz*. It was notable for its ingenuity. In 1962 Frank Morris and brothers John and Clarence Anglin used crudely fashioned tools to bore their way into the utility cavity behind their cells. They covered the holes with paintings, built rafts out of raincoats and modelled dummy heads with scraps of soap to avert suspicion until the morning, giving them time to make their getaway. They were never found and, though presumed dead, they are still wanted by the FBI.

HEAD 2 HEAD UNUSUAL PRISONS

1. SMALLEST


© LymeRegis

Sark prison

Located on the tiny Channel Island, this is thought to be the most diminutive jailhouse in the world. It can only hold a maximum of two people.

2. MOST HOMELY

San Pedro prison

Found in La Paz, Bolivia, this prison is more like its own little neighbourhood with restaurants, a school and even a hotel.

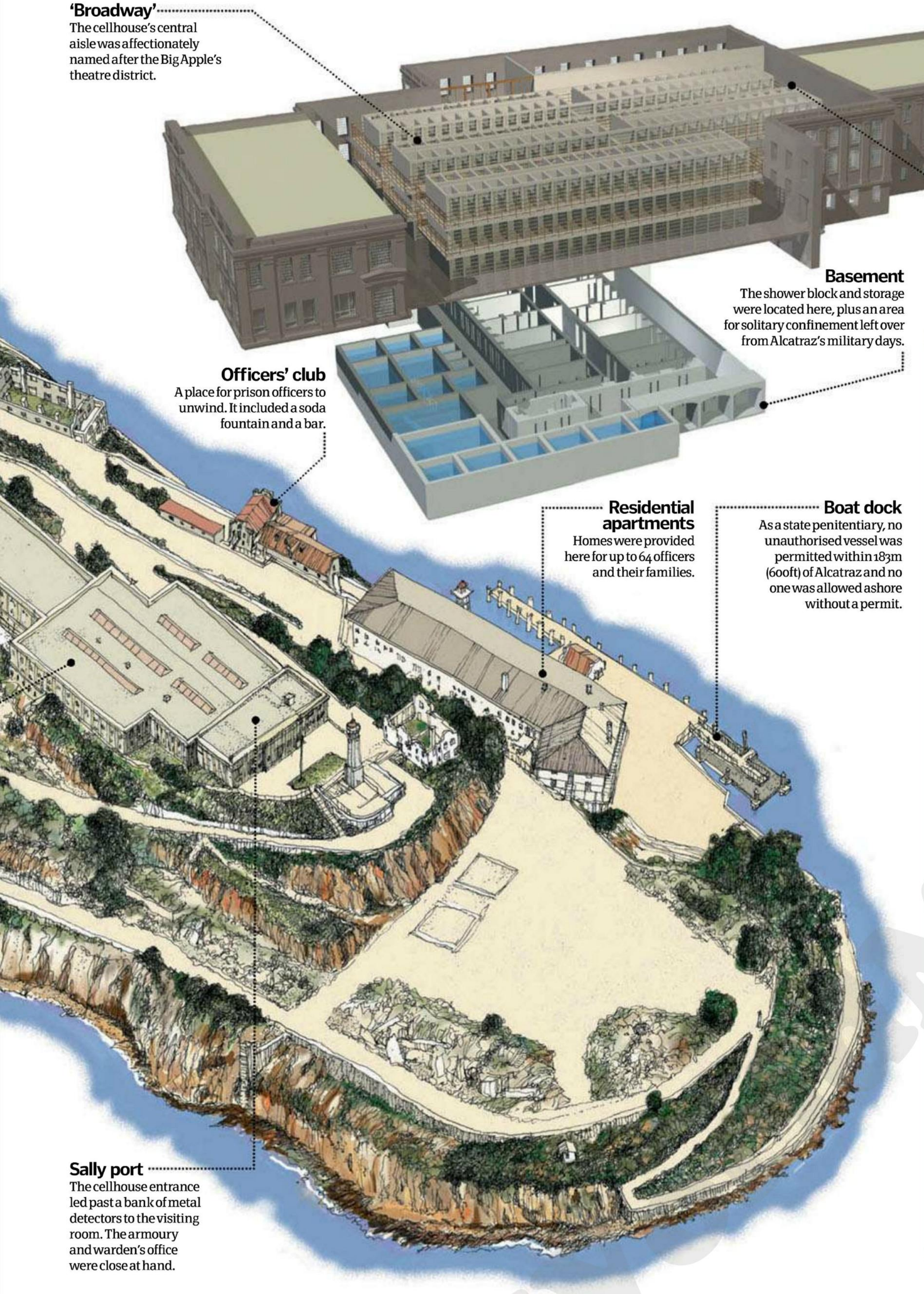
3. SWANKIEST


© Daniela Ebner

Justizzentrum Leoben

One of the most luxurious jails must be the glass and stainless steel Justice Centre in Leoben, Austria, a joint prison/court complex.

DID YOU KNOW? Alcatraz was named after the birds that once inhabited the island, derived from the Spanish for pelican

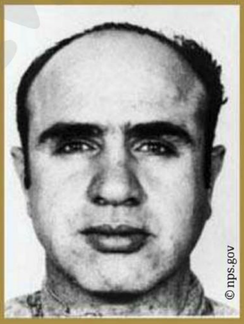


2x illustration © Ormsby and Thickstun Interpretive Design

Rogues' gallery

Alcatraz was designed to house America's most notorious and dangerous criminals, partly to isolate the highest-profile inmates from influencing residents in other prisons and partly to stand as a high-visibility example. Alcatraz's most infamous inmate was Chicago underworld kingpin Al Capone, who terrorised parts of the US between the Twenties and early-Thirties. He was incarcerated at Alcatraz in 1934 and transferred to Terminal Island Correctional Institution in 1939, with a fraction of the influence he had during the Prohibition era.

Other notable criminals who succumbed to the full force of the US penal system included kidnapper George 'Machine Gun' Kelly, Bonnie and Clyde accomplice and bank robber Floyd Hamilton, Ma Barker gang member Alvin 'Creepy' Karpis and murderer Robert 'Birdman' Stroud, who was portrayed in the 1962 film classic *The Birdman Of Alcatraz* by Burt Lancaster.


© nps.gov

The notorious crime boss Al Capone served just over six years at Alcatraz

BRAIN DUMP

Because enquiring minds want to know...

Ask your questions

Send us your queries using one of the methods opposite and we'll get them answered

MEET THE EXPERTS

Who's answering your questions this month?

Luis Villazon

Luis has a degree in Zoology from Oxford University and another in Real-time Computing. He's been writing about science and tech for years. His sci-fi novel *A Jar Of Wasps* is published by Anarchy Books.

Shanna Freeman

When Shanna isn't researching and writing about the latest in the fields of space and science, she's mother to a precocious and very active toddler who has started to ask tough questions of her own.

Rik Sargent

Rik is an outreach officer at the Institute of Physics where he works on a variety of projects aimed at bringing physics into the public realm. His favourite part of the job is travelling to outdoor events and demonstrating 'physics busking'.

Mike Anderiesz

Long-time **How It Works** contributor and seasoned tech and computing journalist Mike has 15 years' experience of explaining the ins and outs of the most cutting-edge gadgets, hardware and home entertainment products.

