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- **How to beat jet lag**
- What airport scanners can see
- **Why your body isn't flat**

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ELECTRONIC TATTOOS
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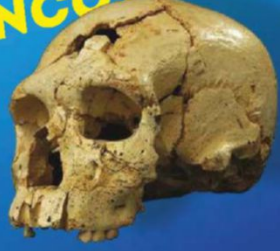

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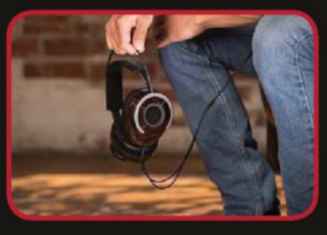

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WELCOME

LAST YEAR I visited beautiful Down House in Kent, where Charles Darwin lived. While I was there, I imagined him sitting in his old study, writing his famous theory about evolution by natural selection. Darwin's ideas still endure to this day, but now scientists are finding out more about how evolution really works. Nessa Carey brings us up to date on the emerging field of epigenetics on p48.

This summer, exciting things are happening. Formula E zooms into the UK with races in London on 27 and 28 June. Find out more about the gadgetry inside these cars on p72. Sticking with futuristic technology, Solar Impulse 2 – the solar-powered plane – is on course to complete its groundbreaking round-the-world flight very soon. Turn to p56 to track its trip.

July marks the 30th anniversary of *Back To The Future*, the film that saw Marty McFly travel back in time. But what would happen if we tried this in real life? John Gribbin examines time travel paradoxes on p40.

Elsewhere, we examine the prospects of life on Pluto (p32), ask Prof Melvin Konner why women are superior to men (p46), and explain dark matter in 10 minutes (p76). Enjoy the issue!

Graham

Graham Southorn, Editor

PS Don't miss our August issue, on sale 23 July 2015

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THIS MONTH WE...

...had a fantastic day at the Cheltenham Science Festival. We met some scientists, enjoyed a selection of talks and got up close with wonder product of the moment: graphene.

...narrowly missed our heads as we tried out the DJI Phantom 3 quadcopter. It comes complete with a 1080p camera that can livestream to YouTube. We pit it against other cameras on p88.

...found out how to clone a mammoth. Listen to our interview with evolutionary biologist Beth Shapiro in our podcast: www.sciencefocus.com/podcasts

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APPEARING IN THIS ISSUE...

Nessa Carey

Nessa is author of *Junk DNA* and *The Epigenetics Revolution*. On p48 she uncovers the latest news about epigenetics and finds out whether Darwinian evolution needs a rewrite.

John Gribbin

Science writer and astronomer John examines some mind-bending time travel paradoxes on p40, inspired by the 30th anniversary of *Back To The Future.*

Helen Pilcher

On p106, Helen tells us more about intelligent killing machines, such as those in the new *Terminator* movie. Her book on de-extinction, *Bring Back The King*, is published next year.

Govert Schilling

Poor Pluto. Its planet status was ripped away in 2006. But the New Horizons mission could change all that. Science writer and astronomer Govert investigates on p32.

WANT TO SUBSCRIBE? Turn to p30 to get five issues of *BBC Focus* for just £5

SUBSCRIBER BONUS On p30, **Robert Matthews** explores the ways in which probability can tell us more about the Universe

COVER: NASA/JOHNS HOPKINS UNIVERSITY, MANIPULATION BY ANDY POTTS

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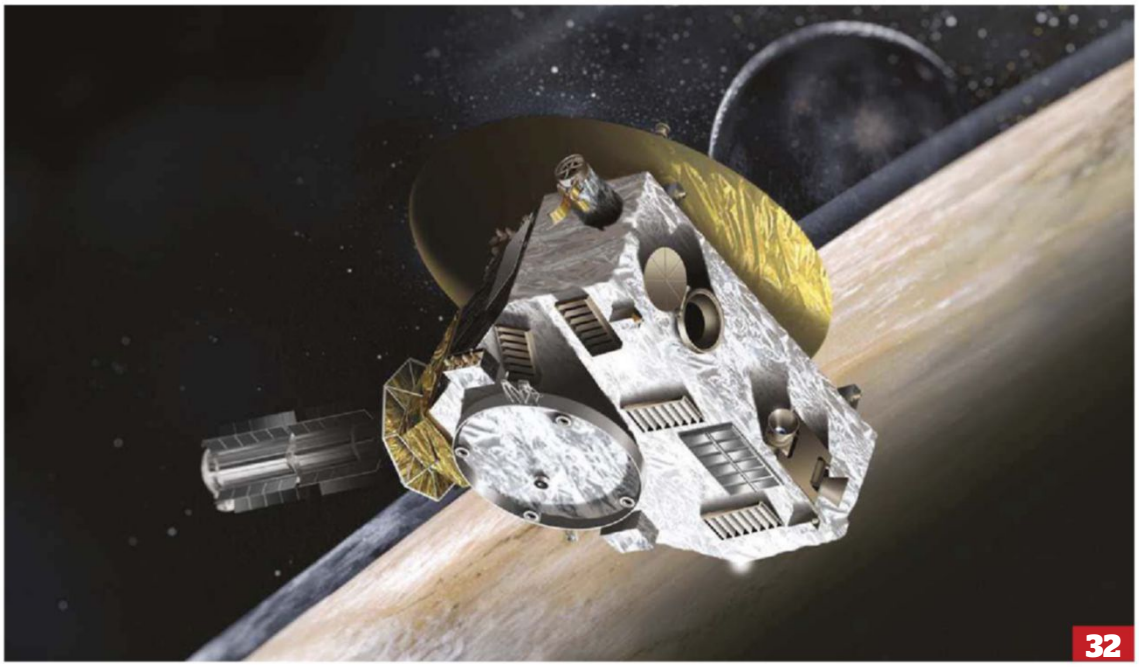
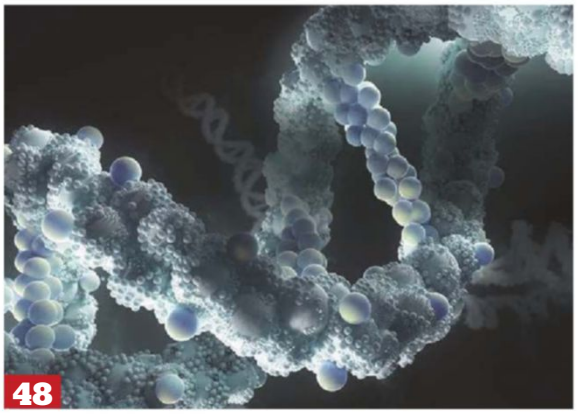
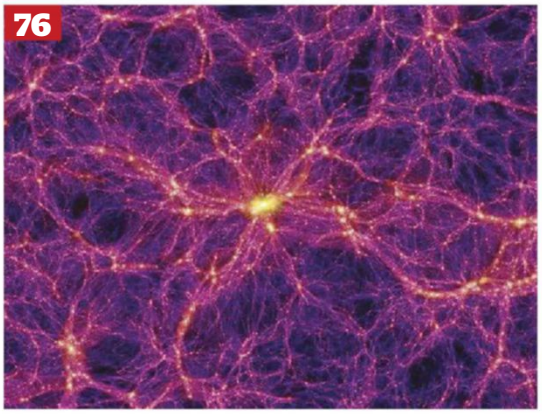
ON THE COVER

FEATURES







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Awe-inspiring images from the world of science

MegaPixel

Flipping freezing

THIS GIANT HUNK of gleaming ice is the underside of a recently overturned iceberg. When icebergs are irregularly shaped or melting, they can become imbalanced and flip over, releasing energies comparable to that of an atomic bomb.

"An iceberg will flip depending on its geometry as well as its density. If it is tall and skinny, it will tip over," explains Justin Burton, Assistant Professor of Physics at Emory University, Atlanta.

While iceberg flips rarely occur, increases in temperature due to climate change are making it more common, he says.

The newly exposed underbelly of the iceberg has not been sullied by snow, debris or weathering, so light can shine through it more easily, giving it a vibrant, aquamarine hue.

"The blue colour means it came from depth and was formed under pressure," says Burton. Bubbles and air pockets were pushed out of the ice, meaning that the light can travel further into the iceberg before scattering. "The further it travels, the more red it absorbs and the bluer it looks," adds Burton.

PHOTO: ALEX CORNELL

MegaPixel

Cake hole

OCCUPYING A SPACE of 34km^3, Tagebau Hambach is the largest open-pit coal mine in Germany. The mine is so vast that it would take 340 Royal Albert Halls to fill it. Gigantic bucket-wheel excavators, each about the length of seven London buses, hew out great chunks of material, exposing cascading layers of sand, soil and coal as they go.

"The excavator wheels have large teeth that dig continuously, throwing the material onto a series of conveyor belts and towards the mine output," explains Guido Steffen of RWE, the company that runs the mine. "There's no need for them to separate the materials because nature has already created these distinct soil layers like a piece of cake."

The vast size of the mine means it can produce up to 40 million tonnes of coal every year, he says.

PHOTO: BERNHARD LANG/GETTY

For more great pictures, follow us on
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MegaPixel

Fizzy drink

THESE ICY PANCAKES are pockets of methane gas, frozen beneath the surface of Lake Minnewanka in Banff National Park, Alberta, Canada. The gas is produced by microbes that help to decompose plant and animal remains on the oxygen-starved lakebed.

"If oxygen is lacking, then microorganisms will process organic material by anaerobic pathways that produce methane as a by-product," says Prof Mary Edwards of the University of Southampton.

Small amounts of methane dissolve in the water and diffuse out of the lake without anyone noticing, but larger collections of the gas rise to the surface in bubbles. When the surface of the lake is frozen, the bubbles have nowhere to go and freeze beneath it, as can be seen in this picture.

"They're in columns because bubbles come from particular points where there is a tiny crack," says Prof Edwards. "As the lake gradually freezes from the surface downwards, it captures a longer and longer column of the bubbles coming up from the bottom."

PHOTO: PAUL ZIZKA

REPLY

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MESSAGE OF THE MONTH

Concorde might have had its day, but commercial supersonic flights could still make a comeback

Hypersonic hopes

IN THE JUNE issue's Q&A, I enjoyed the question about supersonic flight. Your expert says that HyperMach plans to fly a hypersonic [over five times the speed of sound] prototype aircraft in roughly eight years time, but it will cater for around 20 passengers.

In 2012, I attended a series of lectures by Peter Finlay. Finlay was a former Chief Flight Engineer with the British Airways Concorde fleet and is still involved in the aviation industry. In his last lecture, he told us about a company called Reaction Engines, which is founded by Alan Bond. Reaction Engines claims they will be able to build a plane with normal takeoff/landing that can transit to hypersonic speeds and then land again as normal, using one type of engine for propulsion. The result will be a plane capable of travelling from London to Sydney in five hours while carrying 200 passengers. Finlay said that Reaction Engines is aiming to do this "in a few years".

Reaction Engines has been contacted by the European Space Agency (ESA) and the United States Air Force Research Laboratories, who have conducted feasibility studies on the engines and are very interested in the progress Reaction Engines has made. Of course, these engines might not see the light of day as the cost of development may be beyond a reasonable amount. But still, I'm sure that we will see supersonic, if not hypersonic, aircraft in our skies again.

Adrian Goodison, Cleethorpes

Write in and win! The writer of next issue's Message of the Month wins a Goodmans Aspect Bluetooth Soundbar, worth £99.99. This compact soundbar and home speaker has a magnetic base, so you can position it horizontally or vertically. And you can use NFC technology to easily pair the soundbar to Bluetooth devices for streaming music. **goodmans.co.uk**

Why the big Moon?

In June's Q&A, Amirhassan Montazer asked why the Moon appears larger than normal on the horizon. We perceive the sky not as a round dome, like a massive upside-down egg cup, but rather as a flattened dome, like an upside-down cereal bowl (a shallow one). Because of that, when we see the Moon high up in the sky our brain believes that it is closer to us than when we see it way over on the horizon (the flattened bowl is much closer to us above our head than it is on the horizon).

The argument given in your Q&A says that the Moon seems bigger on the horizon because we can compare it to trees and buildings. This seems plausible, yet the theory is somewhat weakened by the fact that we also envisage the Moon as being bigger when we see it on the horizon out at sea. The ocean has no useful reference points that we can compare the Moon to, so why does it still appear larger?

David Canning, Nottingham

You raise a good point about the ocean's horizon, David. We hope astronomers can help us understand this intriguing phenomenon soon! ***– Ed***

Going underground

In 'Britain Beneath Our Feet' (June, p58) you failed to mention that PLUTO is an acronym for Pipe Line Under The Ocean.

John Williams

Operation PLUTO supplied fuel to the UK during WWII

PHOTO, ISTOCK, SANG-YOUL PARK, UC RIVERSIDE, ANDREW GASSON, ANDREW

Drought tolerant plants: handy for lazy gardeners

Does drought-tolerant = GM?

In the April issue, there is a news story called 'Drought tolerant plants' (p27). It says that "researchers have used synthetic biology techniques to help plants conserve water". Is that the same thing as GM? Or am I missing something?

Jason Goodyer replies: *When plants encounter drought they naturally produce abscisic acid, which is a stress hormone that reduces their water consumption. It turns on a receptor (a special protein) that reduces water loss from the plant. This effect can be reproduced by spraying the plants with abscisic acid. Synthetically producing abscisic acid is expensive, so the team genetically engineered these receptors to respond to a chemical called mandipropamid instead, which is much cheaper to make.*

Electric magic

Referring to the article on p81 of the June issue concerning the BMW i8 car, I am rather confused by the mention of "a third tiny electric motor that helps recharge the lithium battery". An electric motor does not generate electricity so could not help to recharge a battery. Perhaps the motor drives an alternator in which case the motor must receive current from somewhere – if from the battery, then it is a closed circuit with the battery recharging itself. I would appreciate an easing of my confusion.
Jack Wilson, Hampshire

Where we've written 'motor', we should have said 'generator'. The petrol motor powers a small, high-output generator that helps recharge the battery. ***– Ed***

The BMW i8's generator charges its battery

The big question

As a layman non-scientist, I greatly enjoy and appreciate the insights I gain from *BBC Focus*. From this perspective, it seems to me that the 'elephant in the cosmological room' is life – what is it, where does it come from, when does it arrive and what happens to it when we can no longer perceive it? There seems to be a resounding silence regarding these matters.
Geraint Lewis, Aberystwyth

Last year, a molecule called isopropyle cyanide was detected in a gas cloud in deep space. This is important because it has a structure that's similar to amino acids, which are the building blocks of life. So potentially, astronomers are on the way to answering your questions. ***– Ed***

Forgotten floods

I was delighted to read Helen Czerski's column in the July issue of *BBC Focus*. It gave a clear explanation of why dry plant pots do not absorb water at once. This could be the reason why there are occasionally flash floods in the Cotswolds and presumably in other hilly areas too. After a very dry spell in July or August, a cloudburst on the hilltops does not immediately wet the fields on which it falls, because the water cascades downhill producing flooding below. In medieval times, such events were known as Margaret Floods because they tended to occur in the few weeks preceding or following St Margaret's Day on 20 July.

Records listed by the Chipping Campden History Society show a number of instances of such floods locally – and it was after the latest, on 20 July 2007, that I found a reference to the historic name of such an event. It seems that St Swithin's Day is now remembered, perhaps because it affects the whole country. The title of Margaret Floods has been more generally forgotten.
Miss RJ Wilson, Chipping Campden

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DISCOVERIES

News and views from the world of science

EDITED BY **JASON GOODYER**


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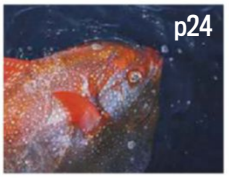
SUB-ZERO SCIENCE
The trials of research in an area where pens freeze, batteries pack up and faces go numb


p12

HEAD BANGING
Archaeologists may have found the earliest ever murder victim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FIN-TASTIC FISH
Discover why this animal is similar to birds and mammals

THE BIG STORY

FIRST LAB-GROWN LIMB TRANSPLANT

This rat biolimb could revolutionise medicine

CALL IT THE body shop of the future: a team based at Massachusetts General Hospital has grown a fully functioning rat forelimb and successfully transplanted it onto a living animal. The technique could lead to the development of biological replacement limbs for amputees.

First of all, the team took a limb from a deceased rat and treated it with a detergent to strip away the soft tissue, leaving behind the basic network of bones, veins and tendons.

Muscle cells are injected into the scaffold of the rat limb

PHOTO: BERNHARD JANK M D/OTT LABORATORY/MASSACHUSETTS GENERAL HOSPITAL CENTER FOR REGENERATIVE MEDICINE

The basic network of bones, vessels and tendons remained

Next, they re-fleshed the limb using cells taken from the recipient, which greatly reduces the possibility of the limb being rejected. This involved injecting vascular cells into the main artery to regenerate veins and arteries, and injecting muscle cells called myoblasts into the appropriate areas of the 'scaffold' to encourage muscle to grow. After leaving it to develop in a nutrient solution for five days, they electrically stimulated the muscles to further promote formation.

When transplanted onto an anaesthetised animal, the limb quickly filled with blood that was able to circulate normally. To determine whether the muscles were functioning, the team stimulated them with electrical pulses and found the animal's limb could flex.

"The composite nature of our limbs makes building a functional biological replacement particularly challenging," explains researcher Harald Ott. "Limbs contain muscles, bone, cartilage, blood vessels, tendons, ligaments and nerves – each of which has to be rebuilt and requires a specific supporting structure called the matrix. We have shown that we can maintain the matrix of all of these tissues in their natural relationships to each other, that we can culture the entire construct over prolonged periods of time, and that we can repopulate the vascular system and musculature."

The team also successfully stripped baboon forearms of their cells to confirm the feasibility of using this approach for humans. However, the next step will be figuring out how to integrate the transplanted limb's nerves into the recipient's nervous system.

"In clinical limb transplantation, nerves do grow back into the graft, enabling both motion and sensation, and we have learned that this process is largely guided by the nerve matrix within the graft," says Ott. "The next steps will involve replicating our success in muscle regeneration with human cells and expanding that to other tissue types, such as bone, cartilage and connective tissue."

TIMELINE
A history of transplant medicine

1997
Dr Charles Vacanti from the University of Massachusetts famously creates the earmouse. This rodent has an ear-shaped piece of cartilage grown onto its back.

1999
US surgeon Prof Warren C Breidenbach performs the first long-term successful hand transplant in Louisville, Kentucky. The patient had lost his hand in a fireworks accident.

2011
Surgeons at Sweden's Karolinska University Hospital transplant a trachea into a cancer patient. The trachea is made from a polymer and covered with the patient's stem cells.

2013
A team at Japan's Yokohama University grows tiny functioning human livers using stem cells. Lab-grown organs could eventually solve the problem of organ shortages.

GOOD MONTH/ BAD MONTH

It's been good for:

DOG OWNERS
WANT TO LEARN to speak dog? You need the latest software created by researchers in Hungary. The algorithm that the team developed can recognise the age and sex of the dog and could even help to interpret the levels of aggression, fear or distress of the animal.

THE FORGETFUL
THESE DAYS THERE'S a password for everything: email, bank accounts, online shopping... remembering them all can be a challenge. Well, help may be on the way. A team at New York's Binghamton University has created the 'brainprint' reader – a device that records the unique pattern of brain activity created as a person reads a certain set of words – that could be used in place of a password.

It's been bad for:

BATS
STREETLIGHTS MAY MAKE us humans feel safer at night but they're bad news for bats. Researchers at Lancaster University have found bats are less likely to fly between trees in brightly lit areas creating 'ecological deadzones'. This could lead to less diversity in bat populations.

HOUSE SHARERS
IF YOU SHARE your bathroom with others you might want to think about buying a new toothbrush. At least 60 per cent of the toothbrushes tested by the American Society for Microbiology harboured faecal matter. To make things worse, there was an 80 per cent chance that the faecal matter on the toothbrush did not belong to its owner.

PHOTO: BERNHARD JANK M D/OTT LABORATORY/MASSACHUSETTS GENERAL HOSPITAL CENTER FOR REGENERATIVE MEDICINE, ISTOCK X2, GETTY

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The perils of sub-zero science

DAVID SHUKMAN
The science that matters

The Lance was deliberately embedded in the Arctic pack ice, to monitor how it changes over the course of a year

RESEARCH CAN OFTEN be done in the warmth of a laboratory. But to study how the Arctic is changing, you need to be prepared to brave some punishing conditions.

On a recent visit to film a Norwegian expedition 800km (500 miles) from the North Pole, the cold was so intense that batteries that should have lasted hours lost all power in a minute, and on one particularly brutal day, when the wind chill was -47°C, icicles formed on our eyelashes. I tried to write some notes but my biro froze, and my face was so numb I had to massage it before trying to record a few words on camera.

We were there to report on research into the state of the Arctic Ocean as the region warms at twice the rate of the rest of the world. Earlier this year, the maximum extent of the winter sea ice was the lowest since records began more than 30 years ago. No one can tell when summers will see no ice at all at the roof of the world, but to improve forecasts for when that might happen, the Norwegian Polar Institute set out to monitor the life cycle of the ice as it forms in winter and melts in summer.

Its research vessel, The Lance, was deliberately jammed into the pack ice to provide scientists with a ringside seat, and we saw how they diligently measured the ice – data that will help to calibrate readings from planes and satellites. The irony is that, despite our living in the space age, a lot of research still involves a pick and shovel. To deploy tracking devices, to verify the snow depth or to check the thickness of the ice, you need to dig a hole, and I got roped in too.

The scientists were adamant that their task was simply to gather the most reliable information, not to jump to any easy conclusions about global warming. But all the signs suggest that the ice is becoming thinner, and that the Arctic wildlife is responding. Change on this scale could affect patterns of global weather. The timing remains uncertain, but a pretty dramatic transformation seems to be under way.

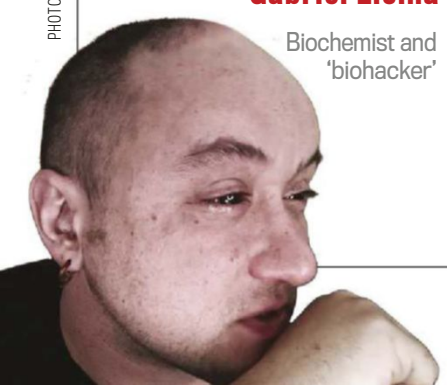
DAVID SHUKMAN is the BBC's Science Editor. @davidshukmanbbc

PHOTO: PAUL DODD/NORWEGIAN POLAR INSTITUTE, GABRIEL LICINA

WHO'S IN THE NEWS?

Gabriel Licina

Biochemist and 'biohacker'



Er... what's a biohacker?
Citizen scientists who conduct DIY experiments such as implanting 'enhancements' such as magnets into their bodies. Based in Seattle, Licina was co-founder of a now-defunct group of biohackers called Science for the Masses.

So what's he been up to?
He had his friend drop a solution of Chlorin e6 (Ce6), a chemical that's similar to chlorophyll, into the conjunctival sac of his eyes.

That sounds dangerous... why on Earth did he do that?
Remarkably, it improved his ability to see in the dark. In tests in a dark forest, he was able to spot people standing up to 49m way. Apparently, the substance influences the way light-sensing rods function in the retina.

Even so, we probably shouldn't try this at home, right?
Right. The researchers say that the substance could affect the cellular structure of the eye. Regardless, deliberately putting chemicals into your eyes is not a sensible thing to do and is generally best avoided.

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10 DISCOVERIES THAT WILL SHAPE THE FUTURE

10 Fish sunscreen

It was previously thought that the fish obtained the gadusol from their diet

ZEBRAFISH NATURALLY PRODUCE a chemical called gadusol that acts as a natural sunscreen. The substance protects the fish from UV radiation, which is the component of sunlight that causes sunburn. Researchers at Oregon State University have figured out how to produce the chemical using genetically engineered yeast. With further study, the researchers think they may be able to create tablets and lotions to help protect human skin.

9 Fat-fighting flora

NEED TO LOSE a few pounds? Celastrol, a compound extracted from the thunder god vine, has been found to reduce food intake and cause a 45 per cent decrease in the bodyweight of obese mice. Harvard researchers discovered that the compound enhances the action of an appetite-suppressing hormone called leptin and

Eat this to get a Zeus-like body

8 Ultra-light metal

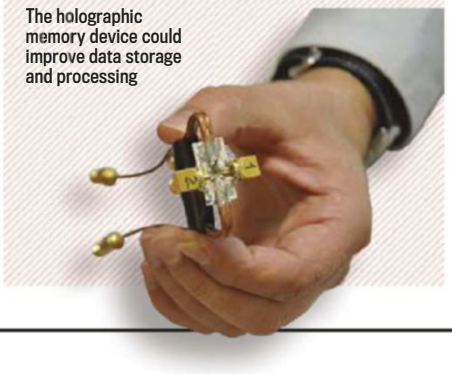
THIS MIGHT FLOAT your boat: engineers in New York have created a metal composite less dense than water. The material consists of a magnesium alloy framework peppered with hollow silicon carbide spheres and could be used to build cars, boats or lightweight aquatic vehicles.

The floaty metal won't be available as a bath toy

7 Holographic speech recognition

FED UP OF your smartphone's voice recognition mistakes? A team at the University of California has created a holographic device capable of storing and searching through millions of patterns in as little as 100 nanoseconds.

The holographic memory device could improve data storage and processing



6 Wearable screens

HIPSTERS TAKE HEED: the tattoo of the future will be electronic. Researchers in Seoul have created an ultra-thin LED display from quantum dots that can be placed directly onto skin like a sticker. It has a resolution of 2,500 pixels per inch and could be used as a wearable screen for smart devices.

The display is far superior to others on the market

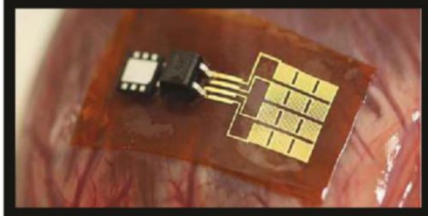
PHOTO: ISTOCK, ERIC SMITH, JOHN ROGERS/UNIVERSITY OF ILLINOIS AT URBANA CHAMPAIGN, ANTOINE CULLY, MIT, MAX HAMEDI, UC RIVERSIDE, NYU POLYTECHNIC SCHOOL OF ENGINEERING

5 Wi-Fi light bulbs

NOW HERE'S A bright idea. A team in Malaysia has come up with [redacted] The technique takes advantage of the fact that the plasma inside the tubes has conducting properties similar to a regular metal antenna. This technology could help eliminate dead spots in buildings.

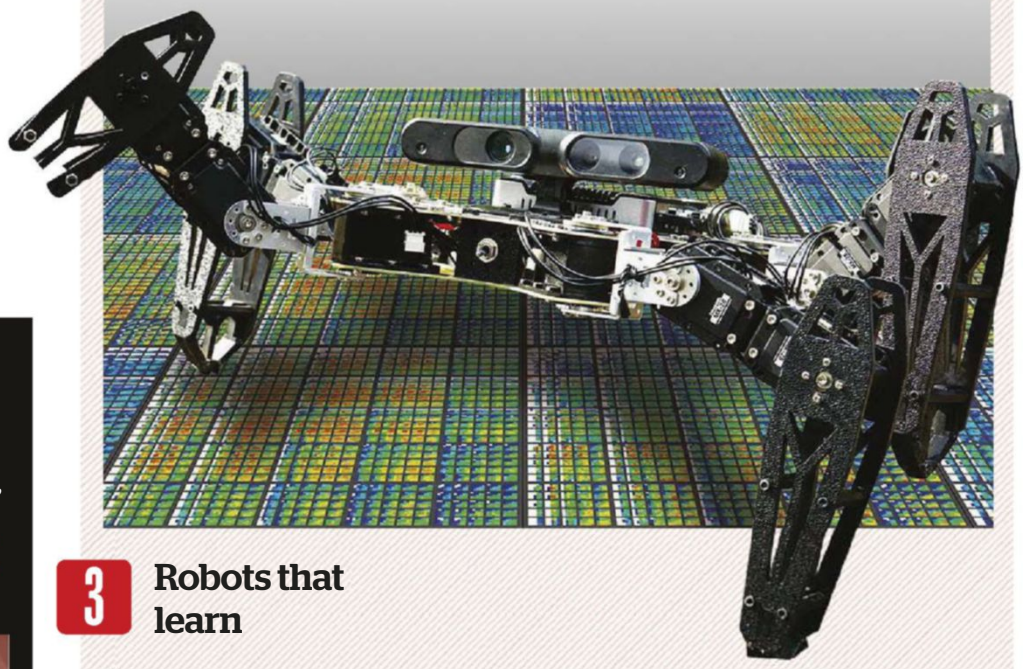
4 Personal energy

A TEAM IN the US has created thin, flexible devices that can harvest energy from body movements. The technology could be used to power biomedical implants or wearables.



The devices are made of lead zirconate titanate

This robot keeps going when knackered... aaaaand it's the Terminator



3 Robots that learn

ROBOTS THAT 'LEARN' how to recover from damage have been created by a team at the University of Wyoming. [redacted] It works by using a trial and error algorithm. For example, after damaging two of its six legs, one of the robots was able to figure out the most effective way of moving using its remaining limbs in just a few minutes. The research was inspired by the ways in which animals learn how to walk after losing a leg.

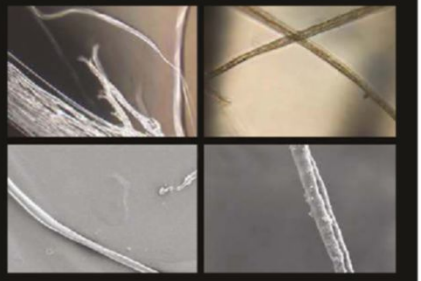
2 Wooden batteries

YOUR NEXT CAR could be powered by wood. Researchers from Sweden have used nanocellulose taken from wood pulp to create a flexible, high storage battery. [redacted] The team processed the nanocellulose fibres to create an elastic, foam-like material. This was then treated with a conductive ink to produce a 3D battery. The battery's structure enables the storage of significantly more power in less space than conventional batteries.

Despite being soft and squishy, the battery is still strong

1 Synthetic spider silk

AS FAR AS wonder materials go, spider silk is one of nature's finest. Now, researchers at MIT have figured out how to recreate it in the lab. The team genetically modified bacteria to produce the same proteins used by spiders. It could be used in biomedical applications such as sutures and replacement organs.



The fibres can be made to different thicknesses

ARCHAEOLOGY

First ever murder victim discovered?

Cranium 17 has been painstakingly pieced together from 52 separate fragments over a 20-year period

IT'S NOT THE nicest way to go: getting bashed on the head twice before being tossed down a cave shaft. But that's what appears to have happened in what could be one of the first cases of murder in human history.

Researchers at Binghamton University have found the remains of some 28 individuals dating back 430,000 years – around the time modern humans are thought to have first appeared – in the Sima de los Huesos ('pit of bones') in northern Spain. Among them was a near-complete skull, named Cranium 17, composed of 52 fragments recovered from a 13m- deep shaft over the last 20 years.

Sima de los Huesos in northern Spain is a treasure trove of ancient bones

Through the use of modern forensic techniques, the team has determined that the two fractures were likely to have been caused by blows from the same object, hitting from slightly different angles around the time of the individual's death. They conclude that the most likely cause of the injuries was an attack by another individual.

Furthermore, if this individual was already dead before reaching the caves, they were likely to have been carried there by other humans. This suggests that early humans are likely to have been responsible for amassing the bodies at the site, potentially providing evidence of funerary behaviour.

"Evidence for interpersonal violence in the human fossil record is relatively scarce, and this would appear to represent the coldest cold case on record," said researcher Rolf Quam. "This is really good evidence for an intentional role for humans in the accumulation of bodies at the bottom of this pit, and suggests the hominins from this time period were already engaging in complex cognitive behaviours."

ASTRONOMY

Milky Way 'weighed' more accurately

THERE'S ONE OBVIOUS problem facing anyone who wants to weigh a galaxy – you can't just whip out a set of scales and place it on them. Estimations of the mass of our Galaxy, the Milky Way, have therefore included a huge margin of error. But now a team at Columbia University has developed a more accurate method and used it to determine that the mass of the Milky Way is 210 billion times that of the Sun.

The Milky Way consists of roughly 100 billion stars that form a gigantic disc around 100,000 light-years across. The whole thing is orbited by a stream of stars produced by dissolving 'globular clusters'. Through observing the motions of these stars, the team were able to figure out the gravitational attraction created by the Milky Way, and so infer its mass.

"Globular clusters are compact groups of thousands to several millions of stars that were born when the Universe was still very young," said researcher Andreas Küpper. "They orbit the Milky Way and slowly disintegrate over the course of billions of years, leaving a unique trace behind. Such star streams stick out from the rest of the stars in the sky much as contrails from airplanes stick out from regular clouds."

The researchers used data from the Sloan Digital Sky Survey, which scanned the sky from the Northern Hemisphere for 10 years to create a detailed map of the stars in the sky. They focused on the stream produced by a globular cluster named Palomar 5, which had a pattern of wiggles in its path caused by our Galaxy's gravitational pull.

By creating millions of models of our Galaxy using Columbia's Yeti supercomputer, the researchers were able to find a match and estimate the Milky Way's mass with an uncertainty of just 20 per cent, compared to the previous 400 per cent.

The Milky Way may be home to as many as 100 billion planets

PHOTO: JAVIER TRUEBA/MADRID SCIENTIFIC FILMS, ISTOCK

INSIDE SCIENCE

ROBERT MATTHEWS

Seen any flying ants yet? They can teach us about maths...

NATURE IS AMAZING, isn't it? Every year around this time the nation's ants put on an Annual Festival Of Flying. Winged ants start swarming over the pavements before taking to the air in search of mates.

As a kid, I was fascinated by why ants chose one day over another to put on their show. Clearly something clever was going on, as there's no point being a frisky ant if everyone else stays home.