Aneel Bhangu

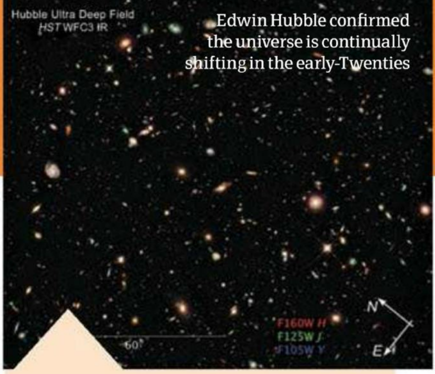
Aneel is a training academic surgeon working in London. His research interests include advanced cancers and medical statistics, with his clinical interests including planned surgery for rectal cancers and emergency surgery for trauma.

What's stopping us from building a tower that goes up to space?

James Graham

The main challenge in building a tower which extends past the upper reaches of Earth's atmosphere is there are currently no known materials that would be strong enough not to buckle under their own weight. However, this hasn't stopped many scientists and engineers devising ways that it could be possible, along with high-profile bodies such as NASA investing in research into how it could be done. The accepted view of how this might work involves building from the top down, where the top would be a large mass in geosynchronous orbit around Earth (orbiting the planet yet staying in the same position at all times). The 'tower' would most likely be a thin yet strong cable or tether that could be climbed by mechanical means to deliver payloads into space. Building from the top down (towards the ground) would need to be balanced by building up (away from Earth), where the upwards building would act as a counterweight to keep the geosynchronous orbit in check. Exciting developments in the manufacture of new materials such as carbon nanotubes – extremely strong for how little they weigh – could be the perfect candidate. However, finding the huge amount of carbon that we would need is the next hurdle to overcome.

Rik Sargent



Edwin Hubble confirmed the universe is continually shifting in the early-Twenties

Every object absorbs some colours and reflects the colour that we can see, but do the absorbed ones have any effect?

Gayan Madusanka

The different colours we see represent a spectrum of wavelengths and frequencies of light. If a jumper is red then it reflects frequencies associated with red light, while absorbing the other colours. An important property of a material that determines which colours it will reflect or absorb is the resonant frequency of its electrons. Different electrons have different frequencies at which they like to vibrate – a bit like how a tuning fork always plays the same note when struck. This resonant frequency dictates the preference of electrons to absorb or reflect various colours, or frequencies, of light. The energy from light that they absorb is most commonly transferred to vibration energy in the atoms, meaning the material heats up, but only nominally.

Rik Sargent

If the cosmos is always expanding, what is it expanding into?

Faye Atkinson

We've known since 1922 that the universe has been changing since it came into being, but we're still not sure about all the details. A better word might be stretching, rather than expanding. If the cosmos is infinite, then it's always been infinite and it will stretch forever; it's not expanding into anything. If it's finite, it may be stretching out something else, but we can only postulate. Currently astronomers believe the universe is either infinite or somehow folds back on itself.

Shanna Freeman

What makes the wind blow?

Luke Knight (11)

Wind is the movement of large bodies of air. Air is made up of gas molecules and those molecules are already whizzing around – that's what makes air a gas instead of a solid. But the motion of individual molecules is chaotic. They are constantly bouncing off one another and changing direction. When you add all the trillions of tiny collisions together, you get an overall pressure that increases as the temperature rises, because the molecules are moving faster. Air at the equator gets heated by the Sun more than air at the poles so it exerts a greater pressure and pushes the colder air out of the way. Because the Earth is also rotating, the atmosphere gets pulled into huge vortices. These rotating pressure systems move across the planet and we feel the result as wind. The exact pattern of the wind is further complicated by differences between the temperature of the land and sea, obstructions from mountains and buildings and even the energy released when water vapour condenses as rain. This is why predicting the weather is so hard!

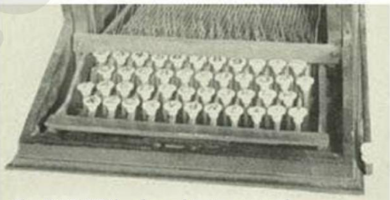
Luis Villazon

Who made the first QWERTY keyboard?

Oisin Goddard (10)

Modern keyboards are based on the system devised for the very first typewriter, patented in 1873 by the Milwaukee printer Christopher Latham Sholes. His model used a piano-style keyboard of two rows of keys arranged alphabetically. This ran into problems when the metal typebars linked to the keys jammed if pressed too quickly. The solution was to separate commonly used letter pairs like 'th' so the typebars jammed less often. This system was called QWERTY, after the first letters of the top row. Contrary to popular myth, it wasn't intended to deliberately slow down typists, but rather help them work more efficiently. After Remington picked up the manufacturing rights to Sholes' typewriter, the QWERTY system was continually modified, shifting the position of less important keys and adding new ones. The whole QWERTY system took on a new life with the advent of electronic typewriters before IBM adopted it in the Sixties for its first PC keyboards. Since then, there have been many improvements, such as the addition of function keys.

Mike Anderiesz



The QWERTY keyboard in its original form on a Sholes typewriter

Can we eat ostrich eggs? Find out on page 84

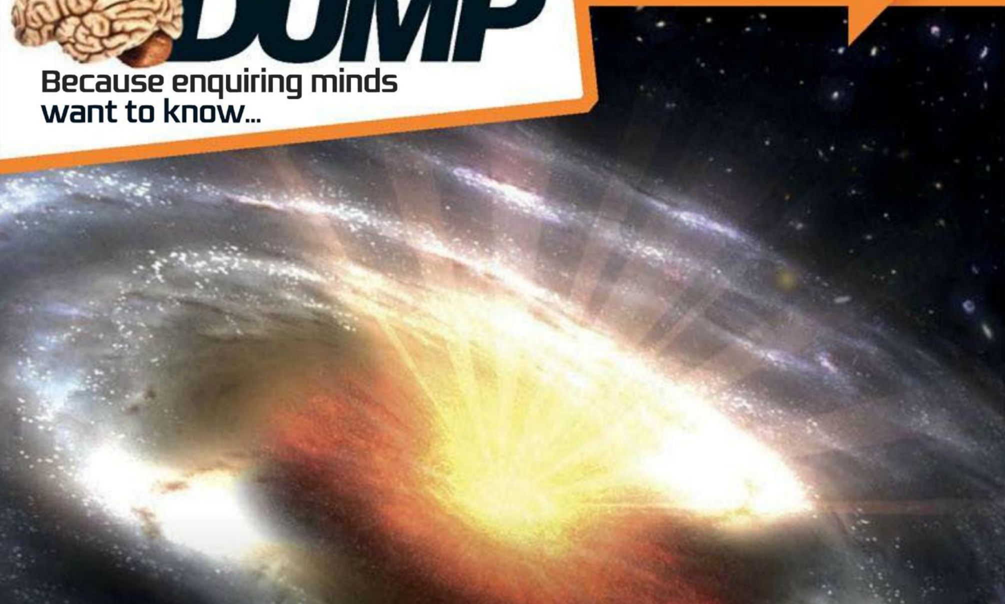
BRAIN DUMP

Because enquiring minds want to know...

Why do we see faces in clouds? Find out on page 85

Want answers?

Send us your questions using one of the methods opposite and we'll get them answered



Where does light end up when it enters a black hole?

Anshuman Saha

■ Many have grappled with this question since the Thirties when it became widely accepted that black holes might exist. Einstein's theory of general relativity tells us that all mass deforms space and time, causing paths taken by particles to bend towards the mass. At the event horizon of a black hole – the boundary in space-time through which matter and light cannot escape once crossed – the deformation of space and time is so strong, there are simply no paths that lead away from the black hole. Once matter or light has crossed the event horizon, it becomes impossible to determine what happens to it afterwards, since information from that event can never reach an outside observer.

Rik Sargent

Can we eat ostrich eggs?

Vince Dawes

■ Not only can you eat them but they are delicious, surprisingly healthy and available online or even in certain supermarkets. Ostrich eggs contain more magnesium and iron, a lot less cholesterol and a little less saturated fat than the equivalent serving of chicken eggs. They provide less vitamin A and E and less zinc, but that's not really the problem with adding them to a balanced diet – it's the practicality. Ostrich eggs typically weigh around 1.4 kilograms (three pounds), the equivalent of two dozen chicken eggs. They also take up to 90 minutes to hard boil and, at 2,000-plus calories per egg, will need 15 very peckish adults to finish. Oh, and you'll probably need a chisel or electric drill to break into the shell too!

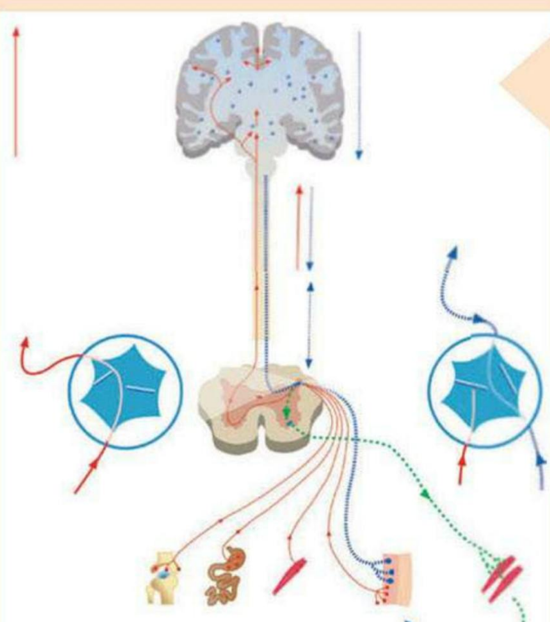
Mike Anderiesz

Why do Persian cats have flat faces?

Mishak Heyman

■ Not all Persian cats do have flat faces – the traditional, or doll-faced Persian, actually has a muzzle. In the late-Fifties, some cat fanciers decided a spontaneous mutation was a desirable trait, and began breeding Persians to have shorter and shorter muzzles until they had high noses and flat faces. This ultra-typed Persian cat became the breed standard according to the Cat Fanciers' Association. At its most extreme, a Persian cat with these features runs the risk of having deformed tear ducts and perpetually runny eyes, so some are calling for a return to the traditional breed.

Shanna Freeman



Hot and cold signals can sometimes get mixed up in transit to the brain

If I touch something really hot, why is there a noticeable delay before I feel it, and why does it feel cold at first?

Robert Ansil

■ The spinal cord runs in two directions: towards the brain (receptors) and down to the muscles (effectors). An upwards-running pathway, called the spinothalamic tract, detects pain and temperature. There are both hot and cold receptors in the skin. When you touch something extremely hot, it can cause 'over-stimulation', meaning that both hot and cold receptors are activated, as well as pain receptors. If the cold message travels back to your brain first, it will get there moments before the hot sensation. However, this phenomenon certainly doesn't affect everyone. No matter what you sense, a reflex arc will stimulate your muscles and force you to withdraw your limb in under a second.

Aneel Bhangu

Building a spaceship in orbit (like the ISS) is a sound idea, but other factors like cost are always a major consideration

Why doesn't NASA take parts into Earth orbit and build a spaceship to go to Mars up there, like the ISS?

Stefan Rogers-Coltman

■ There are a few reasons why we haven't sent a manned flight to a planet like Mars yet. The distance is one. At their closest Mars and Earth are still 80.5 billion kilometres (50 billion miles) away, or about seven months. They'll need supplies on board for all that time. Even if advances in rocketry can reduce the time, once on Mars astronauts will have to wait up to a year and a half to return, when the orbits of the planets align just so. A spaceship big enough to contain all the necessary supplies would be too big to launch from Earth's gravity given our current technology, so we could theoretically build on the Moon or in orbit. But launching parts up over time like that could get expensive. Beyond these issues, astronauts going to Mars would be exposed to high levels of radiation as well as suffer the effects of microgravity (losing about one per cent of their bone mass each month). There would be psychological fallout from being so far from home too.

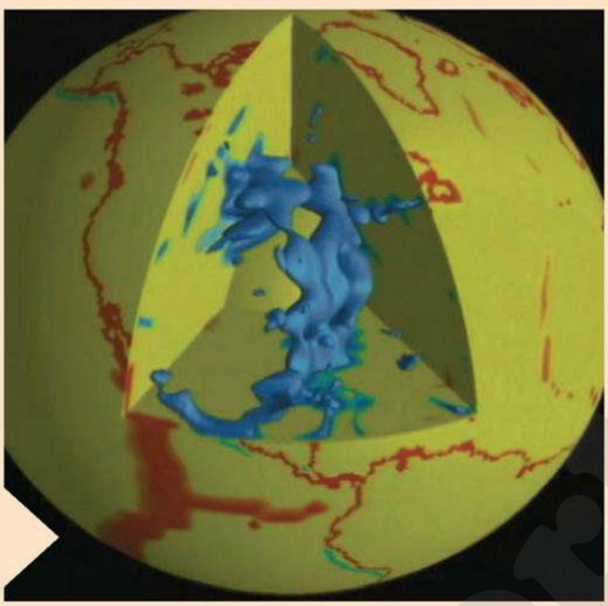
Shanna Freeman

What is the Farallon Plate?

Andrew John

■ During the Permian period, about 300 million years ago, all of the Earth's landmass was joined together into a single continent called Pangaea. What would eventually become the Americas was on the west coast of Pangaea and the tectonic plate that comprised the seabed that lay to the west of that is known as the Farallon Plate by geologists. When Pangaea began to break up about 200 million years ago, the Farallon Plate slid under North America and into the Earth's mantle. This caused the land above it to buckle upwards to form the Rocky Mountains. The Farallon Islands, 43 kilometres (27 miles) west of San Francisco, are all that is left of the Farallon Plate, which will slide completely beneath America in another 5 million or so years.

Luis Villazon



Why's the Arctic Ocean so flat? Find out on page 86

What is pareidolia?

Farouk Patek

■ Do you ever think you can see your best friend's face in the clouds? What about the Man in the Moon? This is an incompletely understood phenomenon called pareidolia. Many theories exist to explain it, including religious, scientific, evolutionary and psychological explanations. The most likely is that the complex human brain attempts to make patterns out of random data as it tries to interpret it. Evolutionary theories suggest we are pre-programmed to recognise faces, both for protection and defence. Religious theories suggest these patterns come from higher sources. This includes a woman who saw the face of Jesus on a tortilla in 1978; thousands trekked to rural New Mexico to worship it.

Aneel Bhangu

BRAIN DUMP

Because enquiring minds want to know...