Today we still don't know why they choose a particular day. A wonderful example of 'citizen science' run over recent years by the Society of Biology has, if anything, deepened the mystery. Reports by the public of flying ant sightings has shown that weather conditions are important, and can lead to several Flying Ant Days. But there's some rhythmic pattern too: cause unknown.

One thing's for sure: the answer will come from collecting yet more heaps of data and understanding the patterns in them. It's a tried and tested technique as old as curiosity itself.

Countless sightings of the planets led medieval astronomers to find patterns that ultimately led to Newton's Universal Law of Gravitation. In the 1950s, seismologists found a link between the strength and frequency of earthquakes that led to insights into their cause. There's no reason to think the same trick can't work with ants. Indeed, researchers in Spain and the US have recently shown that apparently random movements of foraging ants obey mathematical laws.

Even with stats, we still can't figure out why ants fly on a particular day

The thing is, it's all too easy to fit curves to data and convince yourself you've discovered some profound truth. Some of the most egregious examples of this centre on one of the curves discovered in that ant study: the 'bell curve'.

"The thing is, it's all too easy to fit curves to data and convince yourself you've discovered some profound truth"

This curve was identified in the 18th Century and it emerges whenever lots of separate random variables have a cumulative effect. For example, plotting the frequencies of the total scores achieved by rolling handfuls of dice produces a bell curve. There's a peak at the middle giving the typical outcome, and slopes to either side where the less common values lie.

Surprisingly, you can get away with knowing next to nothing about the variables themselves. As long as they're independent, cumulative and plentiful, you'll get a bell curve. Such curves have been found in studies of everything from human height to the heat left over from the Big Bang.

Clearly, if our data fits a bell curve, we're looking at the cumulative result of lots of random influences, right? Well, yes – but only if we can be sure we have a bell curve. And that's the issue. Real data often produce curves that look bell-shaped, but are the result of different processes.

That can prove disastrous – as mathematicians in the world of finance have discovered to their (and our) cost. Plotting share price movement over time does create something like a bell-like curve. For years this was taken as evidence that the risk of violent market changes could be worked out using bell curves. Yet long-term records reveal that the 'tails' of these curves are much thicker than they should be. That's a symptom of stock prices not actually following the rules needed to produce true bell curves. And that can lead to serious underestimates of financial risk – as the calamities of recent years have proved all too dramatically.

Scientists often marvel at what's been called the 'unreasonable effectiveness of mathematics' in describing the world around us. Having blind faith in that effectiveness is, however, just that: unreasonable. ■

ROBERT MATTHEWS is Visiting Reader in Science at Aston University, Birmingham

ILLUSTRATOR: DEM ILLUSTRATION

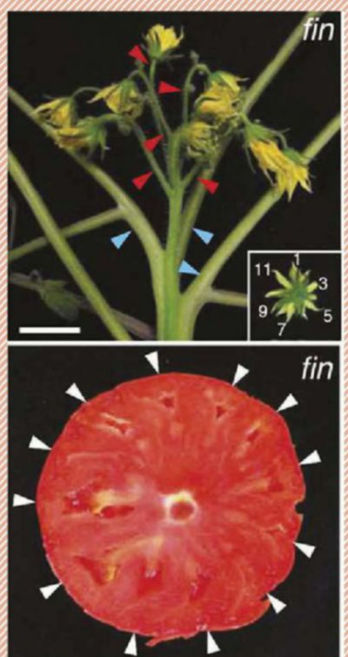
1 MINUTE EXPERT
CLAVATA3

What's that, a new smartphone?
Way off. It's actually the gene that's responsible for making beef tomatoes much bigger and, er, beefier than their more modestly proportioned relatives.

How does it work?
As a team at Cold Spring Harbor Laboratory in New York recently discovered, CLAVATA3 inhibits stem cell production in tomatoes. Mutations in this gene cause the fruit to produce more stem cells than usual, resulting in the formation of gigantic beef tomatoes.

What can it be used for?
By manipulating the mutations in CLAVATA3, the researchers say it is possible to fine-tune the size of the tomatoes.

Would it work in other plants?
Yep. The gene is present in all plants and may work in the same way. So look forward to a future filled with giant fruit for all.



As annotated above, beef tomato plants have extra branches, while the fruits contain more seed compartments than their wild relatives

Among other benefits, having warm blood makes opah less susceptible to fungal infections

ZOOLOGY

Warm-blooded fish discovered

MEET THE OPAH, the first fully warm-blooded fish known to science. The large, silvery-orange creature, also known as the sunfish, moonfish or Jerusalem haddock, lives hundreds of metres beneath the surface in chilly, dimly lit waters, where its warm blood gives it a competitive advantage over its cold-blooded rivals. Fish that inhabit such cold depths tend to be slow and sluggish, but the opah constantly flaps its wing-like fins to heat its body, which helps to speed up its metabolism, movement and reaction times.

"Before this discovery, I was under the impression this was a slow-moving fish, like most other fish in cold environments," says Nicholas Wegner of the USA's National Marine Fisheries Service, who was lead author of the paper in *Science* that revealed the findings. "But because it can warm its body, it turns out to be a very active predator that chases down agile prey such as squid, and can migrate long distances."

Wegner realised there was something different about

THEY DID WHAT?!
Researchers create a part-human yeast

What did they do?
Though yeasts are made of just a single cell, compared to the trillions of cells that make a human, we share thousands of similar genes with them. Four hundred and fifty of these are essential for the survival of yeast. Researchers at the University of Texas replaced the yeast version of each of these with the human version, creating hundreds of new strains of yeast, each of which included a single human gene.

What did they find?
Nearly 50 per cent of the 'humanised' yeasts that the Texas researchers created survived, and were even able to reproduce. This shows that, thanks to the stability of DNA, yeast and humans retain their links to a common ancestor – even after billions of years of independent evolution.

PHOTO: NOAA X2, BIOCARBON ENGINEERING, RAINIS VENTA, LIPPMAN LAB/CSHL

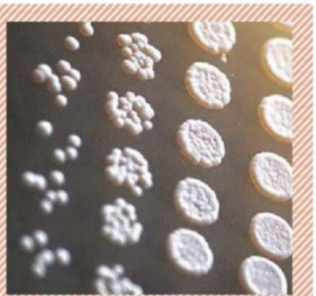
Some opah species can grow up to two metres in length. Nicholas Wegner for scale

the opah after noticing an unusual network of blood vessels in its gill tissue. Vessels that carry warm blood into the fish's gills, he discovered upon closer inspection, wind around those carrying cold blood back to the body. This acts like a heat exchanger, transferring warmth from the warmer to the colder blood.

This means it can keep its body at higher temperatures than the surrounding environment, in a manner similar to mammals. A few other fish such as tuna and some sharks were already known to be able to warm specific parts of their bodies, such as muscles, to boost their swimming performance. But none of them do this anywhere near as effectively as the opah.

"Nature has a way of surprising us with clever strategies right where you least expect them," Wegner says. "It's hard to stay warm when you're surrounded by cold water but the opah has figured it out."

Why did they do that?
The work could be used to study diseases caused by genetic mutations. By comparing different strains of yeast with different versions of the same human gene, researchers could study how such mutations affect a person's health. The work could also have applications in testing new drugs.



Yeast cultures growing on an agar plate. They don't *look* very human...

PATENTLY OBVIOUS with James Lloyd

inventions and discoveries that will change the world

Clever crockery

ON A DIET, but fed up with tracking your meals? The SmartPlate can do it all for you. Created by US company Fitly, the plate's three embedded cameras snap the contents of your meal and send the images to a smartphone app, where object recognition algorithms identify your grub. Built-in load sensors also weigh the food, telling you the exact nutritional value of what you're eating. The app even recognises restaurant meals, so there's no getting away with that cheeky cheeseburger.
Patent pending

True colours

COLOUR VISION DEFICIENCY can make TV confusing: a recent Champions League match left many viewers baffled when an all-red Liverpool took on all-green Ludogorets. But now there's a simple adaptor from UK company Spectral Edge to remedy this. Eye2TV plugs into the back of any TV with an HDMI socket and tweaks on-screen reds and greens so they're easily distinguishable. The effect is barely perceptible to colour-normal people, so everyone can watch the same programmes.
Patent application number: WO2015004437

Sown by drone

WITH THE WORLD'S rainforests disappearing faster than we can replant them, the race is on to find an effective way to save our trees. So how about firing seeds from the sky using an army of drones? That's the solution proposed by NASA engineer Lauren Fletcher and his team at BioCarbon Engineering. The unmanned drones will first create a detailed map of the terrain, so that the right plant can be dropped in the right location. Then they will go about reforesting the area, zipping along just three metres above the ground. At each planting site, a pre-germinated seed will be fired towards the soil, with the seed encapsulated in a hydrogel so that it has all the nutrients it needs to grow into a healthy tree.

With two operators, the team aims to plant around 38,000 trees per day – 10 times the rate of hand-planting. Eventually, they hope to ramp this up to a billion trees a year.
Patent pending

"And with this drone, I will save the rainforests!" cackled failed supervillain Fletcher

EARTH

Climate change not slowing down

IT SEEMS THAT climate change deniers may have to rethink their favourite argument: global warming has not gone through a pause or hiatus as once thought.

A study carried out by the National Oceanic and Atmospheric Administration (NOAA) has found that global warming has been happening just as quickly in the last 15 years as it did in the latter half of the 20th Century. The apparent pause was due to gaps in the data.

"Adding in the last two years of global surface temperature data and other improvements in the quality of the observed record provide evidence that contradicts the notion of a hiatus in recent global warming trends," says the NOAA's Thomas R Karl. "The rate of warming over the first 15 years of this century has been as fast or faster than that seen over the last half of the 20th Century."

The study contains more measurements of both sea surface temperature and air temperature on the land. The NOAA researchers also used data that had been collected from buoys, which was significantly more accurate than that collected from ships.

"In regards to sea surface temperature, scientists have shown that data collected from buoys are cooler than ship-based data," explains researcher Thomas C Peterson. "To accurately compare ship measurements and buoy measurements over the long-term, they need to be compatible. Scientists have developed a method to correct the difference between ship and buoy measurements, and we are using this in our trend analysis."

At regular intervals, research buoys transmit data via satellites

BIOLOGY

Light reactivates lost memories

A TEAM AT MIT is shedding light on how memories are recalled, in research that could lead to more effective treatments for amnesia or degenerative brain disorders. The researchers are using a technique called optogenetics, which involves adding proteins to neurones (nerve cells) to allow them to be activated by light.

In 2012 the team found that groups of neurones in the hippocampus undergo enduring chemical changes when the brain acquires a new memory. If they are then reactivated by a trigger such as a sight or smell, the memory is recalled. These neurones are known as 'memory engram cells'. The process of learning and experience involves the strengthening of synapses, the structures that let neurones send signals to one another.

This effect is known as long-term potentiation (LTP). But by administering a compound called anisomycin – which prevents neurones from synthesising proteins – after mice had formed a new memory, the team was able to prevent the synapses from strengthening, so when the team attempted to reactivate the memory a day later using an emotional trigger, they could find no trace of it. "Even though the engram cells are there, without protein synthesis those cell synapses are not strengthened, and the memory is lost," explains researcher Susumu Tonegawa.

However, when the researchers used optogenetic techniques, they found that the mice exhibited all the signs of recalling the memory in full.

"If you test memory recall with natural recall triggers in an anisomycin-treated animal, it will be amnesiac, you cannot induce memory recall," Tonegawa says. "But if you go directly to the engram-bearing cells and activate them with light, you can restore the memory."

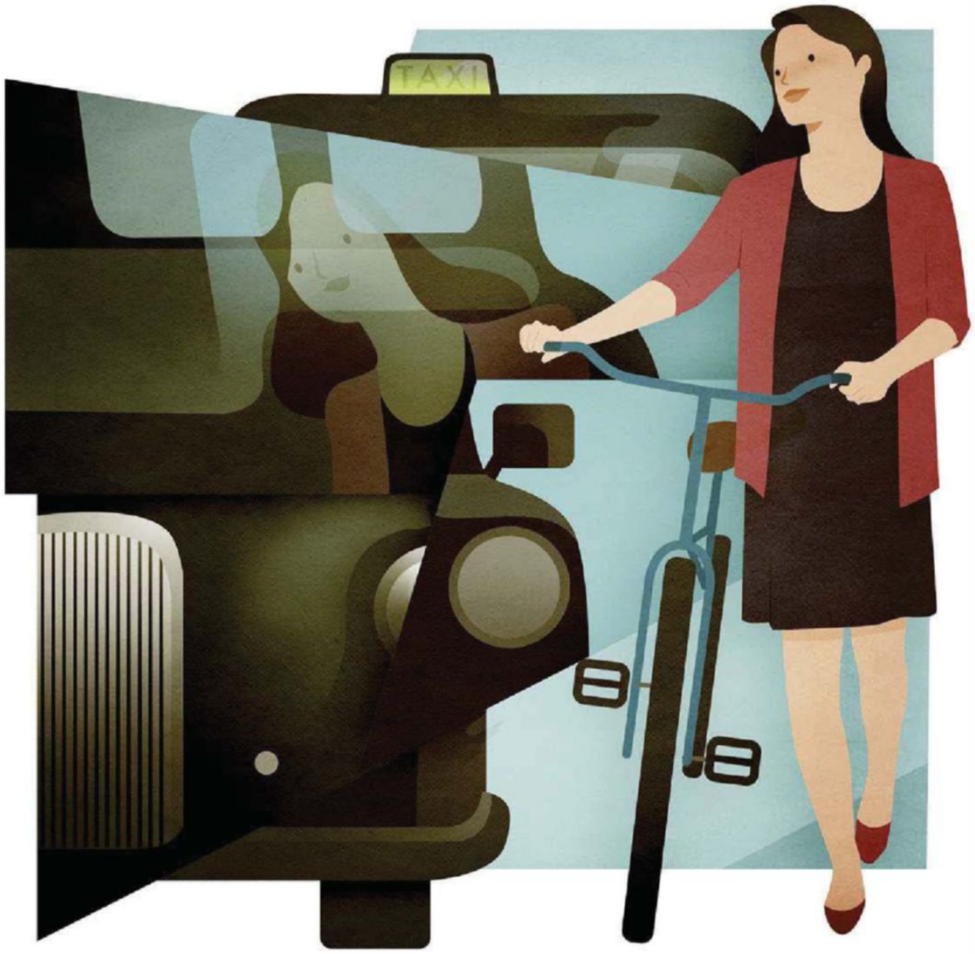
Groups of neurones in the brain's hippocampus experience chemical changes when memories are created

PHOTO: JAMIE MONCRIEF/UNOW, SCIENCE PHOTO LIBRARY

EVERYDAY SCIENCE

HELEN CZERSKI

Why black cabs make pretty good mirrors



WHO WOULD HAVE thought that staring at a taxi could be interesting? I live in London and cycle to work every day, so I'm very used to waiting behind black cabs at traffic lights. Last week, I was idly watching the distorted reflection of my bike in the glossy black paint of the cab sitting in front of me, and it suddenly occurred to me that this is a very odd thing to do. We know that black surfaces are black because they absorb all colours. But I could see the colour of my top and the handlebar tape. This shiny black surface was a pretty good mirror. At the next set of traffic lights, there was a white car in front of me, and my reflection wasn't nearly as clear. But white surfaces reflect all colours equally – surely necessary for a mirror. What's going on?

Glossy surfaces are glossy because they reflect light in a very organised way. Light that arrives at the surface from a particular angle is reflected away at exactly that angle on the other side. It's like bouncing a ball off the ground – bounce it straight down, and it comes straight back up. Bounce it at an angle, and it bounces off at that same angle. So glossy paint is reflective because it's got a very smooth top surface that light bounces off, and it reflects all colours equally. But if it reflects all colours, how is it also black? The trick here is that the surface splits the incoming light. Some light is reflected perfectly, barely touching the surface. But some travels down into the paint itself. Down there, all colours are absorbed. So I could see the black taxi because it was perfectly reflecting some of the light around it, and perfectly absorbing the rest.

As I pedalled further along the road, I thought about shiny white objects such as plastic, marble and white glass. No amount of polishing will turn those into mirrors. I watched my reflection in each white car that went by. Light coming from my bright red cycling jacket was hitting the surface and being split, so that some light waves got to explore the inside of the paint layer. Inside the paint is a mini house of mirrors – lots of particles that bounce light around like pinballs. Eventually the light bounces out of the paint, but it leaves in a random direction. And this is why I found it harder to see my reflection in the white cars. I could see the perfect reflections, but they were mixed in with all the random light rays from all sorts of other directions.

"Our brains are so adept at interpreting shiny, colourful objects that we almost never notice that they're doing it"

A red car went past. This time, not all light that got down into the paint was getting out. Pigments in the house of mirrors were absorbing all the colours that weren't red, and only red light got to escape.

What the taxi made me think about was that the light from a painted surface comes from two entirely separate places. To get at least some perfect 'mirror' reflection, all you need is a smooth surface. What's underneath is irrelevant. No perfect mirror can have a colour, because no light ever gets beneath its surface. Therefore, there are no clues to what's inside. But colour is all about what's inside the paint, and some light will always sneak below the paint surface. It's only this light that bounces around and is filtered before it comes out again, giving the object its colour. Our brains are so adept at interpreting shiny, colourful objects that we almost never notice that they're doing it.

I love the idea that when you're seeing a coloured object, you're seeing inside it, even if it's only a little way. And now I've got something to keep me entertained in traffic jams! ■

DR HELEN CZERSKI is a physicist, oceanographer and BBC science presenter whose most recent series was *Super Senses*

ILLUSTRATOR: ANDREW LYONS

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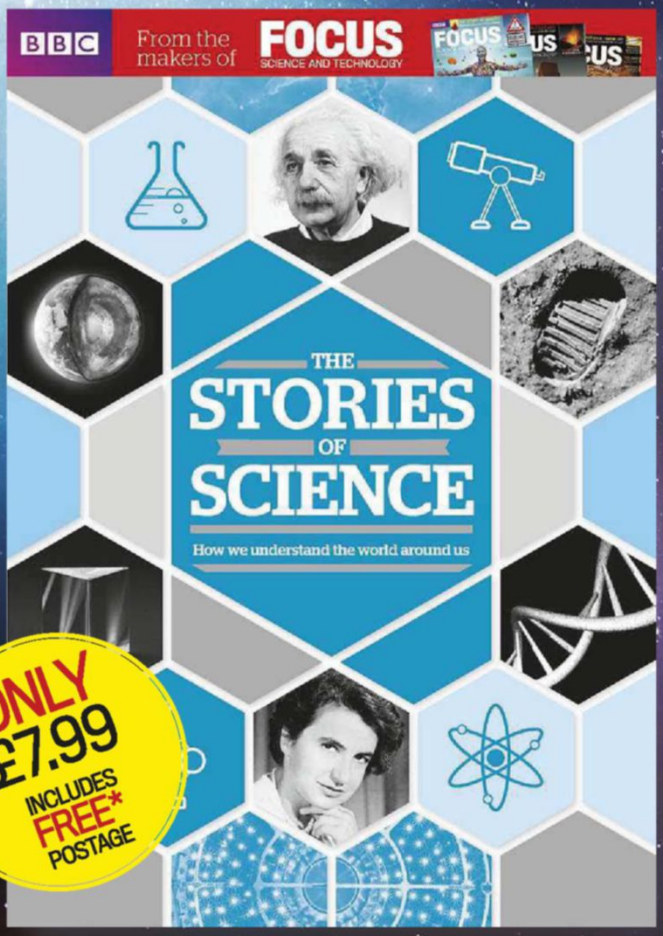

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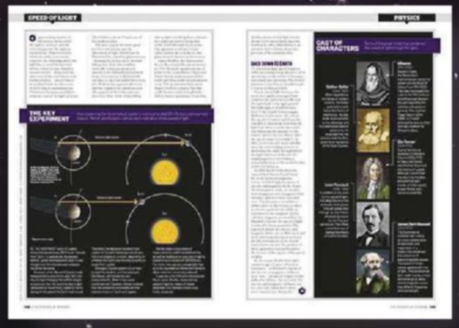

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INTO THE FUTURE

STEPHEN BAXTER

Can we save Earth's biological diversity from extinction?

THE NEW FILM *Jurassic World* gives us a glimpse of a marvellous but extinct biota. The dinosaurs died out 65 million years ago, probably due to the effects of a massive asteroid impact. This was one of five massive 'great extinctions' that have left identifiable scars in the fossil record.

It's becoming increasingly apparent that today we are living through a sixth extinction. This time, we are the cause. As reported in the science journal *Nature* in December 2014, 41 per cent of all the planet's amphibians, 26 per cent of the mammals and 13 per cent of the birds are in danger of extinction. The causes are the continuing spread of activities like agriculture, fishing and logging; pollution; the introduction of invasive species like goats and rats; and climate change. We appear to have been implicated in the extinction of high-profile species in the past, from giant Ice Age fauna like the mammoths to our closest cousins, the Neanderthals.

What should we do about it? Zoos and other organisations are already trying to save the more 'glamorous' threatened species like pandas, tigers and elephants – it's easy for us to empathise with the plight of such creatures. But it's becoming clear that the loss of much less impressive species could have a drastic impact on our own lives. We depend on 'ecosystem services' provided by many creatures. Worms grind up our waste and turn it into soil, while three-quarters of the world's food production is thought to depend on bees and other pollinators. Yes, save the orangutan – but save the creepy-crawlies too.

Could we bring back long-dead species, as well as those under threat?

What of the longer term? We won't go extinct. It seems unlikely that anything short of the destruction of all life on Earth could entirely eliminate a smart, adaptable species like us. But that means the sixth extinction will have a unique feature lacking in all the others: the presence of intelligent life in the aftermath. And we will surely have a role in shaping the world's recovery from that extinction. It seems unlikely, for example, that we would ever allow the evolution of a competitor – another animal as smart as we are. This could take the form of a much-evolved monkey or rat, perhaps.

"It may be we are guilty of causing the world's sixth great extinction, but perhaps we can mitigate that guilt"

Perhaps our goal now should be to save as much of Earth's biological richness as possible, even if not in the form of living creatures, to provide raw material for the recovery. There are already 'gene banks' storing millions of seeds from food plants and wild plant species. And the Frozen Zoo at San Diego hoards frozen cell samples from 800 species of animals. Cloning of plants and animals is in its infancy, but maybe some day species that would otherwise have been lost could be brought back and released into a suitable wilderness.

There are even suggestions that we should consciously save as much diversity as possible – which would give life the best chance possible of adapting to the unknown environments of the future. One initiative by the Zoological Society of London gives threatened species EDGE scores. This stands for Evolutionarily Distinct and Globally Endangered, and helps highlight one-of-a-kind animals on the brink of extinction. Those with high scores, such as the aardvark and platypus, are the most threatened.

It may be we are guilty of causing the world's sixth great extinction, but perhaps we can mitigate that guilt by planning how we will manage the world's recovery afterwards. It is hard to imagine a more challenging responsibility for any intelligent species. ■

STEPHEN BAXTER is a science fiction author who has written over 40 books. His latest is *Ultima*, published by Orion

ILLUSTRATOR: ANDY POTTS

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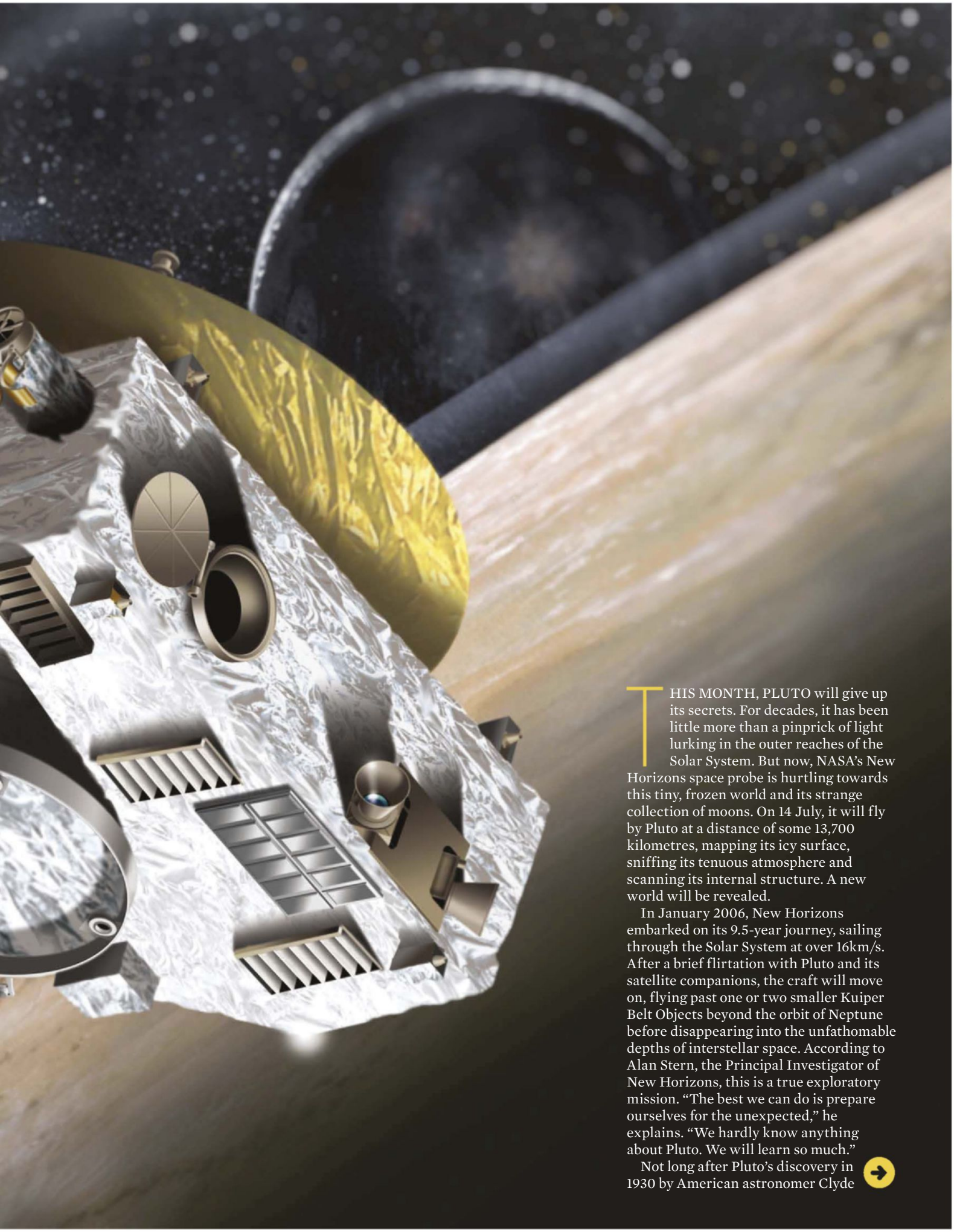
As NASA's New Horizons spacecraft nears Pluto, **Govert Schilling** explores what we might find waiting for us on this alien world

Artist's impression of New Horizons visiting dwarf planet Pluto

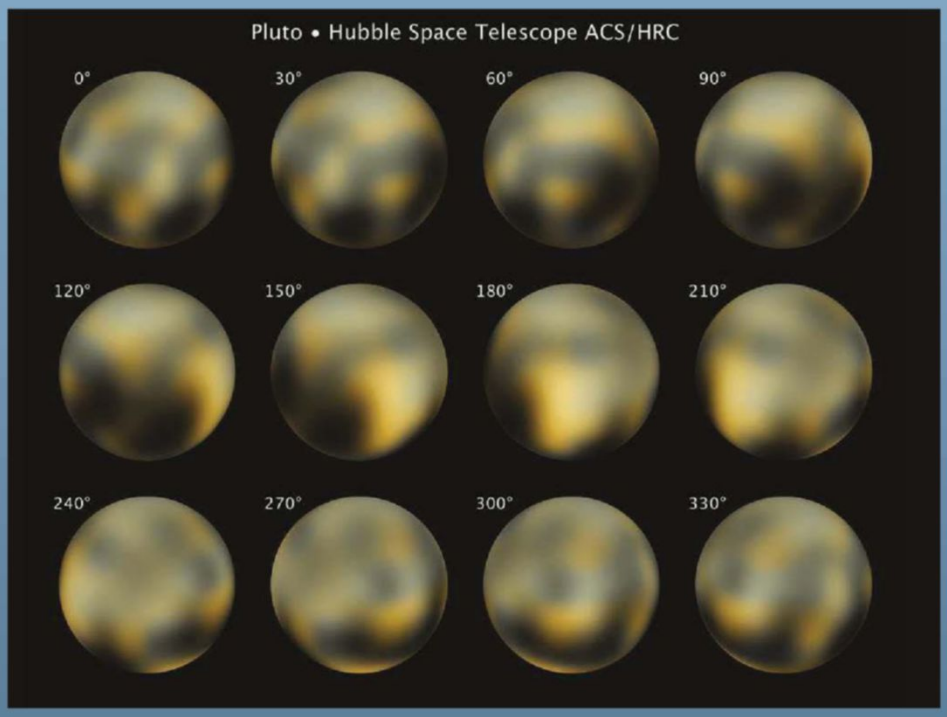
PHOTO: NASA



THIS MONTH, PLUTO will give up its secrets. For decades, it has been little more than a pinprick of light lurking in the outer reaches of the Solar System. But now, NASA's New Horizons space probe is hurtling towards this tiny, frozen world and its strange collection of moons. On 14 July, it will fly by Pluto at a distance of some 13,700 kilometres, mapping its icy surface, sniffing its tenuous atmosphere and scanning its internal structure. A new world will be revealed.

In January 2006, New Horizons embarked on its 9.5-year journey, sailing through the Solar System at over 16km/s. After a brief flirtation with Pluto and its satellite companions, the craft will move on, flying past one or two smaller Kuiper Belt Objects beyond the orbit of Neptune before disappearing into the unfathomable depths of interstellar space. According to Alan Stern, the Principal Investigator of New Horizons, this is a true exploratory mission. "The best we can do is prepare ourselves for the unexpected," he explains. "We hardly know anything about Pluto. We will learn so much."

Not long after Pluto's discovery in 1930 by American astronomer Clyde



Above: Clyde Tombaugh discovered Pluto back in 1930

Left: Views of the entire surface of Pluto, as captured by the Hubble Space Telescope between 2002 and 2003

PHOTO: NASA/HUBBLE, GETTY, NASA X5, IAU, ALAMY

Tombaugh, it became evident that this tiny rock at the edge of the Solar System was odd. First of all, it's small – even tinier than our own Moon. Second, it follows a strange, highly elliptical path around the Sun, strongly skewed with respect to the more circular orbits of the other planets. During part of its 248-year orbit, Pluto is closer to the Sun than Neptune. Last but not least, Pluto's moon Charon, discovered in 1978, is so large that astronomers liked to think of the pair as binary planets.

Even the Hubble Space Telescope has been unable to uncover Pluto's secrets, let alone Charon's. Most of what we know has been deduced from detailed observations of mutual eclipses of the two bodies, and from studies of starlight passing through Pluto's thin atmosphere during rare cases where Pluto passes in front of a distant star. Thus, astronomers have gauged diameters (2,300 kilometres for Pluto and 1,200 kilometres for Charon), and made crude maps of dark and light regions on the surface.

Surprisingly, much more has been revealed by studying the many smaller siblings of Pluto that populate the Kuiper Belt – a thick, broad region beyond Neptune's orbit. The first Kuiper Belt Object was discovered in 1992. Since then, some 1,500 have been found. Pluto turns out to be just one of the largest members of a huge population of icy bodies – remnants from the Solar System's early youth. Mapping the colours and orbital characteristics of Kuiper Belt Objects has enabled scientists to reconstruct the migratory evolution of the giant planets.

As king of the Kuiper Belt, Pluto returned to the scientific spotlight, but it lost its planetary status in the process. Nine years ago, the International Astronomical Union (IAU) decided to reclassify Pluto as a dwarf planet, despite strong opposition from a vocal minority of American planetary scientists, including Stern. At that time, New Horizons had just been launched as NASA's first mission to the ninth planet in the Solar System. At the mission website, it still says that "the definition of a planet continues to be debated" and "most

4,760,000,000

kilometres will be the approximate distance travelled by New Horizons between its launch in January 2006 and the flyby of Pluto on 14 July 2015

PLUTO PAST AND PRESENT

18 February 1930
American astronomer Clyde Tombaugh discovers Pluto on plates taken a few weeks earlier at Lowell Observatory in Flagstaff, Arizona.

24 March 1930
Pluto is named after the Roman god of the underworld, following a suggestion by 11-year-old Venetia Burney from Oxford, UK.

22 June 1978
James Christy of the United States Naval Observatory discovers Pluto's large moon, Charon, which orbits the dwarf planet once every 6.4 days.

May 1989
The first ideas for a space mission to Pluto are put forward by a group of 12 planetary scientists, known as the Pluto Underground.

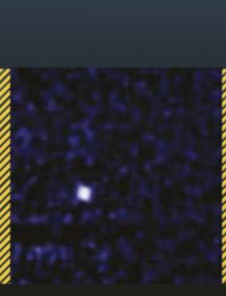
The New Horizons craft was assembled in a clean room prior to its launch aboard an Atlas V rocket

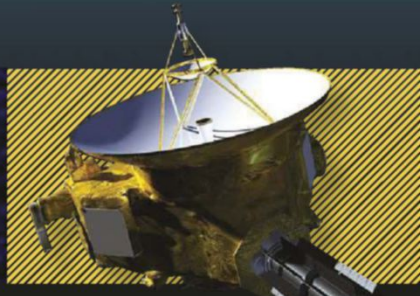
people call Pluto a planet". Stern says he has "no idea" whether or not some astronomers will officially propose to restore Pluto's planethood this summer at the IAU's next triennial General Assembly in Honolulu, Hawaii.