What exists in intergalactic space?

Find out on page 87

Want answers?

Send us your questions using one of the methods opposite and we'll get them answered

Why are there so few waves in the Arctic?

Sarah Jameson

■ The Arctic Ocean is already the smallest of the oceans and it is tightly contained by the landmasses of Russia, Alaska, Canada and northern Europe. This means that large ocean swells from storms around the world don't penetrate the Arctic. In winter virtually the entire surface is frozen and even in summer, ice covers all the deep water in the centre. Without a central landmass – like Antarctica – the Arctic has little temperature variation throughout the year and thus relatively calm weather. The only waves in the Arctic are raised by local winds and generally don't travel very far.

Luis Villazon

Do other mammals have different 'typical' blood pressures to humans?

Chris Atherton

■ Since blood pressure is partially dependent on height and weight, as well as genes, the answer is most definitely yes. Despite recommended levels, even different humans have a range of what is 'typical'. A minimum blood pressure is needed to keep large vessels from collapsing, so the larger the animal (and thus the blood vessels), the higher the blood pressure needs to be. While dogs and cats have similar ranges to human beings, elephants have a much higher average blood pressure to keep their much larger vessels open. While a 'normal' value in human beings might be considered to be 120mmHg (millimetres of mercury), in an elephant 180mmHg is average. To counter this, elephants have much lower resting heart rates.

Aneel Bhangu

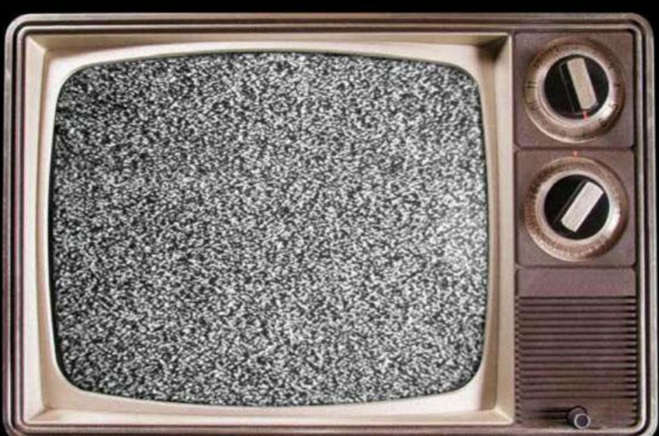
The general rule is: the bigger the animal, the higher the blood pressure

Does TV static really have ties to the birth of the universe?

Lucy Blee

■ Funnily enough, the answer to this is yes and no... Yes, a certain amount of the 'white noise' you see when TV channels are mistuned can be attributed to cosmic background radiation (CBR) – taken as some of the best proof we have of the Big Bang theory. However, other factors included in TV interference are sparks, lightning and solar radiation. And no because as the digital switchover reaches completion in 2013, our televisions will lose their ability to randomly pick up CBR through analogue interference. So if you want to see some aspect of the origins of the universe nearly 13.7 billion years ago, catch it while you can!

Mike Anderiesz

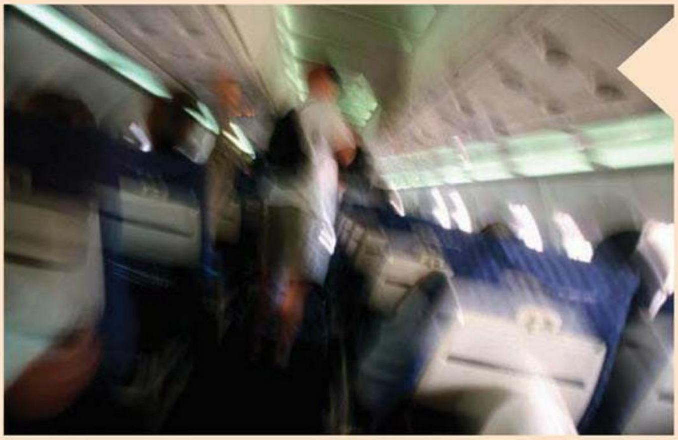


Why does coffee give some people headaches?

Adam Harrison

■ Caffeine is a common stimulant that acts on the central nervous system. Most people know that caffeine comes in tea, coffee, some fizzy drinks and chocolate, but it's in many medicines too. It's also sold in stimulant tablets that some people take to stay awake. Caffeine can both cause and relieve headaches. When in medications, it acts to improve absorption of the other substances in the product, while also causing blood vessels in the brain to constrict slightly, which can relieve headaches caused by dilated veins (eg migraines). However caffeine can also cause headaches; in fact, it's the caffeine withdrawal that causes the pain. Since caffeine normally induces vasoconstriction of the blood vessels in the brain, a sudden lack of it leads to vasodilation (ie the blood vessels swell). This can give a 'pounding' headache, which is relieved as soon as you have some caffeine. It's not just the heavy coffee drinkers who get this; some people can become 'addicted' to very small amounts of daily caffeine.

Aneel Bhangu

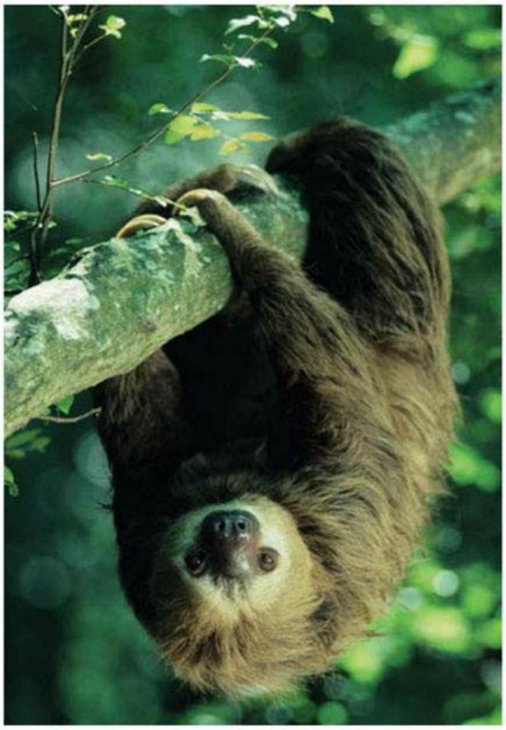


If you jump up on a moving plane, why don't you land farther up the aisle than where you leapt from?

Nathan Young

■ If you jump straight up on a moving plane you will land on the same spot you initially jumped from because the air – and indeed everything else inside the craft – is moving at the same speed as the plane. If it were possible for a stationary observer outside to see you jump, they would witness you moving forward through the air at the same speed as the aeroplane during your leap. Of course, this assumes the plane is moving at a constant speed. If you were to attempt a jump while the aircraft was speeding up or slowing down – and we're certainly not recommending you do! – you wouldn't land in the same spot.

Rik Sargent



Why do sloths generally hang upside down?

Ross Gordon

■ Sloths eat leaves with very little nutritional value; in fact, it takes up to a month for their food to digest. To compensate, they have a metabolic rate about half that of other mammals their size. Since they can't run away from predators or fight them off easily, they hide instead. Hanging below branches makes them less visible to harpy eagles and their claws can grip the branch without using any energy – indeed, sloths won't fall from a tree even if they're shot! Sloths spend so much time upside down that their fur lies the opposite way to most mammals, growing from the paws up to the body.