Of course, the scientific output of the New Horizons mission won't depend on how we label its frozen target. The triangular 480kg craft was built by the Johns Hopkins University Applied Physics Laboratory in Baltimore, Maryland and Stern's Southwest Research Institute in Boulder, Colorado. It is outfitted with seven instruments, including a high-resolution camera, two spectrometers to study surface and atmospheric composition, two instruments to study fields and particles, a dust counter, and a radio science

16.26

km/s is the launch velocity of New Horizons, the fastest spacecraft ever to leave Earth orbit





5 January 2005
Caltech astronomer Mike Brown, aka 'Plutokiller', discovers Eris. This Kuiper Belt Object is as large as Pluto, sparking a debate about the definition of the word 'planet'.

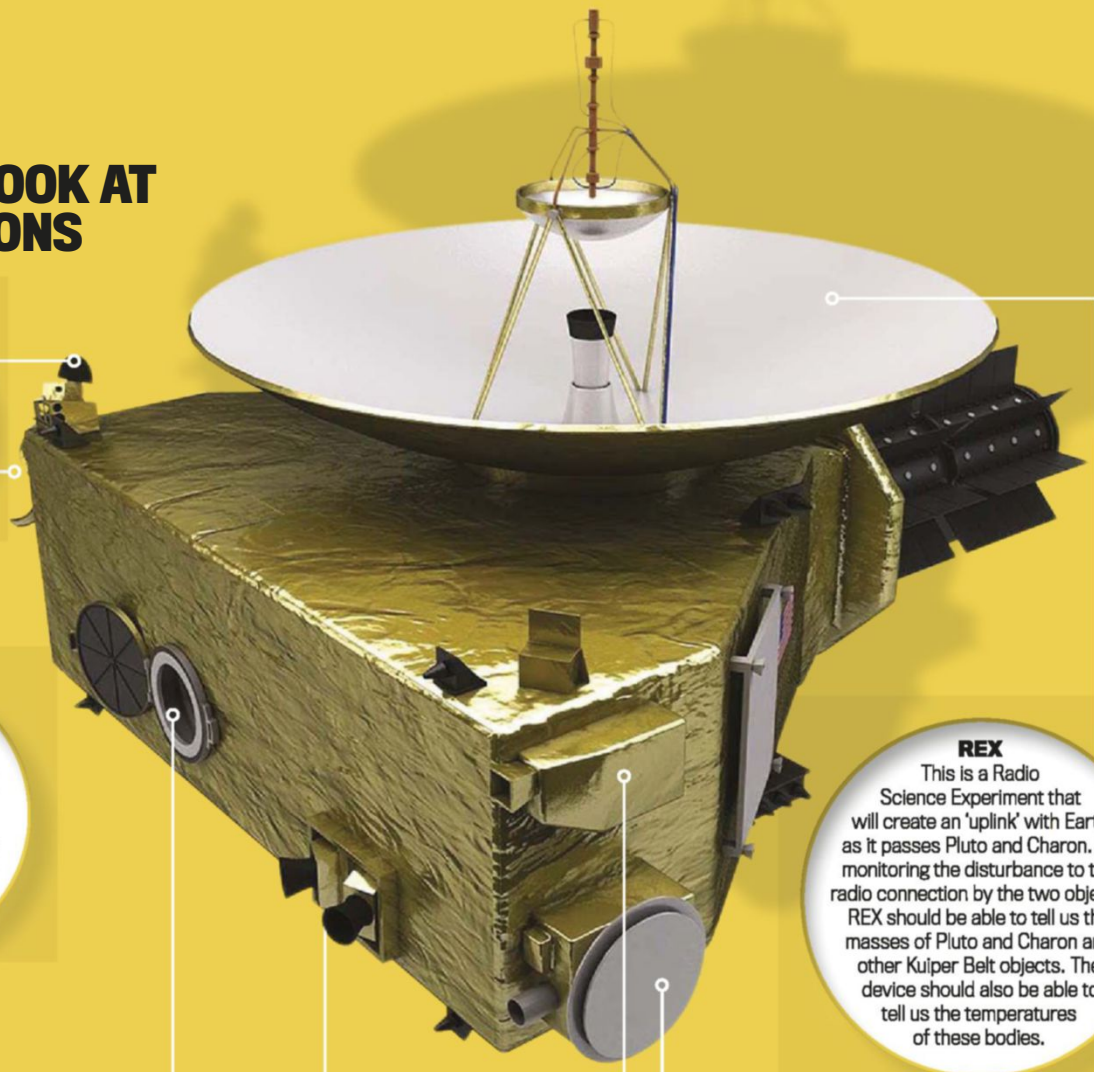
19 January 2006
Using an Atlas V rocket, NASA launches the New Horizons craft from Cape Canaveral Air Force Station in Florida. It starts its lengthy mission.

24 August 2006
During its 26th triennial General Assembly in Prague, Czech Republic, the International Astronomical Union votes to reclassify Pluto as a dwarf planet.

2011/2012
Two more small satellites of Pluto – Styx and Kerberos – are discovered on photos made with the Hubble Space Telescope.

14 July 2015
Around 11:50 UTC, New Horizons flies by Pluto at a distance of some 13,700km and a relative velocity of 13.8km/s.

A CLOSER LOOK AT NEW HORIZONS



PEPSSI
The Pluto Energetic Particle Spectrometer Science Investigation will take a close look at the particles as they leave Pluto.

SWAP
The solar wind that's blowing around Pluto will be tracked by the SWAP device. It will monitor how the wind reacts with particles escaping from the dwarf planet's atmosphere (around 75kg leave every second).

REX
This is a Radio Science Experiment that will create an 'uplink' with Earth as it passes Pluto and Charon. By monitoring the disturbance to this radio connection by the two objects, REX should be able to tell us the masses of Pluto and Charon and other Kuiper Belt objects. The device should also be able to tell us the temperatures of these bodies.

LORRI
The Long Range Reconnaissance Imager device is effectively a digital camera with a large telephoto telescope attached. This will allow us to get up close with Pluto. LORRI will provide the best-ever images of Pluto and the Kuiper Belt, and will look for craters and geysers.

SDC
The Venetia Burney Student Dust Counter is the first science instrument on a NASA planetary mission that's been designed, built and flown by students. As New Horizons glides through the Solar System, it will measure the concentration of dust particles throughout.

ALICE
This UV imaging spectrometer will provide the first complete picture of Pluto's atmosphere. It should be able to tell us what gases cling to the planet and how abundant they are.

RALPH
New Horizons' 'eyes' are situated here. It consists of an array of sensors designed to map Pluto's landscape at a resolution of 250 metres per pixel. It'll also be hunting for features like frozen nitrogen, water and carbon monoxide.

PHOTO: SCIENCE PHOTO LIBRARY, JAMES BYARD/WUSTL

1,873

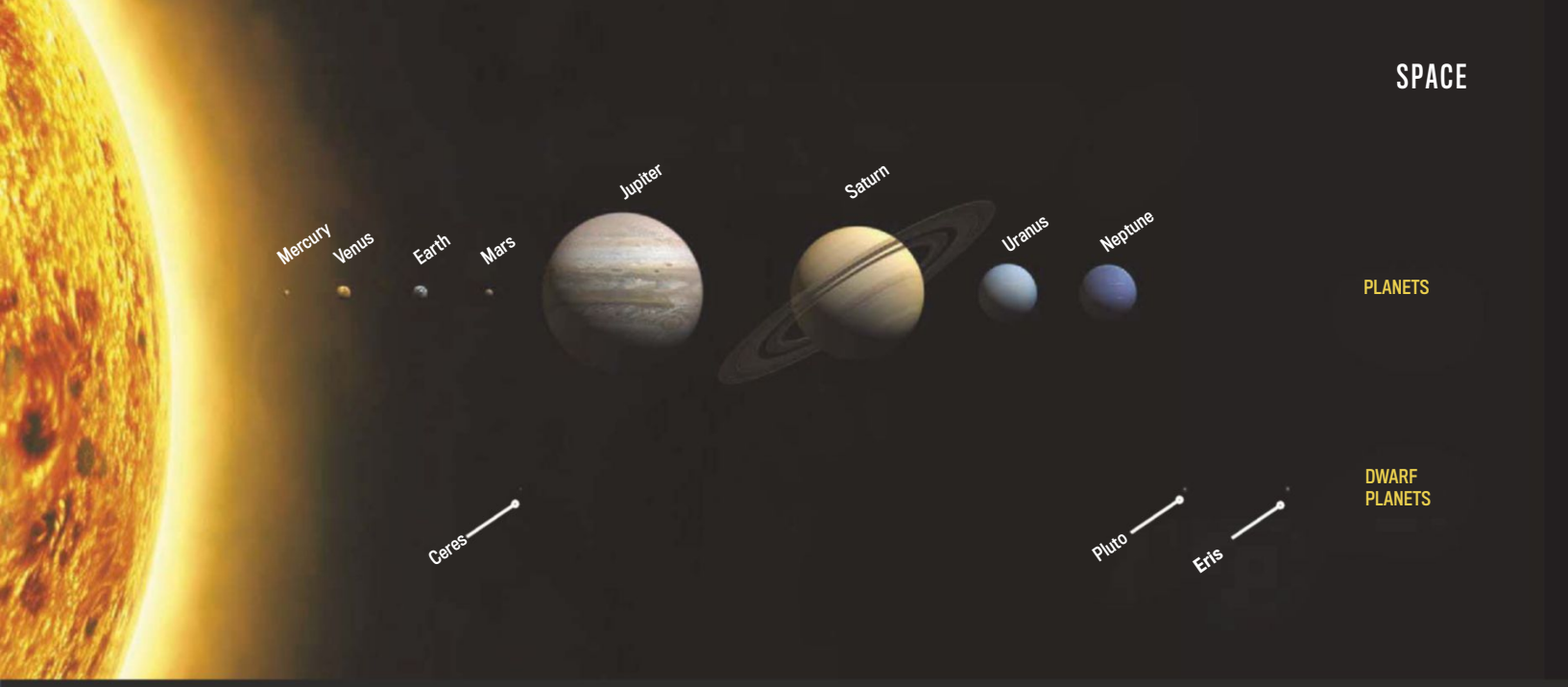
days were spent in hibernation by New Horizons during its trip; it woke up on 6 December 2014

experiment. A plutonium-powered radioisotope thermoelectric generator provides some 200W of power during the Pluto encounter, while communication with Earth will be maintained by a 2.1m high-gain antenna.

New Horizons' radio signals will take some 4.5 hours to reach Earth, and because of the huge distance and the relatively low transmitter power, the craft's data rate will be low. "We'll receive dozens of photos within a day after closest approach," explains Stern. "But we're collecting data a hundred times faster than we are able to transmit them. It will take over a year to send all of it back." Also, because of the delay, the whole encounter has to be pre-programmed into New Horizons' onboard computer. "We've prepared ourselves for over 250 possible contingencies," says Stern. "My biggest worry is that something happens that we haven't thought of."

Apart from Pluto's largest moon, Charon, New Horizons will also study the dwarf planet's four minor satellites, two of which hadn't even been detected at the time of launch. The small satellites are close to, but not exactly in, orbital resonance with Charon. According to Stern, this could mean that the satellite system is relatively young. "We may find additional small satellites, or maybe even a tenuous system of rings."

However, the most exciting finds may stem from the study of Pluto's surface and



Could Pluto become a planet again?

WHEN THE International Astronomical Union (IAU) reclassified Pluto as a 'dwarf planet' back in August 2006, a number of American planetary scientists were quite upset. After all, Pluto orbits the Sun, it is round, it has moons, it has a (tenuous) atmosphere and geology, so why can't it be a proper planet?

The 'degradation' of Pluto was motivated by the discovery of hundreds of Kuiper Belt Objects beyond Neptune's orbit. The IAU came up with a rather vague definition of the word 'planet' that excluded Pluto, based on the fact that it hasn't been able to gravitationally 'clear the neighbourhood around its orbit'.

No one is really happy with the IAU definition, so could critics turn the decision around at the IAU's next General Assembly in Honolulu, Hawaii? IAU General Secretary Thierry Montmerle from the Institut d'Astrophysique de Paris doesn't think so. "There must be a valid scientific reason to reverse an earlier decision," he explains. "Moreover, the deadline for putting forward new resolutions to vote on has passed."

Then again, there are no sanctions for not following the IAU rules, so astronomers such as New Horizons Principal Investigator Alan Stern are free to keep calling Pluto a planet, if they so wish. Meanwhile, Prof David Weintraub of Vanderbilt University in Nashville, Tennessee expects that the New Horizons results will force astronomers to reopen the debate all over again.

"It's just a small group of Americans," sighs Montmerle. "But even there, they are a minority."


Bill McKinnon thinks Pluto could have a hidden ocean

interior. Like some of the icy satellites of Jupiter and Saturn (notably Europa and Enceladus), Pluto may display some form of 'ice volcanism', with active geysers spewing crystals of frozen nitrogen, methane and water into space.

Planetary scientist Bill McKinnon of Washington University in St Louis, Missouri, says he is one of those people who thinks it's even likely that Pluto possesses an internal ocean, hidden beneath a thick layer of ice.

Everyone knows that water is one of the main requisites for the emergence of life as we know it, the other two being organic molecules and energy. So who knows, if Pluto has a subsurface ocean, it might harbour microorganisms, just as astrobiologists have suggested is the case for Europa and Enceladus. Unfortunately, New Horizons won't be able to answer that question, so the existence of Plutonian life will remain speculative for many decades to come.

Even if there is nobody on Pluto to notice the flyby of New Horizons, extraterrestrial civilisations may one day run into the tiny craft. Just in case, Hawaiian artist Jon Lomberg has proposed to upload a 'self-portrait of humanity' into the spacecraft's computer memory after it has completed its mission. Previously, Lomberg worked with American astronomer Carl Sagan to create the famous Voyager Golden Record with its selection of various sounds, images and greetings from Earth. Lomberg says: "Like the Voyager Record, this will be both a message from Earth and a message to Earth. The very act of creating it will be a powerful reminder that we all share a common heritage and future on this 'pale blue dot' we call Earth." ■


The Voyager Golden Record

Find out more

BBC TWO

To watch a clip from *The Planets Revisited* describing how Clyde Tombaugh discovered Pluto, visit **http://bbc.in/yeSmEG**

GOVERT SCHILLING is an astronomer and science author who has written over 50 books

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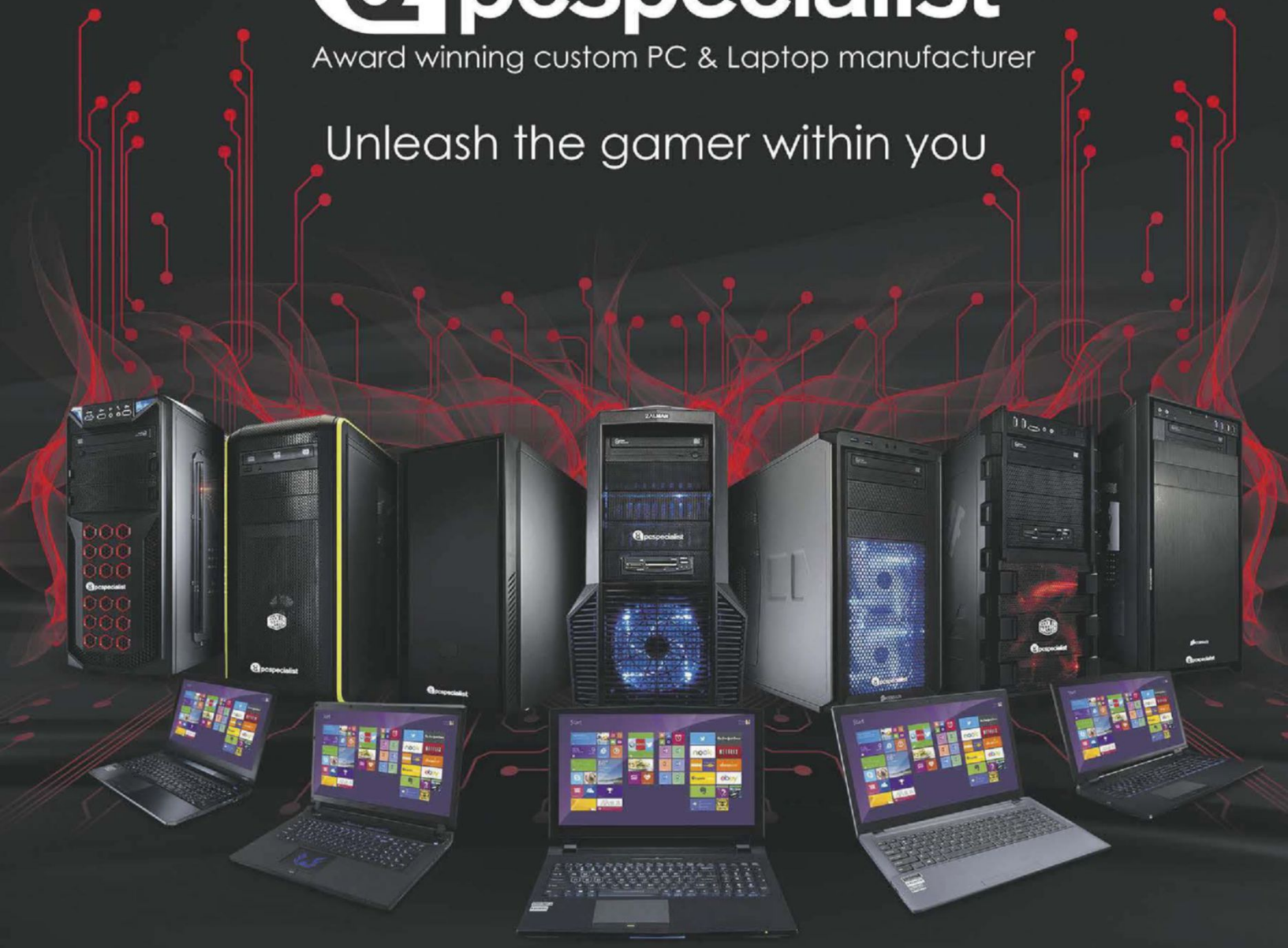

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THE TROUBLE WITH TIME TRAVEL...

With the cult 1980s film *Back To The Future* celebrating its 30th anniversary this month, **John Gribbin** takes a look at the mind-warping paradoxes the concept throws up

ILLUSTRATOR: MAÏTÉ FRANCHI PHOTO: KOBAL COLLECTION

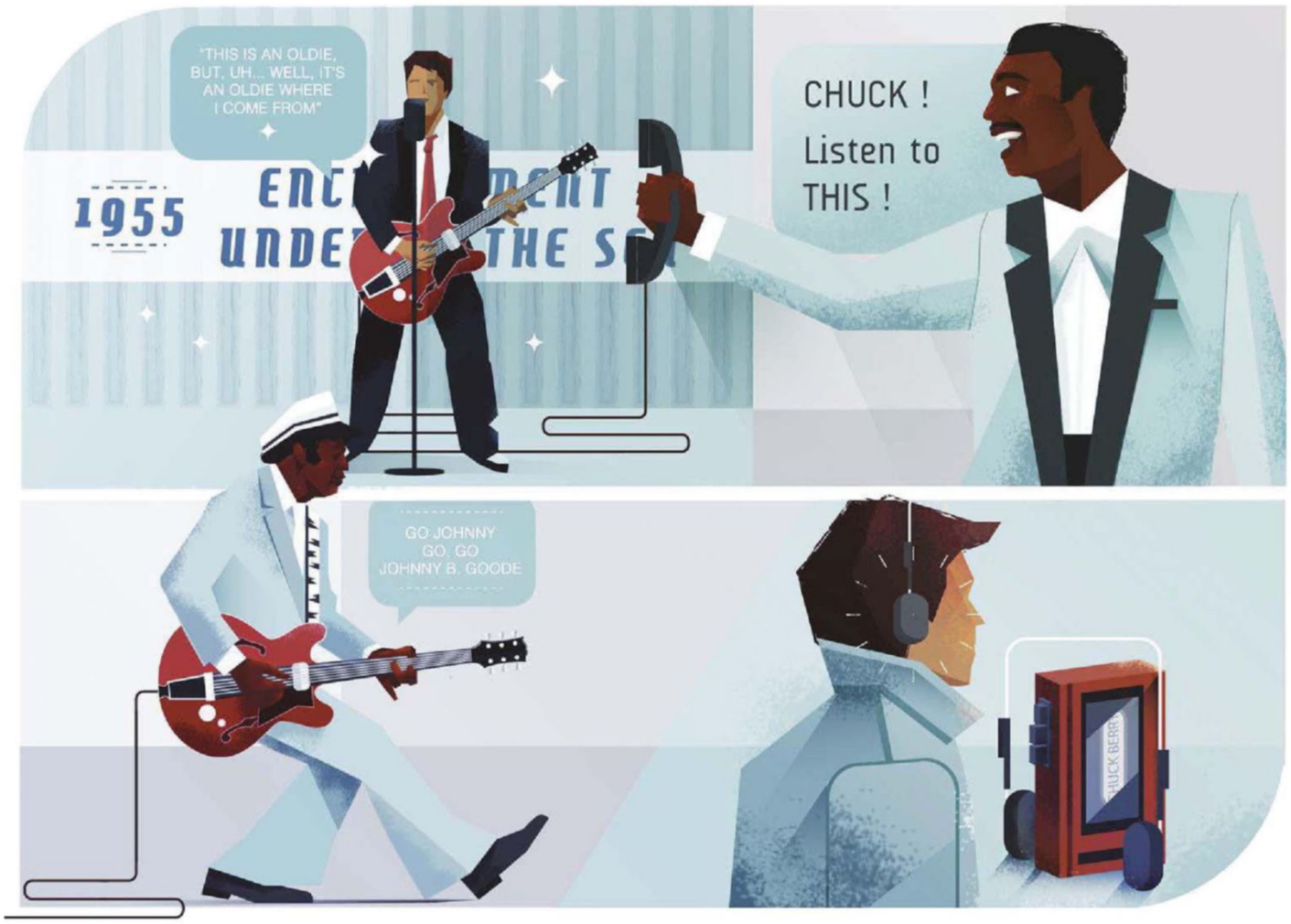
THE GRANDFATHER PARADOX

TIME TRAVEL paradoxes – or strictly speaking, puzzles – come in many varieties. But the classic example is the so-called Grandfather Paradox. In the traditional version of the story, a time traveller goes back in time and either accidentally or deliberately (if you are in a macabre mood) kills his own grandfather, before the time traveller's father has been conceived. So the time traveller is never born, so he never goes back in time, so his grandad never dies, so the time traveller is born. And so on.

A variation on this theme is used as a key plot device in *Back To The Future*. If Marty McFly accidentally prevents his own parents falling in love and marrying, he will not exist. But as the science fiction writer Robert Heinlein put it, "a paradox can be paradoctored." Marty does change the past, but in a positive way. He comes home to a different, better future than the one he left. But what happened to the 'original' future?

One idea loved by sci-fi writers, and with some basis in scientific fact, is the 'many worlds' version of quantum mechanics. This states that all possible realities exist in some sense side by side. Think of the many worlds like the branches of a tree, each with its own version of history. If you went back in time, into the trunk of the tree, and then forward again, you might go 'back' up a different branch from the one you came down. You go back in time and stop your parents meeting, then forward in time up the branch in which they never met and you were never born. That's okay, just as if you were born in London then moved to New York, the fact that you were not born in New York doesn't mean you don't exist. There would, though, be one timeline in which the traveller had vanished, never to return (as in HG Wells's original time travel story, *The Time Machine*) and another with a person who has no parents. Complicated, but not paradoxical.

Marty's parents securing his future



THE BOOTSTRAP PARADOX

ROBERT HEINLEIN presented my favourite time travel paradox in all its glory in 1941, in his short story *By His Bootstraps*. The tale gave its name to the paradox and it is often used in science fiction.

In this paradox, an item or a piece of information is passed from the future to the past, becoming the same item that is passed from the past to the future. In the case of *By His Bootstraps*, the item is a notebook found by the main character, Bob Wilson in the far future. He takes it, then travels to an earlier point in the future and uses the useful translations within the book to help establish himself as a benevolent dictator. When the notebook becomes worn and dog-eared, he copies the information into a fresh notebook and discards the original. Towards the end of the novel, he muses that there were never two notebooks – the new one is the one that was found by him when he arrived. Mindbending!

One easy-to-follow example of the Bootstrap Paradox can be seen in *Back To The Future*. At the dance in 1955, Marty McFly gets on stage and sings "an oldie" where he comes from: Chuck Berry's *Johnny B. Goode*. Chuck's cousin, Marvin, is present at the dance and holds up a phone so Chuck can listen in. Inspired by the sound, Chuck later releases the song and Marty would then hear it in the future. But who wrote it?

Robert Heinlein melted our brains with his short story *By His Bootstraps*

ILLUSTRATOR: MAÏTÉ FRANCHI PHOTO: SCIENCE PHOTO LIBRARY, CORBIS

POLCHINSKI'S PARADOX

THE GRANDFATHER PARADOX and the Bootstrap Paradox seem more like science fiction than serious science. But there is one variation on the theme that is taken very seriously by scientists, and has been discussed in research papers published in respectable journals. Their interest is fired by the fact that there is nothing in General Relativity that forbids time travel. In the language of General Relativity, closed time-like curves, or CTCs, are allowed. A CTC is a path through space-time that ends up back where it started, at the same point in space and time.

The Russian physicist Igor Novikov proposed that the way to fix paradoxes would be if there was some law of nature that ensured only self-consistent time loops would be permitted. Together with US theoretical physicist Kip Thorne and other colleagues, he developed a way of picturing this to make the point. It starts with wormholes, those theorised tunnels through space-time that are also allowed by relativity theory.

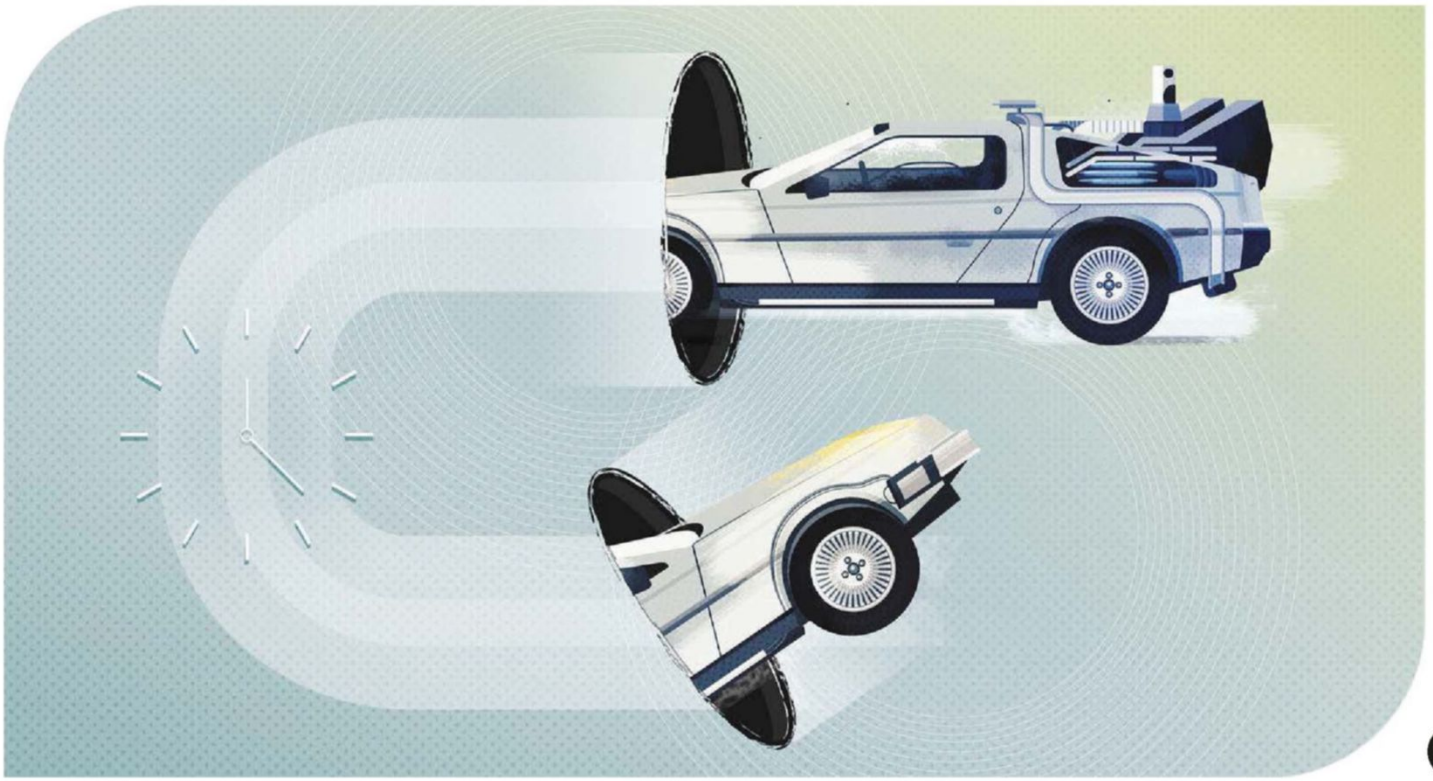
A wormhole can be set up (in principle) with one mouth of the tunnel next to the other mouth, but with the second mouth in the past of the first mouth. Joseph Polchinski, another US theoretical physicist, pointed out how this could lead to a paradox. If a billiard ball (theoretical physicists love billiard balls) is rolled into the first mouth of the wormhole at just the right speed and angle, it will come out of the second mouth just in time to cannon into its younger self and prevent the younger self going into the tunnel. This is Polchinski's Paradox.

But this is not the whole story. There are also self-consistent CTCs. If the billiard ball is approaching the mouth of the tunnel, its older self can emerge from the second mouth and give its younger self a glancing blow exactly right to send it through the wormhole in such a way that it will emerge to give itself a glancing blow that does the same thing. There are many possible consistent trajectories of this kind. In the most extreme case, the 'second' ball emerges from the tunnel and knocks the 'first' ball completely away, but in turn it gets deflected into the wormhole, where it then takes the place of the 'first' ball.

A bunch of rather hairy calculations showed that there is never a system like this where there are no self-consistent trajectories, and that in some cases there can be an infinite number of self-consistent solutions to the equations.

All of this lends weight to Novikov's conjecture, sometimes more grandly referred to as Novikov's Self-Consistency Principle. This states that time travel is allowed, but paradoxes are forbidden. This could resolve the Grandfather Paradox – if you go back and try to kill your grandfather, something will always go wrong. Take a gun to shoot him, and the bullet will misfire; poison his wine, and someone else will drink it, and so on.

Wormholes can present mind-bending paradoxes



BACK TO THE FUTURE: HITS AND MISSES

In *Back To The Future's* 1989 sequel, *Back To The Future Part II*, Marty and Doc travel forward in time to 2015 where they are greeted with more out-there tech than you can shake a flux capacitor at. Now that we've made it to 2015 for real, which of the cult film's predictions have actually come true?

MISS - FLYING CARS

Sci-fi writers have been predicting the arrival of flying cars for decades now, so it's no surprise the *BTTF* team gave the 2015 DeLorean a 'hover conversion'. But despite being a long-term favourite, flying cars have yet to be proven truly viable.

HIT - WEARABLE TECH

While it may so far have failed to appeal to all but the most dedicated Glass-hole, there's no denying that Google's wearable display looks eerily similar to the high-tech specs worn by the McFly family at the futuristic breakfast table.

MISS - SMART CLOTHING

For anyone caught in a downpour without an umbrella, a jacket with a built-in dryer would be a godsend. But shoes that tie themselves? Surely that's just lazy. Regardless, neither product is about to hit the shops any time soon.

HIT - VIDEO CALLS

Another perennial sci-fi staple, the video call, is now so deeply ingrained in everyday life it almost seems passé. But again, the *BTTF* guys got in on the act in 1989 with a video-calling system that's practically indistinguishable from Skype, Google Hangouts and FaceTime today.

MISS - HOVERBOARDS

The closest thing to a functioning hoverboard so far dreamed up is the Hendo. However, as it needs a special surface on which to function, it's not quite up there with the hoverboard from the movie. It's probably for the best; there are more than enough ways of ending up in the A&E department as it is.

ILLUSTRATOR: MAÏTÉ FRANCHI PHOTO: ALAMY X5, CERN, PRESS ASSOCIATION

THE TWIN PARADOX

THIS IS THE most scientifically sound and least paradoxical of all.

Special Relativity tells us that moving clocks (including biological clocks) run slow. This has been tested by experiments in accelerators like the Large Hadron Collider. Particles with a known lifetime when stationary in the lab 'live' longer when they are moving close to the speed of light.

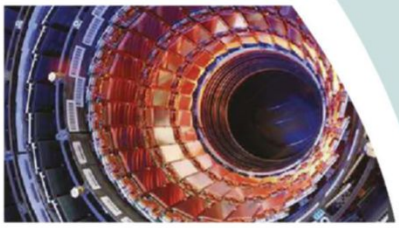
Wormholes, although permitted by the rules, have not yet been seen, so in that sense they are hypothetical. But time dilation has been seen; it is a fact. So if one member of a pair of twins goes on a journey at a sizeable fraction of the speed of light, he or she will age more slowly than the twin who stayed at home. And when the travelling twin returns home, he or she will be younger than the twin who stayed behind. Literally younger, in biological terms.

From the point of view of the travelling twin, time has passed more rapidly on Earth. After a year in the spaceship, they might return to find that 100 years or more have passed on Earth. It is one-way time travel into the future, as explored in sci-fi stories such as *Planet Of The Apes*.

But hang on. Special Relativity says that all observers are equivalent, doesn't it? Why can't the travelling twin say that they are at rest, while the Earth and the other twin go on a journey into the future? All inertial observers, those in straight lines at constant speed relative to each other, are equivalent. Acceleration changes the rules of the game, and in order to get home the traveller has to decelerate and then accelerate back in the opposite direction. In the extreme example often used by paradoxers, this turnaround is instantaneous. As the cosmologist Hermann Bondi once told me, if you give each twin a paper bag full of eggs to hold, at the end of the experiment you will find the traveller covered in egg, while the stay at home twin is clean. They are not 'equivalent'.

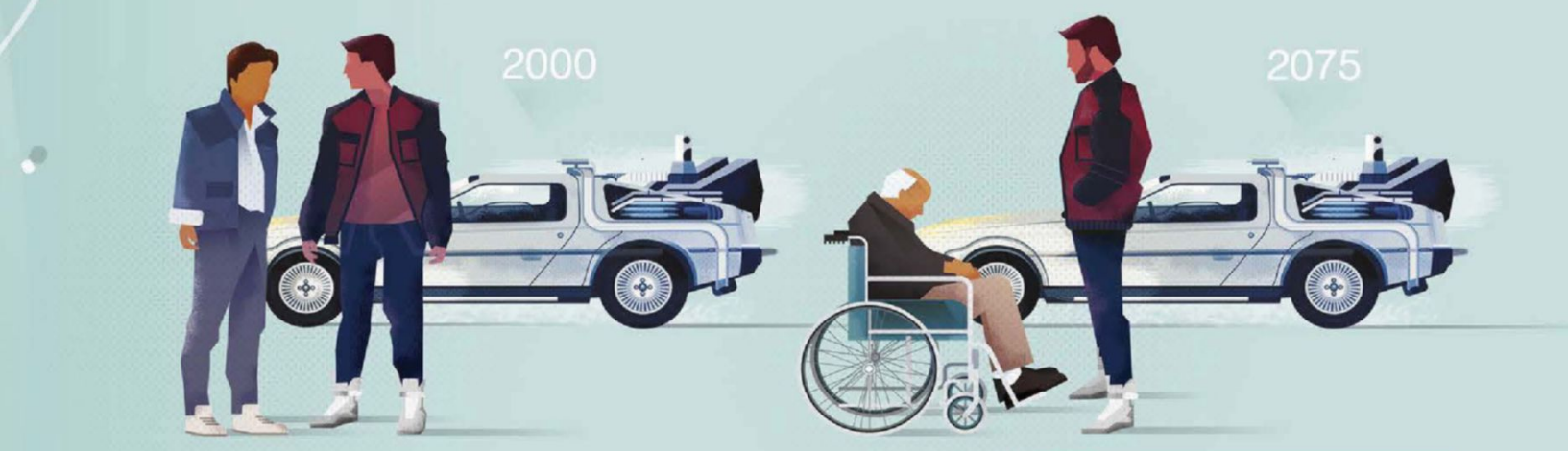
All of this can be described accurately using equations, and the result is the same. This kind of time travel is solid science, and it works. One snag: unless you can find a handy wormhole, there is no way to get back from the future. But that is a great idea for a film title... ■

The LHC proved that clocks run slow



A future world in *Planet Of The Apes*

Cosmologist Hermann Bondi



JOHN GRIBBIN is a science writer, astronomer and astrophysicist. His books include *Einstein's Masterwork* and *Timeswitch*

ARE WOMEN BETTER THAN MEN?

In his new book, anthropologist **Melvin Konner** argues that women are in many ways superior to men. **Jason Goodyer** asks him whether the human race needs men at all...

DO YOU AGREE?

Are women superior to men? Get in touch on Twitter at @sciencefocus

PHOTO: ANN CALE KRUGER, ALAMY, GETTY, ISTOCK

Why are you interested in differences between the sexes?
I had a more classical, modern, liberal view of sex differences when I was very young. I thought there were no important contributions of biology to the differences in male and female psychology and behaviour. I thought all of the differences were due to cultural influences of upbringing and media and so on. But after doing research on child development in Botswana among the Bushmen, and comparing them with preschool children in London, I saw the sex difference in physical aggression – hitting, kicking, wrestling and so on – was there in both places. Then I started to rethink the question and learned a lot more about the genetic and hormonal differences between males and females. I came to the conclusion that there are a limited number of areas of behaviour where biology can help to explain the differences.

What are the examples of this?
Testosterone levels are far higher in men than women after puberty. But it turns out they are also higher in male foetuses. A number of lines of experiment have converged to convince me and other people, though not everyone, that testosterone operating on the male brain before birth makes it somewhat different to the female brain. Modern imaging studies show that the part of the brain that generates violent impulses, the amygdala, is larger in men than in women. It's also dotted with receptors for testosterone. Plus, the part of the brain that inhibits those violent tendencies, the frontal lobes, is more active in women than men. For me, that adds up to the conclusion that men are more predisposed towards aggression and it's got a biological explanation.

In the book you say that male domination is an anomaly, and that for most of history women have played a more prominent role...
The Bushmen in Botswana did exemplify a male predominance in physical aggression. But it also showed me that in a very small face-to-face society, the decision-making processes inevitably includes women. Men might tell you that they're superior to women in some way or another – you will hear that from men in most cultures – but in a culture like this they can't exclude women from participation. It would be really stupid to do so because you need all the intelligence and good ideas you can get to survive in such a challenging environment. That's the way our ancestors lived for scores of thousands, or even hundreds of thousands of years.

So what happened?
At the beginning of the period we call the 'rise of civilisation' – after the invention of agriculture – people settled down in large, dense populations. You didn't have a face-to-face society anymore. You started to have specialised roles: you had a priesthood, a military, a merchant class. These became male-dominated because there was a critical mass of men that could get together and exclude women. Another way to think of it is that in the previous period with the small face-to-face culture, there was no real separation between private space and public space. In the more dense populations, when you had a real separation, men began to exclude women from public space and just relegated them to the home and the children. That prevailed for thousands of years until a century and a half or maybe two centuries ago, when women started to make inroads into various areas of public life.

"I have it on pretty good authority that most women don't want to see the end of men but it is a technical possibility"

You use a lot of colourful examples from the animal kingdom. What can animals tell us about humans?
It tells us that there is a lot of variety out there. You don't see males dominating everywhere. There are species in which the females are larger and more dangerous than the males. I love the example of the praying mantis. There they are in mid-copulation and she bites his head off! He keeps right on going. She gets the sperm donation and eats the rest of him. He's making a sacrifice for the nourishment of his offspring. So it's not universal in nature for males to predominate. You also get snails shooting darts carrying sperm at each other. These are species where each individual is both male and female. But there is still a battle of the sexes – even without sexes. Each individual in the mating act is trying to get an advantage over the other one. What that tells us is that conflict is inherent in nature; we can't expect to eliminate it in sex. But we might be able to change the arrangements so that the conflict is less damaging and maybe less frequent.

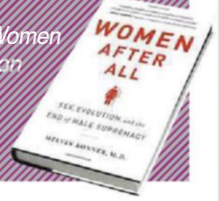
Are there any examples of this in the animal kingdom?
We have two very close relatives among the apes: the chimpanzee and the bonobo. They have different levels of violence and different patterns of sex. Chimpanzees are very violent: males kill other males, they are violent towards females and there is coercive sex. In bonobos there is conflict but it doesn't reach anything like the same level. People call them the 'make love, not war' species. Females keep males in line by having coalitions among themselves. But it looks like a great society for males too. They get plenty of sex and they don't have to fight for it like the chimps do. I think of bonobos as a kind of model for our future as females get more influential.

Could we ever go beyond this and have a human race without men?
Technically, yes. Some people think because I talk about this I'm in favour of it. I'm not. But scientists have reverse engineered skin cells to make eggs and sperm. This raises the possibility that a gay or lesbian couple will be able to have biological children in the not too distant future. Two men could have their genes joined and two women could. But there's a difference: the men would have to borrow a womb from a woman, but the women wouldn't need to because they will have two of them. I have it on pretty good authority that most women don't want to see the end of men but it is a technical possibility. ■

Find out more

sciencefocus.com/podcast
Listen to the extended interview with Melvin Konner on our podcast

Read Melvin's book *Women After All: Sex, Evolution And The End Of Male Supremacy* (£16.99, WW Norton & Co)



Bridging the gap between NATURE

PHOTO: GETTY

and NURTURE

Scientists are uncovering the ways in which diet, lifestyle and the environment can affect your genes. As **Nessa Carey** discovers, this may change the face of evolution as we know it...

FRANCIS CRICK AND James Watson became household names for their 1953 discovery of the structure of DNA, and that breakthrough formed the basis for our understanding of how attributes are passed on from one generation to the next. But DNA – the genome – isn't the whole of the story. Since the 1970s, the role of the 'epigenome' has come under ever greater scrutiny. The epigenome is the name given to tiny chemical modifications made by factors such as environment and diet to DNA and the proteins it wraps around. And studying these modifications has thrown up some surprising results. While your green eyes or dark skin are due to the DNA you inherited from your mother, your wiry build could have something to do

with how your grandmother was living while she was carrying her.

The extraordinary process of development starts with a single cell with limitless potential and ends, in humans, with trillions of cells that have become specialised. Several decades ago, no one knew what happened to the DNA when cells became specialised. One hypothesis was that cells got rid of the DNA they no longer needed. For example, brain cells would 'lose' genes that code for haemoglobin, the pigment that carries oxygen in the blood, while liver cells would abandon DNA coding for keratin.

In the 1970s Prof John Gurdon, working first in Oxford and subsequently in Cambridge, disproved this theory. He removed the nuclei from frogspawn and replaced them with the nuclei from adult frog cells. The frogspawn developed into

Almost all tortoiseshell cats are female. The orange and black coat colour genes are carried on the female sex chromosomes, known as X chromosomes. One of each pair of X chromosomes is randomly silenced by epigenetics early in development, and this creates the beautiful patchwork patterns in the feline fur.

EVERYDAY EPIGENETICS: CATS

HOW IT WORKS

How epigenetic modifications are expressed within the structure of our DNA, and passed on to our children

THE DNA IN our cells is not a long, stringy molecule. Instead, it's curled around proteins called histones. DNA winds around a cluster of eight histone proteins, then continues on a little before winding around another cluster. This process is repeated millions of times in every cell. It allows our cells to package about two metres of DNA into a nucleus only a fraction of a millimetre in diameter.

When a cell receives signals from the environment, tiny chemical modifications are made to the DNA and to the histone proteins. These are called epigenetic modifications, and they regulate expression from the DNA. There is a huge range of different modifications, especially to histone proteins, and they come in a dizzying array of combinations, creating vast flexibility in gene expression. And because cells pass on the same pattern of epigenetic modifications to daughter cells when they divide, these effects on gene expression are maintained.

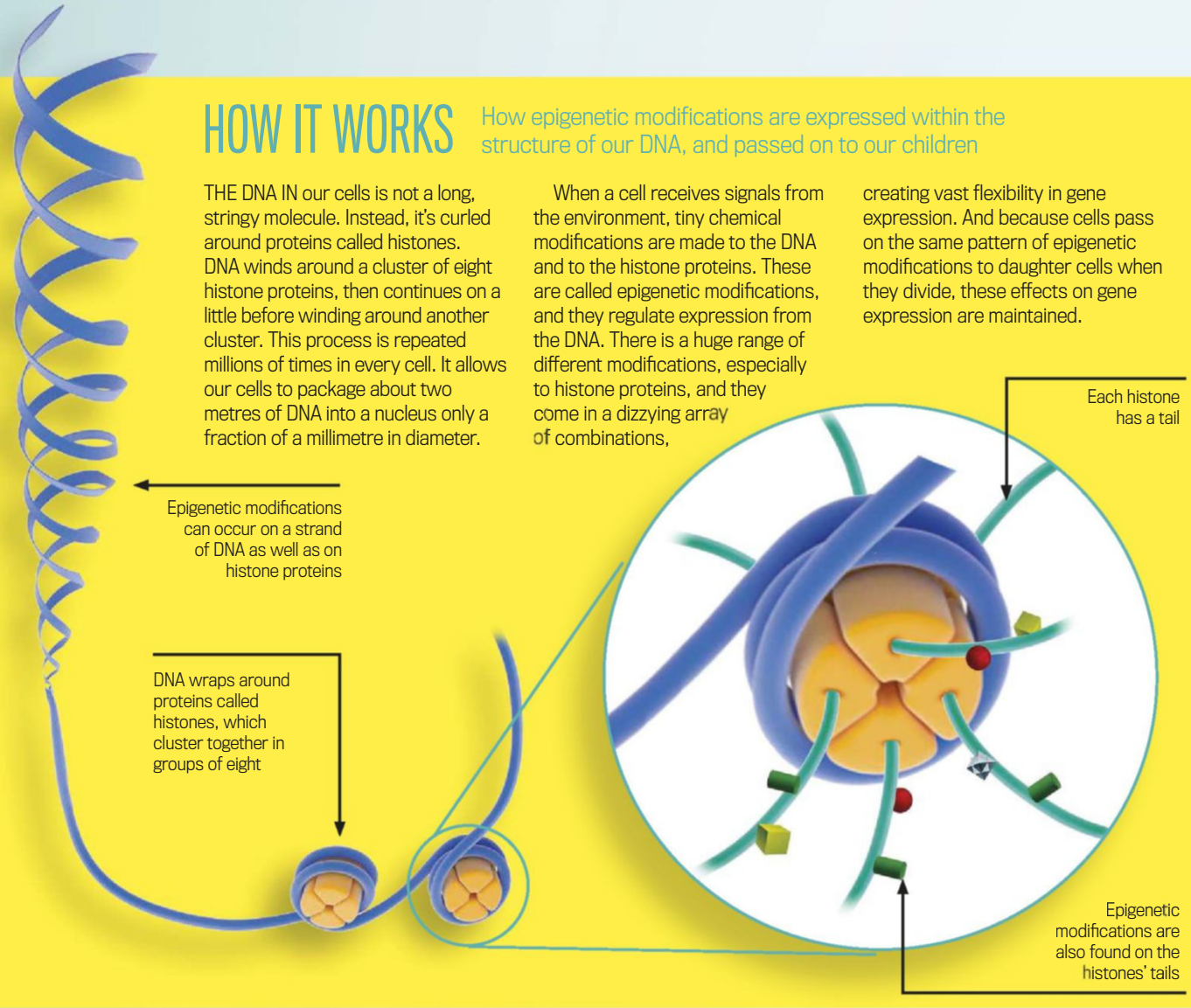
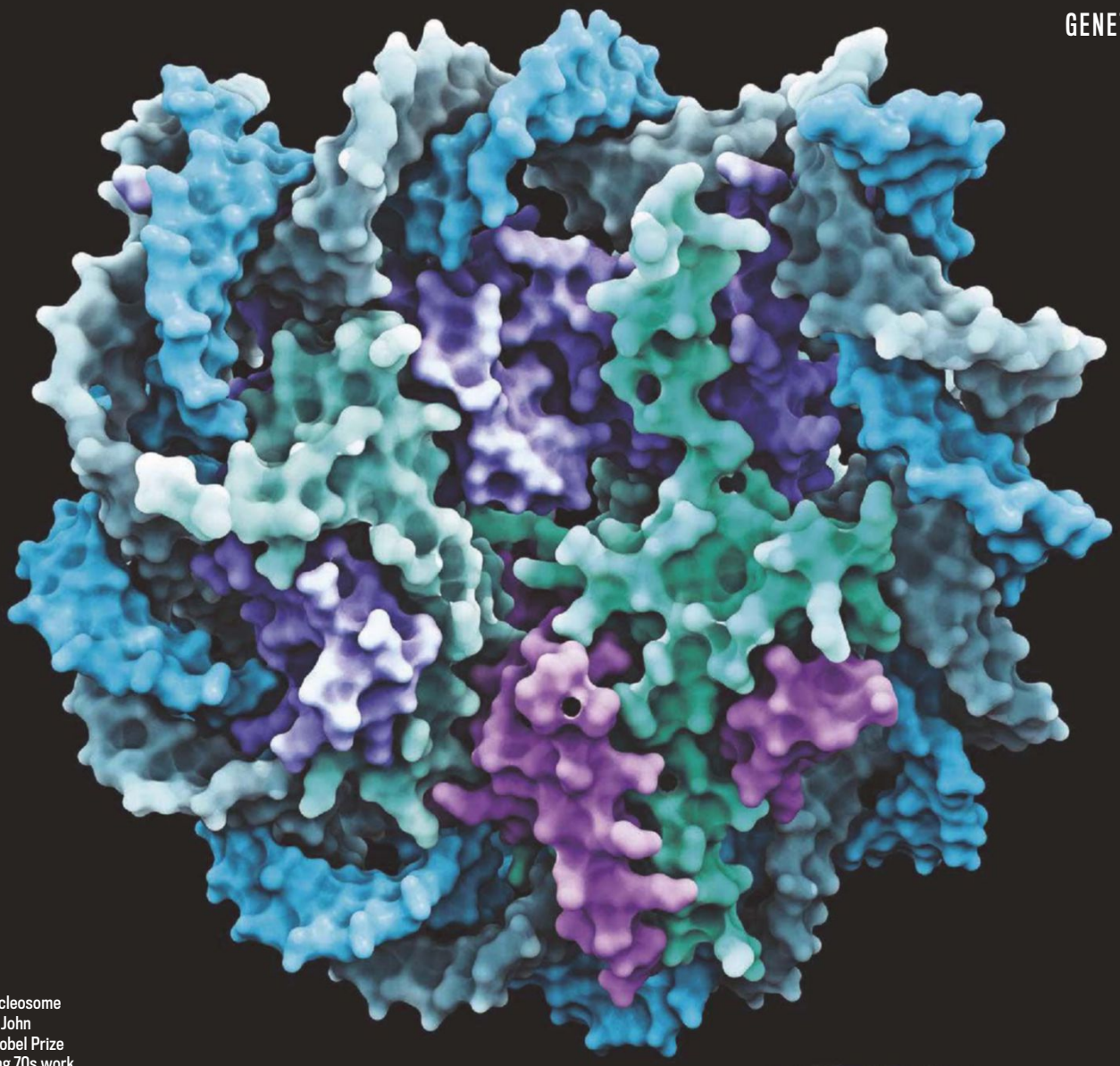


PHOTO: SCIENCE PHOTO LIBRARY X2, PRESS ASSOCIATION



Right: A DNA nucleosome
Below right: Sir John Gurdon won a Nobel Prize for his pioneering 70s work on genetics in frogs

tadpoles and finally frogs. This demonstrated that there is no difference in the DNA of different cells from an individual. In 1996, Ian Wilmut, Keith Campbell and colleagues at the Roslin Institute proved that the same is true in mammals when they cloned Dolly the sheep, using a nucleus from an adult sheep mammary cell.

The birth of epigenetics

In 2012, Gurdon was awarded a Nobel Prize for his work. Over the decades since his discovery, researchers – such as those at the multinational Roadmap Epigenomics Project – have made enormous strides in identifying the mechanisms behind epigenetic phenomena. These mechanisms are dependent on tiny chemical modifications to DNA, and to certain proteins called histones that are associated with our genetic material (see 'How it works', left). These modifications are referred to as 'epigenetic modifications'.

Hundreds of different enzymes can add or remove epigenetic modifications at different positions on the genome, and hundreds of other proteins can bind to various combinations of

EVERYDAY EPIGENETICS: SEA BASS

Mammal gender is genetically determined, based on the presence or absence of a Y chromosome. However, in young European sea bass, water temperature causes epigenetic changes, and this determines their gender. There's a similar mechanism in crocodiles. It's possible, therefore, that climate change may disrupt sex distribution in such species.

modifications and change the way the genome is used. These epigenetic modifications change in response to environmental stimuli, and allow our cells to adapt their expression of particular genes to a change in circumstance. Epigenetics therefore provides the bridge between nature (our genome) and nurture (our environment).

Epigenetics in humans

Some epigenetic responses to the environment are established early in life, such as in the first trimester of human pregnancy. An example of this has previously been seen in the Netherlands. Towards the end of WWII, certain regions of the country suffered catastrophic food shortages. Calorie intake dropped to less than 40 per cent of normal levels for a period of several months that became known as the 'Hunger Winter'. Babies conceived during this period were normal at birth, but as they matured they began to show increased levels of adult obesity and Type 2 diabetes. This is because their genes were epigenetically modified during early development to enable the individuals to make the best use of what scarce nutrition there was. This would be an advantage if the famine had continued, but in a society with limitless access to food, this epigenetic alteration is problematic.

The original invitations for parents in the southwest UK to take part in the Avon Longitudinal Study of Parents and Children, AKA 'Children of the 90s'

Dutch children during the 'Hunger Winter' of 1944-45. The epigenetic effects of the Netherlands' wartime famine are still being experienced today

Epigenetics provides researchers with a new way of understanding the foetal origins of adult disease, and is actively investigated in long-term epidemiological studies such as the Avon Longitudinal Study of Parents and Children that has been following nearly 15,000 families since the early 1990s. Rodents that experience traumatic early life experiences establish epigenetic neuronal patterns that affect their stress levels in adulthood. Similar mechanisms may underlie the negative effects that early childhood abuse has on adult mental health in humans.

Epigenetics and heredity

We know that genetic information is passed on from parent to child, but what about epigenetic information? In the 1980s, Prof Azim Surani at the University of Cambridge demonstrated that this does happen. In fact, successful reproduction in placental mammals positively *requires* transmission

PHOTO: ISTOCK, UNIVERSITY OF BRISTOL, GETTY X3, ALAMY, JAMES SMITH/THE GURDON INSTITUTE, NEDERLANDS FOTOMUSEUM

"Epigenetic modifications change in response to environmental stimuli, and allow our cells to adapt their expression of particular genes to a change in circumstance"

of appropriate epigenetic modifications from both parents. Using in vitro fertilisation techniques in mice, Surani showed that live animals can only be born if an egg and a sperm nucleus fuse together in an egg. No live young were born if he used two egg nuclei or two sperm nuclei, even though at a genetic level all three situations were identical.

More evidence that epigenetic information is passed on from parent to child comes from a strain of mice called the 'Agouti viable yellow'. These mice can be fat and golden, skinny and brown, or all types in-between. All Agouti viable yellow mice are genetically identical; their differences are caused by epigenetic modifications to a certain region of the genome. The offspring tend to look like

Above: The cloning of Dolly the sheep in 1996 proved that stem and adult cells in mammals both contain the same DNA information

TIMELINE

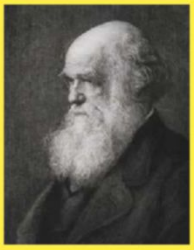
Key discoveries in the history of genetic science

1801

Jean-Baptiste Lamarck attempts to explain speciation – the process by which new species arise – using his Theory of the Inheritance of Acquired Characteristics.

1859

Charles Darwin's *On The Origin Of Species* hypothesises speciation through a process of natural selection, based upon random variation between individuals.



1863

Gregor Mendel's work on peas gives birth to the ideas of 'units of inheritance' and recessive and dominant alleles, but is neglected until over 30 years after his death.

1953

Francis Crick, Rosalind Franklin (pictured), James Watson and Maurice Wilkins determine the structure of DNA, opening up the way for our molecular understanding of genetic inheritance.

1980s

Azim Surani demonstrates that both genetic and epigenetic information are transmitted to the offspring during mammalian reproduction.

their parents, showing that they are inheriting this epigenetic information. But it's not always perfect – some of the baby mice are different from their parents, which demonstrates that the transmission of epigenetic information is fuzzy. The proportion of the offspring that have a different appearance varies in response to environmental stimuli, such as giving alcohol to the mothers.

So according to the research carried out on the mice, epigenetic information is passed on from parent to offspring and can also be influenced by the environment. This raises the next question: can epigenetically-mediated responses to the environment be passed on from parent to offspring?

Classical Darwinian models of evolution would say no, as this idea has more in common with the theory of inheritance of acquired characteristics proposed by Jean-Baptiste Lamarck, the 19th Century French naturalist who was Darwin's main rival. But this certainty is increasingly coming under threat. There are some indications from the Dutch Hunger Winter subjects, for example, that the metabolic defects suffered by those who experienced famine in childhood are now being passed on to future generations.

Epigenetics and evolution

Unfortunately, it is incredibly difficult to separate the effects of genetics, epigenetics and environment in human populations. So for greater certainty, researchers have once again turned to rodents.

A number of studies have shown that when male rodents are malnourished, their offspring are metabolically impaired. But it's experiments using fear-conditioning techniques that have really shaken up the field. Male mice were trained to associate a particular smell with an electric shock, and after repeated exposures the smell alone was enough to trigger a fear response. When the

NATURAL SELECTION EXPLAINED

NATURAL SELECTION IS a process driven by random variation – changes in DNA sequence that are passed on from parent to child. If a particular variation confers an advantage under the prevailing environmental conditions, the individual carrying that variation has more chance of surviving to breeding age, and of breeding successfully.

This will pass on their DNA sequence, and increase the number of individuals in the next generation carrying that variation. When this continues over millennia, it drives the process of speciation. And even within shorter periods, it can affect how populations develop. For example, the variation in the haemoglobin gene that makes people susceptible to the genetic condition beta thalassemia also gives them a degree of protection from malaria. This is why levels of beta thalassemia are highest in countries where malaria has historically been endemic, such as Greece and Turkey.

Recently we have discovered that epigenetic modifications may also be passed on from parent to child.

EVERYDAY EPIGENETICS: TWINS

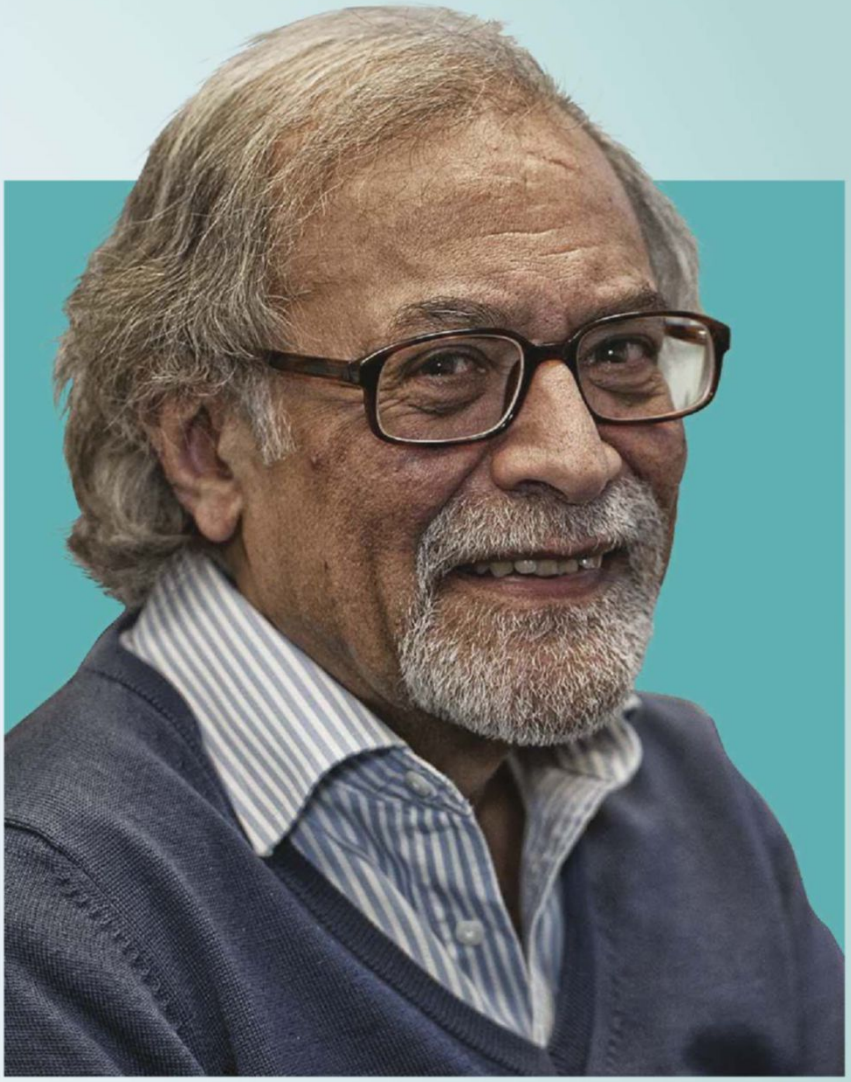
Identical twins are rarely exactly the same, despite sharing the same DNA code. In extreme cases, one twin may have a devastating disease such as schizophrenia while the other is healthy. This disparity reflects growing epigenetic differences between the twins, usually as a combination of responses to the environment and also random variability in the epigenetic modifications in their cells.

PHOTO: ISTOCK X2, JAMES SMITH/THE GURDON INSTITUTE, GETTY

"Mice were trained to associate a particular smell with an electric shock. When the mice's offspring were tested, they were also frightened by the smell"

offspring of the mice were tested, they were also frightened by the smell, even though they had never been exposed to the electric shock. The mice also had the same epigenetic modifications to key genes in the brain as their traumatised fathers.

Does this mean that the Darwinian model of evolution is dead? Of course it isn't, even though there are now epigeneticists who refer to themselves as neo-Lamarckians. Most of the time, eggs and sperm are protected from epigenetic changes to the environment, and relatively few newly established modifications are likely to make it through to the next generation. Even when they do, the modifications and the effects they cause tend to die out within a few generations. This is what we would expect, as epigenetic alterations are intrinsically unstable.



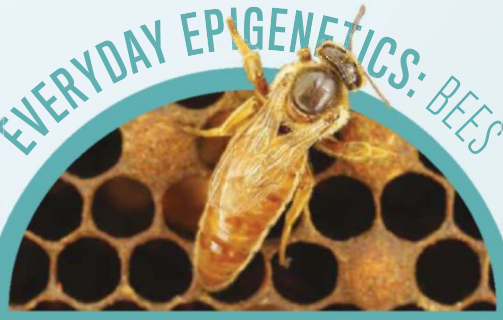
Prof Azim Surani demonstrated in the 1980s that epigenetic information is passed from parent to child in mammals

But this transfer of epigenetic information across generations probably provides short-term advantageous adaptations to temporary changes in the environment without affecting the underlying genetic code that has evolved over thousands of years. The epigenetic inheritance takes place under certain conditions, but is unlikely to be a major player in long-term natural selection.

Despite this, there is an increasing and facile tendency to 'blame' epigenetic inheritance for current problems, especially with respect to the human obesity epidemic. Fascinating though this field is, it's not a get-out. The most important things that are happening to your health are happening here and now: no one gains weight in 2015 just because their grandad had a fondness for doughnuts in the 1960s! ■

NESSA CAREY is a molecular biologist and author of the books *Junk DNA* and *The Epigenetics Revolution*

EVERYDAY EPIGENETICS: BEES



Queen bees are physically very different from workers, and can live 20 times longer. But there's nothing genetically special about queen bees: they are just the product of a different feeding regime in early life. This leads to epigenetic modifications that maintain queenly gene expression patterns.

FLYING

PHOTO: SOLAR IMPULSE

SOLAR

Solar cells across the top of the wings power the engines during the day

After 12 years of painstaking design and testing, Solar Impulse 2, an aircraft powered by sunlight alone, is due to complete its round-the-world trip. **Dr Neil Ashton** reports

SOLAR IMPULSE 2 took to the skies of Abu Dhabi on 9 March 2015 to start its incredible 35,000km (22,000 mile) journey round the planet. If all goes to plan, it will touch down in August, making it the first solar-powered aircraft ever to complete such a journey.

The brains behind the project are the Swiss duo of psychiatrist Bertrand Piccard and businessman/pilot André Borschberg, two men who broke several solar flight records with their earlier aircraft Solar Impulse 1.

Despite its success, the men were driven to achieve more. "I wanted to show that you can achieve incredible goals with clean renewable energy, such as flying around the world without a single drop of fuel," Piccard says.

Between them they secured funding from

The Solar Impulse 2 has a wingspan of 72 metres, wider than that of a Boeing 747

ALL PHOTOS: SOLAR IMPULSE

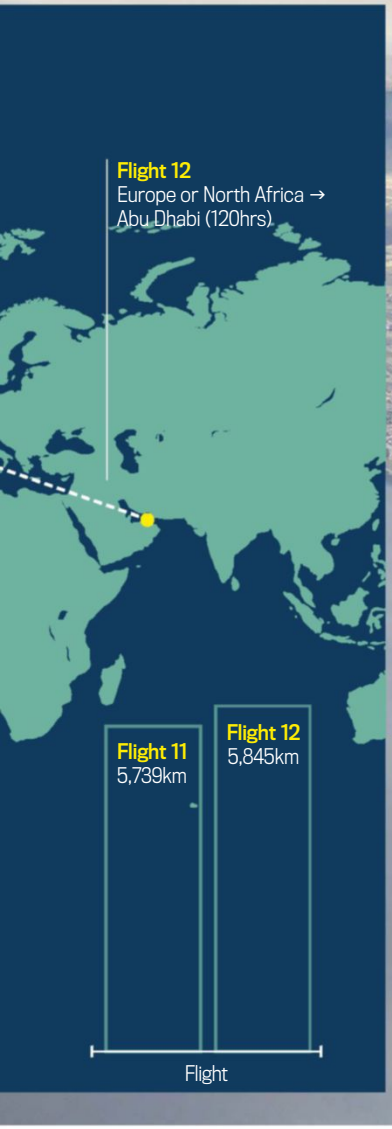
AROUND THE WORLD IN 25 DAYS

The total journey will take place over five months. During that time, less than one month will actually be spent in flight, racking up the air miles...

HOW FAR?

Solar Impulse 2 will travel 35,000km over the course of 12 flights

"Solar Impulse 2 is somewhat different in appearance from a conventional aircraft"



more than 90 partners, including massive names such as Google and Omega, to raise the 150 million Swiss francs the project has so far cost, and amassed a skilled team of over 80 specialists and engineers.