Luis Villazon

What lies between the galaxies?

Sam Smith

■ Intergalactic space is what lies between the galaxies and many experts believe it to be filled with some kind of super-thin gas. Then again, there is also the theorised dark matter, the mysterious substance that emits neither light nor radiation and is estimated to account for around 85 per cent of the matter in most galaxies. Recent breakthroughs at the Large Hadron Collider could one day throw much more light on this and other questions about the formation and structure of the universe – but until someone accurately measures either dark matter or intergalactic space itself, it's all just theory.

Mike Anderiesz

THE KNOWLEDGE

GAMES / BOOKS / GADGETS / TOYS

FOR CONNOISSEURS OF KIT AND SAVANTS OF STUFF

USB typewriter

Price: £458/$699

Get it from: www.usbtypewriter.com

We are currently typing this review, to the great consternation of the rest of the team, with a USB typewriter. That is to say, an old typewriter that's been converted into a USB keyboard. It's wacky, we'll give it that, and it's also quite functional, with a Back Space key and an old-style return (complete with typewriter 'ping') acting as expected with any digital document. It's enormously inefficient compared to a standard USB keyboard and a fully converted antique typewriter could set you back several hundred pounds, although you can buy the USB kit and convert your own typewriter for under £50 ($80). It's compatible with some tablet devices too, another string to the bow of a gadget that will appeal to novelty lovers.

Raspberry Pi

Price: £25.92/$25

Get it from: www.raspberrypi.org

A rather tasty slice of tech emerged earlier this year called the Raspberry Pi. It's essentially a very small (credit card-sized) yet elegant computing solution that lets you do pretty much anything you could with a normal PC. And because the brains behind the device worked hard to minimise the production cost, it's also very cheap. The snag? Well, apart from high demand making it short in supply, the Raspberry Pi is effectively a bare-bones computer. But it doesn't take a rocket scientist to get to grips with the basics. If you're comfortable installing your own operating system then you should be fine setting up a Raspberry Pi as a tiny media system, console or for dozens of other uses. You will need an SD card for storage and a possible chassis (available separately), but gram for gram, this has to be the most versatile computer in the world.

HOW IT WORKS EDITOR'S CHOICE AWARD

Optical Illusions

Price: £15.99/$19.99

Get it from: www.dk.com

DK's *Optical Illusions* hardcover can't hope to replicate the same impact of a street artist working their perspective magic on the pavement, but this 30-page book is still capable of captivating even the most jaded souls. Within are several dozen optical illusions from old classics to newer designs that have emerged over the decades with advances in our understanding of how the brain and eyes work. *Optical Illusions* is suggested for 7-12 year olds, but it's quite capable of engaging anyone of any age for half an hour or so.

HOW IT WORKS

TYPEWRITER TECH

A mechanical keyboard is connected to a basket of typebars. When pressed, it's guided by a segment channel up to the unit's ribbon. When struck by the head of the typebar the corresponding ink-covered letter is printed onto the sheet of paper.

HOW IT WORKS

PI ORIGINS

This device was invented by the Raspberry Pi Foundation, a charity set up by Cambridge University colleagues in order to promote computer science and amateur programming.

HOW IT WORKS

HOW MICROPHONES WORK

Sound vibrates a thin diaphragm of material, which transfers this energy into other components that convert it into an electrical signal. Mics are transducers – devices that convert energy from one form into another.

Tiki USB microphone

Price: £59.99/$59.99

Get it from: www.bluemic.com

Noise-cancelling and intelligent sound used to be the exclusive domain of headphones and headsets – but not any more. Those looking for high-quality recording from their portable mic would do well to consider the Tiki USB microphone. It switches from intelligent speech mode to natural recording, an ideal solution for Skype or conference calling and recording acoustic audio sounds, respectively, eliminating unwanted background noise and all the while enhancing the targeted audio. It's money worth spending if you can't risk your audio being spoiled by lo-fi technology.

HOW IT WORKS

STREET ILLUSIONS

Optical illusions have become hugely popular among street artists recently, who use converging lines and shadows in their art to trick our brains into perceiving holes in the road, deep pools and more.

Bayan Audio 3 speaker dock

Price: £159.99/$N/A

Get it from: www.bayanaudio.com

A beefy base and good-quality amplified sound are generally the main requirements of a speaker dock. On that basis, the Bayan Audio 3 should meet your needs, although you do get more than that. In the same way that bigger audio systems emulate surround sound, this device emulates stereo while adjusting for the effects of potential interference from mobile phone and other radio signals. It's sturdy too and, though we can't say it would suit all as a replacement for a home stereo system, you get a lot of boom for your buck.

HOW IT WORKS

IPHONE DOCK CHARGING

Apple iPod and iPhone dock adaptors exist that allow you to charge newer Apple devices in old docks. These work by sitting on top of the dock and re-routing the power from the old pin configuration to the pins of your new device.

HOW IT WORKS

HOW HELICOPTERS FLY

Regardless of whether it's a model or a full-scale chopper, helicopters obey the same rules of physics. The angled rotor spins and cuts the air, pushing it downward and causing the helicopter to lift.

Helo TC Assault

Price: £49.99/$59.99

Get it from: www.griffintechnology.com

We'll take any excuse to play with toys in the office, especially flying ones capable of irritating the rest of the **How It Works** team! Stick four AAA batteries into the Helo TC Assault's flight transceiver, download the free app to any iPhone, iPad or smartphone device and you're ready to take off. The controls are straightforward enough: a tactile slider on your device's touchscreen accelerates the rotors while a virtual joystick and buttons control pitch, yaw and direction. That's the theory anyway… The TC Assault suffers from the same problem as other remote-controlled choppers. Holding it aloft and flying it in the direction you want it to go for more than a second or so is impossible – it's like trying to stop a helium balloon on a string from doing what it wants in a crosswind. The TC Assault does shoot twin plastic missiles on command though, which by the sheer merit of annoying your workmates goes a long way towards redeeming this toy.

APPS OF THE MONTH

Brought to you by **Apps Magazine**, your essential guide to the best iPhone and iPad apps available on the Apple App Store

iPad: Creatures of Light

Price: Free

Developer: American Museum of Natural History Entertainment Ltd

Version: 1 **Size:** 484MB **Rated:** 4+

Creatures of Light came to be thanks to the American Museum of Natural History, and a new exhibition celebrating natural bioluminescence. A large portion of the app is dedicated to immersive diagrams and animations of the science behind this phenomenon, making the entire subject feel more accessible, which helps you to appreciate the information and images of firefly shows even more. The interface is also not to be scoffed at, with animated backgrounds on a lot of the text-heavy screens to help prevent the app becoming too serious.

Verdict:

iPhone: Camera Awesome

EDITOR'S CHOICE AWARD

Price: Free

Developer: SmugMug

Version: 1.04 **Size:** 18.1MB

Rated: 4+

Camera Awesome seems to have taken its inspiration from Doctor Who's TARDIS, in that from the outside it looks like a standard photo-editing app, but open it and you're presented with a much larger world. The Awesomize feature alone comes with a host of scrollbars to modify your snaps. It appears developer SmugMug has thought of everything.