Of course, the aircraft had to be designed from scratch. Simply fitting solar cells to an existing aeroplane would not be enough. Solar Impulse 2 is somewhat different in appearance from a conventional aircraft. Weight is of premium importance. While its slender wings measure 72 metres, wider than those found on a Boeing 747 jumbo jet, they are less than 1 per cent of the weight due to the use of carbon fibre composites. The lightweight design was carried through to the rest of the aircraft and the whole thing clocks up just 2.3 tonnes on the scales, which is about the same as a family car.

The energy gathered from the array of more than 17,000 solar cells lining the wings is used to drive four propeller engines, which together produce a total of 70 horsepower, the same power as a small car. Inside the engine housings are lithium polymer batteries, which are charged up during the day by the solar panels to provide the necessary power for the night. To be as efficient as possible, Solar Impulse 2 flies much more slowly than a typical aircraft, at speeds of between 35km/h and 140km/h (22-87mph) depending on the altitude. It cruises at altitudes of up to 8.8 kilometres (5.5 miles) during the day,

HIGH FLYER

The Solar Impulse 2 is ultra-small and lightweight, yet it can still approach the altitudes of standard aircraft

Frame
The plane's frame is made from lightweight carbon fibre ribs wrapped with rigid polyurethane foam to provide insulation for the pilot and the equipment. This is then covered in a flexible plastic film coated with the same weatherproofing treatment used on the 2014 World Cup football to keep the elements at bay.

Batteries
Four lithium polymer batteries provide the power to the engines during the night. They are charged up during the day by the solar cells. The batteries are insulated by a high-density foam and are mounted in the four engine housings. Their total weight is 633kg, just over a quarter of the aircraft's weight.

Engines
Four propeller engines, each generating 17.4 horsepower, are mounted beneath the wings. These engines are powered by the solar panels during the day and then from the batteries at night. The entire system is 94 per cent efficient – a new world record.

Solar cells
The craft is powered by more than 17,000 solar cells capable of collecting up to 340kWh of solar energy per day. They are located across the top of the wings, fuselage and tailplane. Each cell is just 135 micrometres thick.

ALL PHOTOS: SOLAR IMPULSE

COCKPIT
There's not much room to stretch in Solar Impulse 2's cabin

The cabin of Solar Impulse 2 measures just 3.8m^3, barely larger than the front of a typical car. To save weight, the craft is not pressurised. This means the pilots require oxygen, provided by six on-board bottles. They are also subject to extreme temperature variations between -40°C and 40°C. A multipurpose seat acts as a bed and toilet, which when fully reclined also allows the pilot to perform physical exercises. Behind the seat is a parachute and a life raft in case of emergencies.

Pilots
Flying continuously for five days and nights puts an incredible strain on the pilots, with sleep deprivation being a major issue. In fact, they only nap for 20 minutes at a time. The low weight of the aircraft also means it is more sensitive to air turbulence and crosswinds. A team of experts situated at the mission control centre in Monaco work with the pilots to navigate around dangerous weather patterns and prepare for takeoffs and landings.

Along with André Borschberg, Bertrand Piccard (pictured) will be piloting the craft around the world

close to those at which commercial airlines fly. As the Sun is setting, the pilot shuts off the engines and drops down to 1,524 metres (5,000 feet) over four hours of gliding to save power. The engines are then turned back on and run on power stored in the batteries for the rest of the night. The whole cycle begins again when the Sun rises.

The trip around the globe has been split into 12 individual flights. Solar Impulse 2 embarked on its journey when it took off from Abu Dhabi and started flying east. Over the course of the trip, the craft will cross both the Pacific and Atlantic Oceans before eventually returning to Abu Dhabi.

There is only enough space for one pilot in the aircraft, so after each flight, which can last up to five days, pilots swap over and the aircraft is inspected for damage. Flying for this length of time is a major challenge for the pilots, especially as they are confined to a space not much larger than the front seats of a typical car.

Presuming everything goes as intended, the next logical question to ask is whether solar technology could ever find its way into

"Flying for this length of time is a major challenge for the pilots"

SPAN THE SKY

Solar Impulse's wings are just 1 per cent the weight of a Boeing 747's

Solar Impulse 2
72m

Boeing 747
68.5m

commercial aircraft. At this stage it seems unlikely that it could provide the necessary power by itself. However, NASA's Subsonic Fixed Wing team are currently looking into hybrid power technology and are hoping to achieve a 50 per cent reduction in aircraft carbon emissions by 2050.

It could be that over the coming decades we will start to see some of the technology Solar Impulse is pioneering making its way into commercial aircraft. But for now, solar-powered flight remains the preserve of a select few record-breaking mavericks. ■

DR NEIL ASHTON researches aerospace engineering at the University of Manchester

Q&A YOUR QUESTIONS ANSWERED

BY OUR EXPERT PANEL

SUSAN BLACKMORE
Susan is a visiting psychology professor at the University of Plymouth. Her books include *The Meme Machine*

DR ALASTAIR GUNN
Alastair is a radio astronomer at the Jodrell Bank Centre for Astrophysics at the University of Manchester

ROBERT MATTHEWS
After studying physics at Oxford, Robert became a science writer. He's Visiting Reader in Science at Aston University

GARETH MITCHELL
Starting out as a broadcast engineer, Gareth now writes and presents *Click* on the BBC World Service

LUIS VILLAZON
Luis has a BSc in computing and an MSc in zoology from Oxford. His works include *How Cows Reach The Ground*

EMAIL YOUR QUESTIONS TO questions@sciencefocus.com
or post to *Focus* Q&A, Tower House, Fairfax Street, Bristol, BS1 3BN

Q **JAMIE WATTS,** POOLE

How long can a newspaper be stored before it disintegrates?

A **IT'S TOO EARLY to say. There are still a few surviving copies of the first newspaper printed in Britain, and those date from 1665. The British Newspaper Archive actually has most editions of every newspaper published in the UK since 1800. Provided it is kept in a dark, dry place, paper is extremely durable. The oldest surviving piece of paper was discovered in Wuwei in China. It was made around 150AD, which is only 45 years after paper itself was invented! Modern newspaper archives are digitised now as well, but the paper copies will last for a while yet. LV**

That ceiling needs dusting...

PHOTO: GETTY

In Numbers

36

days a year are spent answering work emails by the average British employee. Londoners each receive about 9,000 emails annually

MARY LOWELL, SOUTHWOLD

What is the maximum height a cat can fall from and survive?

A WHEN A CAT falls, it reflexively twists its body in mid-air so that its feet face downwards. There are documented cases of cats falling from the 32nd storey of New York skyscrapers and surviving. But landing unscathed is far from guaranteed. One 1987 study in the *Journal Of The American Veterinary Medical Association* looked at 132 cats that had fallen an average of 5.5 storeys and survived. It found that a third of them would have died without emergency veterinary treatment. Interestingly, injuries were worse in falls less than seven storeys than in higher tumbles. The researchers think that this is because they reach their terminal velocity after falling about seven storeys (21m), which means they stop accelerating. They then relax, allowing better distribution of impact. **LV**

Catwoman was well overdue a waxing appointment

RICHARD WARD, LUTTERWORTH

Has Earth ever had more than one Moon?

A NO OBSERVATIONS OR theoretical claims for additional moons of the Earth have ever been substantiated. However, some astronomers have speculated that there may have been a companion moon very early in Earth's history. An impact with this 'other' moon may help explain how the Moon's nearside is low and flat and is dominated by volcanic maria (or 'seas'), whereas the far side is mountainous and deeply cratered. It can also explain the distribution of certain chemical elements on the Moon. However, other processes can also account for these observations, so the 'other moon' idea is still hypothetical.

The Earth does, however, have some very small satellites that could be classed as moons. In 2006 a tiny asteroid, 2006 RH120, was discovered in Earth's orbit. This 'captured' object remained in Earth orbit for 13 months before returning to a solar orbit. These 'temporary' moons are thought to be quite common. **AG**

The Moon isn't as lonely as you'd think

TERRY REES, MANCHESTER

How did winged seeds evolve?

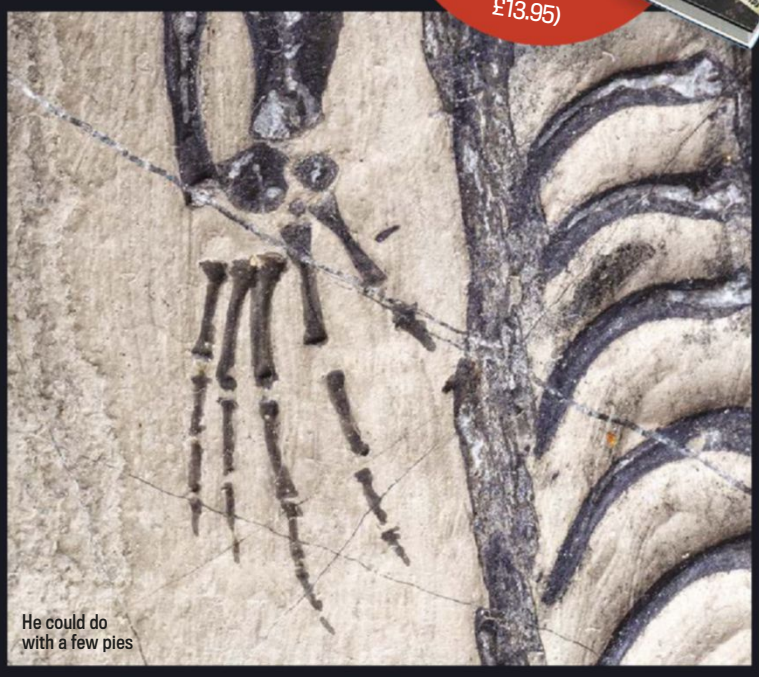
A EARLY TREES HAD wind-borne spores rather than seeds. About 365 million years ago some plants evolved seeds with a food store, to give the developing embryo a head start. These were heavier, so the early conifers began to evolve seed coats with enlarged ribs or vanes to help catch the wind. By 270 million years ago, a tree called *Manifera talaris* had developed seeds with wings that allowed them to spin as they fell. The seeds were variable; some had two equal wings, some had one wing much bigger than the other and some had just one wing. But aerodynamic reconstructions have shown that a single, asymmetric wing makes seeds fall the slowest. Evolution favoured this design because the seeds were spread further by the wind. Today, all conifers with winged seeds use a single asymmetrical helicopter wing. **LV**

I believe I can fly...

PHOTO: ISTOCK X5, SCIENCE PHOTO LIBRARY

WINNER!
Ben Arthur wins *Abominable Science!* by Daniel Loxton and Donald Prothero (Columbia University Press £13.95)

QUESTION OF THE MONTH



He could do with a few pies

Q **BEN ARTHUR,** HULL

Why did we evolve five digits on each limb, and not another number?

A **ALL LAND VERTEBRATES today are descended from a common ancestor that had four legs, with five toes on each foot. This arrangement is known as the pentadactyl limb. Some species have subsequently fused these fingers into hooves or lost them altogether, but every mammal, bird, reptile and amphibian traces its family tree back to a pentadactyl ancestor that lived around 340 million years ago.**

Before, there were animals with six, seven and even eight toes on each foot, but they all went extinct at the end of the Devonian period, 360 million years ago. These other creatures were more aquatic than the pentadactyl animals. Evidence in the fossil record suggests that their ribs weren't strong enough to support their lungs out of water and their shoulder and hip joints didn't allow them to walk effectively on land. We don't know the exact reasons behind the late Devonian extinction, but it seems to have killed off the coral reefs and reduced the oxygen levels in shallow coastal waters and rivers. This environment would have favoured fish species that were able to survive in the open sea, and animals that were able to climb out of the water.

There's nothing particularly special about having five toes that allowed the pentadactyls to do this; they just happened to be the ones with the other important adaptations for life on land. All the other groups went extinct before they evolved them. LV

Q **CHARLIE GILES,** MAIDSTONE

Are electric trains really better than diesel?

Electric trains: even more overpriced seats to enjoy

A TO DATE, THE focus on electrification in the UK has been on marginally quicker journeys, but electric trains are also more reliable, quieter and cleaner. The more compact and efficient power units also allow 20 per cent more seats per train. **RM**

Q **PAUL LESLIE,** BY EMAIL

How much skin does a human shed in their life?

A ACCORDING TO A 2011 study published in the journal *Environmental Science & Technology*, we shed between 0.03 and 0.09g of skin every hour. That sounds like almost nothing, but over the course of a lifetime it adds up to about 35kg, or roughly half your bodyweight. Most of this is in the form of tiny flakes, which make up a major constituent of house dust.

Interestingly, the same study found that the squalene oil on shed skin reacts with harmful ozone in houses, offices and aeroplanes, so dust can actually improve the air quality. **LV**

All-you-can-eat buffet for dust mites

TOP 10
LONGEST ANNUAL ANIMAL MIGRATIONS

1. Arctic tern
Distance:
90,000km
(55,923 miles)

2. Sooty shearwater
Distance:
64,000km
(39,768 miles)

3. Bluefin tuna
Distance:
40,000km
(24,855 miles)

4. Humpback whale
Distance:
25,000km
(15,534 miles)

5. Grey whale
Distance:
22,000km
(13,670 miles)

6. Northern elephant seal
Distance:
21,000km
(13,049 miles)

7= Leatherback turtle
Distance:
20,000km
(12,427 miles)

7= Great white shark
Distance:
20,000km
(12,427 miles)

9. Globe skimmer dragonfly
Distance:
17,000km
(10,563 miles)

10. Adelie penguin
Distance:
13,000km
(8,078 miles)

PHOTO: ISTOCK X10, JJ HARRISON, GILBERT VAN RYCKEVORSEL/TAG A GIANT, SEA PICS, NASA, ALAMY, GETTY

Q **PHIL FRIESEN,** VICTORIA, CANADA

Is atmospheric oxygen declining, and does it matter?

Ocean eddies could cause dead zones

A **OXYGEN MAKES UP one-fifth of the air we breathe, but it's the most vital component – and it does seem to be declining. The main cause is the burning of fossil fuels, which consumes free oxygen. Fortunately, the atmosphere contains so much oxygen that we're in no danger of running out soon.**

According to the Scripps Institution of Oceanography, monitoring stations point to an annual loss of just one oxygen molecule for every five million air molecules. They have also found hints that the ecosystem is compensating for some of the loss.

A more pressing problem may be the loss of dissolved oxygen in the water. 'Dead zones' with less than 5 per cent of the amount of oxygen needed for the majority of marine creatures are most common around polluted coastlines. But in April, researchers announced the discovery of dead zones in the North Atlantic – the first ever found in the open ocean. These appear to be linked to naturally-formed eddies, inside which oxygen-consuming plants can settle and grow. Whether such eddies will become more common with global warming is unclear. RM

Q **ALEX ROUND,** LONDON

Can you be allergic to a smell?

A EVEN IF YOU are allergic to peanuts, the smell of peanut butter won't set off a reaction. Chemicals called pyrazines cause the smell, whereas the peanut proteins that cause the allergy aren't normally volatile enough to inhale as an aroma. Cooking can release large enough particles to set off allergies to many foods; even then it isn't the smell that is triggering this, it's the cloud of food proteins.

There is, however, a phenomenon known as 'chemical sensitivity'. Here, sufferers report headaches and nausea from the aroma of paint fumes and perfume. This isn't medically recognised in the UK, though, and it certainly does not count as an allergy. **LV**

You can never have too much peanut butter

Q URSY REYNOLDS, GLOUCESTERSHIRE

What happens in our brain when we learn languages?

A SPECIFIC BRAIN AREAS increase in size and function, including Broca's area, which is usually in the left hemisphere and involved in language production. When children grow up bilingual, both languages are processed in the same area. Yet when adults learn a second language, a separate area develops close to the first.

Some adults learn more quickly than others and one study showed differences in the brain areas that changed: the hippocampus and Broca's area altered most in the fast learners and the motor cortex in slower students. Some effects depend on the person's first language. For example, native Japanese speakers cannot readily distinguish 'r' and 'l' when learning English because in their brains both these sounds activate the same area. In native English speakers, however, the sounds activate distinct areas.

More generally, learning a new language improves brain function, providing better memory, more mental flexibility and creativity, and can even delay the onset of dementia. **SB**

"This would be so much easier if I had a babel fish"

Q PETE HOLMES, ABERDEEN

Why are bees in decline?

If honeybees disappear, you can wave goodbye to your fave toast topping

A IT'S A COMBINATION of several different factors. Honeybees are vulnerable to the *Varroa destructor* mite that was introduced accidentally from Southeast Asia. There is also evidence that many pesticides, particularly the neonicotinoid class of chemicals, can weaken bees' immune systems. This makes them more vulnerable to bacteria, fungi and viruses. **LV**

Q RICHARD O'NEILL, GLASGOW

Do phones get heavier with each download?

A DATA IS STORED as 1s and 0s in the memory. The presence of a 1 or 0 is represented by an accumulation or absence of electrons. Charged particles have mass, but it is merely the distribution of electrons that varies rather than their quantity. Another way of thinking about it is that the atoms in the memory have magnetic-like properties. Groups of atoms align in one direction or the other according to whether they are storing a 1 or a 0 and will possess differing amounts of energy according to how they are aligned. As energy is equivalent to mass, we could argue that adding data to a device makes it a few millionths of a millionth of a gram heavier. **GM**

Just 1s and 0s

Q NICOLAI SMITH, EASTWOOD

What does chlorine do to our eyes?

A CHLORINE GAS REACTS with the water on your eye to form hydrochloric acid, which can cause blindness. The chlorine in pools is a safer combination of hypochlorous acid and hypochlorite ions. But this can react with urine, sweat and by-products in the water to form chloramines that cause irritation. Irritation can also occur when water washes away the protective film on your eyes, which then allows infections from lingering bacteria. **LV**

Goggles can protect your eyes from pee in the pool

Q VAL MCCLEAN, VIA EMAIL

What causes jet lag?

A JET LAG, OR desynchronosis, occurs when our internal body clock is out of sync with the time of day, causing tiredness and difficulty sleeping. It's commonly brought on by long-haul air travel, but it takes more than just a long journey to give you jet lag. "If you flew from England to South Africa, even though it's a long flight, there's no jet lag because there's no time zone transition," says biological rhythms expert Prof Jim Waterhouse. "The difference [with jet lag] is that it messes up the body clock."

Animals, plants and bacteria all have an internal clock. In humans, this circadian clock is found at the base of the brain, in a structure known as the suprachiasmatic nucleus.

"What it does in humans is make us active in the daytime, and inactive and able to go to sleep at night," says Waterhouse. "This clock gives you stability, so that if you do wake up in the middle of the night you've got a better chance of getting back to sleep."

When we fly to a different time zone, the change is too dramatic for our clocks. "The body clock is slow to adjust, and that mismatching causes jet lag," he says. Environmental cues like mealtimes and the light-dark cycles of the days help the clock to adapt, but how long it takes depends on how far you've travelled.

"It's equivalent to about one or two time zones per day," says Waterhouse. "If you fly to Los Angeles, which is eight time zones to the west of us, it'll take you about four days to adjust."

Jet lag is much worse flying east – forward in time, essentially – than when you fly west, and it's because our body clocks don't keep perfect time. "The body clock tends to run rather slow. It doesn't run with a period of 24 hours, but rather with a period slightly more than that: about 24-and-a-half," explains Waterhouse. "So it's easier for the clock to delay because it naturally wishes to do so."

Our slow-running body clocks are also the reason why over 90 per cent of travellers to Australia from the UK choose to stay up for 12 hours longer, rather than try to sleep 12 hours earlier. It's still not clear why jet lag hits some people harder than others, but genetics, fitness and age have all been suggested.

Jet lag: ruiner of holidays

Six tricks to help avoid jet lag

Travelling long-haul this summer? Science can help beat the pain...

Choose the right trip
If you like staying up late, it could be a sign your body clock runs slower than average. People like this find it easier to fly west, but much harder to fly east.

Prepare yourself
If you can, shift your sleep patterns before you fly. If you're flying east, going to bed and getting up a few hours earlier the week before will reduce the difference when you arrive.

Use the flight
Give yourself more time to adapt by changing your watch as soon as you board the plane. You'll have to eat and sleep according to the time at your destination as well.

Keep drinking
Dehydration doesn't help, so drink plenty of water and stay off the coffee. The air on a plane is drier than on land, so you'll probably need to drink more than you usually would.

Catch some rays
Daylight helps you adjust, so go for a walk outside when you arrive. If it's night-time, avoid using laptops and phones; these give off light that confuse your body.

Time capsules
Melatonin tablets are proven to help with trips east if they're taken at the right time, a few hours before bed. In the UK, you'll need a doctor to check it's okay for you.

Do frequent flyers get jet lag?

SADLY FOR FREQUENT flyers, including cabin crew, your body doesn't adapt to various time zone changes any faster with experience. Try the useful tricks on the right, and you might be better able to deal with jet lag in the future.

RICHARD HODSON has a BSc in biomedical science from King's College, London and edits the *I, Scientist* blog

PHOTO: ISTOCK X2, COBALT LIGHT SYSTEMS

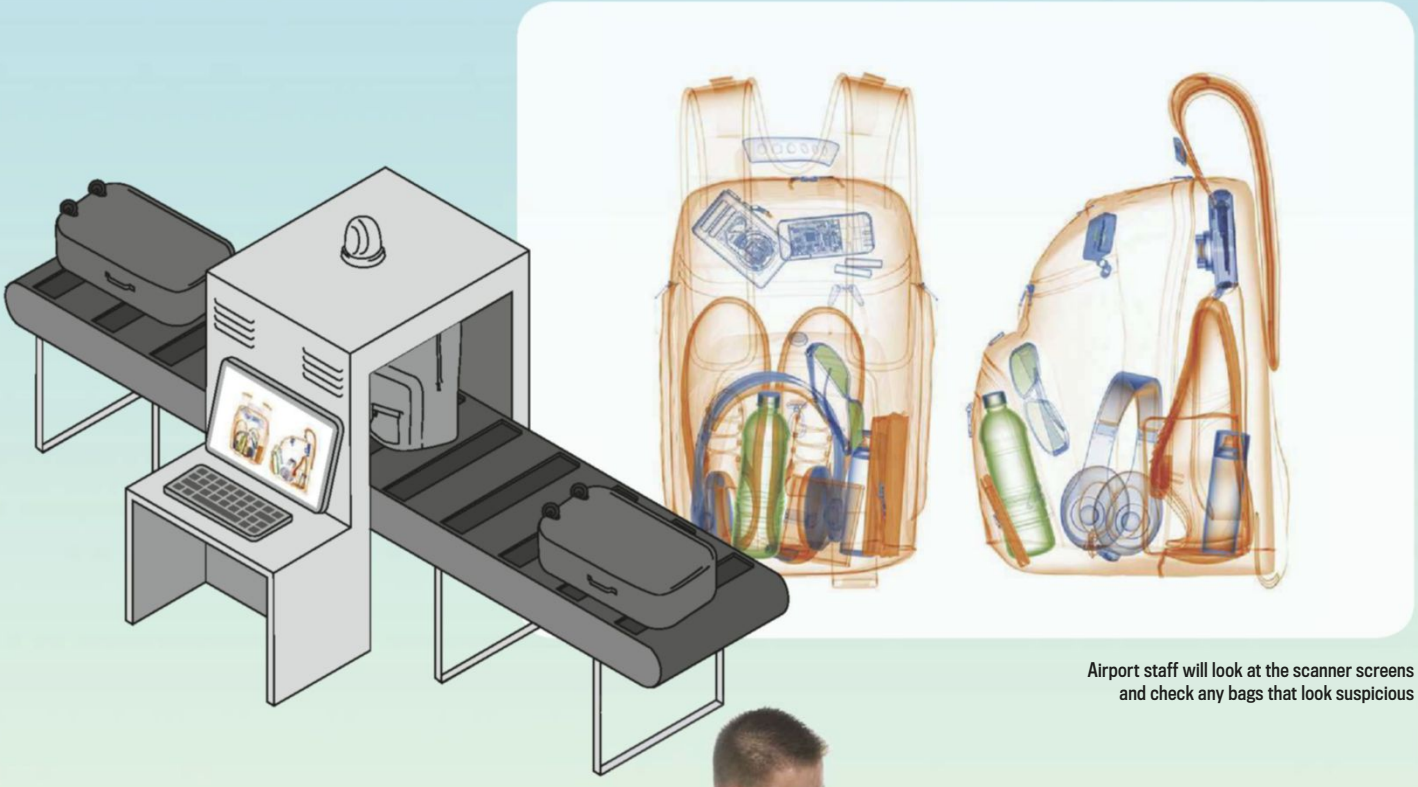
Q CARL BAILEY, DUNDEE

How does an airport scanner work?

A WHILE YOU'RE STEPPING through an airport metal detector in your socks, your hand luggage is going on a different trip: into an X-ray scanner. They're used to build a picture of what's inside your bags, and allow security staff to check anything that looks suspicious. X-rays launched from one side of the machine are picked up by a pair of detectors on the opposite side. As your bag enters through the lead-lined curtains, it crosses the path of these X-rays and absorbs some of the energy they carry. This means that the X-rays that passed through your stuff have less energy than those that sailed straight past.

When the X-rays hit the first plate-like detector, their energy and position is recorded. They continue towards the second detector, but a filter between the two blocks low-energy X-rays: the second detector collects only high-energy X-rays. By comparing the two detectors' outputs, the machine can construct an image showing not just the position of objects, but also roughly what they're made of and their density.

Organic materials like paper, food and explosives are orange, while blue or green are used for metals and glass. The denser the material, the darker the colour.



Airport staff will look at the scanner screens and check any bags that look suspicious

An end to liquid restrictions?

LIQUID RESTRICTIONS IN hand luggage could be lifted by 2016, thanks to a machine currently being tested in European airports that can identify liquids in seconds.

The microwave oven-sized Insight100 uses lasers to identify compounds, even without removing them from their containers. It harnesses something called the Raman effect. This is where the wavelength of light changes when it bounces between molecules. These changes in wavelength are unique to a compound, allowing these so-called 'Raman signatures' to be used to identify anything from tea to liquid explosives. The machine works with gels and powders too, and can even identify multiple compounds mixed together.

Insight100 could mark the end of frustrating hand luggage restrictions

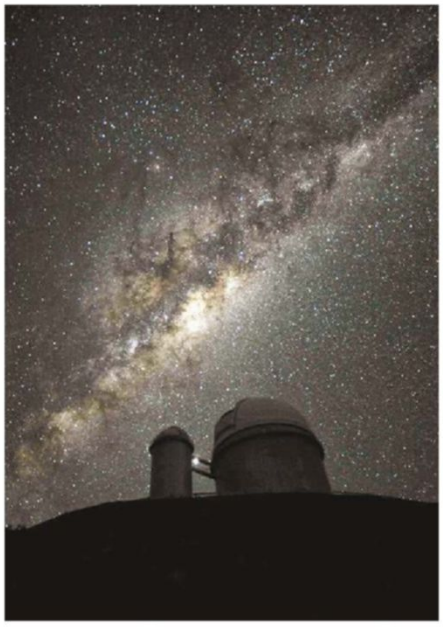
Did you know?

The hottest chilli in the world is the Carolina Reaper. It has an average rating of 1,569,300 Scoville Heat Units

CHRIS HUNT, MANCHESTER

Is it possible to estimate our position within the entire Universe?

A OUR 'POSITION' WITHIN the Universe is an entirely relative concept. We can easily define our position relative to the Sun and planets, and with respect to the nearest stars. We can also establish our approximate location within the spiral arms of the Milky Way, even though we are nestling within it. We have even determined the relative position of the Milky Way within its local group of galaxies and with respect to even more distant clusters of galaxies. But there is no universal reference frame to which we can 'attach' our position in the cosmos. The Big Bang happened everywhere at once and the Universe has been expanding ever since. So every point in the Universe can be regarded as being the 'centre' of the expansion. Since the Universe may not actually have a physical edge (only an observational one), there is no sense in the idea of an 'absolute' position. **AG**



Milky Way: we're in it, but where is it?

ANDREW CARR, LEAMINGTON SPA

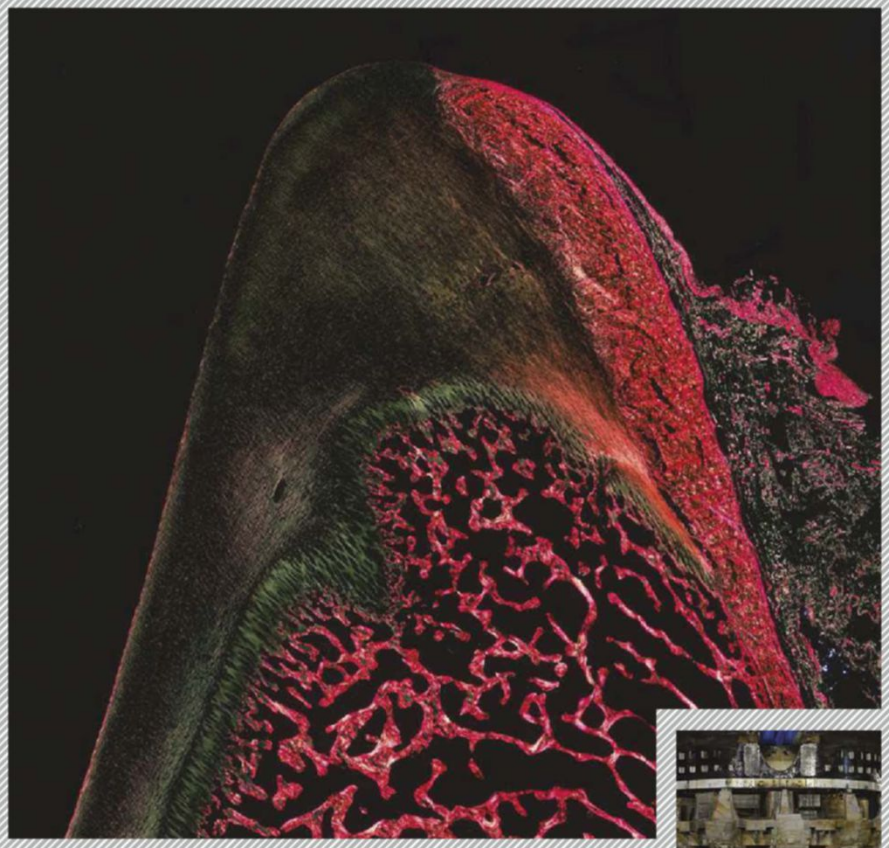
Are women really better at multitasking?

A MAYBE, BUT THE brain cannot handle two complex tasks at once, so what looks like clever multitasking is more often switching quickly between two or more tasks. This is an inefficient way of working because the brain has to decide when to switch and remember each task.

In many laboratory tests, men and women do equally well. In a more realistic study, men and women under time pressure had to juggle simple mathematics problems, answer the phone and decide how to find something lost in a field. During the study, the women were found to be calmer, better organised and planned more carefully than the men. But even if this difference is real, we still don't know whether it is biological or culturally imposed. **SB**

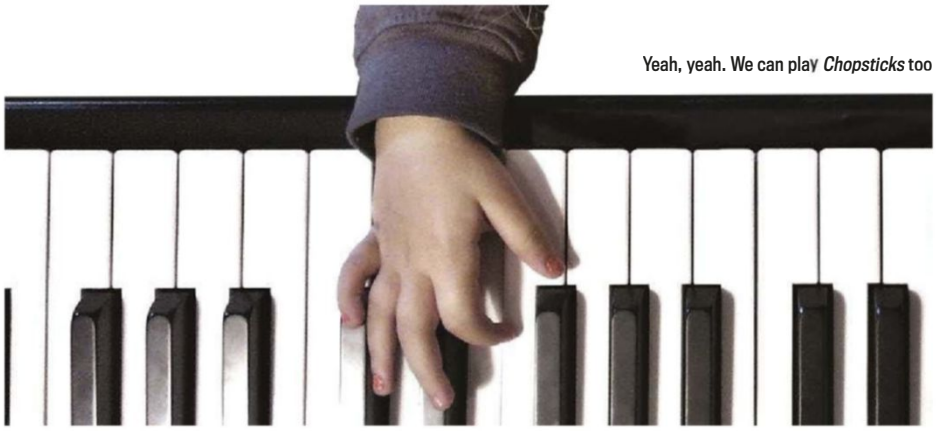
Dangers of multitasking number 52: accidentally applying superglue to ear

WHAT IS THIS?



KNOW THE ANSWER? Submit your guess now at **sciencefocus.com/qanda/what**

LAST MONTH'S PICTURE Alex Crowe correctly guessed a tunnel-boring machine



Yeah, yeah. We can play *Chopsticks* too

LUKE AZZOPARDI, MALTA

Are talents genetic or learnt?

A BOTH. SOME PEOPLE are born with greater potential, but without hard work and practising their talent will come to nothing. Music is a good example, with some evidence of genetic differences. For example, a study of 500 twins found that 80 per cent of tone deafness is inherited. Another found genes associated with serotonin release, which were related to musical creativity.

Chess is another good example: an analysis of 14 studies of top chess players and musicians concluded that only about 30 per cent of the variation between performers could be accounted for by their hours of practice. In contrast, a study of British musicians found that top performers had practised a lot more, but learned no faster than less skilled players.

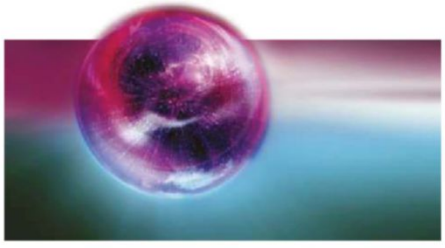
A popular theory is that it takes 10,000 hours of practice to become an expert at something, and there is probably a degree of truth in this. But if your genes give you an aptitude for and enjoyment of chess, maths, music or football, you are surely more likely to put in those long hours. **SB**

CHRIS HUNT, MANCHESTER

How can the Universe expand faster than the speed of light?

A WHEN ASTRONOMERS REFER to the 'expansion' of the Universe they are referring to the abstract concept of space-time. Space-time is the 'fabric' of the Universe, consisting of three physical dimensions and the additional 'dimension' of time. When an object is in motion, it changes its position within this 'grid' of space-time.

The speed of light is only a limit for objects within space-time, not actual space-time itself. So, there is no conundrum in space-time expanding at (or greater than) the speed of light. **AG**



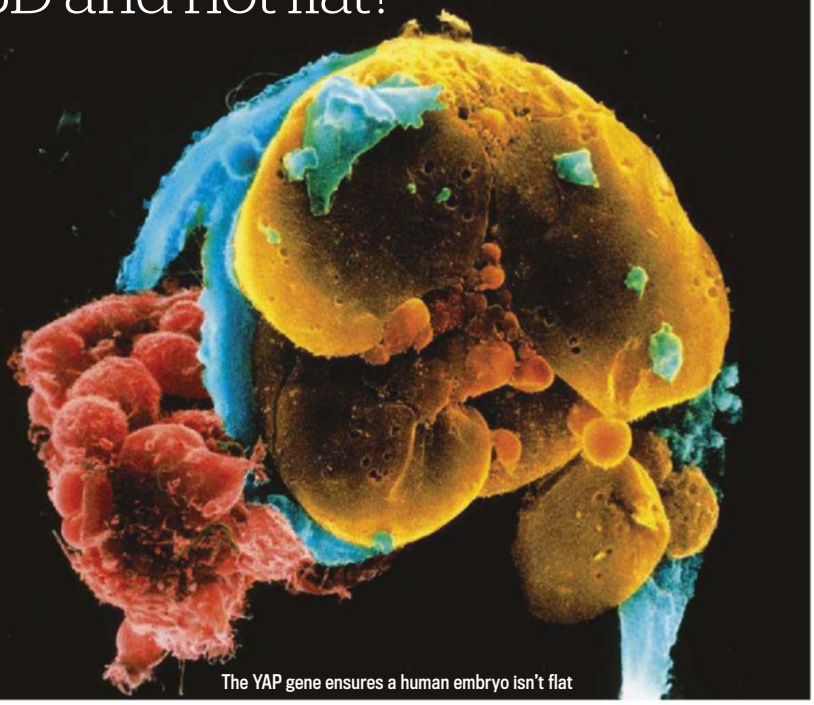
The Universe plays by its own rules

AMELIA ROTH, CIRENCESTER

Why are our bodies 3D and not flat?

A EMBRYOS GROW via the ultimate form of 3D printing. Starting from a single egg, they develop into perfectly-shaped arrangements of over a trillion cells, and just keep on growing until adulthood. But how do cells 'know' to stack together in just the right way, defying the constant tug of gravity?

Earlier this year, a team led by Dr Makoto Furutani-Seiki of the University of Bath announced the discovery of a gene that allows cells to resist gravity and assemble correctly in 3D. Known as YAP, it controls the level of tensile force between cells in embryos, ensuring they keep their shape and alignment against gravity. According to Furutani-Seiki, the effect is like those toy figures whose joints are held together by elastic under tension. If released, the figures collapse in a heap. Something similar happens if YAP is switched off: the resulting mutant looks distinctly deflated. RM



The YAP gene ensures a human embryo isn't flat

PHOTO: ISTOCK X3, RACHEL PALLEN/UNIVERSITY OF LEEDS, SCIENCE PHOTO LIBRARY X2

HOW DOES A FORMULA E CAR WORK?

The final Formula E race of the season zooms through Battersea Park in London on 28 June 2015. **Craig Scarborough** takes a look at the tech inside one of these electric supercars

TYRES

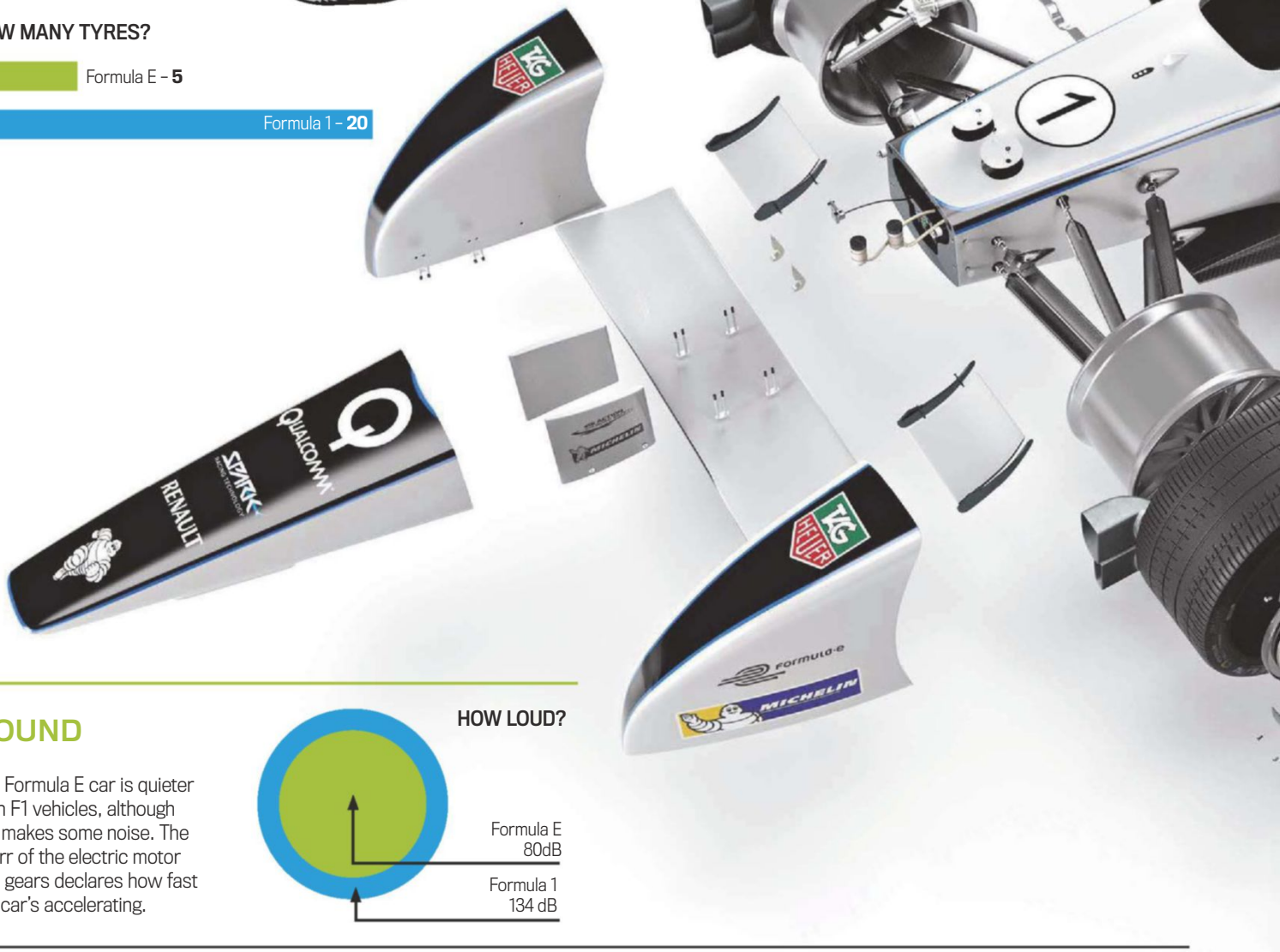
The driver gets just five sets of Michelin all-weather grooved 457mm tyres for the one-day event. F1 in comparison, provides the driver with 20 sets for a three-day race weekend: 13 are dry weather tyres and the rest are wets.

HOW MANY TYRES?

Formula E – **5**

Formula 1 – **20**

The steering wheel has a power boost lever for overtaking

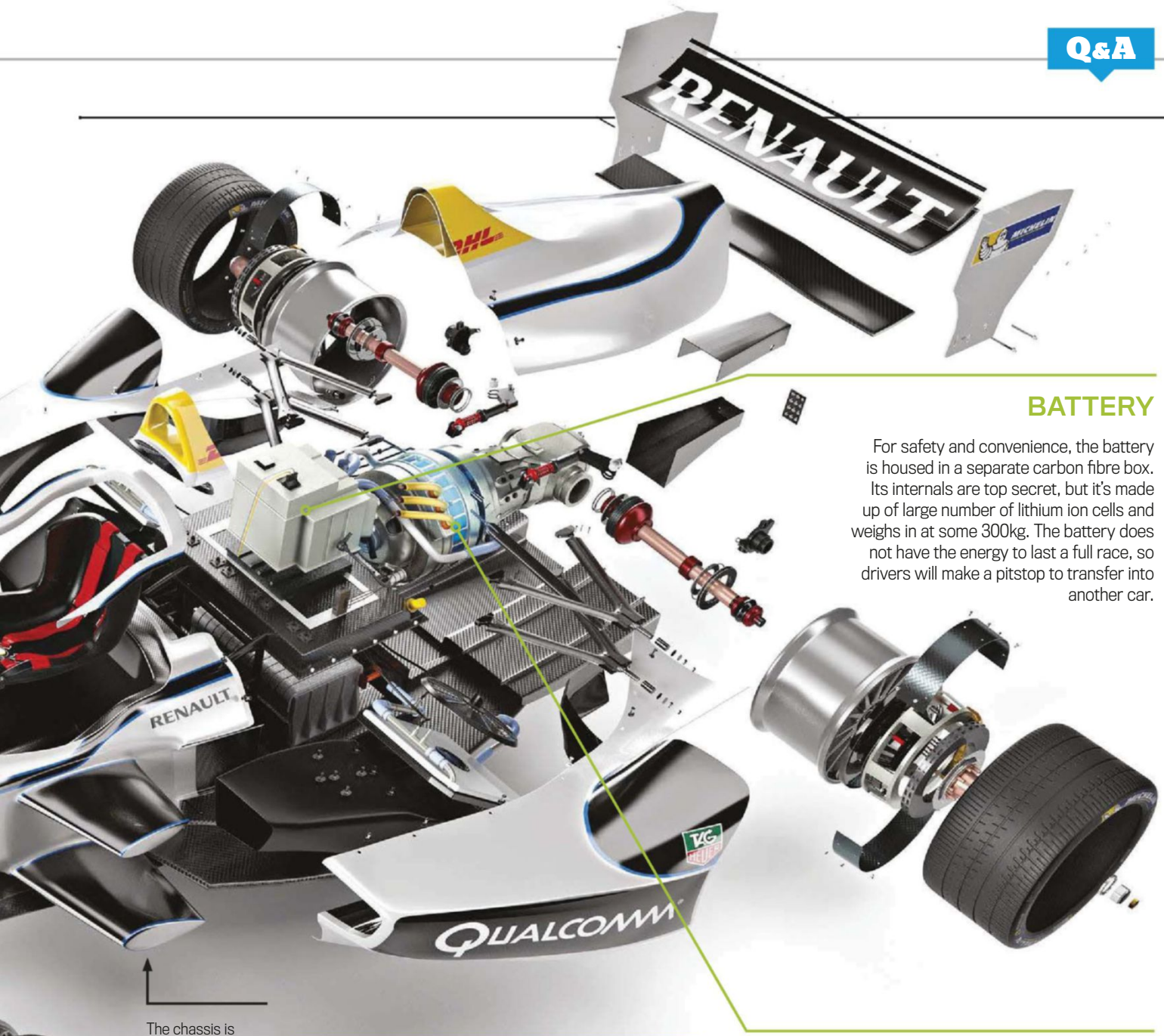


SOUND

The Formula E car is quieter than F1 vehicles, although still makes some noise. The whirr of the electric motor and gears declares how fast the car's accelerating.

HOW LOUD?

ILLUSTRATION: GRAHAM MURDOCH



The chassis is made from carbon fibre and aluminium

BATTERY

For safety and convenience, the battery is housed in a separate carbon fibre box. Its internals are top secret, but it's made up of large number of lithium ion cells and weighs in at some 300kg. The battery does not have the energy to last a full race, so drivers will make a pitstop to transfer into another car.

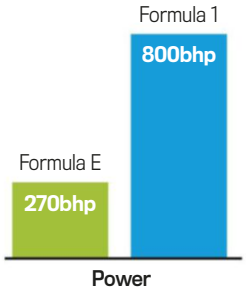
SHAPE

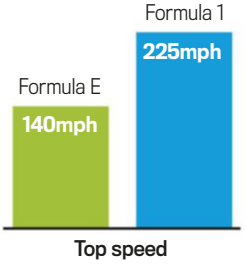
The Formula E car is a little shorter and narrower than an F1 car, although externally they are quite different. Every Formula E car is the same – teams are only allowed to alter the setup of the standard car. The body of the car has been built to optimise aerodynamic efficiency. Formula E cars generate less downforce than F1 cars and have more ground clearance. The driver is cocooned in a 'survival cell', which forms part of the chassis. The survival cell is made to the same FIA safety standards as F1 cars, complete with a roll hoop, padding inside the cockpit, and front, side and rear crash structures.

ENGINE

The Formula E car has a large battery, tiny electric motor and gearbox. Temperature inside these units increases over the course of a race, so cooling is a critical issue for the Formula E car's performance.

A gearbox is used to increase the torque output from the small motor.





CRAIG SCARBOROUGH is a Formula 1 technical writer

Q ELLIS AREY, LEEDS

Why do we lose the sound of our voice when we whisper?

A THE SOUND OF your voice is created when air vibrates the larynx's vocal folds. The pitch depends on how tightly these folds are stretched by your throat muscles. When you whisper, the vocal folds are held apart a short way and stretched so tightly that they can't vibrate. The air passes through in a turbulent rush that creates a mix of lots of different frequencies, which we hear as a high-pitched hiss. **LV**

"Don't forget to buy *BBC Focus* next month!"

Q LINDA SMITH, ST ALBANS

How do we know where sounds are coming from?

If this is behind you, get outta the way

A YOUR BRAIN IS able to do this by comparing tiny differences in the way that sounds affect each ear. A noise coming from the right is slightly louder in your right ear, and reaches it fractionally earlier than your left. A sound in front or behind affects each ear the same way, with intermediate effects in-between. The brain uses these differences, even as small as a 100,000th of a second, to calculate where the sound is coming from. Signals from the ear travel along the auditory nerve to the brainstem, where each individual cell responds to a specific time difference and direction.

Until recently it was assumed that a delay was imposed somewhere between the ears and the brainstem, but it has now been discovered that all of the calculations are done in the brainstem cells, which then signal the result to other parts of the brain – enabling you to hear the sound and know, without thinking, just where it's coming from. **SB**

Q CLAIRE NICHOL, LONDON

Where is all our digital data stored?

A IF OUR DATA is in the cloud, the answer is that we don't know where it is. Our files will be spread across data centres anywhere in the world. Because most cloud providers back up the data across multiple sites, then the chances are your files exist simultaneously in more than one place, possibly across different countries or continents. Your bits and bytes might, for instance, find their way to a data centre like the massive facility at 350 East Cermak in Chicago, reputedly the biggest such storehouse in the world. It occupies a former printer's and telephone exchange that houses storage and processing equipment over an area of 100,000m^2. The servers have a cumulative capacity of 3,000 years' worth of uncompressed video. But that kind of storage is energy hungry, too. The Chicago facility consumes 100MW. In that part of the world, its electricity bill is second only to O'Hare airport. **GM**

350 East Cermak originally housed printing presses and was converted for telecommunications in 1999

Q DAVID WILLIAMS, LYTHAM ST ANNES

What is the lifespan of a water battery?

A BATTERIES CONVERT CHEMICAL energy into electricity using electrolytes. These are ionised fluids whose molecules have a net electrical charge. Water batteries contain powder that becomes an electrolyte when water is added. They have a life of about 1000mA hours, meaning a 10mA LED can be run continuously for about 100 hours. **GM**

NEXT MONTH Over 20 more of your questions answered

For even more answers to the most puzzling questions, see the Q&A archive at **www.sciencefocus.com/qanda**

PHOTO: ISTOCK X2, C.WILLIAM BRUBAKER COLLECTION/UIC DIGITAL

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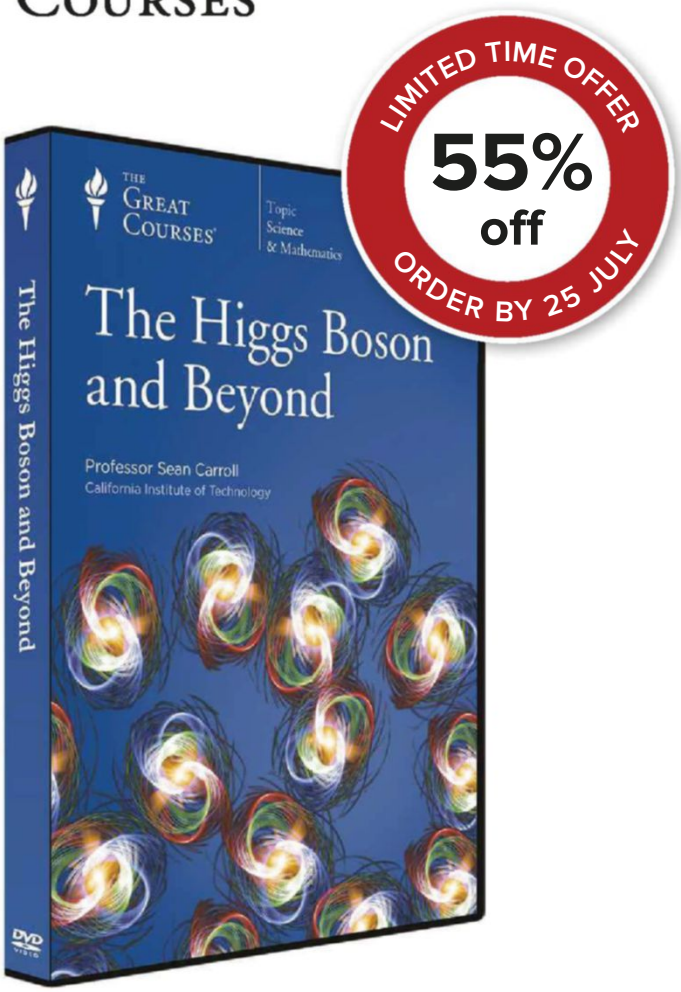

Understand This Triumph of Modern Physics

The recent discovery of the Higgs boson was celebrated around the world. The quest to pursue it cost 10 billion dollars; involved years of international collaboration amongst top physicists, engineers, and other experts; and led to the construction of the single largest and most complex device in the history of mankind. And yet, few people truly understand what the Higgs boson is or why it is so significant.

In **The Higgs Boson and Beyond**, award-winning theoretical physicist Sean Carroll, a brilliant researcher as well as a gifted teacher who excels in explaining scientific concepts to the public, leads you through this thrilling story. He clearly explains the necessary background of the basics of quantum mechanics, the Standard Model of particle physics, and more, helping you realise how the discovery of the Higgs boson validates and deepens our understanding of the universe.

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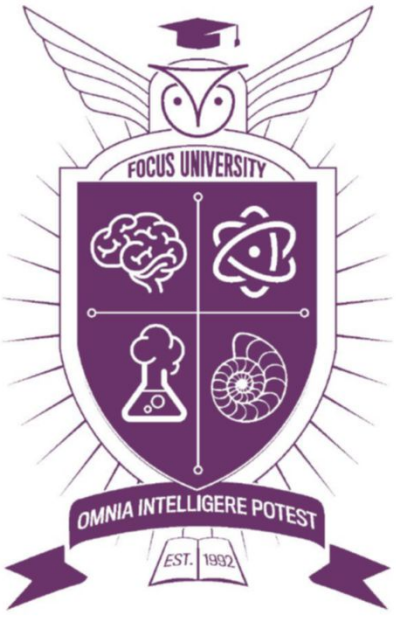


UNDERSTAND DARK MATTER IN 10 MINUTES

For decades, top astronomers have been on an enormous treasure hunt for the Universe's most mysterious substance. We can't see it, so how do we know it even exists? **Colin Stuart** sheds some light

Why do scientists think that dark matter exists?

The first clues that everything in the Universe was not as it seemed came in the 1930s. Swiss-American astronomer Fritz Zwicky was looking at a group of galaxies and working out how fast the individual galaxies were moving. To his surprise, he found them careering around at speeds far greater than he expected. In fact, they were moving so fast that they should have quickly dispersed, breaking away from the gravity of everything else in the cluster. Except they weren't. Zwicky was forced to surmise that there must be more stuff in the cluster that was boosting its overall gravitational pull and keeping the galaxies tied together. The discrepancy wasn't small either. He estimated there was 400 times more matter present than he could see. At a loss to explain what this mysterious material was, he simply called it 'dunkle materie' – the German for dark matter.

Around the same time, Dutch astronomer Jan Oort was forced to invoke something similar. He was looking at the stars orbiting near the edge of the Milky Way. He expected to find that the further he looked from the galactic centre, the slower the stars would be rotating around it. This idea isn't dissimilar to our Solar System: the further a planet is from the Sun, the longer it takes to orbit it. But that's not what Oort found. The outer stars were zipping about faster than they should be. In order to explain why they stayed bound to the Milky Way despite their lofty speeds, he supposed there was some invisible material with gravitational power spread throughout the Galaxy. By 1980, American astronomer Vera Rubin had spotted the same effect in around 100 other galaxies. Whatever this invisible stuff was, it was widespread.

Today, an effect known as gravitational lensing provides even more evidence to suggest there is something strange going on. If we see a large amount of mass, say a cluster of galaxies, move in front of a distant light source, then the foreground object is able to bend the light from the background object around it. This light creates a series of arcs that can join together to form what's known as an 'Einstein ring'. The more mass there is, the greater the amount of bending. Yet there is often not enough visible mass in the cluster to account for the amount of bending we observe. Again, there must be extra mass that's hidden from view.

Vera Rubin studied a large number of galaxies and found that the effects of dark matter are widespread

PHOTO: SCIENCE PHOTO LIBRARY X2

What do scientists think dark matter is?

Physicists have a cookbook for the Universe known as the Standard Model of particle physics. By using its recipes, they can account for the behaviour of forces and the way particles interact with one another. This model has been validated many times over, including by experiments at CERN's Large Hadron Collider. The book's final missing page was the recently discovered Higgs boson.

And yet there is nothing within those recipes that allows physicists to cook up anything with the observed behaviour of dark matter. It has to be able to interact with normal matter via gravity, and yet in order to remain hidden it cannot interact with light. In an attempt to explain this behaviour, physicists have come up with a new type of particle: Weakly Interacting Massive Particles (WIMPs). They are 'weakly interacting' because they don't interact with light, and 'massive' because they interact via gravity.

When astronomers run computer simulations of a Universe that evolves with dark matter in the form of WIMPs, they get a structure

What is this ?

When astronomers look at the Universe on the largest scales they see huge clusters of galaxies strung out on long filaments, which border enormous cosmic voids. They explain this distribution by suggesting dark matter provides a 'scaffold' by drawing ordinary matter together with its gravitational influence.

Dark matter timeline

1932

Dutch astronomer Jan Oort (1900–1992) discovers that the stars on the outer edge of the Milky Way are orbiting faster than expected. He assumes something invisible must be holding onto them.

1933

Swiss-American Fritz Zwicky (1898–1974) observes galaxies in the Coma Cluster moving so fast they should escape the cluster, unless there is an additional material keeping hold of them.

1937

US astronomer Sinclair Smith (1899–1938) finds a similar effect to Zwicky's in the Virgo Cluster of galaxies. Smith dies of cancer just one year later at the age of 39.

1966

Japanese physicist Hironari Miyazawa (1927–) is the first to put forward a version of supersymmetry, an idea that goes beyond the Standard Model and might explain what dark matter really is.

1980

US astronomer Vera Rubin (1928–) publishes a landmark paper showing the same effect that Oort observed, but in over 100 other galaxies. Our neighbour, Andromeda, was included.

1983

Israeli physicist Mordehai Milgrom (1946–) puts forward the idea that the strange rotation of stars in galaxies could be explained if gravity varied on different scales, an idea called Modified Newtonian Dynamics (MOND).

PHOTO: WEIZMANN INSTITUTE OF SCIENCE, SCIENCE PHOTO LIBRARY X2, CORBIS, ALAMY

that is a pretty solid match for the distribution of galaxies that we see today. A theory for physics beyond the Standard Model called supersymmetry also seems to fit with this picture.

Other explanations have been considered in the past, including MACHOs. Standing for MAssive Compact Halo Objects, the idea is that there are big objects such as black holes ghosting unseen through the Milky Way. When we add up all the mass we can see, we aren't including them, hence why we underestimate the mass of the Galaxy. However, observations and modelling of the early Universe has cast significant doubt over this idea. For now, WIMPs is definitely the frontrunner.

What are scientists doing to find dark matter?

How do you find something that is, by definition, hidden from view? You certainly can't see it. To make things worse, WIMPs are so ghostly that they almost always pass straight through normal matter – including any detector you build to snare one. To put it into perspective, dark matter is so abundant that billions of dark matter particles are streaming unhindered through you every single second. And yet, on average, in any five-minute period only one of these dark matter particles interacts with an atom of normal matter in your body.

This idea that dark matter particles do occasionally deign to interact with normal matter is the basis for the Large Underground Xenon (LUX) experiment deep under the surface of South Dakota in the US. Scientists have commandeered an abandoned gold mine and set up a dark matter detector 1.6km (one mile) down. Consisting of 370kg of liquid xenon shielded by 264,979 litres of water, it is designed to pick up the occasional WIMP interacting with the xenon. Should a WIMP recoil off a xenon atom, the atom is accelerated through the liquid, causing a flash that can be picked up by the surrounding banks of super-sensitive cameras.

Scientists might also be able to detect dark matter when it interacts with itself in a process known as annihilation. When this happens, it is thought a cascade of 'normal' particles is produced and we should be able to

pick that up. One such experiment is the Alpha Magnetic Spectrometer (AMS-02) currently strapped to the International Space Station. It is trying to pick up evidence of atomic shrapnel coming from WIMP annihilations near the galactic centre.

The Sun could help too. As the biggest thing in the Solar System it should be acting as a giant cosmic vacuum cleaner, sweeping up dark matter particles as it treks through the Galaxy. Some of the dark matter particles should annihilate inside the Sun, producing a stream of normal particles. Unfortunately, the Sun is so dense that almost all of these daughter particles remain trapped inside. However, one type of particle – neutrinos – would make it out and travel across space to us. Experiments such as IceCube, stationed on Antarctica, are set up to gather these telltale signals.

Then there is the Large Hadron Collider (LHC). On 5 May 2015 the experiment began smashing protons together after a two-year shutdown designed to boost the machine's power. It is hoped that by colliding particles together with greater energy than ever before, nature might begin to reveal more secrets of its inner workings. Perhaps we will even glimpse evidence of supersymmetry, the theory that goes beyond the Standard Model and is consistent with a WIMP explanation of dark matter. Crucially, however, if the LHC continues to find no evidence for supersymmetry then it may fire the starting gun in the race to find an alternative explanation for why so much of the Universe's mass appears to be 'missing'.

Could dark matter be something else?

So far we've been assuming that dark matter is tangible, something that truly exists. But what if it doesn't? What if it's a phantom – a symptom of the fact that we don't understand gravity properly? That's exactly what proponents of a theory called Modified Newtonian Dynamics (MOND) advocate.

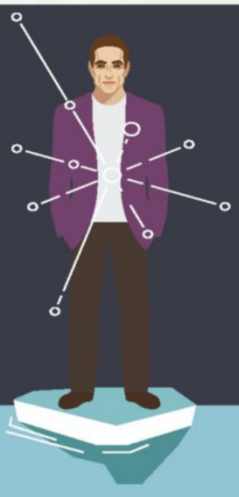
Remember, one of the original reasons dark matter was introduced was to account for the fact that stars in the Milky Way don't slow down the further they are from the galactic centre, unlike the planets of our Solar System. But what if there is one rule for gravity on small scales (like a solar system) and another for large scales (like a galaxy)? While Newton's laws of gravity allow us to send people to the Moon or spacecraft to the planets, stretching those rules to regions to which they don't apply might explain why we're puzzled by the strange motions of stars.

The idea was first put forward by Israeli physicist Mordehai Milgrom in 1983. He suggested that the strength of gravity could become stronger where acceleration levels are small (just like at the edge of a spiral

DARK MATTER IN NUMBERS

86

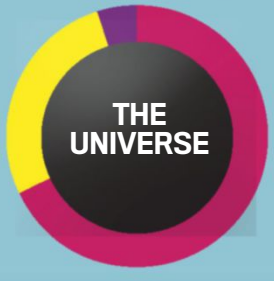
strings carrying detectors were lowered 2,500 metres below the surface of the Antarctic ice as part of the IceCube experiment. This is hunting for evidence of dark matter annihilations.



If they exist, billions of dark matter particles are passing through your body every second. Only around 100,000 a year interact with the atoms inside your body.

264,979

litres of water are needed to shield the subterranean LUX dark matter detector from being contaminated by radiation from the Earth's surface.



The Universe is thought to be made of 68 per cent dark energy, 27 per cent dark matter and just 5 per cent normal matter.

13 terraelectronvolts

is the record-breaking energy with which the new souped-up Large Hadron Collider is smashing particles together in an attempt to unlock the secrets of dark matter.

Jargon buster

DARK MATTER ANNIHILATION
The process by which two dark matter particles come together, creating a cascade of new particles. We're attempting to detect this with various experiments around the world and in space.

GALAXY
A large collection of stars in space, like a city for stars. Ours is called the Milky Way and has around 200 billion stars.

GRAVITATIONAL LENSING
A prediction of Einstein's General Theory of Relativity, which says that mass bends light. However, astronomers often see more bending than the amount of visible material present would suggest.

NEUTRINO
A small, almost massless particle created by nuclear reactions inside the Sun. Additional neutrinos may be created by dark matter annihilations and detecting them would be a big breakthrough

STANDARD MODEL
The recipe book that particle physicists use to explain a lot of the subatomic world. It contains rules regarding how particles interact with forces and light.

SUPERSYMMETRY
An idea that goes beyond the Standard Model and says every 'normal' particle has a supersymmetric partner particle. The lightest of these supersymmetric particles could be responsible for dark matter.

PHOTO: NASA/JPL-CALTECH/ESO/R. HURT, LSST PROJECT X2, SCIENCE PHOTO LIBRARY

galaxy). These ideas can help to explain some details about how galaxies work in ways that the dark matter theory cannot. However, there is currently no reason to suspect that gravity behaves differently on different scales and MOND struggles to explain why galaxies cluster together in the way they are observed to do. A final criticism has been that Newton's picture of gravity is no longer the best gravitational theory we have – that accolade belongs to Einstein's General Relativity. Work continues to try and make the MOND theories 'relativistic'.

Has dark matter got anything to do with dark energy?

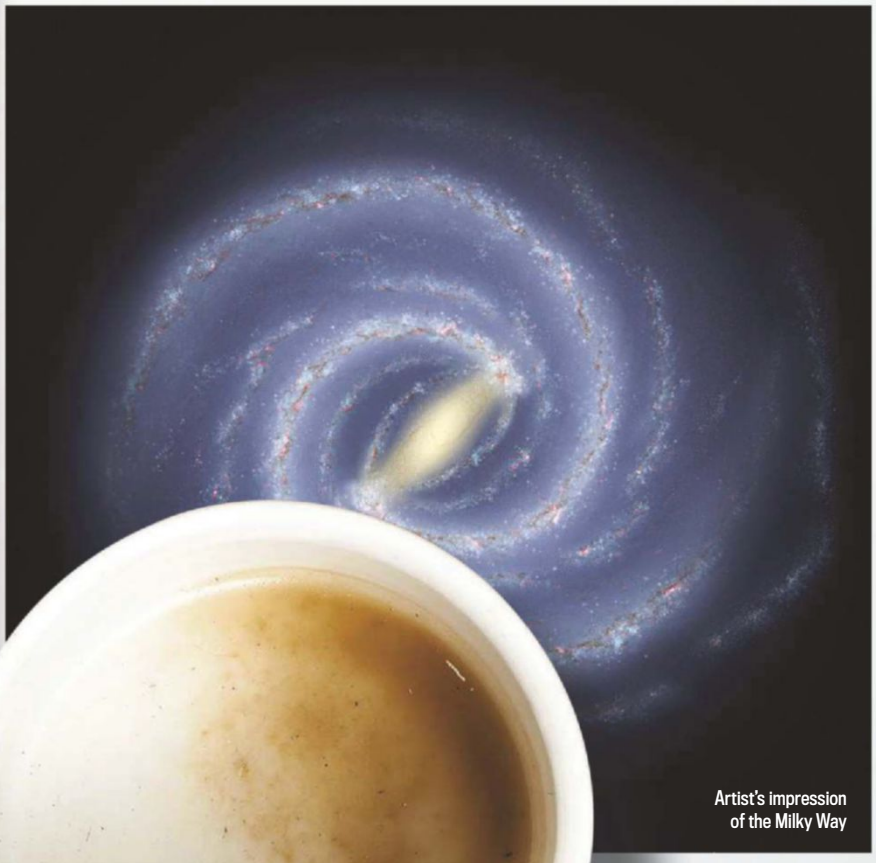
No. Dark energy is the name given to the mysterious entity thought to be accelerating the overall expansion of the Universe – a sort of anti-gravity. In contrast, dark matter can be thought of as gravitational glue that helps bind galaxies and clusters of galaxies together. The fact they both share the same adjective indicates our collective ignorance about the true nature of both – we're literally in the dark as to what they are.