Verdict:

Soundbar audio

Those tinny flatscreen speakers just won't cut it any more – let's get serious about sound…

Orbitsound T9

Price: £199/$N/A

Get it from: www.orbitsound.com

A hell of a kick comes out of these little boxes, which straddle the line between high-end dock and mid-low TV audio. Apparently the shorter and more horizontally aligned of the Orbitsound T9's main components qualifies as a mini-speaker bar, though there's little difference between this and many an iPod dock we've reviewed. It's nothing to complain about though, especially once the T9 is turned on. It has a respectable punch to the audio and the kind of bass bound to have your neighbours a-knocking if it's past the 11pm threshold. Orbitsound's spatial sound technology means stereo audio will follow you wherever you are in the room, and a dock allows for easy smartphone and Apple device playback, with standard line-in and a surprising digital optical feed for higher-tech audio. The T9 does tend to distort when it approaches maximum volume, but this is a compact device designed for games consoles and bedroom setups rather than full home cinema systems, so this shortcoming is easily excused.

Verdict:

Roth Sub Zero

Price: £149/$N/A

Get it from: www.rothaudio.co.uk

It's refreshing to see a British tech company present a challenge to the audio giants. Roth's answer to the terrible state of affairs that are flatscreen TV-integrated speakers is the Sub Zero. And if simplicity equals cool, then this soundbar easily deserves its name. Plug the audio into the Sub Zero, then the Sub Zero into its power source and you're in business. Not that Roth's follow-up to the BAR 1 is an unsophisticated piece of kit – it's just very well designed. Mini jack, RCA or optical, all input functions can be selected with or without the supplied remote so you can be up and running in less than a minute of getting the Sub Zero out of its box. The sound quality really belies the price too: it's equal to anything we've heard that's half the Sub Zero's RRP again, with a warm bass and incredibly unmuddied mid-tones coming from an integrated subwoofer system. It might not be a brand you're familiar with, but don't allow the suspiciously reasonable price tag to set the alarm bells ringing – the Roth Sub Zero is a bona fide bargain.

Verdict:

Yamaha YHT S401

Price: £399/$699.95

Get it from: http://yamaha.com

Nudging the brink of mid-range audio is Yamaha's YHT S401 with some impressive stats. It has a 250-Watt total output plus a 100-Watt subwoofer, several inputs that include multiple HDMI and digital optical, several sound modes, FM tuner and 7.1 surround tech. It's not true surround sound, of course, but the Air Surround Xtreme (not to be confused with IntelliBeam technology) is Yamaha's slant on the kind of acoustic magic available today that tricks your ears into thinking you're immersed in sound. It's no dead ringer for a quality 7.1 speaker setup, but it is head and shoulders above a standard stereo soundbar. Plus, rear speakers are an optional add-on, so you can connect them for a true 5.1 system. The woofer is reassuringly heavy and the tri-speaker bar will span the length of most flatscreen TVs, but that's only a testament to the kind of sound this system puts out. Even if, when pushed to high volume, the bass tends to drown out other sounds, it's a tasty bit of kit so long as you're happy to shell out a little more cash.

Verdict:

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HOW TO...

Essential skills for surviving in the modern world delivered step by step

FELL A TREE WITH A CHAINSAW

Follow these simple steps and you'll be a lumberjack in no time

1 Groundwork

First of all, a fall path must be determined. This is where the tree will drop once cut and, ideally, should be devoid of other trees, rocks and buildings, etc. It's crucial to weigh up all eventualities, and if a tree could potentially fall on a number of objects it's best left for a professional. Note: it's always easier to make a tree fall in the direction it's already leaning.

© Thinkstock

2 Notch

With the fall path – and a retreat path – worked out, put on your safety gear. Nex, you need to make a notch, a wedge-shaped incision in the direction you want it to fall. There are different types of notches, but here we'll use the Humboldt. Take the chainsaw and cut into the tree horizontally at waist level to roughly a third of the trunk's diameter. Then cut once more beneath the initial incision at an angle so you get a V-shaped, 45-degree-plus wedge.

3 Backcut

You should now be able to remove the notch easily. Inspect its cleanness as inconsistencies can affect the direction the tree falls. If all is well we can make the final backcut. This is made on the opposite side of the trunk to the notch and should run horizontally through it at the same level as the notch's top edge. Importantly, when cutting, you need to stop when there is one-tenth of the tree stump left between the notch and the backcut.

4 Timber!

As soon as you have this small slice of trunk between the notch and the backcut it's time to get out of there! The direction of a safe retreat from any tree should be diagonal – never move directly back as when it falls it can generate kickback. As for distance? The farther the better, as falling trees can create a lot of noise and collateral damage. Now's your chance to yell "Timber!" as a final warning.

5 Bucking

If all has gone to plan your tree is now safely on the ground. But the real work has just begun as now the tree needs to be limbed – the removal of all its branches – and then bucked – the sawing of it into logs. Always stand on the uphill side of the lumber just in case it rolls.

FLY AN APACHE HELICOPTER

How It Works gets some hot tips from Apache pilot Captain Alex Harris of 4 Regiment Army Air Corps on flying one of the planet's most cutting-edge choppers

1 How do you get off the ground in an Apache?

We can take off vertically into the hover like any other helicopter, but when we are heavily laden we prefer to conduct a running takeoff, using a runway like an aeroplane. For both techniques we will pull the collective lever up to increase power from the engines and change the angle of attack of the rotor blades, which together generate more lift. When the helicopter's lift is greater than the weight, we go up!

2 Tell us about some of the unique instrumentation within this helicopter.

The British Army's version of the Apache is very advanced. All the instrumentation is displayed on glass screens and the crew can switch between the instruments and data displayed depending on the needs of the mission. There are cameras on the front of the aircraft that display an infrared picture to us through the monocle over our right eye. We use this image both for flying and operating the Apache's weapon systems. Our helmets have sensors in them allowing us to slave the cameras and the gun to point wherever our heads are facing.

3 How are the Apache's weapons deployed?

We have three sights that we can use to fire the weapons: the helmet-mounted display (HMD), the Modernised Target Acquisition and Designation Sight (MTADS) and the Fire Control Radar (FCR). All three can be used to fire the Apache's trio of main weapon systems: 30-millimetre (1.2-inch) cannon, Hellfire missiles and rockets. The primary sight is the MTADS, which has a powerful built-in laser that directs laser-seeking missiles all the way to the target. The FCR can find targets several kilometres away and it passes co-ordinates to the radar missiles, which will then autonomously track and hit the target. The HMD is very useful for self-defence and we can engage targets simply by looking at them through our monocle, selecting the cannon and pulling the trigger.

Weapons include rockets, missiles and a 30mm (1.2in) cannon

4 What kind of special manoeuvres can you perform in this aircraft?

The Apache is highly manoeuvrable; it can fly a loop and conduct some pretty impressive wing-over manoeuvres. If we are engaged by a threat we can very rapidly lose height simply by rolling the aircraft on to its side and reducing power. Once we near the ground we can pull the power in and the aircraft will transition back to level flight very

6x © MOD

NEXT ISSUE
- Survive a nuclear explosion
- Shear a sheep


Advanced tech in the pilot's helmet enables them to turn the Apache's cameras in whatever direction they're looking

quickly. The pilot is aided by a sophisticated stability system that assists with keeping the helicopter's flight on a smooth profile. The aircraft holds system can put the Apache in a very stable hover, which is useful for using weapons at low level.