You can think of the Universe's history as a tug of war between these two dark entities. When the Universe was young, the galaxies were close together and dark matter dominated – the Universe expanded slowly. Yet as it expanded, the galaxies moved further apart and the collective strength of dark matter on the biggest scales began to wane. Now dark energy is winning the battle and is speeding up the Universe's expansion.

Is there a lot of dark matter?

Dark matter completely dominates the ordinary matter of which people, planets and stars are made. Our Milky Way is thought to be about 90 per cent dark matter and only 10 per cent 'normal' matter (also called baryonic matter). Of all of the matter in the Universe, 85 per cent is dark matter and only 15 per cent is baryonic.

There is one thing to be careful of, however, and that's the distinction between how much of the Universe is made of dark matter and how much of the Universe's matter is dark. According to Einstein's famous equation $E=mc^2$, mass and energy



Artist's impression of the Milky Way

are two sides of the same coin. So cosmologists often talk about the mass-energy of the Universe – all the mass and all the energy put together. In these terms, the Universe is 68 per cent dark energy, 27 per cent dark matter and just 5 per cent atoms. If we discount the energy part, the numbers revert to above – 85 per cent dark matter, 15 per cent baryonic matter.

How will the hunt for dark matter affect me?

As with all science research, practical applications can be hard to predict from the outset. However, many technologies often filter down to use in everyday life. Take CERN, for example. The first webpage was info.cern.ch. This technology was devised to communicate between the facility's computers. One likely spin-off from the dark matter hunt is better digital cameras. The Large Synoptic Survey Telescope is currently under construction. By 2021 it should begin to scour the skies from its mountaintop location in the Chilean desert. Equipped with a 3,200-megapixel camera – the world's largest – it will be able to map out the structure of the Universe in order to test out theories about dark matter. By building such an enormous camera, those new technologies will eventually end up in the commercial photography and medical imaging markets. ■

Chile's Large Synoptic Survey Telescope will help us scour the skies for dark matter

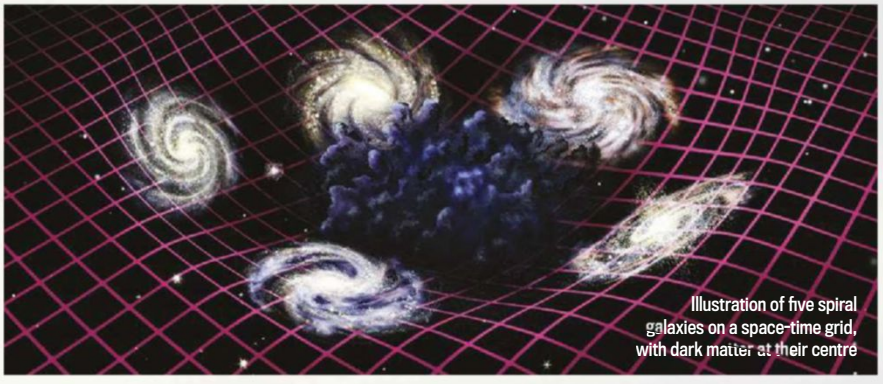


Illustration of five spiral galaxies on a space-time grid, with dark matter at their centre

COLIN STUART is an astronomy writer and author of *The Big Questions In Science*

Find out more

BBC RADIO 4 92–95 FM & 198 LW

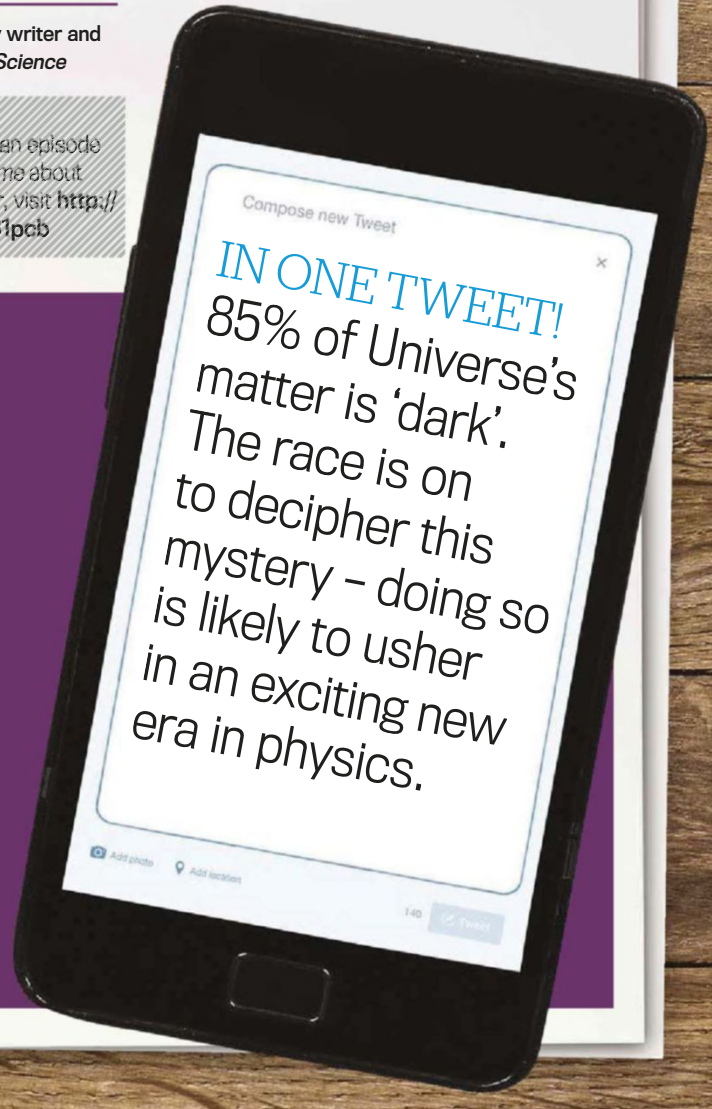
To listen to an episode of *In Our Time* about dark matter, visit http://bbc.in/1C81pcb

NOW EXPLAIN IT TO A FRIEND

1. When astronomers look out into the Universe, they see many phenomena that suggest there is more material in the Universe than can be seen with telescopes. Often, the gravity in a particular location seems stronger, suggesting there must be some invisible stuff contributing the extra gravity.

2. Since we can't see it, we call this stuff dark matter and it is thought to make up around 85 per cent of all the matter in the Universe. Our best idea of what it is made of is an as-yet-undiscovered particle, called a WIMP (Weakly Interacting Massive Particle) after the properties it would need to have.

3. Experiments around the world and in space are looking for evidence of WIMPs interacting with one another. The search has come up empty, prompting some scientists to turn to an alternative theory called Modified Newton Dynamics (MOND) that says gravity varies on different scales.



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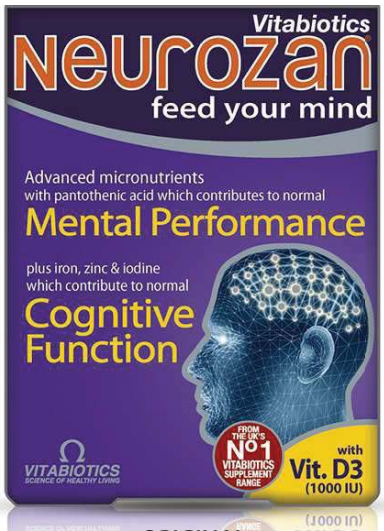

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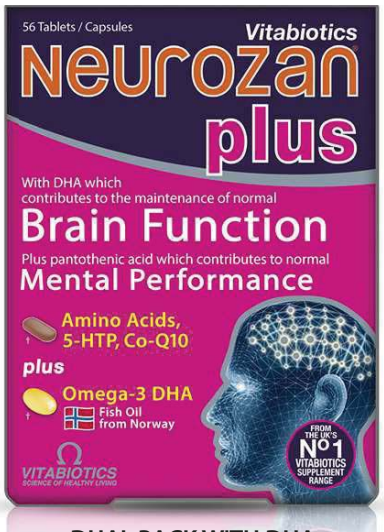

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THE FUTURE OF GADGETS

TECH HUB

EDITED BY **DANIEL BENNETT**

THIS MONTH

ON THE HORIZON

SUPER SLIMLINE SCREEN

LG Display unveils a prototype 1mm-thick OLED screen

www.lgdisplay.com

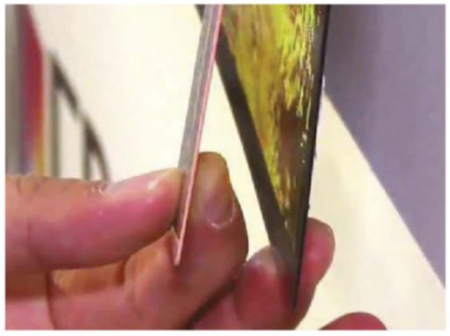
THE ONGOING battle among technology companies to produce ever-thinner screens ramped up a notch in mid-May, when LG Display – part of South Korea's giant LG Corporation – held a press event at its headquarters in Seoul to show off a TV screen that's less than 1mm thick. The screen in question is only a prototype, and sadly there are no plans for it to go into mass production any time soon. But it's a clear indication of LG Display's belief that OLED (organic light-emitting diode) technology represents the future when it comes to TV screens, computer monitors and smartphone displays.

Although it's only risen to prominence in the past decade, OLED has a long history, dating back to the 1950s when French researchers observed that some organic materials are electroluminescent – that is, they give off light when subjected to an electric current. By making use of such materials, OLED screens obviate the need for the backlighting used in 'traditional' LCD/LED screens. This not only makes it easier to create slimmer displays, it also leads to improvements in energy efficiency, as well as offering a higher-contrast picture with deeper blacks. Motion response is also quicker than with LCD displays.

What's more, OLED displays can be printed onto a flexible plastic substrate, enabling the creation of screens such as this new prototype, which can be rolled up and carried around from one place to another – whether that's

The screen eliminates the need for awkward TV cabinets

OLED screens can be mounted on a flexible plastic substrate, enabling them to be rolled up when not in use



We've come a long way from the cathode ray tube...

from the boardroom to a meeting room or simply from the living room to the bedroom. When you want to use it, the display is then wall-mounted using magnetic strips.

OLED displays can use several different architectures, but all essentially consist of anode and cathode layers, with an organic emissive layer and (usually) a conductive layer sandwiched between the two, all mounted on a substrate. AMOLED (active-matrix OLED) screens also include a thin-film transistor layer to switch each individual pixel on and off. The exact specification of the screen that was exhibited in Seoul hasn't been made public, but it's likely to have been constructed using a polyethylene terephthalate (PET) substrate. That's the same kind of polyester-derived plastic used to manufacture fizzy drinks bottles: in other words, such screens needn't be hugely expensive to produce.

Currently, OLED is mostly used in mobile phones, digital cameras, sat-nav units and other portable tech. That's because the high-contrast views offered by OLED work better in bright, sunlit conditions, while OLED's major drawback – the lifespan of screens can't currently compete with that of LCD or LED displays – is less of an issue when it comes to devices that are used only intermittently. Motorola, Nokia, Samsung, HTC and LG all manufacture and sell smartphones with OLED/AMOLED screens, and the technology can also be found in Diesel and Fossil watches, and in some televisions made by Samsung, Sony and, of course, LG.

LG, though, appears determined to lead the field. In January, the company signed a long-term deal with Universal Display Corporation, which holds most of the patents relating to OLED technology, and at the event in Seoul, Sang-Deog Yeo, head of LG Display's OLED Business Unit, said: "OLED is the first display technology sector that Korea will dominate from the beginning." LG is already working to build an 'OLED alliance' with Chinese and Japanese manufacturers, and says it hopes to sell 1.5 million OLED TV panels in 2016.

The display revolution, it seems, *will* be televised.

RUSSELL DEEKS is a freelance science and technology journalist

TECHOMETER

WHAT'S HOT

WINDOWS 10

Microsoft's next operating system will be available as a free download from the end of July. Current Windows users will be able to upgrade for free for the first 12 months, and eagle-eyed users may have already spotted a new toolbar icon that lets you 'reserve' your copy now. Early reports suggest that this version remedies the flaws of the much maligned Windows 8.

WHAT'S NOT

CASH

Cashless payment has overtaken use of notes and coins for the first time. The Payments Council has revealed that cash was used for just 48 per cent of purchases last year, and predicts a further 30 per cent drop in the next decade. The Council suggests contactless payments for small sums, and dwindling numbers of phone boxes and parking meters, have tipped the balance towards cashless payments.

READER POLL

Would you trust news that was generated by robots?

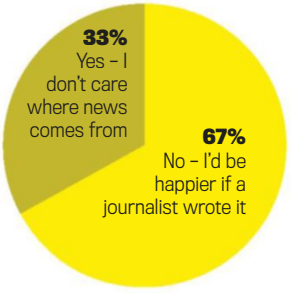
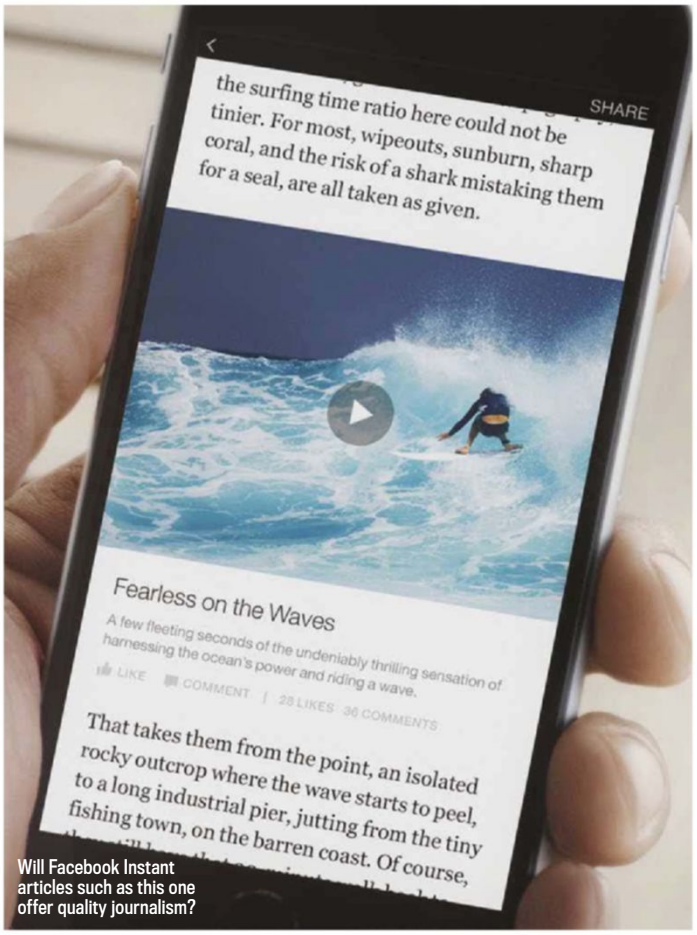


PHOTO: AMAZON, GETTY, MARC HALL/NC STATE UNIVERSITY, FRAUNHOFER IVI

THE NEXT BIG THING

ROBOT REPORTERS



Will Facebook Instant articles such as this one offer quality journalism?

EARLIER THIS year, Facebook announced that it would work with several news organisations – including *The New York Times*, *The Guardian*, and the BBC – to place stories directly into users' news feeds. Stories published using Facebook Instant will load more quickly and keep the style of the original publisher, who will keep all the ad revenue the stories generate – at least for now. The deal, currently only a pilot but likely to be extended, shows how vital social media has become to news organisations, and is a clear sign of how the world of news is changing – and has been for a while.

When Google News launched in 2002, many saw it as a harbinger of the death of the newspaper. It had no editor, just an algorithm that selected news stories from online publications and displayed them according to an index of interestingness known only to Google. More recently, the likes of Associated Press and Yahoo! have been experimenting with computer-generated prose. Both use software from Automated Insights to generate stories about company financial results and sports reports – areas where the quality of prose is felt to be of secondary importance to the accuracy of the data.

Facebook Instant feels like simply another step towards a world in which news stories are written by programs, distributed by algorithms and read on social media. The only thing likely to remain are the familiar brands, so we can choose to have *Guardian*- or *Sun*-flavoured stories sprinkled through our kitten-filled Facebook feeds like the odd healthy prune in a bowl of Sugar Puffs.

So what's wrong with that? If the job news organisations do is better served by Facebook Instant and its complex algorithms, why worry? Well, one concern is that Facebook, Google *et al* see journalism as a sideline, a way of putting people in front of ads. It isn't their primary mission – so if it stops making them lots of money, they're likely to stop doing it. There's also a concern that what results is not actually journalism at all, because what a human news team produces is actually quite fragile and special. A well-written news story puts information in context, offers a voice to each side of an argument and brings the public new knowledge.

Of course, I would say that. I'm a journalist, and I want you to believe in it because it keeps me in work. But simple economics and our seemingly unquenchable desire to live in the eternal present mean you'll probably choose an app-generated story over my carefully crafted prose – at least for your daily news. But I don't think the AIs will be writing *Focus* features for a while yet.

BILL THOMPSON contributes to news.bbc.co.uk and the BBC World Service

FROM THE LAB

Wheels on the bus go round and round thanks to new charging system

WHAT IS IT?

A high-capacity charger for electric buses that has been developed at Germany's Fraunhofer Society, which also gave the world the MP3.

WHY IS THAT A GOOD THING?

Using electric vehicles for public transport is problematic. On average, buses travel 400km (250 miles) a day; to charge an electric one, you either need to fill half the bus with enormous batteries, or keep taking it off the road to charge.

The Fraunhofer chargers can be installed at a bus station, allowing the driver to charge up the vehicle while waiting for passengers to board.

HOW DOES IT WORK?

The driver manoeuvres the vehicle into position under a charging pole, which hooks up to a 'contact head' on the roof of the bus. It takes just 6.5 minutes to charge up specially developed high-capacity batteries. The system has been on test in Dresden since November 2014 and has been performing well.

Electric buses could help reduce smog in city centres

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APPLIANCES OF SCIENCE

1 SELFIE DRONE

If sticking your arm out to take a selfie seems like too much effort, there's a drone that can do the work for you. All you have to do is throw Lily (the drone) into the air while wearing a small tracking device. Aimed at action sports types, the drone is waterproof and will float if it lands in water. It'll also capture all the action in slow motion (120fps) at 720p, or at normal speed in full HD (1080p).

Lily drone
$499 (£325), www.lily.camera

2 POD LIFE

Bricks and mortar are *so* 20th Century... what you need is a pod! The Ecocapsule will support two adults for up to a year. It's cased in solar panels to provide electricity, comes with its own wind turbine if you venture into colder climes and will run off a battery at night. When you fancy a change of scene, the Ecocapsule can be squeezed into a shipping container or simply plonked on top of a trailer.

Ecocapsule
Price TBC, ecocapsule.sk

3 POWER UP

This clip promises to make your AA batteries last up to eight times longer. Most power-hungry gadgets, such as wireless keyboards and mice, need 1.5V to function. But once the battery's output drops below 1.35V, the device declares the battery dead, despite there still being plenty of juice in the cell. The Batteriser works as a voltage booster – taking that otherwise wasted energy and ramping it up to a useable level.

Batteriser
£2, batteriser.com

4 BABY BOOMBOX

While we can't confirm that this is *actually* the world's smallest Bluetooth speaker (one day we'll try them all!), it probably is one of the best for its size and price. For a gadget no bigger than a Kinder egg, the diminutive speaker pumps out some respectable, albeit slightly tinny, sound. Be warned: since there's no screen, it shouts out its functions (like 'Power Off') from your pocket with no warning.

XQISIT B06
£29.99, xqisit.com

5 PUMP IT UP

'Unpack and inflate' are apparently the only two instructions you need to set up this tent. The frame consists of inflatable tubes made out of stiffened plastics, which you can fill with the help of a pump. The geodesic shape helps keep the weight down and ensures that the tent stays upright on a windy day. Inside there's space enough for two happy campers – and two separate 'rooms' if you fall out!

Heim Fistral
€399 (£293), heimplanet.com

6 DIET PHONE

If you liked life better when phones were just phones and Facebook weren't masters of the Universe, this might be the device for you. This white rectangle is a phone without apps, social networks or text messages – what most of us just used to call a mobile phone. And just like phones of olde, the Light Phone will last 20 days on one charge, and has 10 speed dial options instead of a contacts list.

Light Phone
$100 (£65), thelightphone.com

ULTIMATE TEST

CAMERAS EVOLVED

Put your compact camera away: the future of photography is here! Daniel Bennett tests six gadgets destined to change the way we take pictures

NOW THAT MOST of us are walking around with camera-equipped smartphones in our pockets, it's no longer enough for camera manufacturers to keep on simply whacking out last year's point-and-press compact with an extra couple of megapixels chucked onto the image sensor. Instead, the pressure's on to come up with new tricks to tempt you to part with your cash – and to be fair, makers have responded with some pretty innovative ideas. Here are six very different cameras that all showcase different technologies.

PHOTO: THESECRETSTUDIO.NET


PHANTOM
PROFESSIONAL
SONY
20x Optical Zoom
LEICA
DICOMAR
20x OPTICAL ZOOM

£1,999,
panasonic.com

THE SHARP ONE
Panasonic HC-X1000

IT WAS ONLY when our first 4K camera arrived in the office that it dawned on us that we didn't have a 4K-ready display. As it turned out, that wasn't much of a problem: one of the benefits of filming in 4K is that you can cut and crop up to a quarter of your footage and still play it back in full HD (1080p). So we were able to film an entire park, and just crop in on the football match going on in the corner.

But once we got our hands on a worthy display another, harder-to-solve problem arose: it turns out my face isn't 4K-ready either. A 4K camcorder sees everything in breathtaking detail. Put a vista in front of the HC-X100 and it will capture everything from gulls on the rocks to boats on the horizon. Splendid. Unfortunately, turning that 4K sensor back on myself gave a less than splendid result, and left me with a newfound respect for my other half! Ego aside though, this feature-rich camera had us hankering for a 4K TV upgrade.

£249,
polaroid.com

THE QUICK ONE
Polaroid Socialmatic

I'VE HAD A soft spot for Polaroid cameras for some time. Picking up a physical photo moments after taking a picture still feels special, even in the era of digital photography. To capitalise on this, the Socialmatic offers the best of both worlds – a 14MP camera with both a printer and an online connection (via Wi-Fi) for slapping filters on your pics before sharing them with the world. The trouble is, the Socialmatic does neither job particularly well.

The smart features, powered by Google's Android OS, don't run smoothly and the camera itself struggles with dim or overly bright light. On top of that, it's too big to fit in your pocket, the screen's all but impossible to see in sunlight, and the camera only holds 10 pieces of tiny 2"x 3" paper. Despite all this, we still had a lot of fun using the camera indoors, and some of the snaps I took are now pinned to our fridge door. We'd recommend Polaroid's Zip printer instead – it'll give you all the fun but none of the hassle.

PHOTO: THESECRETSTUDIO.NET

THE FLYING ONE
DJI Phantom 3

From £899, dji.com

IF YOU'VE EVER watched footage from a drone on YouTube it was probably filmed by a DJI Phantom. That's because DJI quadcopters are remarkably easy to use, and the latest iteration, the Phantom 3, is no different. Setup is a breeze, takeoff even easier and once it's in the air it practically flies itself. It stays aloft so well thanks in part to some new sensors that DJI has added to the Phantom's underside. These point downwards and check the ground below for patterns that it can lock on to. This way, if the wind blows your drone to and fro it can return to the same spot, even without a GPS lock.

DJI has added new image sensors to the built-in cameras that react to changes in the light intensity. This means that you are not left with any bleached shots as your drone moves from dark to light. And there's also an option for a 4K camera, which is especially useful with drone footage as you can crop in on the detail you want with little loss in quality.

THE CLEVER ONE
Lytro Illum

£1,300 (available at £999), lytro.com

INSTEAD OF CAPTURING a flat image on a single plane, the Illum captures a 'light field' – recording not just where light hits the sensors but also the direction in which it was moving. From this data, the camera's processor can work out the depth between objects and draw up a 3D photo, where you can choose what's in and out of focus *after* a picture is taken. There's a real thrill that comes from touching a photo and seeing it refocus before your eyes, and you can even shift the perspective slightly.

There's no autofocus, but you learn to take photos with as much depth as possible so you've got something to play with. The Illum is much faster than its predecessor, but still takes its time to process each photo, and you won't be able to take bursts of photos like a DSLR. Once you've picked your focus, the 'living images' look sharp – but when you export them as still images, they turn into grainy 4MP snaps. It's groundbreaking, but perhaps not ready for the mainstream yet.

THE BARKING ONE
Motorola Scout 5000

£130,
motorola.com

EVER WONDERED HOW your dog sees the world? We did, and it turns out Bruno, our test dog, sees mostly ankles. Given that Bruno is about a foot high, we arguably didn't need a smart cam to work that out – but that's not the point. Motorola's Scout is a bit of fun for you and your best friend.

The collar-mounted cam houses a GPS tracker and Wi-Fi chip, letting us check in on what Bruno was up to at home while we were at work – which, as it turns out, was mostly sleeping. But if, for example, Bruno was inclined to start barking, the bark detection system would let us know, so we could pick up the phone and shout "bad dog!" via his mic'd up collar. Thankfully that feature was never needed, because any attempts at talking to Bruno ended in bewilderment on his part. You can also set up a 'Geo Fence' whereby you'll get an alert if your pooch wanders beyond set limits. It's good fun, but we'd recommend Scout for a larger dog.

THE SMART ONE
Sony QX100

£299,
sony.com

THE CAMERA WE all use most is the one on our phone, so why not make it better? The QX100 is effectively a smartphone camera upgrade. You connect to the device through its dedicated Wi-Fi network, which turns your phone's screen into its viewfinder. Snap the lens in place with its case and you've got yourself a new camera phone that takes 20-megapixel photos, offers 3.6x optical zoom and can deal with low light.

It's a neat idea that showed up our iPhone's weaknesses, providing richer photos than we'd managed before. The interface is hassle-free, and photos transfer to your phone quickly. The only downside is the size: for the same price you could buy a decent compact camera to slip into your pocket, whereas you'll probably end up popping the QX100 in a bag. But Sony does offer smaller, cheaper versions, and a compact won't offer as many editing and sharing options.

PHOTO: THESECRETSTUDIO.NET

TO DO LIST

WATCH
LISTEN
TOUCH
VISIT
READ

PLAN YOUR MONTH AHEAD WITH OUR EXPERT GUIDE

OF THE MONTH

Royal Society Summer Science Exhibition

THE ROYAL SOCIETY'S Summer Science Exhibition has become an annual favourite on the science festival circuit. This year, the week-long festival returns with 22 exhibits, showcasing the latest research from universities and laboratories around the world.

From fusion and flu to sound and psychology, there's something for everyone at this year's event. At the Face Facts exhibit, learn how people from different cultures interpret facial expressions in a variety of ways. Or if space is more your bag, Plasma Rockets explores the revolutionary fuel that's powering a new generation of spacecraft.

History buffs will also be indulged. There'll be a chance to meet the team behind one of the biggest breakthroughs in recent years: the discovery of Richard III under a car park in Leicester. Find out how scientists, historians, archaeologists and engineers pinned down the identity of this medieval monarch. The king himself won't be present, but the next best thing will be: a life-sized 3D replica of Richard III's skeleton.

Meanwhile, Stonehenge Underground reveals the latest results from the Stonehenge Hidden Landscapes Project. Did you know that the iconic monument is surrounded by a whole host of burial mounds and sacred sites? The new GG-TOP project will aim to go even further by measuring subtle changes in gravity, revealing exciting new archaeological secrets.

As always, there'll be plenty of hands-on opportunities at the event. Measure cosmic rays reaching the venue, command a robot with your voice, electroplate your fingerprint in gold and try your hand at a spot of virtual cow farming (complete with virtual udders and virtual milk, we hope). Other picks include Forensic Femmes Fatales and How To Make A Weather Forecast.

And if that's not enough to satisfy your curiosity, there's a special, adults-only preview the evening before the exhibition officially opens. Oh, and it's all completely free. You'd be a fool to miss out.

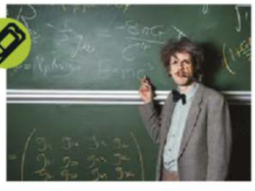
JAMES LLOYD

The Summer Science Exhibition is at The Royal Society, London from 30 June to 5 July. For more info visit sse.royalsociety.org/2015

DON'T MISS!

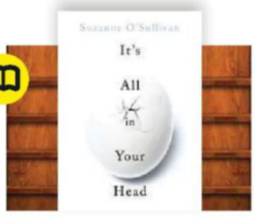
Idris Elba: No Limits

Follow the star of *The Wire* as he satisfies his need for speed. p94



Summer Schools 2015

Keep the kids occupied over the holidays with the Royal Institution's calendar of events. p97



It's All In Your Head

Suzanne O'Sullivan delves into the causes of psychosomatic illnesses in her new book. p98

PHOTO: T MITCHELL

WATCH

TV & ONLINE

WITH JAMES LLOYD

5 JULY

Edwardian Insects On Film

Yesterday, 8pm

Training up to the flyweight division

IN 1910, AMATEUR naturalist Percy Smith released a surreal but pioneering film showing a fly juggling a miniature dumbbell, a cork and other random objects. Many were astonished, while others accused him of fakery. Charlie Hamilton James tells the story of this unsung hero of natural history, and attempts to recreate Smith's original film.

12 JULY

Pluto Encounter

National Geographic, 8pm

Illustration of New Horizons at Pluto

IT'S BEEN HURTLING through the Solar System since 2006, but now the day of reckoning is finally here. On 14 July, the New Horizons spacecraft will fly past Pluto, giving astronomers and the people of Earth an unprecedented look at this mysterious, icy world. See the probe's first high-quality photos in this one-off special.

16 & 17 JULY

Last Steps: The Apollo 17 Experience

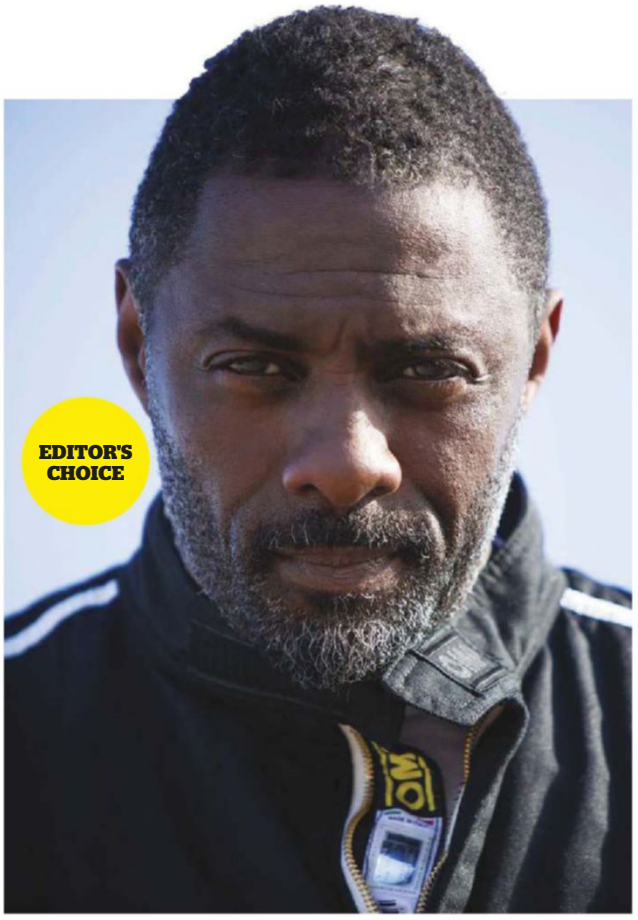
Eden, 9pm

Serious investigation in progress

IT'S EASY TO forget that only 12 individuals have ever walked on the surface of the Moon. The last people to make the trip arrived in December 1972, when Apollo 17 sent Eugene Cernan and Harrison Schmitt to the Taurus-Littrow region of the lunar surface. This two-part film uses breathtaking NASA footage, mission audio and rare interviews to chronicle this final Apollo mission.

PHOTO: GETTY, NASA, NATIONAL GEOGRAPHIC CHANNEL, UKTV

JAMES LLOYD is the editorial assistant at *BBC Focus Magazine*



EDITOR'S CHOICE

FROM 6 JULY

Idris Elba: No Limits

Discovery Channel, 9pm

IDRIS ELBA WAS catapulted to fame by his portrayal of drug lord Russell 'Stringer' Bell in HBO drama *The Wire*. But while Idris is no stranger to high-octane action, it's little known that the actor harbours a secret passion for speed. Fast vehicles, that is.

In this new series, Idris gets to fulfill his boyhood fantasies, taking to the land and air in a series of breakneck challenges. He pushes his body, nerves and technical know-how to the limit as he attempts to master four disciplines: rally driving, drag racing, aerobatics and land speed records. Along the way, he'll have to battle bad weather, claustrophobia, a fear of heights and that scourge of motorists – potholes.

Throughout the series, Idris will be mentored by a stellar cast of professionals, including rally driving legend Jimmy McRae, aerobatics champion Ed Cyster and drag racing superstar Antron Brown.

One of the highlights sees Idris travelling to Pendine Sands – an 11km stretch of beach along the south coast of Wales. Here, he'll attempt to break a land speed record that has stood since 1927, aiming to reach 322km/h (200mph) on sand...

It all sounds like speed demon heaven. Just don't blame us if you decide to ditch your day job and become a wing walker.

They're all hearing aids.

But no one will know.

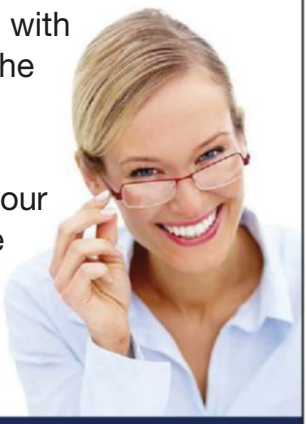
Can't quite hear your wife or husband, the TV, colleagues at work, or the loving words of your grandchildren?

Then these spectacle hearing aids could be the answer if you have a hearing problem.

Stylish frames that cleverly contain and disguise a digital hearing aid in the spectacle arms slip easily into your pocket, purse or handbag. They are a remarkable invention that overcomes two problems at once.

While most people are not bothered by wearing glasses, the same cannot be said for wearing a hearing aid. These specs are brilliant because you wouldn't think they are a hearing aid.

Some people can find it uncomfortable and unnatural to have a hearing aid in their ear but that's not a problem with these as there's nothing in the ear to irritate you.



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LISTEN

BBC RADIO PROGRAMMES

WITH JAMES LLOYD

JULY

The Life Scientific

BBC Radio 4, Tuesdays, 9am

PHYSICIST, AUTHOR AND broadcaster Jim Al-Khalili chats to more leading scientists to find out exactly what inspires them and (possibly) what they have for breakfast every morning. Among his guests this month are brain surgeon Henry Marsh, psychologist Prof Dorothy Bishop and Prof Danielle George, engineer and presenter of last year's Royal Institution Christmas Lectures.

Danielle George finds light bulbs hilarious

JULY

Natural Histories

BBC Radio 4, Tuesdays, 11am

BRETT WESTWOOD CONTINUES his epic series exploring our relationship with plants and animals around the world. This month, hear all about the lions of the Tower of London, discover the enchanting world of coral, and find out what links Harry Potter, the potato and a deadly poison.

FROM 6 JULY

The Infinite Monkey Cage

BBC Radio 4, 4:30pm

ROBIN INCE AND Brian Cox return for a 12th series of musings on all things science. This time, they're peddling their cerebral humour stateside, with four specials recorded in US cities. Expect to see Bill Nye the Science Guy, Eric Idle and Neil deGrasse Tyson.

Robin Ince and Brian Cox monkey around

15 & 22 JULY

Salt

BBC World Service, times TBC

WE SPRINKLE IT on our chips and spray it on our roads, but how much do we really know about salt? Steph McGovern looks at the science and history of this ubiquitous substance, finding out how it's produced, and how much is too much for our bodies.

ONLINE

Sunday Feature: The Anatomy Of The Voice

bbc.co.uk/programmes/b006tnwp/episodes/guide

MEZZO-SOPRANO MARY King tunes into the science of the voice. She speaks to professional singers, a West End casting director and an anatomist to find out how advances in technology have increased our understanding of the larynx and helped singers to make the most of their musical chops.

TOUCH

SMARTPHONE & TABLET APPS

WITH KATE RUSSELL

DIY Nano

iOS 5.0 or later, iPhone/iPad/iPod Touch, The Lawrence Hall Of Science, free

IT'S HARD TO explain something you can't see, which is why *DIY Nano* has pulled together a collection of experiments that kids can do at home to learn all about nanoscale science, engineering and technology. All of the exercises on the app use inexpensive, easy-to-find materials like cornflour, eggs, water and a doll's teacup. Each of the activities comes complete with step-by-step picture instructions, and there is also a collection of videos suitable for ages five and up. The app is very American in style, but the activities still make a good educational aid if your child is learning about nanotechnology concepts.

Stephen Hawking's Snapshots Of The Universe

iOS 6.0 or later, iPad, Random House, 79p

HOW DO PLANETS stay in orbit around stars? Are black holes really black? These are just a few of the questions answered by the inimitable Prof Stephen Hawking in this engaging iPad app. Through a series of 10 interactive experiments, the principles of physics and astronomy controlling the Universe are explained in a way that feels more like a game than a learning experience. The app is suitable for ages nine and up, but there is plenty of written and video content from Hawking to intrigue anyone who's keen to learn more.

NASA (APOD) Lite - Live Wall

Android 2.1 or later, 8-Bit Mage Software, free

TURN THE SCREEN of your Android phone into an ever-changing montage of universal wonders with this live wallpaper app. Once installed you'll need to head to Settings>Personalise>Choose Wallpaper>Live Wallpapers, and then select the NASA (APOD) Lite collection. It costs just 75p to upgrade to the paid version of the app, which will allow you to tweak some extra settings. The wallpaper cycles through NASA's Astronomy Picture of the Day image archive, which is filled with nebula, planets, stars, galaxies and more, all gently moving and transitioning to give the impression you are looking through a window into deep space.

KATE RUSSELL is a technology journalist and BBC *Click* presenter

PHOTO: BBC, PAUL WILKINSON, WIKI/MAGNUS MANSKE, JOHN HINTON, GETTY, RICHARD KENWORTHY

VISIT

EVENTS & EXHIBITIONS

WITH JHENI OSMAN

7 JULY

From Mars To The Multiverse

Venue Cymru, Llandudno, 6:30pm-7:30pm, £4, venuecymru.co.uk

ASTRONOMER ROYAL LORD Martin Rees (pictured) reveals how the Universe unfolded from the Big Bang and answers a host of other intriguing questions.

9 JULY

Mind Change

Life, Newcastle, 6pm-7pm, £3, life.org.uk

PROF SUSAN GREENFIELD explains why she believes long-term exposure to computers and gaming is harmful to the human brain.

13 JULY

Bright Club Newcastle

The Stand Comedy Club, 8:30pm-10pm, £4, thestand.co.uk

LAUGHING WHILE LEARNING – what better way to spend an evening? Head along to this thinking person's variety night, which mixes science, comedy, music and art.

13 JULY

The Tale of Sir Humphry Davy And His Miners' Safety Lamp

Aberystwyth University, 11am, free, learnedsocietywales.ac.uk

TO HELP PREVENT horrific explosions in coal mines, the Miners' Safety Lamp was introduced and revolutionised the industry. Find out how it worked and the story behind the man who invented it.

21 JULY

Go8Bit Presents... Wi-Fi Wars!

Royal Institution, London, 7pm-8:30pm, £12, rigb.org

BRING YOUR TABLET or smartphone to this interactive comedy show, where comedians battle it out on classic video games. The loser has to perform forfeits.

23 JULY

Cosmic

Cambridge Science Centre, admission applies, cambridgesciencecentre.org

ENTER ANOTHER WORLD as you get hands-on at this brand new exhibition at the Cambridge Science Centre. Explore spacecraft, stars and the Solar System.

EDITOR'S CHOICE

27 JULY - 28 AUGUST

Summer Schools 2015

Royal Institution, London, prices vary, rigb.org

WONDERING HOW TO get the kids out of the house this summer? Well fear not: the Royal Institution is hosting an action-packed programme of events during the holidays, aimed at ages seven to 18. For the youngest, there are half-day workshops on everything from mathematical origami to earthquake engineering, while teenagers can attend full-day courses on codebreaking, cosmology, forensics, robotics and much more besides. Sessions in the L'Oréal Young Scientist Centre will even give participants a feel for hands-on lab work.

24-26 JULY

Deer Shed Festival

Baldersby Park, North Yorkshire, admission applies, deershedfestival.com

DISCOVER YOUR INNER Einstein at this festival and enjoy shows by Punk Science and the CHaOS Science Roadshow. You can even meet Andy Chipling, who competes in paper plane events around the globe. Who knew such contests existed?!

28 JULY

Human Error

Royal Institution, London, 6pm-7:15pm, £12, rigb.org

AS TECHNOLOGY ADVANCES, human error remains. We've all forwarded the wrong email to a colleague, or forgotten an internet password. Sarah Wiseman reveals her tricks to avoid those blips.

31 JULY

Natural History Museum Lates

Natural History Museum, London, 6pm-10pm, free entry, nhm.ac.uk/lates

HEAD ALONG TO this child-free evening of music, food, drinks and discovery. Additional charges for exhibitions.

READ

THE LATEST SCIENCE BOOKS REVIEWED

Hardback Paperback

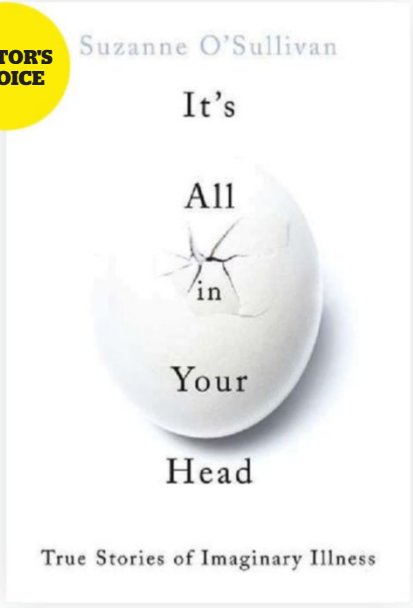
It's All In Your Head

True Stories Of Imaginary Illness

Suzanne O'Sullivan

Chatto & Windus H £13.99

EDITOR'S CHOICE



PSYCHOSOMATIC ILLNESSES AND their associated symptoms are very real, but are caused by psychological rather than biological factors. This does not prevent considerable stigma being attached to them, even by sufferers themselves – reports abound of researchers receiving death threats when they investigate the psychological causes of certain conditions such as chronic fatigue syndrome. It is into this delicate and controversial area that neurologist Suzanne O'Sullivan delves with her book *It's All In Your Head*.

In style and format, the book resembles Oliver Sacks' *The Man Who Mistook His Wife For A Hat*. O'Sullivan is an experienced neurologist, and each chapter is based around patients who display extreme examples of a psychosomatic condition. O'Sullivan's skilful writing shows these patients as real individuals, rather than simply as vessels for interesting symptoms, and she tackles more detailed medical and neurological aspects of the subject in an easily understandable, organic style, adding to the narrative rather than disrupting it.

It would be easy for each chapter to become formulaic (patient has illness; experts find no physical cause; it's found to be psychosomatic; repeat), but O'Sullivan avoids this by breaking up the predictable structure with historical perspectives on illness, her own experiences, similar cases and more. It's an effective tactic, although sometimes overdone, with diversions and tangents sometimes lasting so long you are surprised when the narrative returns to the patient the chapter is nominally about.

There are other issues. There are several instances where the story of the patient ends abruptly with them seeing a psychiatrist. This probably makes medical sense as, being a neurologist, this is where O'Sullivan's direct involvement ends, but it still makes for frustrating reading at times.

Perhaps the main concern is that, throughout the book, O'Sullivan goes to admirable lengths to emphasise how psychosomatic illnesses are real and very debilitating, regularly and nobly criticising her own early, cynical reactions. However, the title and tagline of the book suggest a far more dismissive and judgmental tone – one likely to anger those afflicted. People shouldn't judge books by their covers, but they shouldn't stigmatise ill people either, and yet much of this book is about how they do exactly that.

■■■■□

"O'Sullivan shows patients as real individuals, not simply as vessels for interesting symptoms"

PHOTO: JONATHAN GREET

DR DEAN BURNETT is a neuroscientist and comedian who lectures at Cardiff University

MEET THE AUTHOR

Suzanne O'Sullivan

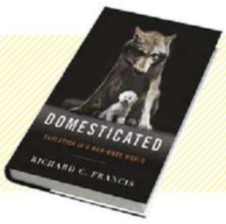
What are the typical symptoms of a psychosomatic illness?
Any symptom you can think of has been the manifestation of a psychosomatic disorder – it's known as the chameleon of illnesses. As a neurologist, I often see people with very dramatic forms, which could be seizures, paralysis or blindness. Or it might be something less dramatic like a headache or a feeling of dizziness.

How is it diagnosed?
Physical disease has to be ruled out in the first instance. It's extremely important that [the patient] has all the appropriate tests before we come to the conclusion that it may be a psychological illness.

Is it often caused by stress?
There are multiple causes, and it's a bit different in everyone. Many of the people with the more extreme forms have suffered psychological trauma, such as sexual abuse or loss of a loved one, but in a lot of people there's no specific event. It might be an accumulation of life stressors, or it may be something that's behavioural or based on perception.

How is it treated – can drugs help?
If we can make the diagnosis quickly, then help the person to understand what the trigger was, that might be all they need to get rid of the symptoms. If their symptoms are more prolonged, they'll probably need to be referred to a psychiatrist or a psychologist. They might benefit from treatments like cognitive behavioural therapy, but someone who's been disabled for years might also need intervention from physiotherapists, social workers or occupational therapists.

MORE ON THE PODCAST
Listen to the full interview with Suzanne O'Sullivan at sciencefocus.com/podcasts



Domesticated

Evolution In A Man-Made World

Richard C Francis

WW Norton & Co (H) £17.99

URBAN LIFESTYLES MEAN that pets provide the only regular contact many of us have with live animals. Then there are the animals we eat, and the remainder of the animal kingdom is 'wildlife'. Biological science has long seen domesticated animals as artificial, inferior creatures. This book sets the record straight, describing the histories of domestic mammals from laboratory mice to Santa's reindeer. These are brought up to date with new information from their DNA sequences, accompanied by the biologist's trademark acronyms: pigs are now classified according to their PERVs (Porcine Endogenous Retroviruses) and polydactyly (extra toes) in cats is caused by a gene called Sonic Hedgehog.

We are mammals too, so logically Francis's book concludes with a section on our own 'domestication': the interplay between culture and genetic change that makes us what we are today. For example, there are mutations that have enabled many (but by no means all) of us to digest the lactose in cow's milk. An essential read for anyone interested in the stories of the animals in our homes and on our plates.

■■■■□

JOHN BRADSHAW is the author of *In Defence Of Dogs* and *Cat Sense*

The Weather Experiment

The Pioneers Who Sought To See The Future

Peter Moore

Chatto & Windus (H) £20

THE NAME OF Admiral Robert FitzRoy is familiar to mariners because of the sea area that bears his name. But to meteorologists, FitzRoy is a hero: he founded the Met Office and gave us the term 'forecast'. Now, 150 years after his tragic death, FitzRoy is at the centre of an engrossing account of the pioneers of scientific weather prediction.

Author Peter Moore introduces us to a rich cast of largely forgotten players in one of the great intellectual dramas of the 19th Century. When they began their quest, the weather seemed beyond rationalisation, yet through assiduous data collection and careful analysis they began to find the pieces of a puzzle that is still far from complete. And at the centre of it all is the difficult and ultimately doomed character of FitzRoy himself, committed to turning new insights into life-saving forecasts.

Moore marshals the myriad stories into a compelling narrative. He is especially strong on the role of human foibles and personality clashes in the emergence of a new science. While his grasp of technical intricacies is sometimes flawed, this biography is an impressive achievement.

■■■■□

ROBERT MATTHEWS is Visiting Reader in Science at Aston University, Birmingham

Chilled

How Refrigeration Changed The World And Might Do So Again

Tom Jackson

Bloomsbury (H) £16.99

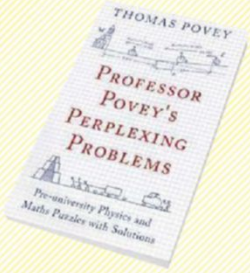
ALBERT EINSTEIN INVENTED a type of fridge. Emperor Nintoku declared 1 June Japan's National Day of Ice. The average banana contains enough calories to heat 2kg of water by 50°C. Like a well-stocked refrigerator, this book is packed with tasty morsels and more substantial meals too, as Jackson takes us from ancient Mesopotamia to teleportation, via the science of cooling things down.

There are tricky ideas in *Chilled*, such as the difference between temperature and heat, or the nature of subatomic forces. Jackson handles them deftly, without too much technical language, and how much we take refrigeration for granted soon becomes evident. It hasn't just transformed our eating and shopping habits, it's contributed to technologies such as maglev trains and medical scanners. Without it, we'd have no neon lights, artificial fertilisers or Higgs Boson.

Once, passengers floated around the Caribbean on the Great White Fleet's chilled banana boats. At times, this book feels like you're on such a voyage: being entertained by a knowledgeable host, and gathering information from all ports.

■■■□□

TIMANDRA HARKNESS is a science journalist and comedian



Professor Povey's Perplexing Problems

Thomas Povey

Oneworld (P) £18.99

HOW BIG A helium balloon would you need to lift an average man? This question is one of many in Povey's compilation of his favourite scientific puzzles. Topics range from geometry and probability to optics and electricity, and Povey uses quirky scenarios to liven up what could otherwise be dry questions. Sherlock Holmes and a missing emerald inspire a question about ballistics, while readers' understanding of gravity is tested with a tycoon who wants to advertise on the Moon.

Although many of the puzzles require a working knowledge of A-Level physics, Povey helpfully rates the questions on difficulty, from one to four stars. There are also hints to assist totally baffled readers. The answers appear straight after the questions, which can make it hard to avoid accidentally seeing the solution, but this is a minor flaw in an otherwise impressive hoard of physics and maths puzzles. Whether you want to learn some new methods or brush up on old skills, this book is a fun way to do it.

■■■■□

DR ADAM KUCHARSKI studies disease dynamics and has a PhD in applied maths

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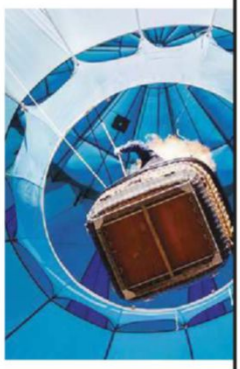

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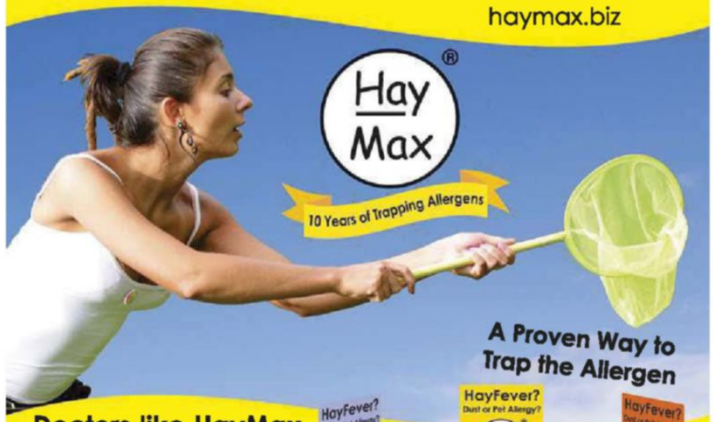

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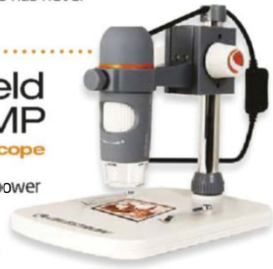

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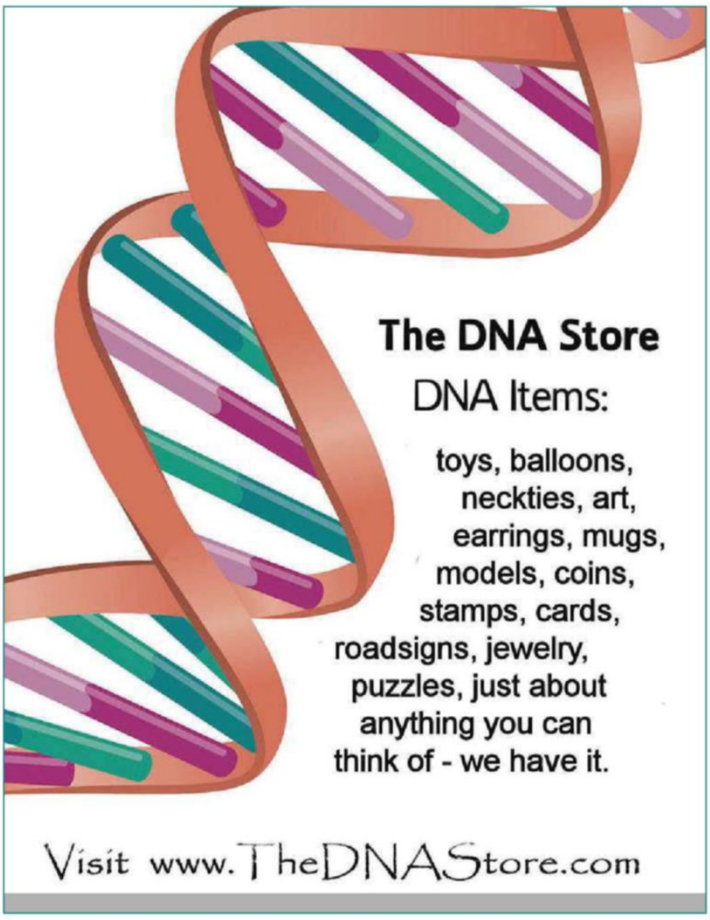

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COURSES AND EDUCATION

How I improved my memory in one evening

"Of course I place you! You're Bob Jones of Birmingham. If I remember correctly — and I do remember correctly — John Earnshaw, the supermarket man, introduced me to you at the dinner of the Bowls Club three years ago in October." The assurance of this speaker in the crowded corridor of the Hilton Hotel in Manchester compelled me to look at him. "He is Dr. Bruno Furst, the most famous memory expert in the world," said my friend Bob Clark.

When I met Dr. Furst he rather bowled me over by saying: "There is nothing miraculous about my remembering anything I want to remember. **You can do this as easily as I do.**"

"That is alright for you, Dr. Furst," I interrupted, "you have given years to it. But how about me?" "Mr. Heap," he replied, "I can teach you the secret of a good memory in one evening. **I will prove it to you**."

He didn't have to, his Course did - I got it the next day. **Dr Bruno Furst's Course is fantastic!**

My advice to you is don't wait another minute. Send for full details of Dr. Furst's amazing Course, available free on request (see the coupon below). You will be astounded to learn what a wonderful memory you could have and what a difference it could make to your life!

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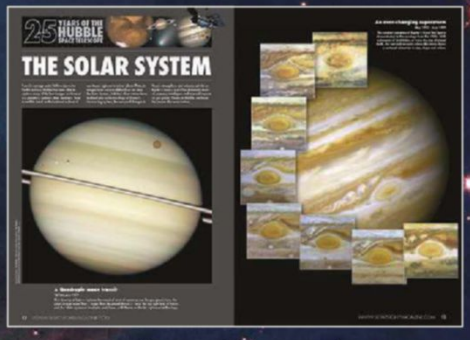

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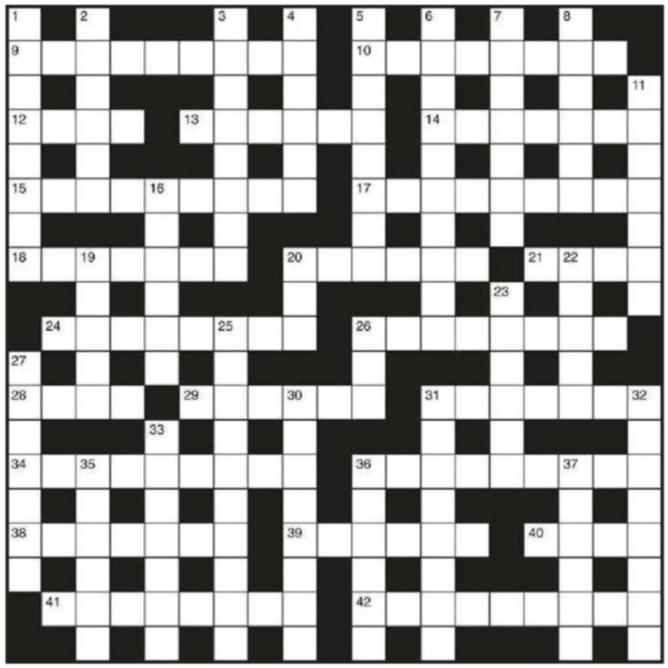
FOCUS CROSSWORD No 179

More online Solve puzzles from BBC Only Connect hosted by Victoria Coren Mitchell at http://bbc.in/1vCOzuY



ACROSS

9 Health centre is initially round, sloping the same way (9)
10 Tempest not affecting Parliament buildings (8)
12 First man to encounter a barrier (4)
13 Hide display unit (6)
14 Article on beam gets pressure treatment (7)
15 Man United redesigned outer coverings (9)
17 Consider gold telescope (9)
18 Mother left song as a complaint (7)
20 Quiet and shy about one old form of exercise (6)
21 Growth of doctor on ship (4)
24 Longed to have a small drink, having flippers (8)
26 Mention about Roy breaking large mineral (8)
28 Hard-worker outside city of stone (4)
29 Fish, having no current at the surface (6)
31 Somewhat surrounded by fat cord (7)
34 Choose staff at eastern terminal (9)
36 Monotonous sound follows fire at plant (9)
38 Generous politician (7)
39 Wild dogs – alternatively, a pointer (6)
40 Hand over new hostage (4)
41 New coins, say, causing skin discolouration (8)
42 Folds in hepatic development (9)

DOWN

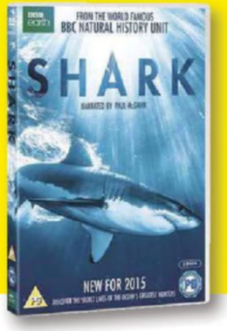
1 One hesitation, following giant element (8)
2 Pool around the French territory (6)
3 A don can work with a snake (8)
4 Part of the eye clears differently (6)
5 No coordination when variable neutron turns grey (8)
6 Imaginary creature has time to wave hairy foot (5,5)
7 A couple of Frenchmen using tree gauge (7)
8 Child at home with fellow worker (6)
11 Conifer gives fancy ending to reporters (7)
16 River is in state of the sea (6)
19 They're not clerics and are upsetting Italy (5)
20 Cushion at home (3)
22 Only it's a terribly old port (5)
23 Surface temperature on Mars, say (6)
25 Expert to use lamps to see contents of cell (10)
26 Copper gives daughter second-hand food (3)
27 Heart all broken by cockatoo (7)
30 Honest – actors are mine (8)
31 Girl has rods fixing spinal curvature (8)
32 Deterioration of soldiers in a diet experiment (8)
33 Directions have entry about volatile liquid (7)
35 Worried more by early development (6)
36 Father right to fetch plaster (6)
37 Scripture lessons have a lot about bridge (6)

SOLUTION TO CROSSWORD No 176

Ian Glenn, Martin Bishop, Brian Duncan, Stephen Millard and Alan Pyatt each solved issue 280's puzzle and receive a copy of *David Attenborough's Conquest Of The Skies* (Sky, £14).

WIN! *SHARK*

The first five correct solutions drawn will each win a copy of *Shark* (BBC, £20.42). Entries must be received by 5pm on 23 July 2015. See below for more details.



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Post entries to *BBC Focus Magazine*, Summer 2015 Crossword, PO Box 501, Leicester, LE94 0AA or email a scan of the completed crossword or a list of answers to summer2015@focuscomps.co.uk by 5pm on 23 July 2015. Entrants must supply name, address and phone number. Immediate Media, publisher of *BBC Focus Magazine*, may contact you with details of our products and services or to undertake research. Please write 'Do Not Contact' on your email or postal entry if you do not want to receive such information by post or phone. Please write your email address on your postal entry if you would like to receive such information by email.

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Entrants must be UK residents (inc Channel Islands) aged 18 or over. Immediate Media employees are not eligible to enter. By entering participants agree to be bound by these terms and conditions and that their name and county may be released if they win. Only one entry permitted per person. No responsibility is accepted for lost, delayed, ineligible or fraudulent entries. Entries received after the closing date will not be considered. Immediate Media (publisher of *BBC Focus Magazine*) will only ever use personal details for the purposes of administering this competition unless you permit otherwise. Read more about the Immediate Privacy Policy at www.immediatemedia.co.uk/privacy-policy. The winning entrants will be the first correct entries drawn at random after the closing time. The prize and number of winners will be as shown above. The winners will be notified within 30 days of the closing date by post. Immediate Media's decision is final and no further correspondence relating to the competition will be entered into. If the winner cannot be contacted within one month of the closing date, Immediate Media reserves the right to offer the prize to a runner-up.

HOLLYWOOD SCIENCE

Killer robots in Terminator Genisys

HE SAID HE'D be back and he only went and did it. Fresh from his work placement as Governator of California, this month sees an ageing Arnold Schwarzenegger return to his rightful role as the Terminator in the franchise's fifth instalment. In *Terminator Genisys*, it's humans against machines. There are melty metal men, robots with guns, and accents so thick they make Cheryl Fernandez-Versini sound like Mary Poppins. You know the score. Yada yada yada.

In contrast to Arnie, killer robots of the future are unlikely to look like a pair of tights stuffed with walnuts. Instead, they'll come in the form of unmanned aerial vehicles. Driven by computer algorithms and armed with sophisticated tech, the drones would detect, select and kill targets without our involvement. It's a chilling thought.

And if you think the technology is too far off to worry about, think again. The Israelis already have autonomous radar-destroying drones, while the South Koreans use machine gun-wielding robots to defend their border with the North. 'Automatic target recognition', where computers determine the target but humans pull the trigger, is already under development. Next generation drones like BAE Systems' Taranis or Northrop Grumman's X-47B could find themselves hosting this tech. "We're already blurring the lines between human- and machine-controlled decisions about attack," says Thomas Nash, Director of Article 36, a UK-based organisation campaigning to ban devices of this nature.

"Let's hope legislation gets here in time to avert *Terminator 6: Geriatric Day*"

But the final step, removing all human involvement, is a line that should never be crossed. "It would de-humanise violence, conflict and killing in a way that is morally repugnant," says Nash. "This is about human life and dignity. Machines will never understand that. We need legal protection in place that says this is something that humanity as a whole doesn't want."

With this in mind, the United Nations recently held its second meeting on the subject, where representatives of the world's major military powers tried to thrash out what constitutes meaningful human control – the level of involvement that is needed to kill someone on the battlefield or in law enforcement. There are many instances where weapons such as landmines and cluster bombs have been banned at the international level, and discussions like this are a necessary first step towards international legislation. But with the best will in the world, any treaty or formal ban is at least a year or two away. Let's hope the legislation covers Hollywood and that it gets here in time to avert *Terminator 6: Geriatric Day*. ■

HELEN PILCHER is a science writer and comedian. She tweets from @Helenpilcher1

ILLUSTRATOR: ALEXANDER WELLS

TREATING PROSTATE CANCER QUESTIONS & ANSWERS

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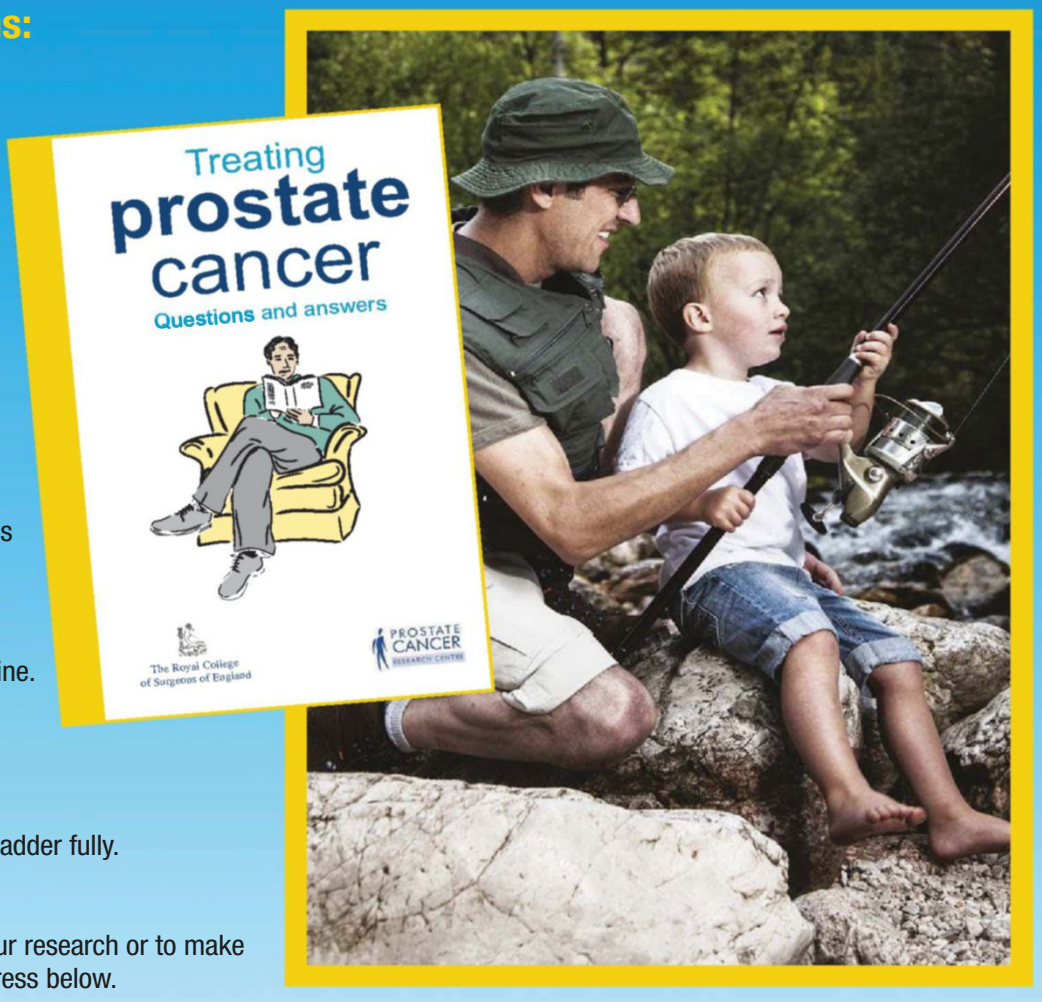
- to help you become better informed about prostate cancer and its treatment.
- to guide you in the decisions you will make about your care with your doctor.

It cannot replace talking to your GP or hospital doctor.



Symptoms of prostate problems

Listed below are some of the symptoms which are usually caused by benign disease, not prostate cancer. So do not worry if you have any of these symptoms but go to your doctor to have them checked.

- Difficulty or pain in passing urine.
- Having to rush to the toilet to pass urine.
- Frequent visits to the toilet, especially at night.
- Starting and stopping while urinating.
- Dribbling urine.
- A feeling of not having emptied the bladder fully.
- Blood in your urine.

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