5 How do you go about landing an Apache?

The Apache is able to land like any other helicopter in that, by reducing the collective lever and power demand, the lift will reduce and the weight of the aircraft will cause it to descend. This can be done very quickly if required and all that is needed at the bottom is a slight application of power to cushion the landing. We can also land like an aeroplane and conduct a running landing on a runway or a ship, which is useful if we are heavy or short on power.

6 Why is the Apache so highly rated among military helicopters?

The Apache has been tried and tested by the American military over many years so it already has a very good reputation. The UK Apache is as technologically advanced as battlefield helicopters get right now so is admired across the aviation community. Where the UK Apache has made its name though is on operations in Afghanistan and Libya, where we provide firepower to the soldiers on the ground. By combining the technology of the aircraft with the attitude and professional aggression of the pilots the Apache is often seen as mission-essential equipment. Infantry know that if they get into trouble an Apache is minutes away and the sight of one is often enough to scare off an enemy. It can be a deterrent without even having to resort to firepower.


Apaches are ideally suited for taking off from sites with limited space like aircraft carriers, though they can also take off like a normal plane

electronics and follow the manufacturer's instructions.

TEST YOUR KNOWLEDGE

ENJOYED THIS ISSUE? WELL, WHY NOT TEST YOUR WELL-FED MIND WITH THIS QUICK QUIZ BASED ON THIS MONTH'S CONTENT?

1 What is the average life span of a great white shark?
A: ____________

2 Which body does the acronym IEEE represent?
A: ____________

3 On which coastline is the Durdle Door rock arch?
A: ____________

4 What size can a male narwhal's tusk grow to?
A: ____________


© NASA

5 How high did the plume from 1815's Mount Tambora volcanic eruption reach?
A: ____________


© SPL

6 Who discovered the first free radical?
A: ____________

7 Which is the closest planetary nebula to Earth?
A: ____________

8 How fast could the velociraptor accelerate in miles per hour?
A: ____________

9 What is the top speed of the Shelby GT500 muscle car?
A: ____________

10 By what percentage is Eris bigger than Pluto?
A: ____________

ENTER ONLINE

at **www.howitworksdaily.com** and one lucky reader will win not just one but a duo of cutting-edge land rover models, courtesy of Airfix

> ISSUE 37 ANSWERS
1. Airbus A320 **2.** Little Boy **3.** 309.6m **4.** Thomas Newcomen **5.** 8,000 **6.** 63,600kg **7.** 1780 **8.** Ara ararauna **9.** 420 tons **10.** 27.5%

INBOX

Feed your mind. Speak your mind

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© Thinkstock

This summer Colorado has seen some of the most destructive forest fires in the state's history

© ThyssenKrupp

Get in touch!

We enjoy reading your letters every month. So keep us entertained by sending in your questions for the mag, comments on what you like/don't like, or any science-related news you want to share.

FANTASTIC PRIZE FOR LETTER OF THE MONTH!

WOWee ONE™

WIN A WOWEE ONE PORTABLE SPEAKER

This issue's top letter wins a WOWee One Classic portable speaker. This turns any surface into a bass amplifier using gel technology, and is compatible with all iDevices and other mobile gadgets.

Win! A WOWee One portable speaker

Letter of the Month

Native know-how

Dear **How It Works**,
The distressing article on Colorado's inferno (issue 36) left me fearing that the efforts being made to extinguish the fires will only worsen matters in the long run. The Native American Indians knew the value of controlled burning to promote new growth and, crucially, to burn away tinder before it could accumulate into sufficient fuel to feed an inferno, just waiting for a lightning bolt to spark it. The damage wrought in Colorado made for terrifying reading with 35,323 hectares (87,284 acres) burnt in the High Park area alone. The question in my mind is: why was the environment allowed to produce the massive quantities of fuel that must have been building up for years? Maybe the authorities should consult a few more Native Americans.
Alan Thomas, Shepperton, UK

Thanks for writing in with your thoughts on this story, Alan. Sometimes this kind of native knowledge is brushed aside to give way for conventional Western 'wisdom'; sometimes the knowledge is lost or unknown to the authorities; and sometimes – on a more cynical (yet unfortunately realistic) note – money and industry can override any environmental concerns. It's difficult to know for sure which of these factors (if any) was to blame for the Colorado fires, but whether a disaster is man-made or natural, it's interesting to see nature find a way. In the case of disastrous forest fires, there are some shrubs and trees that are serotinus – ie they depend on fire to release seeds from their casings. Glad this article prompted some thought – we hope you will enjoy the WOWee portable speaker which you've won for your insightful letter.

With the current understanding and technology we can only make an educated guess at how black holes work

© NASA

Is there a hole in that theory?

Is it actually possible to send a satellite or a probe through a black hole?
Shawn Trumbly

HIW: Hi Shawn. It's not possible to send a probe through a black hole for a few reasons. For one, the nearest black hole to us is V4641 Sgr, which is thousands of light years away. We have barely managed to send a probe out of our own Solar System yet. V4641 Sgr was just discovered in 1999 and we know very little about it, so just finding a black hole is an inexact science. Then even if we could manage to get a probe into one, it wouldn't be able to return any images or data because of the very nature of black holes: the gravity is so strong that no light of any kind (including radio waves) can escape.
Answered by Shanna Freeman

I'm a believer!

The person enquiring about the 'taboo' subject of UFOs should be informed that they are indeed real. Little else is known.
R N Hadley, Hectorville, Australia

Core learning

Dear HIW team,
I was reading issue 36's Brain dump when an article headed 'What's the deepest hole we've ever dug?' caught my eye. You answered it by saying that the deepest hole ever dug was 12,262 metres (40,230 feet). But you also stated that at around 1.5 million metres (4.9 million feet) down temperatures would exceed more than 300 degrees Celsius (572 degrees Fahrenheit), more than any drill can cope with. But what if we made a drill with a core of, say, reinforced steel or titanium and coated it with the heat-proof material they make spacesuits out of? Would we be able to get deeper then? It probably wouldn't work, but it was just a thought. I've just got a couple more comments about your magazine before I finish: I think it's great – in fact, I've probably learnt more from it than I have from my seven years at primary school!
Harvey Wilson (11)

The Bagger 288 can excavate around 240,000 tons of material every day!

"Curiosity landed safe and sound and is currently surveying its surroundings and taking photos"

Curiosity could kill the rover…

Hi **How It Works**,
Love issue 36, especially the 'Life on Mars' feature – but just one thing: I don't even think this new rover will make it to Mars. Those 'seven minutes of terror' will be the end of Curiosity. The problem is that NASA has a tried-and-tested system of landing vehicles on Mars and now they're going for a really big rover and, instead of sticking to a proven parachute drop, they've got a rocket booster. There's just too much that can go wrong. Oh well, Spirit and Opportunity had a good run and it was good while it lasted!
Ioan Griffiths, Cardiff, UK

HIW: You spoke too soon, Ioan! Perhaps it seemed improbable, but Curiosity has landed safe and sound in Gale Crater and, at the time of writing, is currently surveying its surroundings, taking photos and zapping rocks so the engineering team can determine how to safely advance. You must hand it to the NASA team – they're pretty adept at the business of Mars exploration.

Metal monster

I really loved your '7 engineering wonders of the world' article (issue 35). I think the wonder that wowed me the most was the Krupp Bagger 288. I still can't believe such a monster exists. I mean, a bulldozer can fit into just one of the buckets on its excavating arm – insane! Why would anyone need such a thing? Surely a fleet of mining vehicles could do the same job and for cheaper? Anyway, keep bringing these mind-boggling things to my attention, **HIW**!
Carly Sarson

What's happening on… Twitter?

We love to hear from **How It Works**' dedicated readers and followers, with all of your queries and comments about the magazine and what you'd like to see explained. Here we select a few of the most interesting tweets that we've received in the last month.

TheHubbard
@HowItWorksmag
To add to the brilliance of the day with the exciting news Curiosity landed, my new @HowItWorksmag arrived!

MegabyteTND
@HowItWorksmag
If you made a sphere from a one-way mirror, with the shiny side inside, and shone light in it, what would happen?

blogofjchen
@HowItWorksmag
On holiday, first thing I'll do on return is read my new How It Works mag

xadusx
@HowItWorksmag
This is ASM! Technology for life! Thanks to @howitworksmag for feeding me this kind of news

kyrachristenson
@HowItWorksmag
Just sat down to read my new issue of @HowItWorksmag. What an amazing magazine! Lazy Sunday, ahhh…

HOMOsapian86
@HowItWorksmag
Loving issue 36. WOW! A cheetah going that fast – never going in a race against one, that's for sure :D

alunvaughan
@HowItWorksmag
Feeding my brain with my new discovery @HowItWorksmag :-) It keeps my inquisitive inner child happy!

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Imagine Publishing Ltd
Richmond House, 33 Richmond Hill
Bournemouth, Dorset, BH2 6EZ
+44 (0) 1202 586200
Web: www.imagine-publishing.co.uk
www.howitworksdaily.com
www.greatdigitalmags.com

Magazine team

Editor **Helen Laidlaw**
helen.laidlaw@imagine-publishing.co.uk
01202 586215

Editor in Chief **Dave Harfield**
Features Editor **Robert Jones**
Features Editor **Ben Biggs**
Art Editor **Helen Harris**
Senior Sub Editor **Adam Millward**
Head of Publishing **Aaron Asadi**
Head of Design **Ross Andrews**

Contributors
Mike Anderiesz, Emma Bastian, Aneel Bhangu, Shanna Freeman, Tom Harris, Jonny O'Callaghan, Ormsby and Thickstun Interpretive Design, Lynsey Porter, Dave Roos, Rik Sargent, Michael Simpson, Adam Smith, Luis Villazon, Jonathan Wells, Emily S. Damstra

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01202 586442
hang.deretz@imagine-publishing.co.uk

Account Manager Liz Tucker
01202 586431
liz.tucker@imagine-publishing.co.uk

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Head of International Licensing Cathy Blackman
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Circulation
Head of Circulation Darren Pearce
01202 586200

Production
Production Director Jane Hawkins
01202 586200

Founders
Group Managing Director Damian Butt
Group Finance and Commercial Director Steven Boyd
Group Creative Director Mark Kendrick

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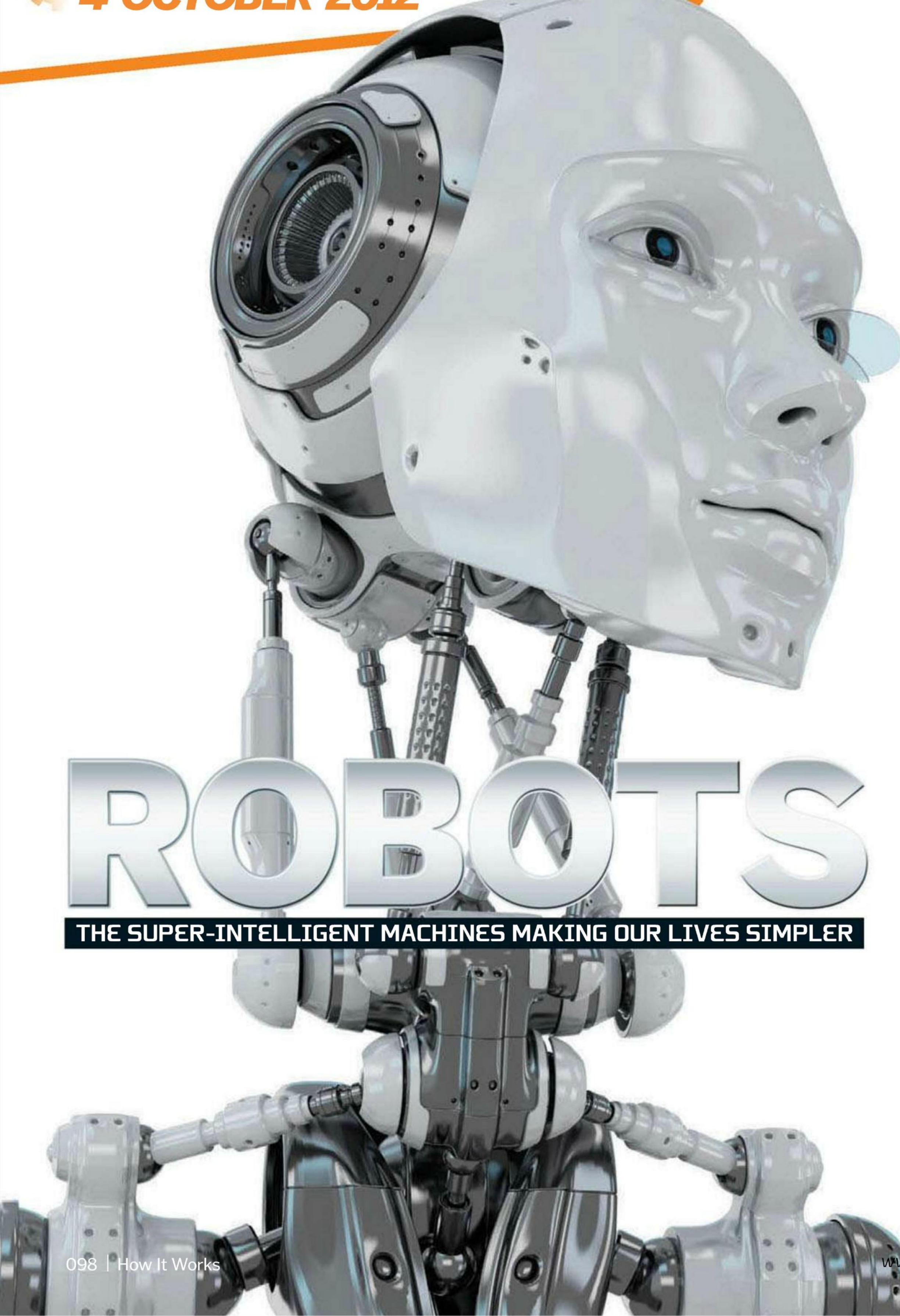

ROBOTS

THE SUPER-INTELLIGENT MACHINES MAKING OUR LIVES SIMPLER

ANSWERED NEXT ISSUE

What happened in the Industrial Revolution?

How was Earth's tallest tower constructed?

What can bring on anaphylactic shock?

How do spacecraft dock with the ISS?

What's inside this armour-plated reptile?

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